VEGETATION AS AN INDICATOR OF ROCK TYPES IN THE NORTHERN SWISSHELM MOUNTAINS, SOUTHEASTERN ARIZONA

by

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ABSTRACT

The northern Swisshelm Mountains of southeastern Arizona present a striking mosaic of vegetative patterns. Climatic and terrain factors seem insufficient to explain many of these patterns. Pronounced lithologic diversity, however, attracted me to investigate the influence of the substratum on the distribution of vegetation. Accordingly, I sampled vegetation by means of a line traverse and control quadrats employed to include as many lithologic types within the area as possible. Residual soils on limestone, silicified limestone, and rhyolite were sampled, as were two alluvial soils occurring within the area. Investigation focused on identifying plant species that indicate lithologic types within the specified area. In addition, I investigated the reliability and effectiveness of these indicator species, their validity on different slope aspects and on alluvial materials, and the soil properties influencing their distribution. Based on these investigations a strong correlation between certain species and the substratum on which they were growing became evident and I determined eight species which I considered as being both reliable indicators of rock type and sufficiently common in

the study area to be useful. Finally, I examined the influence of substratum on structure of vegetation and use of indicator vegetation in indicating geologic features.

CHAPTER 1

INTRODUCTION

A striking mosaic of vegetative patterns characterizes the northern Swisshelm Mountains in southeastern Arizona. Igneous and sedimentary rocks form a contact that trends generally northwest across the study area. Separating these two distinct rock types are limited alluvial deposits often obscuring the actual contact and making its detection difficult. There is, however, a strong correspondence of vegetation to geology and terrain in the area when viewed by one familiar with the local vegetation and aware of lithological patterns. When the relationships of vegetation to the substrata are understood for a particular area, indicator plants can offer considerable aid in identifying rock types, fault zones, intrusions, and contacts between formations. Such geologic features can often be mapped in the field at a distance of several miles by noting distinct and easily observable changes in the vegetation. With the use of aerial photographic coverage of a particular area even greater mapping accuracy is possible.

During the past century increased interest has been directed toward a better understanding of relationships between plants and their environment. It has been well recognized that plants do not occupy the earth in a haphazard manner, but instead confine themselves to certain critical environmental conditions to which they are best adapted. From the time a seed germinates it is acted upon by a battery of environmental factors. Depending upon the genetic makeup and tolerances of the plant it either flourishes, remains within the environmental complex as a stunted or otherwise restricted form, or dies. In this sense every plant is an indicator.

The concept of indicator plants has been given recognition by Clements (1920, p. 28) who stated that ". . . each plant is the product of the conditions under which it grows, and is thereby a measure of those conditions." Sampson (1939, p. 156) inferred a similar relation stating that the indicator concept ". . . is based on a cause and effect relationship, where the effect is taken as a sign of the cause."

Naturally the variables which affect plant growth are numerous and interacting in their influence. The effect of geographic position with respect to latitude, distance and direction from the coast, and major relief features works mainly through climatic factors to divide the earth into broad vegetation formations. In addition, other geographic factors such as micro relief, slope direction, slope angle, and elevation, through influences on surface and soil climates and aspects of drainage, further tend to restrict and group plant life. Edaphic conditions, i.e., soil and parent material, however, can often be seen to exert an overriding influence on vegetation in areas of limited extent. Relationships between plants and the materials on which they grow are often striking and readily apparent to the casual observer.

Within comparatively small areas in the northern Swisshelm Mountains plant life exhibits considerable variation. Single species forming almost pure stands in a few locations are nearly absent in surrounding communities, and the tendency for an aggregation of certain species into characteristic vegetation types on preferred locations is well marked. Climatic and terrain factors seem insufficient to explain many of these patterns, first because the areal extent of the region is so limited, and secondly because there is too little relief to affect marked changes in the vegetation, although influences of slope and exposure can be seen. Furthermore, relationships between soils and parent materials are quite strong because most of the soils in the area are lithosols on moderate to steep slopes and thus tend to remain shallow, immature, and rocky. Pronounced vegetative diversity and presence of varied geologic substratum in the area strongly suggest an investigation of the influence of rock types on the vegetation pattern.

The general purpose of this study is to examine the vegetation encountered within a specified area of the Swisshelm Mountains and to analyze its distribution, particularly with respect to lithologic differences occurring within the area. The region has been utilized by the University of Arizona Geology Department as an area for training students in geologic field mapping. Although a detailed geologic map has not been published and the geology is complex, the information gathered by their students and instructors provided essential data for this study. Knowledge gained from this investigation will hopefully add to existing information on indicator species and also provide evidence for the usefulness of plants in disclosing lithologic differences and structure.

CHAPTER 2

LITERATURE ON INDICATOR PLANTS

Many variables affect the distribution of a species. Five basic factors are generally considered as being most influential in regard to plant distribution. Billings (1952) listed climatic, edaphic, geographic, pyric, and biotic groups which he then broke down into forty-two factor subdivisions, each having one or more aspects through which it affects plant life. He viewed the entire plant system as being bound up in a holocenotic environmental complex consisting of interrelated factors affecting plants through time. In this sense, Billings concluded that, "Every plant species is distributed according to its own genetically determined tolerance limits, providing time has been sufficient to allow it to occupy the whole potential environment open to it" (p. 263). He further concluded that it is possible to use vegetation as an indicator of environment provided the tolerances of the characteristic species are known and the vegetation sufficiently analyzed by floristic methods (p. 264).

Indicator plants, species which are considered as being indices or measures of habitat, have received considerable attention by workers in the past. Fernald (1919,

p. 67) reported that as early as 300 B.C., Theophrastus recognized distinct differences in vegetation at contacts between different geologic substrata. Although other workers contined to investigate the usefulness of indicator plants through Medieval times and into the nineteenth century, the subject has received more attention during the twentieth century.

The productivity of undeveloped land in the western United States became a matter of utmost concern. For this reason much of the work centered around the investigation of plants as indicators of agricultural productivity. Particularly noteworthy are the works of Clements (1920) who covered rather broadly the climax formations of western North America and the value of agricultural, grazing, and forest indicators in various regions; Shantz and Piemeisel (1924) who discussed climatic, soil moisture, and wilting coefficient relationships for various desert shrubs and their relation to agricultural productivity; and Sampson (1939) who outlined the concept and status of plant indicators and dealtwith their value in evaluating land-use problems.

Through the years investigators have stressed different factors in interpreting plant-environment relationships and the distribution of vegetation. Mather and Yoshioka (1968) discussed the importance of climate in affecting plant development. They concluded that water surplus or deficit, evapotranspiration, and soil moisture storage, not precipitation and temperature, are the active climatic factors affecting vegetation.

In a classic study on the vegetation of desert mountain ranges Shreve (1922) discussed the importance of elevation and slope exposure on the distributional limits of a species. Cumming (1952) pursued the study of slope differences and exposure on range vegetation in even greater detail in a specified area of Santa Cruz County, Arizona. Through their work in transplanting certain species to various elevational environments, the direct effect of altitude on plants was investigated experimentally by Clausen, Keck, and Hiesey (1940).

Warming (1909) considered soil moisture relations to be the overriding influence on the distribution of vegetation. Cowles (1901a) expressed a similar opinion as to the role of soil moisture, but stressed heavily the influence of topography and soils in regulating soil moisture. He stated that in local conditions where climate is essentially the same, differences in vegetation are produced by soil conditions which ". . . are chiefly determined by surface geology and topography" (p. 78). Schimper (1903, p. 100) had expressed a similar view of this controversy stating, "In a region with several kind of soils, but with the conditions determining the existence of vegetation otherwise the same throughout, there are always certain species of plants that are found only on calcareous soils, and others only on sileceous soil, whilst a third group is more or less indifferent."

In a study dealing with the influence of climate and soil on vegetation in the Southwest, Pearson (1931) implied that it was more the physical than the chemical composition of the soil that affected plant growth. Fireman and Hayworth (1952), however, analysed three desert shrubs for pH, soluble salts, and exchangeable sodium and found a distinct relationship between the chemical properties of soils and the species growing on them.

In addition to their usefulness as measures of climate, soil conditions, and agricultural feasibility, plants have been found to be indicators of water (Cannon, 1913; Meinzer, 1927), caliche conditions (Shreve and Mallory, 1933), salinity (Marks, 1950), and ore bodies (Cannon, 1957).

There has been some disagreement in the past as to the role played by geologic parent material in the formation of soils. Shantz (1938, p. 836) in Soils and Men: Yearbook of Agriculture, indicated that plant communities correlate with developed soil which is ". . . often quite independent from the parent material from which the soil was originally formed." Lutz (1958) on the other hand, reviewed the nature of geology and soils in relation to vegetation and indicated that there are ". . . strong relations between geology and soil on the one hand, and vegetation, soils, and geology on the other" (p. 75). He stated that young soils (lithosols) especially in areas of considerable slope where erosional forces keep them in a constantly immature condition, owe their characteristics to parent material (p. 76). He cited the mineral composition, texture, and structure of underlying rocks as all having a direct or indirect influence on the soil and hence on the vegetation (p. 82).

Substantial literature is available to provide evidence that parent material and the soils derived therefrom exert a profound influence on the occurrence and response of vegetation: (Cowles, 1901; Schimper, 1903; Blumer, 1908; Fernald, 1919; Shreve, 1922; Cain, 1931; Cuyler, 1931; Mason, 1946; Billings, 1950; Puri, 1950; Whittaker, 1954a, 1954b; Walker, 1954, and Kruckeburg, 1954; Rzedowski, 1955; Cannon, 1957; Wells, 1962; Saunier, 1964; Whittaker and Niering, 1968; and others).

In a study of the endemic flora of the Napa Lake region of California, Mason (1946) found that high concentration of endemics in the area was due to great edaphic diversity, and ". . . especially to the fact that this diversity involves peculiar rocks and their associated minerals" (p. 257). He further stated that of the three aspects of plant dynamics--environment, physiology of the individual, and genetics of the population . . .

> only the environmental conditions independently occupy area and hence constitute the precise determinants of particular patterns of potential area of species, and, that of the environmental factors, the edaphic factor is most apt to occur in small, sharply defined areas and hence might be looked upon as a determinant of narrow paths of endemism (p. 241).

Fernald (1919) supported the idea of the chemical influence of subsoil on plant distribution. Within his study area he found Pinus banksiana confined to acid soils and Thuja occidentalis chiefly occupying basic soils. Shreve (1919, p. 293) emphasized the limiting effect of parent material on vegetation concluding that desert species ". . . reach higher elevations on volcanics than on gniess, and the highest elevations on limestone." Shreve (1922, p. 274) found that on the granitic slopes of the Santa Catalina Mountains ocotillo (Fouquieria splendens) reaches its highest limits at an elevation of approximately 5,600 feet. On the limestone of the Swisshelm Mountains it reaches an atltitude of 6,700 feet.

In a study of scattered pine stands in the Sierra Nevada Mountains, Billings (1950) found no substantial difference in the physical properties of the soils derived from altered and unaltered parent material and attributed relic pine stands, with their characteristic lack of undergrowth, to the greater acidity of the chemically altered andesite they occupied. He concluded the vegetative differences must be due to chemical tolerances of the pines.

The distribution of shrub live oak, Quercus turbinella, has been investigated by Saunier (1964). In studying the occurrence of this shrub on three different substrata, he found it to be better developed on quartz diorite than volcanic basalts or sedimentary rocks of the area.

Ecological studies of serpentine soils have provided additional evidence as to the role of parent material in influencing vegetation. Walker (1954, p. 259) indicated that in many instances vegetation serves to delineate geologic discontinuities and stated that in the North Coast Ranges of California, ". . . serpentine areas can be distinguished at a glance from the oak-grass vegetation of non-serpentine hills." He found that the intolerance of the serpentine was not the physical property of the soil, but the low calcium level of the soils.

In central Texas, Cuyler (1931) experimented with the usefulness of plant indicators in mapping geologic formations. He noted that plant associations of two or more dominant species proved to be reliable indicators of the geology of the area. Although he also found grass cover to change with each formation, he stated that ". . . woody vegetation is apparently much more prominant and tends to change consistantly with each change in geologic formation" (p. 68). Cuyler also found plant indicators valuable in mapping geologic features such as contacts, faults, anticlines, and synclines. He stressed that with further development of aerial photography this system of mapping geology could be greatly enhanced ". . . especially wherever it is necessary to produce a map of a large area in limited time" (p. 78).

More recently, Rzedowski (1955) and Whittaker and Niering (1968) treated the distribution of plants in relation to rock types. Both studies involved floristic and vegetative differences between linestone and igneous materials.

Rzedowski (1955) investigated the southwestern portion of the Mexican state of San Luis Potosí. He studied the vegetation and flora of fourteen outcrops of adjoining igneous and limestone parent material. He largely confined his sampling to solid rock outcrops, noting that many of the species which he considered calcicoles or calcifuges on solid parent material, became "ambiguous" on alluvium. From his data based on the fourteen localities and some control samples, he compiled tables of plant species he considered to be calcicoles (plants growing solely or predominantly in an alkaline medium) and calcifuges (plants growing solely or predominantly in an acid medium) and also a list of species which serve as indicators of limestone and igneous rock types. It is interesting to note that he found much greater diversity in plants growing on limestones than on igneous substrata.

Concerning different vegetation types (he sampled six) on each substratum, he found that the least difference occurred in his Zacatal (grassland) and Matorral submontano (piedmont scrub) types; intermediate in difference were Chaparral and Encinar, and the two types exhibiting the greatest difference on varying substrata were Matorral desertico calcicola (desert calcicole scrub) and Matorral cactus-mezquite (cactus-mesquite scrub), the first strictly confined to limestone and the second to igneous material.

