.5/1977

INTERACTIONS BETWEEN PRONGHORN ANTELOPE AND FERAL HORSES IN NORTHWESTERN NEVADA

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Interactions Between Pronghorn Antelope and Feral Horses in Northwestern Nevada

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Wildlife Management

by

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May 1979

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ACKNOWLEDGEMENTS

I am grateful to the members of the Renewable Natural Resources Department, University of Nevada, Reno, for their encouragement and assistance in the conduct of this study. Special thanks go to the members of my graduate committee: Dr. Donald A. Klebenow (Chairman) and Dr. J. Wayne Burkhardt of the Renewable Natural Resources Department and Dr. Stephen H. Jenkins of the Biology Department. They were all willing to listen to me at any time and generally allowed me to convince myself of a course of action on the subject of that particular discussion. Thanks are especially due to Dr. Robert C. Beall, formerly of the Renewable Natural Resources Department, who served as my major advisor and director of research prior to his departure from the University. My many discussions with Dr. Beall led to my research project, and his standard comment, "Ain't research fun?" helped in maintaining my enthusiasm during the less enthralling portions of my field research. Thanks also go to the U.S. Fish and Wildlife Service personnel of the Charles Sheldon Antelope Range for their assistance and adjustment of schedules to fit my research needs.

Last, but definitely not least, I want to thank my family: my wife, Pat, for her willingness to become a "research widow" and for her assistance in research and preparation of this paper; my daughter, Amanda, for her assistance in laboratory work; and my son, David, for his two summers with me in the field, where he became a "mini-biologist" and a friend of animals.

ABSTRACT

A study of interactions between pronghorn antelope (*Antilocapra americana*) and feral horses (*Equus caballus*) was conducted during two summers at the Sheldon Antelope Range in northwestern Nevada. Visual observations were used to determine watering and foraging interactions and fecal analysis was performed to determine diet overlap. A total of 142 measurable instances of watering were recorded and analyzed to determine if the juxtaposition of horses affected antelope drinking and loafing times. Numerous grazing and meeting situations between the two species were observed to determine if either interfered with the activities of the other. Results indicated a lack of interference competition between antelope and horses at water or under grazing or moving situations. No acts of aggression were observed between the species. There was some evidence of a degree of symbiotic relationship existing between them. Fecal analysis indicated dietary overlap of approximately 12.8 percent, with phlox (*Phlox hoodii*), the second most abundant forb in the study area, being the only plant species to contribute over five percent to each species' diet.

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INTRODUCTION

The ever-increasing human population of the United States has, without doubt, had a detrimental effect on wildlife populations. Humans have appropriated for their own use that land which they desired. These actions have resulted in decreased quantity and quality of natural habitat for wildlife, especially the larger or less human-tolerant species.

The pronghorn antelope *(Antilocapra americana)* is one species whose population has been greatly affected by human expansion. Nelson (1925) estimated that there were 35 million pronghorn in North America in 1805. During the next century, this population decreased to some 13,000 (Hoover et al. 1959). From that low point, the population increased to an estimated 385,500 by 1964 (Yoakum 1972).

Proper management of this remnant herd of a once enormous population is necessary if the antelope is to remain an important large game animal. The resource manager must have all available information concerning the ecology of the pronghorn, including its interactions with other ungulates, in order to accomplish this required management. It is the intent of this paper to report the results of a study of interactions between pronghorn antelope and feral horses *(Equus caballus)* during the summer months in a sagebrush-bunchgrass community in northwestern Nevada.

The term "feral" is used in preference to the term "wild" because the wild horse became extinct in North America by the end of the Pleistocene epoch and did not appear again until reintroduced by early Spanish colonists (Hickman and Hickman 1972). From this reintroduction, the population of feral horses has grown to numbers in excess of 60,000, primarily in the western United States (Monroe 1977). This growing population of horses is a factor that must be considered by western rangeland managers (Cook 1975).

It is, therefore, my desire that this study will contribute to our knowledge of both pronghorn and horses and their interactions. Should this be the case, it will serve as a management tool for those resource managers operating in the intermountain sagebrush-bunchgrass biome.

LITERATURE REVIEW

The food habits of pronghorn have been well documented for the sagebrush-bunchgrass vegetative community. Ferrel and Leach (1950 and 1952) analyzed stomach contents of 83 antelope taken in California during spring, fall, and winter. They reported that browse, principally big sagebrush *(Artemisia tridentata)*, made up the bulk of the spring and winter diet, while forbs comprised over half of the fall diet. Mason (1952), in studying the Hart Mountain, Oregon antelope, found the most important year-round food source to be sagebrush with forbs contributing heavily to the diet during the summer months. In their study of food preference of penned antelope in Wyoming's Red Desert, Severson and May (1967) found the most important summer foods to be Douglas rabbitbrush *(Chrysothamnus viscidiflorus)* and big sagebrush. Olsen and Hansen (1977) found that sagebrush was the most important food source for pronghorn and that diet diversity increased during the summer. The Olsen and Hansen study provides the only available reference to diet overlap between antelope and feral horses in the sagebrush-bunchgrass community. They reported an extremely small similarity (4 ± 4%) in the diets of these two species. This observation is supported by a study in the cold desert region of eastern Nevada, where the Bureau of Land Management found the summer diet of feral horses was composed of 92 percent grasses, while the pronghorn's diet was 95 percent shrubs and forbs (G. W. Cropper, pers. comm.). It appears that little overlap of diets is to be expected in areas with plentiful resources, but in areas with a limited food supply, this overlap might be considerable. Hansen (1976) reported that the most important food plant for feral horses in southern New Mexico was

Russian thistle *(Salsola kali)*. This testifies to the survivability of the feral horse. His New Mexico study also showed the lowest percentage (50%) of grasses and grass-like plants that he had observed in horse diets from six states. On the other hand, only two studies could be located which reported grasses in excess of five percent of an antelope's diet (Hjersman and Yoakum 1959, Mitchell and Smoliak 1971). This, too, would indicate a lack of serious diet overlap under conditions of forage plentitude. Daily forage requirements for antelope and horses have been reported as 3.1 and 2.5 percent of total body weight respectively (Stoddard and Smith 1955, Thomas 1974). Average weights were estimated at 410 kg for horses (G. Cropper, pers. comm.) and 45 kg for antelope (Pyshora 1977). Based on these estimates, the daily forage requirements were 10.25 kg for horses and 1.395 kg for antelope.

Little has been reported on water requirements of either antelope or feral horses. Beale and Smith (1970) found that the pronghorn of western Utah did not use free water when the moisture content of abundant forbs exceeded 75 percent. However, during the hot, dry summer, the daily requirements averaged 2.8 liters per animal. In a similar study in Wyoming, Sundstrom (1968) reported daily water requirements varied from 0.3 liters per day in May to 4.5 liters per day in August. However, neither study reported on drinking frequency. Water requirements of a domestic 454 kg horse vary from 15 to 57 liters per day depending on ambient temperature, activity, and reproductive condition (Evans et al. 1977). It was also recommended that horses be watered frequently during the day. Pellegrini (1971) reported that feral horses in Mineral County, Nevada watered every other night and remained at the water hole all night.

However, the U.S. Forest Service was able to inventory feral horses in eastern Nevada by time-lapse photography of water holes during the day (Baxter 1977). This was an indication that these animals also water during daylight hours. A thorough literature search failed to reveal any information on interactions between antelope and feral horses in either grazing or watering situations.

The primary aim of this paper is to report any competition that exists between antelope and feral horses in the Charles Sheldon Antelope Range. The definition of interspecific competition preferred by this author is that used by Miller (1967:6): "Biological competition is the active demand by members of two or more species at the same trophic level for a common resource or requirement that is actually or potentially limiting." This definition has been expanded to include, in part, that of Krebs (1972:211) who stated that ". . . if the resources are not in short supply, competition occurs when the organisms seeking the resource nevertheless harm one or other in the process." Competition which exists for a limited resource is termed exploitation competition, and an interference component exists when organisms harm one another in seeking a needed resource, regardless of its availability (Krebs 1972).

The exploitation component of competition for food resources can be determined, with reservations, by comparing dietary overlap of sympatric species to the availability of the relevant foodstuffs. Hansen and Ueckert (1970:640) stated, "The contribution of individual plant species to the diets of sympatric herbivores and the availability of these plants are essential criteria for determining if dietary competition exists." Cody (1974) stated that the mere analysis of stomach contents can give an extremely biased picture of the ecological overlap between species. This could be true were stomach contents used for analyzing the overlap of diets between two species with different feeding habits or areas. This would mean that each was obtaining food not available to the other and, regardless of the degree of overlap, competition would not exist. This should not be the case where the two species under consideration were large terrestrial herbivores feeding in the same general area, and where samples used were composited from 15 or more fecal subsamples.

Several methods are available for collecting data for determination of an herbivore's diet: direct observation, fistulation of either esophagus or stomach, stomach removal, and feces collection. When dealing with a free-roaming large herbivore population, fecal analysis may be the most feasible method.

Direct observation would require the ability to observe from extremely close ranges, or an estimation of how much of a certain plant was removed by an animal and which animal took it, should more than one species be present. Fistulation would require excessive handling of wild animals to the point that the animal would be tame rather than wild. Analysis of stomach contents would be destructive sampling that would require the sacrifice of animals. These drawbacks would be eliminated through the use of fecal analysis, a method that requires nothing more than that material the animal no longer needs.

A microscopic technique for identifying plants eaten by herbivores was developed by Baumgartner and Martin (1939). This technique has been refined and used to study food habits of domestic sheep (Croker 1969), quokkas (Storr 1960), ground squirrels, crickets and grasshoppers

(Hansen and Ueckert 1970), bighorn sheep (Todd and Hansen 1973), meadow voles (Neal et al. 1973), deer (Anthony and Smith 1974), free-roaming horses (Hansen 1976), free-roaming horses, cattle, elk, sheep and pronghorns (Olsen and Hansen 1977), and snowshoe hares (Wolff 1978). Numerous verification studies of the accuracy of fecal analysis have been performed (Sparks and Malechek 1968, Free et al. 1970, Anthony and Smith 1974, Dearden et. al. 1975, Vavra et al. 1978, Havstad and Donart 1978). These studies have reported that the microscopic analysis of feces provides an accurate representation of herbivore diet. Westoby et al. (1976) reported on three problems identified in their study of the accuracy of quantifying artificially compounded mixtures of vegetative material. These problems were: (1) wrong name applied to all fragments of one material, (2) attempt and failure to name material which was not reliably identifiable, (3) miss material altogether. These problems cannot be eliminated but their effect could be reduced. Collecting reference material during the same time period that fecal samples were collected would reduce errors due to phenological stage. Constant referral to photomicrographs and reference slides would reduce misidentification. Rare plants may be missed during analysis, but this should not negate the results since their contribution to either diet would be negligible.

Schroder and Rosenzweig (1975:16) stated, "The only necessary and sufficient means of demonstrating the existence of competition between two species is to observe the numerical responses of the presumed competitiors to perturbation of one or both species." Although perturbation analysis should show competition, it is felt that the inclusion of the word *only* is excessively restrictive. The interference component could be ascertained, although possibly not quantified, by observation of the interaction between two species for a limited resource, i.e., food or water. Dietary overlap for a limited food item should indicate the exploitation component of competition. Additionally, perturbation analysis would be difficult, if not impossible, for studying competition between large, long-lived mammals existing on public domain.

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STUDY AREA

The Charles Sheldon Antelope Range (Fig. 1) was established in 1939 for the purpose of preserving, studying and managing pronghorn antelope and other wildlife species (U.S. Dept. of the Interior 1969). This range contains over one-half million acres and supports a stable pronghorn population of approximately 800 animals (B. Wiseman, pers. comm.).

The study area was located in the northwestern portion of the Sheldon Antelope Range, approximately 270 km north of Reno, Nevada. There were an estimated 100 antelope and 115 horses in this area during 1977. The 1978 populations were estimated at 85 antelope and 195 horses. The study area consisted of approximately 40 square kilometers of North Rock Springs Table, known as Horse Heaven (Fig. 1). It was rolling country broken by an occasional valley. Elevations ranged from 1,890 m in the northwest to 2,010 m at the summit of a north-south ridge which bisected the area.

Average temperatures during the summer months of 1977 and 1978 (Table 1) were characterized by high daytime and low nighttime readings.

Table 1. Average temperatures (C) in the study area.

	1977		1978	
	High	Low	High	Low
June	25.1	4.0	21.6	-0.3
July	27.2	3.4	27.4	2.9
August	26.1	3.4	25.8	2.3

The differential between highs and lows exceeded 20 C for each of the six summer months monitored. The average annual precipitation for the past

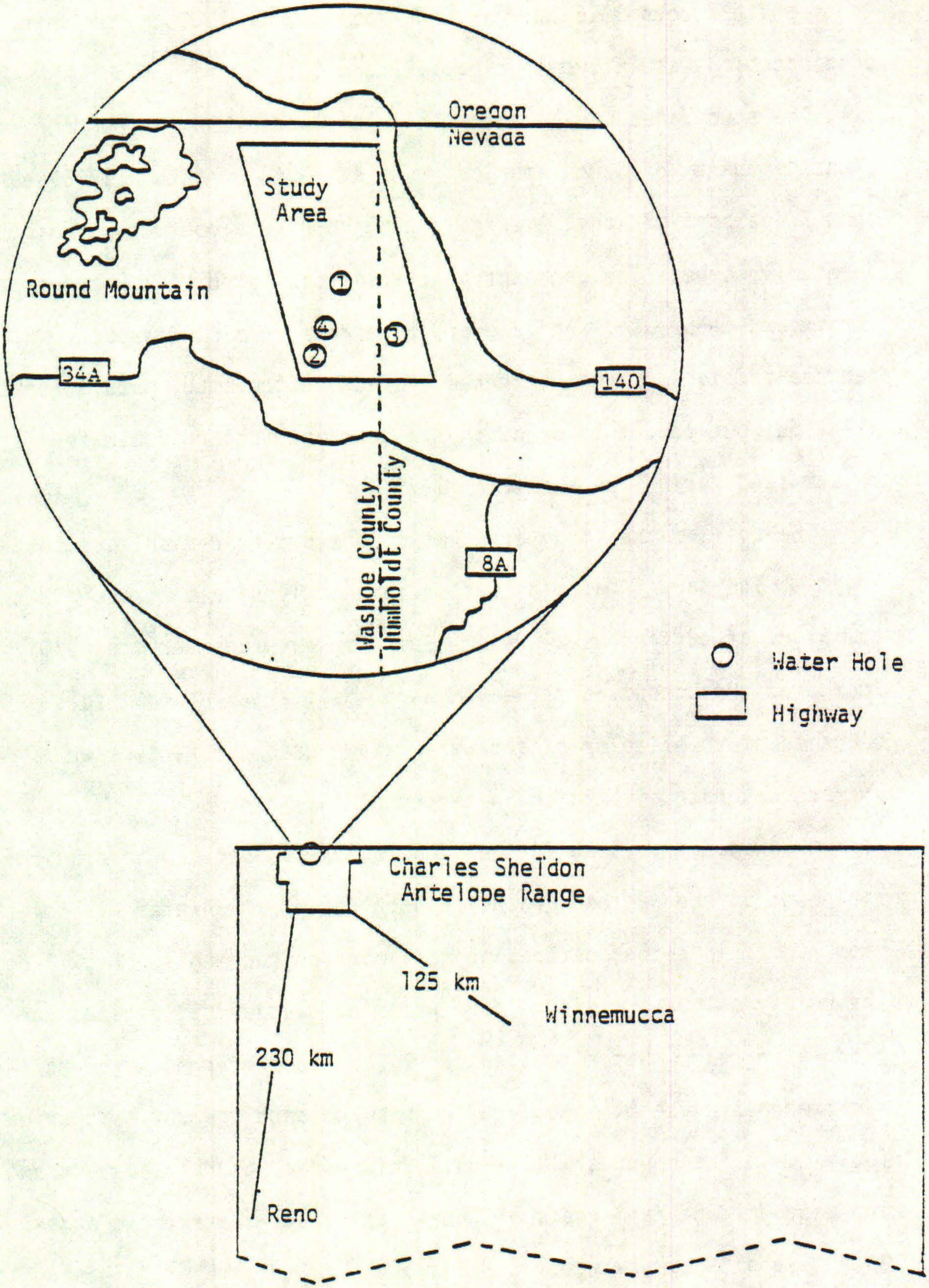

Fig. 1. Location of study area.

ten years has been 19.5 cm, varying from 14.3 to 30.9 cm per year. Total precipitation was 15.9 cm during 1977 and 27.6 cm for 1978.

The study area was located within the sagebrush and bunchgrass major plant community of North America (Kuchler 1964). Yoakum (1972) estimated that 27 percent of North America's pronghorn antelope occupy this vegetative type. The dominant vegetation consisted of low sagebrush *(Artemisia arbuscula)* and Sandberg bluegrass *(Poa sandbergii)*. Numerous patches of big sagebrush occurred throughout the study area. Forbs were plentiful but tended to be patchy in distribution and some species failed to set seed during the summer of 1977.

The soil of the study area was of the order Aridisols, suborder argids. The parent material was predominantly basalt residuum with some admixture of tuffaceous alluvium (Soil Conservation Service 1970). Scattered throughout Horse Heaven were small areas of mollisols. Recent deposits of rhyolite or basalt were laid over old lake sediments. The surface was rock covered and water runoff was rapid.

The water situation in the study area was adequate to provide for the needs of the resident wildlife population. All water was collected from runoff in either natural or man-improved cachments. Fig. 1 portrays the relative location of the four watering places that existed during a good water year. Water hole number 1 was the preferred water hole and received heavy use by both feral horses and antelope until it dried up (July 6, 1977 and August 1, 1978). This was a natural cachment and was the most distant from roads and human activity. Water hole number 2 consisted of one man-improved and two natural cachments. These water holes received little antelope and no horse activity until water hole number 1 dried up and the horses moved to the west in late summer. These water holes dried up in mid-July, 1977, and contained water all summer, 1978. Water hole number 3 was a man-improved cachment and received little activity before number 2 dried up, but the bulk of horse and antelope activity, after this. This water hole held sufficient water to meet the needs throughout both summers. Water hole number 4 was a small natural cachment that contained no water in 1977 but had water until mid-July 1978. Some antelope used this water, but no evidence of horse use could be found.

Other ungulates that used this area were mule deer *(Odocoileus hemionus)* and domestic cattle *(Bos taurus)*. Deer used the area frequently for water and less so for browsing along the bluff edges. Suitable deer habitat, but with less water, existed to the east and south of the study area. Livestock grazing was not permitted during 1977, but approximately 250 cattle were in the study area during portions of the summer of 1978.

METHODS AND MATERIALS

Based on available information on location of feral horse and antelope usage, six agronomy cages were positioned on May 29 and 30, 1977. Four cages were located on Round Mountain and two in Horse Heaven. These cages, each 2.5 by 4 m, were used in an attempt to predict forage production within the study area. At the end of the growing season for each forage type, ground cover was determined for each plant which was totally within the exclosure and current year's growth was removed. Plant diameter was determined by measuring the longest and shortest diameter of the plant and averaging these values. Crown diameter was determined for shrub and forb species and basal diameter for grasses. Vegetative clippings were placed in paper bags and allowed to air dry for a minimum of two months prior to weighing. Current year's growth was weighed to the nearest one-tenth gram. Covariance and regression analysis were used to determine whether plant diameters could be used to predict production. This type of analysis was deemed appropriate because the parameter measured was affected little by grazing activity.

Vegetative data for the study area was obtained from 50 systematically located 0.5 by 20 m strip transects during July 1977. Transects were located without regard to vegetative type. The only areas excluded from sampling were bluff faces. In the two cases where this affected sampling, the plot was displaced to the nearest location that eliminated the obstacle. All plants whose measured component fell totally or partially within a transect were included in the survey. Crown diameter and the estimated percentage of the crown within the plot were recorded for all shrubs and forbs by species. Basal diameter and the percentage within the plot were recorded for all grass species. A computer program, SHELM1, was written and used to obtain percent cover and density for all species of vegetation within each study plot.

Fecal samples for diet comparison were collected during the latter phases of vegetative sampling. These samples were collected in the vicinity of the only water hole within the study area that still contained water. Antelope feces were collected from animals observed defecating, to preclude the possibility of including feces from mule deer that frequented the area. Subsamples weighing about 4 g each were collected from separate fecal groups until 20 subsamples were obtained for each species. The subsamples were then combined by species to form the sample for analysis. Anthony and Smith (1974) reported that subsamples from 15 pellet groups were adequate to describe deer diets in Arizona. Samples were placed in airtight plastic bags and kept frozen until final preparation for analysis.

Specimens of all known plant species in the study area were collected for identification and preparation of reference slides. Plants were identified by the use of Munz (1968) and Hitchcock et al. (1955-69) and verified, where possible, by comparison with known specimens in the Nevada Agricultural Experiment Station Herbarium. Detailed instructions for reference slide preparation are outlined in Appendix A. These reference slides were studied in detail for approximately two weeks and black-and-white photomicrographs were made of diagnostic characteristics. This detailed study was followed by the preparation of a dichotomous key based on characteristics of the leaf portion of the plants (Appendix B). The leaves of grasses were found by Davies (1959) to have the greatest diagnostic value, due to leaf cell structure not being greatly affected by phenological stage of the plant. The lack of a key for all plant parts did require additional effort when analyzing feces, but the time spent was less than that required for the preparation of additional keys.

The next step in the learning process was the quantification of unknown mixtures of plants from the study area. A fellow graduate student prepared these mixtures in quantity. Continued work with test mixtures increased the writer's knowledge of the plants involved until test mixtures were repeatedly analyzed within five percent accuracy. This accuracy is considered sufficient by the Colorado State University Composition Analysis Laboratory (R. M. Hansen, pers. comm.).

Microscope slides of fecal material were prepared as outlined in Appendix A. Fecal analysis was performed by noting species occurrence in 20 systematically located fields on each of five slides for a total of 100 fields. One hundred fields have been reported as adequate to describe an herbivore's diet (Martin 1955, Sparks and Malechek 1968, Free et al. 1970, Todd and Hansen 1973). The contribution of each plant species to an herbivore's diet was determined using the frequency conversion technique developed by Sparks and Malechek (1968). In this technique, the presence of a species in a microscope field is noted, but the number of such fragments is disregarded. This frequency is then converted to relative density using the tables developed by Fracker and Brischle (1944). Sparks and Malechek (1968) reported no loss in accuracy using this method, as compared with counting all fragments of all species appearing in each field.

Correction factors for any over- or under-estimation of species contained in hand-compounded mixtures have been developed (Dearden et al. (1975). Such correction factors were not applied in this study because Hansen (R. M. Hansen, pers. comm.) stated that the increased work load does not justify the slight increase in accuracy.

Data concerning antelope-horse interaction at water holes was collected by observation through a 15X-45X spotting scope. Each observation of antelope watering was recorded by time of day, number of antelope, drinking time, loafing time, number of horses and their distance from the water. Antelope were identified as male, female, or kid. Drinking time was determined by timing, with a 0.1-second stop watch, the amount of time that an antelope remained in a drinking posture at the water. Drinking posture was defined as head over the water and body perpendicular to the water's edge. Small periods of surveillance by the animal were not deducted from drinking time. Loafing time consisted of all time the antelope remained in the vicinity of the water, less drinking time, prior to obvious departure behavior. When actually departing the vicinity of the water hole, an antelope usually acted as though it had a destination in mind, that is, it moved off without hesitation or loitering. This procedure was modified for a period during the summer of 1978 to include cattle when they were present in the study area. This data was analyzed using analysis of covariance and regression to determine if horse proximity had an effect on antelope use of water.

A second method of data collection on water hole interactions was attempted. This method entailed the use of a Minolta movie camera with time-lapse capability, similar to that used by the U.S. Forest Service in eastern Nevada (Baxter 1977). This camera was implaced in the vicinity of the water hole and adjusted to expose one frame per minute. The desire was to photograph all animals watering during daylight so that a customer list could be developed. Also, any interactions would be recorded on film as verification for visual observation. This method did work as expected for horses and in many cases, allowed for band identification. Due however to the small size and coloration of antelope and the physical layout of the water holes, the system photographed far too few antelope (many less than visually observed) to be of any value. Since this method of data collection was considered a failure, it will not be further discussed in this paper.

During the early phases of this study, all observations of horse-antelope interactions during grazing or movement were recorded as to number of antelope, number of horses and a description of the interaction. After 30 such observations, with the results never varying, it was decided to define a normal behavior pattern and record only those incidents that appeared unusual. The normal was considered to be that the antelope would give way to horses, usually keeping a distance of approximately ten m between the two species. One exception to this was in the case of a stud fight, when all animals, horse and antelope alike, scattered. This portion of the study will be discussed qualitatively rather than quantitatively later in this paper.

Standard statistical procedures were used to analyze all data (Snedecor and Cochran 1976). Statistical significance was accepted at the 95 percent level of assurance unless otherwise noted.

RESULTS AND DISCUSSION

The agronomy cages failed to produce the desired results. They had been positioned, by necessity, prior to summer dispersion of feral horses. The horses were concentrated in one large herd on the flat area between Round Mountain and Horse Heaven. Antelope were scattered throughout the study area. When the horses did disperse, they all moved east to Horse Heaven and remained there during the summer. As a result of this movement, this study was concentrated on Horse Heaven and consequently, only two agronomy cages were in the actual study area. Despite this, all six cages were treated as projected and material clipped and weighed.

Fifteen plant species were identified within the agronomy cages while a total of 54 species of vegetation were found within the study area as a whole (Table 2). Only five species were found in numbers sufficient for further analysis. An analysis of covariance performed on available data showed that a significant difference existed in the diameter to production relationship between cages for low sagebrush and Thurber's needlegrass *(Stipa thurberiana)*. Sandberg bluegrass, squirreltail *(Sitanion hystrix)*, and sand wort *(Arenaria spp.)* were essentially uniform throughout, but were of little value because they played an insignificant role in diet overlap, as determined by fecal analysis. The agronomy cages failed to reveal the true species diversity of the study area due to inadequate sampling. This fact points out the necessity that production sampling methods closely parallel or be an integral part of other vegetative sampling procedures.

Vegetative sampling by transect was designed to be used with the data collected from the agronomy cages to predict forage production.

Table 2. Vegetational characteristics of the study area.

Common Name (*Scientific Name*)	[a]Freq.	[b]Cover Percent	[c]C.I.	Density Plant/m^2	C.I.
Shrubs					
Low sagebrush (*Artemisia arbuscula*)	98	21.2	±2.43	3.28	±0.433
Big sagebrush (*A. tridentata*)	14	3.6	±3.11	0.07	±0.022
Mountain mahogany (*Cercocarpus ledifolius*)	d				
Twistleaf rabbitbrush (*Chrysothamnus viscidiflorus*)	64	2.9	±1.07	0.69	±0.263
Bitterbrush (*Purshia tridentata*)	10	1.6	±2.34	0.01	±0.015
Snowberry (*Symphoricarpos parishii*)	4	0.1	±0.25	0.002	±0.004
Grey horsebrush (*Tetradymia canescens*)	8	0.1	±0.15	0.01	±0.015
Totals		29.5	±4.11	4.06	±0.465
Forbs					
Western yarrow (*Achillea millefolium*)	d				
Mountain dandelion (*Agoseris spp.*)	2	e	--	0.01	±0.024
Wild onion (*Allium spp.*)	d				
Pussytoes (*Antennaria spp.*)	d				

Table 3. Continued.

