GEOLOGIC AND EDAPHIC FACTORS INFLUENCING PLANT DISTRIBUTIONS AT SIPHON CANYON, COCHISE COUNTY, ARIZONA

by

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DEDICATION

To

Paul S. Martin

and to my family

Jim, Alexandra, and Calliandra Lombard

with all my love

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ABSTRACT

Vegetational variability within a desert grassland region of southeastern Arizona was studied on five Paleozoic rock formations and two alluvial deposits. The lithologies of the formation and deposits included: quartzite; mixed lithology primarily of siltstone, sandstone, limestone and limey shale; and three limestones. The purpose of the study was to examine the correspondence between perennial vegetation patterns and assemblages growing on the different lithologies and the geologic and edaphic characteristics of the lithologies. Density of individual plant species, percent vegetative cover, and percent rock and rock fragment cover were recorded from three 20x5 meter quadrats located on each geologic unit and one 20x5 meter quadrat located on each alluvial deposit. Soil samples were obtained from each quadrat for laboratory analysis for pH, organic carbon, inorganic carbon, and sand, silt and clay fraction. The soil depth to bedrock or petrocalcic soil horizon was recorded from excavated soil pits across each formation. The soil and rock units for each formation were described.

Compositional affinities of vegetation from each site were analyzed using TWINSPAN (Two-way Indicator Species Analysis) and Curtis-Bray polar ordination. Results indicate differences in both plant assemblages and in relative abundance of plant species on each of the rock formations. Several species of plants were growing on only one geologic unit. Lithologic factors such as the physical nature of the

rock, lithologic composition, color, and type landform and physical and chemical edaphic factors such as surface rockiness, soil type, and soil depth determine the vegetational distribution.

1. INTRODUCTION

Differences in vegetation growing on different geological substrates are of interest to geologists because plants often indicate different rock types beneath the soil and therefore can be used as mapping tools (Cuyler, 1931). Different lithologies such as a granite or a limestone are populated by very different plant communities (Whittaker and Niering, 1968; Bradbury, 1969; Wentworth, 1976, 1981, 1985). Rock characteristics such as fractures, weathering patterns, density, and color (Whittaker and Niering, 1968; Shreve, 1922), and soil properties such as texture, surface rockiness, and chemistry (Ezcurra et al.,1987; Yang, 1950) play an important role in controlling moisture retention and soil temperatures and thus plant distribution, richness, and composition. To the ecologist, the relationship between plants and geological substrate is one of many factors that influence plant species patterns, richness, and population dynamics (Shreve, 1915; Billings, 1952; Wentworth, 1976; Whittaker and Niering, 1986; Matthews et al., 1991; Partridge et al., 1991).

In the southwestern United States, vegetation growing on different substrates has been studied by many investigators. Shreve (1919, 1922) noted vegetational differences between plants growing on rocks of "different mineralogic character". He described how the vegetational distribution along elevational gradients was different if the plants were growing on intrusive igneous rocks such as gneiss and granites, extrusive igneous rocks such as basalt and rhyolite, or limestones (Shreve, 1922). Shreve (1922) also recognized that soils derived from different substrates may differ in moisture penetration, water holding capacities, and rates of evaporation .

The ecologists Whittaker and Niering (1968a, 1968b) contrasted the vegetation growing on acidic soils of granite with the vegetation growing on basic soils of limestones in the Santa Catalina Mountains near Tucson, Arizona. They studied climate, soil, slope, elevation, and plant competition and used gradient analysis of the vegetation to determine the relationship between the vegetation and environmental characteristics.

Bradbury (1969) examined plant species that grew on limestones, rhyolites and alluvium in the Swisshelm Mountains in southeastern Arizona to determine which plants species were exclusive to each rock type. For example, *Quercus toumeyi* was confined to rhyolite and *Ceanothus greggii*, *Condalia spathulata*, *Cowania mexicana*, *Dalea formosa*, *Mortonia scabrella*, *Parthenium incanum*, and *Quercus pungens* were typically found on limestone. He demonstrated that the plant distribution was correlated to differences in soil chemistry and physical data.

Crosswhite (1983a, 1983b) discussed southwestern plant species which are indicators of specific geology and soil conditions. He mentioned the preference of *Castilleja* species for selenium-rich soils, *Penstemon thompsoniae* for gypsum soil, *Crossosoma bigelovii* for rhyolite, and *Larrea tridentata* for areas bounded by petrocalcic horizons. He states that along with soil chemistry and geological differences, physical characteristics such as texture and particle size may also be important factors (Crosswhite, 1983b).

Wentworth (1976, 1981, 1985) continued the work of Whittaker and Niering (1968b) comparing the vegetation found on granites and limestones in the Mule Mountains and limestones in the Huachuca Mountains of southeastern Arizona. His study areas started at lower elevations than Whittaker and Niering's Santa Catalina Mountain sites. He presented different methods of direct and indirect gradient analysis to interpret vegetation distribution data.

Warren et al. (1992) published a flora of Fort Bowie National Historic Site. They identified eleven different plant associations growing on different geologic settings. None of the geologic formations in the Fort Bowie National Historic Site report occur in my study site.

The studies by Shreve (1915,1922), Whittaker and Niering (1968a, 1968b), and Wentworth (1922) encompassed large areas of land which change significantly in elevation, slope, or aspect. In all cases the major plant communities gradually change from xeric vegetation to mesic vegetation with an increase in elevation. In this study the site size is restricted, the overall slope constant, the aspect is to the southwest, and presumably the climate is uniform. The objective of this study is to describe the variation in perennial vegetation within a region of desert grassland occupying a variety of lithologies and to specifically examine which geologic and edaphic factors influence local plant distributions. The study site is located between the Dos Cabezas and Chiricahua Mountains in Cochise County, Arizona in the vicinity of Apache Pass. All data were obtained within a 200 square kilometer area on southwest facing hillslopes at altitudes 1402 meters to 1457 meters above mean sea level. At this site the five geologic formations include: the Bolsa Quartzite, Abrigo Formation (a mixed lithology), El Paso Limestone, Portal (or Martin) Formation (a limestone), and Escabrosa Limestone.

2. STUDY SITE LOCATION AND DESCRIPTION

Willcox, Arizona in Cochise County, between the Dos Cabezas and Chiricahua Mountains (Figure 1). The area is approximately 200 square km in Section 1, T 15 S, R 28 E and found on the U.S.G.S. Bowie Mountain North 7.5 minute quadrangle. The site is on three southwest hillslopes where the five geologic units are exposed and is bounded in part by Siphon Canyon which drains northward out of the Chiricahua Mountains (Figure 2). Elevation at the site ranges from 1402 m at Siphon Canyon to 1457 m at the top of the Bolsa Quartzite ridge. Average slope of the hills is 27 degrees. The vegetation of Siphon Canyon has been described as a Desert Grassland with Chihuahuan floristic influences (Brown et al.,1979; Wentworth,1976).

2.1 Climate

The climate of Siphon Canyon is continental with hot summers and temperate winters. Daily temperatures can range from 34 degrees C (100 degrees F) in July to below 0 degrees C at night in the winter. There are approximately 190 frost-free days (Soil Conservation Service, 1980). Snowfall occasionally occurs but does not persist. The average annual temperature is 15.6 degrees C (60 degrees F) (Warren et al., 1992).

Rain usually falls in the summer and winter months with summer

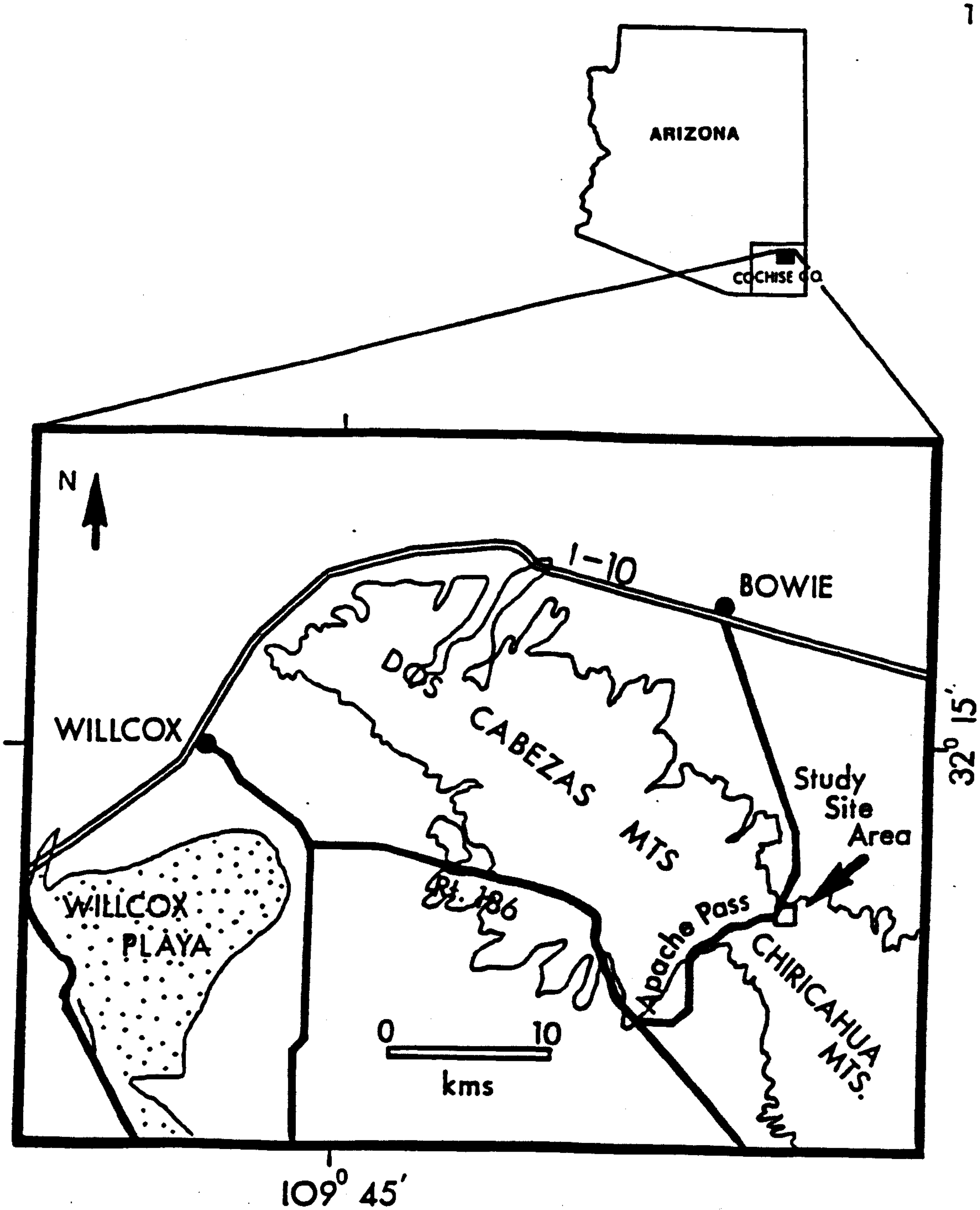


Figure 1: Location of study site

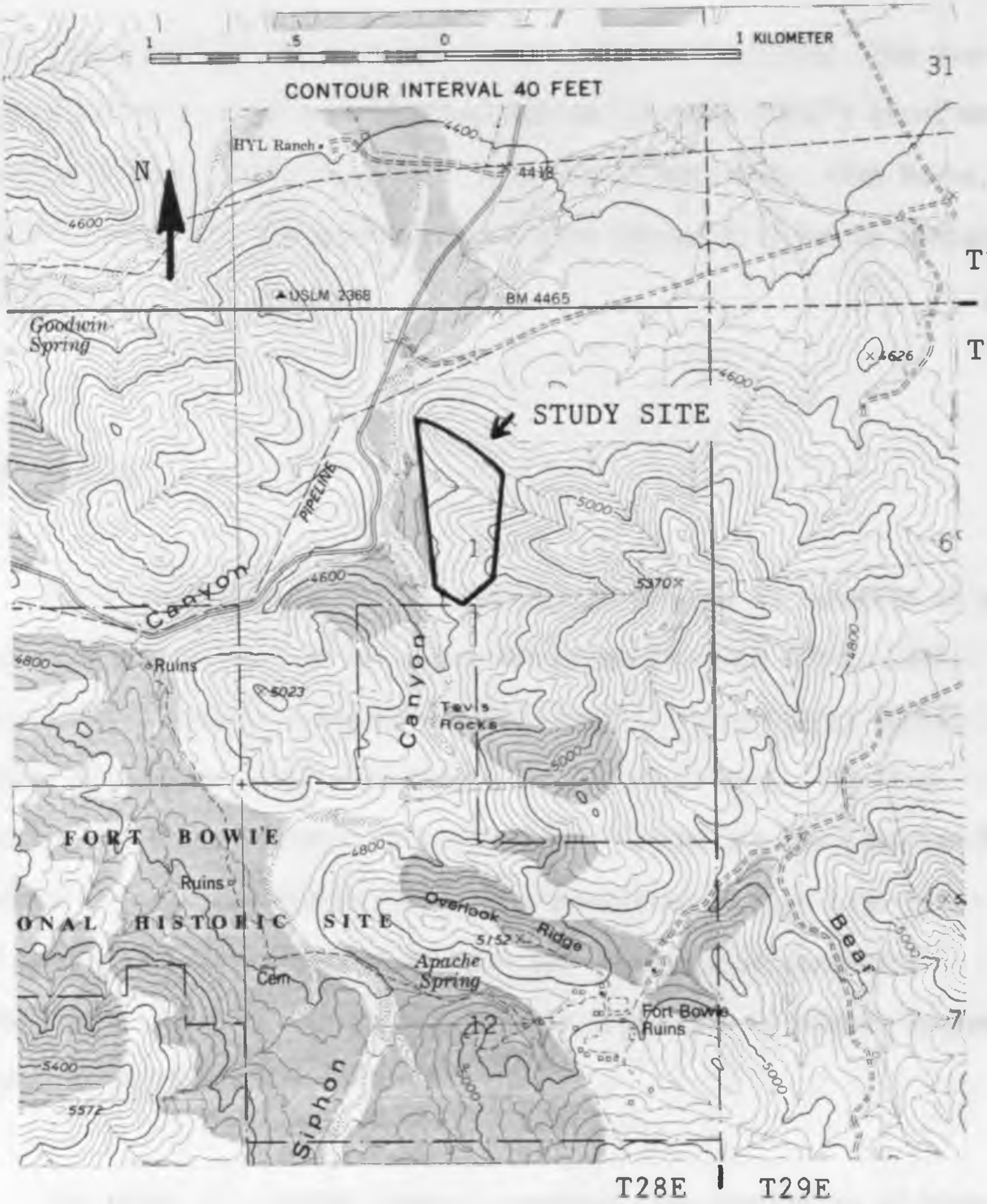


Figure 2: Topographic map of Siphon Canyon, Cochise County, Arizona study site. From Bowie Mountain North Quadrangle, U.S.G.S. 7.5 minute series.

rains being heavier and more consistent (Wentworth, 1976). The average precipitation from 1976 to 1992 was 488 mm per year (19.2") (Fort Bowie National Historic Site records). Detailed climate data from Bowie, Arizona located to the northeast of Siphon Canyon is given by Wentworth (1976).

2.2 Geology

The mountainous region of southeastern Arizona is referred to as the Mexican Highlands of the Basin and Range Province (Hunt, 1967). The geology of Paleozoic rocks near Apache Pass is described by Sabins (1957) and Bryant (1968) and mapped in 1984 by Drewes. The five southwest- facing geologic units at Siphon Canyon are the Cambrian Bolsa Quartzite, Cambrian Abrigo Formation, Ordovician El Paso Limestone, Devonian Martin or Portal Formation and Mississipian Escabrosa Limestone. Detailed descriptions of the formations of Siphon Canyon are given in the results section that follows.

Two areas of alluvial deposits derived from weathering of rocks on the adjacent hillslopes were also studied. One fan-shaped area occurs on the hillslope between the Abrigo Formation and the El Paso Limestone and the other alluvial deposit is between the El Paso Limestone and the Martin Limestone. The alluvial deposits consist of gravelly sandy loams with calcium carbonate accumulations below the land surface.

The topography of the site is varied due to the different weathering patterns of the lithologies present (Figure 2, 3). The Bolsa Quartzite and Escabrosa Limestone are resistant lithologies which form cliffs. The Abrigo formation erodes into very gentle slopes with resistant sandstone ledges. The El Paso and Martin limestones form an intermediate topography of ledges and gentle slopes.

2.3 Soils

Soils at Siphon Canyon are described by Vogt (1980). The El Paso Limestone, Portal Formation, and Escabrosa Limestone are classified as part of the Mabray-Rock outcrop complex. Vogt (1980) describes the soils as shallow, well drained, very gravelly loams on steep to moderately steep mountains and hills that are intermingled with rock outcrops. "Permeability is moderate above bedrock, and available water capacity is low. ...The water supply capacity is 9 to 11 inches. Surface runoff is medium to rapid. The hazard of soil blowing is slight and threat of water erosion moderate." (Vogt, 1980, page 23).

Soils on the Bolsa Quartzite and Abrigo Formation are described as part of the Atascosa-Chiricahua-Rock outcrop complex (Vogt, 1980, p. 10). The brown to reddish brown soils are on steep to sloping hillslopes and are described as shallow, well drained stony to gravelly sandy loams which increase in clay content with depth. Permeability,

Figure 3: Aerial photograph of Siphon Canyon, Cochise County, Arizona. Photo from Cooper Aerial Survey Company.

water capacity, surface runoff, soil blowing capability, and water erosion threat is similar to the Mabray Series. The water supply capacity range is slightly lower than the Mabray Series at 8 to 10 inches.

The nearly level alluvial soils are deep, well-drained soils classified as Santo Tomas soils. The surface is cobbley fine sandy loams and there are greater than 35 percent coarse fragments (Vogt,1980, p. 5). The soils are derived from different sources of parent materials and are described by Vogt as being stratified with finer and coarser fractions (Vogt, 1980, p. 60).