Sampling species distribution and floristic relations on the north slope of the Santa Catalina Mountains, Arizona, Whittaker and Niering (1968) made traverses and conducted "special sample series" on various rock types. In comparing the vegetation supported by diorite and limestone they noted that several species occurred on both alkaline and acid soils. These included Juniperus deppeana, Quercus arizonica, and Garrya Wrightii. They found that these species tended to restrict themselves to the moister areas of the limestone compared with diorite. This statement is similar to the findings of Saunier (1964), who noted that the chaparral species of his study area were better developed on diorite than on volcanic and sedimentary rocks.

Whittaker and Niering also recognized the close relation of the limestone vegetation of the Santa Catalina Mountains to that of Mexican communities of the Chihuahuan Desert. They state that the community in the Santa Catalinas ". . . has special interest as a northwesternmost representative of a major Southwestern, predominantly Mexican, complex of communities and vegetation patterns on limestone, differing from those on other soils, which extends to Texas and Chihuahua and beyond."

Another aspect of the use of indicator plants has been in botanical prospecting (Cannon, 1957; Hawkes and Webb, 1962; and Malyuga, 1964). Cannon (1957) indicated that ore bearing beds can be found up to a depth of seventy feet below the surface by sampling the tips of tree branches or mapping indicator plants. In her work on the Colorado Plateau she found certain species of Astragalus to be an excellent indicator of uranium and various Eriogonum species to be associated with sulphur deposits.

Russian workers have been particularly active in the science of what they term "indicator geobotany".

Vereiskii and Vostokova (1966) have provided a Guidebook for the Determination of Lithological Composition of Surface Deposits and the Depth of Occurrence of Ground Water. The work is a key set up in couplet form to the different indicator plants in the Soviet Union and the phenomena they indicate.

Chikishev (1965) edited a work containing over forty articles on the subject of indicator geobotany. He indicated that the research in the Soviet Union is mainly concerned with

> . . . (1) discovery of indicators, (2) estimation of their effectiveness and reliability, (3) investigation on the biology and ecology of indicators and the nature of their relationship to the indicator object, (4) indicator zonation, (5) indicator mapping, and (6) the possible use of indicators in the national economy [p. 2]

The extent of their work can readily be seen from the following quotation, p. vii):

> Geobotanical indicator research (indicator geobotany) is at present being applied in resolving a wide range of scientific and practical problems. It is being used in the agricultural evaluation of territories (in connection with the compilation of soil maps), in engineering and geological surveys (for highway construction in swamps, deserts, and districts where soil terrain are saline, for surveys in the districts where ground is frozen, and also for small scale engineering and geological surveys), for evaluating hydrogeological conditions in irrigated districts, for studies on swamps intended for industrial and agricultural uses, in prospecting for certain species of useful fossils, and so on.

CHAPTER 3

STATEMENT OF PROBLEM

Investigations of plants as indicators of soil conditions, ground water, and minerals have contributed considerably to the literature concerning indicator plants. Much more limited but equally important is the literature treating the correlation of vegetation associations or individual species with the rock types on which they grow. That plant indicator studies should be influenced by economic motives is perhaps quite natural; however, this does not exclude the need for basic investigations aimed at understanding the relationships between plants and lithologic features in specific localities, a necessary forerunner to fully understanding the intricate balances linking the plant world and its environment. This investigation in the northern Swisshelm Mountains of southeastern Arizona has the following objectives relating to vegetation as an indicator of rock types:

1. To attempt to identify individual species or groups of species of plants that appear to correlate well with rock types within the specified area. I did this mainly through field observations based on familiarity of vegetation and geology of the area. To further aid in this

end I compiled floristic and lithologic maps of the study area.

2. To ascertain the reliability and effectiveness of identified indicator species by a) analyzing distributional data on plants obtained in the field by means of line traverse and control quadrats, and by, b) comparing local indicator species with those other investigators have found in differing localities.

3. To investigate variation of pertinent species according to slope aspects. I considered it significant to determine whether plants that seem to be accurate indicators of rock types on one aspect of a slope behave similarly on other aspects, and to note the behavior of individual species within indicator associations on varying slope aspects.

4. To examine the problem of chemical versus physical properties of soils in influencing vegetation. For this purpose I obtained soil samples from the study area. Although they are far from being complete analyses, they provide sufficient data from which general observations are made.

5. To investigate the influence of sediments derived from various parent rocks on the distribution of vegetation. Many studies involving plant indicators of geologic substratum have been concerned only with residual

materials, i.e., developed in place from underlying bedrock. In this investigation, however, I have examined vegetation occupying alluvial deposits and attempted to evaluate existing correlations.

6. To compile a list of plant species that are both reliable indicators of rock type in the area and sufficiently common in the area to be useful, based on the above analyses, and disregarding those species which cannot be regarded as indicators of rock type even though their classifications as calciphiles and calciphobes in the study area are valid.

7. To examine the extent to which the physiognomy of the vegetation is influenced by lithologic differences, i.e. are different vegetation types a reflection of varying rock types? To aid in this objective I compiled a structural vegetation map of the study area.

8. To note in what ways, if any, vegetation indicates stratigraphy and geologic structure in the study area.

CHAPTER 4

STUDY AREA

The study area is located in the northern Swisshelm Mountains, Cochise County, Arizona (Fig. 1). The area is approximately twenty-five miles north of Douglas, Arizona and is accessible by the Chance Mine road which enters the Swisshelm Mountains from the northeast off the Rucker Canyon road.

The Swisshelm Mountains are part of the elevated upland extension of the Sierra Madre Occidental of Mexico. They trend NW-SE parallel to the Chiricahua Mountains and project from the Pedregosa range north-northwestward into the Sulphur Springs Valley. The area investigated, approximately four square miles, comprises the southeastern quarter of Section 35, the southern half of Section 36, R 27 E, T 19 S; Section 1, the eastern half of Section 2, the northeastern quarter of Section 11, R27 E, T20 S; the southwestern quarter of section 31, R 28 E, T 19 S; the western half of Section 6, and the northwestern quarter of Section 7, R 28 E, T 20 S. The area is shown on the Swisshelm Mountain Quadrangle (U.S.G.S. 15 minute series).

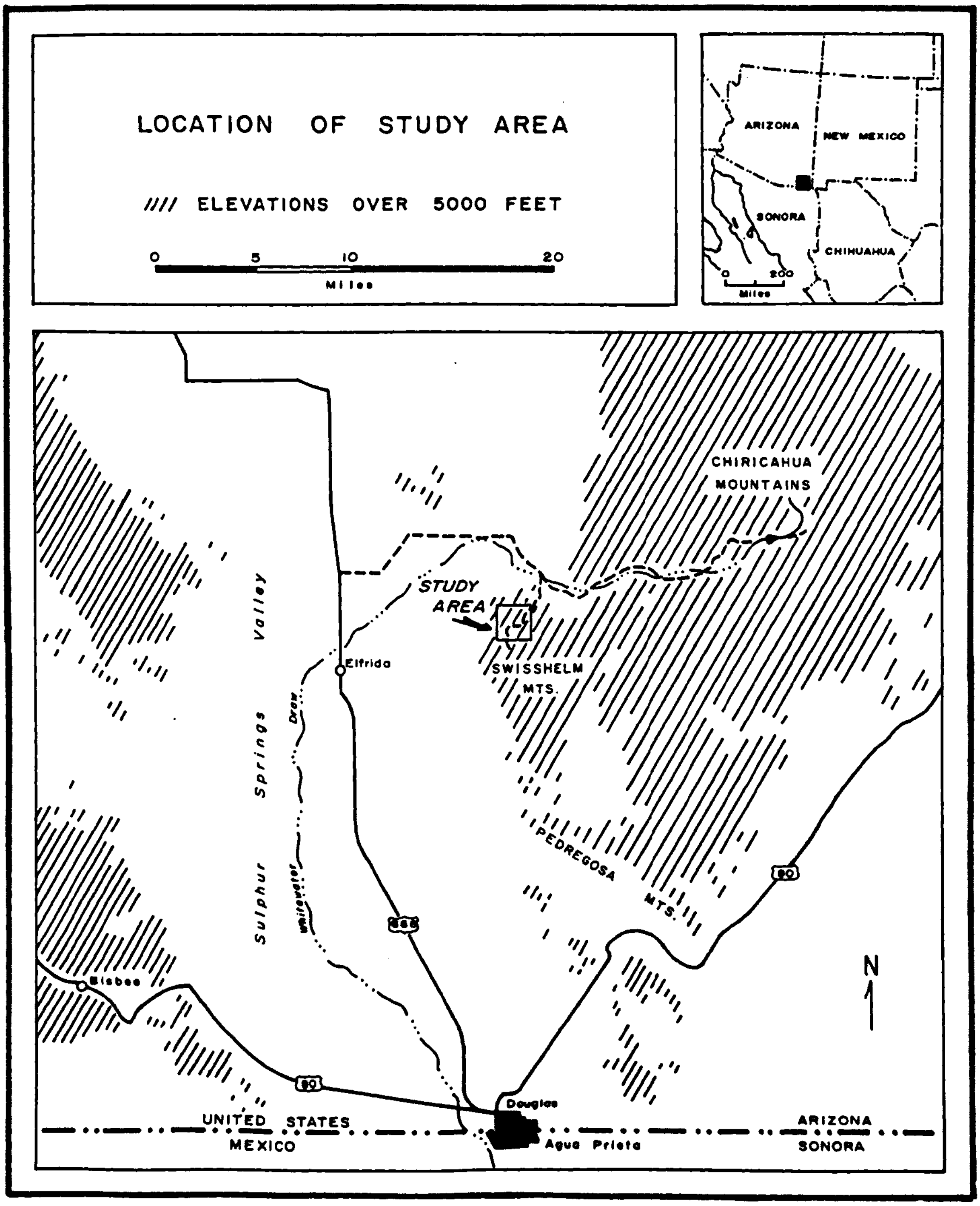

Fig. 1. Location of Study Area

CHAPTER 5

CLIMATE

In general the climate of the study area--one of rather high summer temperatures, low rainfall, and low relative humidity--tends to limit the growth and development of vegetation. This fact is especially apparent when the vegetation is found to respond to conditions locally supplementary to climate, such as north facing slopes and intermittent water courses, which provide necessary moisture otherwise unavailable because of climatic limitations.

The climate of the area falls within the semi-arid steppe (BSk of Koeppen) classification. Southeastern Arizona is characterized by a distinct biseasonal precipitation regime. In late June as the subtropical high pressure system over the eastern Pacific intensifies and moves northeastward, warm, moisture-laden air is drawn into the Southwest from the Gulf of Mexico. As a result, extreme southeastern Arizona receives over seventy percent of its annual precipitation between the months of May and October (Green and Sellers, 1964, p. 13). For most southeastern Arizona stations, however, this length span can be considerably reduced. Rucker Canyon, Chiricahua National Monument, and Douglas, for example, the stations nearest the area, receive their highest mean monthly precipitation totals in July, August, and September from intense thunderstorms. Winter rain is the result of frontal conditions associated with the cyclonic storms off the north Pacific. Precipitation from these storms is generally lighter and long continued, but less reliable in occurrence. Light snow falls are common in the winter months, but duration of snow on the ground is short.

Although no published climatic data is available for the study area, information from two nearby stations of similar altitude has been utilized as being reasonably representative.[1] The Rucker Canyon station (elevation 5,370 feet) for which there is not temperature data available, shows a mean annual precipitation of 19.06 inches. It is located approximately twelve miles from the study area. Precipitation records from Chiricahua National Monument, approximately twenty miles distant and at an elevation of 5,300 feet, indicated 18.63 inches mean annual precipitation.

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[1] Two persons living within the boundaries of the study area supplied me with unsubstantiated precipitation data. Mr. J. F. Rydbom recorded annual totals ranging from 18 to 23 inches over a five year period at an elevation of approximately 5,400 feet. Mr. Kuykendall's record (elev. 5,120 feet) indicated an average annual precipitation of approximately 19 inches for an undetermined length of record, and he confirmed that he generally received slightly less summer precipitation than his neighbor.

Chiricahua National Monument records indicate a mean annual temperature of 57.6°F. Field experience in both the National Monument and the study area suggests that the mean annual temperature of the area investigated in the Swisshelm Mountains is a few degrees higher than this figure. I believe that the daily maximum temperatures during the summer months are higher in the study area than those recorded at Chiricahua National Monument. This would increase the monthly means in summer and result in a higher overall annual mean, assuming winter means remained essentially the same.

Temperature variations in the area are considerable. Chiricahua National Monument has recorded a high of 109°F (July 1909) and a low of -10°F (January 1913). By averaging mean annual morning and evening relative humidity totals, the figure 47.5 percent mean annual relative humidity is calculated for Chiricahua National Monument. Although these figures were recorded at 0600 and 1800 hours respectively, lower mid-day values would probably be more important in terms of stress on plants. Climatological data for the two weather stations utilized follow in Tables 1 and 2.

Table 1. Monthly Mean Precipitation for Rucker Canyon, Cochise County, Arizona. Elevation 5,370 Feet. Period of Record, 1893-1957. (After Green and Sellers, 1964)

Month	Precipitation Mean Inches
Jan	1.21
Feb	1.27
Mar	1.14
Apr	0.56
May	0.36
Jun	0.80
Jul	4.33
Aug	3.91
Sep	1.87
Oct	1.31
Nov	1.00
Dec	1.30
Year	19.6

Table 2. Monthly Mean Precipitation, Temperature, and Relative Humidity for Chiricahua National Monument, Cochise County, Arizona. Elevation 5,300 Feet. Period of Record, 1909-1919, 1948-1963. (After Green and Sellers, 1964).