Common Name *(Scientific Name)*	[a]Freq.	[b]Cover Percent	 [c]C.I.	Density Plant/m^2	 C.I.
Rock cress *(Arabis spp.)*	50	e	--	0.10	±0.047
Sand wort *(Arenaria spp.)*	60	0.4	±0.15	1.81	±0.735
Aster *(Aster scopulorum)*	42	0.2	±0.12	0.76	±0.445
Woolypod locoweed *(Astragalus purshii)*	22	e	--	0.14	±0.157
Locoweed *(A. spp.)*	24	0.1	±0.07	0.18	±0.119
Balsamroot *(Balsamorhiza spp.)*	70	0.8	±0.31	0.82	±0.330
Paint brush *(Castilleja spp.)*	6	e	--	0.01	±0.007
Goosefoot *(Chenopodium rubrum)*	d				
Tansey mustard *(Descurainia pinnata)*	d				
Austin's daisy *(Erigeron austinae)*	6	e	--	0.02	±0.040
Fleabane *(E. bloomeri)*	66	0.1	±0.06	0.89	±0.449
Wild buckwheat *(Eriogonum latens)*	60	0.3	±0.13	0.27	±0.106
Wild buckwheat *(E. microthecum)*	22	0.2	±0.12	0.10	±0.084
Wild buckwheat *(E. spp.)*	8	0.1	±0.20	0.02	±0.021

Table 3. Continued

Common Name (*Scientific Name*)	[a]Freq.	[b]Cover Percent	[c]C.I.	Density Plant/m²	C.I.
Green gentian (*Frasera spp.*)	6	e	--	0.02	±0.028
Stemless goldenweed (*Haplopappus acaulis*)	24	0.2	±0.11	0.16	±0.098
Iris (*Iris missouriensis*)	d				
Peppergrass (*Lepidium perfoliatum*)	d				
Prickley gilia (*Leptodactylon pungens*)	14	0.2	±0.19	0.11	±0.112
Lupine (*Lupinus spp.*)	20	0.6	±0.52	0.50	±0.483
Evening primrose (*Oenothera tanacetifolia*)	d				
Hounds-tongue (*Penstemon speciosus*)	d				
Beard-tongue (*P. spp.*)	6	e	--	0.19	±0.268
Phlox (*Phlox hoodii*)	20	0.6	±0.25	1.04	±0.535
Cinquefoil (*Potentilla spp.*)	d				
Dock (*Rumex spp.*)	d				
Dandelion (*Taraxacum officinale*)	d				
Clover (*Trifolium macrocephalum*)	2	e	--	0.06	±0.129

Table 3. Continued.

Common Name (*Scientific Name*)	[a]Freq.	[b]Cover Percent	[c]C.I.	Density Plant/m^2	C.I.
Death camus (*Zigadenus spp.*)	d				
[f]Unknown forbs	4	e	--	0.01	±0.017
Totals		3.8	±0.65	7.23	±1.794
Grass and Grass-Like					
Bluebunch wheatgrass (*Agropyron spicatum*)	16	0.1	±0.08	0.07	±0.064
Cheatgrass (*Bromus tectorum*)	4	e	--	--	--
Sedge (*Carex spp.*)	d				
Great Basin wildrye (*Elymus cinereus*)	d				
Idaho fescue (*Festuca idahoensis*)	d				
Meadow barley (*Hordeum brachyantherum*)	d				
Foxtail barley (*H. jubatum*)	24	0.1	±0.08	0.38	±0.341
Wiregrass (*Juncus spp.*)	d				
Junegrass (*Koeleria cristata*)	2	e	--	0.02	--
Mat muhly (*Muhlenbergia richardsonis*)	d				

Table 3. Continued

Common Name (*Scientific Name*)	[a]Freq.	[b]Cover Percent	[c]C.I.	Density Plant/m^2	C.I.
Sandberg bluegrass (*Poa sandbergii*)	98	1.7	±0.33	6.20	±0.957
Squirreltail (*Sitanion hystrix*)	90	0.3	±0.09	1.39	±0.374
Thurbers needlegrass (*Stipa thurberiana*)	28	0.2	±0.13	0.22	±0.159
[f]Unknown grass	58	0.2	±0.08	1.01	±0.491
Totals		2.5	±0.38	9.29	±1.237
Grand Totals		35.8	±4.32	20.58	±2.310

[a]Plot size: 10 m^2 (0.5 x 20 m).
[b]Crown cover for shrubs and forbs, basal cover for grasses.
[c]Confidence Interval ($P < .05$).
[d]Species was not recorded in sample plot.
[e]Cover less than 0.05 percent.
[f]Unknown plants either grazed too low or were too weathered for identification.

The sampling process was laborious and time-consuming and, with the failure of the cages to produce usable results, did not produce the desired estimates of forage production. It did, however, allow for the estimation of percent cover and density (Table 2).

The total vegetative cover (basal for grass plus crown for shrubs and forbs) was estimated to be 35.8 ± 4.32 percent with the bulk of this coming from low sagebrush at 21.2 ± 2.43 percent. Other shrubs contributed lesser amounts for a total shrub crown cover of 29.5 ± 4.11 percent and a density of 4.06 ± 0.465 plants per square meter. Total forb crown cover was 3.8 ± 0.65 percent with no species contributing in excess of one percent. The forb density was much higher than shrubs at 7.23 ± 1.794 plants per square meter with sand wort and phlox *(Phlox hoodii)* being the two major contributors. Grasses provided less ground cover (2.5 ± 0.38%) than the other plant groups but grass density was greatest with a 9.29 ± 1.237 plants per square meter. By far the most common plant in the study area was Sandberg bluegrass with over six plants per square meter. This was the only plant, other than sagebrush and rabbitbrush, that contributed ground cover in excess of one percent. This grass, however, receives little if any, summer use due to its early maturation. As can be seen from the species list (Table 2), the study area produced a highly diverse and relatively dense (20.58 ± 2.310 plants per square meter) vegetative community.

The patchy nature of the vegetation is evident when examining the frequency of plant appearance. Three species were recorded in only one plot, while only nine species appeared in over one-half of the plots. The number of individual plants appearing in the 10 square meter plots varied from 100 to 458. Those plots with few plants were generally in the more fertile areas with larger plants, while the high density plots were usually those with poor soil and an abundance of small desert adapted plants such as bluegrass, sand wort, and phlox.

There were plant specimens collected in the study area that did not appear in a plot and would, therefore, be considered rare. Some of these rare plants were used by horses or antelope, as subsequent fecal analysis indicated. This fact illustrated the difficulty of obtaining complete information while working with populations of free-roaming animals covering a relatively large area. It was evident that pockets of certain types of vegetation were missed during the sampling process. The study area was selected based on use during daylight hours; therefore, it is quite possible that the study animals grazed outside the designated study area during the hours of darkness. It is felt that this does not invalidate the study because none of these rare plants contributed significantly (over 5%) to either herbivore's diet.

Fecal analysis indicated a wide range of plant species taken by both feral horses and pronghorn antelope (Table 3). Each herbivore species, however, appeared to have certain plant species that it preferred. In the case of the pronghorn, the combination of western yarrow *(Achillea millefolium)*, Austin's daisy *(Erigeron austinae)*, and cinquefoil *(Potentilla spp.)* made up 17.3 ± 9.27 percent of diet, while only a trace (less than 0.05% cover) of these species were found in the vegetative sampling. This indicated that these plants were highly preferred during July, 1977. Bluebunch wheatgrass *(Agropyron spicatum)* and Thurber's needlegrass made up 37.8 ± 10.32 percent of the feral horse diet, while

Table 3. Botanical composition of feral horse and pronghorn antelope diets in northwestern Nevada, July, 1977.

Species	Diet Composition (Percent ± Confidence Interval) Antelope	Horse
Shrubs		
Artemisia spp.	18.0 ± 6.01	0 ---
Chrysothamnus viscidiflorus	14.0 ± 3.71	1.3 ± 1.18
Purshia tridentata	11.0 ± 3.71	0.2 ± 0.61
Symphoricarpos parishii	0.8 ± 1.53	0 ---
Totals	43.7 ± 5.23	1.5 ± 1.26
Forbs		
Achillea millefolium	3.7 ± 2.10	0 ---
Arenaria spp.	0.5 ± 0.92	3.1 ± 2.28
Aster scopulorum	0 ---	1.6 ± 2.36
Astragalus spp.	3.6 ± 1.43	0 ---
Balsamorhiza spp.	0.3 ± 0.72	0.6 ± 1.14
Castilleja spp.	0 ---	0.2 ± 0.61
Chenopodium rubrum	1.7 ± 1.54	0 ---
Erigeron austinae	7.7 ± 3.69	1.5 ± 1.41
E. bloomeri	2.2 ± 0.90	0 ---
Eriogonum spp.	12.2 ± 4.38	0 ---
Iris missouriensis	0.3 ± 0.72	0 ---
Leptodactylon pungens	2.7 ± 3.87	1.2 ± 1.77
Lupinus spp.	0 ---	5.7 ± 3.42
Oenothera tanacetifolia	1.1 ± 1.44	0 ---
Penstemon spp.	4.9 ± 2.46	0.9 ± 1.04
Phlox hoodii	5.0 ± 3.88	7.5 ± 3.20
Potentilla spp.	5.9 ± 3.48	0.4 ± 0.65
Taraxacum officinale	0.3 ± 0.78	0 ---
Unknown forb	1.6 ± 0.82	0.3 ± 0.67
Totals	53.5 ± 6.15	23.0 ± 4.37
Grass and Grass-Like		
Agropyron spicatum	0 ---	7.8 ± 2.21
Bromus tectorum	1.3 ± 1.10	0 ---
Elymus cinereus	0 ---	0.2 ± 0.55
Hordeum brachyantherum	0 ---	1.6 ± 1.70
H. jubatum	0 ---	12.8 ± 5.25
Koeleria cristata	0 ---	7.2 ± 1.55
Muhlenbergia richardsonis	0 ---	0.5 ± 1.38
Poa sandbergii	0 ---	0.9 ± 1.23
Sitanion hystrix	0.3 ± 0.78	13.3 ± 1.59
Stipa thurberiana	0.9 ± 1.60	30.0 ± 8.11
Carex spp.	0.3 ± 0.72	0 ---
Juncus spp.	0 ---	0.8 ± 1.05
Unknown grass	0 ---	0.4 ± 0.68
Totals	2.5 ± 2.63	75.6 ± 4.42

grazing on rabbitbrush but horses were never observed using this shrub. The other two species under discussion here, Austin's daisy and prickley gilia *(Leptodactylon pungens)*, are both low growing plants making direct observation of grazing virtually impossible. The fact that antelope and horses used Austin's daisy, when it was rare, indicated that it was an actively sought after plant by both species. This was an indication of potential competition, but should not be weighed too heavily since the slight use by horses is not exceptionally precise. Prickley gilia was more common and did not contribute significantly to either species' diet and should therefore not be considered as a source of serious competition.

The two diets were compared by two statistical methods, Spearman's rank correlation coefficient (r_s) (Snedecor and Cochran 1976) and Kulcyzenski's similarity index (SI) (Oosting 1956). The results of neither of these methods should be taken as absolute values. Rather, these values are indicators of diet similarity or dissimilarity and as such should be mutually supportive in nature.

Spearman's r_s is computed using the formula:

$$r_s = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}$$

where d is the difference in ranks between the paired observations and n is the number of paired observations. The rank correlation can range from +1 to -1, complete concordance to complete discordance. This is the most widely used measure of diet overlap. Its use in this case may therefore enable this experiment to be compared with like studies and lend support to later findings.

The result of the computation in this study is r_s = -0.327. This indicates some degree of discordance. The diets are statistically the total cover of the two species was only 0.3 ± 0.21 percent. This again indicated highly preferred forage species. During vegetative sampling, it was difficult to find needlegrass that had not been grazed except where protected by other vegetation. This latter observation indicated to this author that horses may be reluctant to force their way into sagebrush plants to obtain grass when other forage is more readily available.

There were 23 different plant species identified in antelope feces and 22 species in horse feces. A comparison of plant growth forms utilized by the two herbivores displayed the divergent preferences. Shrubs contributed 43.7 ± 5.23 percent to the antelope diet while only 1.5 ± 1.23 percent to that of the horse. Grasses were just the opposite, with the horse diet being 75.6 ± 4.42 percent grass, while the antelope used only 2.5 ± 2.63 percent grass. Forbs contributed significantly to both diets, comprising 53.5 ± 6.15 percent of antelope and 23.0 ± 4.37 percent of horse diets.

Fecal analysis revealed that 12 plant species were taken to some degree by both horses and antelope (Table 3). It must be noted, however, that of these 12, only phlox contributed significantly (5% or more) to both herbivore diets. This plant was the second most abundant forb available (1.04 ± 0.535 plants per square meter) within the study area and was in full bloom during the period that the fecal samples were collected. Three other plant species contributed over one percent to the diet of both herbivore species. Rabbitbrush use by antelope (14.0 ± 3.71%) was an expected result, but the horse use (1.3 ± 1.18%) of this shrub was not confirmed by visual observation. Antelope were frequently observed different ($P < .10$) which is consistent with the relatively small diet overlap discussed above and quantified below.

Kulcyzenski's similarity index (SI) was used to compute the amount of overlap that existed between the diets of horses and antelope. It is computed using the formula:

$$SI = \frac{\sum 2W}{\sum (a + b)} \times 100$$

where W is the lesser percentage of a food species in the diets being compared and a + b is the sum of the percentages of that species in both diets. The results of this analysis showed that there was a 12.78 percent overlap between feral horses and pronghorn antelope in the study area during July 1977. The subject species shared that percentage of the total forage selected. This index is, of course, valid only for the location and conditions that existed at the time the sample was taken.

An extension of Kulcyzenski's index which may be used as a management tool is that developed by Sazama (1975), which estimates forage made available to a herbivore by removal of another herbivore from the range. This procedure uses the formula:

$$DU_A = \frac{DMI_R \times SI}{DMI_A}$$

where DU_A is the increased days-use of forage made available to herbivore species A, DMI_R is the daily dry matter intake rate of herbivore species R removed from the range, DMI_A is the daily dry matter intake rate of herbivore A, and SI is Kulcyzenski's similarity index. Average weights were estimated at 410 kg for horses and 45 kg for antelope. Computations based on the above assumptions indicate that the removal of one horse would make additional forage available sufficient for 0.939 or approximately one antelope.

This information would be valid only for the location and conditions that existed during the summer of 1977. Because this conversion number is site specific, it would be of considerable value to resource managers to have like conversions available to them for various sites and conditions under their control. A more common practice is to transform antelope numbers into Animal Unit Months and apply this calculation to vast areas under all conditions (Hjersman and Yoakum 1959). This latter practice could prove detrimental to both the wildlife concerned and to their habitat. Based solely on weight, one horse consumes approximately the same amount of dry forage as seven antelope. However, when considering dietary overlap, the replacement ratio is approximately one to one. Replacement stocking levels established on a weight basis could place excessive pressure on the overlap vegetation and cause its elimination from the habitat. This loss would require the affected herbivores to switch diet or to migrate to new feeding areas.

The factors controlling the population sizes of the *potentially* competing species and the role of the food items used in common must be known in order to assess the significance of dietary overlap. If both populations were limited by factors other than food resources, e.g., predation or social behavior, dietary overlap may be of no consequence and should not be considered as competition. The additional food made available to one species by a reduction in numbers of the other species concerned would not be utilized. There would be no numerical response by one species to removal of the other. An exception must be made for food items that are actively sought after and taken whenever found. Such food items are always in danger of local extinction due to their desirability. Management of the area should not be based on the preservation of highly desirable species, unless the inclusion of this item in the diet was essential to at least one of the species concerned. In this study, Austin's daisy might be considered a highly desirable species. It was a rare plant (Table 2) and was found in both antelope (7.7 ± 3.7%) and horse (1.5 ± 1.4%) diets. Further research on the role of Austin's daisy is required before the competition for this plant can be assessed.

The feral horse population at the Sheldon Antelope Range is controlled by trapping and removal. The factors limiting the antelope population are not known at this time. If it were assumed that this population is limited by food resources, the overlap vegetation takes on a much different role. Under this assumption, a reduction in horse numbers would make more forage available to antelope and the antelope population should increase by a number equal to the number of horses removed. The manager should be aware of this one to one replacement rather than to expect each horse to be replaced by seven antelope, as would be expected considering only forage requirements based on animal weight.

The resource manager must consider wildlife food requirements when determining stocking levels of exotic animals, e.g., seasonal livestock grazing. The diet overlap and the role of the overlap vegetation should be known. He must also know the population limiting factors of the wildlife concerned. Where the wildlife population is limited by food resources, the manager must determine the role of the overlap vegetation. If a plant within the overlap is a limiting factor, the manager must not permit the stocking of additional herbivores or he may be faced with a reduction in the resident population. Where overlap food items are not limiting factors, the manager may act as discussed below. Where the wildlife population is limited by factors other than food, the manager must consider the role of any overlap vegetation. In the event that overlap vegetation is essential to wildlife, the manager must stock exotics at the rate based on the demonstrated diet overlap and the availability of the plant species. Should the overlap vegetation be plentiful, or highly preferred plants, the manager should be able to stock at a rate based on daily dry forage requirements of the exotic species without affecting wildlife populations.

It must be noted that stocking levels based on dietary overlap could result in under-utilization of those plants used exclusively by one herbivore. This could, in turn, allow these unused plants to out-compete and displace those plants used by the resident herbivore. This reduction of preferred plants would lead to the deterioration of the habitat in terms of the resident population.

The results of the investigation into water hole interactions between horses and antelope indicate a lack of competition for water. Worthy of note, but not statistically valid, was the observation that antelope continue to utilize a water hole three to four days after horses have deserted it due to poor water quality. Water hole number 2 (Fig. 2) dried up both summers while experiencing extensive use by both species. On both occasions, the horses transferred their attention to water hole number 3 (Fig. 2) when the water in hole number 2 reached some unacceptable level. Antelope continued to use water hole number 2 even though the sediment load was such that cracks would be evident on the surface when the water was not roiled. This would indicate that antelope are adapted to utilize a poorer quality of water than horses. Because of this, it would appear that the antelope could out-compete horses during a drought year. This should not be taken as conclusive, since a badly lamed horse was observed to survive for four days by ingesting mud for water. This was a strayed domestic horse which was subsequently picked up by its owner and recovered fully. This indicated that horses will use poor quality water if necessary, but do not if better water is available.

During the summer of 1978, a total of 142 measurable observations were made of antelope watering. The observations were partitioned into four categories:

I. Horses within 800 m of the water (N = 51).

II. Horses (or cattle) over 800 m from, but in sight of, the water (N = 27).

III. Horses (or cattle) out of sight of the water (N = 43).

IV. Cattle within 800 m of the water (N = 21).

Additionally, there were 35 usable observations of antelope watering made during the procedures test in the summer of 1977. These observations all fell into Category I.

An analysis of covariance was performed to determine if the 1977 observations could be combined with the 1978 data. This test compared the number of antelope and watering times of each set of data. The results of this analysis indicated that these relationships were significantly different for the two years, with antelope drinking longer during a dry year (1977) than during a wet year (1978). This difference cannot be explained by temperatures because the average highs were comparable during both periods (Table 1). Wind data were not available, but higher wind velocities in 1977 could have caused increased water loss due to evaporation which would, in turn, require increased intake. The 1977 data will not be further discussed in this paper.

An analysis of variance was used to ascertain if any differences existed in the sizes of the watering antelope herds between the four categories. The results of this analysis failed to reveal any significant difference between the four categories. Since all antelope herds were considered to be from one population, comparative statistical analysis could be performed.

Analysis of covariance comparing drinking times, adjusted for antelope numbers, between the four categories indicated no significant difference existed. Like tests conducted by adjusting drinking times with previous night's low temperature, current day's high temperature, and horse numbers and distance from water produced the same results. It is evident from this that antelope are not particularly concerned with the presence of other herbivores when they are drinking. Antelope and horses were observed on numerous occasions drinking together within an estimated five m of one another. Antelope also drank concurrently with cattle, although not as frequently as with horses. When drinking with horses, antelope tend to dash from the water when horses paw the water or cross the water hole directly toward them. This same reaction was observed when only antelope were watering and a dominant male splashed water.* Therefore, it is believed to be a reaction to the unexpected rather than actual fear of a horse. Antelope appeared to have favored watering places at the water hole and would wait if horses occupied the places rather than water elsewhere. Antelope would generally move directly to their seemingly preferred places when horses occupied other parts of the water hole edge. In the case of water hole number 2 (Fig. 2), preferred entries were at the east and west ends. Little antelope watering took place elsewhere. These areas were the flattest approach to the water hole and afforded good visibility of the water hole from a distance. When watering at water hole number 3 (Fig. 2), the preferred places were at the extreme eastern end for small groups or singles. This area was the flattest approach to the water with good visibility. Large herds would water at the west end where a man-made cachment had resulted in a relatively high earthen dam and reduced visibility. This indicated that antelope prefer watering places with the best possible visibility but will forego this preference when in large herds. This indication was supported by a comparison of the natural versus the man-improved portion of water hole number 2 (Fig. 2). Analysis of covariance indicated that antelope spent more time ($P < .10$) drinking at a natural as opposed to a man-improved water hole. This is probably due to two factors: reduced visibility caused by the dam; and the extreme posterior-high position required for reaching water in a bulldozer-dug cachment. Resource managers should be aware of this preference and construct cachments as naturally as possible.

Testing for loafing time differences was performed through analysis of covariance, adjusting for the same factors as were used for drinking times. This analysis indicated that a significant difference existed between the loafing times of antelope among the four categories. The

Duncun's Multiple Range test showed that antelope spent a significantly longer time loafing when horses were in sight of, but over 800 m from, the water hole. Multiple Regression performed on this treatment yielded an r^2 value of less than 0.01, indicating a total lack of correlation between the numbers of antelope in a herd and the loafing time. Further examination of the data revealed that it was marked by severe extremes, ranging from a doe herd of 11 animals loafing for 0.6 minutes to a 3-buck herd that bedded for 88.5 minutes. When these observations and two other extremes, 2-buck herds that loafed for 59.3 and 39.1 minutes each, were removed, the analysis of covariance indicated that there was no significant difference between the categories. This, like the analysis of drinking times, indicated that the antelope in the study area were unaffected in their loafing habits by the presence or absence of other large herbivores.

The observation of horse-antelope interactions under feeding or movement situations produced similar, though not quantifiable, results as did that of water hole interactions. In over 1,000 hours of observation, not one single act of aggression was noted between the two study species. Antelope normally gave way to moving horses, but did so with little disruption of their activities. The usual avoidance maneuver was that of walking perpendicular to the direction the horse was moving for 10 to 15 m and then resuming the former activity. This is probably just respect for a larger animal rather than a response triggered by former ill treatment. Exceptions to this rule usually resulted when the antelope appeared to be startled by the sudden appearance of the horse. Antelope would then run for a greater distance than when they walked. This latter behavior was also noted to occur on the sudden appearance of coyote *(Canis latrans)*, raven *(Corvus corax)* and sage grouse *(Centrocercus urophasianus)*, all of which are common in the study area. This is even a departure from the usual, in the case of coyotes, since the normal antelope reaction is one of curiosity followed by aggressive behavior.

One observation of a horse touching an antelope was observed. A territorial male antelope was standing in a horse trail observing a coyote at a distance when he was approached, from the rear, by a small band of horses. The lead mare of the band stopped at a distance of less than a meter. After a pause of a few seconds, and when the antelope did not move, the mare placed her nose between his back legs and lifted that part of him off the trail. The reaction of the antelope was swift and decisive--he rapidly departed the area. But after running approximately 100 m, he stopped and resumed his inspection of the coyote. This action was not considered agressive in nature, because the horse gave the antelope ample time to move prior to taking any action.

Observations were made which could indicate that some degree of symbiosis may exist between feral horses and pronghorn antelope. On numerous occasions, antelope, startled by human activity, were observed running toward bands of horses. In some cases, the initial stimulus was strong enough to cause the antelope to continue to run beyond the horses. In these cases, the antelope herd would run in one of two patterns, either on a relatively straight course or in an exaggerated zigzag fashion. It was noted that when the antelope ran straight past the horses, the only reaction of the horses would be one of curiosity. However, on all four occasions that the antelope ran the zigzag pattern, the horses would also run off in the same direction preceding the antelope. Three of these occasions were human evoked while the fourth was instigated by several coyotes feeding on a horse carcass.

On three separate occasions, it was observed that herds of antelope, upon approaching a water hole, ceased movement and waited some distance from the water with all members looking intently into the water hole. On two of these occasions, the antelope waited until horses entered the water hole and then proceeded to the water hole and drank simultaneously with the horses. In the third case, the antelope watered only after a raven flew onto the edge of the water hole. This may indicate that, when unsure of conditions, an antelope will use other organisms as a guide. These actions indicated that a symbiotic relationship may exist between antelope and other species, including feral horses.

CONCLUSION

This study indicated that there was little competition existing between pronghorn antelope and feral horses in Horse Heaven during the summers of 1977 and 1978. The two species water and forage together freely, with antelope giving ground only when directly approached by horses. No aggressive action was observed by either species toward the other species.

The only area where a minor degree of competition may exist is in diet. The results of Kulcyzenski's and Sazama's formulas applied to the fecal analysis data indicated that horses and antelope share approximately 12 percent of their diets and, therefore, antelope and horse may exist in the area on a 1:1 replacement ratio.

Additional work is needed on a more comprehensive dietary overlap study at Sheldon Antelope Range and other areas to determine if more severe competition may exist at other times of the year.

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APPENDIX A

DETAILED INSTRUCTIONS FOR THE PREPARATION OF REFERENCE AND FECAL MATERIAL MICROSCOPE SLIDES

These instructions follow, in part, those received from the Colorado State University Composition Analysis Laboratory (R. M. Hansen, pers. comm.).

Reference Slide Preparation:

1. Plants to be used were separated by plant parts: leaves, stems, and reproductive parts.

2. Material was oven dried for 24 h at 100 C to remove moisture.

3. Material was ground in a Wiley mill through a 20-mesh screen (1 mm openings).

4. Ground material was washed in hot water over a 200-mesh screen (0.074 mm openings) to remove extraneous solubles and extremely small nondiagnostic particles.

5. Material was soaked in household bleach (Clorox) to remove pigments. The time was variable according to how pale the material appeared to the naked eye. Maximum time used was approximately 15 minutes.

6. Material was rewashed in hot water over the 200-mesh screen to remove bleach and impurities caused by the bleaching action.

7. A small quantity of material was transferred to a glass slide mounting.

   Note: As practice for fecal slide preparation, where the amount of material must be approximately the same for all slides, a template was fabricated to result in three identifiable fragments per microscope field at 125 power. This template was fashioned from a 0.8 mm thick eave gutter-hanger by drilling 5 mm diameter holes at 2.5 cm intervals for a total of 5 holes. This allowed preparation of five slides at a time with the proper amount of material when using 22x22 mm cover slips.

8. Three drops of Hoyer's mounting medium were applied to and thoroughly mixed with the material on the slide. Hoyer's mounting medium is made by combining 200 g chloral hydrate crystals with 20 cc glycerine and adding 30 g photopurified gum arabic and 50 cc water.

9. A clean dissecting probe was used to distribute the material evenly over an area approximately the size of the cover slip.

10. A cover slip was placed over the material and the slide heated over an alcohol burner until all material was boiling evenly.

    Note: A comparison was made between the use of plastic and glass cover slips. Plastic cover slips produced the best results due to their ability to conform to the outline of plant fragments, thereby producing a thinner slide.

11. The slide was removed from the flame and immediately placed on a wet sponge to remove air bubbles.

12. The slide was then dried and transferred to the microscope for examination.

13. When microscopic examination revealed that material was sufficiently bleached to make identification possible, the four remaining slides of the same species were prepared in the same manner.

14. When microscopic examination revealed that the material had not been sufficiently bleached, a sub-routine was inserted between steps 7 and 8 above.

    7a. Two to three drops of Hertwig's clearing solution were added to and thoroughly mixed with material on the slide. Hertwig's clearing solution is made by combining 270 g of chloral hydrate crystals with 19 cc of 1 normal hydrochloric acid and adding 60 cc glycerine.

    7b. The slide was heated over the alcohol burner until solution was evaporated.

    Note: Some practice of step 7b is required to prevent burning of the plant material.

15. Slides were placed in an oven and baked at 55 C for 24 h minimum. This heating sets the mounting medium and renders a permanent slide.

Fecal Material Slide Preparation

1. Fecal material was removed from the freezer and emptied into beakers.

2. Beakers were covered with paper towels to preclude accidental contamination while allowing moisture to escape.

3. Material was oven dried at 100 C for 24 h to remove any moisture.

4. Material was ground in a Wiley mill through a 20-mesh screen.

5. Material was placed in a large clean jar with a sealing lid and agitated for 15 minutes to thoroughly mix the subsamples.