3. METHODS

3.1 Field Methods-Vegetation

A survey of perennial plants on each geologic unit was conducted between September 1992 and March 1993. Plant species not identified in the field were collected and later identified by botanists associated with the University of Arizona Herbarium. Species names and authorities are from Kearney and Peebles (1960), Lehr (1978), Benson (1981), and Gould (1981).

Three quadrats (four quadrats on the El Paso Limestone), each 20m x 5m, were used for measuring plant cover on each of the five geologic formations. One quadrat was used on each alluvial deposit (Figure 4). The quadrats on the five lithologies were positioned perpendicular to strike of the bedding plane. The quadrats on the alluvial areas were positioned along the same trend as the rock types. Each quadrat was subdivided into one meter by one meter areas (Figure 5). For each species, the total number of individuals and estimated percentage of canopy coverage was recorded. The percentage of rock fragment coverage was also estimated for each meter-square area and slope was measured with a clinometer.

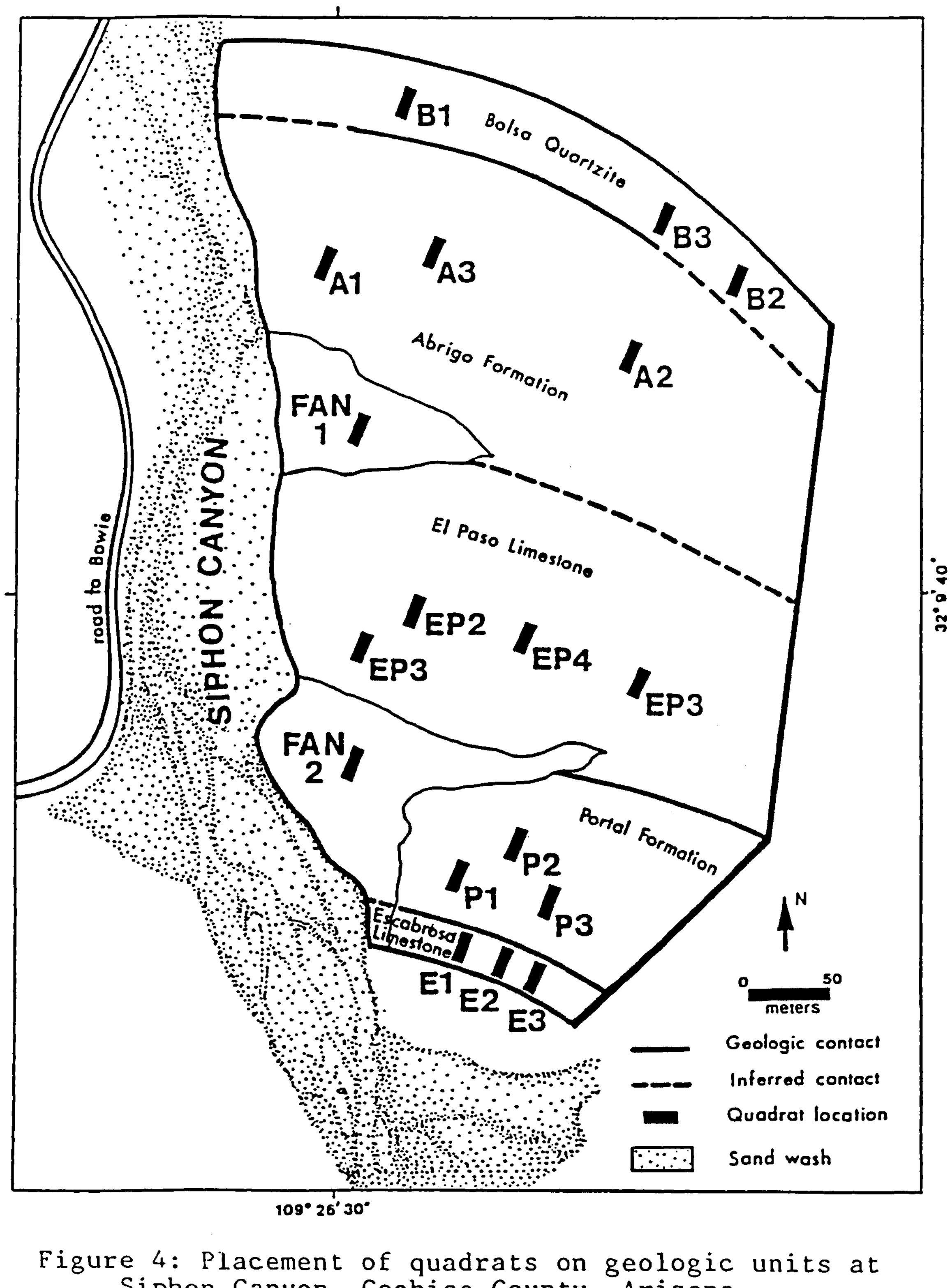


Figure 4: Placement of quadrats on geologic units at Siphon Canyon, Cochise County, Arizona

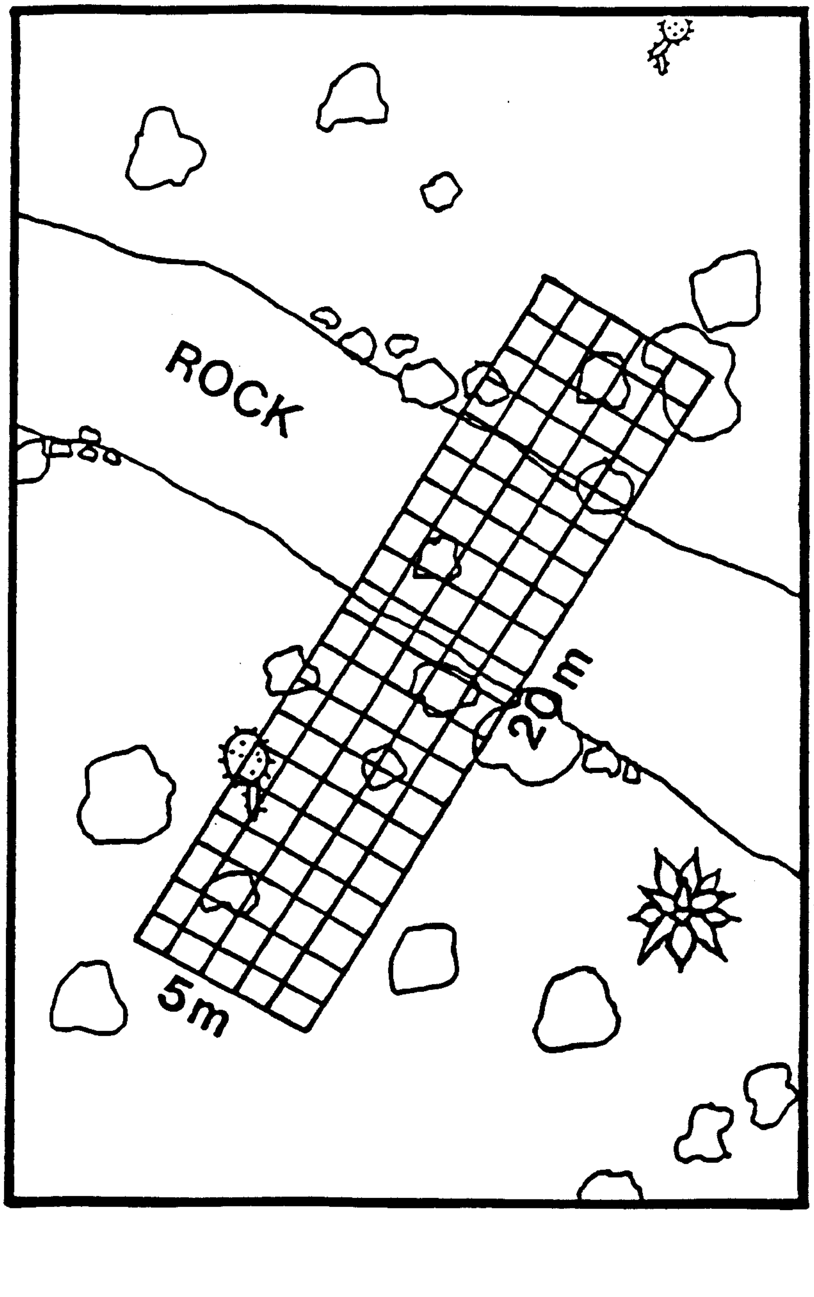


Figure 5: Typical position of quadrat with respect to strike of rock units and location of 1m x 1m areas within a 20m x 5m quadrat

3.2 Geology

Each lithology present at Siphon Canyon was described. Color, composition, grain size, bedding characteristics, presence fossils or chert nodules, sediment texture, average thickness, strike, dip, and structural deformation were recorded and each formation was photographed.

3.3 Soil

A soil sample to a depth of 10 cm was obtained from each quadrat for physical and chemical analysis. The soil pit was further dug until either bedrock or petrocalcic horizon was encountered and the depth and soil was described. Photographs of the soil surface were taken for each lithology.

3.4 Laboratory methods-soil

Preparation and analysis of the physical and chemical properties of the soil were conducted at the University of Arizona Soil, Water, and Plant Analysis Laboratory and at the Desert Laboratory on Tumamoc Hill in Tucson. Soil samples were analyzed for percentages of sand, silt, clay; pH; inorganic carbon; organic carbon; and total carbon. Duplicate and control samples were analyzed in each procedure to check quality control and accuracy.

Particle size distribution of the soil into sand, silt and clay fractions was measured using the hydrometer method (Gee and Bauder, 1979). Soil size fraction data were then classified using the soil texture names described in Hendricks (1985).

Total and organic carbon values were obtained using a high temperature combustion method. Half of the duplicate soil samples were treated with 10% phosphoric acid to remove any inorganic carbon; the other half were not treated. A 10-20 mg sample, crushed using a ball mill was analyzed using a Carlo Erba NA1500 NCS Analyzer. Inorganic carbon was the difference between the total carbon amount and the organic carbon value.

PH was measured from the aqueous extract obtained from a 50 g sample soil mixed with 50 milliliters distilled deionized water.

3.5 Data Analysis

Two standard methods were used to investigate the similarity between plant assemblages in each of the 18 quadrats (Gauch, 1982).

A two dimensional ordered table was constructed from the plant relative coverage data from each of the 18 quadrats using the computer program TWINSPAN (Hill, 1979). The program generated a Braun-Blanquet type ranking of each plant species by percentage relative coverage as follows: 1= less than 2% cover, 2= 2-5%, 3= 5-10%, 4= 10-20%, 5= greater than 20%. Each species was then sorted into an ordered table. From the ordered table, a dendrogram was constructed that showed the compositional affinities among the various sites classifying the most closely related plant species assemblages.

Relative coverage data were also analyzed with the two-dimensional polar technique of Bray and Curtis (1957) using the program ORDIFLEX (Gauch, 1977). An ordination graph was constructed, clustering the most similar plant species assemblages.

4. RESULTS

4.1 Vegetation

A total of seventy-four perennial plant species was recorded from all quadrats (Table 1). A list of all plants found is in Appendix A. The greatest diversity of species, 38, occurs in quadrats on the El Paso Limestone. The least diverse quadrats were on alluvial deposits (19 species) (Table 2). Percent cover of vegetation was greatest on the Abrigo Limestone and least on the cliffy rock units of the Escabrosa Limestone and the Bolsa Quartzite (Table 2).

The data for species abundance for each quadrat are given in Appendix B. The most abundant species on each of the geologic units are given on Table 3. The most abundant species overall include fairy duster (*Calliandra eriophylla*), ocotillo (*Fouquieria splendens*), mariola (*Parthenium incanum*), prickly pear (*Opuntia phaeacarpa*), and side oats grama (*Bouteloua curtipendula*). *Agave palmeri*, *Gutierrezia microcephela*, *Opuntia phaeacantha*, and *Bouteloua curtipendula* occurred on at least one quadrat of all geological units. *Juniperus erythrocarpa*, *Parthenium incanum*, *Fouquieria splendens*, and *Aloysia wrightii* were observed on all geologic units.

Shrubs are the dominant structural type on all units except on the

TABLE 1: Plant species found on quadrats examined at Siphon Canyon Cochise County, Arizona.

SPECIES

Acacia greggii
Agave palmeri
Aristida purpurea var. fendleriana
Aristida purpurea var. longiseta
Aristida purpurea var. nealleyi
Aristida sp.
Artemisia ludoviciana
Astrolepis cochisensis
Ayenia filiformis
Baccharis brachyphylla
Bouteloua curtipendula
Bouteloua eriopoda
Bouteloua hirsuta
Bouteloua repens
Brickellia baccharidea
Bumelia lanuginosa
Calliandra eriophylla
Cassia bauhinoides
Celtis reticulata
Cevallia sinuata
Cheilanthes lindheimeri
Croton pottsii
Dalea formosa
Dalea wrightii
Dasylirion wheeleri
Digitaria californica
Digitaria cognata
Dyssodia acerosa
Echinocereus pectinatus
Eragrostis intermedia
Eragrostis lehmanniana
Elymus elymoides
Ericameria laricifolia
Ferocactus wislizenii
Forsellesia spinescens
Fouquieria splendens
Galactia wrightii
Gaura cf. coccinea
Gutierrezia microcephala
Hedeoma nanum
Heteropogon contortus
Isocoma tenuisectus
Janusia gracilis
Juniperus erythrocarpa
Leptochloa dubia
Lesquerella fendleri

TABLE 1: *Continued*

SPECIES

Lippia wrightii
Lycurus setosus
Macrosiphonia brachysiphon
Mammillaria microcarpa
Menodora scabra
Muhlenbergia emersleyi
Muhlenbergia porteri
Opuntia leptocaulis
Opuntia phaeacantha
Opuntia spinosior
Panicum hallii
Parthenium incanum
Pellaea truncata
Perezia nana
Prosopis velutina
Rhus microphylla
Setaria macrostachya
Sphaeralcea laxa
Stipa eminens
Thelesperma longipes
Thamnosma texana
Trachypogon secundus
Tridens muticus
Tridens pulchellus
Verbena gooddingii
Yucca baccata
Zinnia acerosa

Table 2: Summary of plant diversity and coverage

FORMATION	TOTAL SPECIES	SPECIES PER QUADRAT	PERCENT COVERAGE
Bolsa Quartzite	32		
Quadrat 1		24	17 %
Quadrat 2		16	25 %
Quadrat 3		23	29 %
average		21	24 %
Abrigo Formation	33		
Quadrat 1		24	41 %
Quadrat 2		15	59 %
Quadrat 3		20	49 %
average		20	50 %
El Paso Formation	38		
Quadrat 1		26	23 %
Quadrat 2		28	38 %
Quadrat 3		19	26 %
Quadrat 4		20	34 %
average		23	30 %
Portal Formation	30		
Quadrat 1		22	33 %
Quadrat 2		19	49 %
Quadrat 3		18	46 %
average		20	43 %
Escabrosa Limestone	36		
Quadrat 1		23	21 %
Quadrat 2		26	25 %
Quadrat 3		26	31 %
average		25	26 %
Alluvial Fans	19		
Alluvial Fan 1		16	51 %
Alluvial Fan 2		9	25 %
average		12	38 %

TABLE 3: List of species with 5% or greater relative cover on each geologic formation

GEOLOGIC FORMATION	COMMON NAME	SPECIES NAME	STRUCTURE	PERCENT COVER
BOLSA QUARTZITE	Turpentine bush	*Ericameria laricifolia*	shrub	29.7 %
	Trachypogon	*Trachypogon secundus*	grass	16.9 %
	Ocotillo	*Fouquieria splendens*	shrub	10.0 %
	Galactia	*Galactia wrightii*	vine	7.6 %
	Astrolepis	*Astrolepis cochisensis*	fern	7.5 %
ABRIGO FORMATION	Prickly pear	*Opuntia phaeacantha*	cactus	22.0 %
	Fairy duster	*Calliandra eriophylla*	shrub	13.4 %
	Side oats grama	*Bouteloua curtipendula*	grass	12.0 %
	Turpentine bush	*Ericameria laricifolia*	shrub	11.7 %
	Cat claw acacia	*Acacia greggii*	shrub	7.9 %
	Black grama	*Bouteloua eriopoda*	grass	5.7 %
EL PASO LIMESTONE	Mariola	*Parthenium incanum*	shrub	16.6 %
	Side oats grama	*Bouteloua curtipendula*	grass	12.7 %
	Ocotillo	*Fouquieria splendens*	shrub	12.3 %
	Fairy duster	*Calliandra eriophylla*	shrub	11.2 %
	Palmer's agave	*Agave palmeri*	succulent	7.3 %
	Feather plume	*Dalea formosa*	shrub	5.4 %
	Banana yucca	*Yucca baccata*	succulent	5.3 %
	Prickly pear	*Opuntia phaeacantha*	cactus	5.0 %
PORTAL FORMATION	Snakeweed	*Gutierrezia microcephala*	herb	16.2 %
	Black grama	*Bouteloua eriopoda*	grass	9.9 %
	Ocotillo	*Fouquieria splendens*	shrub	9.6 %
	Fairy duster	*Calliandra eriophylla*	shrub	9.5 %
	Sotol	*Dasylirion wheeleri*	succulent	9.4 %
	Feather plume	*Dalea formosa*	shrub	6.9 %
	Side oats grama	*Bouteloua curtipendula*	grass	5.5 %
	Desert sumac	*Rhus microphylla*	shrub	5.3 %
	Mariola	*Parthenium incanum*	shrub	5.3 %
	Banana yucca	*Yucca baccata*	succulent	5.1 %

TABLE 3: *Continued*

GEOLOGIC FORMATION	COMMON NAME	SPECIES NAME	STRUCTURE	PERCENT COVER
ESCABROSA LIMESTONE	Ocotillo	*Fouquieria splendens*	shrub	18.6 %
	Fairy duster	*Calliandra eriophylla*	shrub	14.0 %
	Mariola	*Parthenium incanum*	shrub	10.2 %
	Astrolepis	*Astrolepis cochisensis*	fern	9.3 %
	Sotol	*Dasylirion wheeleri*	succulent	5.7 %
	Palmer's agave	*Agave palmeri*	succulent	5.2 %
ALLUVIAL FANS	Mariola	*Parthenium incanum*	shrub	24.0 %
	Snakeweed	*Gutierrezia microcephala*	herb	21.5 %
	Mesquite	*Prosopis velutina*	tree	17.3 %
	Black grama	*Bouteloua eriopoda*	grass	14.4 %
	Side oats grama	*Bouteloua curtipendula*	grass	5.5 %
	Three awn	*Aristida purpurea var. nealleyi*	grass	5.0 %

alluvial fans. The alluvial fans are covered with grasses. Grasses are subdominants throughout except on the Abrigo Formation where cacti and succulents are second in prevalence (Table 4)

4.2 Substrate Specific Species

Species which occur only on one geologic unit include *Galactia wrightii*, *Ayenia filiformis*, *Cheilanthes lindheimeri*, *Macrosiphonia brachysiphon*, *Bumelia lanuginosa* growing only on the Bolsa Quartzite; *Perezia nana*, *Baccharis brachyphylla*, *Verbena gooddingii*, and an unknown species confined to the Abrigo Formation; *Cassia bauhinoides* and *Menodora scabra* on the El Paso Limestone; *Dalea wrightii* and *Gaura* cf. *coccinea* on the Portal Formation; *Brickellia baccharidea*, *Forsellesia spinescens*, *Digitaria cognata*, *Celtis reticulata*, *Thelesperma longipes*, *Tridens mutica* and *Thamnosma texana* on the Escabrosa Limestone; and *Opuntia leptocaulis* and *Elymus elymoides* on the alluvial fans (Table 5).