	Temperature			Relative Humidity	
Month	Maximum °F	Minimum °F	Precipitation Mean Inches	Morning	Evening
Jan	55	29	1.56	61	41
Feb	58	30	1.19	63	41
Mar	64	33	1.18	57	32
Apr	72	38	0.58	53	28
May	81	43	0.37	44	22
Jun	92	53	1.09	42	25
Jul	89	59	4.67	65	40
Aug	87	58	4.10	75	45
Sep	84	53	1.18	67	38
Oct	75	43	0.83	63	38
Nov	64	34	0.78	59	38
Dec	56	29	1.10	63	41
Year:	73.1	42.0	18.63	56	36
Extreme:	109	-10	30.34 10.56	--	--

CHAPTER 6

GEOLOGY AND PHYSIOGRAPHY

The Siwsshelm Mountains are a linear, tilted, fault block mountain range of the Mexican Highland section of the Basin and Range physiographic province (Fenneman, 1931, p. 380, and map). Characteristic of this province, the range is flanked by an extensive bajada grading into the Sulphur Springs Valley on the west. To the east a rolling terrain rises gradually toward the more massive Chiricahua Mountains. The southern continuation of the range is marked by smaller isolated peaks extending southward into Mexico. The range is approximately two miles wide and ten miles long, and trends N 20°W. Terrain is rugged consisting, to a large extent of steeply dipping beds, deeply dissected by intermittent streams.

The study area is bounded on the west by linear limestone ridges. In the northwest corner these trend westerly and rise, step-like, to an elevation of approximately 5,600 feet, the local relief being only approximately 1,500 feet. In the southwest corner, these ridges fail to exhibit any particular trend and form rounded and elongated peaks, the highest of which reaches an elevation of 6,073 feet. The eastern half of the study area consists of volcanic hills with a considerably more rolling terrain. Separating two volcanic hills near the center of the region studied is a limited area of valley fill, and small terraces of alluvium occur scattered throughout the study area. Slope gradients over the region studied are quite varied ranging commonly from approximately 5° to over 20° on the limestone ridges. On the volcanic hills to the east, gradients are generally somewhat less. There is more area of nearly level terrain in the eastern half of the study area, although extensive areas of truly flat land are lacking.

Drainage from the Swisshelm Mountains is predominantly to the east and west eventually reaching the Whitewater Draw which skirts the range to the north and west and continues southward down the Sulphur Springs Valley. The study area is drained by three intermittent tributaries which flow north-northwesterly out of the mountains and enter the Whitewater Draw which, at this point, flows westward around the northern end of the Swisshelm range from a source in the Chiricahua Mountains.

The range consists primarily of sedimentary rocks of Paleozoic and Mesozoic age with late Paleozoic limestones being the most predominant type (Rogers, 1954, p. 3). These limestones contain abundant sandstone and quartzite and some finer grained clastics. Two prominant limestone formations occurring within the study area are

Pennsylvanian to Permian in age and belong to the Naco group. They are differentiated on the basis of clastic content--the Horquilla Formation having less than 50% clastics, and the Earp Formation having more than 50%. In addition, there are scattered outcrops of silicified limestone over the area which were formed by the percolation of warm, silica charged water through fissures of the preexisting limestone.

Capping down faulted blocks of limestone in the eastern portion of the study area is a remnant layer of rhyolitic volcanic flow. This probably covered the whole range at one time. These red, reddish gray, and yellowish acidic lavas contain numerous phenochrysts of quartz, feldspar, and mica, and are thought to be of Tertiary age (Meinzer and Kelton, 1913). In the extreme eastern corner of the study area the volcanic material is of a much lighter color and its texture considerably more ashy than the surrounding rhyolite. This flow contains more potash and silica than do the other volcanics encountered in the study area.[2]

Exposed on the western face of the range is an extensive outcrop of the granitic intrusion which forms the core of the Swisshelm anticline. It is thought to be of Laramide origin (Loring, 1947). Granite is exposed only

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[2] Information provided by Professor Spencer Titley of the Geology Department, University of Arizona.

in the extreme southwest corner of the study area, however. A small outcrop of "diorite porphery," andesite, described by Loring (1947, p. 47) as being ". . . a much altered basic sill ranging in thickness from four to over fifty feet," occurs in the south center of the study area. Loring estimated its age to be Cretaceous or early Tertiary.

Minor deposits of more recent geologic origin also occur in the study area. Shallow deposits of alluvium exist in some valley bottoms, a few of which have been recently dissected. There are also shallow sheets of colluvial material masking lower portions of steeper slopes in the area. Soils on these deposits are poorly developed and in reaction range from basic to mildly acidic, depending on source of alluvium. Loring (1947, p. 45) found that in the southern section of the study area ". . . the valley fill contains some locally derived limestone, but is comprised mostly of bolsa quartzite, ranging from sand size to two-foot boulders." Beds of active washes in the area contain a higher percentage of sand and lesser amounts of clay and silt than valley fill deposits.

An active geologic history has created the complex geology of the Swisshelm Mountains (Fig. 2). Structure has been affected by four major periods of tectonic activity.

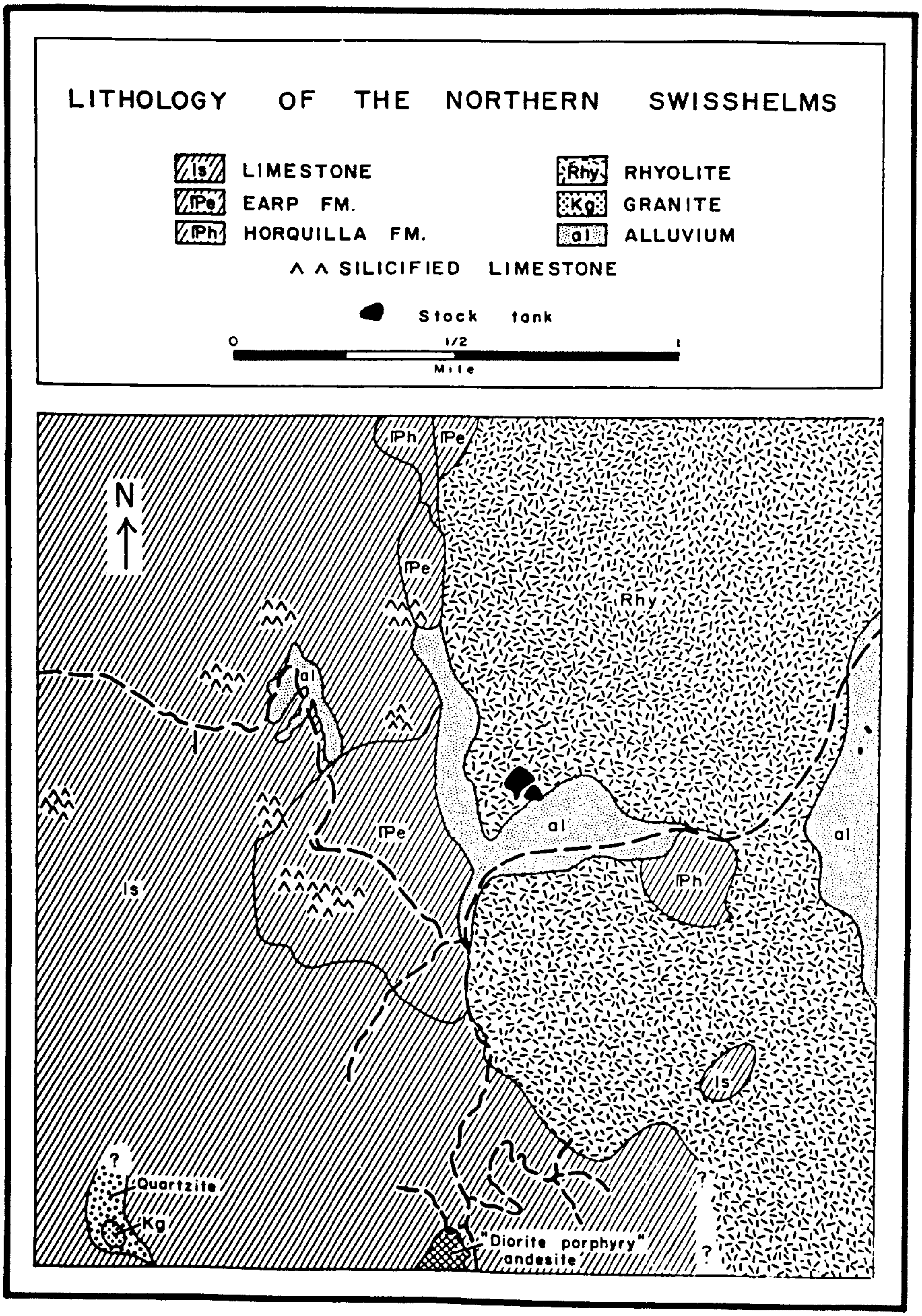

Fig. 2. Lithology of the Northern Swisshelms

Rogers (1954, p. 21) listed the following:

> 1) Ordivician-Devonian eperiogenic upwarp represented by the disconformity between lower Ordivician and upper Devonian rocks; 2) Mid-Mesozoic orogenic movements evidenced by the marked angular unconformity between Paleozoic limestone and the lower Cretaceous Bisbee group; 3) Laramide upper Cretaceous activity which produced the extensive NW-SE thrusts throughout the area; 4) Post compressional late Tertiary Basin and Range normal faulting which offset the older thrusts and probably partially controlled the present extent of the Swisshelm range.

The last two activities listed were the most influential in shaping the range into its present characteristic structure and form.

Among the probable lithologic factors influencing local vegetation are chemical composition of the rock types, their structure, texture, and pH and moisture holding capacity of soils they give rise to.

CHAPTER 7

VEGETATION

According to Shreve (1917, map; 1942, p. 236) the vegetation of the area investigated in the Swisshelm Mountains belongs to the Desert Grassland Transition region. The eastern half of the study area shows striking similarity to what Shreve (1915, p. 25) has labeled Lower Encinal, however.

Other workers have classified the vegetation on lower mountains, bajadas and basin fills of southeastern Arizona under different nomenclatures; however, the species and structural characteristics remain similar. For example, Nichol (1937, p. 198) considered the region to be occupied by the Desert Grass type of his Grassland natural division. According to his vegetation map of northeast Mexico, Brand (1936) considered the vegetation adjacent to the region on the Mexican side of the boundary to be Mesquite grassland. With increasing elevation this grades into his agave-juniper classification of the Sierra Madre Occidental. Harshberger (1911, p. 640) included southeastern Arizona in the lower elevation division of his Western Sierra Madre region, and Clements (1920, p. 170) classified the same region as being the western division of his Southern Desert Scrub.

Of course the above classifications are only intended to serve as generalizations of existing plant life. The different vegetation types were attempts to characterize vegetation over large areas rather than to describe in detail the species of any specific locality. Although the region has been described as Desert Grassland, accuracy is gained in the case of the Swisshelm Mountains by placing emphasis more on the shrubby, "desert" nature of the vegetation than on the grasslands which are more characteristic of the bajadas flanking the mountain mass. Areas of what can be considered a true continuous desert grassland are very limited within the study area, especially on rocky slopes composed of limestone.

The Swisshelm Mountains are part of the mountainous barrier separating two great desert regions. The more elevated Chihuahuan Desert lies to the east occupying a strip of the Mexican Plateau from southern New Mexico to the Mexican state of Zacatecas. West of the Sierra Madre Occidental and its northern extentions lies the lower, more arborescent Sonoran Desert of Sonora, southwestern Arizona, and Baja California.

Located in an upland zone between two deserts, the study area displays, as mentioned earlier, significant desert qualities, attributable in part perhaps, to the influence of limestone substratum on the distribution of desert species (Shreve, 1922). The vegetation of southeastern Arizona has been recognized by several observers as having closer affinities to the Chihuahuan Desert flora to the east, than to that of the Sonoran Desert west of the area studied (Shreve, 1942, p. 235; Benson and Darrow, 1954, p. 15; Martin, 1963, p. 8; Lowe, 1964, p. 20). Indeed, Martin (1963, p. 8) found that eleven species out of seventeen less common forms associated with Larrea in Coahuila, Mexico, a distance of over 1,000 kilometers away, occur also in southeastern Arizona. He remarked, "the floristic homogeneity is notable."

The study area is characterized, for the most part, by various mixed shrub associations and communities. These have been classified into six generalized vegetation types for descriptive purposes (Fig. 3).

The most extensive vegetation type in the study area has been designed as mixed dense shrub (Fig. 4). This type is largely confined to the highly calcareous substratum, however, its presence on other materials was noted in a few instances. Three components of this type, although not included in the map, were recognized: The dominant species on north-facing slopes are Rhus choriophylla, Cowania mexicana, Cercocarpus breviflorus, and Mortonia