6. Ground material was washed in hot water over a 200-mesh screen to remove endogenous solubles and small particles.

7. The remainder of the procedure is as outlined in Steps 5 through 15 for reference material. Test slides made indicated that, in all samples of animal feces collected, bleaching with Clorox was sufficient and produced better results than the use of Hertwig's solution.

<u>Note</u>: The reason for making the fecal material slides permanent was to preclude movement of fragments during microscopic examination.

APPENDIX B

A DICHOTOMOUS KEY TO AID IN THE IDENTIFICATION OF EPIDERMAL FRAGMENTS OF SELECTED FLORA IN THE CHARLES SHELDON ANTELOPE RANGE, NORTHWESTERN NEVADA WITH ILLUSTRATIVE PHOTOMICROGRAPHS

1. The following key was designed as a tool, to be used in conjunction with photomicrographs, to aid in the determination of plant species that are components of the feces of large herbivores feeding in northwestern Nevada. It was not designed for absolute determination of all plant species.

2. The key is based on characteristics of leaf components of the species collected from the study area (Table 3). Like species growing under different conditions may vary slightly and may not fit this key.

3. Identification characteristics can usually be seen at 125X magnification, but it was learned that 250X magnification increases confidence of positive identification.

4. Microhistological terms used in this key follow those used by Metcalfe and Clarke (1950), Metcalfe (1960), and Cutler (1969).

5. Small fragments of plant material seldom contain multiple diagnostic characteristics after passing through a herbivore's digestive tract. Therefore, all clues must be consolidated to identify some species. Trichomes seldom remain attached to the epidermal fragments but serve as valuable clues as to the presence of certain species within the sample. There must be some degree of transfer of clues from one fragment to another in order to validate a characteristic that does not appear in the key.

6. Fragments from individual species may, and normally do, key to more than one couplet.

7. Numbers in parentheses refer to photomicrograph plates in this appendix. Photomicrographs were taken at 250X unless otherwise noted.

A.	Cells primarily linear in arrangement	B
A.	Cells usually not linear in arrangement	C
B.	Two sizes of cells present - long cells and two types of short cells (suberose and silica)	Key No. 1
B.	Not as above	Key No. 2
C.	Cell outline irregular, lobed (jigsaw puzzle)	Key No. 3
C.	Not as above	D
D.	Cells somewhat regular in outline, Triangular through polygon to round	Key No. 4
D.	Cells irregular, not as above	Key No. 5

KEY NUMBER 1

1.	Microhair present (1a)	*Muhlenbergia richardsonis*
1.	Microhair absent	2
2.	Macrohair present	3
2.	Macrohair absent	25
3.	Stomata present	4
3.	Stomata absent	17
4.	Prickles present	5
4.	Prickles absent	9
5.	All stomata subsidiary cells with straight sides (9a)	*Koeleria cristata*
5.	Stomata subsidiary cells not as above	6
6.	Prickle height approximates .016 mm (2a)	*Festuca idahoensis*
6.	Prickle height exceeds .016 mm	7
7.	Prickle height approximates .02mm (3a)	*Agropyron spicatum*
7.	Prickle height exceeds .02 mm	8
8.	Prickle height approximates .024 mm (4a)	*Stipa thurberiana*
8.	Prickle height approximates .032 mm (1b)	*Muhlenbergia richardsonis*
9.	Macrohair less than .08 mm in length (5c)	*Hordeum jubatum*
9.	Macrohair exceeds .08 mm in length	10
10.	Macrohair less than .12 mm in length (5a)	11
10.	Macrohair exceeds .12 mm in length	13
11.	Stomata length exceeds .04 mm (7c)	*Elymus cinereus*
11.	Stomata length less than .04 mm	12
12.	Stomata length exceeds .032 mm (5b)	*Sitanion hystrix*
12.	Stomata length less than .032 mm (2b)	*Festuca idahoensis*
13.	Macrohair length less than .16 mm (3b)	*Agropyron spicatum*
13.	Macrohair length exceeds .16 mm	14
14.	Stomata length greater than width (4b)	*Stipa thurberiana*
14.	Stomata length less than or equal to width	15
15.	Stomata subsidiary cells straight (9a)	*Koeleria cristata*
15.	Stomata subsidiary cells convex	16
16.	Stomata subsidiary cells low-dome shaped (8b)	*Bromus tectorum*
16.	Stomata subsidiary cells triangular shaped (1c)	*Muhlenbergia richardsonis*

17. Macrohair less than .08 mm in length (6c) — *Hordeum jubatum*
17. Macrohair exceeds .08 mm in length — 18

18. Macrohair less than .12 mm in length — 19
18. Macrohair exceeds .12 mm in length — 21

19. Cell walls smooth in vicinity of hairs — 20
19. Cell walls sinuous in vicinity of hairs (5c) — *Sitanion hystrix*

20. Cells relatively short and wide (7d) — *Elymus cinereus*
20. Cells relatively long and narrow (2c) — *Festuca idahoensis*

21. Macrohairs less than .16 mm in length (3b) — *Agropyron spicatum*
21. Macrohairs exceed .16 mm in length — 22

22. Macrohairs moderately long and flexuose (4c) — *Stipa thurberiana*
22. Macrohairs straight or slightly bent — 23

23. Macrohairs with swollen bases (desk pen) (9b) — *Koeleria cristata*
23. Macrohairs not as above — 24

24. Macrohairs appear rigid with slightly swollen base (1d) — *Muhlenbergia richardsonis*
24. Macrohairs appear flexible with sunken base (8c) — *Bromus tectorum*

25. Stomata present — 26
25. Stomata absent — 43

26. Prickles present — 27
26. Prickles absent — 33

27. All stomata subsidiary cells with straight sides (9a) — *Koeleria cristata*
27. Stomata subsidiary cells not as above — 28

28. Prickle height approximates .016 mm (2a) — *Festuca idahoensis*
28. Prickle height exceeds .016 mm — 29

29. Prickle height approximates .02 mm (3a) — *Agropyron spicatum*
29. Prickle height exceeds .02 mm — 30

30. Prickle height approximates .024 mm — 31
30. Prickle height exceeds .024 mm — 32

31. Distal outline of prickle straight (6a) — *Hordeum brachyantherum*
31. Distal outline of prickle curved (4a) — *Stipa thurberiana*

32. Prickle height approximates .028 mm (9d) — *Poa sandbergii*
32. Prickle height approximates .032 mm (1b) — *Muhlenbergia richardsonis*

33. All stomata subsidiary cells with straight sides (9a) *Koeleria cristata*
33. Stomata subsidiary cells not as above 34

34. Stomata length exceeds .06 mm (7c) *Elymus cinereus*
34. Stomata length less than .06 mm 35

35. Stomata length exceeds .04 mm (7a) *Hordeum jubatum*
35. Stomata length less than .04 mm 36

36. Stomata length equal to or less than width 37
36. Stomata length exceeds width 38

37. Stomata subsidiary cells low-dome shaped (8b) *Bromus tectorum*
37. Stomata subsidiary cells triangular shaped (1c) *Muhlenbergia richardsonis*

38. Stomata length less than .032 mm 39
38. Stomata length exceeds .032 mm 40

39. Stomata subsidiary cells low-dome shaped or straight sided (4b) *Stipa thurberiana*
39. Stomata subsidiary cells high-domed or triangular shaped (2b) *Festuca idahoensis*

40. Cell wall sinuations shallow (6b) *Hordeum brachyantherum*
40. Cell wall sinuations deeper 41

41. Stomata outline square in appearance (10a) *Poa sandbergii*
41. Stomata outline ovate in appearance 42

<u>Note</u>: Silica cells or bodies must be present for the remainder of this key.

42. Suberose pairs rare (5d) *Sitanion hystrix*
42. Suberose pairs common (3c) *Agropyron spicatum*

43. Suberose pairs consist of large cork and small silica cells 44
43. Suberose pairs not as above 46

44. Suberose pairs relatively small (4b) *Stipa thurberiana*
44. Suberose pairs relatively large (8a) *Elymus cinereus*

45. Silica bodies longer than wide with sinuous outline 46
45. Silica bodies not as above 48

46. Bodies small with deep indentation (4d) *Stipa thurberiana*
46. Bodies large with shallow indentation 47

47. Bodies only slightly longer than wide (9c) *Koeleria cristata*
47. Bodies much longer than wide (10b) *Poa sandbergii*

48. Silica cells square and alternate with cork cells in long rows (1c) *Muhlenbergia richardsonis*
48. Silica cells not as above 49

49. Silica cells rectangular and alternate with cork cells in long rows (6c) *Hordeum brachyantherum*
49. Silica cells not as above 50

50. Silica cells much longer than wide with straight sides (8d) *Bromus tectorum*
50. Silica cells not as above 51

51. Silica cells are mid-length between long and cork cells (2d) *Festuca idahoensis*
51. Silica cells appear as silicified long cells 52

52. Silica cell sides deeply indented (5b) *Sitanion hystrix*
52. Silica cell sides less deeply indented 53

53. Silica cells appear between the veins (3d) *Agropyron spicatum*
53. Silica cells appear over the veins (7b) *Hordeum jubatum*

KEY NUMBER 2

1.	Cells usually longer than 4 times width	2
1.	Cells usually shorter than 4 times width	33
2.	Prickles present (10c)	*Carex spp.*
2.	Prickles absent	3
3.	Macrohairs present	4
3.	Macrohairs absent	12
4.	Branched hair present (19a)	*Descurainia pinnata*
4.	Hair not as above	5
5.	Two-armed hair present (19d)	*Artemisia arbuscula*
5.	Hair not as above	6
6.	Uniserrate, multicellular hair (pod-like) present (21a)	*Lepidium perfoliatum*
6.	Hair not as above	7
7.	Uniserrate multicellular hair with knees present (13a)	*Leptodactylon pungens*
7.	Hair not as above	8
8.	Arachnoid multicellular hair present (14a)	*Phlox hoodii*
8.	Hair not as above	9
9.	Large unicellular hair present (exceeds .2 mm) (12a)	*Iris missouriensis*
9.	Hair not as above	10
10.	Short, stout unicellular hair with rounded tip present (21d)	*Arenaria spp.*
10.	Hair not as above	11
11.	Short unicellular hair with rounded tip (13b)	*Leptodactylon pungens*
11.	Short unicellular hair with pointed tip (23b)	*Penstemon spp.*
12.	Crystals present	13
12.	Crystals absent	15
13.	Rod-like crystals present (12b)	*Iris missouriensis*
13.	Clustered crystals present	14
14.	All cells linear in arrangement (22a)	*Arenaria spp.*
14.	Linear cells in bands, bordered by irregular cells (20a)	*Artemisia arbuscula*
15.	Stomata present	16
15.	Stomata absent	24

16. Stomata arranged in rows 17
16. Stomata arranged randomly 20

17. Interstomatal distance exceeds 3 times cell width (22b) *Arenaria spp.*
17. Interstomatal distance less than 3 times cell width 18

18. Interstomatal distance approximates or exceeds twice stomata length (21b) *Lepidium perfoliatum*
18. Interstomatal distance approximates stomata length 19

19. Cell walls straight (11c) *Allium spp.*
19. Cell walls sinuous (10d) *Carex spp.*

20. Cell walls strongly lobed (13c) *Leptodactylon pungens*
20. Cell walls essentially straight 21

21. All cells linear in arrangement (19b) *Descurainia pinnata*
21. Linear cells in bands bordered by irregular shaped cells 22

22. Cells essentially square at joint (23c) *Penstemon spp.*
22. Cell juncture not as above 23

23. Cell wall appears dashed at certain focus (20a) *Artemisia arbuscula*
23. Cell wall appears entire at any focus (14b) *Phlox hoodii*

24. Cell walls strongly lobed (13d) *Leptodactylon pungens*
24. Cell walls not as above 25

25. Cell walls sinuous (grass-like) (11a) *Carex spp.*
25. Cell walls not as above 26

26. Cells elongate-hexagon (11d) *Allium spp.*
26. Cells not as above 27

27. Cell length exceeds 10 times cell width 28
27. Cell length less than 8 times cell width 30

28. Cells extremely elongate-hexagon (12c) *Iris missouriensis*
28. Cells not as above 29

29. Cells so long, juncture difficult to locate (21b) *Lepidium perfoliatum*
29. Cell length barely exceeds 10 times width (19b) *Descurainia pinnata*

30. Cell walls appear "dashed" at certain focus 31
30. Cell walls appear entire at any focus (14b) *Phlox hoodii*

31. All cells linear in arrangement (22a) *Arenaria spp.*
31. Linear cells in bands bordered by irregular shaped cells 32

32. Cells usually irregular at juncture (20a) *Artemisia arbuscula*

32. Cells usually square at juncture over 2 cell widths from irregular shaped cells (23c) *Penstemon spp.*

33. Stalked capitate glands present *Zigadenus spp.*

33. Stalked capitate glands absent 34

34. Hairs present 35

34. Hairs absent 42

35. Branched hairs present 36

35. Hair not as above 37

36. Branches less than .03 mm in length (35d) *Arabis spp.*

36. Branches greater than .04 mm in length (34c) *Astragalus spp.*

37. Heavy pointed unicellular hair present (exceeds .2 mm) (12a) *Iris missouriensis*

37. Hair not as above 38

38. Heavy rounded unicellular hair present (24a) *Zigadenus spp.*

38. Multicellular uniserrate hairs present 39

39. Hair cells approximately equal in length 40

39. Terminal cell of hair elongated 41

40. Hairs erect, perpendicular to plant surface (36a) *Castilleja spp.*

40. Hairs lie at angle to plant surface (15a) *Chrysothamnus viscidiflorus*

41. Hair base cell moderately dumbbell shaped (24d) *Balsamorhiza hookeri*

41. Hair base cell moderately ovate (25d) *Balsamorhiza sagittata*

42. Crystals present 43

42. Crystals absent 44

43. Rod-like crystals present (12b) *Iris missouriensis*

43. Crystals in bundles (24b) *Zigadenus spp.*

44. Stomata present 45

44. Stomata absent 49

45. Stomata length exceeds .04 mm 46

45. Stomata length less than .03 mm 47

46. Cells hexagon in outline (24c) *Zigadenus spp.*

46. Cell walls parallel (straight and curved) (15b) *Chrysothamnus viscidiflorus*

47. Cell walls sinuous (11b) *Juncus spp.*

47. Cell walls straight 48

48. Cell junctures perpendicular to cell wall (12d) *Iris missouriensis*
48. Cell junctures variable (pointed to square) (35c) *Arabis spp.*

49. Cells hexagon in appearance . 50
49. Cell walls essentially parallel 51

50. Cell length essentially equal, hexagon shape strong (24c) *Zigadenus spp.*
50. Cell length variable, hexagon shape weak (12d) *Iris missouriensis*

51. Cell outline appears "dashed" under certain focus (35c) *Arabis spp.*
51. Cell outline appears entire at any focus 52

52. Hair base cell holes numerous (34b) *Astragalus spp.*
52. Hair base cell holes sparse 53

53. Hair base cell holes ovate (15b) *Chrysothamnus viscidiflorus*
53. Hair base cell holes round 54

54. Cells modified around hair base cell holes (25a) *Balsamorhiza hookeri*
54. Cells surrounding hair base cell holes not modified (36d) *Castilleja spp.*

KEY NUMBER 3

1.	Papilla present	2
1.	Papilla absent	3
2.	Cell outline distinct, elongate papilla cells appear as separate from epidermal cells (13d)	*Leptodactylon pungens*
2.	Cell outline indistinct, papilla appears to be part of epidermal cells (14c)	*Phlox hoodii*
3.	Macrohair present	4
3.	Macrohair absent	10
4.	Hair uniserrate, multicellular, terminal cell whip-like (26a, 26b)	*Achillea millefolium*
4.	Hair not as above	5
5.	Hair uniserrate, multicellular with enlarged base, cells of equal length (26d)	*Erigeron austinae*
5.	Hair not as above	6
6.	Hair long, pod-like in appearance (21a)	*Lepidium perfoliatum*
6.	Hair not as above	7
7.	Hair unicellular with swollen tips (36c)	*Frasera spp.*
7.	Hair not as above	8
8.	Hair long, arachnoid, multicellular (14a)	*Phlox hoodii*
8.	Hair not as above	9
9.	Hair long, uniserrate, multicellular, cells short and wide (28b)	*Taraxacum officinale*
9.	Hair uniserrate, multicellular with enlarged junctures or short unicellular hairs with blunt tips (13a, 13b)	*Leptodactylon pungens*
10.	Cells much longer than wide, linear in arrangement	11
10.	Cells may be longer than wide, but not arranged linearly	12
11.	Lobes seldom exceed one-half cell width (13c)	*Leptodactylon pungens*
11.	Lobes often equal to or greater than cell width, may be bordered by straight sided cells (14b, 14d)	*Phlox hoodii*
12.	Numerous cells elongate but not linear in arrangement (26c)	*Achillea millefolium*
12.	Few cells elongate	13
13.	Modified macrohair base cells present (27a)	*Erigeron austinae*
13.	Not as above	14

14. Cells diverse in shape but generally of one size (36d) *Frasera spp.*

14. Cells diverse in shape and size 15

15. Cells appear coarse, broad lobed (21c) *Lepidium perfoliatum*
15. Cells appear less coarse, narrow lobed (28c) *Taraxacum officinale*

KEY NUMBER 4

1. Hair present 2
1. Hair absent 15

2. Stalked capitate gland present (29a) 3
2. Not as above 4

3. Hair short stout, unicellular (29b) *Potentilla spp.*
3. Hair long, multicellular (36a) *Castilleja spp.*

4. Branched hairs present 5
4. Hairs not as above 6

5. Cells random in arrangement, generally round (35d) *Arabis spp.*
5. Cells arranged in circular patterns, generally oblong (19c) *Descurainia pinnata*

6. Hair unicellular with enlarged tip 7
6. Hair not as above 8

7. Hair short (.04 mm), flexuose (29d) *Chenopodium rubrum*
7. Hair long (.08 mm), straight (36c) *Frasera spp.*

8. Hair cylindrical, unicellular with round tip (22c) *Penstemon speciosus*
8. Hair not as above 9

9. Hair uniserrate, multicellular 10
9. Hair not as above 11

10. Hair stands perpendicular to surface (36a) *Castilleja spp.*
10. Hair lies parallel to surface (30c) *Rumex spp.*

11. Hair unicellular, straight, long or short 12
11. Hair unicellular, long, arachnoid 14

12. Hair long, straight or curved with modified base (31b, 31c, 31d) *Lupinus spp.*
12. Hair not as above 13

13. Hair robust, straight or curved with enlarged base (29b) *Potentilla spp.*
13. Hair less robust, lacking enlarged base (32a, 32b) *Symphoricarpos parishii*

14. Hair of one size, crystals lacking, hair base cells location independent of cell structure (37a, 37b) *Tetradymia canescens*
14. Hair of two sizes, crystals may or may not be present, hair base cells always at juncture of four or more cells (16a, 16b, 16c) *Eriogonum spp.*

15. Crystals present 16
15. Crystals absent 18

16. Cell walls thick (30d, 31a) *Rumex spp.*
16. Cell walls thin 17

17. Hair subcell holes always at juncture of four or more cells (16c) *Eriogonum spp.*
17. Hair subcell holes lacking or not evident (30a) *Chenopodium rubrum*

18. Stomata round 19
18. Stomata ovate 20

19. Diameter small (16d) *Eriogonum spp.*
19. Diameter larger (22d) *Penstemon speciosus*

20. Length exceeds .04 mm (36d) *Frasera spp.*
20. Length less than above 21

21. Length exceeds .036 mm (30b) (23a) *Chenopodium rubrum* or *Penstemon speciosus*
21. Length less than above 22

22. Length exceeds .03 mm (32c) *Symphoricarpos Parishii*
22. Length less than above 23

23. Small, less than .024 mm long, low domed (35c) *Arabis spp.*
23. Larger than above 24

24. Stomata numerous (16d) *Eriogonum spp.*
24. Stomata sparse (29c) *Potentilla spp.*

KEY NUMBER 5

1. Hairs present 2
1. Hairs absent 21

2. Hairs two- or three-armed 3
2. Hairs not as above 5

3. Hairs two- and three-armed to complex (32d) *Agoseris spp.*
3. Hair always two-armed (20c) 4

4. Irregular cells accompanied by linear cells (20a) *Artemisia arbuscula*
4. All cells irregular in shape (20d) *Artemisia tridentata*

5. Hairs multicellular, uniserrate silicified (37c) *Astor scopulorum*
5. Hairs not as above 6

6. Hair branched (34c) *Astragalus spp.*
6. Hair not as above 7

7. Hair unicellular 8
7. Hair multicellular 14

8. Hair tip enlarged (36c) *Frasera spp.*
8. Hair not as above 9

9. Hair short 10
9. Hair long 12

10. Hair stout, "dagger-like", clumpy (17a, 17b) *Purshia tridentata*
10. Hair not as above 11

11. Hair appears flexible, enlarged base (18a) *Oenothera tanacetifolia*
11. Hair appears stiff, shorter than above (23b) *Penstemon spp.*

12. Hair arachnoid (17a, 17b) *Purshia tridentata*
12. Hair tends to be straight or abruptly bent 13

13. Hair long, curving, base modified (33c, 33d) *Astragalus purshii*
13. Hair with abrupt bends, linear cells may be present (14a, 14b) *Phlox hoodii*

14. Hair composed of only 2 cells 15
14. Hair composed of more than 2 cells 17

15. Terminal cell flattened, hair base unmodified (27c, 27d) *Erigeron bloomeri*
15. Terminal cell round, hair base modified (25c) 16

16. Base cell "dumbbell" shaped, enlarged cell juncture (24d, 25b) *Balsamorhiza hookeri*
16. Base cell ovate, cell juncture not enlarged (25c) *Balsamorhiza sagittata*

17. Hair long, cells short and wide (28b) *Taraxacum officinale*
17. Hair not as above 18

18. Hair robust, length less than five times base cell length (34d) *Haplopappus acaulis*
18. Hair less robust, length greater than five times base cell length 19

19. Base cells compressed, terminal cells elongate (26d, 27b) *Erigeron pustinae*
19. Cells of approximate equal length 20

20. Hair long, oriented parallel to vegetative surface (15a) *Chrysothamnus viscidiflorus puberulus*
20. Hair shorter, oriented perpendicular to vegetative surface (15c) *Chrysothamnus visicidiflorus lanceolatus*

21. Crystals present 22
21. Crystals absent 23

22. Crystals formed as a bundle (18b, 18c) *Oenothera tanacetifolia*
23. Crystals formed as a cluster (17c) *Purshia tridentata*

23. Stomata round 24
23. Stomata ovate 25

24. Stomata diameter exceeds .03 mm (28a) *Erigeron bloomeri*
24. Stomata diameter less than .03 mm (23d) *Penstemon spp.*

25. Stomata length equals or exceeds .04 mm 26
25. Stomata length less than .04 mm 31

26. Stomata width equals or exceeds .04 mm (33a, 33b) *Agoseris spp.*
26. Stomata width less than .04 mm 27

27. Stomata width equals or exceeds .036 mm (15d) *Chrysothamnus visicidiflorus*
27. Stomata width less than .036 mm 28

28. Stomata elongate length exceeds width by .02 mm (36d) *Frasera spp.*
28. Stomata ovate, length exceeds width by less than .02 mm (20b) *Artemisia arbuscula*

29. Stomata length less than .03 mm 30
29. Stomata length exceeds .03 mm 32

30. Stomata appears elevated from vegetative surface (17d) *Purshia tridentata*
30. Stomata not as above 31

31. Stomata numerous, hair base cells much larger than surrounding cells (26d, 27a) *Erigeron austinae*
31. Stomata sparse, hair base cells modified but much smaller than above (34a) *Astragalus purshii*

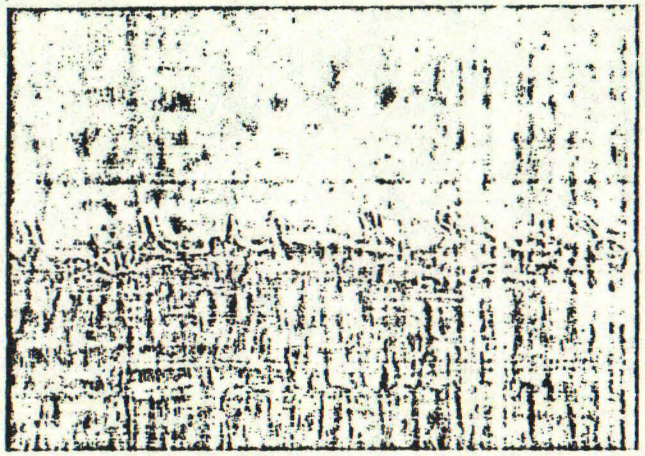
32. Cell outline irregular to the point of appearing jagged (18d) *Oenothera tanacetifolia*
32. Cell outline not as above 33

33. Cell walls thick, stomata numerous (37d) *Aster scopulorum*
33. Cell walls thin, stomata numerous or few 34

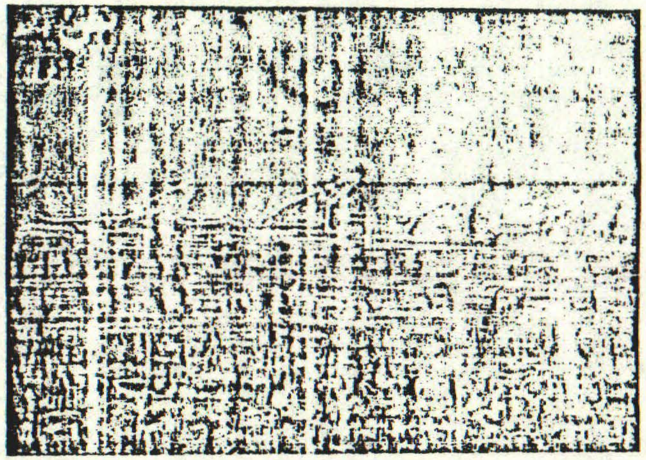
34. Stomata numerous 35
34. Stomata rare 36

35. Cell outline appears dotted (35a, 35b) *Haplopappus acaulis*
35. Cell outline appears entire (25c) *Balsamorhiza sagittata*

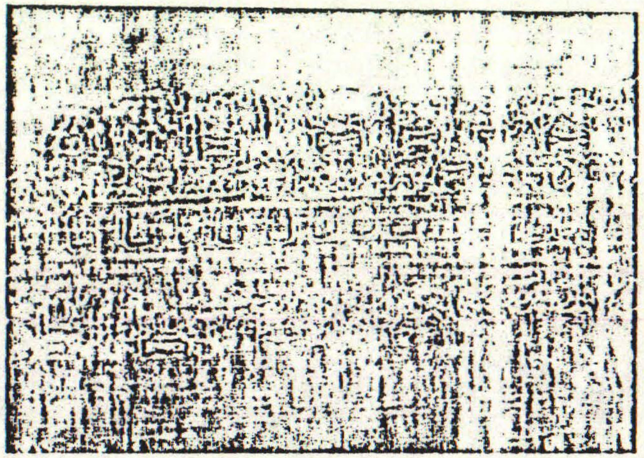
36. Cell smaller, more elongate, with more distinct angles (20d) *Artemisia tridentata*
36. Cell larger, rounder, with few distinct angles (28d) *Taraxacum officinale*