4.3 Dendrogram Results

The dendrogram (Table 6) constructed from the data in Figure 6, shows that generally, the plant species which are most closely associated occur on the same geologic unit. Four divisions of the dendrogram correspond to the presence or absence of specific plant

TABLE 4: Average percentage of plants grouped by vegetative structure type for each geologic formation.

STRUCTURE	BOLSA	ABRIGO	EL PASO	PORTAL	ESCABROSA	ALLUVIUM
	................GEOLOGIC FORMATION[a]..................					
GRASSES	32 %	25 %	27 %	22 %	19 %	30 %
SHRUBS	43 %	40 %	50 %	38 %	49 %	28 %
TREES	0 %	4 %	0 %	1 %	<1 %	17 %
CACTI AND SUCCULENTS	7 %	26 %	18 %	20 %	16 %	2 %
FERNS	9 %	2 %	1 %	<1 %	9 %	0 %
HERBS	9 %	3 %	4 %	18 %	6 %	23 %

[a] BOLSA = BOLSA QUARTZITE
ABRIGO = ABRIGO FORMATION
EL PASO = EL PASO LIMESTONE
PORTAL = PORTAL FORMATION (or MARTIN FORMATION)
ESCABROSA = ESCABROSA LIMESTONE
ALLUVIUM = ALLUVIAL FAN DEPOSITS

TABLE 5: List of species found exclusively on a particular geologic formation

BOLSA QUARTZITE:	
HERBS/VINES	*Ayenia filiformis*
	Galactia wrightii
SHRUB	*Macrosiphonia brachysiphon*
TREE	*Bumelia lanuginosa*
FERNS	*Cheilanthes lindheimeri*
	Notholaena lemmoni
	Notholaena standleyi
ABRIGO FORMATION:	
HERBS	*Baccharis brachyphlla*
	Verbena gooddingii
	Perezia nana
EL PASO LIMESTONE:	
HERBS	*Cassia bauhiniodes*
	Menodora scabra
SHRUB	*Dalea wrightii*
PORTAL FORMATION:	
HERB	*Zinnia acerosa*
ESCABROSA LIMESTONE:	
HERB	*Brickellia baccharidea*
SHRUBS	*Forsellesia spinescens*
	Thamnosa texana
ALLUVIAL FANS:	
GRASS	*Elymus elymoides*
CACTUS/SUCCULENT	*Opuntia leptocaulis*

TABLE 6: Ordered table of relative cover of perennial species on all Siphon Canyon quadrats

SPECIES	QUADRAT[a]																	
	E1	E2	E3	L2	P1	P2	P3	L1	L3	L4	A2	A3	F1	F2	B1	B2	B3	A1
Yucca baccata	-	-	-	3[b]	-	3	3	-	1	4	-	-	-	-	-	-	-	2
Tridens muticus	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Forsellesia spinescens	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Juniperus erythrocarpa	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Celtis reticulata	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brickellia baccharidea	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thelesperma longipes	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thamnosma texana	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia ludoviciana	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Digitaria cognata	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eragrostis lehmanniana	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cevallia sinuata	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida purpurea var. fendleriana	-	-	1	4	-	-	1	-	1	-	-	-	-	-	-	-	-	-
Aristida purpurea var. nealleyi	-	4	-	1	-	4	-	-	1	1	-	-	1	-	-	-	-	-
Bouteloua hirsuta	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stipa eminens	-	-	-	-	-	-	-	1	3	2	-	-	-	-	-	-	-	-
Dalea formosa	2	2	1	4	4	4	1	3	-	-	-	-	-	-	-	-	-	-
Rhus microphylla	-	1	2	-	4	-	2	-	-	2	-	-	-	1	-	-	-	-
Dalea wrightii	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Gaura cf. *coccinea*	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Dyssodia acerosa	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Zinnia acerosa	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Croton pottsii	-	-	-	1	1	1	-	1	-	-	-	-	-	-	-	-	-	-
Sphaeralcea laxa	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Hedeoma nanum	1	-	1	1	1	2	1	1	-	-	-	-	-	-	-	-	-	-
Cassia bauhinoides	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Menodora scabra	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Panicum hallii	1	1	1	1	1	-	-	2	3	1	-	1	1	-	-	-	-	-
Aristida sp.	3	-	-	1	2	-	-	3	1	1	1	1	3	-	-	-	-	-
Tridens pulchellus	-	-	-	1	-	-	-	1	-	1	-	-	1	1	-	-	-	-
Aristida purpurea var. longiseta	-	2	4	2	1	1	1	1	-	-	-	-	-	-	-	-	-	-

TABLE 6: *Continued*

SPECIES	QUADRAT[a]																	
	E1	E2	E3	L2	P1	P2	P3	L1	L3	L4	A2	A3	F1	F2	B1	B2	B3	A1
Bouteloua eriopoda	-	-	-	1	4	3	4	1	3	2	-	4	3	4	-	-	-	1
Parthenium incanum	4	2	4	4	1	2	4	4	4	5	1	-	5	5	-	-	-	1
Elymus elymoides	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Unknown	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Verbena gooddingii	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Isocoma tenuisectus	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
Opuntia leptocaulis	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Heteropogon contortus	2	1	2	-	-	-	-	1	-	1	1	3	-	-	-	-	1	-
Calliandra eriophylla	4	3	5	4	3	3	4	4	4	4	4	4	-	-	-	-	1	3
Prosopis velutina	-	-	-	-	2	-	-	-	-	-	3	2	5	2	-	-	-	1
Gutierrezia microcephala	2	1	1	2	5	4	4	2	2	2	3	2	4	5	-	1	-	1
Agave palmeri	3	3	2	3	3	1	2	4	2	2	2	2	1	-	-	1	2	1
Dasylirion wheeleri	3	3	1	-	-	4	4	1	-	-	-	-	-	-	3	-	-	-
Lesquerella fendleri	-	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-	-
Astrolepis cochisensis	2	3	3	1	1	1	1	1	1	1	-	-	-	-	4	1	-	-
Bouteloua curtipendula	2	2	3	3	3	2	3	4	4	3	4	2	-	4	1	2	3	4
Lycurus setosus	1	1	1	1	-	1	1	1	1	-	-	-	-	-	-	1	1	1
Aloysia wrightii	-	1	3	-	1	1	-	1	1	4	-	2	-	-	-	-	-	2
Fouquieria splendens	5	5	3	3	4	3	3	4	4	3	-	3	-	-	2	4	4	2
Opuntia phaeacantha	2	2	3	1	-	1	1	1	4	2	5	4	2	-	4	-	1	4
Opuntia spinosior	-	-	-	-	-	-	-	1	-	-	-	1	-	1	-	-	1	-
Digitaria californica	1	-	-	-	-	-	1	-	1	1	-	-	-	-	1	-	1	1
Mammillaria microcarpa	-	-	1	1	-	-	-	-	-	1	-	1	-	-	1	1	1	1
Echinocereus pectinatus	-	1	1	1	-	-	-	-	-	-	-	-	-	-	1	-	1	-
Leptochloa dubia	1	1	1	-	-	-	-	-	-	-	2	-	1	-	1	2	2	-
Setaria macrostachya	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-
Acacia greggii	-	-	-	1	-	-	-	1	-	-	3	2	3	-	2	-	-	4
Ferocactus wislizenii	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-
Janusia gracilis	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1
Bouteloua repens	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	1	1
Muhlenbergia porteri	-	-	-	-	1	-	-	-	-	-	-	1	1	-	1	1	1	2

TABLE 6: *Continued*

SPECIES	QUADRAT[a]																	
	E1	E2	E3	L2	P1	P2	P3	L1	L3	L4	A2	A3	F1	F2	B1	B2	B3	A1
Ericameria larcifolia	-	-	-	-	-	-	-	1	-	-	-	4	-	-	5	5	5	5
Pellaea truncata	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	1	1
Eragrostis intermedia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	2
Trachypogon secundus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5	4	1
Bumelia lanuginosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Macrosiphonia brachysiphon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Cheilanthes lindheimeri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-
Ayenia filiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-
Perezia nana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Baccharis brachyphylla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Galactia wrightii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	2	-
Muhlenbergia emersleyi	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	3	-
SUMS OF COLUMNS	23	26	26	28	22	19	18	26	19	20	15	20	16	9	24	16	23	24

[a] Quadrat site locations are abbreviated as follows: B- Bolsa Quartzite, A- Abrigo Formation, L- El Paso Limestone, P- Portal Formation, E- Escabrosa Limestone, F- Alluvial Fans. The site numbers refer to quadrat numbers shown on Figure 4.

[b] Numbers indicate different percent relative cover as follows: 1= less than 2%, 2= 2 to 5%, 3= 5 to 10%, 4= 10 to 20%, 5= greater than 20%.

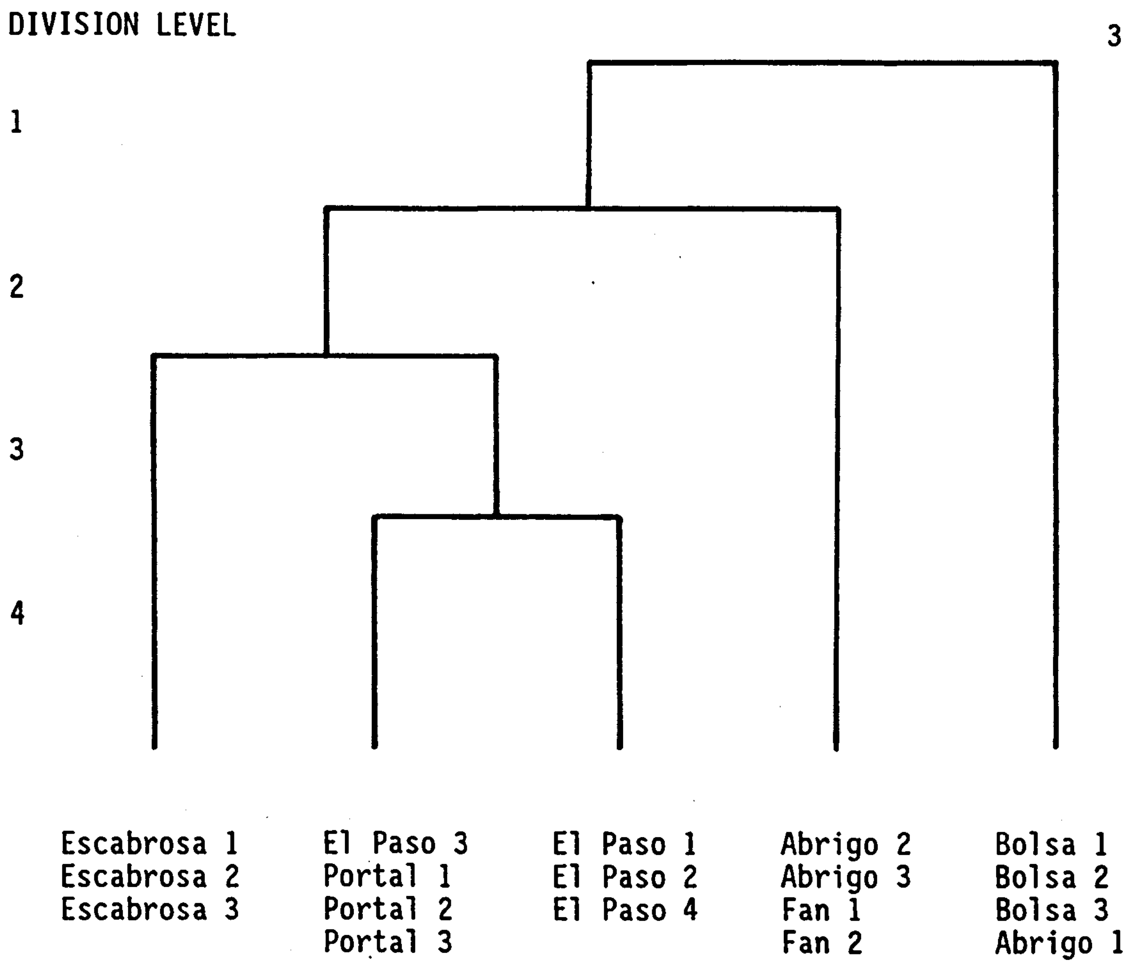


Figure 6: Dendrogram produced from the ordered table information showing the grouping of quadrats based on plant assemblage data. Quadrat locations are shown on Figure 4. Division levels are described in the text.

species. Plant assemblages from the three quadrats of the Bolsa Quartzite are closely related to the first quadrat of the Abrigo Formation because of the presence of *Trachypogon secundus* and *Eragrostis intermedia*. The species are set apart from other geologic units because of the presence of *Perezia nana*, *Baccharis brachyphylla*, and the absence of *Aristida* species and *Panicum hallii*. The second division separates the alluvial deposits and the remaining Abrigo quadrats from the Bolsa Quartzite-Abrigo 1 group and the limestones units because of the presence of *Verbena gooddingii*, *Isocoma tenuisectus*, an unknown vegetative plant, *Opuntia leptocaulis* and *Elymus elymoides* and the absence of the above mentioned species on the Bolsa-Abrigo 1 group and *Astrolepis cochisensis*, *Lycurus setosus*, *Aristida purpurea* var.*longiseta*, *Hedeoma nanum*, *Dalea formosa*, and *Aristida purpurea* var. *fendleriana*. Further division occurs within the limestones themselves. The third division separates the indicator plants found on the Escabrosa Limestone from the plants found on the El Paso Limestone and Portal Formation. Finally, the fourth division divides the assemblages found on quadrats one, three, and four of the El Paso Limestone from the assemblages found on the Portal Formation and the second quadrat of the El Paso. The second El Paso quadrat is included with the Portal because of the absence of *Heteropogon contortus* and inclusion of *Lesquerella wrightii*. Other distinctive plants on the Portal Formation include *Dalea wrightii*, *Gaura* cf. *cocciinea*, *Zinnia acerosa*. The presence of *Stipa eminens* and *Cassia bauhinoides* distinguishes the El Paso group from the Portal Formation and the other geologic units.

4.4 Ordination Results

Results from the ordination indicate there is clustering within the limestones although it is less definitive than the dendrogram (Figure 7). Separation between the Bolsa Quartzite and Abrigo Formation, and the limestones and the alluvial deposits occurs on the y axis. The separation of points along the x axis might be due to surface coverage.

4.5 Geology Descriptions

Complete geologic descriptions of each formation are on Figure 8. A stratigraphic column showing the geologic units and the lithologic character of each unit are on Figure 9. Figure 9 also shows the relative resistance to weathering of each rock type and the average thickness of the units. The average strike of the bedding planes is 303 degrees to 308 degrees and the average dip ranges from 40 degrees to 52 degrees. Although the units are tilted, no apparent faults or folds deformed the rocks in the study site.

The cliff-forming Bolsa Quartzite is moderately fractured and

FIGURE 7: Ordination for Siphon Canyon, Cochise county, Arizona. Data are from 100 1m x 1m samples taken from each 20m x 5m quadrat on the geologic units. Each point represents a quadrat location as shown on Figure 4. B = Bolsa Quartzite, A = Abrigo Formation, EP = El Paso Limestone, P = Portal Formation, E = Escabrosa Limestone, F = Alluvial Fan.