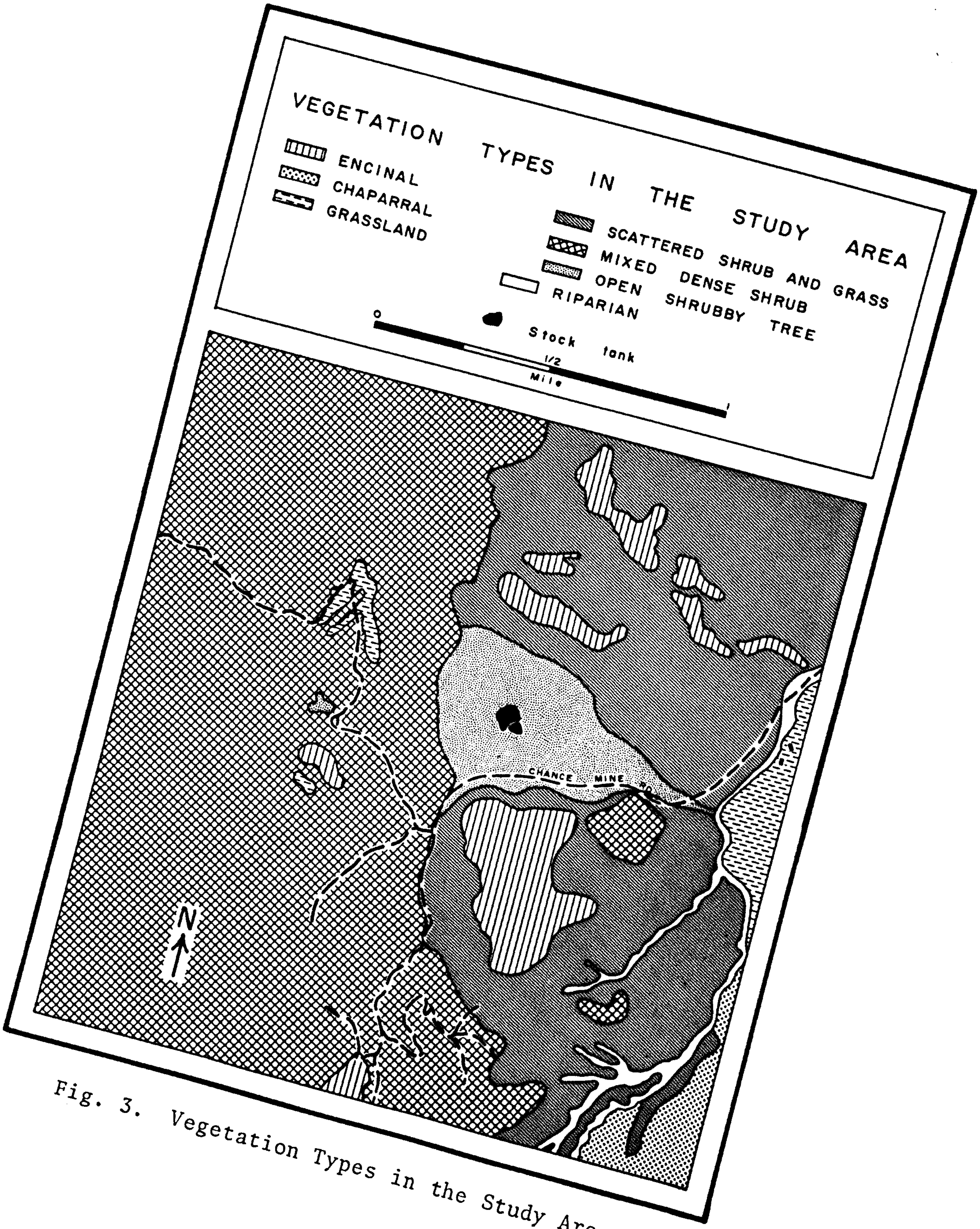

Fig. 3. Vegetation Types in the Study Area

Fig. 4. Mixed Dense Scrub

scabrella. Scattered throughout, however, are Nolina microcarpa, Yucca baccata, and Agave Parryi. The more arid south-facing slopes support Rhus microphylla, Fouquieria splendens, Acacia vernicosa, and Opuntia Spp. in abundance. Two low-lying, rounded limestone hills near the center of the study area support Mortonia scabrella in almost pure stands.

A second type, simple scattered shrub, is most characteristic of alluviated areas. The dominant species of this vegetative class is Prosopis juliflora (Fig. 5). Nolina microcarpa, Acacia constricta, and Agave Parryi begin to replace mesquite on the higher colluvial slopes surrounding alluvial deposits. Creosote bush (Larrea tridentata) is quite rare.

Several species of oak occur on some northern slopes and in a few clumps on fairly level terrain. These are the dominants of a third vegetation type labeled as encinar (Fig. 6). This is characterized by a woodland of low, open, round-crowned oak trees and occasional junipers with grass beneath. The dominants encountered in this vegetation type were Quercus arizonica, Q. oblongifolia, Q. Emoryi, Juniperus deppeana, and J. monosperma.

Riparian vegetation exists along washes which receive intermittant water throughout the year (Fig. 7). The species characteristic of this type are Quercus Spp.,

Fig. 5. Simple Scattered Shrub

Fig. 6. Encinal

Fig. 7. Riparian Vegetation

Baccharis sarothoides, B. glutinosa, Sapindus Drummondii, and rarely, Vitis arizonica. Chrysothamnus nauseosis is also a conspicuous riparian form on the limited area of flood plain in the region (Fig. 8).

The vegetation type designated as scattered shrub and grass encompasses three major subtypes. Pure stands of grass are fairly limited in the region investigated, and where they do occur it is quite possible that they are, in part, influenced by human occupance as they reach their greatest extent in the vicinity of a ranch located in the study area. Although grasses were not treated in this study, the principal genera encountered were Bouteloua, Aristida, and Hilaria.

Also included within the scattered shrub and grass vegetation type are areas of Agave-Gramineae Spp., and Nolina microcarpa-Agave-grass associations (Fig. 9) which are essentially discontinuous grassland with beargrass and agave scattered throughout. These elements of the vegetation are characteristic of the rolling hills comprising the eastern half of the study area.

The final conspicuous vegetation type of the study area is located in the southeastern corner of the region. Here, at an elevation almost 1,000 feet lower than some of the mixed desert shrub communities of the limestone ridges, occurs what has been designated on the basis of structure,

Fig. 8. Riparian Vegetation (<u>Chrysothamnus</u>)

Fig. 9. Scattered Shrub and Grass

a chaparral (Fig. 10). The vegetation, for the most part, is thick-leaved and scrubby. *Arctostaphylos pungens*, *Garrya Wrightii*, and *Quercus Toumeyi* are common throughout this section. Due to the presence of *Pinus cembroides* and *Juniperus* Spp. within this vegetative type, it might be regarded by some observers as a pinon-juniper transition, but if so, it is apparently reached on an edaphic rather than an altitudinal basis.

Since the vegetation map provides only a general, structural picture of vegetative types, a floristic map (Fig. 11) was compiled in order to portray more accurately the mosaic of communities and associations found over the study area. A list of woody species encountered in the study area is included in Appendix A.

Fig. 10. Chaparral Vegetation

Fig. 11. Floristic Map of Vegetation.

SPECIES TYPES*

1. Gramineae Spp.
2. *Nolina*, *Prosopis*, *Rhus* Spp., grass
3. *Fouquieria*, *Agave*, grass
4. *Prosopis*, grass
5. *Prosopis*, *Ephedra*, grass
6. *Prosopis*, *Acacia*, *Nolina*, grass
7. *Mortonia*
8. *Mortonia*, grass
9. *Mortonia*, *Rhus* Spp., grass
10. *Rhus* Spp., *Cercocarpus*, *Mortonia*
11. *Fouquieria*, *Dasylirion*, *Nolina*, *Rhus* Spp., *Mortonia*
12. *Fouquieria*
13. *Fouquieria*, *Dasylirion*, *Agave*
14. *Fouquieria*, *Opuntia*, *Lippia*
15. *Fouquieria*, *Dasylirion*, *Erythrina*
16. *Fouquieria*, *Dasylirion*, *Nolina*, *Rhus* Spp.
17. *Fouquieria*, *Acacia*, *Agave*
18. *Rhus* Spp., *Nolina*, *Fouquieria*, *Acacia*
19. *Rhus* Spp., *Acacia*
20. *Rhus* Spp., *Nolina*
21. *Rhus* Spp., *Ceanothus*, *Cowania*
22. *Fallugia*, *Rhus microphylla*
23. *Nolina*, *Cowania*, *Rhus* Spp., *Quercus* Spp.
24. *Rhus* Spp., *Ceanothus*, *Cowania*, *Juniperus* Spp.
25. *Quercus* Spp., *Juniperus* Spp., grass
26. *Quercus* Spp.
27. *Quercus* Spp., *Arctostaphylos*, *Garrya*
28. *Quercus* Spp., *Juniperus* Spp., *Agave*, grass
29. *Agave*, *Dasylirion*, grass
30. *Nolina*, *Agave*, *Dasylirion*
31. *Cowania*, *Nolina*, *Agave*
32. *Acacia vernicosa*
33. *Acacia*, *Baccharris*, *Prosopis*
34. *Opuntia*
35. Chrysothamnus
36. *Fouquieria*, *Nolina*, *Rhus* Spp.

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*For convenience generic names have been utilized in the legend. For complete Latin names of specific genera see Appendix A. Plants within each species type are not necessarily listed in order of dominance within communities.

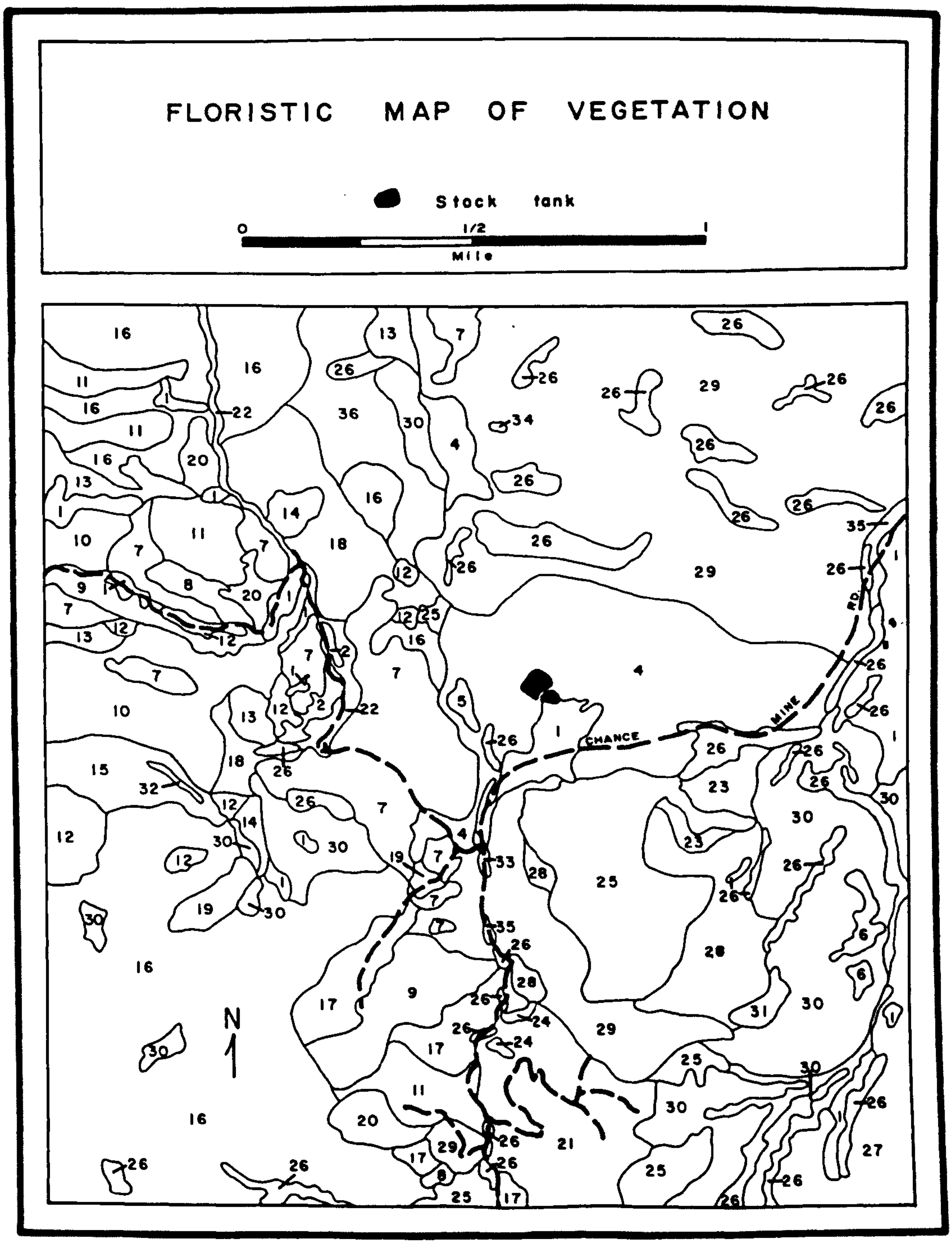

Fig. 11. Floristic Map of Vegetation

CHAPTER 8

HUMAN OCCUPANCE

The scope of this investigation is focused solely on the vegetation as it exists today and its correlations to the substratum. However, man's presence in the area has, of course, influenced the ecology and plant life to some extent. Because data is lacking to measure any changes in the vegetation or the degree of man's impact on the land in the area, and also because evaluating his impact is not a purpose of this investigation, only a brief account of man's presence in the region is presented to suggest the possible magnitude of his influence.

Before 1870 there were very few white settlers in or near the Sulphur Springs Valley (Schultz 1964, p. 17). Only for the last ninety years or so has there been effective human activity in the Swisshelm Mountains, if the rather undefendible assumption is made that the Indians did little to alter the habitat. For the last twenty years the most intense of the human activities that once functioned in the area has been at a standstill.

Economic activity in the Swisshelms has been dominated by two major forms of livelihood. The first, mining, was begun in 1885 after the Apache threat had been quelled in southeastern Arizona. The second, cattle ranching, was probably introduced to the area during the open range era beginning about 1870 and lasting until 1909.

John Scribner of Tombstone, Arizona, is said to have made the first ore discovery in the area in 1885 when he located the Mountain Queen Claim (Loring 1947, p. 58). He worked this mine until 1913 shipping his ore out to Webb, at that time located four miles north of Elfrida. Since then this mine has changed hands and been leased several times. This and succeeding mines in the region produced direct-smelting lead ore and small amounts of silver and gold (Loring 1947, p. 56).

The Mammoth Mine and the Whale Group were located by John Swisshelm in 1898, and these too have been under various managements. The most recent mining activity was begun in 1945 by Brown and the Rydbom brothers, and although some of the equipment remains, this operation has also ceased.

Cattle ranching activity is still present in the area. The ranch located within the bounds of the study area is said to have been originally homesteaded in 1911, two years after the passing of the Enlarged Homestead Act of 1909. The ranch is presently owned by Mr. Kuykendall.

Although the cattle industry is thought to have been quite influential in regard to vegetation change and shrub invasion (Humphrey 1958; Hastings and Turner 1965, and others), the presence of cattle in the Swisshelm Mountains has probably done considerably less to affect the vegetation than in other areas of the Desert Grassland. This is due principally to the fact that more than fifty percent of the study area is composed of limestone which has never been reported to produce rich grasslands in desert environments. Also much of the area is steep and rugged and avoided by cattle, and permanent water sources are lacking which tends to restrict its carrying capacity to some extent. In addition, much of the soil over the region is extremely shallow and rocky and better suited to the production of shrubs than grass. But the fact that cattle have been present in the area for at least fifty-eight years certainly suggests that they have influenced the ecology of the region to some extent.