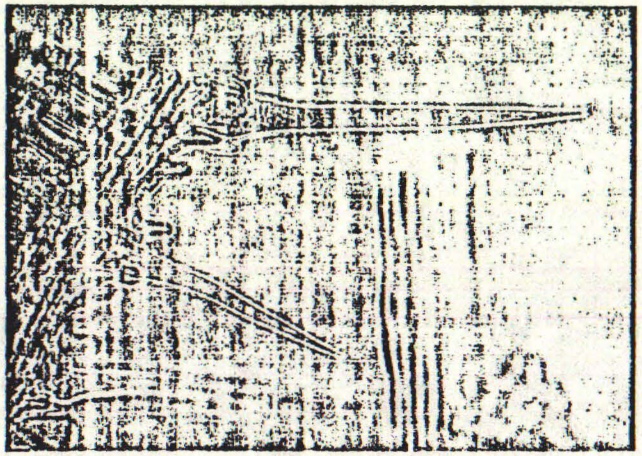
1a. *Muhlenbergia richardsonis*



1b. *Muhlenbergia richardsonis*

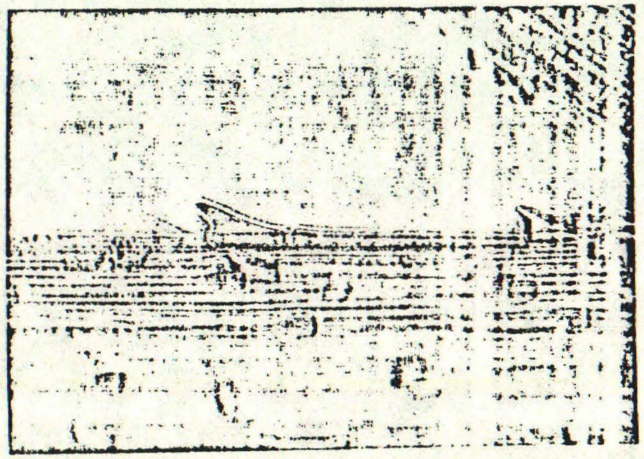


1c. *Muhlenbergia richardsonis*

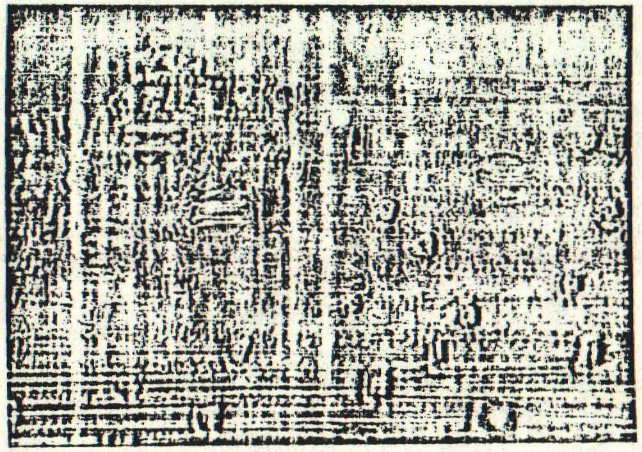


1d. *Muhlenbergia richardsonis*

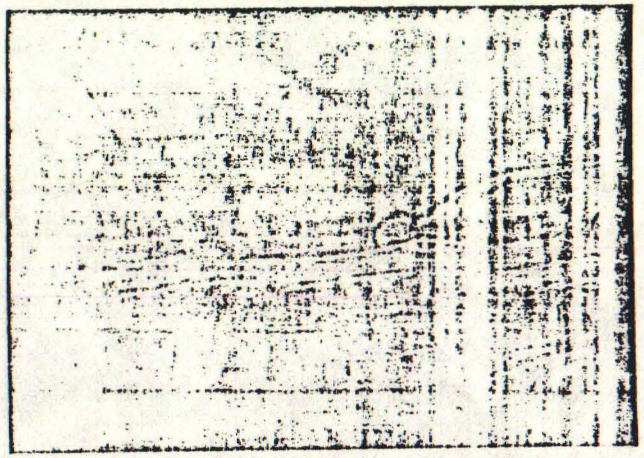
Plate 1



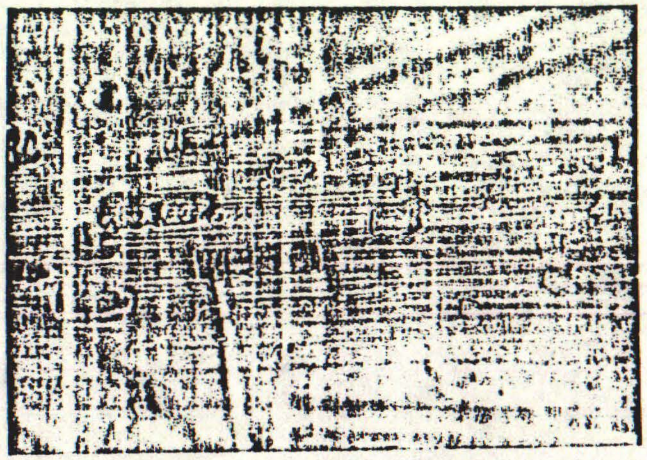
2a. *Festuca idahoensis*



2b. *Festuca idahoensis*

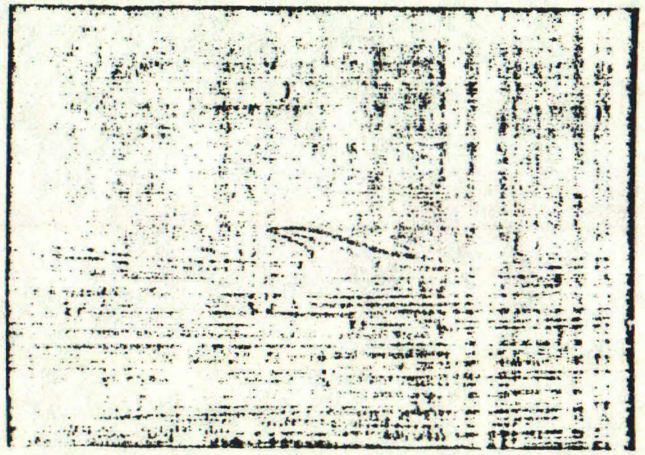


2c. *Festuca idahoensis*

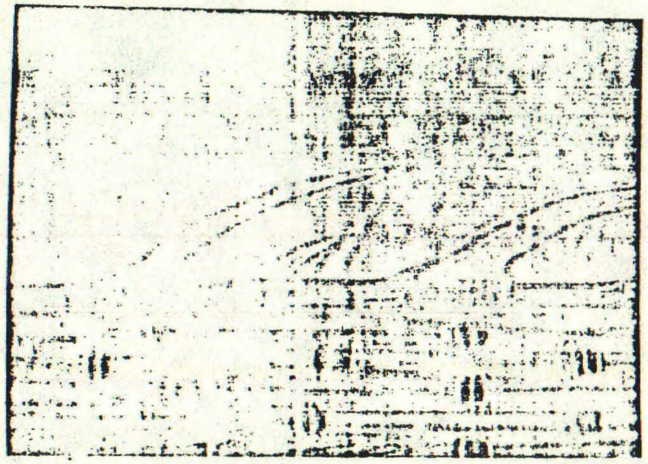


2d. *Festuca idahoensis*

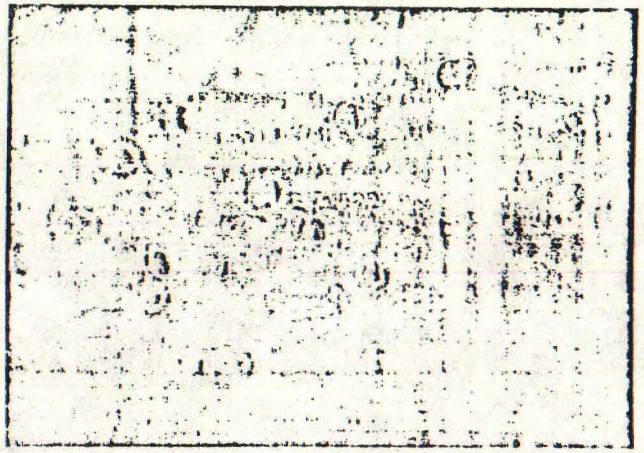
Plate 2



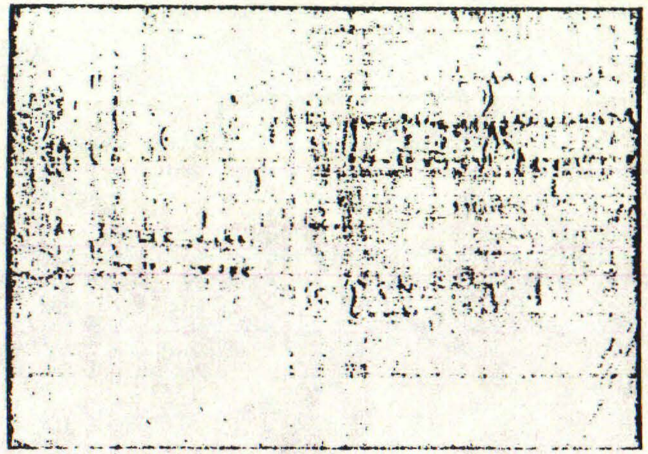
3a. *Agropyron spicatum*



3b. *Agropyron spicatum*

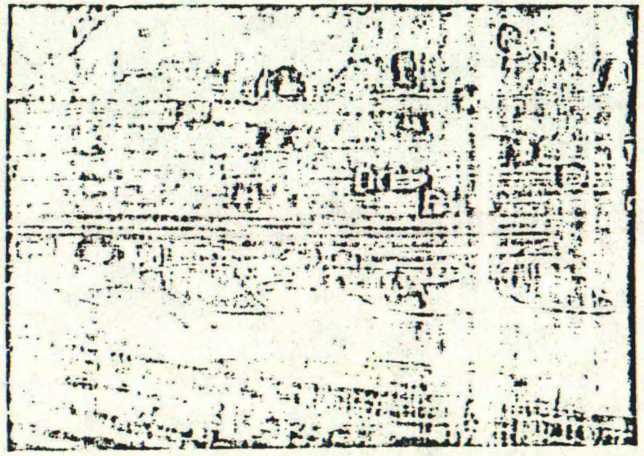


3c. *Agropyron spicatum*

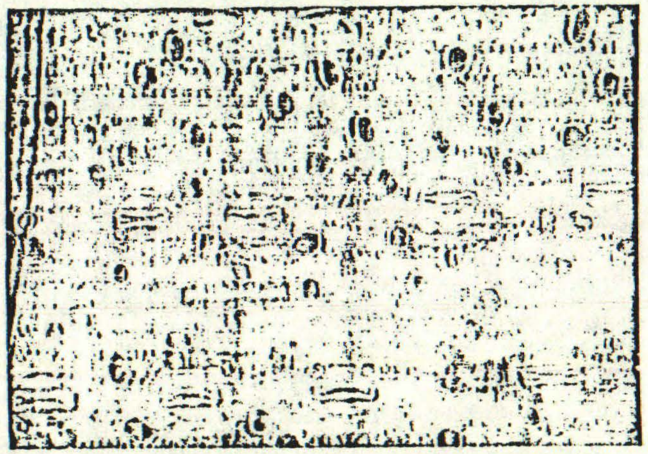


3d. *Agropyron spicatum*

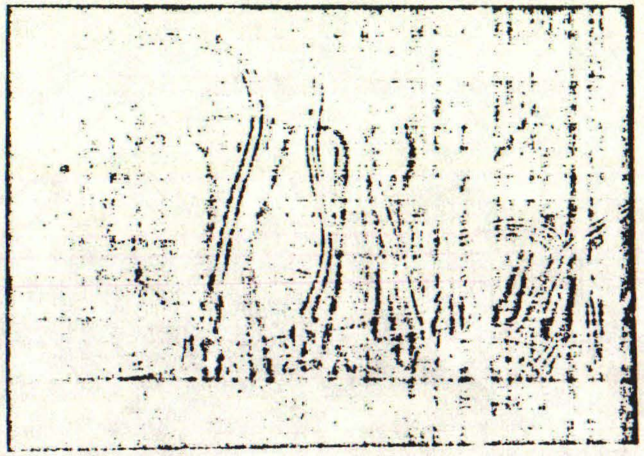
Plate 3



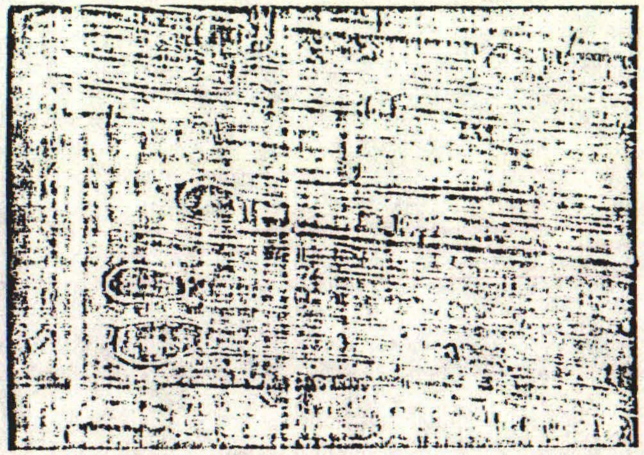
4a. *Stipa thurberiana*



4b. *Stipa thurberiana*

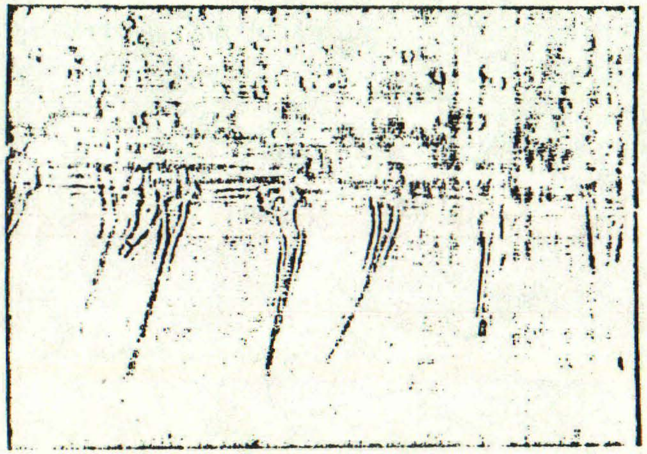


4c. *Stipa thurberiana*

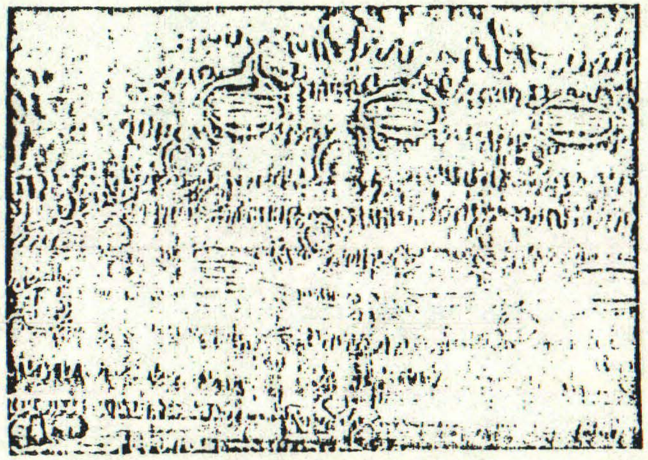


4d. *Stipa thurberiana* -

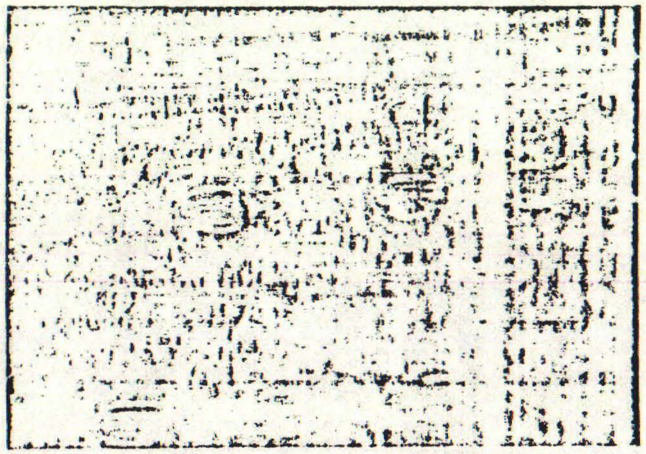
Plate 4



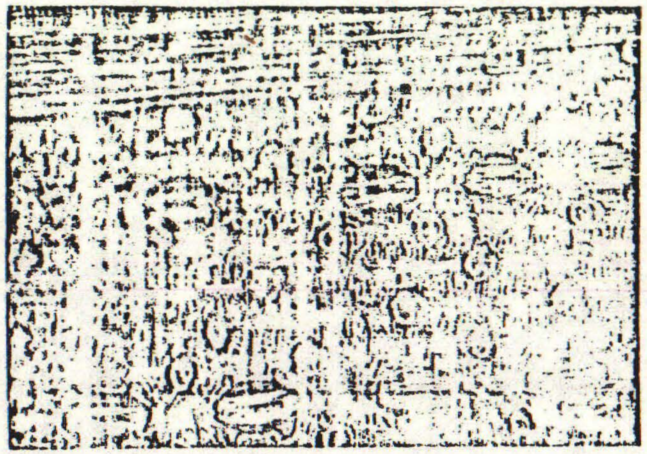
5a. *Sitanion hystrix*



5b. *Sitanion hystrix*

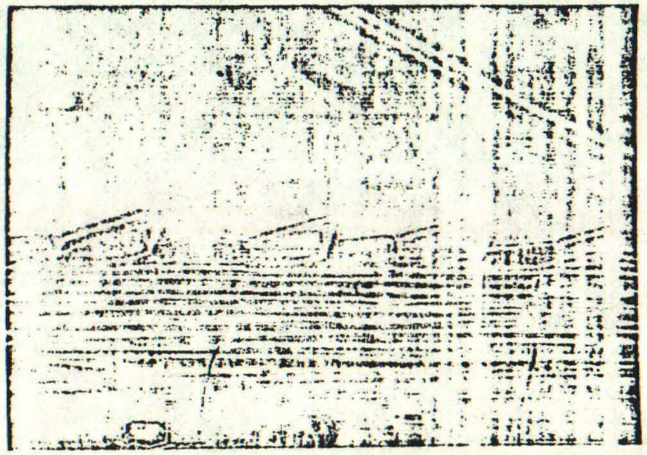


5c. *Sitanion hystrix*

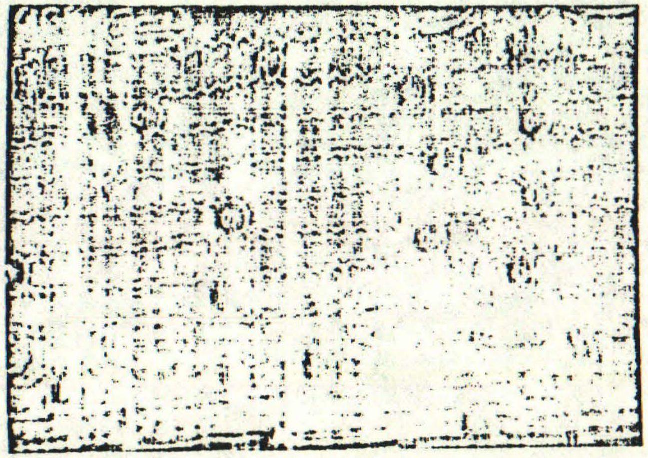


5d. *Sitanion hystrix*

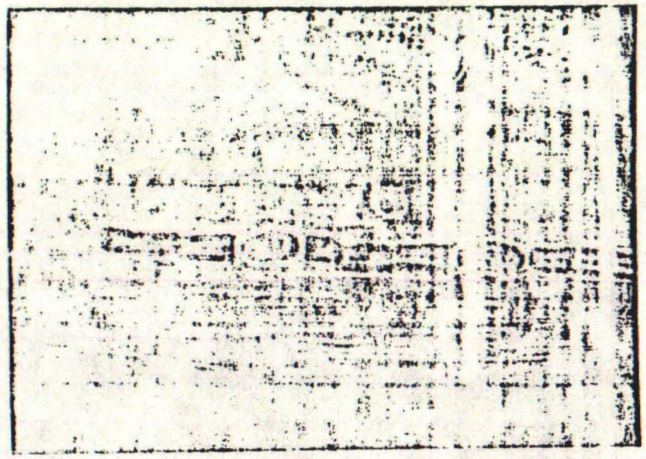
Plate 5



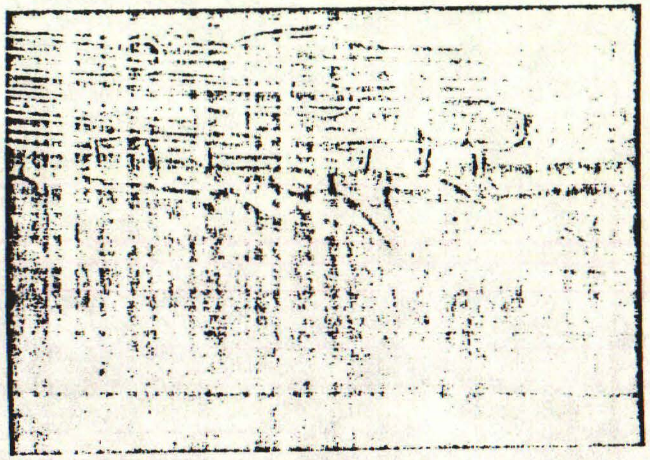
6a. *Hordeum brachyantherum*



6b. *Hordeum brachyantherum*

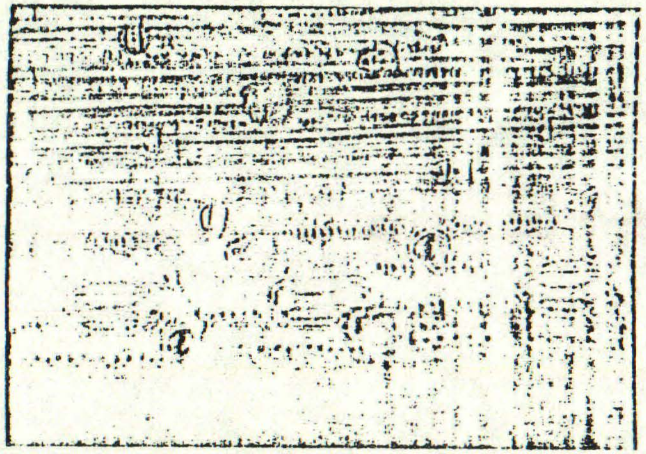


6c. *Hordeum brachyantherum*



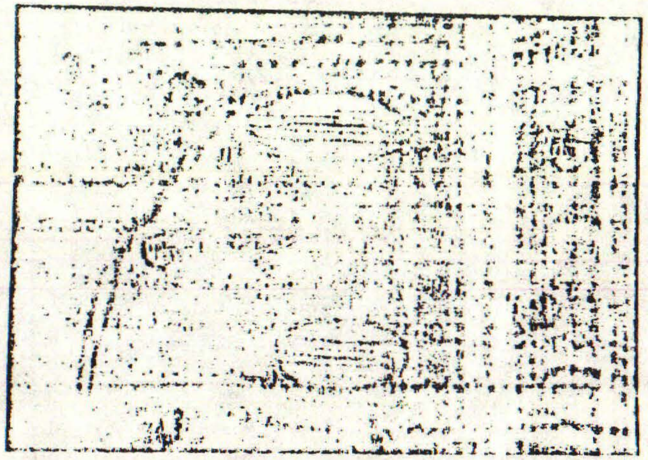
6d. *Hordeum jubatum*

Plate 6

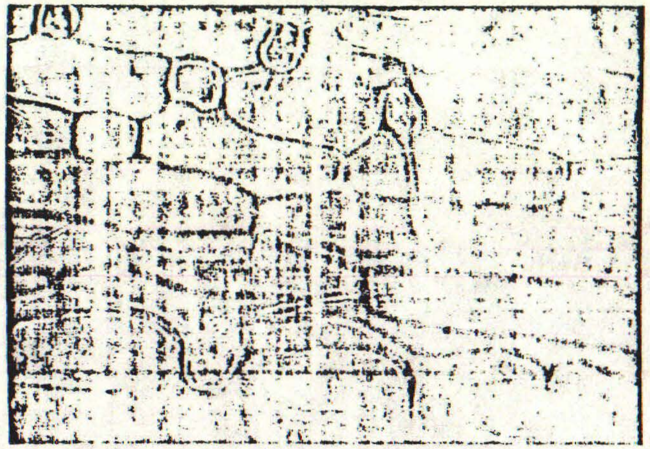


7a. *Hordeum jubatum*

7b. *Hordeum jubatum*

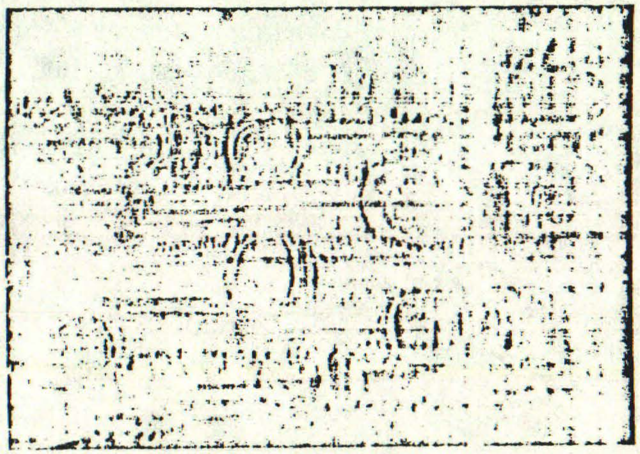


7c. *Elymus cinereus*