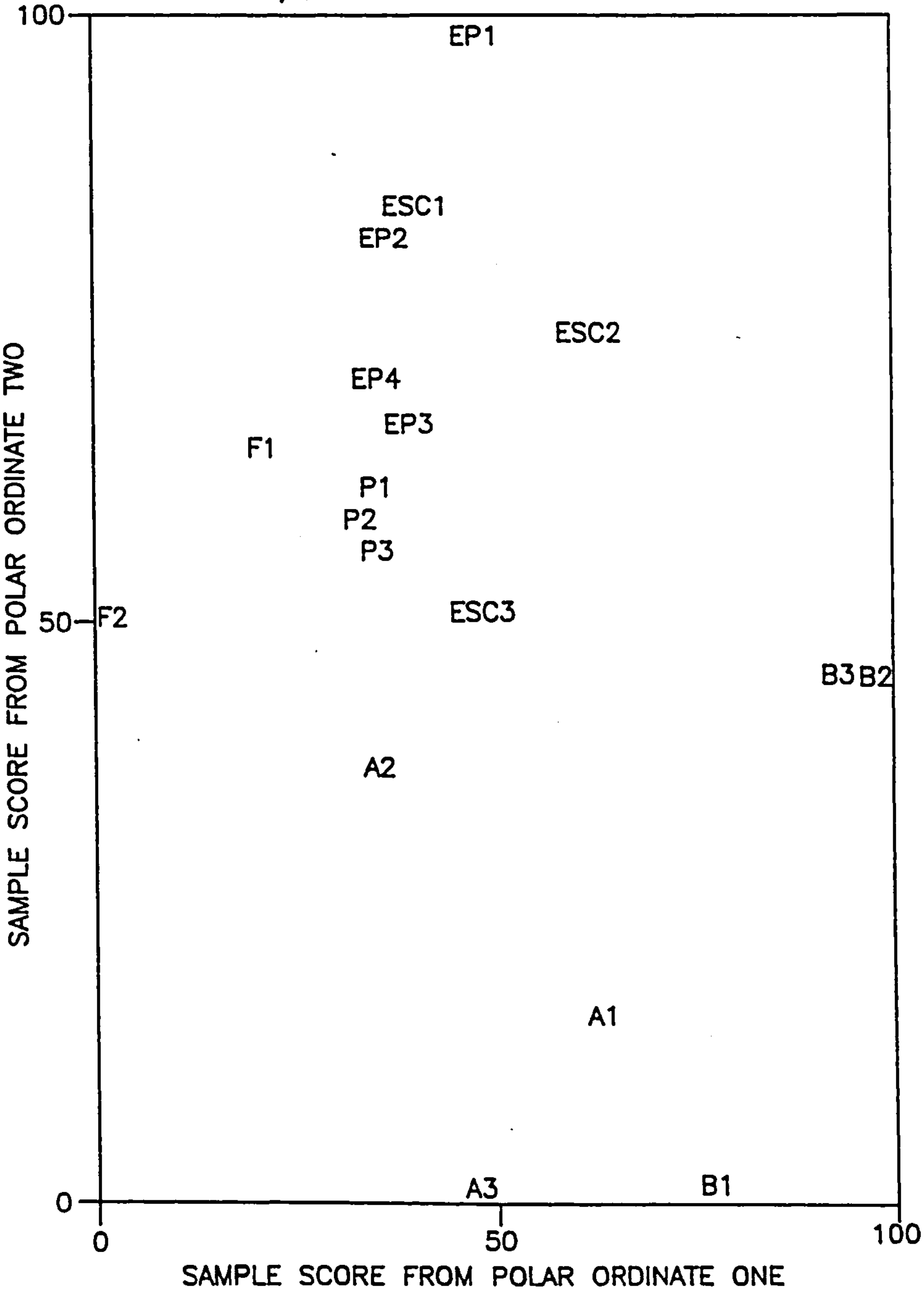


FIGURE 8: Lithologic descriptions of the geologic formations at Siphon Canyon, Cochise County, Arizona.

GEOLOGIC FORMATION	LITHOLOGIC DESCRIPTION
BOLSA QUARTZITE	Quartzite; light pink, tan,or light gray; fine to coarse grained; massive to thick bedded, often crossbedded; resistant, cliff former; 38 meters thick.
ABRIGO FORMATION	Sandstone, siltstone, shale, and limestone; sandstone is pink to tan, others medium to dark gray; fine to medium grained; thin to medium bedded; forms gentle slopes; 133 meters thick.
EL PASO LIMESTONE	Limestone and dolomite; medium blue-gray; medium to fine grained; medium bedding; irregularly shaped pink to tan chert nodules, crinoidal debris; some iron staining; forms step-like gentle slopes; 130 meters thick.
PORTAL FORMATION (or MARTIN FORMATION)	Limestone, dolomite, and shale; medium gray with tan sandy lenses, dark gray shale, yellow-orange iron staining; medium to fine grained; medium to thin bedding; fossil hash and crinoidal debris, a few chert chert nodules; erodes differentially into gentle, ledgey slopes; 85 meters thick.
ESCABROSA LIMESTONE	Limestone; light gray, pink or white ; coarse to medium grained; massive to thick bedded; fossil hash and crinoidal debris; weathers to pockets and rills, typical "tear-pants" surface texture; resistant, forms steep cliffs; 19 meters thick.
ALLUVIAL FANS	Unconsolidated to partly consolidated gravel, sand, silt, clay, with cobbles and boulders; derived from nearby outcrops; thickness ranges from less than one to more than 5 meters.

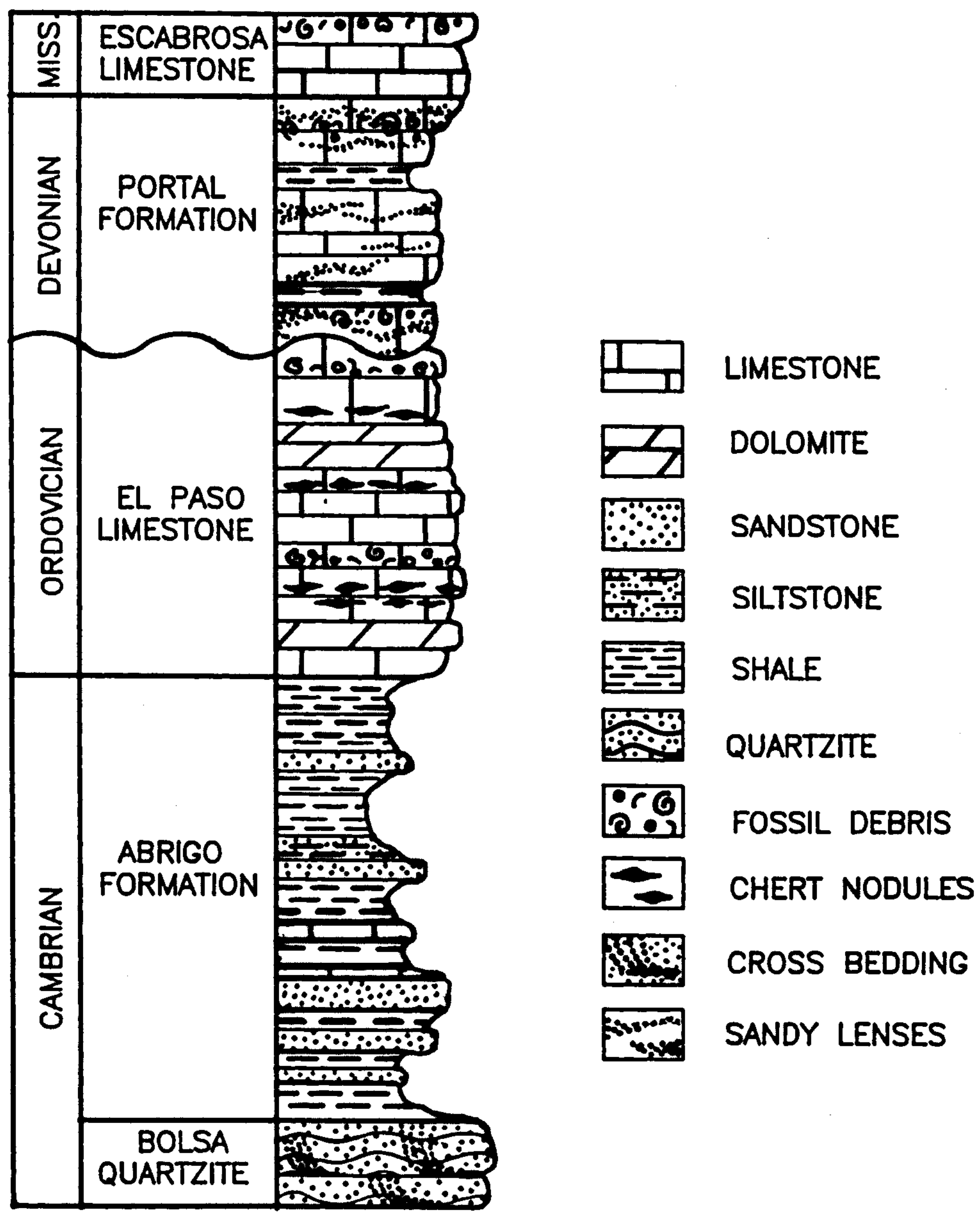


FIGURE 9: Stratigraphic column of the geologic formations at Siphon Canyon, Cochise County, Arizona

erodes into fragments ranging in size from large boulders to gravel. The large boulders create steep unstable boulder piles devoid of any vegetation. As further break-up of the rock occurs, there is stabilization of the slope and deposition and retention of soil in relatively flat terraces between bedding planes. Most of the plants grow upon the terraces. Some grasses and ferns also grow in joint fractures which provide fairly deep catchments for soil. The surface coverage ranges from boulders to gravel (Figure 10a).

The Abrigo Formation consists of interbedded sandstone, siltstone, shale, and limestone. The shale and siltstone are fractured along thin bedding planes and erode easily. The unit generally erodes into gravel- to clay-sized particles and forms gentle slopes. However, the resistant sandstone beds form low ledges that cause soil to accumulate and retain cobbles and gravel of quartzite and sandstone from the Bolsa Quartzite upslope. The surface is often cobble to gravel covered (Figure 11a).

Each limestone lithology is very distinctive. The El Paso Limestone is a blue-gray limestone and dolomite with chert nodules and occasional fossil debris. The unit is fractured and weathers mostly into angular and subangular gravel. Where the limestone is resistant to weathering, the rock forms small ledges that locally trap soil. Partial coatings of calcium carbonate are prevalent on surface fragments of gravel (Figure 12a).

Figure 10a: Vegetation on the Bolsa Quartzite

Figure 10b: Surface cover on the Bolsa Quartzite

Figure 11a: Vegetation on the Abrigo Formation

Figure 11b: Surface cover on the Abrigo Formation

Figure 12a: Vegetation on the El Paso Limestone

Figure 12b: Surface cover on the El Paso Limestone

Figure 13a: Vegetation on the Portal Formation

Figure 13b: Surface cover on the Portal Formation

Figure 14a: Vegetation on the Escabrosa Limestone

Figure 14b: Surface cover on the Escabrosa Limestone

Figure 15a: Vegetation on Alluvial Fan 1

Figure 15b: Surface cover on Alluvial Fan 1

Figure 16a: Vegetation on Alluvial Fan 2

Figure 16b: Surface cover on Alluvial Fan 2

Layers in the less resistant Portal Formation are medium to thick limestone and dolomite with thin to very thin bedded dark gray interbedded shale. The rock is medium gray with distinctive tan silty sand lenses. Iron staining is present throughout the unit. The rock erodes into flat cobble to gravel-sized pieces and the shaley component erodes into thin, platy rectangular pieces. Because the formation is less resistant to weathering, the slopes are more gentle and less ledgy than the El Paso Limestone. Calcium carbonate coats 30 percent of the surface rocks. The surface is armored with cobble- to gravel-sized pieces of thin, platy limestone (Figure 13a).

The steep cliff-forming Escabrosa Limestone consists of coarse grained limestone rich in crinoid and fossil debris. The bedding is massive to thick. With time, the Escabrosa breaks into gravel and smaller pieces. Soil collects in fractures and weathered pockets into which the plants establish (Figure 14a).

4.6 Soil Descriptions

The soils on the El Paso Limestone are classified as gravelly loams while the soils of the Abrigo Formation, Portal Formation, Escabrosa Limestone, Bolsa Quartzite, and the alluvial deposits are classified as gravelly sandy loams (Figure 17, Table 7). The sand fraction is largest in soils from the alluvial locations and the Abrigo

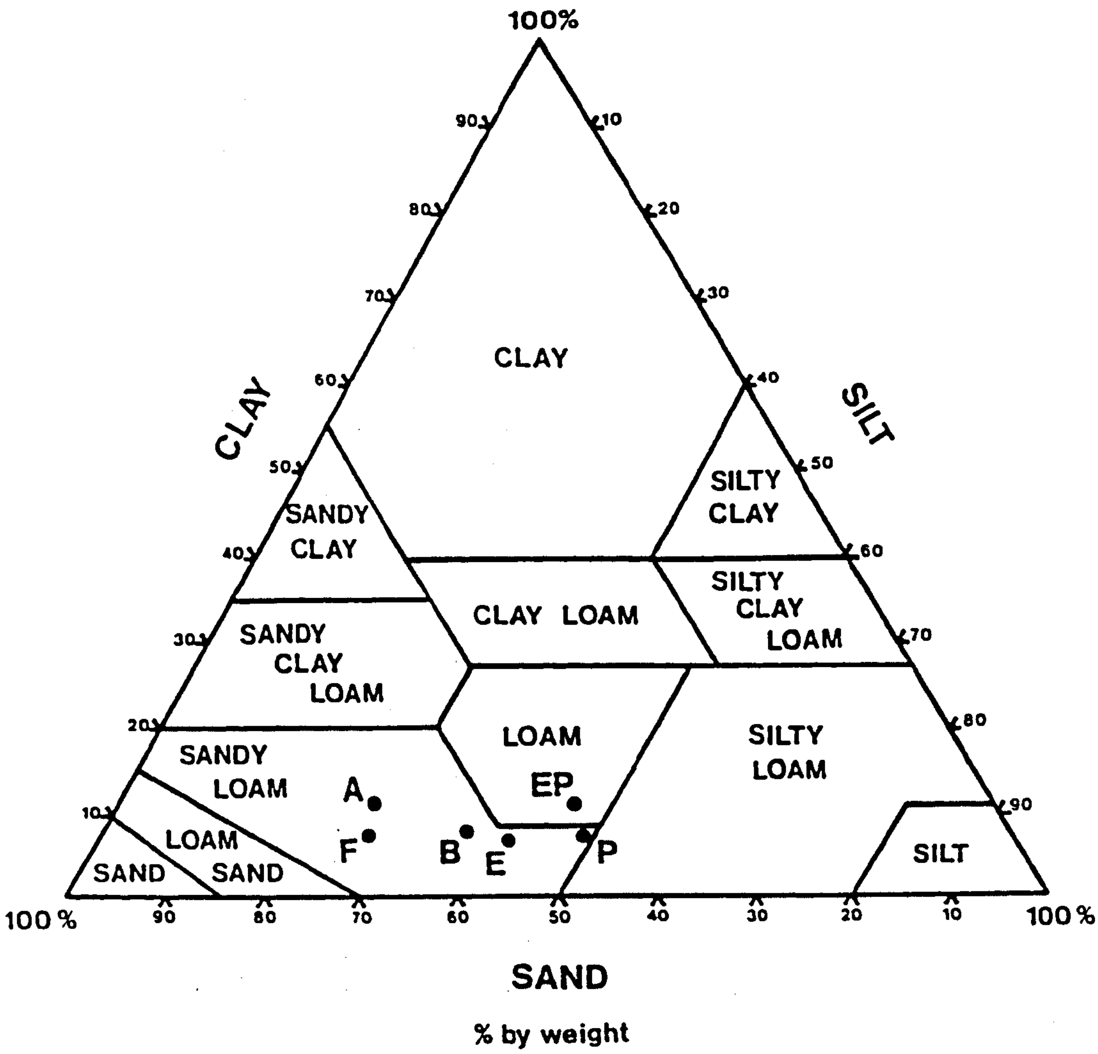


Figure 17: Soil texture diagram for samples obtained from geologic units. B= Bolsa Quartzite, A= Abrigo Formation, EP= El Paso Limestone, P= Portal Formation E= Escabrosa Limestone, F= Alluvial fans

Table 7: Textural and chemical analysis of soils from each geologic formation at Siphon Canyon, Cochise County, Arizona.

	GEOLOGIC FORMATION					
	BOLSA	ABRIGO	EL PASO	PORTAL	ESCABROSA	ALLUVIAL FANS
MEAN PARTICLE SIZE (n=3)						
SAND	54.5 %	62.7 %	43.7 %	43.7 %	51.6 %	64.9 %
SILT	36.7 %	26.1 %	45.8 %	48.8 %	41.8 %	27.6 %
CLAY	8.6 %	11.0 %	10.4 %	7.4 %	6.5 %	7.4 %
MEAN pH (n=3)						
PH	6.37	6.79	8.01	8.03	7.98	8.05
CARBON ANALYSIS (n=3)						
INORGANIC	0.2 %	0.1 %	3.0 %	3.9 %	2.6 %	2.3 %
ORGANIC	1.5 %	0.9 %	2.6 %	1.6 %	3.0 %	2.6 %
TOTAL	1.6 %	1.0 %	5.6 %	5.5 %	5.8 %	4.9 %

Formation. The silt fraction is largest in soils on the limestones. The clay fraction is largest in soils on the Abrigo Formation and El Paso Limestone. Descriptions of the soils are found on Figure 18.

Generally, the soil depths to bedrock are shallow. The alluvial soils are the deepest followed by the Abrigo Formation soils (Figure 18). Little or no soil horizon development was observed in the excavated soil pits except on the alluvial deposits. Soils on the alluvial deposits contain a calcareous layer or Bk horizon approximately 13 cm deep. The accumulation of calcium carbonate is mainly as disseminated lime in the soil matrix or as thin coatings on gravel and cobbles.

From the chemical analysis of the soil data (Table 7) one can divide the different lithologies into two groups by pH and carbon content. Soils on quartzite and mixed lithology are acidic (less than 7.0) and the limestones and alluvium are basic (greater than 7.0). There is more inorganic and organic carbon found in soils on the limestones and the alluvial deposits than the Bolsa Quartzite and the Abrigo Formation. Inorganic carbon is most abundant in the soil from the El Paso Limestone. Organic carbon is highest found in the soil from the Escabrosa Limestone.

FIGURE 18: Field descriptions of soils on different geologic formations at Siphon Canyon, Cochise County, Arizona.

GEOLOGIC FORMATION	SOIL DESCRIPTION
BOLSA QUARTZITE	Gravelly loam; dark brown (10 YR 4/3) to strong brown (7.5YR 4/6); surface cover ranges from angular boulders to gravel; no soil horizon or calcium carbonate; depth 16-51 centimeters (cm); average surface slope 7 degrees.
ABRIGO FORMATION	Gravelly sandy loam; strong brown (7.5 YR 4/6); surface cover of angular of cobbles and gravel composed of quartzite; soil with depth gravel and cobble supported; no soil horizon or calcium carbonate; depth 14- >55 cm; average surface slope 14 degrees.
EL PASO LIMESTONE	Gravelly loam; brown (10 YR 5/3); surface cover of angular, platey, rectangular, or square limestone, quartzite, and chert; some calcium carbonate coated float; hardpan caliche at 10 cm depth at one location; depth 6-34 cm; average surface slope 10 degrees.
PORTAL FORMATION (or MARTIN FORMATION)	Gravelly loam; gray (5 Y 5/1) to grayish brown (2.5 Y 5/2); surface cover angular, platy limestone; 30 percent calcium carbonate coated rocks, calcium carbonate encountered at 13 cm; depth 10-33 cm; average surface slope 13 degrees.
ESCABROSA LIMESTONE	Gravelly loam; brown (10 YR 5/3); surface cover of dirt and limestone gravel, some platey Portal derived limestone on top surface; no soil horizon or calcium carbonate; depth 4-30 cm; average surface slope 10 degrees.
ALLUVIAL FAN NO. 1	Gravelly sandy loam; light brownish gray (2.5 YR 6/2); surface covered with a few limestone and quartzite cobbles and angular to subangular, square to platey gravel, some calcium carbonate coating; greater than 55 cm depth; average surface slope 5 degrees.

