LICHENS AND AIR QUALITY IN SARGUARO NATIONAL MONUMENT

with Chemical Analysis of Chiricahua Lichens

FINAL REPORT

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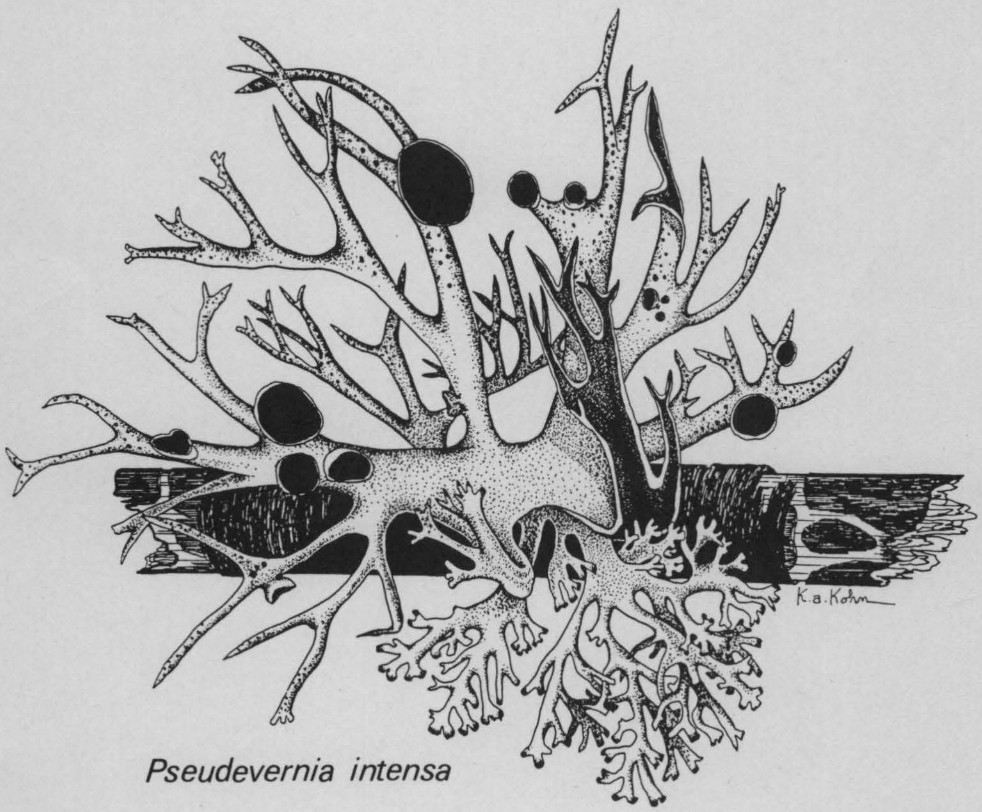

Pseudevernia intensa

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LICHENS AND AIR QUALITY IN SAGUARO NATIONAL MONUMENT

WITH CHEMICAL ANALYSIS OF

CHIRICAHUA LICHENS

Final Report

National Park Service
Contract CX 0001-2-0034

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PREFACE

Under a grant from the National Park Service (USDI CX 0001-2-0034) a lichen study was to be performed in Saguaro National Monument. This study was to survey the lichens of the park, produce a lichen flora, collect and analyze lichens for chemical contents and evaluate the lichen flora with reference to the air quality. This study is to establish baseline data for future restudy and determine the presence of any air quality problems as might be shown by the lichens at the time of the study. In addition, elemental analysis was done on lichens from Chiricahua National Monument but no complete flora was done there. All work was done at the University of Minnesota with frequent consultation with Dr. James Bennett, NPS-AIR, Denver and with personnel in the park.

The park personnel have been very helpful during the field work which has contributed significantly to the success of the project. The study was made possible by funds from the National Park Service. Assistance in identification of some of the problem species was provided by Dr. John Thomson. The assistance of all of these is gratefully acknowledged.

INTRODUCTION

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

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Some are damaged or killed by levels of sulfur dioxide as low as 13 ug/cubic meter (annual average) or by nitrogen oxides at 3834-7668 ug/cubic meter or by other strongly oxidizing compounds such as ozone. Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over 300 ug/cubic meter. The algae of the thallus are the first to be damaged in areas with air pollution and the first indication of damage is discoloring and death of the algae, which quickly leads to the death of the lichen. Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry. The nature of the substrate is also important in determining the sensitivity to sulfur dioxide since substrates with high pH seem to buffer the fallout and permit the persistence of more sensitive species than one would expect. After the lichen dies it disappears from the substrate within a few months to a year as it disintegrates and decomposes (Wetmore, 1982).

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

The two sections of Saguaro National Monument have quite different vegetation. The Rincon Section (east of Tucson) has mountains rising to 2641 meters and has douglasfir

(*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) at the highest elevations with zones of gambel and silver leaf oak (*Quercus gambelii*, *Q. hypoleucoides*) and pinyon pine (*Pinus edulis*) and alligator juniper (*Juniperus deppeana*) at lower elevations with chaparral of manzanita (*Arctostaphylos pungens*) and oak brush. At the lower elevations the cactus scrub is found with *Opuntia*, saguaro (*Carnegiea gigantea*), mesquite (*Prosopis*) and paloverde (*Cercidium*). The Tucson Mountain Section (west of Tucson) is lower in elevation (from 700 to 1450 meters) and has no trees but the same chaparral and desert scrub communities as the lower elevations of the Rincon Section. Most of the rocks and soils are non-calcareous but a few local areas have some calcareous material. The Rincon Section has a few permanent streams and moist valleys but these are absent in the Tucson Mt. Section.

There is very little historical information specific to Saguaro lichens. Fink (1909) and Zahlbruckner (1908 & 1909) reported some lichens collected by J. C. Blumer near Tucson in the desert but apparently Blumer also collected in the Rincon Mts. because Motyka (1936-38) reported one species from Manning Camp. Robert A. Darrow collected in the Rincon Mountains in 1933 and 1934 and in the 1940's. In 1966 C. Wetmore collected at one locality in the Tucson Mt. Section of the park. Weber (1963) reported on the lichens of the Chiricahua Mts. but this mountain range is considerably removed from Tucson and the lichen flora seems to be quite different. Nash & Johnston (1975) summarized the lichens of

Arizona based on the literature but few of these records came from the park.

METHODS

Field work was done during the summer of 1986. One month during June and July was spent collecting in the park and over 1200 lichen collections were made at 38 localities. A complete list of collection localities is given in Appendix I and they are indicated on Fig. 1. Localities for collecting were selected first to give a general coverage of the park, second, to sample all vegetational types, third, to be in localities that should be rich in lichens. At each locality voucher specimens of all species found were collected to record the total flora for each locality and to avoid missing different species that might appear similar in the field. At some localities additional material of selected species was collected for chemical analysis (see below). While collecting at each locality observations were made about the general health of the lichens.

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

LICHEN FLORA

The following list of lichens is based on my collections, historical specimens in the University of Minnesota herbarium and those reported in the literature. While most of the reports of lichens from southeastern Arizona could be used as a guide to the lichens that might be found in Saguaro NM, many of them are from areas too distant or different to be used to indicate a loss of lichens in the park. In the following list only the species reported from Pima County (the county that includes Saguaro NM) and also found during this study are included. The lichens reported in the literature for Pima County but not collected by me are listed in a second list and not included in the main list because many of the names are from other areas and probably do not occur in the park or are based on misidentifications. Those names reported from the Chiricahua Mts. by Weber (1963) have not been included in either list. All nomenclature has been adjusted to agree with present circumscriptions of the taxa where possible. In the first columns the letters indicate the section of the park (T=Tucson, R=Rincon) and the next columns indicate the sensitivity to sulfur dioxide, if known, according to the categories proposed by Wetmore (1983).: S=Sensitive, I=Intermediate, T=Tolerant. S-I is intermediate between Sensitive and Intermediate and I-T is intermediate between

Intermediate and Tolerant. Species in the Sensitive category are absent when annual average levels of sulfur dioxide are above 50ug per cubic meter. The Intermediate category includes those species present between 50 and 100ug and those in the Tolerant category are present at over 100ug per cubic meter.

SAGUARO SPECIES LIST

T	R		*Acarospora americana* Magn. Rudolph, 1953
T	R		*Acarospora bella* (Nyl.) Jatta Magnusson, 1929
	R		*Acarospora chlorophana* (Wahlenb. in Ach.) Mass. Fink, 1909
T			*Acarospora cinereoalba* (Fink) Magn.
T	R		*Acarospora fuscata* (Nyl.) Arn.
	R		*Acarospora fuscescens* Magn.
T			*Acarospora oligospora* (Nyl.) Arn.
T	R		*Acarospora peltastica* Zahlbr. Rudolph, 1953
T	R		*Acarospora radicata* Magn.
T	R		*Acarospora schleicheri* (Ach.) Mass. Magnusson, 1929
			3 additional unidentified species of *Acarospora*
	R		*Arthonia intexta* Almq.
T	R		*Aspicilia alphoplaca* (Wahlenb. in Ach.) Poelt & Leuck.
T			*Aspicilia caesiocinerea* (Nyl. ex Malbr.) Arn.
T			*Aspicilia calcarea* (L.) Mudd
T	R		*Aspicilia cinerea* (L.) Körb. Fink, 1909,
	R		*Bacidia beckhausii* Körb.
	R		*Biatorella microhaema* Norm. in Th. Fr.
	R	I	*Bryoria fuscescens* (Gyeln.) Brodo & Hawksw. Brodo & Hawksworth, 1977
	R		*Buellia aethalea* (Ach.) Th. Fr.
	R		*Buellia disciformis* (Fr.) Mudd Darrow, 1950
	R		*Buellia erubescens* Arn.
T			*Buellia novomexicana* B. de Lesd.
	R	T	*Buellia punctata* (Hoffm.) Mass. Darrow, 1950, Nash, 1973
T			*Buellia retrovertens* Tuck. Zahlbruckner, 1909, Rudolph, 1953
	R		*Buellia spuria* (Schaer.) Anzi
	R		*Buellia stigmaea* Tuck.
	R	I	*Buellia stillingiana* J. Stein.
			3 additional unidentified species of *Buellia*
	R		*Calicium abietinum* Pers.
	R		*Calicium adspersum* Pers.
	R		*Calicium corynellum* (Ach.) Ach.
	R		*Calicium trabinellum* (Ach.) Ach.
T			*Caloplaca amabilis* Zahlbr. Zahlbruckner, 1908, Fink, 1909, Rudolph, 1953
	R	S-I	*Caloplaca cerina* (Ehrh. ex Hedw.) Th. Fr.