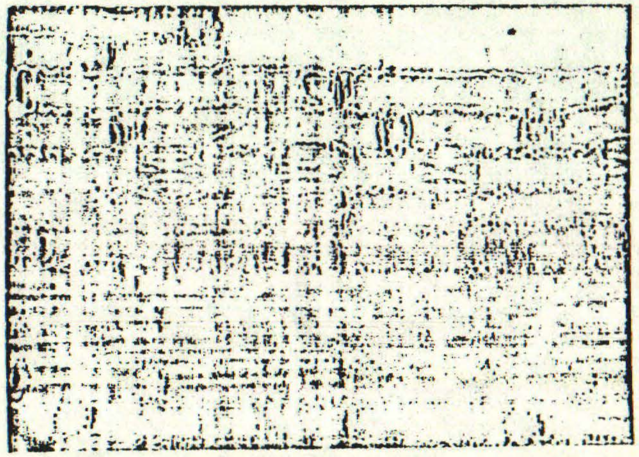


7d. *Elymus cinereus*

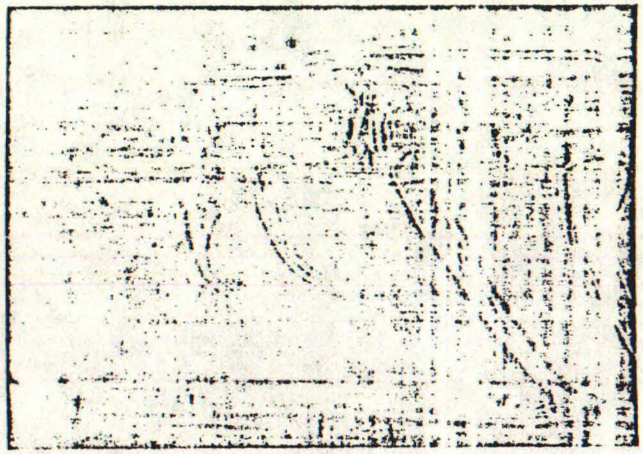
Plate 7



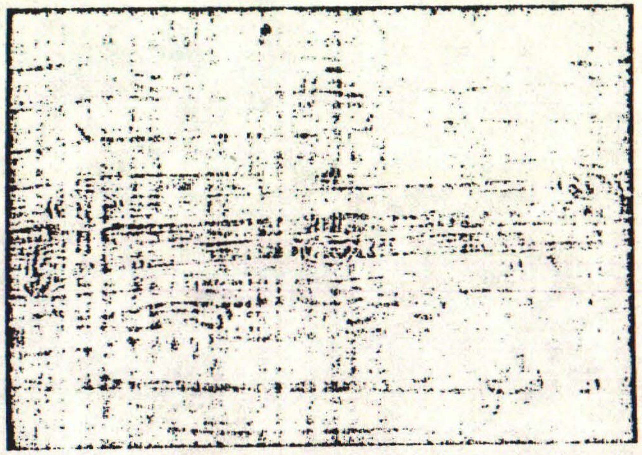
8a. *Elymus cinereus*



8b. *Bromus tectorum*

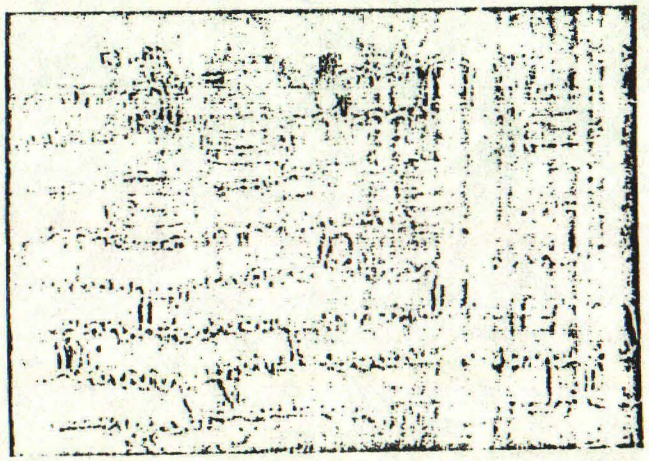


8c. *Bromus tectorum*

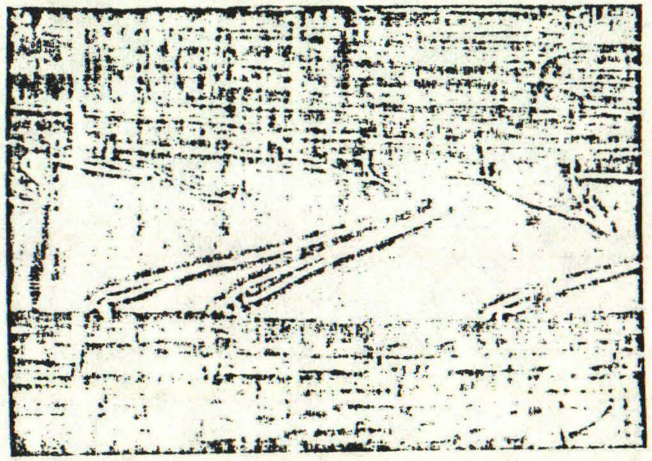


8d. *Bromus tectorum*

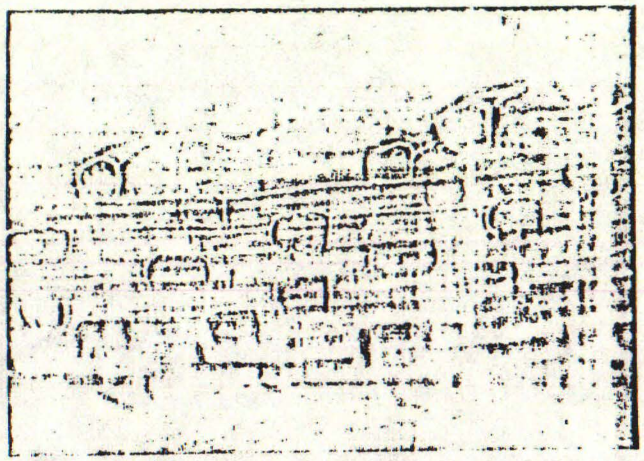
Plate 8



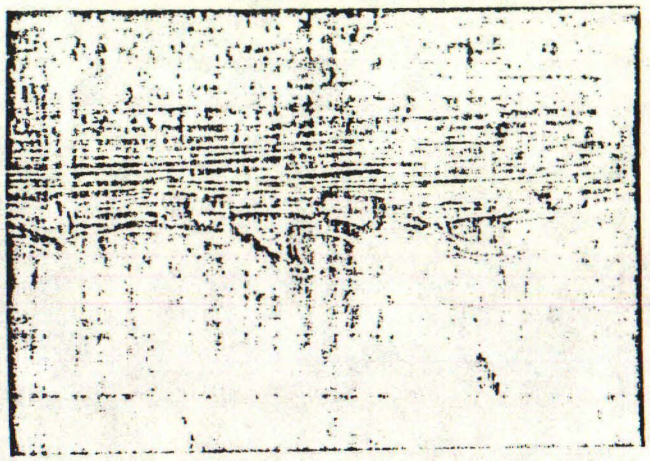
9a. *Koeleria cristata*



9b. *Koeleria cristata*

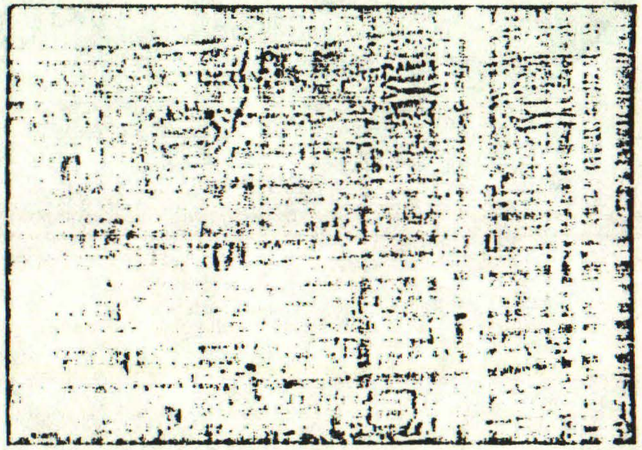


9c. *Koeleria cristata*

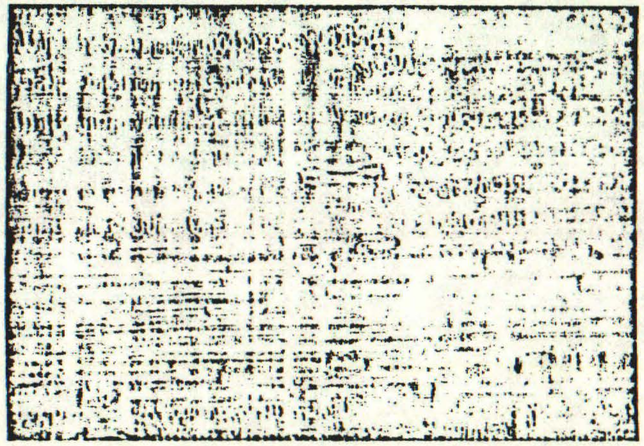


9d. *Poa sandbergii*

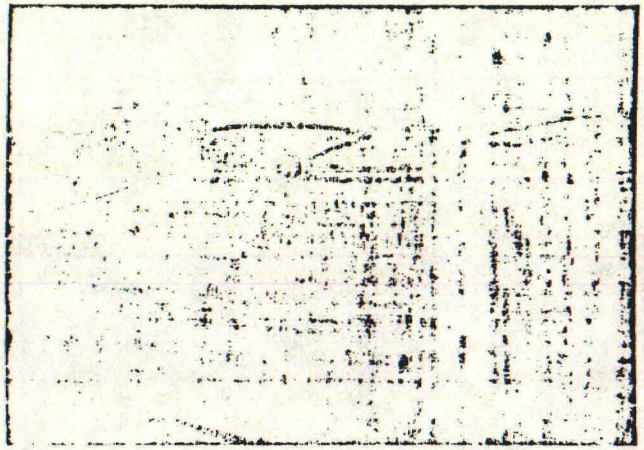
Plate 9



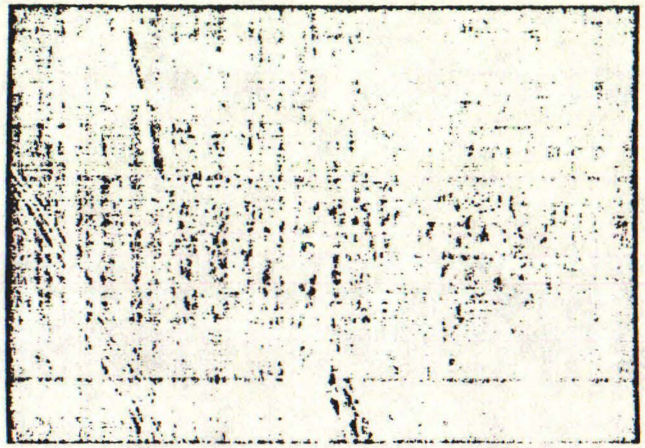
10a. *Poa sandbergii*



10b. *Poa sandbergii*

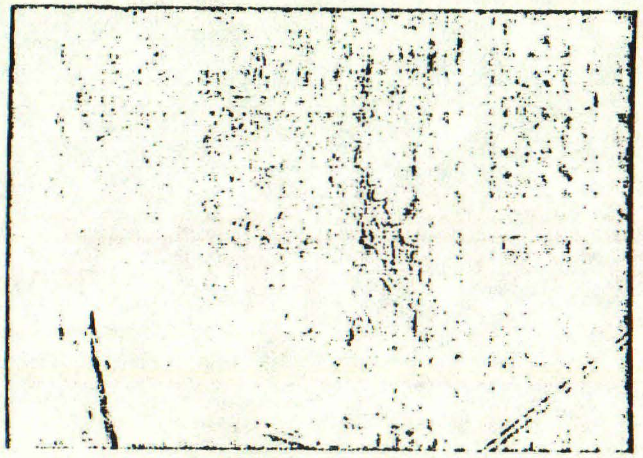


10c. *Carex spp.*

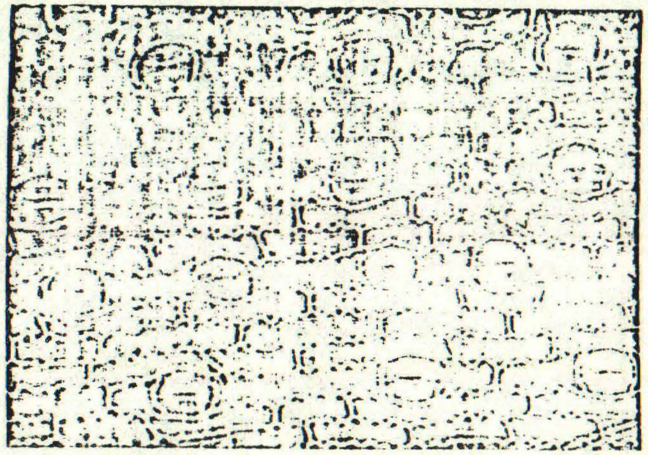


10d. *Carex spp.*

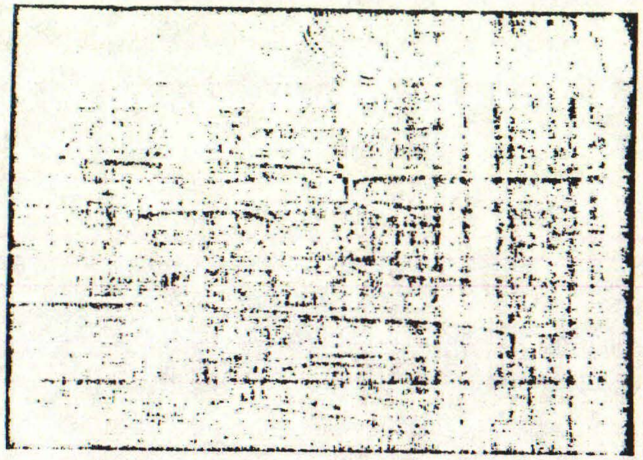
Plate 10



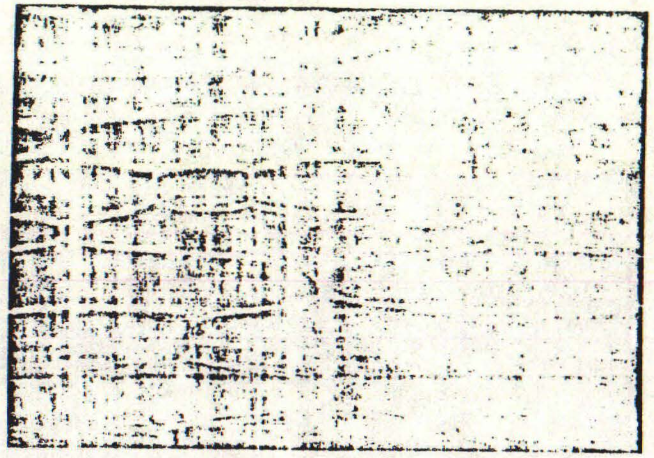
11a. *Carex spp.*



11b. *Juncus spp.*

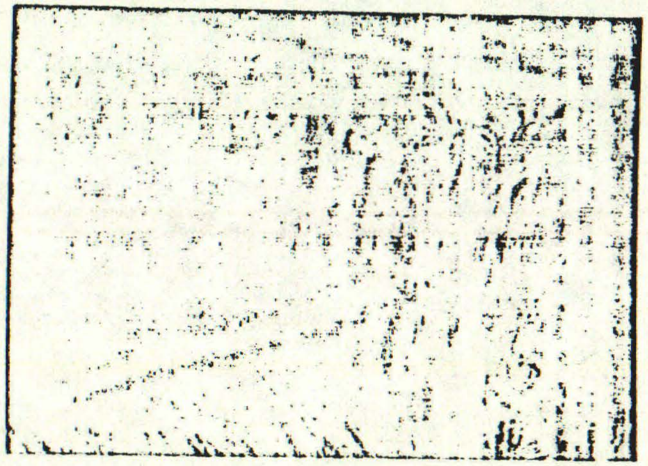


11c. *Allium spp.*

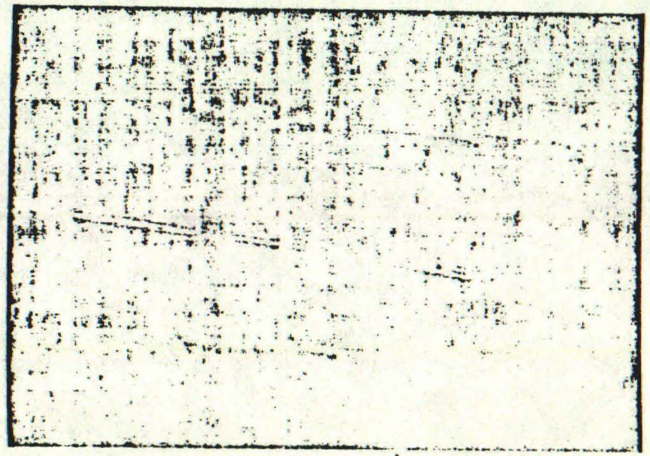


11d. *Allium spp.*

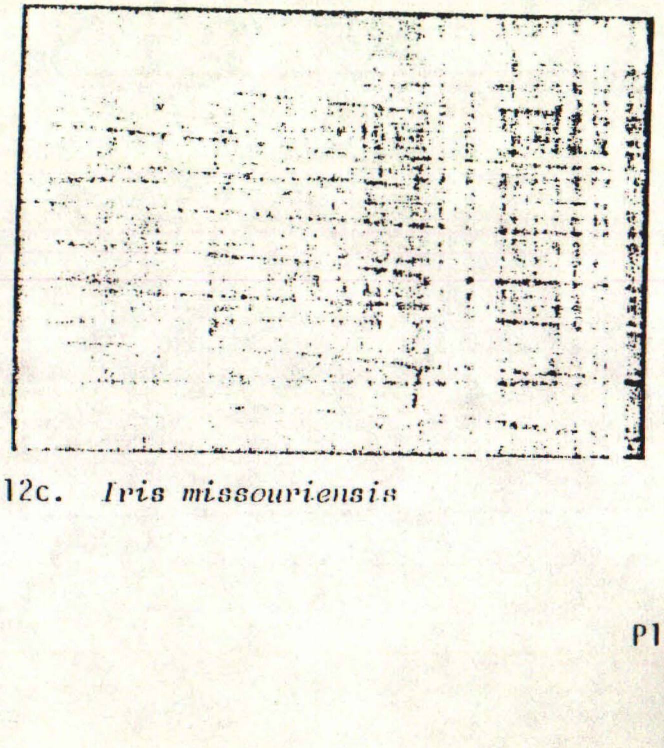
Plate 11



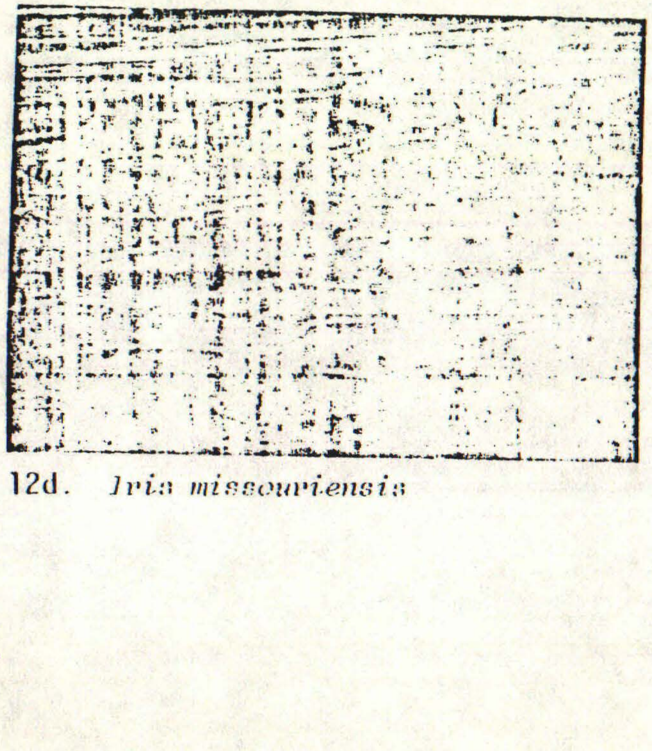
12a. *Iris missouriensis*



12b. *Iris missouriensis*

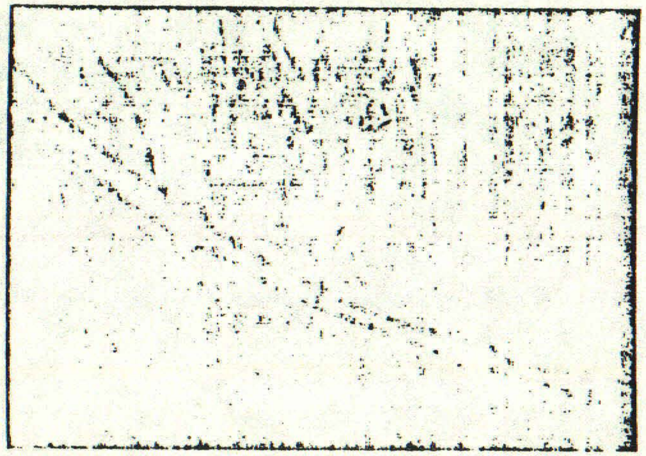


12c. *Iris missouriensis*

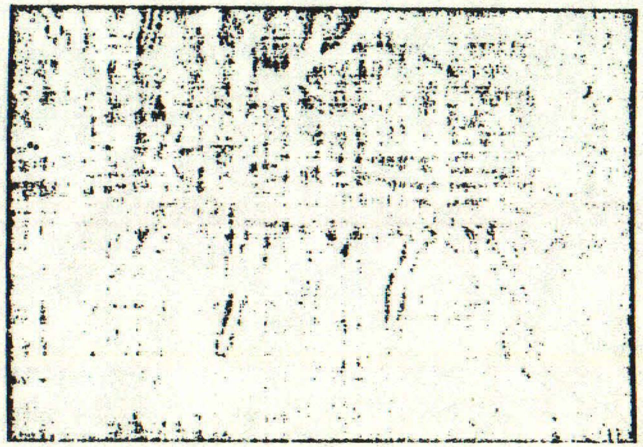


12d. *Iris missouriensis*

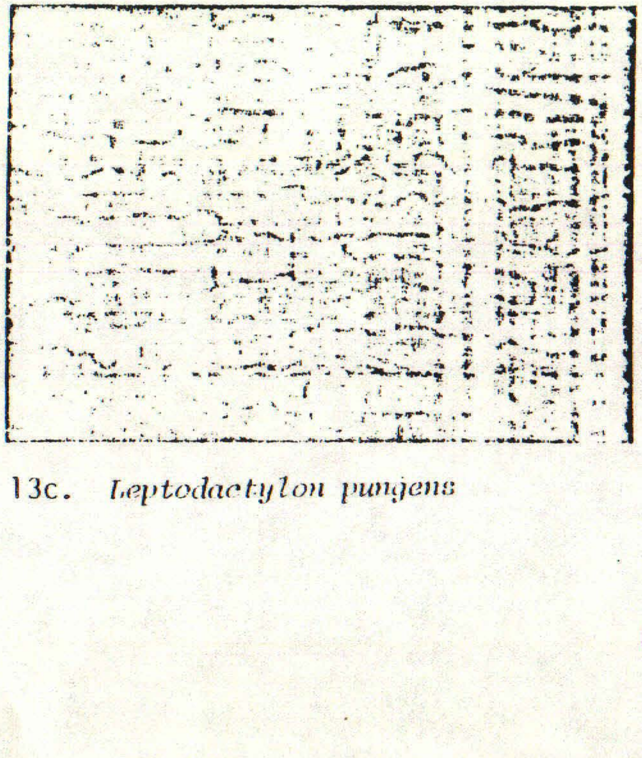
Plate 12



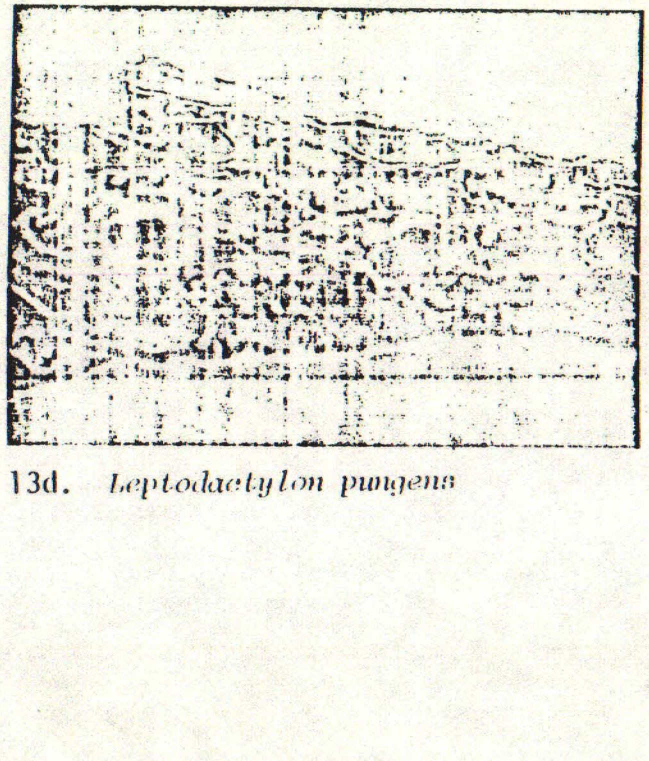
13a. *Leptodactylon pungens*



13b. *Leptodactylon pungens*

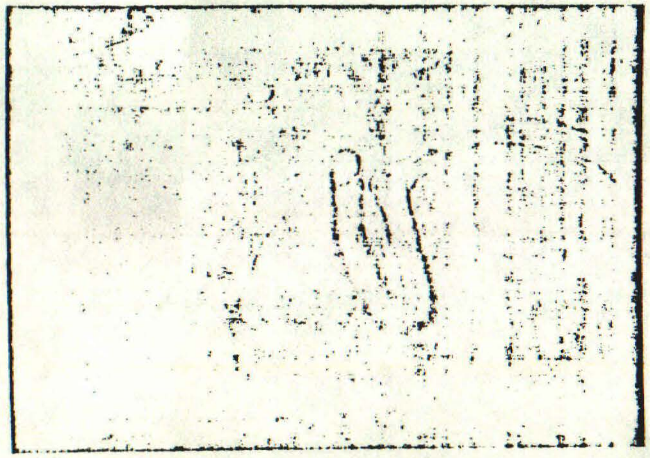


13c. *Leptodactylon pungens*

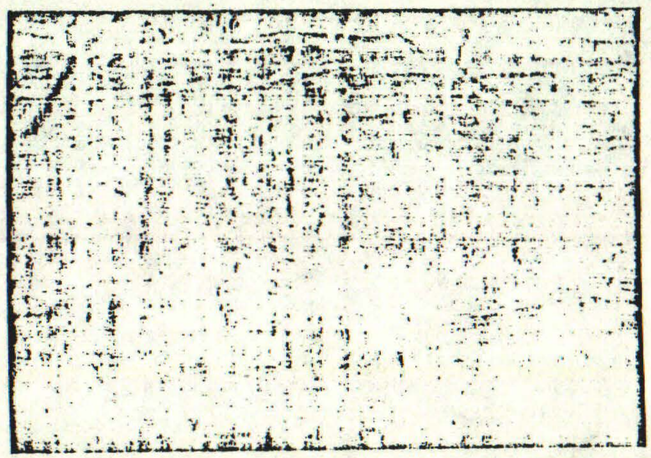


13d. *Leptodactylon pungens*

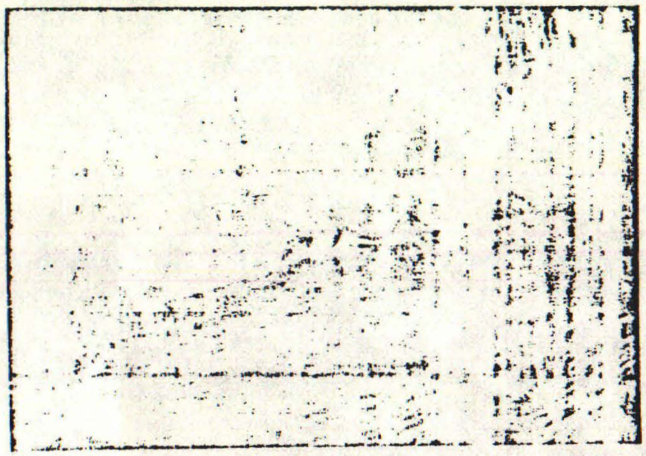
Plate 13



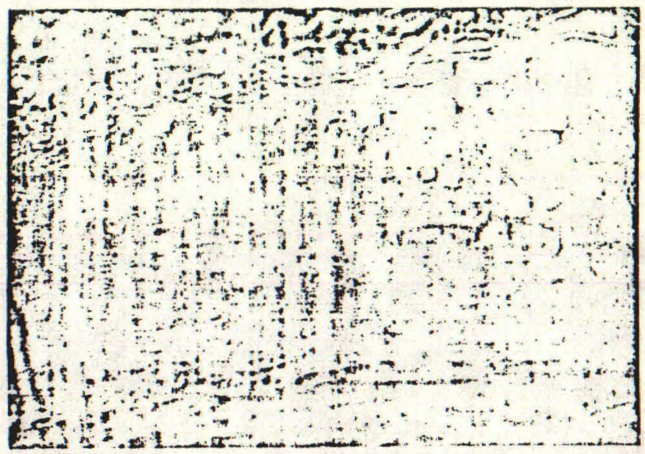
14a. *Phlox hoodii*



14b. *Phlox hoodii*