The marks of past human activity on the landscape are presently seen as small scars and tailings on certain slopes, and old mining roads leading to abandoned shafts. Cattle over the years have left their paths on hillsides and along valley bottoms. Current activity in the area is not lacking, however.

During the period of field investigation I noticed a bulldozer cutting profile sections around a mountain at various localities, so presumably some mining interests in the area still exist. I also noted a more recent form of human activity in the study area. Numerous clumps of beargrass (Nolina microcarpa) had been cropped to the ground and the leaves removed. Since beargrass has relatively little forage value, I assumed that these plants had been cut for thatch, possibly by Mexican Nationals. Upon inquiry I found that the plants had indeed been cut and gathered by Mexican Nationals, but for use in a broom factory located in Agua Prieta, Mexico. This does not kill the plant and actually, according to Mr. Kuykendall, increases the production of flower stalks which do provide some forage for his cattle.

In spite of rather extensive human activity in the region and the effect of cattle on the grassland portions of the study area, the magnitude of man's influence on the vegetation, especially on the rugged limestone slopes, has probably been slight.

CHAPTER 9

METHODOLOGY

Given the favorable circumstances of well-delimited lithology and diverse vegetation within such a limited area, I felt that the most adequate method of sampling the differences in the flora and vegetation on the varied substrata would be to conduct a line traverse across as many lithologic types as possible within the area. In order to minimize the effects of slope aspect, the traverse was run from west to east across the study area, eliminating the influences of north-south exposure as much as possible. The total altitudinal variation of the traverse differed no more than 500 feet, hardly enough to produce marked elevational changes in the vegetation, especially on limestone.

The straight line traverse ran S45°E from a point near the northwestern corner of the study area and included 112 sample sites located at 100-foot intervals along the strip. The plots were circular, having 10-foot radii from a center point on the traverse. The species falling within each plot and the lithologic material on which they were growing were noted. Slope aspect and dominance of species within each plot were also recorded.

In addition to the line traverse, 8 control quadrats were established. Since a complete floristic analysis of the study area is essentially impossible with quite limited time and resources, the 8 control plots serve three purposes. First, they serve as a control or check on the results of the line traverse; second, they serve to make known the vegetative relationships that exist in other portions of the study area that were not present along the traverse; and third, they are established to take into account all the various rock types occurring within the area.

The eight quadrats were subjectively chosen to be representative of the area both from the standpoint of different types of vegetation, and as to the species each site contained. Finally, they were constructed to comprise the greatest variation of lithologic elements existing within the study area.

A total of three samples were made on limestone: Two on the Horquilla Formation, and one on the Earp Formation. Three more were located on igneous material: One on rhyolitic alluvium, one on dark colored rhyolite, and one on a lighter colored rhyolite containing more silica and potash than the latter. The seventh sample was made on silicified limestone, and the final control quadrat was established on a sandy alluvial flood plain located on the eastern edge of the study area.

Each quadrat measured 10 meters square (100 sq m). Although the size of a quadrat should be varied with the communities and habitat conditions which are to be studied, plots of this standard size, in this area, readily conformed to the concept of minimal area. That is to say, the dimensions of the quadrat in each case were of sufficient size to provide enough ". . . space of combination of habitat conditions for a particular stand of a community type to develop its essential combination of species or its characteristic composition and structure" (Cain and Castro 1959, p. 167).

Elevation, slope gradient, slope aspect, position on slope, pH reaction, species present, and coverage of vegetation were determined for each control plot. In addition, samples of soil and bedrock, where it occurred, were collected for analysis. Bedrock samples were taken as near the center of each plot as possible, and soil samples and pH reaction tests were made at a depth of approximately 5 inches, also near the center of each plot.

Soils data were obtained from the University of Arizona Agricultural Experiment station. Analyses included pH using a saturated paste, total soluable salts using a saturated paste extract, total milliequivalents per liter of Mg plus Ca, and a mechanical analysis of the soil measuring percent sand, silt, and clay for each sample.

A floristic vegetation map (Fig. 11) was made in accordance with the method set forth by the California Vegetation-Soil Survey (Kuchler 1967, p. 282), described below.

> Vegetation types by species composition (referred to as'species types') are natural bodies of vegetation classified according to the dominant species growing together in an ecological association. Each woody vegetation element shown on the photograph is classified by one or more species. The herbaceous elements usually are classified by physiognomic or ecological groups of plants, but by species in some cases. Species types are designated by the species symbols. One or more species is shown for each vegetation element (except grass and forbs). The species symbols are listed in order of decreasing abundance. In order to be recorded as a part of a species type, a species must have a coverage of 20% or more of the element it represents.

Patterns were established in the laboratory from an aerial photograph and then checked in the field by overland traverse and field observation. The generalized map of lithology (Fig. 2) was simplified from unpublished field maps of the area made by Professor S. Titley of the Geology Department, University of Arizona. Field work was begun in July of 1968 and continued at infrequent intervals through February 1969.

CHAPTER 10

DISCUSSION

Calciphile, Calciphobe, and Ambiguous Species in the Northern Swisshelm Mountains

Although very limited outcrops of granite, diorite porphyry, shale, and quartzite occur in the study area, limestone and rhyolite are by far the most abundant lithological types present. Furthermore, it is between these two rock types that differences in the vegetation and flora are most apparent in the region. When the vegetational pattern is observed in the field, certain distinct relationships between plant life and the substratum are evident, particularly along the region of the contact between rhyolite and limestone. Based on such observations and in the form of a hypothesis, a preliminary list of plant species exhibiting marked preferences for particular substrata was compiled (Table 3).

In the past the terms calciphile and calciphobe (calcicole and calcifuge) have often been applied to groups of plants exhibiting preferences for alkaline or acid mediums. Various investigators (Schimper 1903; Warming 1909; Yang 1951, and others), however, have noted the importance of the physical properties of the soil in influencing

Table 3. Calciphile and Calciphobe Species. Explanation in the Text.

	Calciphiles	Calciphobes
I	*Calliandra eriophylla*	*Arctostaphylos pungens*
	Cercocarpus breviflorus	*Prosopis juliflora*
	Condalia spathulata	*Quercus Toumeyi*
	Cowania mexicana	
	Dalea formosa	
	Mortonia scabrella	
	Parthenium incanum	
	Quercus pungens	
II	*Acacia vernicosa*	*Acacia constricta*
	Fouquieria splendens	*Eysenhardtia polystachia*
	Lippia Wrightii	*Quercus Emoryi*
	Rhus choriophylla	
	Rhus microphylla	

plant distribution, so it is possible that the presence of calcium in the soil is not necessarily, in itself, the only selective factor governing the distribution of vegetation. Because the meaning of the terms can be readily understood, however, especially when applied to an area predominantly composed of calcareous and igneous rocks, the terms are applied below with recognition of their possible limitations.

Table 3 is composed of two categories (calciphiles and calciphobes) each divided into two groups. Group I consists of plant species which seem to demonstrate strong affinity, to the degree of restriction in some cases, to the substratum. Within Group II are placed those species demonstrating what was considered to be a preference for one substratum or the other. It is interesting to note that calciphiles are more numerous than calciphobes. This is in agreement with the findings of Rzedowski (1955) who noted a similar occurrence in San Luis Potosí, Mexico. Data from the writer's line traverse (Appendix B) also shows a greater diversity of species on limestone. It is also evident from the table that tree forms are more numerous in the calciphobe category. The results of Whittaker and Niering's investigation in the Santa Catalina Mountains, (1968), show a similar relationship.

Reconnaissance also clearly indicated that there occurred in the area several species which were apprently indifferent in regard to lithologic preference. These forms appear to be adapted to both types of substrata. Rzedowski (1955), classified these species in his study area as "ambiguous" and notes that they are not to be confused with "contamination" which is more likely to occur on alluvial deposits (p. 152). The ambiguous species noted in the northern Swisshelms are listed in Table 4.

Table 4. Ambiguous Species

Agave Palmeri
Agave Paryi
Opuntia Spp.
Nolina microcarpa
Dasylirion Wheeleri
Yucca Schotti

Distribution of several of these ambiguous species has been attributed to temperature and moisture preferences. Factors influencing the distribution of cacti have been investigated by Cannon (1916). He found cacti growing in habitats in which soil temperatures were high so that the shallow root systems could make the most of available moisture and heat (p. 442). The greatest concentration of cacti (*Opuntia* Spp.) in the study area are located on south facing slopes which tends to strengthen Cannon's observations. In the Desert Grassland and Oak Woodland of western Santa Cruz County, Arizona, Cumming (1952, p. 29) found that *Dasylirion Wheeleri* and *Nolina microcarpa* were limited entirely to north aspects. Although not as strong a correlation was noted in the northern Swisshelms, the two species do exhibit a preference for more mesic habitats.

Reliability and Effectiveness of Indicator Species

Reliability

To provide a means of investigating the reliability of plants exhibiting a marked tendency for one substratum or another, a line traverse was made trending west to east across the study area. By employing a predetermined sampling interval, i.e., every 100 feet, a reasonably objective measure of reliability of plant species on varying substrata along the traverse was obtained.

One hundred and twelve samples were taken. They were made on three different rock types and on several alluvial deposits with varying degrees of alkalinity and acidity. A total of 44 stops were made on limestone, 25 on rhyolite, 10 on silicified limestone, and 33 on alluvium. Five of the stops on alluvium were in washes and these will be considered in a later section.

Thirty-seven different woody species were encountered along the traverse. One other classification was made to include undifferentiated grassland communities where they occurred as the dominant form. In the following Table 5 only the plants thought to be indicators of rock type will be evaluated. Complete data obtained from the traverse follows in Appendix B.

The strong correlation of calciphiles to the limestone substratum is clearly indicated in the table. Although three species, Calliandra eriophylla, Cercocarpus breviflorus, and Cowania mexicana, happen to occur so rarely along the traverse that their presence may be too limited to be valid statistically, their preference for

Table 5. Reliability of Calciphile Species on Residual Soils. A--percent of stops at which species occurred; B--percent of stops on limestone at which species occurred; C--percent of stops on other rock types at which species occurred; Group I--species demonstrating strong affinity to the substratum; Group II--species demonstrating a preference for the substratum.

	Rock Types					
Species	ls	sil. ls	rhy	A	B	C
(Total plots)	(44)	(10)	(25)			
Calliandra eriophylla	3	-	-	4	7	0
Ceanothus Greggii	4	-	-	5	9	0
Cercocarpus breviflorus	1	-	-	1	2	0
Cowania mexicana	2	-	-	3	5	0
Dalea formosa	4	-	-	5	9	0
Mortonia scabrella	26	1	-	34	59	3
Parthenium incanum	8	-	-	10	8	0
Quercus pungens	4	-	-	5	9	0
(Occurrences-I)	52	1	0			
Acacia vernicosa	6	2	1	11	14	9
Fouquieria splendens	12	1	-	17	27	3
Lippia Wrightii	4	3	-	9	9	9
Rhus choriophylla	5	1	-	8	11	3
Rhus microphylla	8	2	-	13	18	6
(Occurrences-II)	35	9	1			
Total Occurrences:	87	10	1			

limestone is strongly evident by subjective observation. Cliffrose (Cowania mexicana) enabled the writer to locate an outcrop of limestone surrounded by igneous material near the center of the southeast corner of the study area. The shrub was found to grow in abundance in this locality (see Fig. 11) and soil samples taken there proved the soil to be considerably more alkaline than surrounding soils no more than 100 yards distant. It seems reasonable to presume by such evidence that this species, although scarce along the traverse, is a reliable indicator of rock type. Samples of limestone bedrock were also obtained from this locality.

Sandpaper bush (Mortonia scabrella) was the most abundant species encountered along the traverse. Although one plant was found growing on silicified limestone, this can most probably be considered an "accident" or "contamination" due in part, perhaps, to the often highly variable nature of the silicified outcrops. Being formed from limestone, they are obviously found in conjunction with it and often the two rock types are found together in a mixed condition containing pockets of both alkaline and acid mediums.

When the distribution of Mortonia is observed in the field, its confinement to the limestone substratum becomes even more evident, especially along the contact separating the calcareous and igneous rocks, (Fig. 12).

Fig. 12. Contact between Limestone and Rhyolite--
Mortonia and *Prosopis*

The most dense communities of this shrub were found growing in almost pure stands on the more clastic Earp Formation. On the Horquilla and other formations, the population is displaced toward north-facing slopes. Such a tendency would seem to indicate a soil-moisture preference in addition to its restriction to limestone.

The behavior of Lippia Wrightii and Acacia vernicosa is less apparent from the data obtained by the line traverse. When viewed subjectively in the field, and compared with what other investigations have found, however, their classification as having a preference for limestone substratum is strengthened.

The species exhibiting the least reliability subjectively, although indicating a strong correlation for a limestone preference along the traverse, is ocotillo (Fouquieria splendens). Dense stands of ocotillo were found to inhabit rocky outcrops of silicified limestone in the study area, and although it is not completely absent on rhyolite, its presence in Group II as a limestone preference indicator in the study area is considered valid. What is perhaps more indicative of this shrub, however, is its preference for extremely rocky (in some cases growing in crevices in bedrock), shallow soils and dry, southerly slopes.

Table 6 lists the species considered to be calciphobes. Immediately apparent from the table when compared with the list of calciphiles, is its brevity. This may be due in part to some effect of climate (moisture), because the difference in abundance of calciphile species over calciphobe species seems to be more pronounced with increasing aridness (Rzedowski 1955, p. 152). That is, the number of calciphobe species, being, in general, better adapted to arid conditions, tends to remain high while total numbers of calciphobe species decline with increasing aridity. It is also apparent in the literature, especially flora keys, that the calciphobe species seem to receive less recognition as being such than calciphiles. Authors often give recognition to plants exhibiting a preference for limestone, but plant indicators of igneous rock types are seldom differentiated.