	R		Caloplaca chrysophthalma Degel.
T	R		Caloplaca decipiens (Arn.) Blomb. & Forss.
T			Caloplaca discolor (Will. ex Tuck.) Fink
	R		Caloplaca durietzii Zahlbr.
	R		Caloplaca epithallina Lynge
	R		Caloplaca ferruginea (Huds.) Th. Fr.
	R	I	Caloplaca holocarpa (Hoffm.) Wade Darrow, 1950
T	R		Caloplaca laeta Magn.
T	R		Caloplaca microphyllina (Tuck.) Hasse Darrow, 1950
	R		Caloplaca saxicola (Hoffm.) Nordin Fink, 1909
T	R		Caloplaca squamosa (B. de Lesd.) Zahlbr. Nash & Weber, 1974
			9 additional unidentified species of Caloplaca
	R	S-I	Candelaria concolor (Dicks.) B. Stein. Darrow, 1950
T	R		Candelariella aurella (Hoffm.) Zahlbr.
	R		Candelariella deflexa(Nyl.) Zahlbr.
	R		Candelariella efflorescens R. Harris & Buck
T	R		Candelariella rosulans (Müll. Arg.) Zahlbr.
	R	I	Candelariella vitellina (Hoffm.) Müll. Arg. Darrow, 1950
			2 additional unidentified species of Candelariella
T	R		Candelina submexicana (B. de Lesd.) Poelt
T			Catillaria lenticularis (Ach.) Th. Fr.
	R		Catillaria nigroclavata(Nyl.) Schul.
	R		Cetraria coralligera (W. Web.) Hale
	R		Cetraria fendleri (Nyl.) Tuck.
	R		Cetraria weberi Essl.
			2 unidentified species of Chaenothecopsis
	R		Cladonia bacillaris Nyl.
	R		Cladonia bacilliformis (Nyl.) DT & S
	R		Cladonia coniocraea (Flörke) Spreng. Darrow, 1950
	R	S-I	Cladonia fimbriata (L.) Fr.
	R		Cladonia pleurota (Flörke) Schaer.
	R		Cladonia pyxidata (L.) Hoffm.
	R		Cladonia symphycarpa(Ach.) Fr.
T			Collema coccophorum Tuck. Fink, 1909
	R		Collema conglomeratum Hoffm. Darrow, 1950
	R		Collema furfuraceum (Arn.) Du Rietz
	R		Collema fuscovirens (With.) Laund.
	R		Collema subflaccidum Degel. Nash, 1973
T	R		Collema tenax (Sw.) Ach.
			1 additional unidentified species of Collema
	R		Cyphelium tigillare (Ach.) Ach. Darrow, 1950
T			Dermatocarpon acarosporoides Zahlbr.
T	R		Dermatocarpon lachneum (Ach.) A. L. Sm. Fink, 1909
T	R		Dermatocarpon miniatum (L.) Mann Fink, 1909
	R		Dermatocarpon moulinsii (Mont.) Zahlbr.
	R		Dermatocarpon tuckermanii (Rav.) Zahlbr.
T	R		Dimelaena oreina (Ach.) Norm. Hale, 1952
	R		Diploschistes scruposus (Schreb.) Norm.
T			Endocarpon pusillum Hedw. Fink, 1909, Rudolph, 1953
T			Gonohymenia cribellifera (Nyl.) Henss.
T	R		Heppia lutosa (Ach.) Nyl. Wetmore, 1970

	R		Heterodermia diademata (Tayl.) Awas.
	R		Heterodermia rugulosa (Kurok.) Wetm.
	R		Heterodermia speciosa (Wulf.) Trev. Darrow, 1950
	R		Koeberia biformis Mass. Magnusson, 1954
	R		Lasallia papulosa (Ach.) Llano Llano, 1950
	R		Lasallia pensylvanica (Hoffm.) Llano
	R		Lecanora atra (Huds.) Ach. Darrow, 1950
	R		Lecanora atriseda (Fr.) Nyl.
	R		Lecanora caesiorubella subsp. saximontana Imsh. & Brodo Imshaug & Brodo, 1966
	R	I	Lecanora carpinea (L.) Vain. Imshaug & Brodo, 1966
T			Lecanora cenisia Ach.
	R	I	Lecanora chlarotera Nyl.
	R		Lecanora circumborealis Brodo & Vitik.
	R		Lecanora impudens Degel.
T	R	T	Lecanora muralis (Schreb.) Rabenh. Fink, 1909
	R		Lecanora opiniconensis Brodo
	R		Lecanora polytropa (Hoffm.) Rabenh.
	R		Lecanora rupicola (L.) Zahlbr.
	R	I	Lecanora saligna (Schrad.) Zahlbr.
			3 additional unidentified species if Lecanora
	R		Lecidea aeruginosa Borr. in Hook. & Sowerb.
	R		Lecidea anthracophila Nyl.
	R		Lecidea auriculata Th. Fr.
T			Lecidea decipiens (Hedw.) Ach.
	R		Lecidea elabens Fr.
	R		Lecidea friesii Ach. in Liljeb.
	R		Lecidea granulosa (Hoffm.) Ach. Darrow, 1950
T	R		Lecidea icterica (Mont.) Tayl.
	R		Lecidea nipponica Zahlbr.
	R	S	Lecidea nylanderi (Anzi) Th. Fr.
	R	I	Lecidea scalaris (Ach.) Ach.
	R		Lecidea tessellata Flörke
	R		Lecidea turgidula Fr.
	R		Lecidea xanthococca Somm.
			1 additional unidentified species of Lecidea
	R		Lecidella carpathica Körb.
	R		Lecidella euphorea (Flörke) Hert.
	R		Lecidella stigmatea (Ach.) Hert. & Leuck.
	R		Lempholemma cladodes (Tuck.) Zahlbr.
	R		Lepraria finkii (B. de Lesd. in Hue) R. Harris
	R		Lepraria lobificans (Hue) ined.
	R		Leprocaulon gracilescens (Nyl.) Lamb & Ward
	R		Leprocaulon microscopicum(Vill.) Gams in Hawksw. & Skin.
	R		Leptogium arsenei Sierk
	R		Leptogium denticulatum Tuck.
	R		Leptogium furfuraceum (Harm.) Sierk
	R		Leptogium saturninum (Dicks.) Nyl. Darrow, 1950
	R		Leptogium tenuissimum (Dicks.) Körb.
			1 additional unidentified species of Leptogium
	R		Lichenothelia scopularia (Nyl.) Hawksw.
T	R		Lichinella americana Henss.Henssen, 1968

T	R		*Lichinella stipatula* Nyl.
	R		*Micarea hedlundii* Coppins
	R		*Micarea prasina* Fr.
	R		*Mycocalicium subtile* (Pers.) Szat.
	R		*Nephroma helveticum* Ach. Wetmore, 1960
	R		*Nephroma parile* (Ach.) Ach.
	R		*Normandina pulchella* (Borr.) Nyl.
	R	S	*Ochrolechia androgyna* (Hoffm.) Arn.
	R	S	*Ochrolechia rosella* (Müll. Arg.) Vers.
			1 additional unidentified species of *Ochrolechia*
	R		*Pachyospora verrucosa* (Ach.) Mass.
	R		*Pannaria conoplea* (Ach.) Bory
	R		*Pannaria leucophaea* (Vahl) P. M. Jorg.
	R		*Parmelia atticoides* Essl. Esslinger, 1977
	R		*Parmelia brunella* Essl.
	R	I	*Parmelia caperata* (L.) Ach. Darrow, 1950
	R		*Parmelia cetrata* Ach.
	R		*Parmelia conspersa* (Ehrh. ex Ach.) Ach. Fink, 1909, Hale, 1955a, Nash, 1974b
	R		*Parmelia coronata* Ach.
	R		*Parmelia cumberlandia* (Gyeln.) Hale Nash, 1974b
T	R		*Parmelia dierythra* Hale Nash, 1974b
	R		*Parmelia disjuncta* Erichs. Esslinger, 1977
	R		*Parmelia flaventior* Stirt.
	R	I	*Parmelia glabratula* Lamy
T			*Parmelia huachucensis* Nash Nash, 1974b
	R		*Parmelia hypoleucites* Nyl.
T			*Parmelia kurokawae* Hale Nash, 1973, 1974b
	R		*Parmelia infumata* Nyl.
T	R		*Parmelia lineola* Berry Nash, 1974b
T			*Parmelia mexicana* Gyeln. Nash, 1973, 1974b
	R		*Parmelia novomexicana* Gyeln. Nash, 1974b
	R		*Parmelia praesignis* Nyl. Berry, 1941, Darrow, 1950
T	R		*Parmelia psoromifera* Kurok. ex Hale Nash, 1974b
	R	I	*Parmelia saxatilis* (L.) Ach.
	R		*Parmelia soredica* Nyl.
	R		*Parmelia somediosa* Almb.
	R	I-T	*Parmelia subargentifera* Nyl. Esslinger, 1977
	R		*Parmelia subolivacea* Nyl. in Hasse Darrow, 1950, Ahti, 1966, Esslinger, 1977
	R	I	*Parmelia subrudecta* Nyl. Darrow, 1950
	R		*Parmelia substygia* Räs. Esslinger, 1977
	R	I-T	*Parmelia sulcata* Tayl. Darrow, 1950
	R		*Parmelia taractica* Kremp. Nash, 1974b
			3 additional unidentified species of *Parmelia*
T	R		*Parmelia weberi* Hale Hale, 1971, Nash, 1974b
	R	I	*Parmeliopsis aleurites* (Ach.) Nyl.
	R	I	*Parmeliopsis ambigua* (Wulf.) Nyl.
	R	I	*Parmeliopsis hyperopta* (Ach.) Arn.
T			*Peccania subnigra* (B. de Lesd.) Wetm.
	R		*Peltigera collina* (Ach.) Schrad. Nash, 1973
	R		*Peltigera didactyla* (With.) Laund.
	R		*Peltigera elisabethae* Gyeln.