FIGURE 18: *Continued*

GEOLOGIC FORMATION	SOIL DESCRIPTION
ALLUVIAL FAN NO. 2	Gravelly sandy loam; light brownish gray (2.5 YR 6/2); surface covered with angular to subangular limestone gravel, some with calcium carbonate coating, calcium carbonate hardpan at 7 cm at one location; generally greater than 55 cm depth; average surface slope 7 degrees.

4.7 Surface Rockiness

Surface rockiness is expressed as the average percentage of exposed rock outcrop, boulders, cobbles, gravel and bare dirt covering each quadrat surface (Figure 19). The most steep resistant lithologies, Escabrosa Limestone and Bolsa Quartzite, have the largest percentage of bare rock. The most boulders are found on the Bolsa Quartzite followed by the Abrigo Formation while virtually no boulders are found on the El Paso Limestone, Portal Formation, Escabrosa Limestone, or alluvial deposits. The largest percentage of cobbles are on the Portal Formation and the largest percentage of gravel is on the alluvial fans. Bare ground is most often seen on the alluvial deposits. Total surface coverage data by each quadrat is found on Appendix C.

Photographs of the surface of each formation are included to show the differences in surface rockiness and how surface fragments vary in shape, size, and color from rock type to rock type (Figure 10b through 16b). The Bolsa Quartzite typically has the largest fragments (Figure 10b) while the Escabrosa has the smallest (Figure 14b). The shapes range from small angular gravel of the Escabrosa Limestone to the larger platy fragments of the Portal Formation (Figure 13b).

4.8 Surface Color

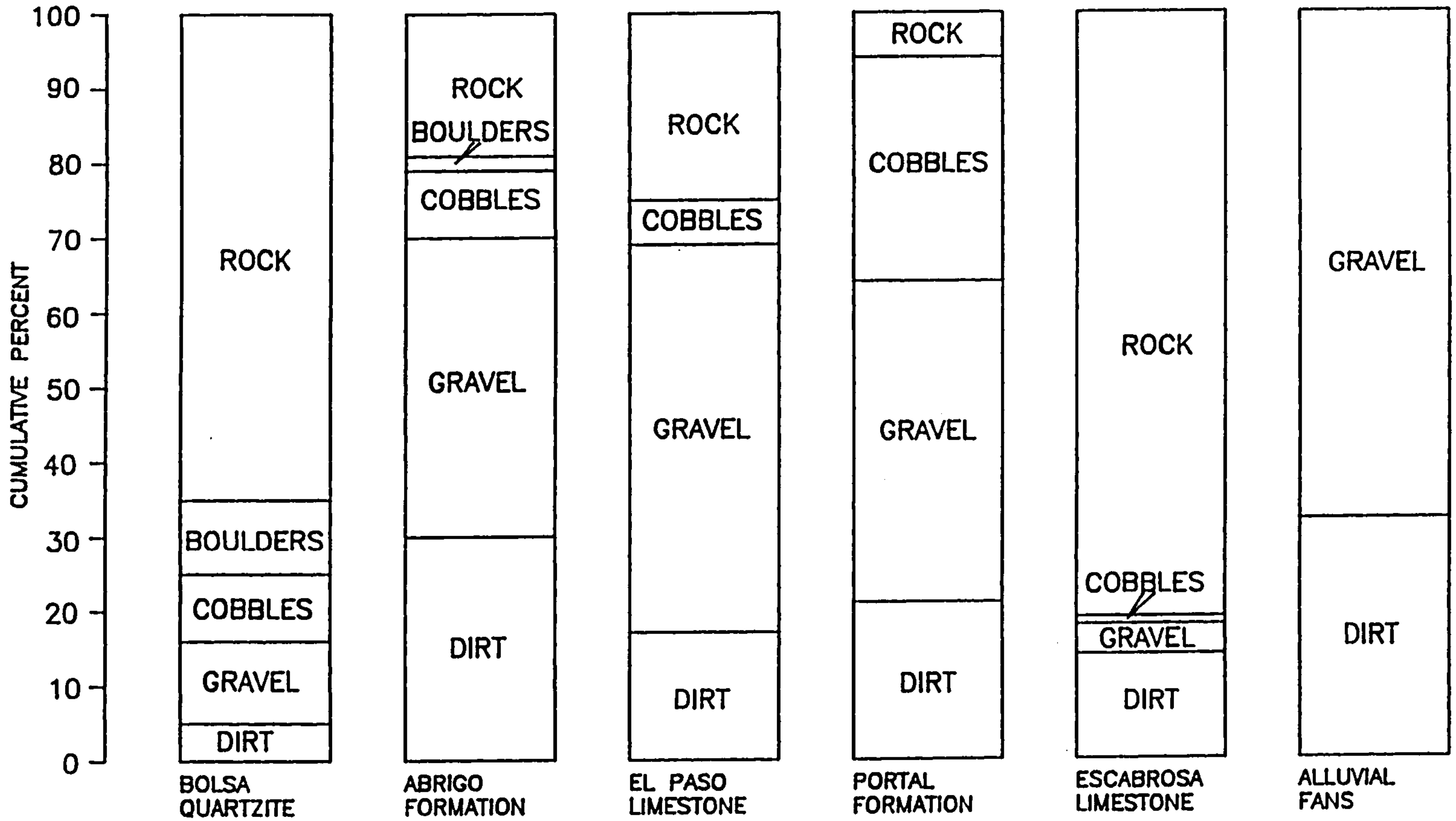


Figure 19: Average percent surface rockiness for each geologic unit

The color of the formations ranges from dark gray of the Portal Formation shales to almost white of the Escabrosa Limestone.

4.9 Slope

The average slope of the terraced land surface on each of the geologic units ranges from 19 degrees on the Portal Formation to 6 degrees on the alluvial fans (Figure 18). Angle of slope varies near ledges and depressions. The overall slope is smallest for the alluvial fans and largest for the Bolsa Quartzite and Escabrosa Limestone (Figure 18).

5. DISCUSSION

The results of this study demonstrate a correspondence between the perennial Desert Grassland vegetation assemblages and the different lithologies. The factors important in determining this correspondence are discussed below.

5.1 Environmental Factors

Some of the environmental factors that influence the distribution of plants include climate, elevation, degree of slope, slope aspect, nature of the host rock, soil properties such as parent material, texture, depth, temperature, moisture and chemistry; surface coverage by plants, rocks and rock fragments; and interaction and competition with other plants (Shreve, 1915, Whittaker and Niering, 1968b; Wentworth, 1976).

In this study, the climatic effect on the vegetation is intentionally minimized because the site area is small (200 square km), the change in elevation is a mere 55 meters, and only a single aspect, the southwest, was sampled. This is in contrast to previous studies by Whittaker and Niering (1968b) and Wentworth (1981, 1985). Whittaker and Niering's Santa Catalina site which encompassed a mountain front embraced 1916 meters in elevation from saguaros to alpine fir (Whittaker and Niering, 1968b). Wentworth studied the vegetational change on two mountain fronts with an elevation change of 500 meters on each (Wentworth, 1981; 1985). His selection of lithologies includes sedimentary, metamorphic, and volcanic outcrops. Also because of the small scale, the pattern of vegetation showing a continuum from xeric to mesic sites with change in aspect (Shreve, 1915; Whittaker and Niering, 1968b; and Wentworth, 1976, 1981, 1985) is not present at Siphon Canyon. All of the plants growing at this southwest-facing site are considered to be typical desert grassland and desert scrub plants indicative of xeric conditions (Whittaker and Niering, 1968b; Wentworth, 1976). Plant competition may be important but the effect is not easily determined by the data presented in this study. Therefore, the properties of the host rock, soil, soil surface, and soil chemistry are important variables for controlling plant density, diversity, and distribution. Each of these factors directly or indirectly influences the amount of soil moisture availability, an important limiting factor in an arid environment. The degree to which the relative influence of each factor and the result on the vegetative assemblages is discussed.

5.2 Host Rock

Each geologic unit has a distinct lithologic composition which determines the topography, weathering, and fracturing of the substrate. Topography and weathering control soil accumulation and runoff

(Shreve, 1915). Steep ridges and cliffs such as found on the Bolsa Quartzite and the Escabrosa Limestone have fewer sites for accumulations of soil and the soil depths are often shallow (Figure 18). Steep areas have more rapid runoff rates than gentle slopes (Shreve, 1915). Fracture density may differ among the consolidated rock types and influence the volume of surface runoff that infiltrates from the rainfall event (Shreve,1915; Whittaker and Niering, 1968b). The above factors may account for the decreased cover on the Bolsa Quartzite and the Escabrosa Limestone (Table 2).

For the El Paso Limestone, Portal Formation, and Abrigo Formation, resistant beds of the rock are interbedded with other lithologies that weather easily. The result of differential weathering is resistant rock "berms" spanned by relatively flat terraces of soil between strata that form sites for soil accumulation, seed germination and plant growth (Figure 20). The resistant rock also disrupts and slows runoff. Microtopographic differences are produced by the alternation of rock and soil and create additional habitats for the vegetation (Partridge, 1991). The unevenness also acts as catchments for eolian debris (Greely et al, 1985). The influence on soil accumulation, moisture retention, and runoff diversion of the berm features is dependent on the resistive nature of the rock and degree of slope (Rosenthal, 1983). The resistant rock berms are thicker, taller, and more pronounced in the El Paso Limestone and the Abrigo Formation and less apparent in the less resistant Portal Formation where the interbedded resistant strata are

Figure 20: Example of rock berm on El Paso Limestone

thinner, shorter and overall slope is steeper. The interbedded lithologies also erode into different materials which affect the texture and chemical composition of the soils and thus the plant assemblages present.

5.3 Soils

Soil texture strongly influences water penetration and retention. The texture is partly controlled by rock type (Rosenthal, 1983). From the results, one would expect virtually all sand in the Bolsa Quartzite soil; clay and silt in the Abrigo Formation and the Portal Formation soils; and silt in the Portal Formation, El Paso Limestone, and Escabrosa Limestone soils. This is not reflected in the data. Instead, over one third of the soil from the Bolsa Quartzite ridge is composed of silt and clays which should not be derived from quartzites; the soils from the El Paso Limestone and the Portal Formation have similar sand, silt, and clay components even though the two formations are lithologically different; and the soil on the compositionally pure Escabrosa Limestone has over 60 percent sand. The differences in the textural components suggests eolian transport of the sediments (Gile et al., 1981, McFadden, 1982). Eolian input of clay, silt, sand and calcium carbonate also possibly mitigates some soil differences produced from the parent materials.

Some chemical differences and soil pH are probably controlled by rock type. Soil pH, which is important for nutrient mineral solubilities and uptake (Wentworth, 1976), is more acidic on soils developed on the Bolsa Quartzite and the Abrigo Formation than on the limestones. The constituents of secondary calcium carbonate in soils on the alluvial deposits can be derived from both eolian influence and local substrate (Gile et al., 1981).

Soil texture and organic matter content strongly control sites where water moisture maybe held and available for plants (Wentworth, 1976). Clay is especially important for soil moisture storage (Hendricks,1985) particularly for short-rooted plants such as cacti and grasses (McAuliffe, personal communication). The soils on the Abrigo Formation which contain the largest quantities of clay have particularly extensive areas of prickly pear (*Opuntia phaeacantha*). The limestones also have high organic content and texture which act like clays in enhancing the moisture storage capacity (Shreve, 1915, 1922). Perhaps this explains why many cacti and succulents are present on the limestones.

5.4 Surface Rockiness

Clustering of the rocks act as a mulch that provides protected sites for germinating seeds and seedlings (Matthews et al.,1991, Fish et al., 1985). The size, shape, and quantity of fragments may increase moisture retention by reducing evaporation at the soil surface and reduce rainfall runoff (Shreve, 1915,1924; Evenari et al, 1971). The Portal formation has the greatest percent surface fragment cover of cobble and gravel combined (Figure 19) and the shapes of the fragments are rectangular and platy. There are more plant species with a greater than 5 percent cover on the Portal Formation than the other lithologies (Table 3) possibly because of the rock mulch effect.

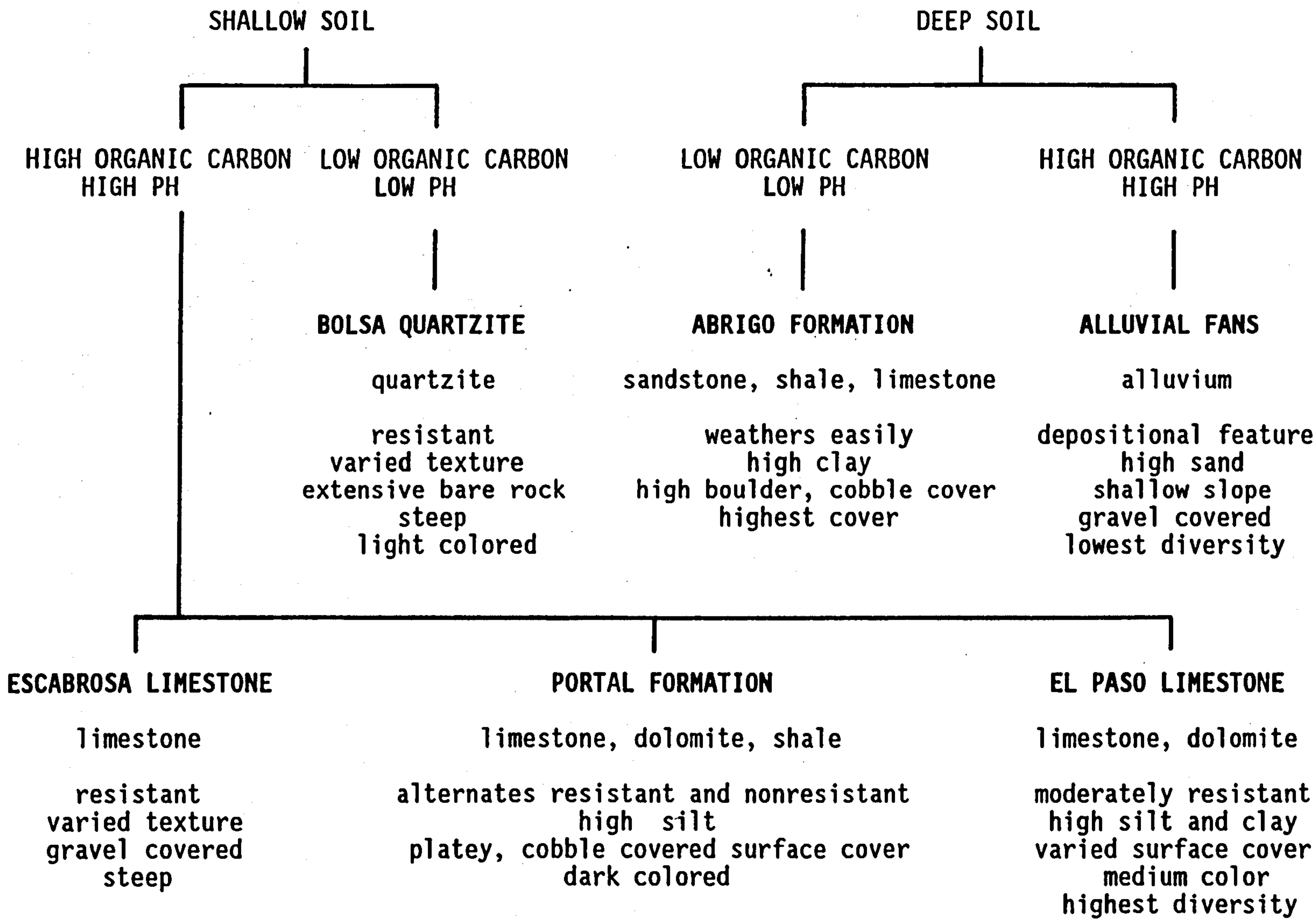
5.5 Color

Rock and soil color influences plant distribution because differential insolation affects soil temperature and moisture retention (Shreve, 1922). Generally a dark soil has a higher temperature and larger potential for water loss (Shreve, 1922). There is a distinct contrast between the light colored lithologies of the Escabrosa Limestone and Bolsa Quartzite and dark colored lithologies of the Portal Formation.

5.6 Summary of Environmental Characteristics

A summary of the distinguishing environmental characteristics for each geologic unit is found on Figure 21. A complex interaction of environmental factors on each lithology affects plant growth,

Figure 21: Summary table differentiating geologic formations by different environmental factors.



establishment, and distribution. The classification of the assemblages by lithology is clear by the ordered table (Table 6) but the interpretation of the ordination (Figure 7), by the x-axis, is difficult. The clustering of points along the x-axis relates each group by lithology but the reason for this distribution is unclear.

5.7 Diversity

The geologic and edaphic conditions for plant growth on each formation are distinctly different, thus varied resources are available. Diversity is greatest on the El Paso and the Escabrosa Limestones and least on the alluvial deposits. The El Paso Limestone has a variety of habitats and resources available. There is a moderate amount of exposed rock, cobble and gravel cover, and fracturing within the unit. The plant canopy structure is varied. Edaphically, the soil is texturally heterogeneous and contains a high amount of organic carbon to retain moisture. Slope on the El Paso is moderate. This is very different from the steep, rocky Escabrosa Limestone which also has a diverse plant community. The plants are restricted to small, shallow gravel-covered pockets and fractures. The soils are similar to the soils of the El Paso and are heterogeneous in texture.