Mesquite (Prosopis juliflora) was the most abundant occurring calciphobe along the traverse, and therefore offers the most reliable data concerning its distribution. Its seemingly strong preference for igneous materials may be due in part to coincidence, however, since it is in the rhyolite sector of the study area that alluvium is best developed and most abundant. As will be discussed in a later section, the preference of mesquite for areas of sufficient soil depth through its root system can tap

Table 6. Reliability of Calciphobe Species on Residual Soils. A--percent of stops at which species occurred; B--percent of stops on rhyolite at which species occurred; C--percent of stops on other rock types at which species occurred; Group I--species demonstrating strong affinity to the substratum; Group II--species demonstrating a preference for the substratum.

	Rock Types					
Species	ls	sil. ls	rhy	A	B	C
(Total Plots)	(44)	(10)	(25)			
Arctostaphylos pungens	-	-	2	3	8	0
Prosopis juliflora	-	2	10	15	40	4
Quercus Toumeyi	-	-	2	3	8	0
(Occurrences - I)	0	2	14			
Eysenhardtia polystachia	1	2	-	4	0	6
Quercus Emoryi	1	3	6	13	24	8
Acacia constricta	2	-	4	8	16	4
(Occurrences - II)	4	5	10			
Total Occurrences	4	7	24			

subsurface water sources is quite strong. Based on traverse data and observation in the field, however, the classification of *Prosopis juliflora* as a calciphobe is considered valid, at least within the confines of the study area.

The two species of oak (*Quercus Emoryi* and *Q. Toumeyi*) and manzanita (*Arctostaphylos pungens*) listed in the calciphobe table were noted to populate either well drained, coarse soils as in the case of Toumey oak and manzanita, or to be markedly displaced to north-facing slopes as in the case of Emory oak. *Quercus Emoryi* was almost absent on the limestone substratum, and where it did occur, it was confined to the more mesic north slopes. *Q. Toumeyi* was not found to inhabit limestone areas at all, and was restricted to sandy, more coarse rhyolitic soils found in the extreme eastern corner of the study area. Manzanita was also most abundant on the light colored rhyolitic soils, but several plants were noted near washes in other localities. From the above distributional preferences it seems reasonable to presume that a moisture factor is also present in influencing the distribution of these species.

Although the occurrence of kidneywood (*Eysenhardtia polystachia*) was not common in the study area and was not recorded at all on rhyolite from the traverse, this species definitely exhibits a marked preference for non-calcareous substrata in the study area. It seemed to be well adapted to rocky, south-facing slopes and attained its highest concentration in the area on a silicified limestone outcrop. It became noticibly less abundant on the surrounding limestones. Kidneywood is not absent on rhyolite as the traverse data would seem to imply, but confines itself to rocky, more southerly slopes on this substratum.

Perhaps the most significant data provided by the line traverse was the fidelity of species, i.e., the degree of restriction of particular species to a particular situation. The highest fidelity of plants to substratum was shown by the eight calciphiles listed as having strong affinities to the substratum in Table 5. These eight species occurred fifty-two times on limestone along the traverse, only once on silicified limestone, and not at all on rhyolite. Calciphile species within Group II demonstrating only a preference for calcareous mediums occurred thirty-five times on limestone, nine times on silicified limestone, and once on rhyolite. The calciphobe species listed in Table 6 showed slightly less fidelity to igneous substratum. The three species occurring within Group I occurred fourteen times on rhyolite, two times on silicified limestone, and not at all on limestone. The remaining three species from Group II occurred ten times on rhyolite, five times on silicified limestone, and four times on limestone. In all, the calciphile species showed a high fidelity to limestone occurring a total of eighty-seven times on that rock type compared with only eleven times on other rock types. Total occurrences of all calciphobe species on rhyolite was twenty-four compared to eleven on limestone and silicified limestone, their fidelity to igneous substratum being somewhat less than that demonstrated by calciphiles.

The control plots offer further information in regard to the distribution of vegetation in the northern Swisshelms. Of the eight quadrats established, six were located in areas which contained evidence of lithologic types in the form of rock outcrops. Two were located on alluvium and will be considered in a later section. The quadrats were located in plant communities which were considered to be representative of the vegetation common to the respective rock types, and therefore the species recorded in each quadrat reflect, to a certain extent, the shrubs common to the three lithologic materials studied. Of course not all the species encountered along the traverse are present in the quadrats, however, they do serve as a control of the traverse data. Only the species considered as calciphiles and calciphobes will be evaluated in the table. For more complete data concerning the quadrats see Appendix C.

Table 7 clearly shows a correlation of calciphiles to limestone substratum and calciphobes to rhyolitic material. The quadrat located on siliceous limestone, Number 4, gives recognition to the fact that ocotillo, (Fouquieria splendens) is present on rock types other than limestone in

Table 7. Calciphile and Calciphobe Species on Control Quadrats 1 Through 6. I--calciphiles; II--calciphobes; 1--Horquilla formation (facing SE); 2--Horquilla Formation (facing N); 3--Earp Formation (level); 4--silicified limestone (facing S); 5--rhyolite (facing SE); 6--light rhyolite (facing W).

Species	Limestone			Silicified Ls	Rhyolite	
I	1	2	3	4	5	6
Dalea formosa	1	-	5	-	-	-
Fouquieria splendens	7	-	-	26	-	-
Calliandra eriophylla	1	-	-	-	-	-
Cowania mexicana	-	6	-	-	-	-
Lippia Wrightii	-	-	-	12	-	-
Mortonia scabrella	2	-	27	-	-	-
Quercus pungens	1	-	-	-	-	-
Rhus choriophylla	-	1	1	-	-	2
Rhus microphylla	4	-	-	-	-	-
II						
Arctostaphylos pungens	-	-	-	-	-	7
Prosopis juliflora	-	-	-	-	2	-
Quercus Emoryi	-	1	-	-	2	-
Quercus Toumeyi	-	-	-	-	-	4

the study area as was noted previously. It is interesting to note, however, the abundance of *Lippia Wrightii* within Quadrat 4. This again may be due, in part, to contamination as was noted previously in the case of *Mortonia scabrella* on silicified limestone. Blumer (1908, p. 120) reported the presence of this species on limestone from the eastern slope of the Swisshelm Mountains, and noted that the plant was strongly influenced by bedrock origin. The distribution of *Lippia Wrightii* has also been reported to be influenced by a temperature-moisture requirement since it exhibits a pronounced aspect preference. Blumer (1908, p. 120), Spalding (1909, p. 126), and the present writer found the shrub to be growing on northerly slopes at low elevations and southern exposures at its higher altitudinal limit. The plant is commonly confined to a rather steep, rocky habitat.

Although more abundant on limestone in the study area, *Rhus choriophylla* was also recorded from Quadrat 6 located on rhyolitic material containing more potash and silica than the darker rhyolite of Quadrat 5. The lighter-colored rhyolite weathers into a more coarse, sandy-textured soil which favors penetration of roots and moisture required by many shrubby species. It is on this rock type that a chaparral-structured vegetation type occurs. It is quite possible that the distribution of Rhus choriophylla is influenced more by physical-textural properties of the soil than by chemical tolerances.

In Quadrat 2 the presence of Quercus Emoryi on limestone substratum can perhaps be explained by two observations. First, the quadrat was located on a north-facing slope which would tend to provide the more mesic habitat conditions required by this species. Secondly, the limestone outcrop on which Quadrat 2 was established is exposed on the lower slope of a higher rhyolitic hill extending above the outcrop. A dense stand of oak inhabits this north-facing rhyolitic slope immediately above the limestone. It seems reasonable to presume, on this basis, that acorns might easily be displaced downward onto the limestone outcrop, greatly increasing the chances for "accident" occurrences.

The remaining species listed in Table 7 follow rather closely the behavior of the calciphiles and calciphobes recorded from traverse data and would seem to substantiate use of these plants as indicators. Although not present along the traverse or in the control quadrats, one species, Condalia spathulata (Squaw-bush) was observed subjectively to exhibit a strong preference for calcareous substratum.

Eleven species encountered along the traverse have not been classified as being either calciphiles, calciphobes, or ambiguous. They were excluded from any category either because the presence of a species was too limited in the area to provide successful analysis, or because of the possibility that other factors might be more influential in affecting their distribution. A list of these species follows in Table 8.

The distribution of the five tree forms in Table 8, (Juniperus deppeana, J. monosperma, Pinus cembroides, Quercus arizonica, and Q. oblongifolia), all present the possibility of factors other than substrata influencing their distribution. Presumably moisture factors are active in regard to the preferences of these species. Cumming (1952, p. 29) noted both Emory oak and Mexican blue oak (Q. oblongifolia) to be confined to north slopes in his study area, and although his study did not mention Arizona oak, a similar relationship holds true for this species in the Swisshelm Mountains. Another species exhibiting moisture preferences is silk tassel (Garrya Wrightii). Whittaker and Niering (1968, p. 7) found this shrub on both limestone and acid soils, but noted its distribution as being displaced to more mesic localities on limestone. The present writer encountered the species only three times along the traverse and two of these occurred in washes

Table 8. Species Not Considered as Calciphiles or Calciphobes or Ambiguous. (because of limited presence in the study area or the possibility of other factors influencing their distribution)

- *Ephedra trifurca*
- *Fallugia paradoxa*
- *Garrya Wrightii*
- *Larrea tridentata*
- *Juniperus deppeana*
- *Juniperus monosperma*
- *Pinus cembroides*
- *Quercus arizonica*
- *Quercus oblongifolia*
- *Rhus trilobata*
- *Zinnia pumila*

on limestone. The third occurred on light-colored rhyolitic material.

Creosote bush (*Larrea tridentata*) was too limited in the area to provide reliable analysis, however, some observations on its distribution will be discussed in a later section. *Rhus trilobata* also falls into this category. In a study of plant communities of sandy soil, Ramaly (1909, p. 316), found this species to grow in pure sand. In the Swisshelm Mountains the shrub was recorded twice along the traverse--once in a sandy wash, and once on the more clastic Earp Formation. These observations seem to verify the preference of this shrub for sandy, well-drained soils.

Grassland communities, where they occurred in almost pure stands, were recorded along the traverse. However, the various species of grass occurring in each stand were undifferentiated because their value as indicators of substrata is, in the first place, less known and secondly, the value of their use in the field is somewhat limited since they are less conspicuous than shrubs or trees and much more effort is required in differentiating species that might indicate lithology, especially at a distance. It can readily be observed in the field, however, that grassland areas are markedly better developed on the north-facing slopes of igneous material or on the rolling rhyolitic hills in the northeastern section of the study area than on the rocky limestone ridges which seem to be more favorable to the adaptation of shrubby species.

Effectiveness

The effectiveness of calciphiles and calciphobes, i.e., the degree to which calciphile and calciphobe species in one area correspond to related plants found to have lithologic preferences in other localities, is difficult to ascertain. Not only do physiologic differences in species within the same genera exhibit contrasting habitat preferences, but environmental conditions and relationships vary greatly from one area to another. It is virtually impossible for one investigator to examine all indicator species everywhere in order to validly determine their effectiveness. It is possible, however, in an attempt to examine this problem, to compare how well local calciphiles and calciphobes correspond with what other investigators have found in different localities. Such a comparison between species in the Swisshelm Mountains and species and genera found to indicate similar lithology in other areas follows in Table 9. Although the regions used in comparison range in distance from the study area from only a few miles to nearly one thousand, and the differences in climate and other environmental conditions are surprisingly great, a certain amount of correlation is evident.

The works of nine authors were utilized in the comparison (Table 9). Five, (Blumer 1908, No. 1; Cuyler 1931, No. 2; Rzedowski 1955, No. 3; Wells 1962, No. 4; and Whittaker and Niering 1968, No. 5) were the products of specific studies related in one way or another to vegetation and the conditions it indicates. Two works used (Benson and Darrow 1954, No. 6; and Kearney and Peebles 1964, No. 7) were keys to flora of Arizona and nearby regions. One (Shreve 1942, No. 8) consisted of a rather general work on the vegetation of desert regions of North America, and one LeSueur 1945 No. 9) involved a study of the vegetation of Chihuahua, Mexico. The indicator studies were made in the following locations: Blumer, southeastern Arizona; Cuyler, central Texas; LeSueur, Chihuahua, Mexico north of parallel 28; Rzedowski, San Luis Potosí, Mexico; Wells,

Table 9. Comparison of Local Calciphile and Calciphobe Plants with Species and Genera Found to Indicate Lithology in Other Areas. S--species comparison; G--genera comparison; C--calcareous substratum; I--igneous substratum; *--specific study; #--mentioned indication; _--most abundant occurrence; I--calciphiles; II--calciphobes. Author explanation in text.

Species	Author								
I	1	2	3	4	5	6	7	8	9
Acacia vernicosa	-	-	-	-	SC*	SC#	SC#	SC#	-
Calliandra eriophylla	-	-	-	-	SCI*	-	-	-	-
Ceanothus Greggii	-	-	-	GIC*	SC*	-	-	-	SC#
Cercocarpus breviflorus	-	-	GC*	GI*	SCI*	-	-	-	-
Condalia spathulata	-	GC*	-	-	GC*	-	-	-	SC#
Cowania mexicana	-	-	GC*	-	-	SC#	SC#	-	-
Dalea formosa	-	-	GC*	-	SC*	-	-	-	-
Fouquieria splendens	-	-	-	-	SC*	-	-	-	-
Lippia Wrightii	SC*	-	GI*	-	SCI*	-	-	-	-
Mortonia scabrella	-	-	-	-	SC*	SC#	SC#	-	-
Parthenium incanum	-	-	GC*	-	SC*	SC#	SC#	-	-
Quercus pungens	-	-	-	-	-	-	SC#	-	SC#
Rhus choriophylla	-	-	-	-	SC*	-	-	-	-
Rhus		GC*	GC*	GI*					
Rhus microphylla	-	-	-	-	SC*	-	-	SC#	-

Table 9. (Continued)

Species	Author								
II	1	2	3	4	5	6	7	8	9
Acacia constricta	-	-	-	-	SCI*	-	-	-	-
Arctostaphylos pungens	-	-	SI*	GI*	SCI*	-	-	-	-
Eysenhardtia polystachia	-	-	GC*	-	-	-	-	-	-
Prosopis juliflora	-	GC*	-	-	SCI*	-	-	-	-
Quercus Emoryi	-	-	-	-	SI*	-	-	-	-
Quercus Toumeyi	-	-	-	-	-	-	-	-	-

San Luis Obispo quadrangle, California; and Whittaker and Niering, Santa Catalina Mountains, Arizona. The comparison of genera to species is done only in the light of interest. Any correspondence to local species is not meant to infer that because similar genera occupy similar substrata, differing species within that genera necessarily do.