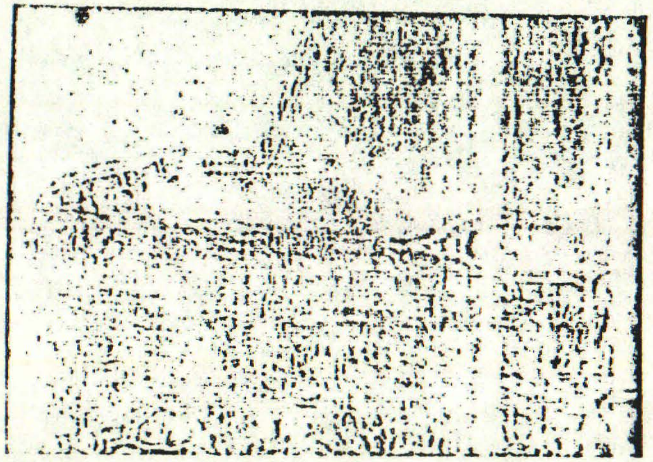


14c. *Phlox hoodii*

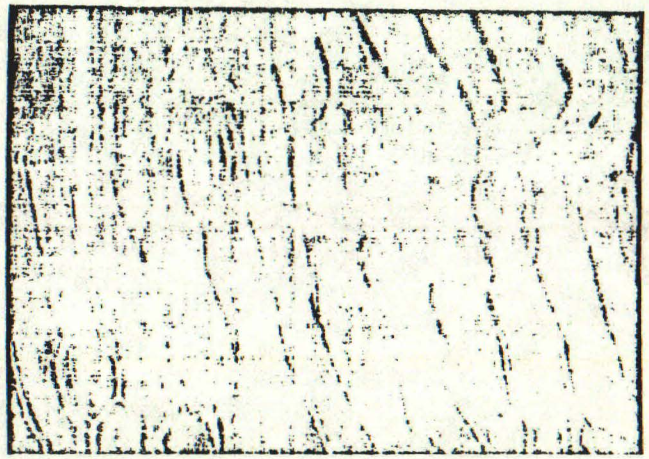


14d. *Phlox hoodii*

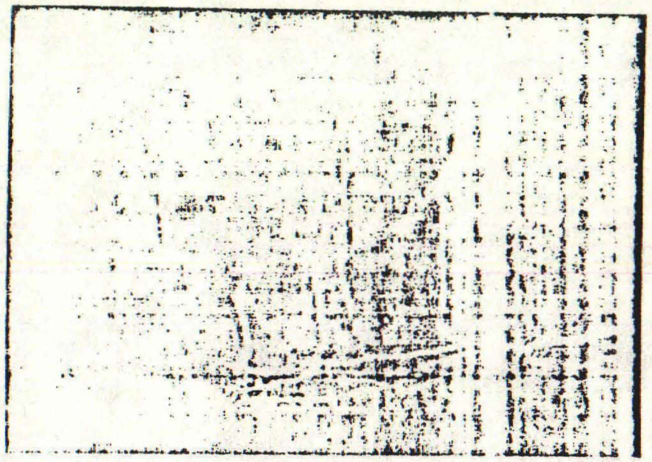
Plate 14



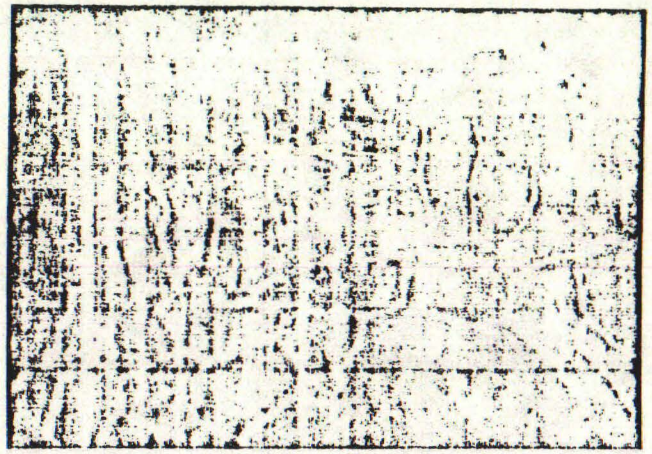
15a. *Chrysothamnus viscidiflorus*



15b. *Chrysothamnus viscidiflorus*



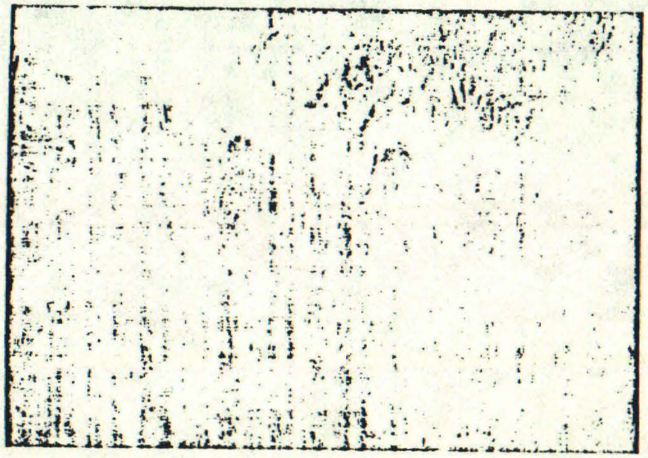
15c. *Chrysothamnus viscidiflorus*



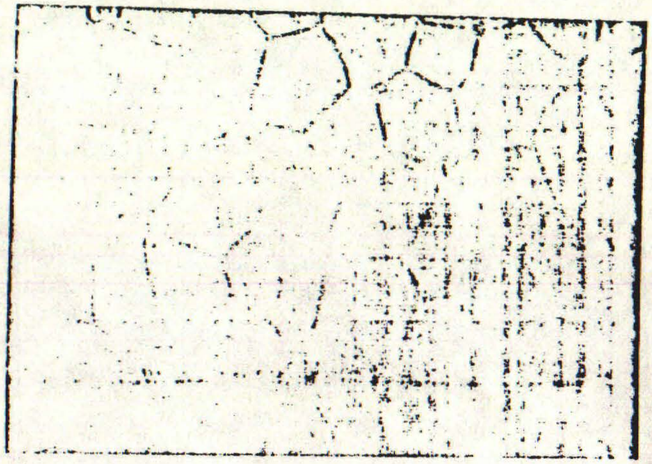
15d. *Chrysothamnus viscidiflorus*

Plate 15

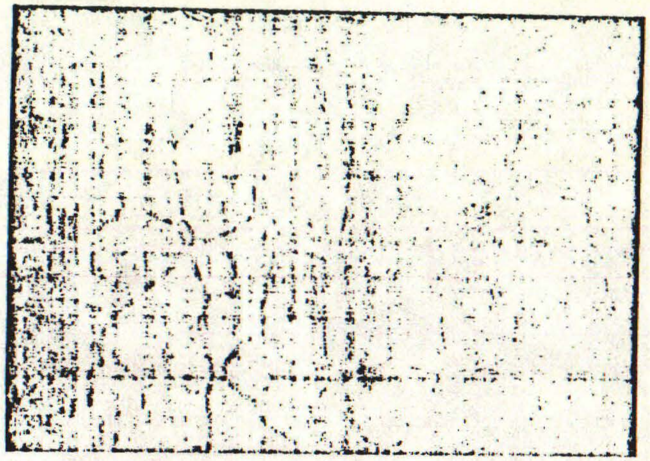
16a. *Eriogonum spp.*



16b. *Eriogonum spp.*



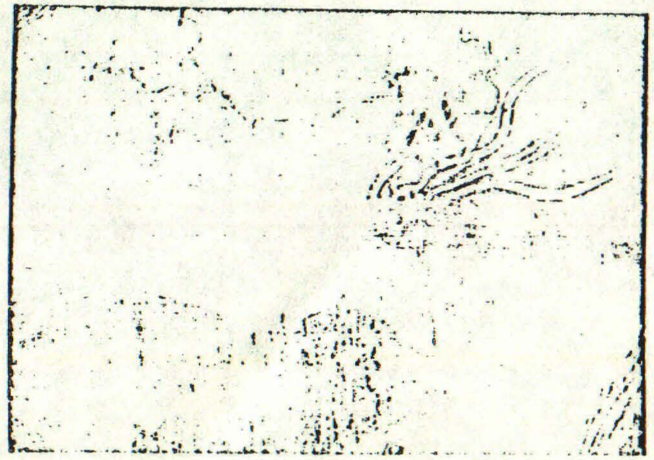
16c. *Eriogonum spp.*



16d. *Eriogonum spp.*

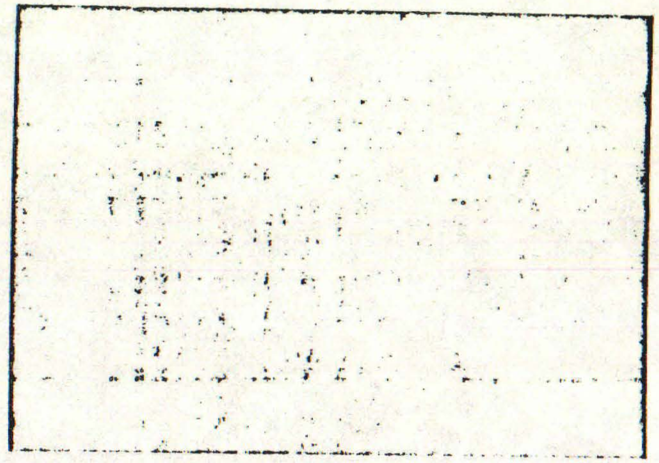
Plate 16

17a. *Purshia tridentata*



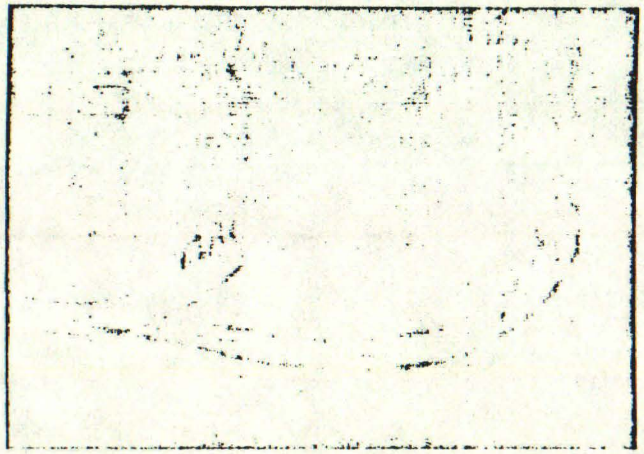
17b. *Purshia tridentata* (100X)

17c. *Purshia tridentata*

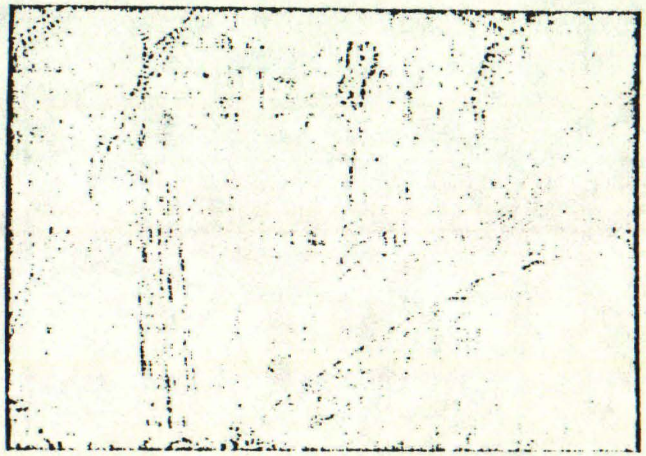


17d. *Purshia tridentata*

Plate 17

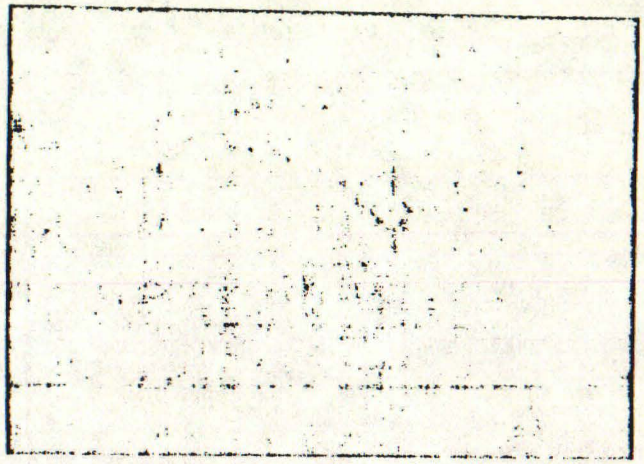


18a. *Oenothera tanacetifolia*



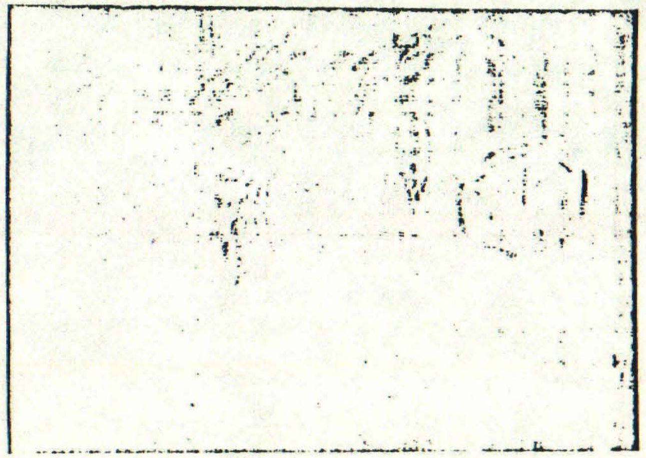
18b. *Oenothera tanacetifolia*

18c. *Oenothera tanacetifolia* (100X)

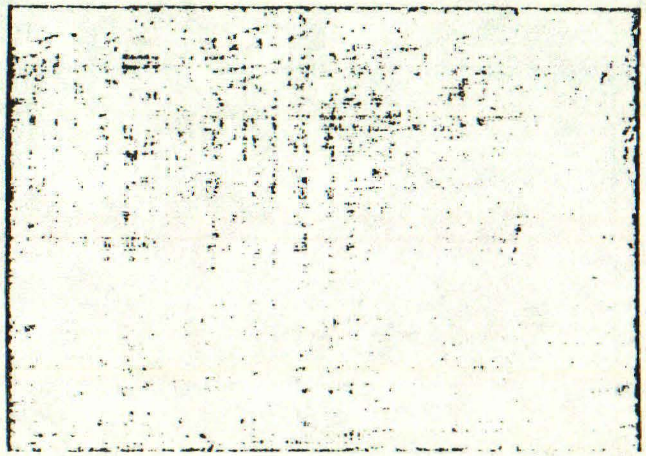


18d. *Oenothera tanacetifolia*

Plate 18

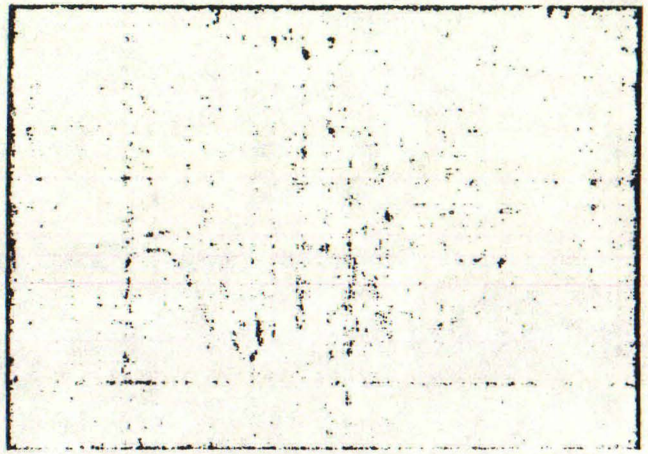


19a. *Descurainia pinnata*



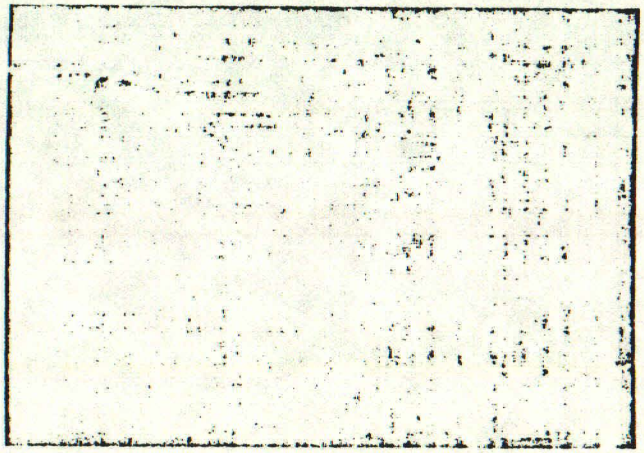
19b. *Descurainia pinnata*

19c. *Descurainia pinnata*

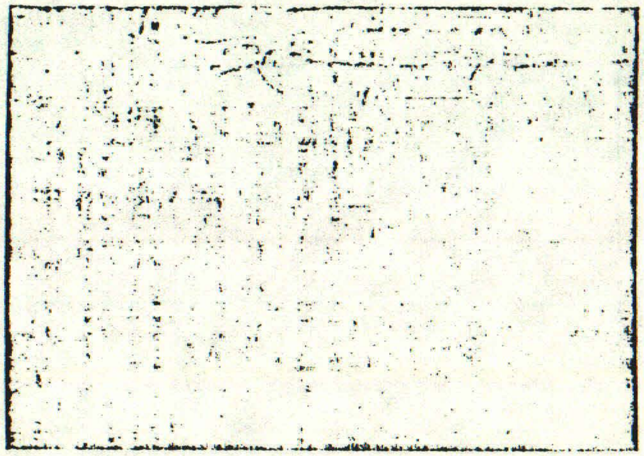


19d. *Artemisia arbuscula*

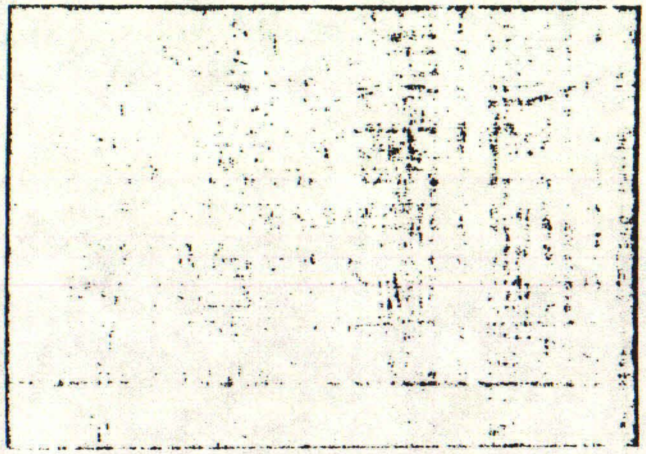
Plate 19



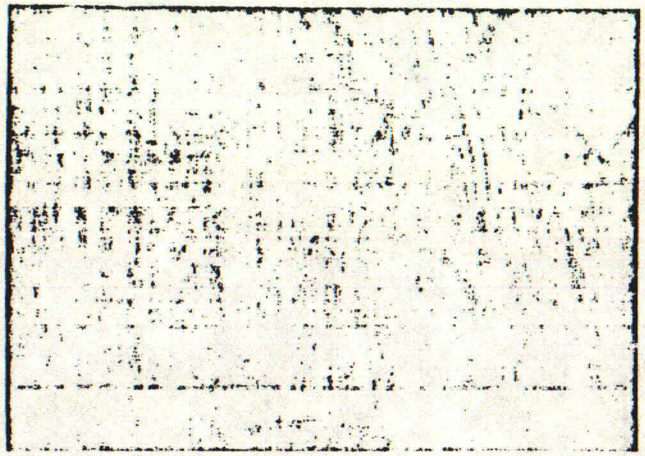
20a. *Artemisia arbuscula*



20b. *Artemisia arbuscula*

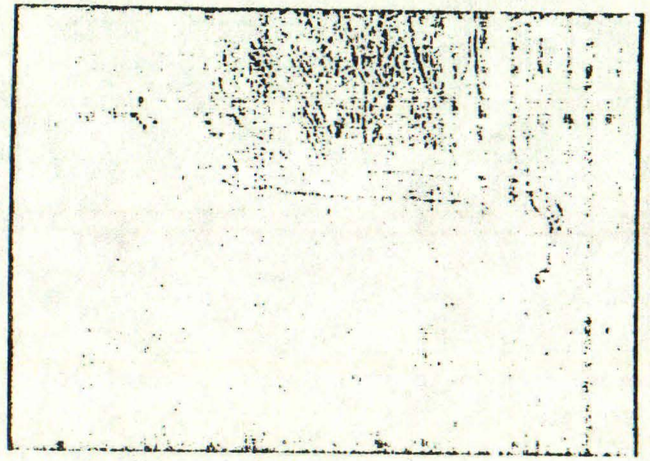


20c. *Artemisia tridentata*

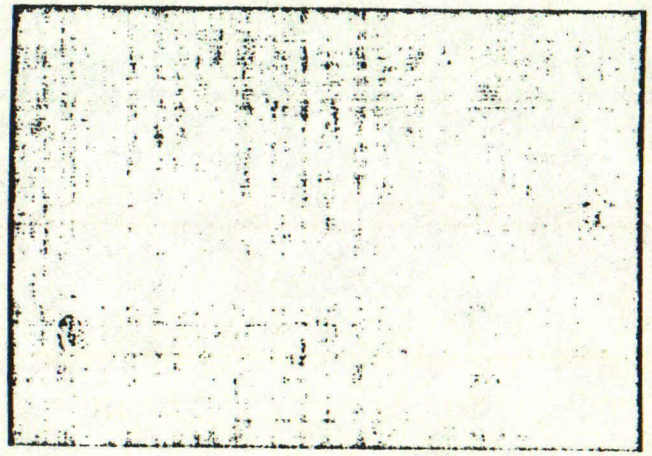


20d. *Artemisia tridentata*

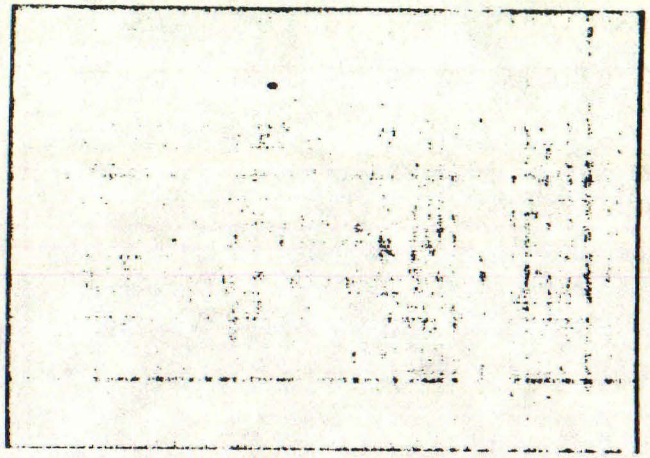
Plate 20



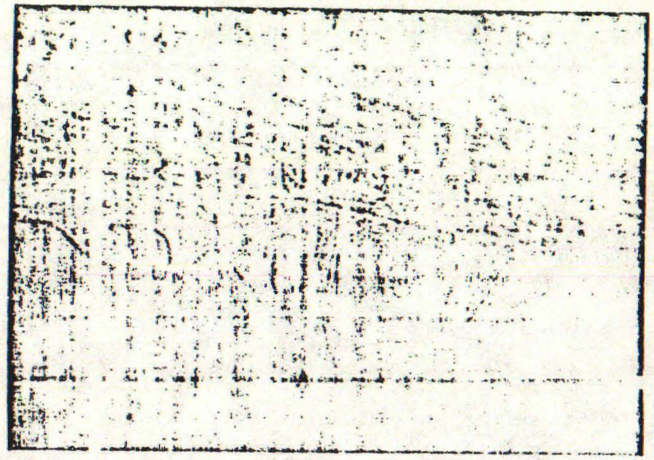
21a. *Lepidium perfoliatum* (100X)