The least diverse unit is the alluvial fans. Here, the soils are deep, sandy, relatively flat, and gravel covered. Heavy rainfall events are drained by channels on either sides of the fans. A petrocalcic horizon retains moisture. The greatest impact on the fans is from livestock. Although the fan unit is most conducive for plant growth because of its depth and stability, it is less diverse than the Escabrosa Limestone or the El Paso Limestone. Three theories based on plant competition that might explain the diversity differences include the environmental heterogeneity hypothesis of Levin (1974), intermediate disturbance hypothesis of Connell (1978), and dynamic equilibrium hypothesis of Huston (1979).

Levin (1974) stated that the more heterogeneous an environment, the greater its diversity because no single competitor can dominate all of the habitats. A more stable, homogeneous environment would promote some plants to gain dominance over and eliminate less fit organisms This would appear true for the high diversity seen on the environmentally variable El Paso Limestone and the low diversity of the rather homogeneous alluvial deposits but fails to adequately explain the high diversity of the Escabrosa Limestone.

Connell (1978) proposed the intermediate disturbance hypothesis which states if the amount of environmental disturbance is moderate and not too frequent and the number of organisms is not reduced too severely, the diversity will be high because the disturbance interrupts the competitive process. Dominant competitors are not able to flourish and less able competitors are not eliminated. If the time between disturbance events is long, there is eventually a competitor which will dominate. Perhaps because the fans experience less erosional disturbance from rainfall, diversity is low and that is why *Parthenium* and *Gutierrezia* dominate. Livestock which selectively consume certain grasses, also reduce the number of competitors. The El Paso Limestone and the Escabrosa Limestone have less livestock disturbance and have a higher amount of erosion because of steep slopes and shallow soils, possibly resulting in higher diversities.

Huston (1979) discussed how the rates of competitive displacement influences diversity. A higher diversity of organisms is seen if the rates of displacement are high because no single competitor becomes dominant and inferior competitors are not eliminated. High rates of erosion may occur on the limestones because of the steepness of slope and the shallow soil. The alluvial deposits are more stable and do not erode as readily. The plants on the fans with higher growth rates eventually dominate.

From the above discussion, the geologic and edaphic characteristics and the role of plant competition are important to the diversity of plants at the site. The different environmental factors provide different resources available for the plants and can influence the impact of a disturbance event and the rate at which the plants are able to recover.

5.8 Substrate Specific Plants

The list of substrate specific or "indicator plants" is found on Table 5 and is useful for identifying a lithology at Siphon Canyon. A more reliable method would be to examine the total plant assemblage present on each lithology. Weaver and Clements (1938) discuss how "plant communities are more reliable indicators [of a substrate] than individual plants" (p. 454) and indicate "conditions, processes, and uses" (p. 454) of the environment. Some plant species reported in the literature as being restricted to specific rock types such as or *Parthenium incanum* to limestone (Bradbury, 1969; Wentworth, 1981) are found on other lithologies at this study site. Perhaps the eolian particles "equalize" aspects of the soil texture or chemistry utilized by plants on all lithologies. Alternatively, resource competition might be so severe that plants occupy a less preferred but available site on a non-calcareous substrate.

6. SUMMARY AND CONCLUSIONS

Five different plant assemblages were recognized on the six different geologic units at Siphon Canyon. The vegetational distribution is attributed to the distinct lithologic and edaphic character of the geologic units. All of the units have factors contributing to the retention of soil moisture, a limiting factor to plants growing in a semi-arid environment. No single environmental variable could explain the vegetative patterns and in the case of species diversity, plant competition may be an important factor.

Important conclusions drawn from this research include:

(i) The formations found at Siphon Canyon are composed of different lithologies and erode differentially creating microtopographical differences and different chemical and textural components. Because of the variability within each geologic unit, different plant assemblages are found on the different geologic units.

(ii) Rock fragments covering the land surface affect the surface air flow, moisture retention, evaporation, and temperature of each geologic unit and provide different microhabitats which affect the distribution, growth, and germination of plants.

(iii) Eolian soils deposit material on all of the lithologic units resulting in a change of texture of soils within each soil; some plants may use this "equalizing" effect to spread beyond the plant's normal distribution.

(iv) The light color of these units affect the amount of reflected insolation, increasing the moisture and decreasing their temperature (Shreve, 1924);

(v) Diversity of the vegetation could be the result of plant competition;

and (vi) Substrate specific plants for this area are listed; some may grow on other lithologies beyond Siphon Canyon.

7. APPENDIX A

Appendix A: List of all identified plant species and the geologic formations where each species occurs at Siphon Canyon, Cochise County, Arizona.

PTERIDOPHYTE

	OCCURRENCE[a]											
ADIANTACEAE												
Astrolepis cochisensis (Godd.) Benham & Windham	B			a	EP		P		E			
Cheilanthes lindheimeri Hook.	B											
Notholaena lemmoni DC. Eaton		b										
Notholaena standleyi Maxon.		b										
Pellaea truncata Goodding.	B		A									

GYMNOSPERMAE

CUPRESSACEAE												
Juniperus erythrocarpa Cory.		b		a		ep		p	E			f

ANGIOSPERMAE

AGAVACEAE												
Agave palmeri Engelm.	B		A		EP		P		E		F	
Dasylirion wheeleri Wats.	B				EP		P		E			
Yucca baccata Torr.			A		EP		P			e		

Appendix A: *Continued*

	OCCURRENCE[a]					
ANACARDIACEAE						
Rhus microphylla Engelm. ex Gray.	b	a	EP	P	E	F
APOCYNACEAE						
Macrosiphonia brachysiphon (Torr.) Gray.	B					
ASTERACEAE						
Artemisia dracunculoides Pursh.	b					
Artemisia ludoviciana Nutt.	b				E	
Baccharis brachyphylla Gray.		A				
Baccharis sarothroides Gray.		a				
Bahia absinthifolia Benth.		a				
Brickellia baccharidea Gray					E	
Brickellia californica (Torr. & Gray.) Gray	b	a				
Dyssodia acerosa DC.		a		p		f
Ericameria laricifolia (Gray) Shinners	B	A	EP			
Gnaphalium wrightii Gray	b					
Gutierrezia microcephala (DC.) Gray	B	A	EP	P	E	F
Isocoma tenuisectus Greene		a				F
Machaeranthera pinnatifida (Hook.) Shinners		a				
Machaeranthera tagetina Greene		a				
Parthenium incanum H.B.K.	b	A	EP	P	E	F
Perezia nana Gray	B	A	ep			
Thelesperma longipes Gray				p	E	
Trixis californica Kellogg	b	a				
Zinnia acerosa (DC.) Gray		a		P		

Appendix A: *Continued*

	OCCURRENCE[a]					
ANACARDIACEAE						
Rhus microphylla Engelm. ex Gray.	b	a	EP	P	E	F
APOCYNACEAE						
Macrosiphonia brachysiphon (Torr.) Gray.	B					
ASTERACEAE						
Artemisia dracunculoides Pursh.	b					
Artemisia ludoviciana Nutt.	b				E	
Baccharis brachyphylla Gray.		A				
Baccharis sarothroides Gray.		a				
Bahia absinthifolia Benth.		a				
Brickellia baccharidea Gray					E	
Brickellia californica (Torr. & Gray.) Gray	b	a				
Dyssodia acerosa DC.		a		p		f
Ericameria laricifolia (Gray) Shinners	B	A	EP			
Gnaphalium wrightii Gray	b					
Gutierrezia microcephala (DC.) Gray	B	A	EP	P	E	F
Isocoma tenuisectus Greene		a				F
Machaeranthera pinnatifida (Hook.) Shinners		a				
Machaeranthera tagetina Greene		a				
Parthenium incanum H.B.K.	b	A	EP	P	E	F
Perezia nana Gray	B	A	ep			
Thelesperma longipes Gray				p	E	
Trixis californica Kellogg	b	a				
Zinnia acerosa (DC.) Gray		a		P		

Appendix A: *Continued*

	OCCURRENCE[a]					
BRASSICACEAE (CRUCIFERAE)						
Lesquerella fendleri (Gray) S.Wats.	B	a	EP	P	e	
CACTACEAE						
Echinocereus pectinatus (Scheidw.) Engelm.	B	A	EP		E	
Ferocactus wislizenii (Englem.) Britton & Rose	B	A				
Mammillaria microcarpa Engelm.	B	A	EP		E	
Opuntia leptocaulis DC.						F
Opuntia phaeacantha Engelm.	B	A	EP	P	E	F
Opuntia spinosior (Engelm.) Toumey.	B	A	EP		e	
CHENOPODIACEAE						
Atriplex canescens (Pursh) Nutt.		a				f
CONVOLVULACEAE						
Evolvulus arizonicus Gray	b					
CROSSOSOMATACEAE						
Forsellesia spinescens (Gray) Greene					E	
EUPHORBIACEAE						
Croton pottsii (Klotzsch) Muell.-Arg. var. pottsii.			EP	P	e	f

Appendix A: *Continued*

	OCCURRENCE[a]					
FABACEAE (LEGUMINOSAE)						
Acacia greggii Gray	B	A	EP			F
Calliandra eriophylla Benth.	B	A	EP	P	E	
Cassia bauhinioides Gray			EP			
Dalea formosa Torr.			EP	P	E	f
Dalea wrightii Gray				P		
Galactia wrightii Gray	B	a				
Prosopis velutina Wooton		A		P		F
FOUQUIERIACEAE						
Fouquieria splendens Engelm.	B	A	EP	P	E	f
LAMIACEAE (LABIATAE)						
Hedeoma nanum (Torr.) Briq.			EP	P	E	f
LOASACEAE						
Cevallia sinuata Lag.				P	E	
LORANTHACEAE						
Phoradendron capitellatum Torr. ex Trel.	b	a	ep			

Appendix A: *Continued*

	OCCURRENCE[a]							
MALPIGHIACEAE								
Janusia gracilis Gray	B		A					
MALVACEAE								
Sphaeralcea laxa Wooton & Standl.		b		a	EP		e	
OLEACEAE								
Menodora scabra (Engelm.) Gray					EP			
ONAGRACEAE								
Gaura cf. *coccinea* Nutt.						P		
PLANTAGINACEAE								
Plantago patagonica Jacq.				a				f
Plantago purshii Roem. & Schult.				a				f

Appendix A: *Continued*

POACEAE

	OCCURRENCE[a]										
Aristida purpurea Nutt. var. *fendleriana* (Stued.) Vasey					EP		P	E			
Aristida purpurea Nutt. var. *longiseta* (Steud.) Vasey					EP		P	E			
Aristida purpurea Nutt. var. *nealleyi* (Vasey) Allred					EP		P	E		F	
Aristida ternipes Cav. var. *ternipes*		b		a							
Aristida species		b			EP		P	E		F	
Bothriochloa barbinodis (Lag.) Herter		b		a							
Bouteloua curtipendula (Michx.) Torr.	B		A		EP		P	E		F	
Bouteloua eriopoda Torr.		b	A		EP		P	E		F	
Bouteloua hirsuta Lag.				a	EP						
Bouteloua repens (H.B.K.) Scribn. & Merr.	B		A								
Bromus rubens L.				a							
Digitaria californica (Benth.) Henr.	B		A		EP		P	E			
Digitaria cognata (Schult.) Pilger.								E			
Elymus elymoides (Raf.) Swezey										F	
Eragrostis intermedia Hitchc.	B		A						e		
Eragrostis lehmanniana Nees.		b			EP			E			
Erioneuron grandiflorum (Vasey) Takeoka						ep					
Heteropogon contortus (L.) Beauv. ex Roemer & Schultes	B		A		EP			E			
Leptochloa dubia (H.B.K.) Nees.	B		A					E		F	
Lycurus setosus (Nutt.) C.Reeder	B		A		EP		P	E			
Muhlenbergia emersleyi Vasey	B							E			
Muhlenbergia porteri Schribn. ex Beal.	B		A				P			F	
Panicum hallii Vasey.			A		EP		P	E		F	
Setaria macrostachya H.B.K.	B		A								
Stipa eminens Cav.					EP						
Trachypogon secundus (Presl) Schribn.	B		A								
Tridens muticus (Torr.) Nash						ep		E			f
Tridens pulchellus (H.B.K.) Hitchc.					EP				e	F	

Appendix A: *Continued*

	OCCURRENCE[a]					
POLYGONACEAE						
Eriogonum abertianum Torr.	b					
Eriogonum wrightii Torr. ex Benth.	b	a			e	
PORTULACACEAE						
Talinum parviflorum Nutt. ex Torr & Gray		a				
RHAMNACEAE						
Condalia warnockii Johnst. var. *kearneyana* Johnst.			ep			
Ziziphus obtusifolia (Hook. ex Torr. & Gray) Gray						f
RUTACEAE						
Thamnosma texana var. *purpureum* (Woot. & Standl.) Woodruff				E		
SAPINDACEAE						
Sapindus drummondii Hook. & Arn.	b					
SAPOTACEAE						
Bumelia lanuginosa (Michx.) Pers. var. *rigida* Gray	B					

Appendix A: *Continued*

	OCCURRENCE[a]					
STERCULIACEAE						
Ayenia filiformis Wats.	B					
SOLANACEAE						
Solanum elaeagnifolium Cav.		a	ep	p		f
VERBENACEAE						
Aloysia wrightii	b	A	EP	P	E	f
Tetraclea coulteri Gray		a				
Verbena gooddingii Briq.		A				
ULMACEAE						
Celtis reticulata Torr.					E	
ZYGOPHLLACEAE						
Larrea tridentata (DC.) Coville			ep	p	e	f
UNIDENTIFIED SPECIES						
herb, green leaves rimmed with purple, no flowers seen		A				

Appendix A: *Continued*

[a] Upper case letters indicate geologic formation where species occurs on a quadrat

B = Bolsa Quartzite
A = Abrigo Formation
EP= El Paso Limestone
P = Portal Formation
E = Escabrosa Limestone
F= Alluvial Fan

Lower case letters indicate geologic formation where species occurs but was not identified within any quadrat.

b = Bolsa Quartzite
a = Abrigo Formation
ep= El Paso Limestone
p = Portal Formation
e = Escabrosa Limestone
f = Alluvial Fan

8. APPENDIX B

APPENDIX B

TABLE OF CONTENTS

TABLE B-1: ABSOLUTE AND RELATIVE PERCENTAGES OF PLANT SPECIES ON 20m x 5m QUADRATS ON THE BOLSA QUARTZITE AT SIPHON CANYON, COCHISE COUNTY, ARIZONA

	........Absolute %........				............Relative %...........				
Species	Quadrat 1	Quadrat 2	Quadrat 3	Sum	Quadrat 1	Quadrat 2	Quadrat 3	Sum	Mean
Grasses									
Aristida purpurea var. fendleriana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Aristida purpurea var. longiseta	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Aristida purpurea var. nealleyi	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Aristida sp.	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Bouteloua curtipendula	21	65	225	311	1.26	2.55	7.59	11.40	3.80
Bouteloua eriopoda	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Bouteloua hirsuta	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Bouteloua repens	3	0	11	14	0.18	0.00	0.37	0.55	0.18
Digitaria californica	10	0	10	20	0.60	0.00	0.34	0.94	0.31
Elymus elymoides	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Eragrostis intermedia	14	248	52	314	0.84	9.72	1.75	12.31	4.10
Eragrostis lehmanniana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Heteropogon contortus	3	0	8	11	0.18	0.00	0.27	0.45	0.15
Leptochloa dubia	17	95	101	213	1.02	3.72	3.41	8.15	2.72
Lycurus setosus	0	6	3	9	0.00	0.24	0.10	0.34	0.11
Muhlenbergia emersleyi	11	47	95	153	0.66	1.84	3.21	5.71	1.90
Muhlenbergia porteri	30	2	26	58	1.80	0.08	0.88	2.76	0.92
Panicum hallii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Setaria macrostachya	4	0	0	4	0.24	0.00	0.00	0.24	0.08
Stipa eminens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Trachypogon secundus	109	749	435	1293	6.55	29.35	14.68	50.59	16.86
Tridens muticus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Tridens pulchellus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Shrubs									
Acacia greggii	35	0	0	35	2.10	0.00	0.00	2.10	0.70
Aloysia wrightii	0	0	0	0	0.00	0.00	0.00	0.00	0.00

TABLE B-1: *Continued*

Species	........Absolute %........				............Relative %...........				
	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Mean
Shrubs (cont.)									
Bumelia lanuginosa	1	0	0	1	0.06	0.00	0.00	0.06	0.02
Calliandra eriophylla	0	0	5	5	0.00	0.00	0.17	0.17	0.06
Dalea formosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Dalea wrightii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ericameria larcifolia	629	528	911	2068	37.82	20.69	30.75	89.26	29.75
Forsellesia spinescens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Fouquieria splendens	35	368	405	808	2.10	14.42	13.67	30.19	10.06
Gaura cf. *coccinea*	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Macrosiphonia brachysiphon	0	0	179	179	0.00	0.00	6.04	6.04	2.01
Parthenium incanum	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Rhus microphylla	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Unknown	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Trees									
Celtis reticulata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Juniperus erythrocarpa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Prosopis velutina	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cacti/Succulents									
Agave palmeri	0	7	130	137	0.00	0.27	4.39	4.66	1.55
Dasylirion wheeleri	150	0	0	150	9.02	0.00	0.00	9.02	3.01
Echinocereus pectinatus	2	0	1	3	0.12	0.00	0.03	0.15	0.05
Ferocactus wislizenii	2	0	0	2	0.12	0.00	0.00	0.12	0.04
Mammillaria microcarpa	7	35	25	67	0.42	1.37	0.84	2.64	0.88
Opuntia leptocaulis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Opuntia phaeacantha	182	0	5	187	10.94	0.00	0.17	11.11	3.70
Opuntia spinosior	0	0	1	1	0.00	0.00	0.03	0.03	0.01
Yucca baccata	0	0	0	0	0.00	0.00	0.00	0.00	0.00