	R		*Peltigera membranacea* (Ach.) Nyl. Thomson, 1950
	R		*Peltigera polydactyla* (Neck.) Hoffm.
	R		*Peltigera praetextata* (Flörke ex Somm.) Zopf
	R		*Peltigera scabrosa* Th. Fr.
T			*Peltula bolanderi* (Tuck.) Wetm.
T	R		*Peltula euploca* (Ach.) Ozenda & Clauz. Wetmore, 1970
T			*Peltula obscurans* (Nyl.) Gyeln. var. *desertericola* (Zahlbr.) Wetm. Wetmore, 1970
T			*Peltula obscurans* var. *hassei* (Zahlbr.) Wetm. Wetmore, 1970
T	R		*Peltula obscurans* var. *obscurans* Zahlbruckner, 1908, Fink, 1909, Wetmore, 1970
T			*Peltula omphaliza* (Nyl.) Wetm. Wetmore, 1970
T			*Peltula placodizans* (Zahlbr.) Wetm. Zahlbruckner, 1908, Fink, 1909, Wetmore, 1970
T	R		*Peltula polyspora* (Herre) Wetm. Wetmore, 1970
			3 additional unidentified species of *Peltula*
	R		*Pertusaria arizonica* Dibb.
	R		*Pertusaria saximontana* Wetm.
			1 additional unidentified species of *Pertusaria*
	R		*Phaeocalicium polyporaeum* (Nyl.) Tibell
T			*Phaeophyscia cernohorskyi* (Nadv.) Essl.
	R		*Phaeophyscia ciliata* (Hoffm.) Moberg Darrow, 1950
T	R		*Phaeophyscia hirsuta* (Meresch.) Moberg
	R		*Phaeohyscia hispidula* (Ach.) Moberg Thomson, 1963, Esslinger, 1978
T	R	I-T	*Phaeophyscia nigricans* (Flörke) Moberg
	R	I	*Phaeohyscia orbicularis* (Neck.) Moberg Darrow, 1950, Thomson, 1963
	R		*Phaeohyscia sciastra* (Ach.) Moberg
	R	I	*Physcia aipolia* (Ehrh. ex Humb.) Furnrohr
	R		*Physcia albinea* (Ach.) Nyl.
	R		*Physcia biziana* (Mass.) Zahlbr.
	R		*Physcia caesia* (Hoffm.) Furnrohr
	R		*Physcia callosa* Nyl. Thomson, 1963
	R		*Physcia mexicana* B. de Lesd.
	R		*Physcia phaea* (Tuck.) Thoms.
T	R	I	*Physcia stellaris* (L.) Nyl. Darrow, 1950, Thomson, 1963
			1 additional unidentified species of *Physcia*
	R	I	*Physconia detersa* (Nyl.) Poelt Thomson, 1963
	R	I	*Physconia distorta* (With.) Laund. Thomson, 1963
	R		*Physconia enteroxantha* (Nyl.) Poelt
	R		*Placynthiella icmalea* (Ach.) Coppins & James
T	R		*Polysporina simplex* (Dav.) Vezda
	R		*Pseudevernia intensa* (Nyl.) Hale & W. Culb. Berry, 1941 Hale
	R	S	*Ramalina pollinaria* (Westr.) Ach.
	R		*Ramalina sinensis* Jatta
	R		*Rhizocarpon disporum* (Naeg. ex Hepp) Müll. Arg. Rudolph, 1953
	R		*Rhizocarpon geographicum* (L.) DC
	R		*Rhizocarpon lecanorinum* Anders
T	R		*Rhizoplaca chrysoleuca* (Sm.) Zopf.

T R Rhizoplaca melanophthalma (DC in Lam & DC) Leuck. & Poelt
R Rinodina applanata Magn.
R Rinodina confragosa (Ach.) Körb.
T Rinodina conradii Körb.
R I Rinodina exigua (Ach.) S. Gray Darrow, 1950
R Rinodina pachysperma Magn.
R Rinodina subminuta Magn.
R Rinodina verrucosa Sheard
4 additional unidentified species of Rinodina
R Sarcogyne clavus (DC in Lam. & DC) Kremp.
R Sarcogyne dakotensis Magn.
T R Sarcogyne privigna (Ach.) Mass.
T Sarcogyne regularis Körb.
R Staurothele fissa (Tayl.) Zw.
R Staurothele fuscocuprea (Nyl.) Zsch.
R Sticta fuliginosa (Hoffm.) Ach. Nash, 1973
R Thyrea nigritella Lett.
R Umbilicaria deusta (L.) Baumg.
R Umbilicaria phaea Tuck.
R Umbilicaria torrefacta (Lightf.) Schrad.
R Umbilicaria vellea (L.) Ach. Llano, 1950
R Usnea cavernosa Tuck.
R S Usnea florida (L.) Web. in Wigg.
R S-I Usnea hirta (L.) Web. in Wigg.
R Usnea lapponica Vain. Darrow, 1950
R S-I Usnea subfloridana Stirt.
R Usnea tristis Mot.
1 additional unidentified species of Usnea
1 unidentified species of Verrucaria
R S-I Xanthoria fallax (Hepp) Arn. Darrow, 1950
R I Xanthoria polycarpa (Hoffm.) Rieber Darrow, 1950
R Xanthoria trachyphylla (Tuck.) ined.
R Xylographa abietina (Pers.) Zahlbr.
R Xylographa vitiligo (Ach.) Laund.

The following list include species reported for Pima County in the literature but not collected during this study in Saguaro NM. They may never have occurred in the park or may be based on different interpretations of the species.

Acarospora cargnegiei Zahlbr. Zahlbruckner, 1908, Fink, 1909, Magnusson, 1929
[Acarospora cineracea (Nyl.) Wedd. Fink, 1909 - misident.]
Acarospora coloradiana Magn. Rudolph, 1953
Acarospora strigata (Nyl.) Jatta Fink, 1909
Acarospora tucsonensis Magn. Magnusson, 1929
Acarospora washingtoniensis Magn. Rudolph, 1953
Aspicilia contorta (Hoffm.) Kremp. Fink, 1909,

Rudolph, 1953
Buellia lepidastra (Tuck.) Tuck. Fink, 1909
[Buellia pullata Tuck. Nash, 1973 = punctata]
[Buellia zahlbruckneri J. Stein. = erubescens]
Caloplaca arizonica Magn. Darrow, 1950
Caloplaca cinnabarina (Ach.) Zahlbr. Fink, 1909
Caloplaca modesta (Zahlbr.) Fink Zahlbruckner, 1908, Fink, 1909, Rudolph, 1953
Caloplaca spaldingi Zahlbr. Zahlbruckner, 1909
Catillaria globulosa (Flörke) Th. Fr. Darrow, 1950
Chaenotheca chrysocephala (Turn. ex Ach.) Th. Fr. Darrow, 1950
Cladonia cariosa (Ach.) Spreng. Darrow, 1950
Cladonia chlorophaea (Flörke ex Somm.) Spreng. Darrow, 1950
[Collema pycnocarpum Darrow, 1950, =conglomeratum v. crassiusculum]
Collema texanum Tuck. Nash & Weber, 1974
Dermatocarpon intestiniforme (Körb.) Hasse Rudolph, 1953
Dermatocarpon peltatum (Tayl.) Zahlbr. Fink, 1909
Dermatocarpon plumbeum (B. de Lesd.) Zahlbr. Nash, 1973
Dermatocarpon rupicola (B. de Lesd.) Zahlbr. Rudolph, 1953
[Endocarpon schaereri (Körb.) Fink Fink, 1909, misident. for pusillum]
Heterodermia galactophylla (Tuck.) W. Culb. Darrow, 1950
Heterodermia hypoleuca (Muehl.) Trev. Darrow, 1950
Lecanora argentata (Ach.) Malme Darrow, 1950
Lecanora badia (Hoffm.) Ach. Nash, 1973
Lecanora bipruinosa Fink Hedrick, 1934
Lecanora caesiorubella subsp. glaucomodes (Nyl.) Imsh. & Brodo Imshaug & Brodo, 1966
[Lecanora cancriformis (Hoffm.) Vain. misident. Darrow, 1950]
Lecanora melaena (Hedl.) Fink Rudolph, 1953
I [Lecanora pallida (Schreb.) Rabenh. misident. Darrow, 1950]
Lecanora rugosella Zahlbr. Nash, 1973
I Lecanora symmicta (Ach.) Ach. Darrow, 1950
Lecanora tesselina (Tuck.) Zahlbr. Nash & Weber, 1974
Lecanora varia (Hoffm.) Ach. Darrow, 1950
Leptogium apalachense (Tuck.) Nyl. Rudolph, 1953
Leptogium juniperinum Tuck. Zahlbruckner, 1908, Fink, 1909
[Massalongia microphylliza (Nyl. ex Hasse) Henss. misident. Rudolph, 1953]
Microthelia micula Körb. ex Körb. Darrow, 1950
Ochrolechia pallescens (L.) Mass. Darrow, 1950
Parmelia ajoensis Nash Nash, 1974a
[Parmelia arseneana Gyeln. Nash, 1974b, =

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novomexicana]
Parmelia bolliana Müll. Arg. Culberson & Culberson, 1956
Parmelia borreri (Sm.) Turn. Darrow, 1950
Parmelia darrowii Thoms. Darrow, 1950
Parmelia exasperata De Not. Darrow, 1950
Parmelia plittii Gyeln. Nash, 1974b
[Parmelia prolixa (Ach.) Carroll Darrow, 1950, = pulla]
Parmelia pulla Ach. Darrow, 1950
Parmelia quercina (Will.) Vain. Darrow, 1950
Parmelia subdecipiens Vain. Nash, 1974b
Parmelia tinctina Mah. & Gill. Nash, 1974b
Parmelia tucsonensis Nash Nash, 1974a
[Parmelia ulophyllodes (Vain.) Sav. = soredica]
Peltigera rufescens Thoms. 1950
Peltula richardsii (Herre) Wetm. Wetmore, 1970
Peltula zahlbruckneri Hasse) Wetm. Nash, 1973
[Pertusaria granulata (Ach.) Müll. Arg. Darrow, 1950, = wulfenioides]
I Pertusaria hymenea (Ach.) Schaer. Darrow, 1950
Pertusaria wulfenioides B. de Lesd. Darrow, 1950
Physcia halei Thoms. Thomson, 1963
[Physconia pulverulenta Poelt Thomson, 1963, = distorta]
[Placynthium microphyllizum (Nyl.) Hasse Rudolph, 1953 = Massalongia microphylliza (Nyl. ex Hasse) Henss.]
Polyblastiopsis lactea (Mass.) Zahlbr. Darrow, 1950
(1941, Darrow, 1950, Hale, 1955b)
Psorotichia schaereri (Mass.) Arn. Fink, 1909
S Ramalina fraxinea (L.) Ach. Darrow, 1950
Rhizocarpon badioatrum (Flörke ex Spreng.) Th. Fr. Nash, 1973
Rhizocarpon grande (Flörke ex Flot.) Arn. Nash, 1973
Rinodina darrovii Rud. Rudolph, 1953
Rinodina laevigata (Ach.) Malme Darrow, 1950
[Rinodina sophodes (Ach.) Mass. misident. Darrow, 1950]
Sarcogyne novomexicana Magn. Nash, 1973
Umbilicaria cinereorufescens (Schaer.) Frey Llano, 1950
Usnea aculeata Mot. Darrow, 1950
Usnea arizonica Mot. Motyka, 1936-38, Darrow, 1950
Usnea erinacea Vain. Darrow, 1950
Usnea mutabilis Stirt. Darrow, 1950
S Usnea variolosa Mot. Darrow, 1950
Verrucaria fuscella (Turn.) Winch Fink, 1909, Rudolph, 1953
Verrucaria nigrescens Pers. Fink, 1909
Xanthoria elegans (Link) Th. Fr. Fink, 1909
Xanthoria lobulata (Flörke) B. de Lesd. Zahlbruckner, 1908, Fink, 1909, Rudolph, 1953

DISCUSSION OF FLORA

This list includes 250 species collected for this study in both sections of the park. There were 65 species found in the Tucson Mt. Section and 223 species found in the Rincon Mt. Section and 38 species were common to both sections. There are an additional 37 unidentified species.