21b. *Lepidium perfoliatum*

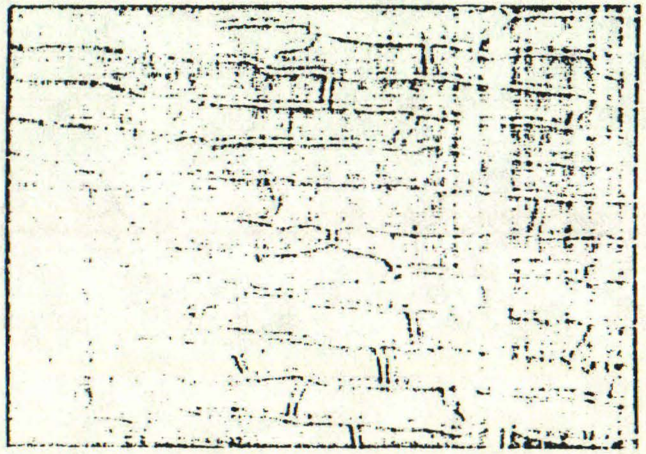


21c. *Lepidium perfoliatum*

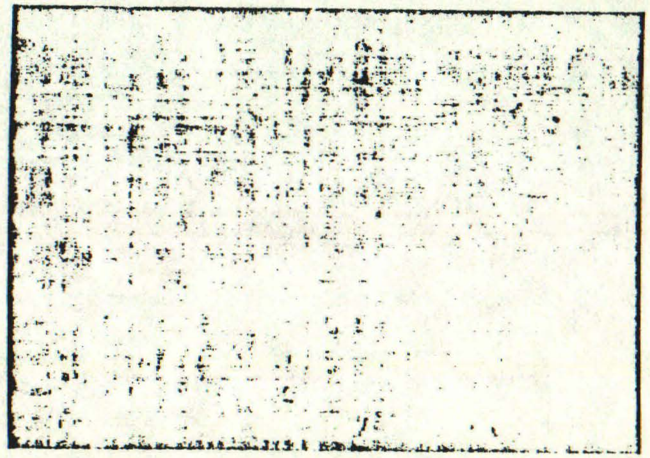


21d. *Arenaria spp.*

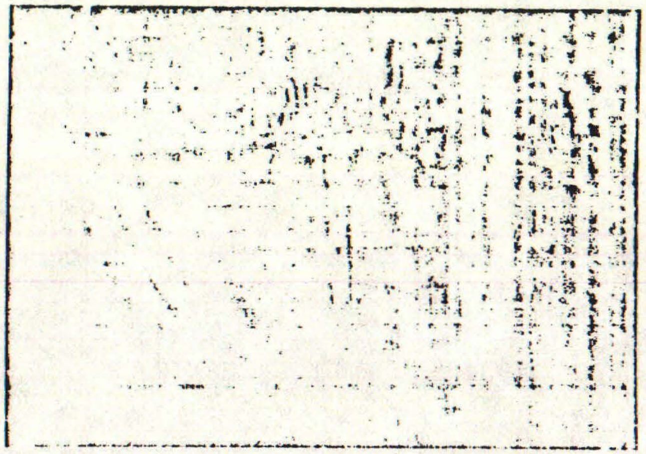
Plate 21



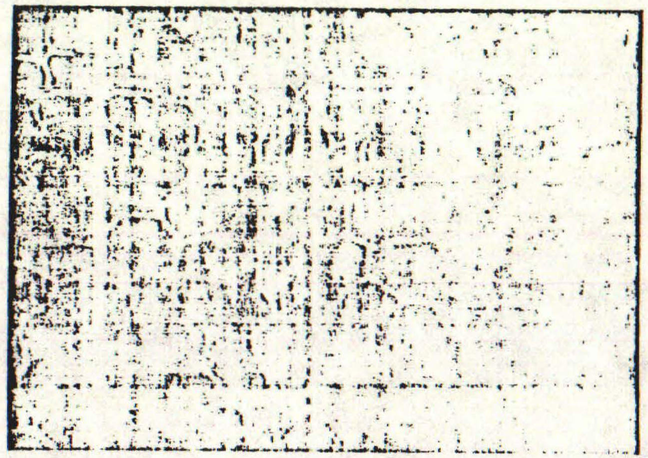
22a. *Arenaria spp.*



22b. *Arenaria spp.*

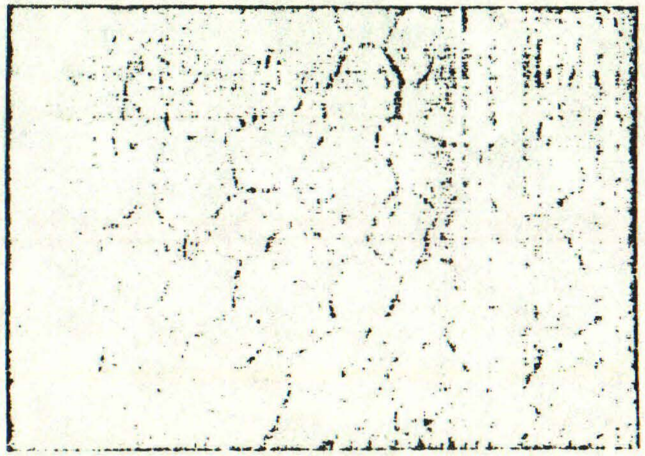


22c. *Penstemon speciosus*

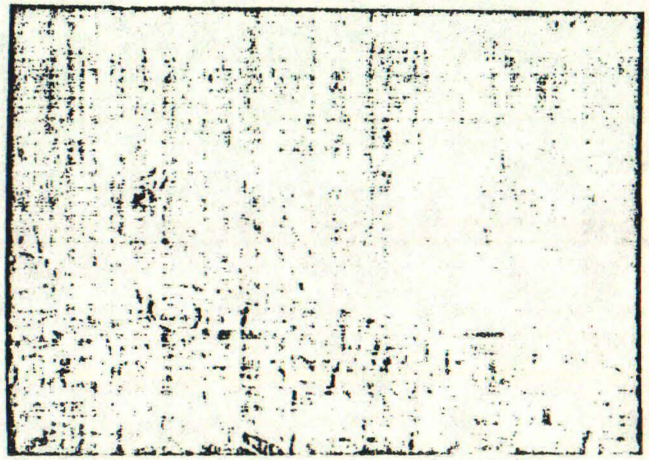


22d. *Penstemon speciosus*

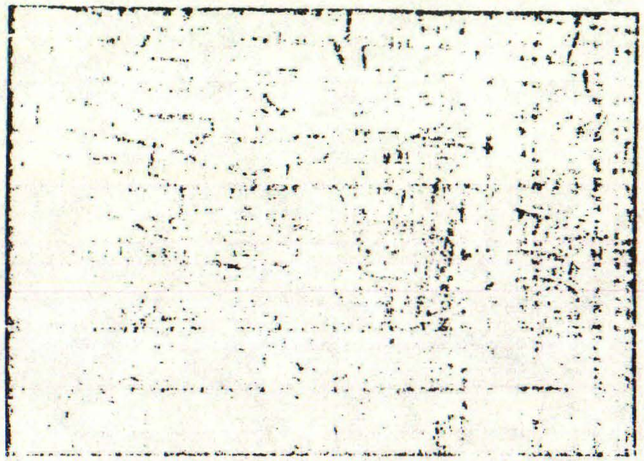
Plate 22



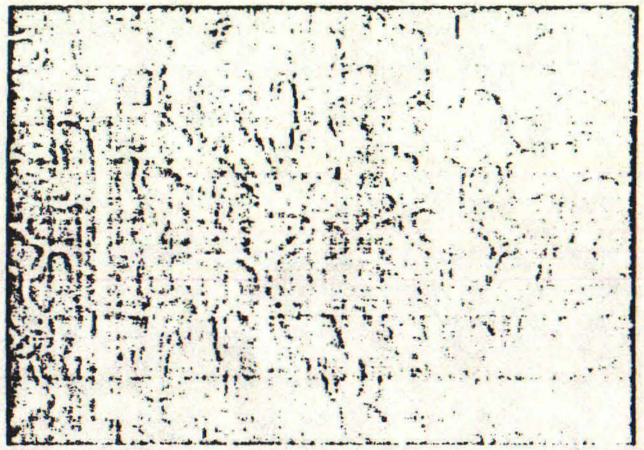
23a. *Penstemon speciosus*



23b. *Penstemon spp.*

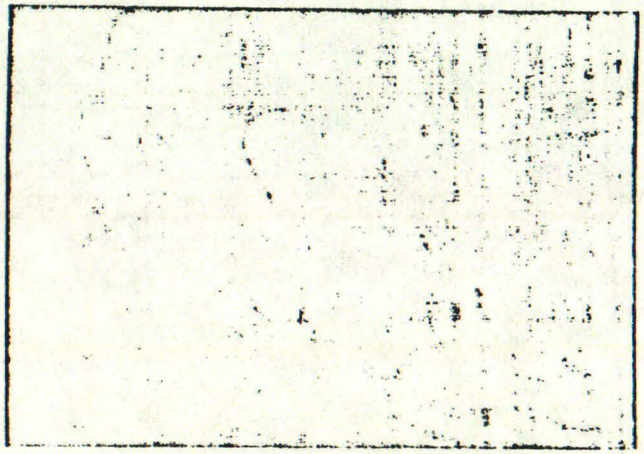


23c. *Penstemon spp.*

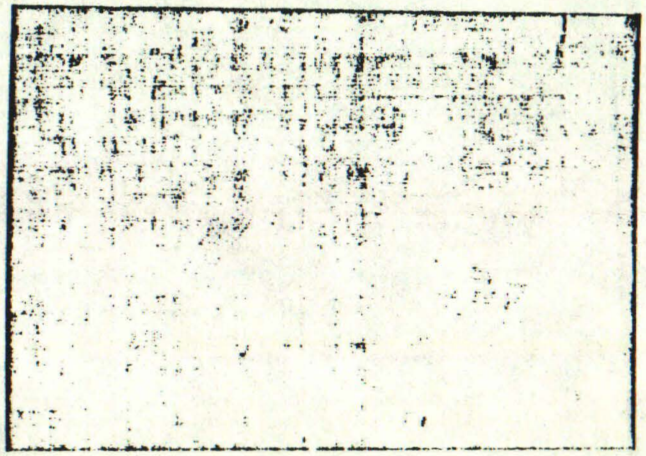


23d. *Penstemon spp.*

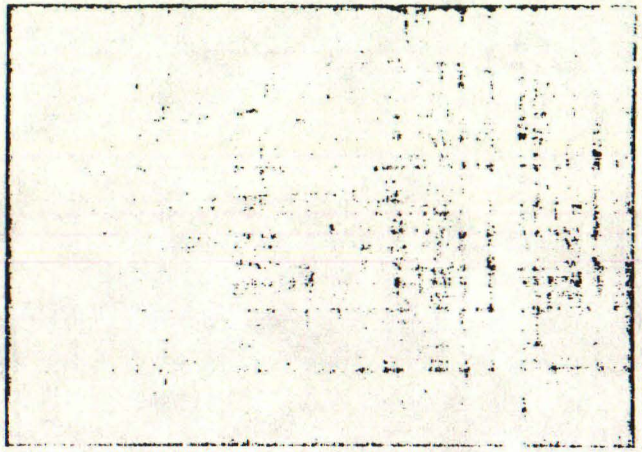
Plate 23



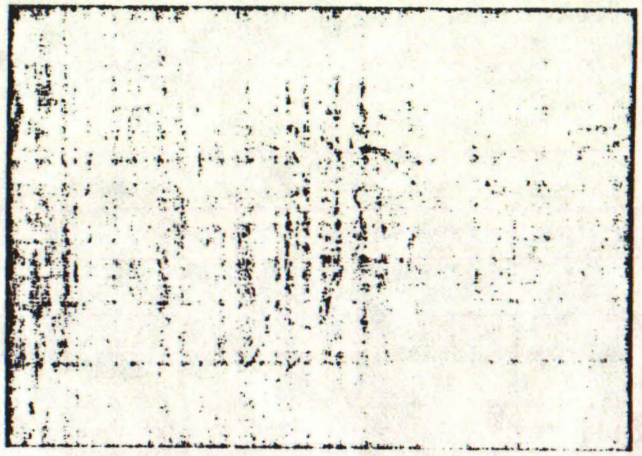
24a. *Zigadenus spp.*



24b. *Zigadenus spp.*

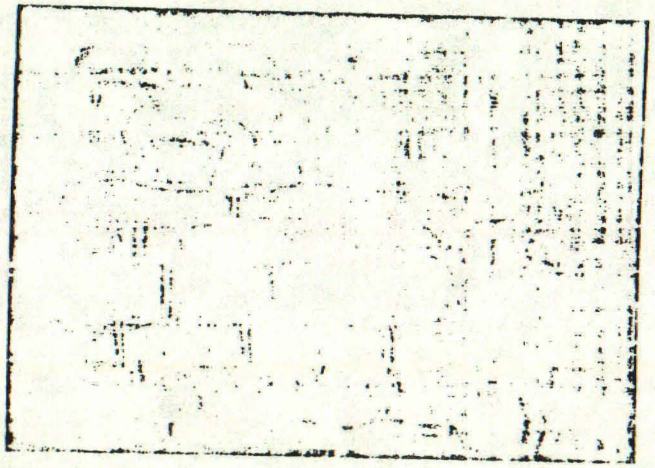


24c. *Zigadenus spp.*

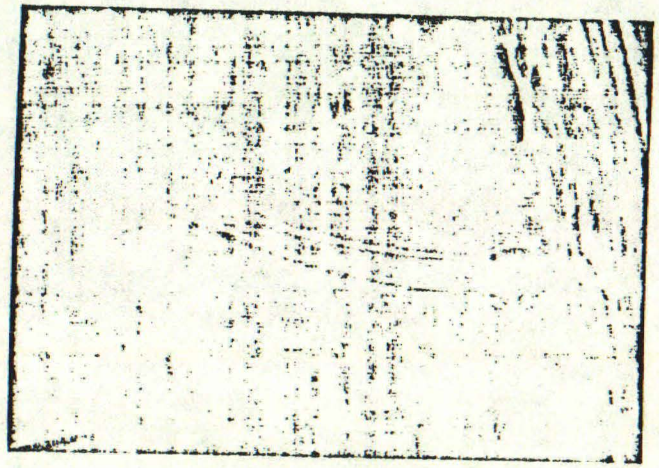


24d. *Balsamorhiza hookeri*

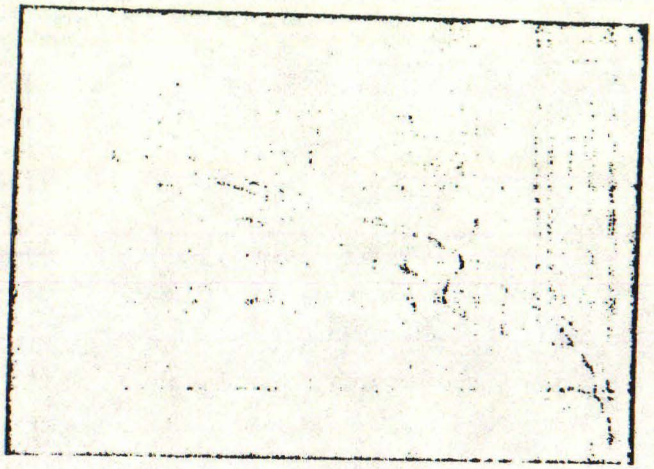
Plate 24



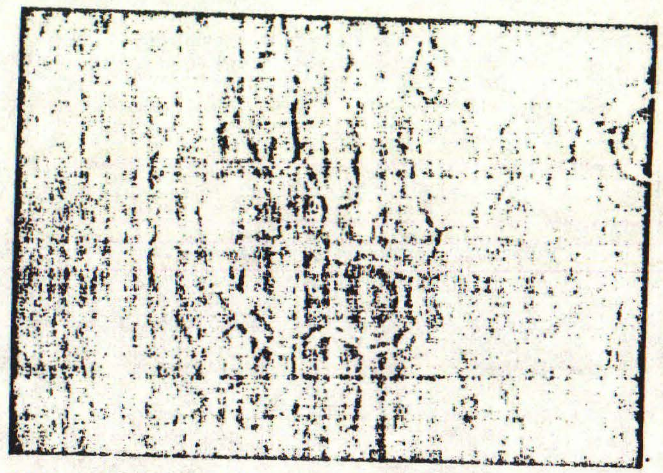
25a. *Balsamorhiza hookeri*



25b. *Balsamorhiza hookeri*

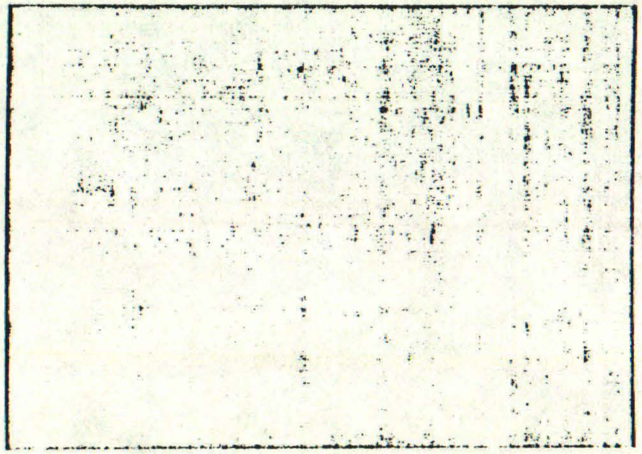


25c. *Balsamorhiza sagittata*

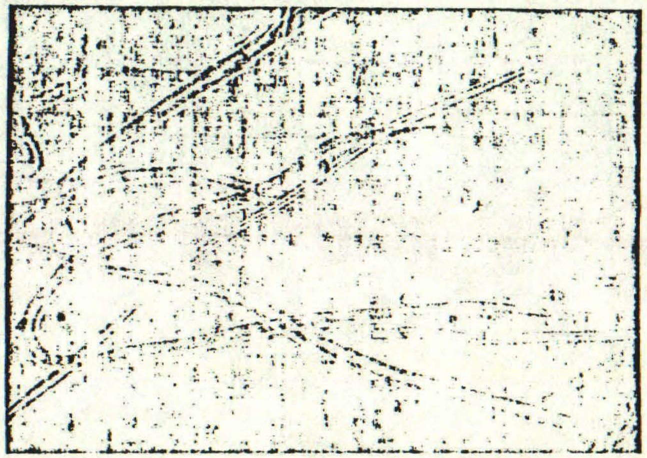


25d. *Balsamorhiza sagittata*

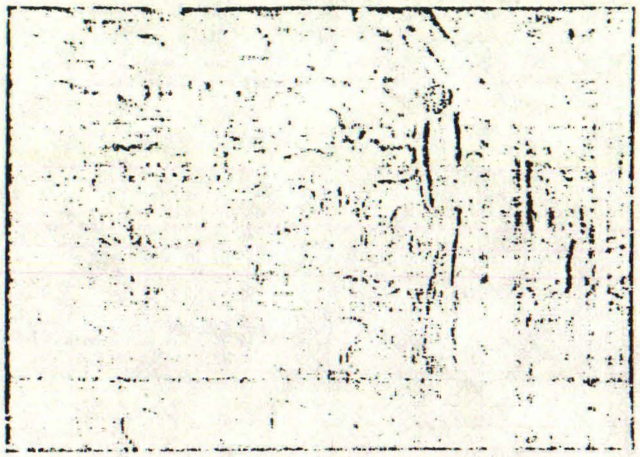
Plate 25



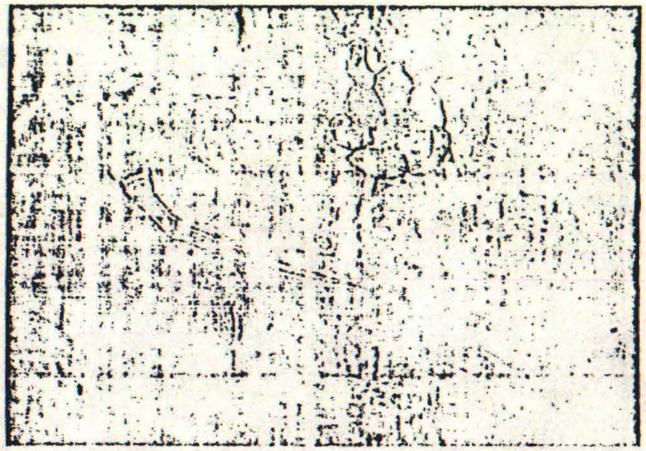
26a. *Achillea millefolium* (400X)



26b. *Achillea millefolium* (100X)

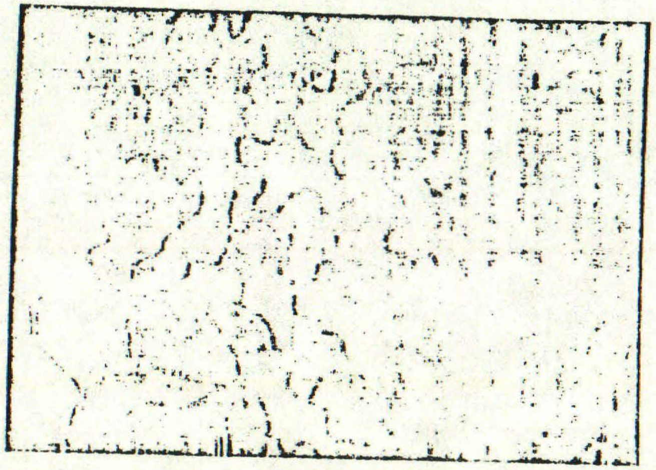


26c. *Achillea millefolium*



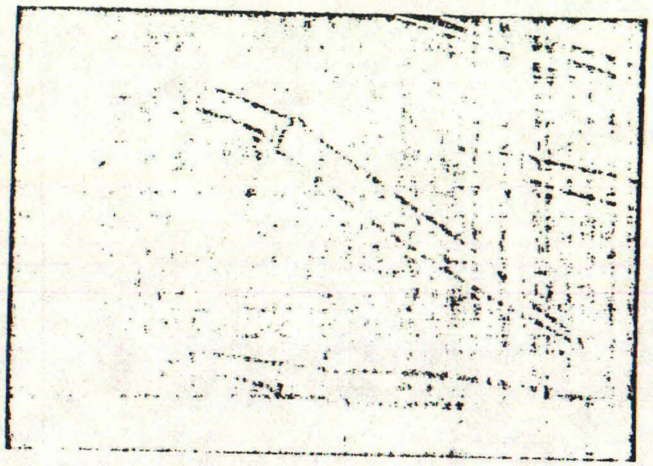
26d. *Erigeron austinae* (100X)

Plate 26

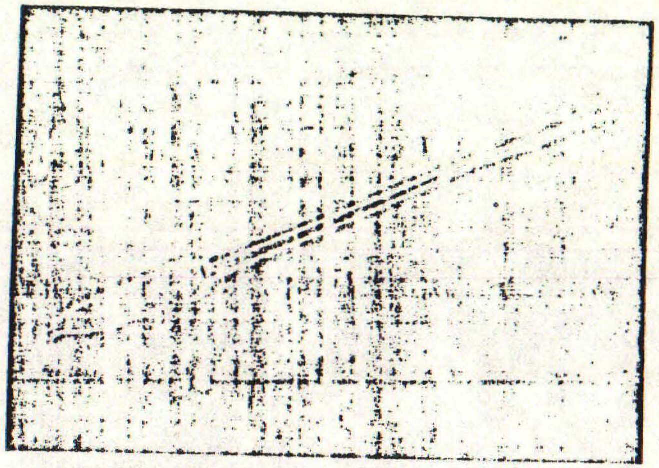


27a. *Erigeron austinae*

27b. *Erigeron austinae* (100X)

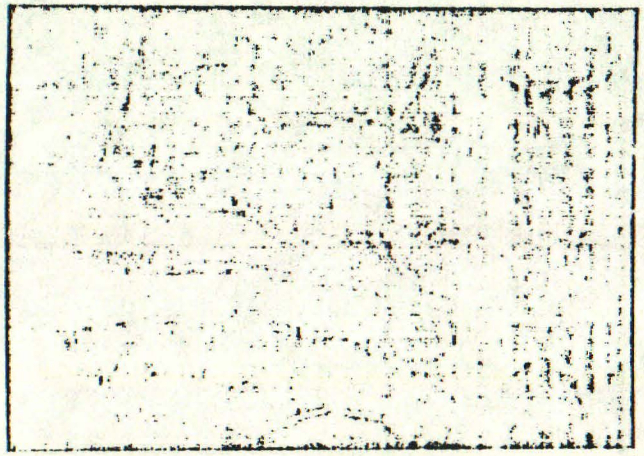


27c. *Erigeron bloomeri*

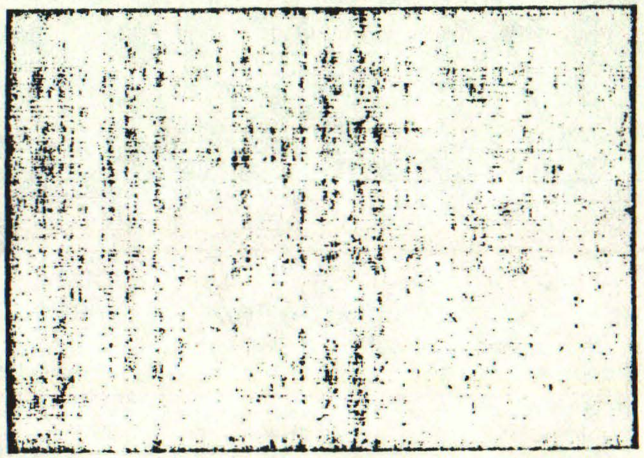


27d. *Erigeron bloomeri*

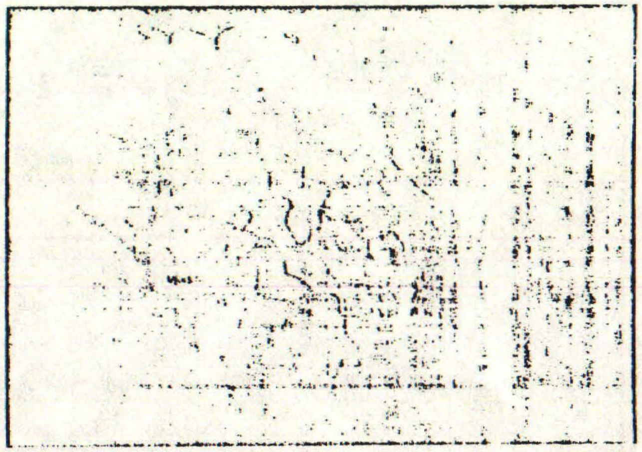
Plate 27



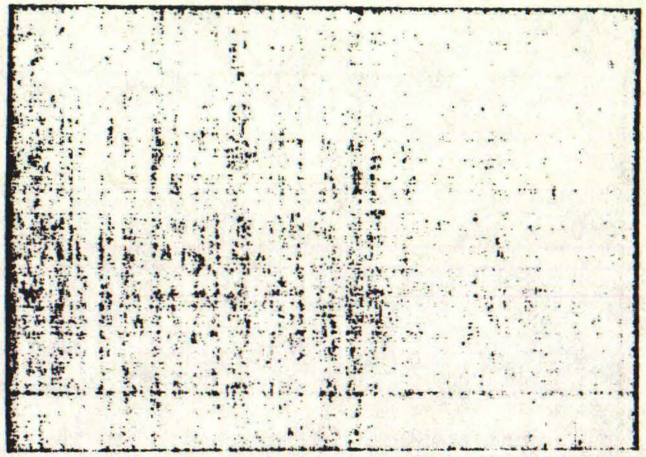
28a. *Erigeron bloomeri*



28b. *Taraxacum officinale*

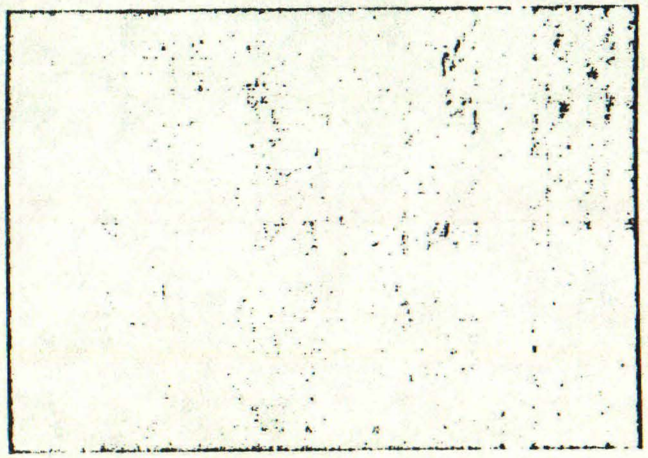


28c. *Taraxacum officinale*

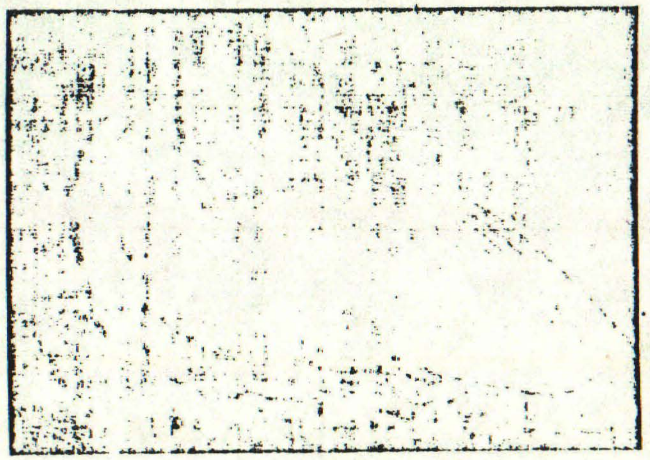


28d. *Taraxacum officinale*

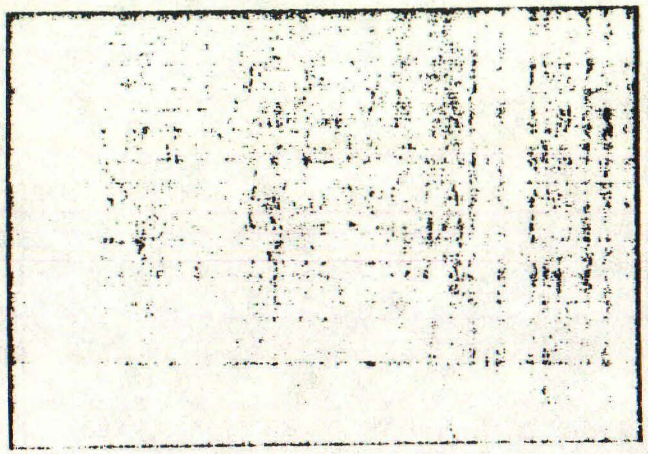
Plate 28



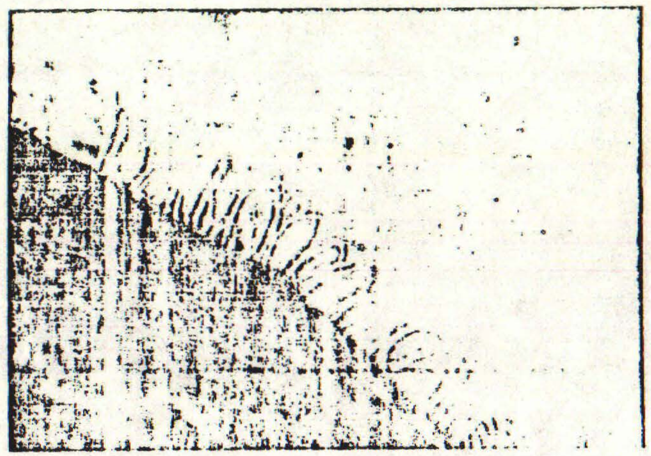
29a. *Potentilla* spp.



29b. *Potentilla* spp.

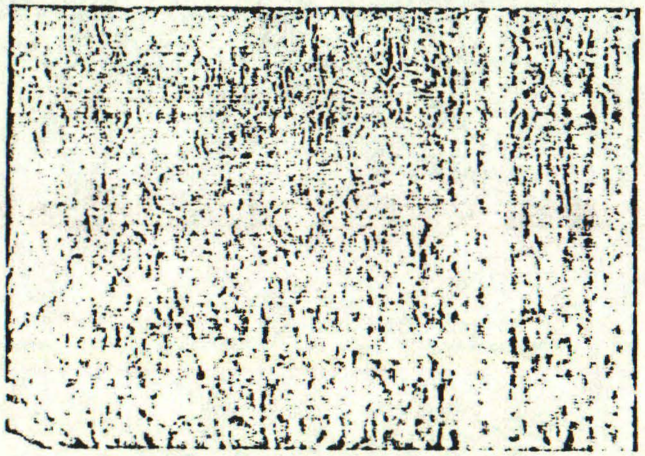


29c. *Potentilla* spp.