From the limited data provided by Table 9, it is evident that there is considerable correspondence between local calciphiles and calciphobes and those that have been found to indicate rock type in other localities. Excluding comparisons which involved genera only, and those which occurred on both rock types, 14 of 20 species in the Swisshelm Mountains were noted by other investigators as exhibiting similar preferences, and 7 of these were noted by more than one investigator. Correspondence is also noticibly better for calciphiles than calciphobes.

The table provides less evidence for the long range effectiveness of calciphiles and calciphobes since the four studies occurring outside Arizona contain a majority of genera comparisons with the exception of the Chihuahuan study. Until a much larger selection of comparable studies and detailed data concerning the physiological requirements of single species within genera is available, determination of the effectiveness of indicator species will remain limited. Based on the data supplied in Table 9, however, it would seem that at least 12 of the calciphiles (based on having at least one speciescomparison) in the northern Swisshelms are substantially valid indicators of limestone in southern Arizona. As will be discussed in a later section, a more reliable list would be somewhat shorter.

Outside Arizona only one calciphobe species (Arctostaphylos pungens), was found to indicate comparable substratum. This comparison was from San Luis Potosí, Mexico. Only generic relationships are comparable for Texas and California.

Effect of Slope Exposure on Indicator Species

In the arid Southwest the effect of slope exposure on the distribution of species is remarkably pronounced. Since this environmental factor is present in the study area, its influences deserve recognition. Although slope aspect data was obtained along the traverse (see Appendix D) its usefulness is very limited for examining the effects of north and south-facing slopes because the traverse was directed west to east to eliminate such influences. However, some subjective observations can be made.

The relationship of vegetation to substrata seems to be more pronounced on south-facing than north-facing slopes where cooler temperatures and more mesic conditions are eliminated as factors influencing the distribution of vegetation.

None of the calciphiles lose their indicative values with changes in slope aspect. However, several species, as mentioned in previous sections, are more concentrated on one slope or another. Cliffrose (Cowania mexicana), one species of sumac (Rhus choriophylla), sandpaperbrush (Mortonia scabrella), mountain mahogany (Cercocarpus breviflorus), Ceanothus Greggii, and squaw bush (Condalia spathulata), all occur in greater abundance on north facing slopes at the elevation of the study area (4500 - 5500 feet). The displacement of Lippia Wrightii to south-facing slopes with increasing elevation has alread- been noted. Species exhibiting a marked preference for south-facing slopes are ocotillo (Fouquieria splendens) Acacia vernicosa, and Calliandra eriophylla.

Emory oak, listed as a calciphobe, does seem to lose to a limited extent its indicative value on north-facing slopes where conditions are favorable to its establishment. It was recorded once on calcareous substratum along the traverse, but on a north-facing slope. The species was also recorded in Quadrat 2 on a north-facing limestone outcrop. It is interesting to note, however, that oaks in the area grow in abundance at lower elevations on the rhyolitic substratum than on the limestone where their presence is quite rare. This phenomena is similar to Shreve's findings (1922, p. 272), who remarked,

> The lowest absolute elevations are reached by encinal and forest on gneiss and granite, and desert forms correspondingly attain lower maximum elevations on those rocks and their derived soils. The vegetational zones are higher on basalt, rhyolite, and other volcanics, and--at least with respect to certain conspicuous species--still higher on limestone.

Indicator values of the remaining calciphobes do not diminish with varying aspects but, as with the calciphiles, several species show marked preferences for certain slopes. Kidneywood (Eysenhardtia polystachia) and whitethorn (Acacia constricta) were noted in greatest concentrations on south-facing slopes. Manzanita (Arctostaphylos pungens) and Toumey oak (Quercus Toumeyi) were recorded only from a rather gentle west-facing slope on well-drained soils and as such, their presence at this locality was not likely due to a slope preference. Mesquite (Prosopis juliflora) is best adapted to level or very gently sloping habitats.

Influence of Soils on Indicator Species

Literature regarding the controversy as to whether the physical or chemical properties of soil are the more important in influencing plant distribution has been briefly mentioned in my review of the literature. In an attempt to examine this problem in the Swisshelm Mountains, soil samples were taken on each of eight quadrats. Six of the quadrats (Numbers 1 - 6, see Appendix C) were located in areas containing outcrops of bedrock on moderate to steep slopes and as such, the material sampled in these quadrats was considered to be residual. These soils were commonly shallow and rocky and hence might be more correctly referred to as lithosols. As such, these young soils owe many of their characteristics to the parent materials from which they evolved. Furthermore, evidence from biogeochemical prospecting points to a strong relationship between chemical composition of parent material, soil, and vegetation (Cannon 1957). Two of the soil samples were taken on alluvium and are discussed in a later section.

Soil reaction data was obtained for each quadrat. This is usually expressed by the pH scale which is the negative log of H ion concentration in the soil solution (Daubenmire 1959, p. 42). Properties of the soil, including pH, respond to changes in environment and vary with soil depth, texture, and other factors. Indeed, McGeorge (1944, p. 419) states that, "Mention is often noted in the literature that there is no such thing as a definite or true soil solution, that there is no such thing as a definite or true base exchange capacity, and finally that there is no such thing as a definite or true pH value." However, the influences of these factors all contribute to behavior of soils and vegetation. Daubenmire (1959, p. 48) also stressed the complexity and difficulty in assessing the chemical, physical, and biological properties of the soil " . . . which vary concomitantly with pH . . . ", yet he emphasized, "Still, no other single value for a soil tells so much about its ecologic character." Table 10 lists the pH values for Quadrats 1 - 6 and two additional soil samples (A and B) from localities representing two different plant communities in close proximity to one another. Complete soils analysis data are listed in Appendix E.

Table 10. pH Values for Soil Samples from Quadrats 1 Through 6 and Soil Samples A and B.

	Rock Type							
	Limestone			Sil. ls	Rhyolite		Calcareous Alluvium	Non calcareous Alluvium
Quadrat	1	2	3	4	5	6	A	B
pH value	7.82	7.72	7.9	5.1	6.5	5.6	7.6	5.7

The table clearly indicates higher pH values for those quadrats located on calcareous parent material. "Basic soil reaction is the result of an abundance of salts of types that hydrolyze to yield strong bases" (Daubenmire 1959, p. 44). The basic salts involved in arid regions are commonly calcium and sodium carbonates. The calcium salts have their origins either from limestone which yields calcium carbonate as it decomposes or from the darker igneous rocks which are low in silica, but high in Ca, Mg, and Fe. Soils derived from parent materials composed of light-colored igneous rocks containing oxides of Na and K, and silica in abundance, however, tend to be more acidic (Daubenmire 1959, p. 44). pH values for the soils obtained in the study area tend to strongly exhibit behavior in accordance with the above statements.

The presence of calciphile species on limestone may be reviewed in Table 5. In comparing Tables 5 and 10, a relationship between calciphile species and pH values of slightly basic reaction becomes evident except in the case of ocotillo (*Fouquieria splendens*) and *Lippia Wrightii*. Both were found in substantial quantities in Quadrat 4 (see Appendix C) on silicified limestone which gave a considerably more acid reaction than limestone. It is interesting to note in soil samples A and B that cliffrose (*Cowania mexicana*) was found to be growing in abundance on the soil having a pH reaction of 7.6. No more than 100 yards distant and at a similar elevation (5,250 feet) and slope aspect, an *Agave*-grass association with some oak and juniper (characteristic of the rhyolitic substratum) was found to occupy the soil type B having a more acid pH value of 5.7. The pH values for Quadrats 5 and 6 and soil sample B indicate slightly acid conditions which correspond to the rhyolite substratum.

Calciphile and calciphobe species have generally been associated with the presence or absence respectively of calcium carbonate. Daubenmire (1959, p. 45) noted that, "The calcium status of a normally drained soil is fairly well correlated with its pH . . . The range 8.3 to 6.0 indicates saturation with bases, among which calcium is the most abundant." Milequivalents per liter of Mg plus Ca obtained in the soil analyses (see Appendix E) showed higher concentrations of Mg plus Ca for soils located on limestone with the exception of Quadrat 3 which was located on the more clastic Earp Formation limestone.

McGeorge (1944, p. 380) noted that a relationship exists between the presence of $CaCO_3$ and pH " . . . but it is not quantitatively related to the percentage of $CaCO_3$ in the soil." However, he concluded that, "Calcareous semiarid soils have higher pH values than non-calcareous soils" (p. 423). It is not, however, the $CaCO_3$ that is directly available to growing plants. De Silva (1934, p. 552) found that in addition to following pH reaction in some cases, " . . . the distribution of calcicoles appears to be correlated with content of exchangeable calcium . . ." and, "The calcifuges appear to follow the soil reaction."

On this basis, calciphiles would tend to grow only on those soils which are quite basic and contain available free $CaCO_3$, or on less basic soils containing exchangeable calcium. Since the value for Ca plus Mg is less and the pH values are lower (more acid) for the soils derived from non-calcareous (rhyolite and silicified limestone) rocks when compared with those derived from calcareous (limestone) rocks in the study area, the importance of the chemical properties of the soil can readily be seen. Furthermore, since the soils are lithosols, the role of parent material in influencing the distribution of vegetation is given support.

Calcium salts tend to act in both direct (chemical effect) and indirect (physical-chemical effect) form (Rzedowski 1955, p. 153). It was once thought that the physical influence of the soil on calciphiles was due to the fact that they occurred on soils containing $CaCO_3$, and that such a medium was light and dry, creating the physical properties required by calciphiles. De Silva (1944, p. 550) found, however, that calciphiles sometimes grew in soils devoid of calcium carbonate, but that in such soils there was a high concentration of exchangeable calcium. Physical properties are involved to some extent, however, since it is ". . . the clay fraction of the soil which is the active agent of exchange phenomena." De Silva concluded that ". . . examination of exchangeable calcium content of the soil reveals a greater significance of the chemical than the physical aspect of the soil in relation to plant distribution, though the physical aspect cannot be wholly ignored" (p. 550).

Mechanical analyses of the soils sampled from Quadrats 1 - 6 and soil samples A and B are listed in Table 11. The soils are broken down into percent sand, silt, and clay. Since it has been customary in plant ecology to differentiate between fine and coarse materials, an additional figure is given which represents the combined silt and clay percentages.

Table 11. Mechanical Analyses of Soils from Quadrats 1 through 6 and Soil Samples A and B. Coarse Fragments Removed.

	Rock Type							
	Limestone			Sil. ls	Rhoylite		Calcareous	Noncalcareous
Quadrat	1	2	3	4	5	6	A	B
% Sand	52	29	24	22	52	63	63	40
% Silt	38	41	45	59	38	27	18	34
% Clay	10	30	31	19	10	10	19	26
% Silt and Clay	48	71	76	78	48	37	37	60

Table 11 offers no immediate relationships between the physical properties of the soil and the parent materials from which they derived. The soils in the study area in the Swisshelm Mountains are shallow and rocky. There is very little profile developed in any of the soils, and soil structure does not seem to differ from one substratum to another. It would seem, however, that soil texture should provide a good indication of the edaphic moisture available to plants. Rzedowski (1955, p. 153) in San Luis Potosí, Mexico, briefly discussed the influence of moisture in the more compacted igneous soils in contrast to the limestone soils of greater permeability. He noted that in the igneous soils edaphic moisture was greater and this was reflected in the vegetal cover.

Because moisture holding capacity is greatest in fine-textured soils (those having relatively high percentages of silt plus clay), one might look to such soils as supporting those species of plants to which a high soil-moisture requirement was necessary. Limestone substratum has been reported as supporting xerophytic species at higher elevations than other substratum, and this phenomenon occurs noticeably in the Swisshelms. Yet, the texture data provided in Table 11 for the few samples taken, indicates finer textured soils on limestone substratum. On this basis there would seem to be a better soil-moisture regime on the calcareous soils. If this is true it is difficult to determine the factors responsible for the distribution of oaks at lower elevations on rhyolite rather than limestone. Other factors are, of course, involved in the complex soil-moisture-plant relationship, and as Shreve (1922, p. 274) mentions, "In the case of limestone soils . . . the texture appears to be favorable to the retention of moisture, and the causes underlying the high altitudinal limits of desert species on these soils requires investigation."

Mechanical analyses of the soils located on the light-colored rhyolite offer some indication of a textural relationship between soil and the vegetation it supports. As has been previously noted, light-colored igneous rocks tend to produce more acidic soils. In addition, Lutz (1958, p. 81) stated that igneous rocks which contain varying amounts of orthoclase, quartz, and plagioclase feldspars, and with smaller amounts of ferromagnesium minerals, generally produce relatively poor soils. The light-colored rhyolite in the study area is, in addition to being less fertile than the finer textured soils, the most coarse-textured of the lithosols, having a 63% sand content.