Because of the dry climate in the park the lichen flora is not particularly rich but there are some localities with microhabitats suitable for the lichens requiring more moisture. The higher elevations of the Rincons, especially on the north slope, provide much wetter conditions than the lower Tucson Mt. Section and this accounts for the larger number of species in the Rincons. The lack of most calcareous substrates further limits the numbers of species present. The large number of species not found in this study but reported for the area are because several of them were described from the area and are synonyms of other species or have never been collected since by anyone. Although there is little historical information available for the park the lichen flora is probably comparable with other areas with similar climate.

This list of species includes many new records for the park. There are still some unidentified specimens and some of these may be undescribed. The most common species are: Pseudevernia intensa, Usnea species and several species of Parmelia on the trees and numerous species of Acarospora, Sarcogyne, Peltula and Caloplaca on the rocks.

There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the park. These observations indicate that there is no air quality degradation in the park due to sulfur dioxide that causes observable damage to the lichen flora.

Since lichens are not known to be sensitive to acid precipitation, no conclusions can be drawn about this environmental contaminant. However, preliminary reports indicate that some species of Umbilicaria do show damage from acid precipitation by dying at the margins (Sigal & Johnston, 1986). No specimens of these lichens were seen in the park with dead margins that might be due to acid rain.

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

There are only a few lichens in the park with known sensitivity to sulfur dioxide according to the list presented in Wetmore (1983) and most of these are not very common and occur only in the Rincon Section. Species in the most sensitive category [S] are usually absent when sulfur dioxide levels are above 50ug per cubic meter average annual concentrations. The species that occur in the park in this category are as follows.

	Number of collections
Lecidea nylanderi (Anzi) Th. Fr.	1
Ochrolechia androgyna (Hoffm.) Arn.	1
Ochrolechia rosella (Müll. Arg.) Vers.	2
Ramalina pollinaria (Westr.) Ach.	5
Usnea florida (L.) Web.	1

The distributions of these species are shown in Fig. 2-6. Although these species are not found at all localities and many are quite rare, there is no indication that the voids in the distributions are due to poor air quality. Some of the localities where collections were made do not have suitable habitats for some of these species.

ELEMENTAL ANALYSIS

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

METHODS

Lichen samples of two species were collected in spunbound olefin bags at six localities in different parts of the park for laboratory analysis. Species collected and the substrates were Pseudevernia intensa (on conifer trees) and Usnea tristis (on conifer trees). In Chircahua National Monument Pseudevernia intensa was only present at one locality but Parmelia hypoleucites was collected at three localities. These species were selected because they are the only ones present in abundance and relatively easy to clean. None of these species was present in the Tucson Mt. Section of Saguaro NM and no other suitable lichen was present for elemental analysis either.

Six localities were selected to represent the geographical extremes of Saguaro and are indicated on the map of collection localities. These localities are: just west of Italian Spring (8100 ft.); Spud Rock (8000 ft.); west of Manning Camp (7800 ft.); Devils Bathtub Spring (7300 ft.) on two different trees; half mile west of Helens Dome (7800 ft.) at the edge of the cliff and also back from the edge; and on the north slope of Rincon Peak (7400 ft.). In Chiricahua the localities were at 6300 ft. in Upper Bonita Canyon; at 5800 ft. in Bonita Canyon across from the campground; and at 5400 ft. in lower Ryolite Canyon. A ten to 20 gram sample of each species was collected at each locality.

Lichens were air dried and cleaned of all bark under a dissecting microscope but thalli were not washed. Three replicate samples from each collection bag were submitted for analysis. One of the collections from Devils Bathtub was ground before splitting to provide an analytical check and this is indicated with a @ in the tables. The collections of _Parmelia hypoleucites_ from Upper Bonita Canyon and Ryolite Canyon in the Chiricahuas were only adequate for two replicate samples.

Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and B were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Celsius for 10-12 hours. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. If the reported values of an element in a sample were at or below the detection limits adjustments were made before determining the means. If only one value was below the detection limit the value was included as 0.7 of the detection limit, if two or more values were below the detection limit no calculations were done for this element.

All of the levels found in the lichens are within typical

Table 1. Analysis of Saguaro Lichens
Values in ppm of thallus

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
P. intensa	936	3365	4536	402	584	411	63.8	29.5	23.3	23.1	3.3	16.8	0.5	0.4	0.6	1360	Ital. Spring
P. intensa	960	3418	5001	407	609	432	61.2	30.6	23.2	24.0	3.3	16.8	0.4	0.4	0.6	1320	Ital. Spring
P. intensa	933	3415	3803	398	545	386	61.4	29.6	24.4	23.5	3.1	14.1	0.4	0.3	0.6	1490	Ital. Spring
P. intensa	939	3789	5606	466	593	393	53.7	46.9	24.9	22.9	3.2	20.3	0.3	0.4	0.6	1750	Spud Rock
P. intensa	1122	4002	6944	480	579	383	53.6	45.7	25.5	22.3	3.2	18.6	<.2	0.4	0.7	1600	Spud Rock
P. intensa	933	3815	5746	473	611	408	52.4	43.9	24.4	22.1	2.9	19.9	0.4	0.4	0.7	1710	Spud Rock
P. intensa	981	3335	4624	452	518	383	53.0	37.2	25.0	19.0	2.9	12.0	0.5	0.3	0.5	1390	Manning Camp
P. intensa	729	2768	3366	381	403	312	54.5	31.3	21.6	16.4	2.8	11.9	1.1	0.7	0.5	1550	Manning Camp
P. intensa	902	3320	4059	430	417	307	59.5	37.5	24.3	18.1	3.2	12.4	0.5	0.5	0.6	1390	Manning Camp
P. intensa	660	2897	4161	386	348	242	64.2	19.3	23.3	12.3	2.8	13.3	0.6	0.3	0.7	1510	Devils Bathtub
P. intensa	644	2797	4321	371	424	300	63.8	19.2	24.3	13.8	3.4	13.9	0.4	0.3	0.7	1460	Devils Bathtub
P. intensa	585	2761	4160	395	510	360	59.0	19.4	24.6	14.6	2.7	15.4	<.2	0.3	0.6	1600	Devils Bathtub
P. intensa	582	2733	5218	367	473	334	64.6	19.8	23.5	16.1	2.1	18.5	0.5	0.4	0.8	1360	@ Devils Bathtub
P. intensa	507	2555	6222	355	495	348	64.5	19.5	22.1	16.1	1.9	18.9	0.3	0.3	0.7	1260	@ Devils Bathtub
P. intensa	549	2682	4871	371	514	372	67.5	19.5	22.8	16.8	2.2	19.2	<.2	0.4	0.6	1180	@ Devils Bathtub
P. intensa	550	2634	5913	368	531	387	67.6	20.3	22.7	17.3	2.2	19.5	0.3	0.4	0.7	1140	@ Devils Bathtub
P. intensa	565	2677	5042	371	509	376	67.8	19.6	23.0	17.2	2.2	19.1	0.6	0.5	0.8	1220	@ Devils Bathtub
P. intensa	552	2671	5578	368	501	357	68.1	19.8	23.0	17.2	2.1	18.6	0.6	0.6	0.8	1270	@ Devils Bathtub
P. intensa	659	3154	2240	475	624	435	84.9	36.7	29.9	19.8	2.9	15.2	<.2	0.4	0.4	1710	W H Dome edge
P. intensa	651	3167	1831	493	699	497	96.6	36.3	30.5	22.4	3.3	15.2	0.5	0.6	0.4	1760	W H Dome edge
P. intensa	611	3028	1502	408	520	373	83.1	28.7	30.5	19.9	2.8	13.6	0.3	0.3	0.5	1700	W H Dome edge
P. intensa	637	3094	4310	449	523	357	82.1	32.4	29.5	17.7	3.2	17.1	<.3	0.2	0.6	1750	W H Dome back
P. intensa	588	3015	4559	454	606	417	82.3	32.3	29.2	19.2	2.9	18.9	<.3	0.4	0.6	1830	W H Dome back
P. intensa	603	3029	4610	471	681	472	87.7	33.4	29.1	20.0	3.1	19.9	<.3	0.5	0.6	1740	W H Dome back
P. intensa	662	3058	3083	439	501	349	86.1	21.9	24.2	15.4	2.7	20.1	0.3	0.3	0.8	1620	Rincon Peak
P. intensa	638	3039	2792	439	490	341	83.7	21.8	23.3	15.7	2.3	21.3	0.3	0.3	0.9	1630	Rincon Peak
P. intensa	679	3014	3383	427	502	351	85.2	21.1	23.6	15.8	2.7	21.3	0.3	0.5	0.8	1700	Rincon Peak
U. tristis	1943	4071	2547	478	406	252	75.8	40.6	22.4	13.0	1.9	6.1	<.3	0.4	0.5	1430	Ital. Spring
U. tristis	1739	3994	2642	467	395	247	78.7	41.0	23.1	13.6	1.9	6.5	<.3	0.4	0.6	1220	Ital. Spring
U. tristis	1320	3664	2418	448	497	319	73.9	36.2	20.9	15.8	2.1	9.6	<.3	0.4	0.7	1240	Ital. Spring
U. tristis	913	3583	3169	521	629	395	72.2	50.7	28.7	17.4	2.4	11.1	<.3	1.0	0.7	1620	Spud Rock
U. tristis	854	3396	4286	497	588	367	74.3	48.4	26.4	16.8	2.3	13.2	<.3	0.7	0.6	1630	Spud Rock
U. tristis	803	3429	3454	534	830	534	80.6	45.8	28.1	21.4	2.7	15.6	0.5	0.9	0.7	1750	Spud Rock
U. tristis	638	3380	7275	700	327	190	85.7	79.4	30.6	11.2	2.4	15.7	0.3	0.3	0.8	1170	Manning Camp
U. tristis	554	2853	5875	614	243	139	69.9	71.5	27.4	8.6	1.8	13.7	0.4	0.2	0.7	1060	Manning Camp
U. tristis	588	2714	5490	586	204	119	68.7	69.4	25.2	7.8	1.5	12.2	<.2	0.2	0.7	1120	Manning Camp
U. tristis	518	2682	7672	473	784	502	123.0	40.2	25.6	16.9	2.8	20.5	<.2	0.7	0.7	1840	W H Dome back
U. tristis	547	2646	4494	518	850	562	117.3	43.1	28.6	18.2	3.1	18.5	0.4	1.0	0.6	1930	W H Dome back
U. tristis	528	2634	5147	531	965	653	124.6	43.4	29.4	19.0	3.1	19.0	1.0	1.0	0.7	1720	W H Dome back
U. tristis	577	2729	2472	557	864	592	143.2	31.0	26.2	17.5	2.9	21.2	0.5	1.0	0.8	1890	Rincon Peak
U. tristis	571	2655	3791	569	932	658	148.0	30.9	25.8	17.5	3.1	19.4	0.8	1.0	0.9	1760	Rincon Peak
U. tristis	561	2640	3692	551	858	601	147.6	30.8	25.5	16.5	3.0	20.1	<.2	0.8	0.8	1420	Rincon Peak