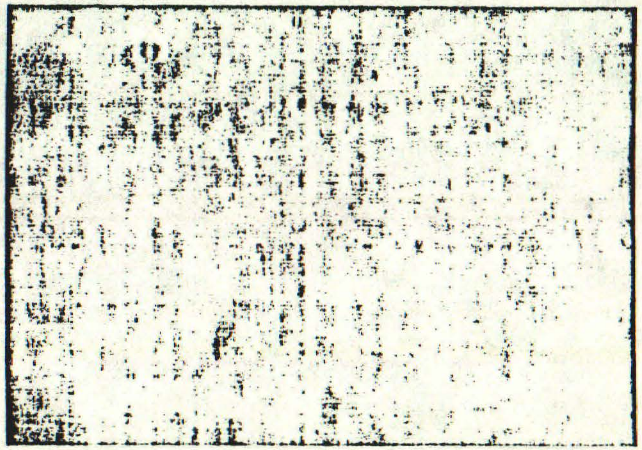


29d. *Chenopodium rubrum*

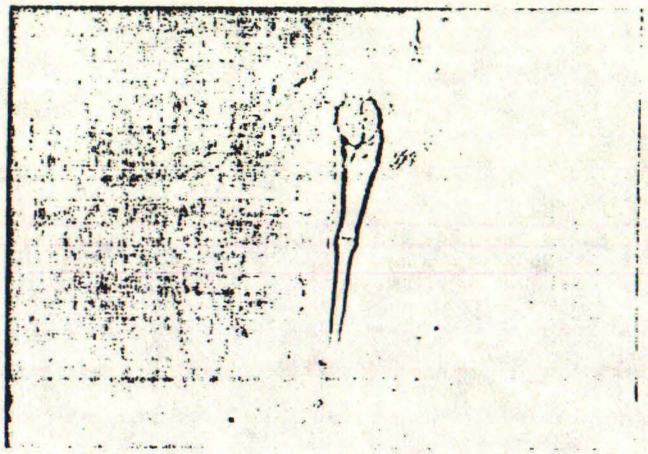
Plate 29



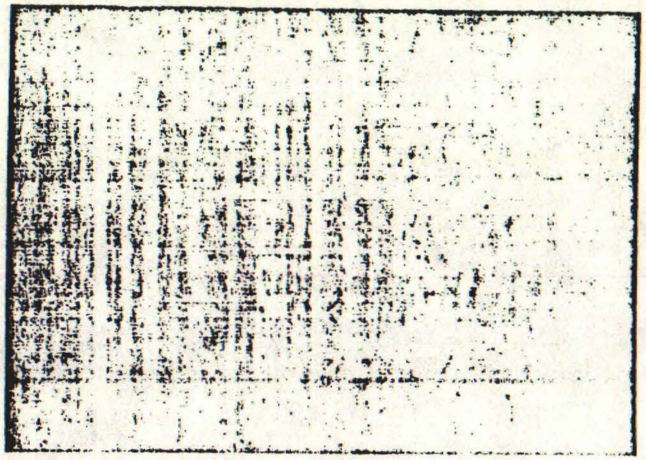
30a. *Chenopodium rubrum*



30b. *Chenopodium rubrum*

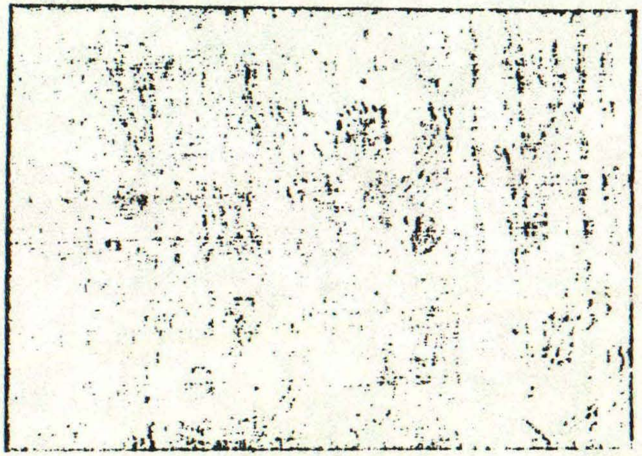


30c. *Rumex* spp.

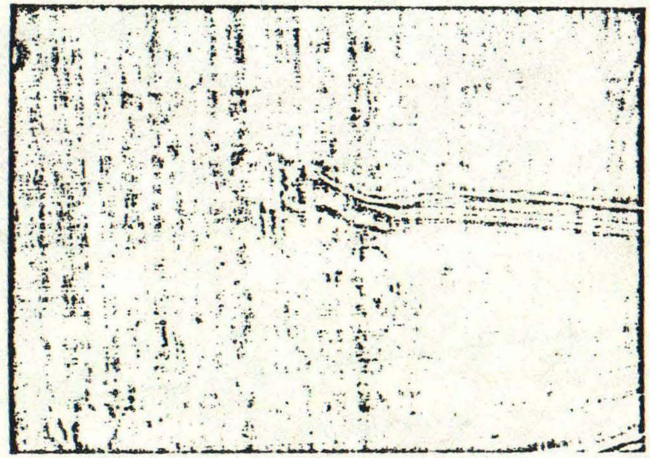


30d. *Rumex* spp.

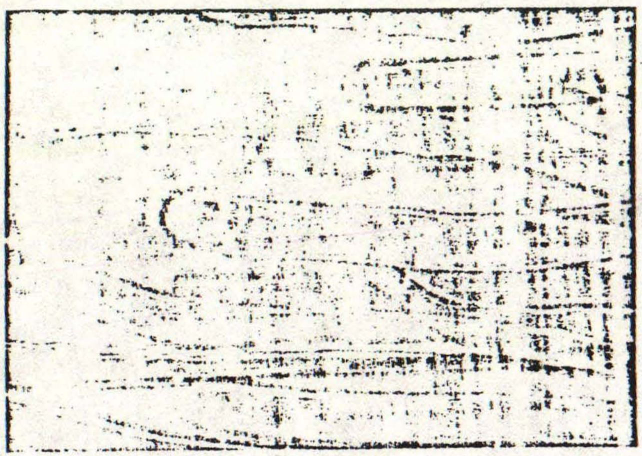
Plate 30



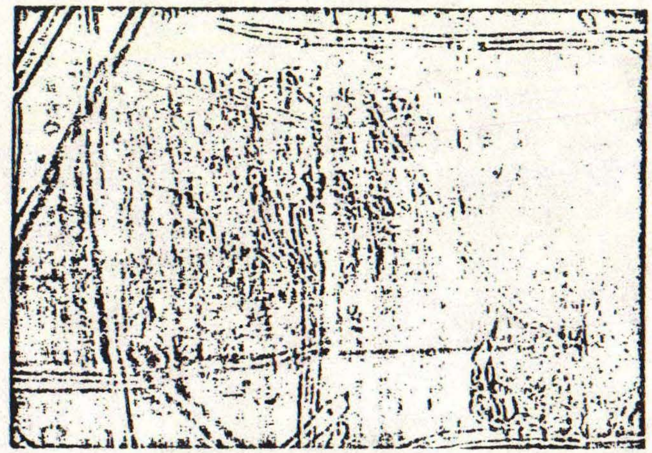
31a. *Rumex spp.*



31b. *Lupinus spp.*

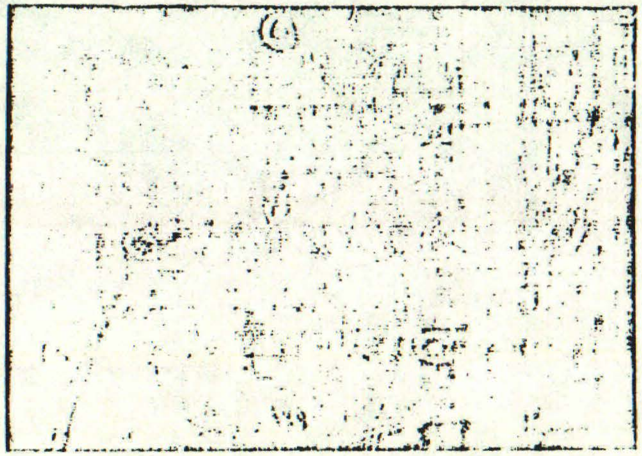


31c. *Lupinus spp.*

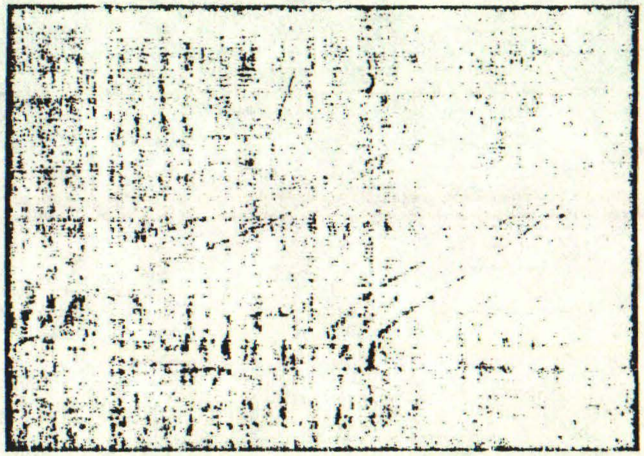


31d. *Lupinus spp.* (100X)

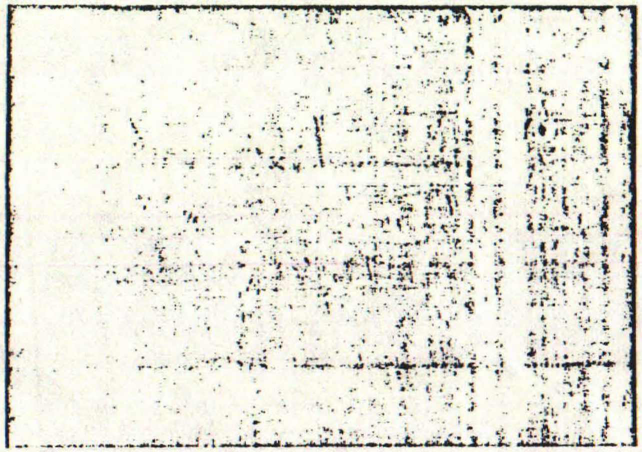
Plate 31



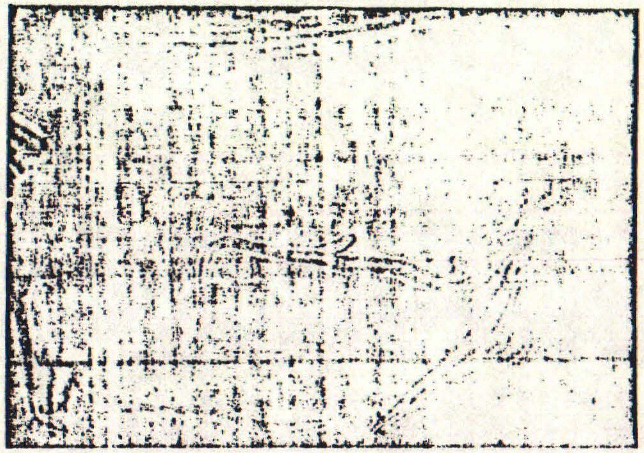
32a. *Symphoricarpos parishii*



32b. *Symphoricarpos parishii*

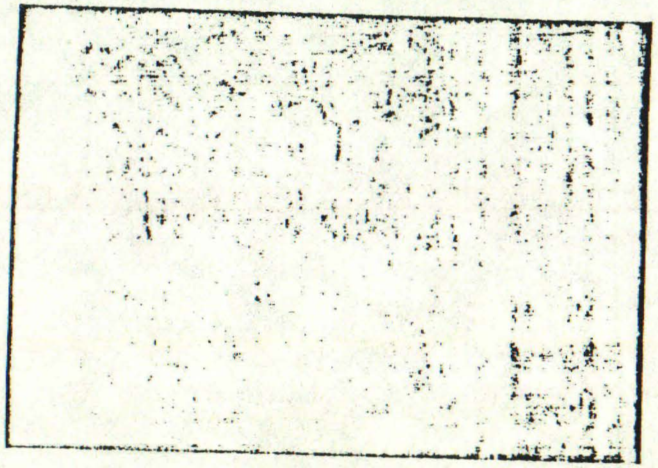


32c. *Symphoricarpos parishii*

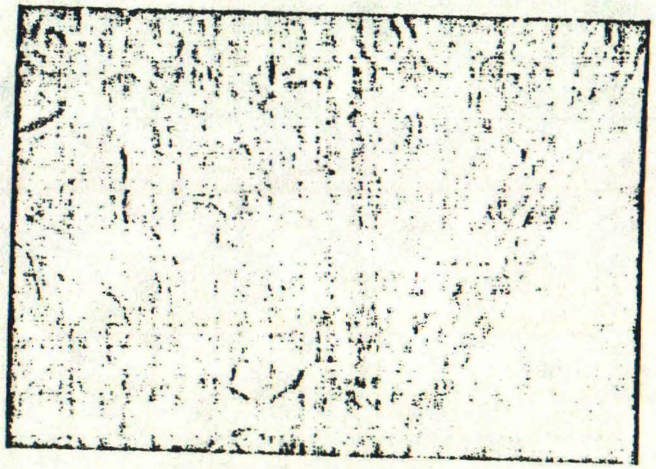


32d. *Agoseris spp.* (100X)

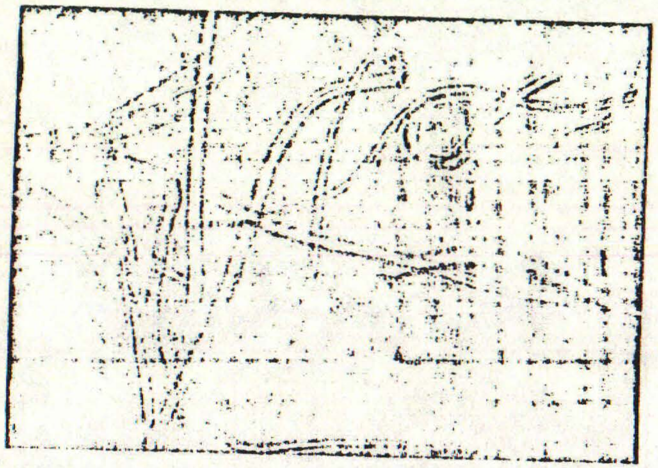
Plate 32



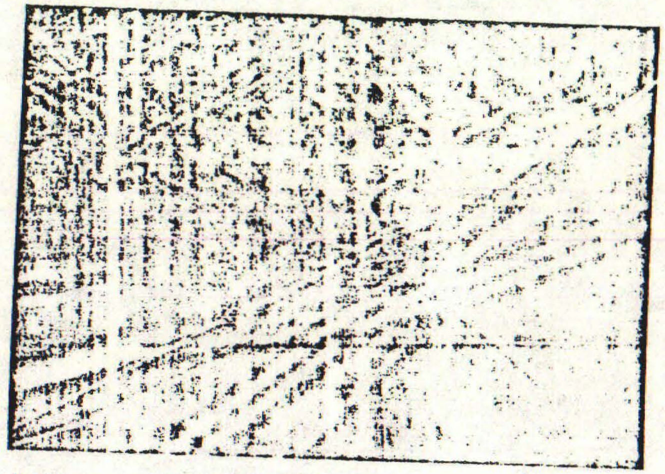
33a. *Agoseris spp.*



33b. *Agoseris spp.*

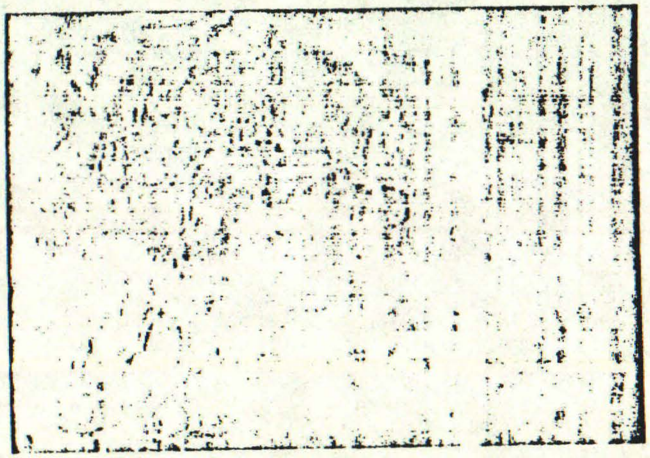


33c. *Astragalus purshii* (100X)

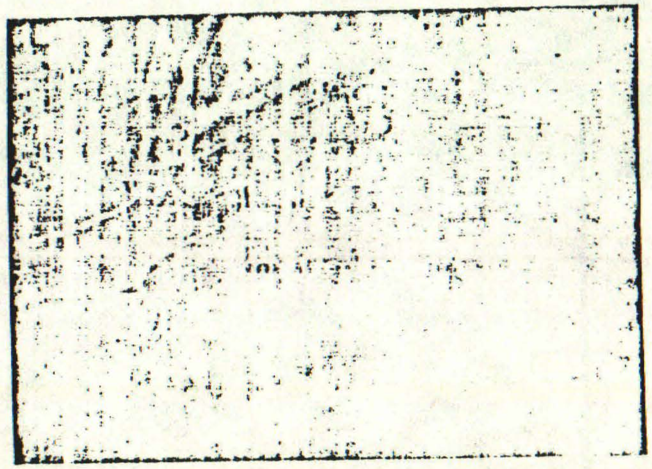


33d. *Astragalus purshii*

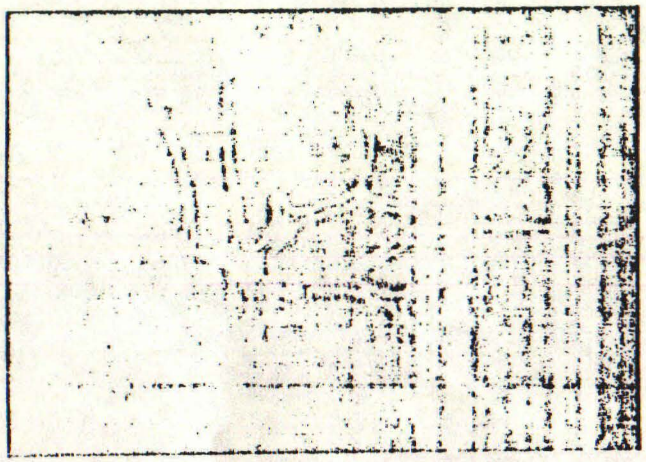
Plate 33



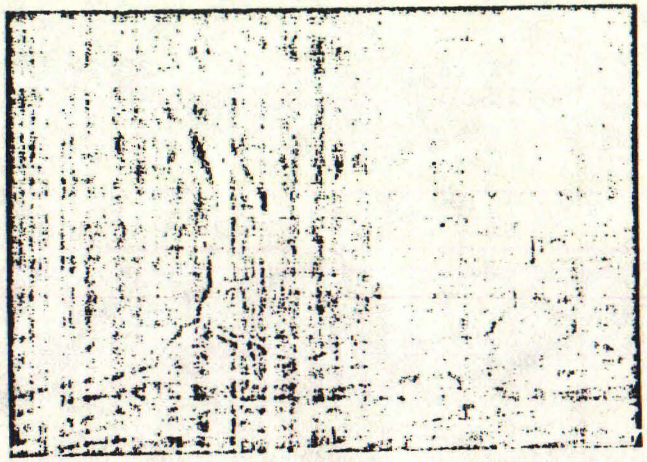
34a. *Astragalus purshii*



34b. *Astragalus spp.*

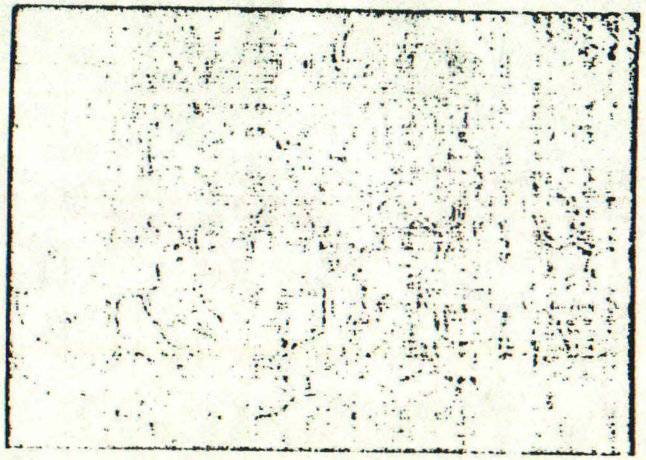


34c. *Astragalus spp.*

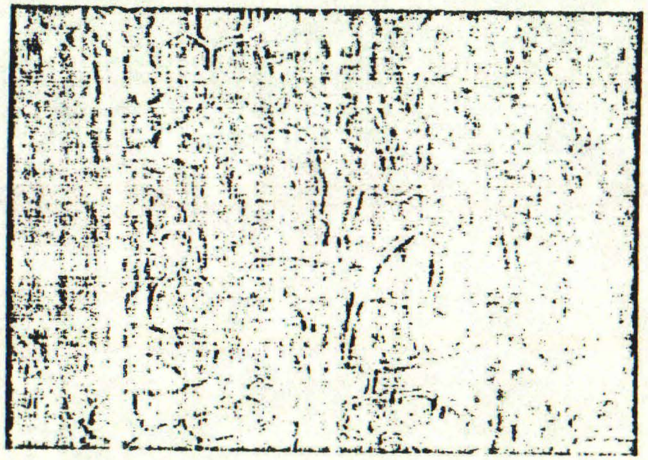


34d. *Haplopappus acaulis*

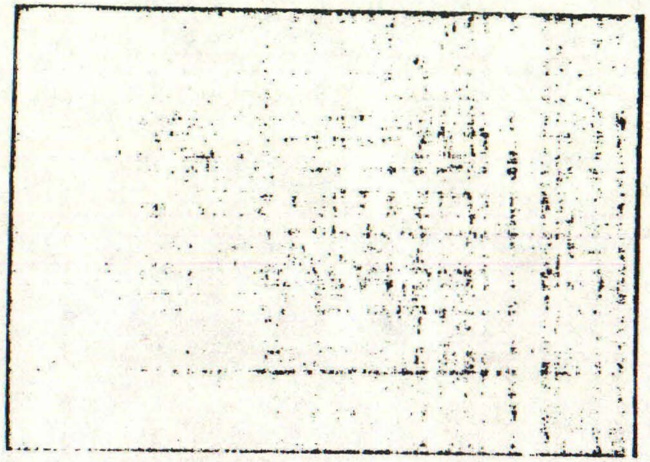
Plate 34



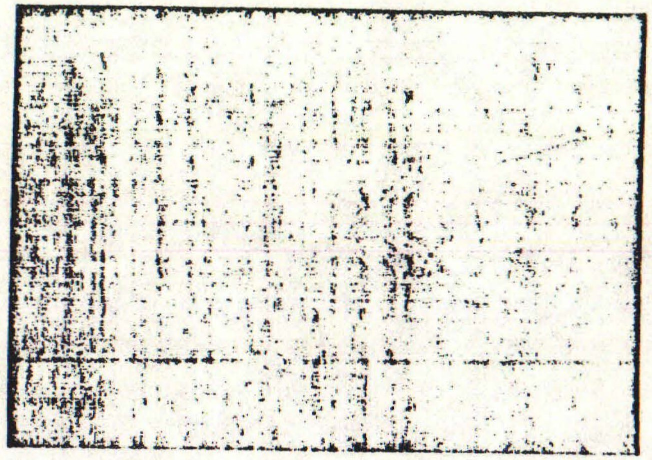
35a. *Haplopappus acaulis*



35b. *Haplopappus acaulis*



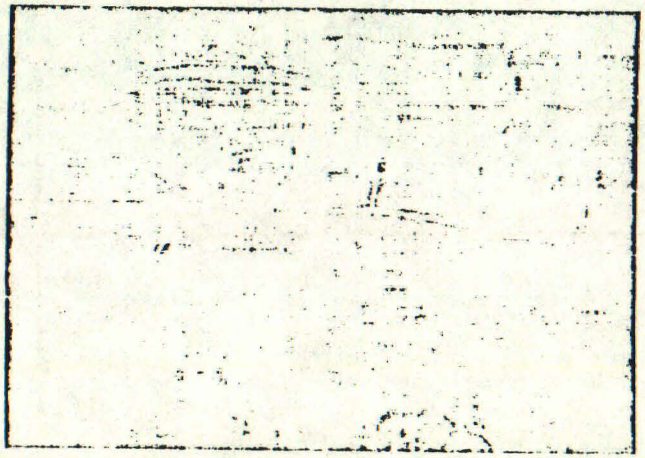
35c. *Arabis spp.*



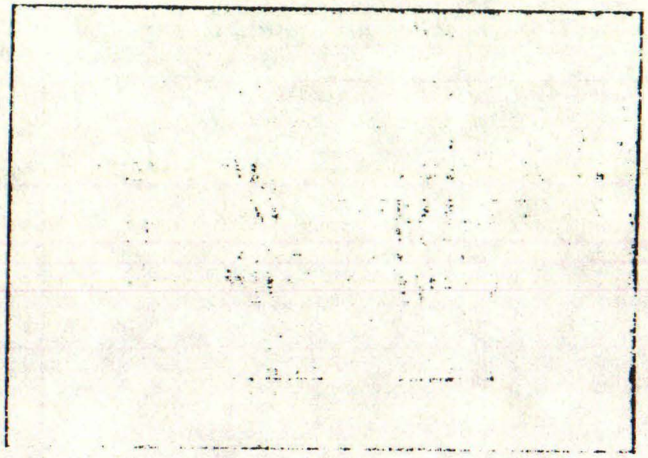
35d. *Arabis spp.*

Plate 35

36a. *Castilleja* spp.



36b. *Castilleja* spp.

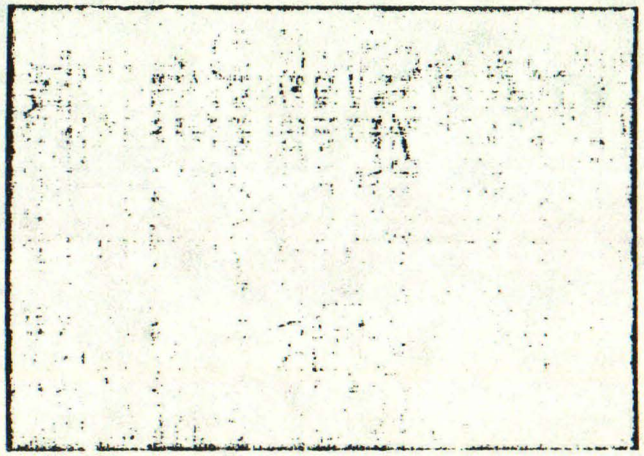


36c. *Frasera* spp.

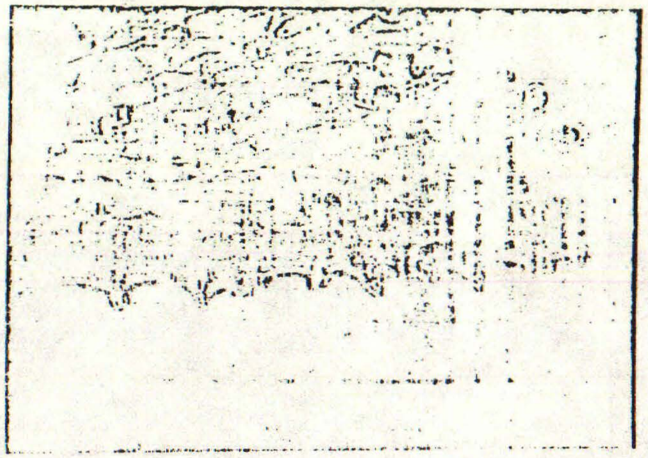
36d. *Frasera* spp.

Plate 36

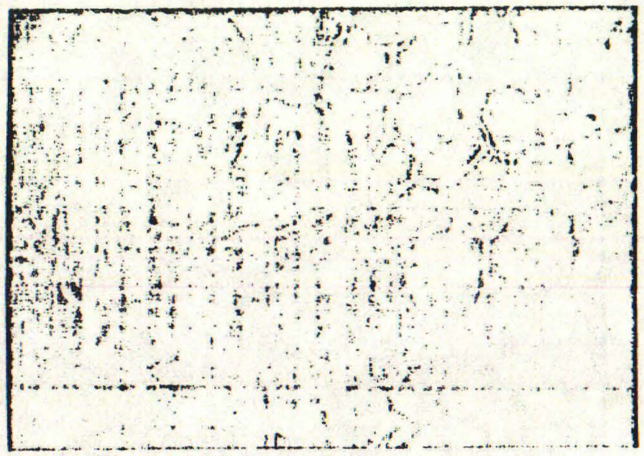
37a. *Tetradymia canescens*



37b. *Tetradymia canescens*



37c. *Aster scopulorum*



37d. *Aster scopulorum*

Plate 37