TABLE B-1: *Continued*

Species	........Absolute %........ Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	............Relative %.......... Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Mean
Ferns									
Astrolepis cochisensis	295	7	134	436	17.74	0.27	4.52	22.54	7.51
Cheilanthes lindheimeri	5	49	0	54	0.30	1.92	0.00	2.22	0.74
Pellaea truncata	5	5	36	46	0.30	0.20	1.21	1.71	0.57
Herbs									
Artemisia ludoviciana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ayenia filiformis	14	0	11	25	0.84	0.00	0.37	1.21	0.40
Baccharis brachyphylla	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Brickellia baccharidea	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cassia bauhinoides	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cevallia sinuata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Croton pottsii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Digitaria cognata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Dyssodia acerosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Galactia wrightii	78	336	147	561	4.69	13.17	4.96	22.82	7.61
Gutierrezia microcephala	0	5	0	5	0.00	0.20	0.00	0.20	0.07
Hedeoma nanum	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Isocoma tenuisectus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Janusia gracilis	0	0	7	7	0.00	0.00	0.24	0.24	0.08
Lesquerella fendleri	1	0	0	1	0.06	0.00	0.00	0.06	0.02
Menodora scabra	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Perezia nana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Sphaeralcea laxa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Thamnosma taxana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Thelesperma longipes	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Verbena gooddingii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Zinnia acerosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
COLUMN SUMS	1663	2552	2963	7178					

TABLE B-2: ABSOLUTE AND RELATIVE PERCENTAGES OF PLANT SPECIES ON 20m x 5m QUADRATS ON THE ABRIGO FORMATION AT SIPHON CANYON, COCHISE COUNTY, ARIZONA

Species	........Absolute %........				............Relative %..........				
	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Mean
Grasses									
Aristida purpurea var. fendleriana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Aristida purpurea var. longiseta	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Aristida purpurea var. nealleyi	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Aristida sp.	0	2	19	21	0.00	0.03	0.39	0.42	0.14
Bouteloua curtipendula	570	1031	239	1840	13.94	17.38	4.91	36.24	12.08
Bouteloua eriopoda	52	0	778	830	1.27	0.00	15.99	17.26	5.75
Bouteloua hirsuta	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Bouteloua repens	2	2	0	4	0.05	0.03	0.00	0.08	0.03
Digitaria californica	4	0	0	4	0.10	0.00	0.00	0.10	0.03
Elymus elymoides	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Eragrostis intermedia	110	0	0	110	2.69	0.00	0.00	2.69	0.90
Eragrostis lehmanniana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Heteropogon contortus	0	92	351	443	0.00	1.55	7.21	8.77	2.92
Leptochloa dubia	0	248	0	248	0.00	4.18	0.00	4.18	1.39
Lycurus setosus	2	0	0	2	0.05	0.00	0.00	0.05	0.02
Muhlenbergia emersleyi	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Muhlenbergia porteri	85	0	95	180	2.08	0.00	1.95	4.03	1.34
Panicum hallii	0	0	2	2	0.00	0.00	0.04	0.04	0.01
Setaria macrostachya	0	10	0	10	0.00	0.17	0.00	0.17	0.06
Stipa eminens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Trachypogon secundus	48	0	0	48	1.17	0.00	0.00	1.17	0.39
Tridens muticus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Tridens pulchellus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Shrubs									
Acacia greggii	510	440	190	1140	12.48	7.42	3.91	23.80	7.93
Aloysia wrightii	185	0	107	292	4.53	0.00	2.20	6.72	2.24

TABLE B-2: *Continued*

Species	Absolute % Quad-rat 1	Absolute % Quad-rat 2	Absolute % Quad-rat 3	Absolute % Sum	Relative % Quad-rat 1	Relative % Quad-rat 2	Relative % Quad-rat 3	Relative % Sum	Relative % Mean
Shrubs (cont.)									
Bumelia lanuginosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Calliandra eriophylla	260	866	945	2071	6.36	14.60	19.42	40.39	13.46
Dalea formosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Dalea wrightii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ericameria larcifolia	964	0	565	1529	23.58	0.00	11.61	35.19	11.73
Forsellesia spinescens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Fouquieria splendens	180	0	320	500	4.40	0.00	6.58	10.98	3.66
Gaura cf. *coccinea*	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Macrosiphonia brachysiphon	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Parthenium incanum	5	60	0	65	0.12	1.01	0.00	1.13	0.38
Rhus microphylla	0	0	3	3	0.00	0.00	0.06	0.06	0.02
Unknown	0	0	3	3	0.00	0.00	0.06	0.06	0.02
Trees									
Celtis reticulata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Juniperus erythrocarpa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Prosopis velutina	50	505	105	660	1.22	8.51	2.16	11.90	3.97
Cacti/Succulents									
Agave palmeri	47	145	211	403	1.15	2.44	4.34	7.93	2.64
Dasylirion wheeleri	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Echinocereus pectinatus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ferocactus wislizenii	0	47	0	47	0.00	0.79	0.00	0.79	0.26
Mammillaria microcarpa	8	0	5	13	0.20	0.00	0.10	0.30	0.10
Opuntia leptocaulis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Opuntia phaeacantha	675	2080	712	3467	16.51	35.07	14.64	66.22	22.07
Opuntia spinosior	0	0	10	10	0.00	0.00	0.21	0.21	0.07
Yucca baccata	155	0	0	155	3.79	0.00	0.00	3.79	1.26

TABLE B-2: *Continued*

Species	........Absolute %........				............Relative %..........				
	Quadrat 1	Quadrat 2	Quadrat 3	Sum	Quadrat 1	Quadrat 2	Quadrat 3	Sum	Mean
Ferns									
Astrolepis cochisensis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cheilanthes lindheimeri	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Pellaea truncata	23	0	2	25	0.56	0.00	0.04	0.60	0.20
Herbs									
Artemisia ludoviciana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ayenia filiformis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Baccharis brachyphylla	48	0	0	48	1.17	0.00	0.00	1.17	0.39
Brickellia baccharidea	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cassia bauhinoides	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cevellia sinuata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Croton pottsii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Digitaria cognata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Dyssodia acerosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Galactia wrightii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Gutierrezia microcephala	69	357	196	265	1.69	6.02	4.03	12.18	4.06
Hedeoma nanum	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Isocoma tenuisectus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Janusia gracilis	11	0	10	21	0.27	0.00	0.21	0.47	0.16
Lesquerella fendleri	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Menodora scabra	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Perezia nana	25	0	0	25	0.61	0.00	0.00	0.61	0.20
Sphaeralcea laxa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Thamnosma taxana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Thelesperma longipes	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Verbena gooddingii	0	20	0	20	0.00	0.34	0.00	0.34	0.11
Zinnia acerosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
COLUMN SUMS	4088	5931	4868	14887					

TABLE B-3: ABSOLUTE AND RELATIVE PERCENTAGES OF PLANT SPECIES ON 20m x 5m QUADRATS ON THE EL PASO LIMESTONE AT SIPHON CANYON, COCHISE COUNTY, ARIZONA

	............Absolute %...........				
Species	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Sum
Grasses					
Aristida purpurea var. fendleriana	0	401	5	22	428
Aristida purpurea var. longiseta	1	103	0	0	104
Aristida purpurea var. nealleyi	0	65	10	16	91
Aristida sp.	179	4	2	52	237
Bouteloua curtipendula	4415	213	496	288	1412
Bouteloua eriopoda	5	46	161	75	287
Bouteloua hirsuta	0	6	0	0	6
Bouteloua repens	1	0	0	0	1
Digitaria californica	0	0	5	1	6
Elymus elymoides	0	0	0	0	0
Eragrostis intermedia	4	0	0	0	4
Eragrostis lehmanniana	0	2	0	0	2
Heteropogon contortus	7	0	0	8	15
Leptochloa dubia	0	0	0	0	0
Lycurus setosus	8	4	3	0	15
Muhlenbergia emersleyi	0	0	0	0	0
Muhlenbergia porteri	0	0	0	0	0
Panicum hallii	56	32	140	33	261
Setaria macrostachya	0	0	0	0	0
Stipa eminens	4	0	193	80	277
Trachypogon secundus	0	0	0	0	0
Tridens muticus	0	0	0	0	0
Tridens pulchellus	1	1	0	1	3
Shrubs					
Acacia greggii	2	40	0	0	42
Aloysia wrightii	5	0	10	350	365

TABLE B-3: *Continued*

Species	Absolute % Quad-rat 1	Quad-rat 2	Quad-rat 3	Quad-rat 4	Sum
Shrubs (cont.)					
Bumelia lanuginosa	0	0	0	0	0
Calliandra eriophylla	296	401	292	347	1336
Dalea formosa	218	461	0	0	679
Dalea wrightii	0	0	0	0	0
Ericameria larcifolia	1	0	0	0	1
Forsellesia spinescens	0	0	0	0	0
Fouquieria splendens	403	470	291	274	1438
Gaura cf. coccinea	0	0	0	0	0
Macrosiphonia brachysiphon	0	0	0	0	0
Parthenium incanum	352	388	392	880	2012
Rhus microphylla	0	0	0	95	95
Unknown	0	0	0	0	0
Trees					
Celtis reticulata	0	0	0	0	0
Juniperus erythrocarpa	0	0	0	0	0
Prosopis velutina	0	0	0	0	0
Cacti/Succulents					
Agave palmeri	236	426	94	147	903
Dasylirion wheeleri	2	0	0	0	2
Echinocereus pectinatus	0	1	0	0	1
Ferocactus wislizenii	0	0	0	0	0
Mammillaria microcarpa	0	2	0	1	3
Opuntia leptocaulis	0	0	0	0	0
Opuntia phaeacantha	1	55	350	153	559
Opuntia spinosior	1	0	0	0	1
Yucca baccata	0	337	10	395	742

TABLE B-3: *Continued*

Species	Absolute %				
	Quad-rat 1	Quad-rat 2	Quad-rat 3	Quad-rat 4	Sum
Ferns					
Astrolepis cochisensis	18	16	44	78	156
Cheilanthes lindheimeri	0	0	0	0	0
Pellaea truncata	0	0	0	0	0
Herbs					
Artemisia ludoviciana	0	0	0	79	79
Ayenia filiformis	0	0	0	0	0
Baccharis brachyphylla	0	0	0	0	0
Brickellia baccharidea	0	0	0	0	0
Cassia bauhinoides	2	0	0	0	2
Cevellia sinuata	0	0	0	0	0
Croton pottsii	13	1	0	0	13
Digitaria cognata	0	0	0	0	0
Dyssodia acerosa	7	48	0	0	55
Galactia wrightii	0	0	0	0	0
Gutierrezia microcephala	79	172	96	79	426
Hedeoma nanum	2	31	0	0	33
Isocoma tenuisectus	0	0	0	0	0
Janusia gracilis	0	0	0	0	0
Lesquerella fendleri	0	23	0	0	23
Menodora scabra	0	13	0	0	13
Perezia nana	0	0	0	0	0
Sphaeralcea laxa	0	0	4	0	4
Thamnosma taxana	0	0	0	0	0
Thelesperma longipes	0	0	0	0	0
Verbena goodingii	0	0	0	0	0
Zinnia acerosa	0	1	0	0	1
COLUMN SUMS	2319	3762	2598	3454	12133

TABLE B-3: *Continued*

Species	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat-4	Sum	Mean
	................Relative %..............					
Grasses						
Aristida purpurea var. fendleriana	0.00	10.66	0.19	0.64	11.49	3.62
Aristida purpurea var. longiseta	0.04	2.74	0.00	0.00	2.78	0.93
Aristida purpurea var. nealleyi	0.00	1.73	0.38	0.46	2.58	0.70
Aristida sp.	7.72	0.11	0.08	1.51	9.41	2.63
Bouteloua curtipendula	17.90	5.66	19.09	8.34	50.99	14.22
Bouteloua eriopoda	0.22	1.22	6.20	2.17	9.81	2.55
Bouteloua hirsuta	0.00	0.16	0.00	0.00	0.16	0.05
Bouteloua repens	0.04	0.00	0.00	0.00	0.04	0.01
Digitaria californica	0.00	0.00	0.19	0.03	0.22	0.06
Elymus elymoides	0.00	0.00	0.00	0.00	0.00	0.00
Eragrostis intermedia	0.17	0.00	0.00	0.00	0.17	0.06
Eragrostis lehmanniana	0.00	0.05	0.00	0.00	0.05	0.02
Heteropogon contortus	0.30	0.00	0.00	0.23	0.53	0.10
Leptochloa dubia	0.00	0.00	0.00	0.00	0.00	0.00
Lycurus setosus	0.34	0.11	0.12	0.00	0.57	0.19
Muhlenbergia emersleyi	0.00	0.00	0.00	0.00	0.00	0.00
Muhlenbergia porteri	0.00	0.00	0.00	0.00	0.00	0.00
Panicum hallii	2.41	0.85	5.39	0.96	9.61	2.88
Setaria macrostachya	0.00	0.00	0.00	0.00	0.00	0.00
Stipa eminens	0.17	0.00	7.43	2.32	9.92	2.53
Trachypogon secundus	0.00	0.00	0.00	0.00	0.00	0.00
Tridens muticus	0.00	0.00	0.00	0.00	00	0.00
Tridens pulchellus	0.04	0.03	0.00	0.03	0.10	0.02
Shrubs						
Acacia greggii	0.09	1.06	0.00	0.00	1.15	0.38
Aloysia wrightii	0.22	0.00	0.38	10.13	10.73	0.20
Bumelia lanuginosa	0.00	0.00	0.00	0.00	0.00	0.00

TABLE B-3: *Continued*

Species	Quad-rat 1	Quad-rat 2	Quad-rat 3	Quad-rat-4	Sum	Mean
	................Relative %.............					
Shrubs (cont.)						
Calliandra eriophylla	12.76	10.66	11.24	10.05	44.71	11.55
Dalea formosa	9.40	12.25	0.00	0.00	21.65	7.22
Dalea wrightii	0.00	0.00	0.00	0.00	0.00	0.00
Ericameria larcifolia	0.04	0.00	0.00	0.00	0.04	0.01
Forsellesia spinescens	0.00	0.00	0.00	0.00	0.00	0.00
Fouquieria splendens	17.38	12.49	11.20	7.93	49.01	13.69
Gaura cf. *coccinea*	0.00	0.00	0.00	0.00	0.00	0.00
Macrosiphonia brachyphon	0.00	0.00	0.00	0.00	0.00	0.00
Parthenium incanum	15.18	10.31	15.09	25.48	66.06	13.53
Rhus microphylla	0.00	0.00	0.00	2.75	2.75	0.00
Unknown	0.00	0.00	0.00	0.00	0.00	0.00
Trees						
Celtis reticulata	0.00	0.00	0.00	0.00	0.00	0.00
Juniperus erythrocarpa	0.00	0.00	0.00	0.00	0.00	0.00
Prosopis velutina	0.00	0.00	0.00	0.00	0.00	0.00
Cacti/Succulents						
Agave palmeri	410.18	11.32	3.62	4.26	29.37	8.37
Dasylirion wheeleri	0.09	0.00	0.00	0.00	0.09	0.03
Echinocereus pectinatus	0.00	0.03	0.00	0.00	0.03	0.01
Ferocactus wislizenii	0.00	0.00	0.00	0.00	0.00	0.00
Mammillaria microcarpa	0.00	0.05	0.00	0.03	0.08	0.02
Opuntia leptocaulis	0.00	0.00	0.00	0.00	0.00	0.00
Opuntia phaeacantha	0.04	1.46	13.47	4.43	19.41	4.99
Opuntia spinosior	0.04	0.00	0.00	0.00	0.04	0.01
Yucca baccata	0.00	8.96	0.38	11.44	20.78	3.11

TABLE B-3: *Continued*

Species	Relative % Quad-rat 1	Quad-rat 2	Quad-rat 3	Quad-rat-4	Sum	Mean
Ferns						
Astrolepis cochisensis	0.78	0.43	1.69	2.26	5.15	0.97
Cheilanthes lindheimeri	0.00	0.00	0.00	0.00	0.00	0.00
Pellaea truncata	0.00	0.00	0.00	0.00	0.00	0.00
Herbs						
Artemisia ludoviciana	0.00	0.00	0.00	2.29	2.29	0.00
Ayenia filiformis	0.00	0.00	0.00	0.00	0.00	0.00
Baccharis brachyphylla	0.00	0.00	0.00	0.00	0.00	0.00
Brickellia baccharidea	0.00	0.00	0.00	0.00	0.00	0.00
Cassia bauhinoides	0.09	0.00	0.00	0.00	0.09	0.03
Cevellia sinuata	0.00	0.00	0.00	0.00	0.00	0.00
Croton pottsii	0.56	0.03	0.00	0.00	0.59	0.19
Digitaria cognata	0.00	0.00	0.00	0.00	0.00	0.00
Dyssodia acerosa	0.30	1.28	0.00	0.00	1.58	0.53
Galactia wrightii	0.00	0.00	0.00	0.00	0.00	0.00
Gutierrezia microcephala	3.41	4.57	3.70	2.29	13.69	3.89
Hedeoma nanum	0.09	0.82	0.00	0.00	0.91	0.30
Isocoma tenuisectus	0.00	0.00	0.00	0.00	0.00	0.00
Janusia gracilis	0.00	0.00	0.00	0.00	0.00	0.00
Lesquerella fendleri	0.00	0.61	0.00	0.00	0.61	0.20
Menodora scabra	0.00	0.35	0.00	0.00	0.35	0.12
Perezia nana	0.00	0.00	0.00	0.00	0.00	0.00
Sphaeralcea laxa	0.00	0.00	0.15	0.00	0.15	0.05
Thamnosma taxana	0.00	0.00	0.00	0.00	0.00	0.00
Thelesperma longipes	0.00	0.00	0.00	0.00	0.00	0.00
Verbena gooddingii	0.00	0.00	0.00	0.00	0.00	0.00
Zinnia acerosa	0.00	0.03	0.00	0.00	0.03	0.01

TABLE B-4: ABSOLUTE AND RELATIVE PERCENTAGES OF PLANT SPECIES ON 20m x 5m QUADRATS ON THE PORTAL FORMATION AT SIPHON CANYON, COCHISE COUNTY, ARIZONA