Analysis of Chiricahua Lichens

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
P. intensa	839	3527	2637	547	1129	826	92.1	19.5	39.0	45.7	2.7	30.7	0.6	0.8	1.9	2110	Chir U Bonita
P. intensa	867	3477	2338	539	1121	820	96.5	19.3	38.8	44.2	2.9	29.7	<.2	0.8	2.0	2270	Chir U Bonita
P. intensa	864	3671	2568	501	943	663	91.6	18.1	36.8	42.3	2.7	27.0	0.7	0.6	2.1	2070	Chir U Bonita
P. hypoleucites	1256	4073	28800	573	1280	780	53.4	151.2	31.5	26.4	2.0	13.6	<.2	0.7	1.7	1110	Chir U Bonita
P. hypoleucites	1357	4144	29611	613	1409	862	59.4	163.2	33.2	29.1	2.2	15.0	0.8	1.0	1.8	1380	Chir U Bonita
P. hypoleucites	1378	4253	51821	690	1261	760	62.4	164.5	31.9	26.3	2.9	15.2	1.1	0.9	1.8	1440	Chir CG
P. hypoleucites	1376	4242	53246	746	1524	929	73.9	171.8	33.9	29.8	3.2	15.6	1.0	1.0	1.9	1440	Chir CG
P. hypoleucites	1426	4380	50348	774	1572	971	74.1	170.7	35.0	30.4	3.4	15.4	1.5	1.1	1.8	1380	Chir CG
P. hypoleucites	1109	3845	49030	643	1219	754	51.6	200.1	24.0	22.0	2.9	13.0	0.5	0.8	1.3	1230	Chir Ryolite Can
P. hypoleucites	1131	3868	46864	610	1093	675	46.2	176.1	23.3	21.7	3.0	13.1	0.4	0.7	1.5	1160	Chir Ryolite Can

@= analytical split replicates

Table 2. Summary of Analysis of Saguaro Lichens
Values in ppm of thallus

<u>Pseudevernia intensa</u>

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	943	3399	4447	402	579	410	62.1	29.9	23.6	23.6	3.3	15.9	0.4	0.4	0.6	1390	Ital. Spring
Std. dev.	15	30	604	4	32	23	1.4	0.6	0.7	0.5	0.1	1.6	0.1	<.1	<.1	89	Ital. Spring
Mean	998	3869	6099	473	594	395	53.2	45.5	24.9	22.5	3.1	19.6	0.3*	0.4	0.7	1687	Spud Rock
Std. dev.	108	117	735	7	16	13	0.7	1.5	0.5	0.4	0.2	0.9	0.1	<.1	<.1	78	Spud Rock
Mean	871	3141	4017	421	446	334	55.6	35.3	23.6	17.8	3.0	12.1	0.7	0.5	0.5	1443	Manning Camp
Std. dev.	129	323	630	37	63	43	3.4	3.5	1.7	1.3	0.2	0.2	0.3	0.2	<.1	92	Manning Camp
Mean	629	2818	4214	384	427	301	62.3	19.3	24.0	13.6	3.0	14.2	0.4*	0.3	0.7	1523	Devils Bathtub
Std. dev.	40	70	92	12	81	59	2.9	0.1	0.7	1.2	0.4	1.1	0.2	<.1	<.1	71	Devils Bathtub
Mean	546	2657	5437	364	494	351	65.5	19.6	22.8	16.3	2.1	18.9	0.3*	0.4	0.7	1267	@ Devils Bathtub
Std. dev.	37	92	701	9	20	19	1.7	0.2	0.7	0.4	0.2	0.3	0.1	<.1	0.1	90	@ Devils Bathtub
Mean	556	2661	5511	369	514	373	67.9	19.9	22.9	17.2	2.2	19.1	0.5	0.5	0.7	1210	@ Devils Bathtub
Std. dev.	8	23	439	2	15	15	0.2	0.4	0.1	0.1	0.1	0.4	0.1	0.1	0.1	66	@ Devils Bathtub
Mean	640	3116	1857	459	614	435	88.2	33.9	30.3	20.7	3.0	14.6	0.3*	0.4	0.4	1723	W H Dome edge
Std. dev.	26	77	370	44	89	62	7.3	4.5	0.3	1.5	0.2	0.9	0.2	0.1	0.1	32	W H Dome edge
Mean	610	3046	4493	458	603	415	84.0	32.7	29.3	19.0	3.1	18.7	‡	0.4	0.6	1773	W H Dome back
Std. dev.	25	42	161	12	79	58	3.2	0.6	0.2	1.2	0.1	1.4	‡	0.1	<.1	49	W H Dome back
Mean	659	3037	3086	435	498	347	85.0	21.6	23.7	15.6	2.6	20.9	0.3	0.4	0.8	1650	Rincon Peak
Std. dev.	21	22	296	7	7	5	1.2	0.5	0.5	0.2	0.2	0.7	<.1	0.2	<.1	44	Rincon Peak

<u>Usnea tristis</u>

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	1667	3910	2536	464	433	273	76.1	39.3	22.1	14.1	2.0	7.4	‡	0.4	0.6	1297	Ital Spr
Std. dev.	318	216	112	15	56	40	2.4	2.7	1.1	1.5	0.1	1.9	‡	<.1	0.1	116	Ital Spr
Mean	857	3469	3636	517	682	432	75.7	48.3	27.7	18.5	2.5	13.3	‡	0.9	0.7	1667	Spud Rk
Std. dev.	55	99	581	19	130	89	4.3	2.5	1.2	2.5	0.2	2.2	‡	0.1	0.1	72	Spud Rk
Mean	594	2982	6213	633	258	149	74.8	73.5	27.7	9.2	1.9	13.9	0.3*	0.2	0.7	1117	Manning C
Std. dev.	42	352	939	60	63	37	9.5	5.3	2.7	1.8	0.4	1.7	0.1	0.1	0.1	55	Manning C
Mean	531	2654	5771	507	867	572	121.6	42.2	27.9	18.0	3.0	19.3	0.5*	0.9	0.7	1830	W H Dome
Std. dev.	15	25	1678	30	91	76	3.8	1.8	2.0	1.1	0.2	1.0	0.4	0.2	<.1	105	W H Dome
Mean	569	2674	3318	559	885	617	146.3	30.9	25.8	17.2	3.0	20.2	0.5*	0.9	0.8	1690	Rincon Pk
Std. dev.	8	48	734	9	41	35	2.7	0.1	0.3	0.5	0.1	0.9	0.3	0.1	0.1	243	Rincon Pk

Summary of Analysis of Chiricahua Lichens

<u>Pseudevernia intensa</u>

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	857	3558	2514	529	1064	769	93.4	19.0	38.2	44.1	2.8	29.1	0.5*	0.7	2.0	2150	U Bonita Can
Std. dev.	15	101	157	25	105	92	2.7	0.7	1.2	1.7	0.1	1.9	0.3	0.1	0.1	106	U Bonita Can

<u>Parmelia hypoleucites</u>

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	1306	4108	29206	593	1344	821	56.4	157.2	32.3	27.7	2.1	14.3	0.5	0.8	1.8	1245	U Bonita Can
Std. dev.	71	50	573	28	91	59	4.3	8.5	1.2	1.8	0.2	1.0	0.4	0.2	0.1	191	U Bonita Can
Mean	1393	4292	51805	737	1452	887	70.1	169.0	33.6	28.8	3.2	15.4	1.2	1.0	1.8	1420	Campground
Std. dev.	28	76	1449	43	167	111	6.7	3.9	1.6	2.2	0.3	0.2	0.3	0.1	<.1	35	Campground
Mean	1120	3856	47947	626	1156	715	48.9	188.1	23.7	21.8	3.0	13.0	0.5	0.8	1.4	1195	Ryolite Can
Std. dev.	16	16	1532	23	89	55	3.8	17.0	0.5	0.2	0.1	0.1	0.1	0.1	0.1	49	Ryolite Can

*= one value at or below detection limit; included as 0.7 of detection limit
‡= two or more values at or below detection limit; not included in calculations
@= analytical split replicates

limits for similar lichens although there are no literature reports on analyses of either of these species. All levels for sulfur in Saguaro are essentially the same. The Devils Bathtub analytical split shows the within-sample variation in the instrument. The levels for sulfur in Chiricahua at Upper Bonita Canyon for Pseudevernia intensa is significantly higher than for the same species in Saguaro. The sulfur levels for Parmelia hypoleucites at different localities in Chricahua are not significantly different but this species is probably a less sensitive accumulator than Pseudevernia. The sulfur levels in lichens tested range from 1117 to 2150 ppm for all samples and these values are near background levels as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980) for other species of lichens. Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. Different species may accumulate different amounts of elements so comparisons are only valid within one species.

Of the other elements, none of the readings in Saguaro are much different at the different localities. In the Chiricahua Mts. Pseudevernia intensa shows significantly higher levels of aluminum, iron, copper, cadmium and maybe zinc. Usnea tristis shows somewhat higher levels of aluminum at Helens Dome and Rincon Peak in Saguaro.

There is obviously some air pollution getting into

Chiricahua NM and the elevated levels correspond with the probable effluents from mining activities south of the park. No significant elevation of any elements are detectable in Saguaro NM.

CONCLUSIONS

<u>SAGUARO NM</u>. There is no indication that the lichens of Saguaro National Monument are being damaged by air quality. The lichen flora is reasonably diverse for such a dry area and there is no impoverishment of the lichen flora in any part of either section of the park. The large difference in numbers of species between the two sections is due to moisture conditions. There are only a few species with known sensitivies to sulfur dioxide in the park and those that are most sensitive are quite rare. This rarity seems to be due more to ecological and climatic conditions than pollution since these species are quite healthy when present. The maps of the distributions of the more sensitive species do not show any significant voids that are not due to normal ecological conditions. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The elemental analyses do not show abnormal accumulations of polluting elements at any locality.

<u>CHIRICAHUA NM</u>. Only elemental analysis was done in this park and this shows detectable air pollution even at the higher elevations where pollution is less. No statement can be made about distributions or other absence of species because these parts of the study were not done there.

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APPENDIX I

Collection Localities

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

Pima County, Arizona, Rincon Mt. Section

54359- 54414 Reef Rock. Just NE of overlook around rock ledges and in pine forest on SE facing slope, elev. 8200 ft. 13 June 1986.

54415- 54454 NW side of Mica Mountain in douglasfir and pine forest, elev. 8600 ft. 13 June 1986.

54455- 54525 North of Spud Rock in upper Joaquin Canyon. In valley with some water, douglasfir and pines, elev. 8000 ft. 14 June 1986. [Elemental analysis locality]

54526- 54571 Helens Dome, around rocks at top and in pine forest, elev. 8200 ft. 14 June 1986. [elemental analysis locality 0.5 miles west of this locality]

54572- 54625 Below Manning Camp. Along stream south of cabin with water, ponderosa pines and oaks, elev. 7800 ft. 15 June 1986.

54626- 54652 Deerhead Spring. On east facing slope near water in oak woodland with some pines, elev. 7100 ft. 16 June 1986.

54653- 54726 On cliff edge south of Man Head. Rocky ridgetop and pine-oak vegetation back from edge, elev. 8100 ft. 16 June 1986.

54727- 54749 Heartbreak Ridge 1 mile N of Happy Valley Lookout. On east facing slope in oak-juniper area with few pines, elev. 7200 ft. 17 June 1986.

54750- 54796 Devils Bathtub Spring. Below falls in valley with pines and rocky slope with oaks, elev. 7300 ft. 17 June 1986. [Elemental analysis locality]

54797- 54861 West of Mica Meadow, N of Duckbill. In valley with water and quaking aspen and pines, elev. 8000 ft. 18 June 1986.

54862- 54905 Cow Head Saddle. On north slope along valley with junipers, oaks and pinyon pine, elev. 6100 ft. 19 June 1986.

54906- Between Helens Dome and Cow Head Saddle on point
54950 extending north from ridge. On ridgetop with ponderosa pines and oaks, elev. 7200 ft. 19 June 1986.

54951- West of Manning Camp. Along ridges and valley with
54989 white pine, ponderosa pine and oaks, elev. 7800 ft. 20 June 1986. [Elemental analysis locality]

54990- North slope of Mica Mt. one quarter mile W of Italian
55049 Spring. Along stream in valley with douglasfir and pine, elev. 8100 ft. 21 June 1986. [Elemental analysis locality]

55050- Below Mica Secondary on East Slope Trail 1 mile E of
55091 Mica Mt. On ridge with oaks, ponderosa pine with juniper and few douglasfir, elev. 7500 ft. 22 June 1986.

55092- 1.5 miles NE of Grass Shack along trail from Madrona
55142 Ranger Station. In oak, pinyon pine and manzanita on ridgetop, elev. 6500 ft. 24 June 1986.

55143- Rincon Peak. On north side of peak in ponderosa pines,
55195 pinyon pines and juniper, elev. 7400 ft. 25 June 1986. [Elemental analysis locality]

55196- 1 mile SW of Happy Valley Saddle on west slope. Near
55211 rocky point along trail to Madrona Ranger Station in oaks, juniper and manzanita, elev. 5600 ft. 26 June 1986.

55212- At east end of Speedway Road at north boundary of park.
55226 On level area and along washes with mesquite, cactus, creosote bush and saguaro, elev. 2800 ft. 28 June 1986.

55227- East of picnic area 1.5 miles SE of headquarters. On
55249 rocky hillside with mesquite, cactus and saguaro, elev. 3200 ft. 28 June 1986.

55250- 2 miles NE of headquarters on loop drive. On hill with
55262 mesquite, saguaro and cactus, elev. 3200 ft. 28 June 1986.

Pima County, Arizona, Tucson Mt. Section

55263- 1.25 miles north of visitor center along Hugh Norris
55292 Trail. In west facing valley in cactus scrub, elev. 2800 ft. 29 June 1986.

55293- 2 miles NW of visitor center across from Sus Picnic
55302 Area. On level outwash with cactus and scrub, elev. 2380 ft. 29 June 1986.

55303- Half mile NW of visitor center near old trail. In

55308 desert scrub and cactus on outwash plain, elev. 2500 ft. 29 June 1986.

55309- 2 miles south of Panther Peak, half mile SE of Cam Both
55322 Picnic Area. Along gulleys in cactus scrub, elev. 2580 ft. 29 June 1986.

55323- Apache Peak. On rocky east slopes and peak with
55344 mesquite, cactus and scrub, elev. 3000 ft. 30 June 1986.

55345- At north base of mountains on Sendero Esperanza Trail.
55355 Along ridges and washes with creosote, cactus and mesquite, elev. 3200 ft. 30 June 1986.

55356- 2 miles NW of Wasson Peak. Along outwash plain with
55361 mesquite, creosote and cactus, elev. 2840 ft. 30 June 1986.

55362- King Canyon. Along stream near picnic area and on
55396 ridges and north facing rocks in mesquite and cactus, elev. 3200 ft. 2 July 1986.

55397- 1.25 miles south of Avra. In level desert scrub with
55404 cactus, creosote, mesquite, elev. 2260 ft. 2 July 1986.

55405- 1.25 miles south of Panther Peak. Along ridges and
55425 washes near old miles with creosote, mesquite and cactus, elev. 2460 ft. 2 July 1986.

55426- Half mile east of visitor center on NW slope of Red
55442 Hills. Rocky north facing slope with cactus scrub, elev. 2700 ft. 3 July 1986.

55443- North of Signal Hill Picnic Area. On rocky ridges with
55467 cactus, mesquite and palo verde, elev. 2420 ft. 3 July 1986.

55468- Contzen Pass. Along north facing cliffs and sides of
55499 dry stream in cactus and scrub, elev. 2400 ft. 3 July 1986.

55500- Wasson Peak. On north side of peak among rocks and
55519 brush, elev. 4680 ft. 4 July 1986.

55520- Half mile NW of Sus Picnic Area. In gently sloping
55527 desert with cactus and scrub, elev. 2320 ft. 5 July 1986.

55528- Half mile west of Ezkiminzin Picnic Area. On NW facing
55549 slope on hill among rocks and cactus and scrub, elev. 2880 ft. 5 July 1986.

55550- Half mile east of Ezkiminzin Picnic Area. On rocky

55563 knoll with cactus and scrub and some creosote bush, elev. 3100 ft. 5 July 1986.

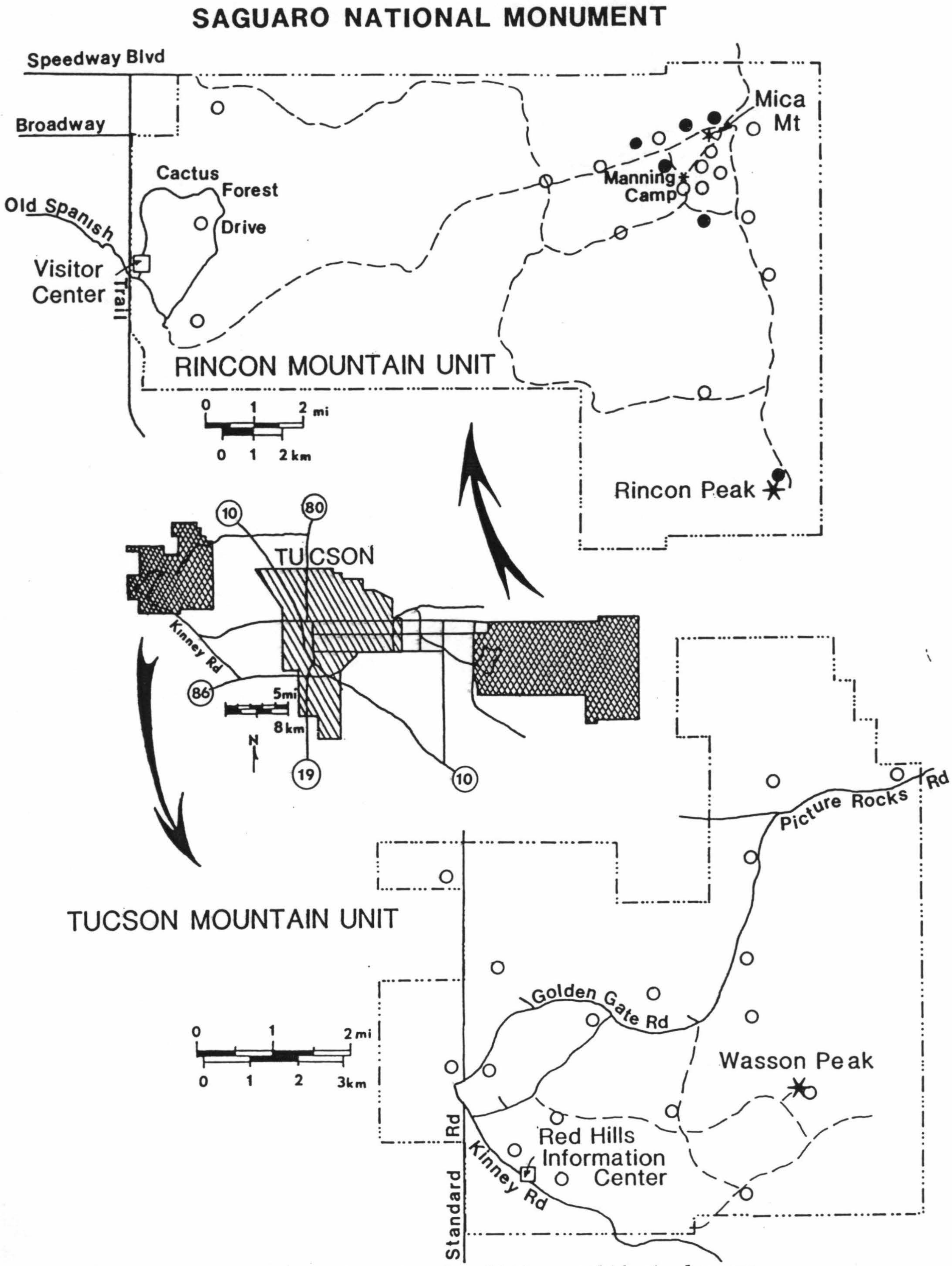

Fig. 1. Open circles are collection localities, solid circles are elemental analysis localities.