Species	........Absolute %........				............Relative %..........				
	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Mean
Grasses									
Aristida purpurea var. fendleriana	0	0	67	67	0.00	0.00	1.45	1.45	0.48
Aristida purpurea var. longiseta	27	37	17	81	0.82	0.75	0.37	1.95	0.65
Aristida purpurea var. nealleyi	0	628	0	628	0.00	12.79	0.00	12.79	4.26
Aristida sp.	126	0	0	126	3.85	0.00	0.00	3.85	1.28
Bouteloua curtipendula	183	150	370	703	5.59	3.05	8.00	16.64	5.55
Bouteloua eriopoda	337	415	511	1263	10.30	8.45	11.04	29.79	9.93
Bouteloua hirsuta	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Bouteloua repens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Digitaria californica	0	0	10	10	0.00	0.00	0.22	0.22	0.07
Elymus elymoides	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Eragrostis intermedia	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Eragrostis lehmanniana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Heteropogon contortus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Leptochloa dubia	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Lycurus setosus	0	2	10	12	0.00	0.04	0.22	0.26	0.09
Muhlenbergia emersleyi	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Muhlenbergia porteri	22	0	0	22	0.67	0.00	0.00	0.67	0.22
Panicum hallii	1	0	0	1	0.03	0.00	0.00	0.03	0.01
Setaria macrostachya	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Stipa eminens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Trachypogon secundus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Tridens muticus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Tridens pulchellus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Shrubs									
Acacia greggii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Aloysia wrightii	25	40	0	65	0.76	0.81	0.00	1.58	0.53

TABLE B-4: *Continued*

Species	........Absolute %........				............Relative %...........				
	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Mean
Shrubs (cont.)									
Bumelia lanuginosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Calliandra eriophylla	186	488	600	1274	5.68	9.94	12.97	28.59	9.53
Dalea formosa	348	496	5	849	10.63	10.10	0.11	20.84	6.95
Dalea wrightii	11	0	0	11	0.34	0.00	0.00	0.34	0.11
Ericameria larcifolia	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Forsellesia spinescens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Fouquieria splendens	485	253	405	1143	14.82	5.15	8.75	28.72	9.57
Gaura cf. *coccinea*	5	0	0	5	0.15	0.00	0.00	0.15	0.05
Macrosiphonia brachysiphon	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Parthenium incanum	40	226	465	731	1.22	4.60	10.05	15.87	5.29
Rhus microphylla	360	0	230	590	11.00	0.00	4.97	15.97	5.32
Unknown	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Trees									
Celtis reticulata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Juniperus erythrocarpa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Prosopis velutina	117	0	0	117	3.57	0.00	0.00	3.57	1.19
Cacti/Succulents									
Agave palmeri	165	19	225	409	5.04	0.39	4.86	10.29	3.43
Dasylirion wheeleri	0	947	680	1627	0.00	19.29	14.70	33.98	11.33
Echinocereus pectinatus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ferocactus wislizenii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Mammillaria microcarpa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Opuntia leptocaulis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Opuntia phaeacantha	0	3	82	85	0.00	0.06	1.77	1.83	0.61
Opuntia spinosior	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Yucca baccata	0	285	435	720	0.00	5.80	9.40	15.21	5.07

TABLE B-4: *Continued*

Species	........Absolute %........				............Relative %...........				
	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Mean
Ferns									
Astrolepis cochisensis	2	11	5	18	0.06	0.22	0.11	0.39	0.13
Cheilanthes lindheimeri	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Pellaea truncata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Herbs									
Artemisia ludoviciana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ayenia filiformis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Baccharis brachyphylla	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Brickellia baccharidea	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cassia bauhinoides	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cevellia sinuata	10	0	0	10	0.31	0.00	0.00	0.31	0.10
Croton pottsii	13	4	0	17	0.40	0.08	0.00	0.48	0.16
Digitaria cognata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Dyssodia acerosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Galactia wrightii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Gutierrezia microcephala	767	715	493	1975	23.43	14.56	10.65	48.65	16.22
Hedeoma nanum	42	171	17	230	1.28	3.48	0.37	5.13	1.71
Isocoma tenuisectus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Janusia gracilis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Lesquerella fendleri	1	0	0	1	0.03	0.00	0.00	0.03	0.01
Menodora scabra	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Perezia nana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Sphaeralcea laxa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Thamnosma taxana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Thelesperma longipes	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Verbena gooddingii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Zinnia acerosa	0	20	0	20	0.00	0.41	0.00	0.41	0.14
COLUMN SUMS	3273	4910	4627	12810					

TABLE B-5: ABSOLUTE AND RELATIVE PERCENTAGES OF PLANT SPECIES ON 20m x 5m QUADRATS ON THE ESCABROSA LIMESTONE AT SIPHON CANYON, COCHISE COUNTY, ARIZONA

Species	........Absolute %........				............Relative %...........				
	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Mean
Grasses									
Aristida purpurea var. fendleriana	0	0	11	11	0.00	0.00	0.36	0.36	0.12
Aristida purpurea var. longiseta	0	67	323	390	0.00	2.63	10.48	13.10	4.37
Aristida purpurea var. nealleyi	0	357	0	357	0.00	14.00	0.00	14.00	4.67
Aristida sp.	2	0	0	152	7.30	0.00	0.00	7.30	2.43
Bouteloua curtipendula	79	69	172	320	3.79	2.71	5.58	12.08	4.03
Bouteloua eriopoda	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Bouteloua hirsuta	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Bouteloua repens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Digitaria californica	2	0	0	2	0.10	0.00	0.00	0.10	0.03
Elymus elymoides	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Eragrostis intermedia	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Eragrostis lehmanniana	0	2	0	2	0.00	0.08	0.00	0.08	0.03
Heteropogon contortus	42	41	76	159	2.02	1.61	2.47	6.09	2.03
Leptochloa dubia	1	5	23	29	0.05	0.20	0.75	0.99	0.33
Lycurus setosus	2	6	7	15	0.10	0.24	0.23	0.56	0.19
Muhlenbergia emersleyi	3	0	0	3	0.14	0.00	0.00	0.14	0.05
Muhlenbergia porteri	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Panicum hallii	2	14	16	32	0.10	0.55	0.52	1.16	0.39
Setaria macrostachya	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Stipa eminens	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Trachypogon secundus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Tridens muticus	0	0	5	5	0.00	0.00	0.16	0.16	0.05
Tridens pulchellus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Shrubs									
Acacia greggii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Aloysia wrightii	40	97	137	0.00	1.57	3.15	4.71	1.57	

TABLE B-5: *Continued*

Species	Absolute % Quadrat 1	Absolute % Quadrat 2	Absolute % Quadrat 3	Absolute % Sum	Relative % Quadrat 1	Relative % Quadrat 2	Relative % Quadrat 3	Relative % Sum	Relative % Mean
Shrubs (cont.)									
Bumelia lanuginosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Calliandra eriophylla	268	221	641	1130	12.87	8.67	20.79	42.32	14.11
Dalea formosa	95	111	50	256	4.56	4.35	1.62	10.54	3.51
Dalea wrightii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Ericameria larcifolia	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Forsellesia spinescens	7	0	0	7	0.34	0.00	0.00	0.34	0.11
Fouquieria splendens	437	694	250	1381	20.98	27.22	8.11	56.30	18.77
Gaura cf. *coccinea*	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Macrosiphonia brachysiphon	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Parthenium incanum	273	105	415	793	13.11	4.12	13.46	30.68	10.23
Rhus microphylla	0	8	70	78	0.00	0.31	2.27	2.58	0.86
Unknown	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Trees									
Celtis reticulata	11	10	21	0.00	0.43	0.32	0.76	0.25	
Juniperus erythrocarpa	3	0	20	23	0.14	0.00	0.65	0.79	0.26
Prosopis velutina	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cacti/Succulents									
Agave palmeri	13	145	146	404	5.42	5.69	4.74	15.85	5.28
Dasylirion wheeleri	142	225	60	427	6.82	8.82	1.95	17.59	5.86
Echinocereus pectinatus	0	1	5	6	0.00	0.04	0.16	0.20	0.07
Ferocactus wislizenii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Mammillaria microcarpa	0	0	10	10	0.00	0.00	0.32	0.32	0.11
Opuntia leptocaulis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Opuntia phaeacantha	64	98	246	408	3.07	3.84	7.98	14.89	4.96
Opuntia spinosior	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Yucca baccata	0	0	0	0	0.00	0.00	0.00	0.00	0.00

TABLE B-5: *Continued*

Species	Absolute % Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Relative % Quad-rat 1	Quad-rat 2	Quad-rat 3	Sum	Mean
Ferns									
Astrolepis cochisensis	41	214	254	709	11.57	8.39	8.24	28.20	9.40
Cheilanthes lindheimeri	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Pellaea truncata	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Herbs									
Artemisia ludoviciana	0	0	10	10	0.00	0.00	0.32	0.32	0.11
Ayenia filiformis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Baccharis brachyphylla	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Brickellia baccharidea	32	21	136	189	1.54	0.82	4.41	6.77	2.26
Cassia bauhinoides	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Cevellia sinuata	0	5	0	5	0.00	0.20	0.00	0.20	0.07
Croton pottsii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Digitaria cognata	0	0	3	3	0.00	0.00	0.10	0.10	0.03
Dyssodia acerosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Galactia wrightii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Gutierrezia microcephala	56	1	23	80	2.69	0.04	0.75	3.47	1.16
Hedeoma nanum	5	0	4	9	0.24	0.00	0.13	0.37	0.12
Isocoma tenuisectus	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Janusia gracilis	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Lesquerella fendleri	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Menodora scabra	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Perezia nana	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Sphaeralcea laxa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Thamnosma taxana	6	11	0	17	0.29	0.43	0.00	0.72	0.24
Thelesperma longipes	58	78	0	136	2.78	3.06	0.00	5.84	1.95
Verbena gooddingii	0	0	0	0	0.00	0.00	0.00	0.00	0.00
Zinnia acerosa	0	0	0	0	0.00	0.00	0.00	0.00	0.00
COLUMN SUMS	2083	2550	3083	7716					

TABLE B-6: ABSOLUTE AND RELATIVE PERCENTAGES OF PLANT SPECIES ON 20m x 5m QUADRATS ON THE ALLUVIAL FANS AT SIPHON CANYON, COCHISE COUNTY, ARIZONA

Species	.....Absolute %.....			........Relative %........			
	Quad-rat 1	Quad-rat 2	Sum	Quad-rat 1	Quad-rat 2	Sum	Mean
Grasses							
Aristida purpurea var. fendleriana	0	0	0	0.00	0.00	0.00	0.00
Aristida purpurea var. longiseta	0	249	249	0.00	10.10	10.10	3.37
Aristida purpurea var. nealleyi	3	0	3	0.06	0.00	0.06	0.02
Aristida sp.	7	0	307	6.04	0.00	6.04	2.01
Bouteloua curtipendula	0	274	274	0.00	11.12	11.12	3.71
Bouteloua eriopoda	488	475	963	9.61	19.27	28.88	9.63
Bouteloua hirsuta	0	0	0	0.00	0.00	0.00	0.00
Bouteloua repens	0	0	0	0.00	0.00	0.00	0.00
Digitaria californica	0	0	0	0.00	0.00	0.00	0.00
Elymus elymoides	7	0	7	0.14	0.00	0.14	0.05
Eragrostis intermedia	0	0	0	0.00	0.00	0.00	0.00
Eragrostis lehmanniana	0	0	0	0.00	0.00	0.00	0.00
Heteropogon contortus	0	0	0	0.00	0.00	0.00	0.00
Leptochloa dubia	1	0	1	0.02	0.00	0.02	0.01
Lycurus setosus	0	0	0	0.00	0.00	0.00	0.00
Muhlenbergia emersleyi	0	0	0	0.00	0.00	0.00	0.00
Muhlenbergia porteri	50	0	50	0.98	0.00	0.98	0.33
Panicum hallii	0	0	10	0.20	0.00	0.20	0.07
Setaria macrostachya	0	0	0	0.00	0.00	0.00	0.00
Stipa eminens	18	0	18	0.35	0.00	0.35	0.12
Trachypogon secundus	0	0	0	0.00	0.00	0.00	0.00
Tridens muticus	0	0	0	0.00	0.00	0.00	0.00
Tridens pulchellus	64	13	77	1.26	0.53	1.79	0.60
Shrubs							
Acacia greggii	270	0	270	5.31	0.00	5.31	1.77
Aloysia wrightii	0	0	0	0.00	0.00	0.00	0.00

TABLE B-6: *Continued*

Species	.....Absolute %..... Quad-rat 1	Quad-rat 2	Sum	........Relative %........ Quad-rat 1	Quad-rat 2	Sum	Mean
Shrubs (cont.)							
Bumelia lanuginosa	0	0	0	0.00	0.00	0.00	0.00
Calliandra eriophylla	0	0	0	0.00	0.00	0.00	0.00
Dalea formosa	0	0	0	0.00	0.00	0.00	0.00
Dalea wrightii	0	0	0	0.00	0.00	0.00	0.00
Ericameria larcifolia	0	0	0	0.00	0.00	0.00	0.00
Forsellesia spinescens	0	0	0	0.00	0.00	0.00	0.00
Fouquieria splendens	0	0	0	0.00	0.00	0.00	0.00
Gaura cf. *coccinea*	0	0	0	0.00	0.00	0.00	0.00
Macrosiphonia brachysiphon	0	0	0	0.00	0.00	0.00	0.00
Parthenium incanum	1106	677	1783	21.77	27.46	49.24	16.41
Rhus microphylla	0	5	5	0.00	0.20	0.20	0.07
Unknown	0	0	0	0.00	0.00	0.00	0.00
Trees							
Celtis reticulata	0	0	0	0.00	0.00	0.00	0.00
Juniperus erythrocarpa	0	0	0	0.00	0.00	0.00	0.00
Prosopis velutina	1535	110	1645	30.22	4.46	34.68	11.56
Cacti/Succulents							
Agave palmeri	4	0	4	0.08	0.00	0.08	0.03
Dasylirion wheeleri	0	0	0	0.00	0.00	0.00	0.00
Echinocereus pectinatus	0	0	0	0.00	0.00	0.00	0.00
Ferocactus wislizenii	0	0	0	0.00	0.00	0.00	0.00
Mammillaria microcarpa	0	0	0	0.00	0.00	0.00	0.00
Opuntia leptocaulis	35	0	35	0.69	0.00	0.69	0.23
Opuntia phaeacantha	165	0	165	3.25	0.00	3.25	1.08
Opuntia spinosior	0	15	15	0.00	0.61	0.61	0.20
Yucca baccata	0	0	0	0.00	0.00	0.00	0.00

TABLE B-6: *Continued*

Species	.....Absolute %..... Quad-rat 1	Quad-rat 2	Sum	........Relative %......... Quad-rat 1	Quad-rat 2	Sum	Mean
Ferns							
Astrolepis cochisensis	0	0	0	0.00	0.00	0.00	0.00
Cheilanthes lindheimeri	0	0	0	0.00	0.00	0.00	0.00
Pellaea truncata	0	0	0	0.00	0.00	0.00	0.00
Herbs							
Artemisia ludoviciana	0	0	0	0.00	0.00	0.00	0.00
Ayenia filiformis	0	0	0	0.00	0.00	0.00	0.00
Baccharis brachyphylla	0	0	0	0.00	0.00	0.00	0.00
Brickellia baccharidea	0	0	0	0.00	0.00	0.00	0.00
Cassia bauhinoides	0	0	0	0.00	0.00	0.00	0.00
Cevellia sinuata	0	0	0	0.00	0.00	0.00	0.00
Croton pottsii	0	0	0	0.00	0.00	0.00	0.00
Digitaria cognata	0	0	0	0.00	0.00	0.00	0.00
Dyssodia acerosa	0	0	0	0.00	0.00	0.00	0.00
Galactia wrightii	0	0	0	0.00	0.00	0.00	0.00
Gutierrezia microcephala	990	582	1572	19.49	23.61	43.10	14.37
Hedeoma nanum	0	0	0	0.00	0.00	0.00	0.00
Isocoma tenuisectus	27	65	92	0.53	2.64	3.17	1.06
Janusia gracilis	0	0	0	0.00	0.00	0.00	0.00
Lesquerella fendleri	0	0	0	0.00	0.00	0.00	0.00
Menodora scabra	0	0	0	0.00	0.00	0.00	0.00
Perezia nana	0	0	0	0.00	0.00	0.00	0.00
Sphaeralcea laxa	0	0	0	0.00	0.00	0.00	0.00
Thamnosma taxana	0	0	0	0.00	0.00	0.00	0.00
Thelesperma longipes	0	0	0	0.00	0.00	0.00	0.00
Verbena gooddingii	0	0	0	0.00	0.00	0.00	0.00
Zinnia acerosa	0	0	0	0.00	0.00	0.00	0.00
COLUMN SUMS	5080	2465	7545				

9. APPENDIX C

Appendix C: Percentage of surface coverage by rock and rock fragments on 20m x 5m quadrats at Siphon Canyon, Cochise County, Arizona

FORMATION NAME	ROCK	BOULDERS	COBBLES	GRAVEL	DIRT
Bolsa Quartzite					
QUADRAT 1	75 %	17 %	2 %	2 %	4 %
QUADRAT 2	60 %	1 %	10 %	23 %	6 %
QUADRAT 3	52 %	0 %	3 %	30 %	15 %
Abrigo Formation					
Quadrat 1	28 %	0.4%	7 %	36 %	29 %
Quadrat 2	0 %	1 %	26 %	44 %	29 %
Quadrat 3	21 %	2 %	9 %	37 %	31 %
El Paso Limestone					
Quadrat 1	27 %	0 %	5 %	67 %	1 %
Quadrat 2	25 %	0 %	7 %	54 %	14 %
Quadrat 3	20 %	1 %	6 %	43 %	30 %
Quadrat 4	28 %	0 %	5 %	43 %	24 %
Portal Formation					
Quadrat 1	5 %	1 %	12 %	61 %	21 %
Quadrat 2	6 %	0 %	40 %	32 %	22 %
Quadrat 3	8 %	0 %	36 %	35 %	21 %
Escabrosa Limestone					
Quadrat 1	82 %	0 %	1 %	7 %	10 %
Quadrat 2	79 %	0 %	0.5%	0.5%	20 %
Quadrat 3	83 %	0 %	2 %	5 %	10 %
Alluvial Fan 1					
	0 %	0 %	0 %	62 %	38 %
Alluvial Fan 2					
	0 %	0 %	0 %	74 %	26 %

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