APPENDIX II

Species Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature, the following species in Saguaro National Monument fall within the Sensitive category as listed by Wetmore, 1983. Sensitive species (S) are those present only under 50ug sulfur dioxide per cubic meter (average annual). Open circles are localities where the species was not found and solid circles are where it was found.

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

All present only in Rincon Sect.

Fig. 2 *Lecidea nylanderi* (Anzi) Th. Fr.
Fig. 3 *Ochrolechia androgyna* (Hoffm.) Arn.
Fig. 4 *Ochrolechia rosella* (Müll. Arg.) Vers.
Fig. 5 *Ramalina pollinaria* (Westr.) Ach.
Fig. 6 *Usnea florida* (L.) Web.

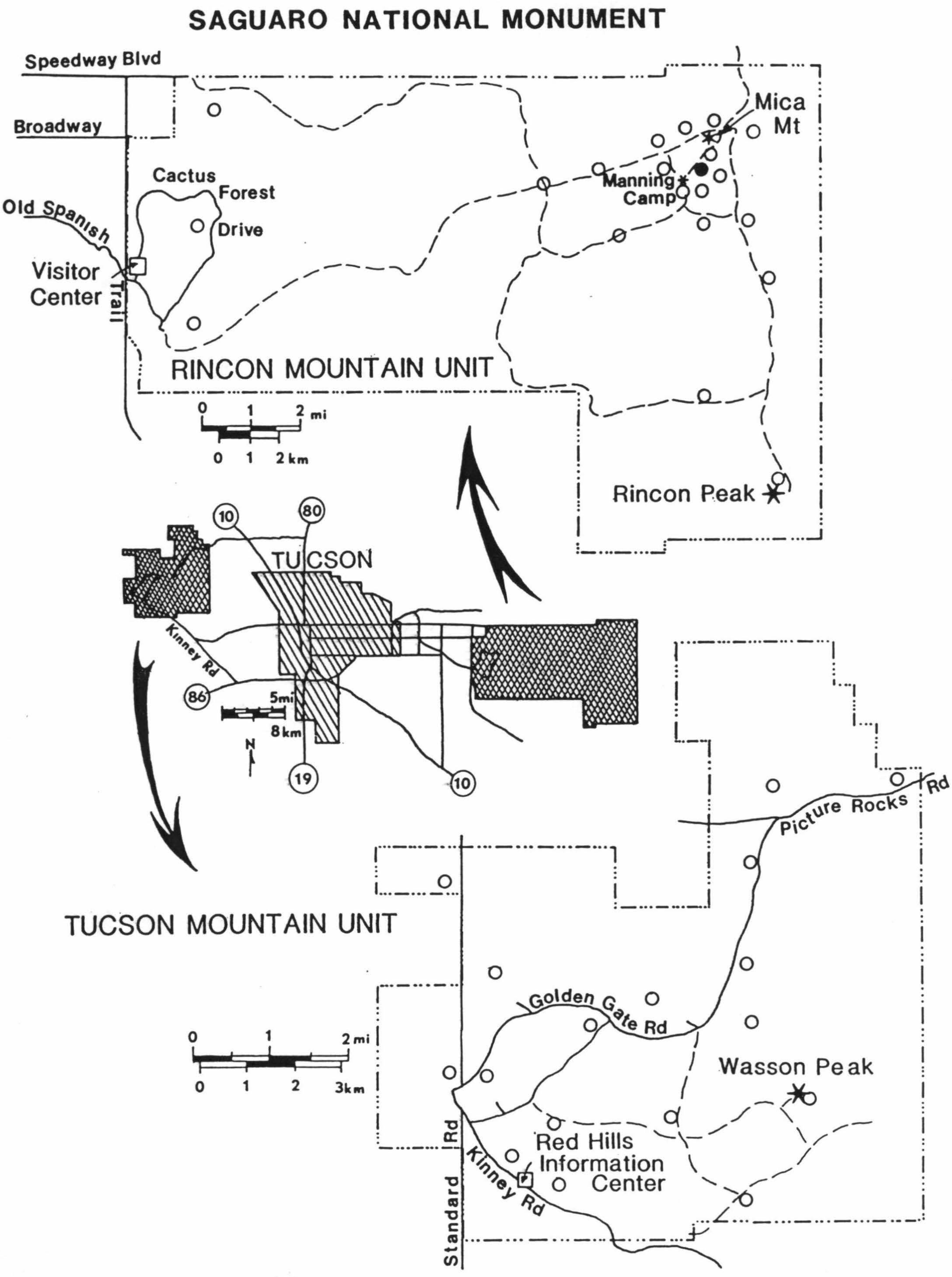

Fig. 2. Lecidea nylanderi (one locality)

SAGUARO NATIONAL MONUMENT

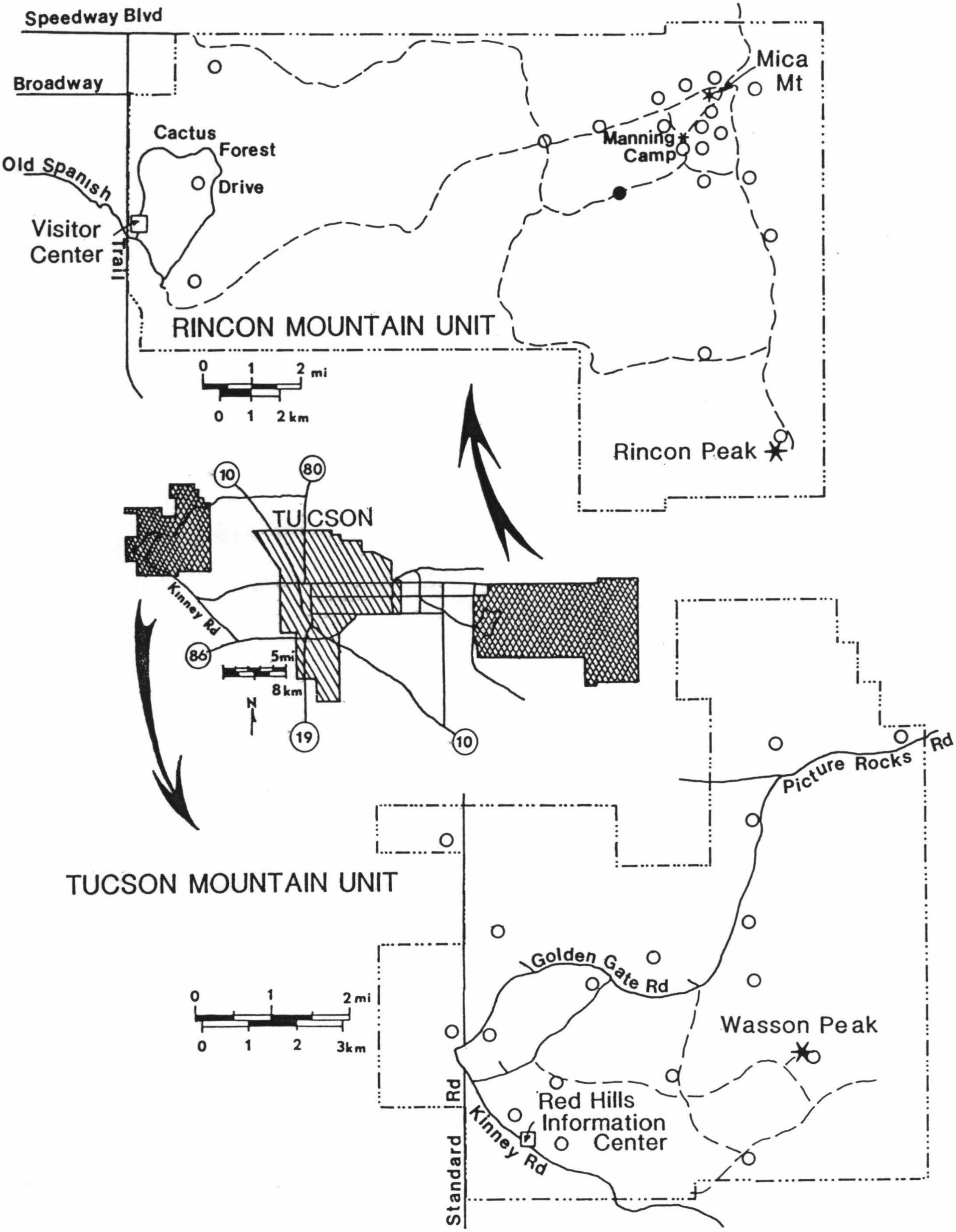

Fig. 3. Ochrolechia androgyna (one locality)

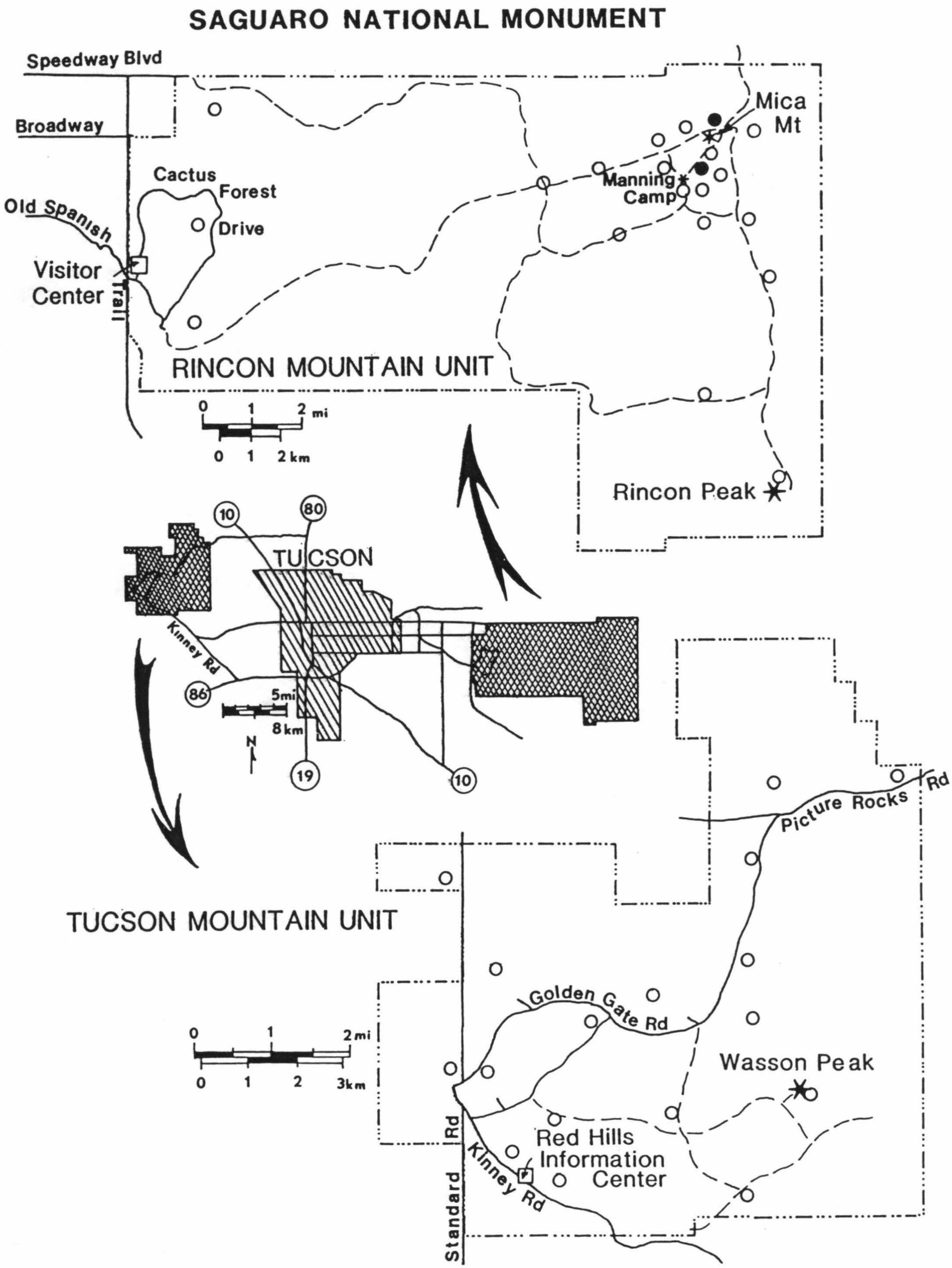

Fig. 4. Ochrolechia rosella (two localities)

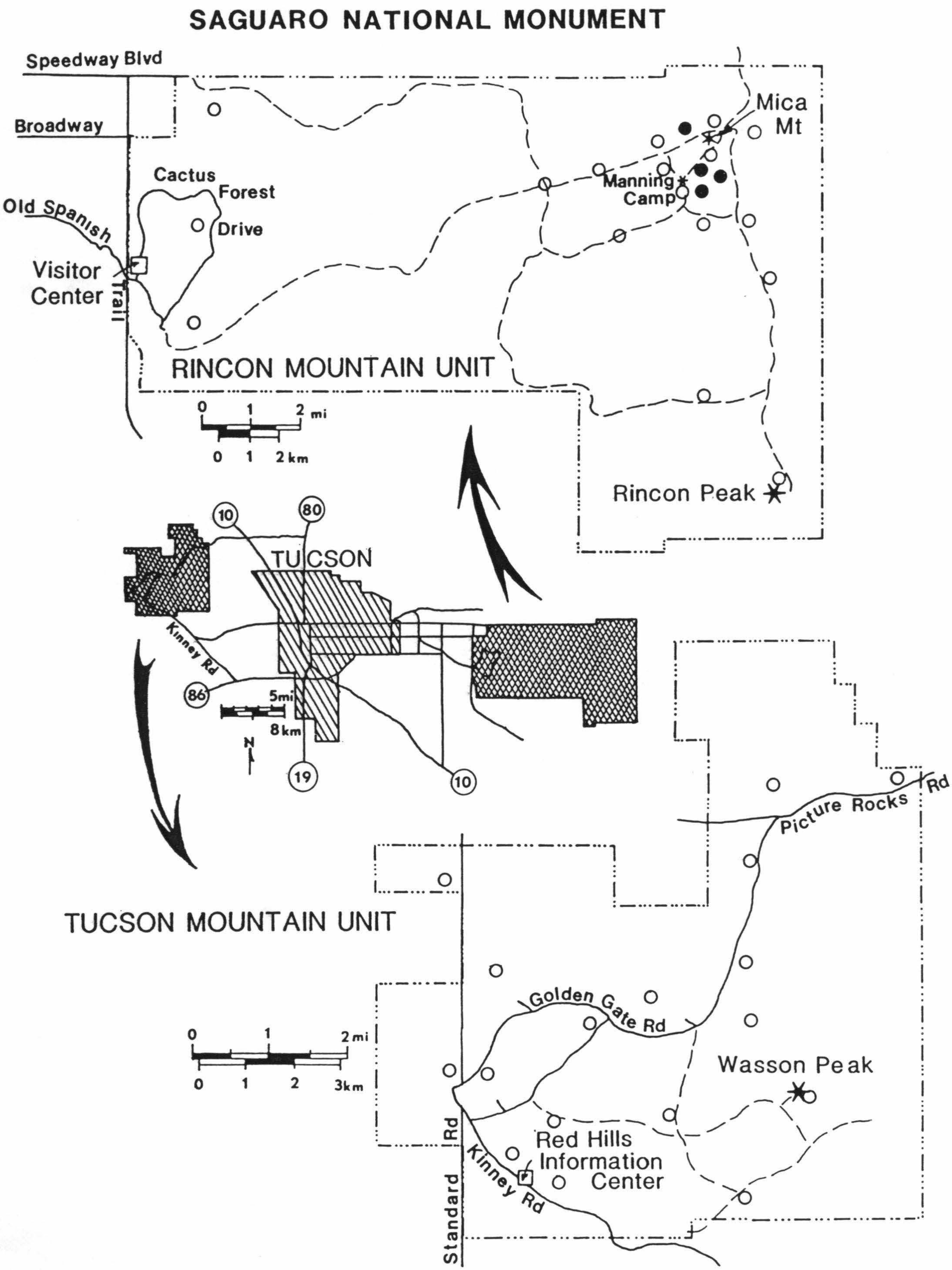

Fig. 5. Ramalina pollinaria (4 localities)

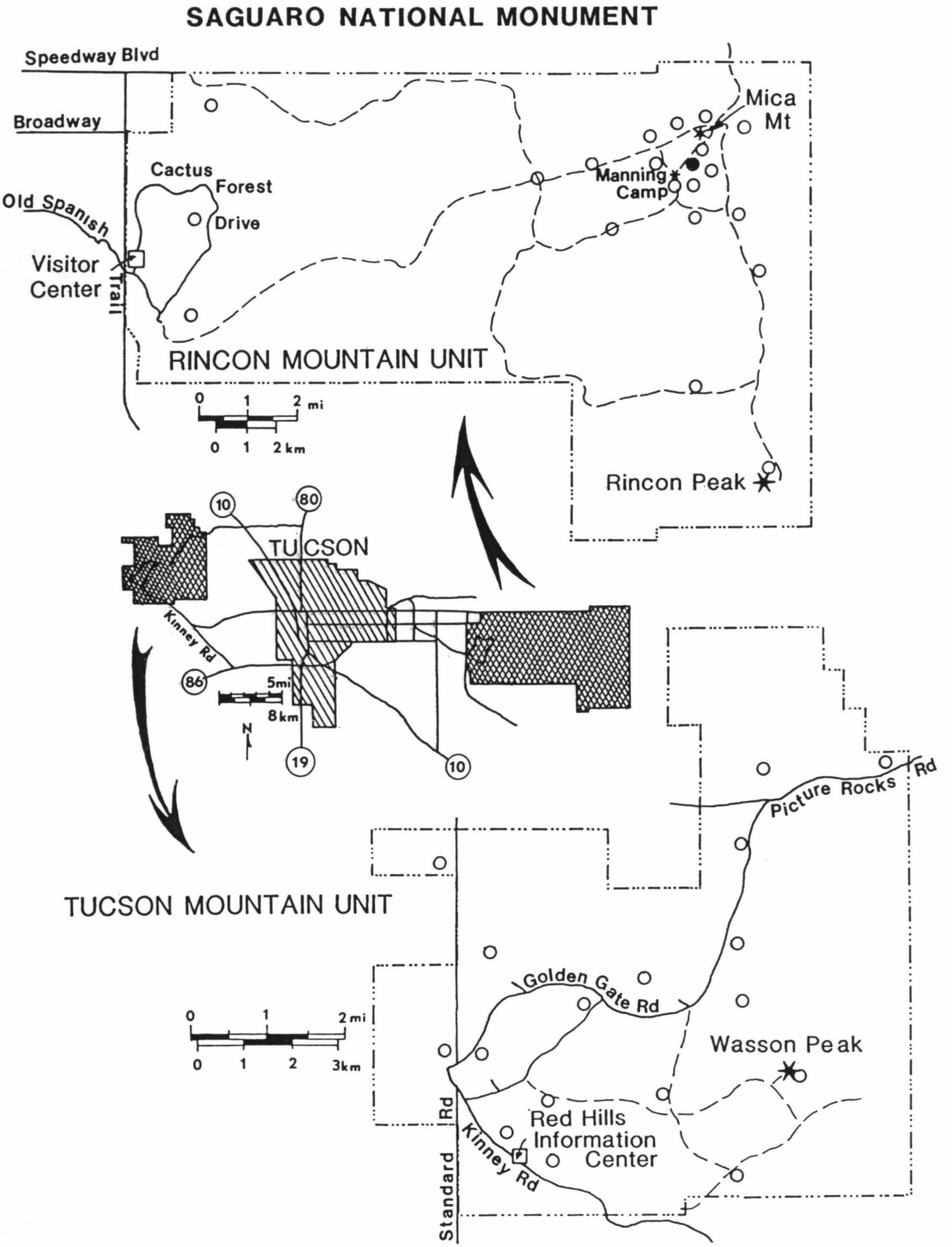

Fig. 6. Usnea florida (one locality)