Saunier (1964), who studied factors affecting the distribution of shrub live oak, maintained that these species of his chaparral vegetation were best developed on coarse, highly fractured and decomposed quartz diorite, and it is often noted in the literature that chaparral is best developed on coarse, even sandy soils. Such a texture does not restrict root penetration needed by the often deep rooted species characteristic of the chaparral vegetation, and in turn, creates a better moisture regime for these plants. The light rhyolite of Quadrat 6 offers such a habitat for a vegetation type similar in structure to chaparral. The substratum in this limited section of the study area is conducive to the growth of such sclerophylls as silk tassel (_Garrya Wrightii_), manzanita (_Arctostaphylos_ pungens), Quercus Toumeyi and other oaks. In addition, several seedlings of pinon (Pinus cembroides) were found in this location as well as juniper (Juniperus Spp.). The presence of these tree forms seems to be in agreement with Daubenmire's (1959, p. 19) general observation that " . . . forests extend farthest into the arid regions on coarse soils [which] can be explained in part by the rapid infiltration and percolation of rain in such soils, as well as by the deeper root systems and greater availability of water there."

Parts per million of soluble salts in the soil solutions of the various samples were also analyzed (see Appendix E). The data indicates that none of the soils are saline, and it is interesting to note that Cannon (1957, p. 402) found cliffrose, mountain mahogany, and Rhus trilobata to prefer habitats of low salt content. Although there seems to be some relationship between pH values and soluble salts in the saturation extract, McGeorge (1944, p. 423) states that " . . . there is no correlation between total salinity and pH values when analyses of a large number of soils are compared."

Indicator Species on Alluvial Deposits

In addition to the residual materials formed in place on the various rock types of the study area, deposits of transported material occupy valley bottoms and saddles along ridges. Because plants also inhabit these materials, it is pertinent to investigate their influence on the vegetation in the area.

A total of thirty-three stops were made on alluvium (five in washes) along the traverse, and two quadrats, numbers 7 and 8, were taken on alluvial materials. In order to determine in what ways these deposits might influence indicator species, dilute hydrochloric acid was used to test the reaction of the various soil materials encountered along the traverse when they were clearly not residual. Although such a procedure only tests whether a given material is basic (reaction) or not basic (no reaction) and does not provide a scalar value for the concentration of hydrogen ions present, its use as a rule of thumb test for determining basic materials has been well proven. Basic and non-basic alluvium correlated well with areas of parent limestone and rhyolite from which they were derived. pH values for the two control quadrats on alluvium were obtained, however (see Appendix E). Table 12 contains data for twenty-one species occurring on alluvium and in washes along the traverse.

Several of the species listed as calciphiles in the study area tend to lose, somewhat, their validity as indicators of alluvium as in the cases of _Rhus choriophylla_, _Lippia Wrightii_, and _Acacia constricta_, however the other

Table 12. Traverse Data for Species Occurring on Basic and Non-Basic Alluvium and in Washes. I--calciphiles; II--calciphobes; III--others.

Species	Basic Alluvium	Non-Basic Alluvium	Wash	% pos.	% neg.	% wash
I						
Acacia vernicosa	-	-	2	-	-	100
Calliandra eriophylla	1	-	-	100	-	-
Ceanothus Greggii	4	-	1	80	-	20
Dalea formosa	2	-	-	100	-	-
Lippia Wrightii	-	2	-	-	100	-
Mortonia scabrella	9	-	-	100	-	-
Rhus choriophylla	-	2	1	-	66	33
Rhus microphylla	3	-	2	60	-	40
II						
Acacia constricta	2	1	1	50	25	25
Prosopis juliflora	2	16	-	11	89	-
III						
Agave Parryi	-	1	-	-	100	-
Opuntia Spp. (cholla)	-	5	-	-	100	-
Ephedra trifurca	1	2	-	33	67	-
Fallugia paradoxa	-	-	1	-	-	100
Garrya Wrightii	-	-	2	-	-	100
Grass Spp.	1	1	-	50	50	-
Larrea tridentata	1	-	-	100	-	-

Table 12. (Continued)

Species	Basic Alluvium	Non-Basic Alluvium	Wash	% pos.	% neg.	% wash
Nolina microcarpa	5	1	1	71	14	14
Opuntia Spp.	2	4	-	33	67	-
Quercus arizonica	-	-	3	-	-	100
Rhus trilobata	-	-	1	-	-	100

calciphile and calciphobe species appear to show some correlation with either basic or non-basic alluvial deposits. Rzedowski (1955) in his study of indicator species in San Luis Potosí, Mexico chose to ignore plant behavior in alluvial and other deposits because of the problem of mixing and overlapping of sediments derived from different parent rock. However, because composition and texture of alluvium are closely related to distance from parent rock and most of the alluvial deposits within the study are are in close proximity to parent material, I have made some observations on the distribution of species inhabiting alluvial areas.

Sandpaper bush (*Mortonia scabrella*) correlated well with basic alluvium which was clearly derived from limestone. Although no pH values are available for alluvium supporting this species it was not found at all on the rhyolitic alluvium having substantiated pH value of 6.9.

Because nine shrubs of Mortonia were found on basic alluvium, in addition to its previously discussed strong correlation to limestone substratum, this plant is the most reliable indicator of calcareous substratum in the study area. Other calciphiles which correlated with basic alluvium were Rhus microphylla, Dalea formosa, Calliandra eriophylla, and Ceanothus Greggii. Calciphobe species, Prosopis juliflora and Acacia constricta offer less correlation.

The most abundant species occurring on alluvium along the traverse was mesquite (Prosopis juliflora). It was present on alluvium with negative reactions in 89% of the occurrences. In Quadrat 7, taken on the same material, thirteen plants were present along with two desert broom brushes (Baccharis sarothoides). A soil sample from this locality provided the figure of 6.9 for its pH value. Such a value, almost neutral, in addition to the fact that mesquite occurred twice (11%) along the traverse on alluvium with a positive reaction, tends to weaken the hypothesis that this species is an indicator of igneous soils. It seems possible that other factors may be more important in influencing its distribution.

In the study area mesquite is a prominent feature on alluvial deposits where there is sufficient soil depth to support its growth. It occurs in greatest densities on nearly level floors and decreases in abundance with increasing elevation on the colluvial material which masks higher slopes. It has also been associated with areas having available ground water (Meinzer, 1927; Shantz, 1938). These two authors have considered mesquite an indicator of ground water rather than anything else, although Spalding (1909, p. 37) noted that quite often the soil in which it was found tended to have less caliche content than those soils occupied by creosote bush (Larrea tridentata).

Two species which were encountered along the traverse on alluvial material deserve mention here. One is the creosote bush (Larrea tridentata) which is limited in study area, but was found to occupy transported soils derived from both limestone and rhyolite material. It was more common basic soils, however. It was noted at higher elevations than mesquite, but still within deep, well drained soils. The physiologic requirements of this species seem to favor a soil-moisture relationship even though seemingly apparent correlations between chemical properties of the soil and its distribution often exist. Martin (1963, p. 11) noted that, "Near the Chiricahua Mountains Larrea occurs commonly only on bajada soils derived from limestone." Both Shreve and Mallory (1933) and Yang (1951), however, have attributed its distribution more to physical than chemical properties of soils. Indeed, Shreve and

Mallory (1933, p. 112) state that, "The chemical properties of highly calcareous soils appear to be of less importance than the physical relation to the growth of Larrea." Only one soil sample on which creosote bush occurred was subjected to mechanical analysis. It revealed a 58% sand content which would suggest a porous, internally drained soil is preferred by this species.

The other species is Mormon tea (Ephedra trifurca) which also occurs in only limited numbers in the study area. It was encountered three times along the traverse, twice on alluvium with a basic reaction and once on alluvium with a negative reaction. Subjectively no correlation with sediments derived from either limestone or rhyolite parent material could be made. It appears to have a preference for sandy, well drained soils. Martin (1963, p. 11), however, noted that "Ephedra, shrubs partial to sand, are much more abundant on the sandy bajadas derived from gniess of the Catalina Mountains than on the stoney bajadas derived from rhyolite of the Tucson Mountains." It seems reasonable to presume that physical properties of the soil are important in influencing the distribution of this species.

Water availability and coarse textured soils seem to be of importance in limiting the distribution of several species in the area. Five stops along the traverse occurred in washes, and the species inhabiting these intermittantly watered localities undoubtedly show a stronger preference for soil moisture conditions than any other factor. Arizona oak (Quercus arizonica), silk tassel (Garrya Wrightii), skunk bush (Rhus trilobata), and Apache plume (Fallugia paradoxa), all fall within this category. Acacia vernicosa was found to be present twice in washes and not at all on alluvium along the traverse, however, preference for calcareous substrata is evidenced by abundance on lithosols derived from limestone.

In the northeastern corner of the study area where there is a limited flood plain along one of the three major washes draining the area, Chrysothamnus nauseosis, rabbit brush, occurs as a dominant (Fig. 8). Since the control quadrats were utilized in order to make known those elements that exist in the study area that are not present along the traverse, as well as to provide controls for traverse data, Quadrat 8 was located within this alluvial habitat. Although rabbit brush is likely an indicator of soil-moisture conditions and influenced by the physical properties of the soil, its occurrence may have also been influenced in part by man. Shantz and Peimeisel (1940, p. 22) in the Escalante Valley, Utah, found that species of Chrysothamnus resulted from abandonment after farming. Small areas around the farmstead in the study area, located on the flood plain, have been cleared in the past for grazing purposes. It is possible that this has created areas of disturbed habitat, perhaps through overgrazing, which, in addition to favorable edaphic conditions, rabbit brush has found less competitive. Ramaly (1909, p. 316) found *Chryosthamnus* to inhabit his "pure sand" community and it is interesting to note that the soil sample from Quadrat 8 indicates the most sandy conditions of the soils sampled (81 percent).

Plant Indicators of Rock Type in the Northern Swisshelm Mountains

The preliminary list of twenty calciphile and calciphobe species in the study area should probably be reduced. As previous analyses indicate, many of the species do indeed exhibit marked preferences for calcareous or igneous substrata, but because of subjective observation in other localities or a seemingly strong preference for factors other than can be attributed to properties of the substratum, their usefulness as indicators of rock types is considerably lessened. Of the fourteen calciphiles (Table 3) 7 present enough evidence in the study area to be labeled indicators of limestone or of alluvial material derived from limestone. Only one of six calciphobes can be used as an indicator of rhyolite in the area (Table 13).

Table 13. Plant Indicators of Limestone and Rhyolitic Substratum in the Northern Swisshelm Mountains, Arizona.

Indicators of Limestone Substratum	Indicators of Rhyolitic Substratum
Ceanothus Greggii	*Quercus Toumeyi*
Condalia spathulata	
Cowania mexicana	
Dalea formosa	
Mortonia scabrella	
Parthenium incanum	
Quercus pungens	

Although the species listed in Table 13 are the ones which provide the most accurate indications of lithology in the study area, the value of the remaining calciphiles and calciphobes should not be underestimated. When the factors influencing the ecological distribution of these species are understood, their use in the field is often as helpful as the plant indicators themselves.

Effect of Substratum on the Structure of Vegetation

Physiognomy, or structure, of vegetation is the ". . . organization in space of the individuals that form a stand" (Dansereau 1957, p. 147). Structural classifications can be based, however, on various characteristics of the stand, association, or vegetation type. Growth form, coverage, function, and stratification are perhaps the most common. In arid regions it is often important to stress the water relations of plants with the ecological classes of vegetation grouped into hydrophytes, mesophytes, phreatophytes, and xerophytes, using a more environmental basis for definition. The degree to which the structure of vegetation is influenced by differences in substratum has received very little attention in the literature, however. Perhaps this is because often very little correlation seems to exist, or perhaps because it is thought that factors other than substrata are responsible for the structural differences.

Studying vegetation in relation to geologic substratum and fire, Wells (1962, p. 102) stated, "Since grassland, shrubland, and forest occur on almost all geological substrata in the San Luis area, it is evident that the nature of the substratum has little direct influence on the physiognomy of vegetation under this range of climate, except when considered in connection with fire. But if the vegetation is regarded from the floristic standpoint, then the nature of geological substratum has a pronounced effect." In a strict sense this statement is probably true in most areas; however, when considered from a broad viewpoint, some generalizations can be made.

Upon entering the study area in the Swisshelm Mountains a pronounced difference in the structure of the vegetation in various sectors becomes evident (compare Fig. 4 and 9). Examination of the substrata that support the various vegetation types reveals distinct contact boundaries between rock types which become even more apparent through corresponding changes in the physiognomy of the vegetation.

When the vegetation of the area is viewed from different structural classes certain correlations with substratum are apparent. Using an environmental definition of structure based on the water relations of plants, for example, mesophytes and phreatophytes are much more common on the rhyolite substratum, with xerophytes more commonly inhabiting limestone. Hydrophytes, of course, are common to both substrata, but confined to washes.

In terms of growth form, herbs and trees are more prevalent on rhyolite while shrubs dominate the limestone substratum. Using a coverage classification it is evident in the field that a much more continuous coverage is characteristic of the shrub vegetation found growing on limestone. On rhyolite areas, however, coverage is dominantly discontinuous or at most, parklike in patches. Broadleaf sclerophylls are more abundant on the rhyolite substratum than the calcareous. There seems to be less variation when a functional structure classification is used, however.

The generalized vegetation types (Fig. 2) in the study area also appear to exhibit correlations to substratum. The scattered shrub and grass is confined primarily to the igneous substratum, whereas mixed dense shrub is found on limestone. Encinal and the open scrubby tree type vegetation both correlate well with rhyolite or its derived soils. In the southeastern corner of the study area, located on the coarse, porous, light colored rhyolite, a broadleaved, evergreen, sclerophyll, chaparral structured vegetation exists which is found on no other material in the area.

Although it is perhaps true in the strict sense that trees, shrubs, and herbs occur on each of the substrata in the area, when the structural forms are considered from the standpoint of their relative abundance on the various rock types certain correlations are apparent. In arid regions where there is a pronounced moisture stress, relationships between plants and the materials on which they are growing are intensified. It seems reasonable to presume that since such distinct patterns in structural vegetation types occur with differences in substratum, all within the same climatic regime, factors of the substratum are involved in influencing the physiognomy of vegetation.

Vegetation as an Indicator of Geologic Features

An interesting application of vegetation is its use as an indicator of geologic features, i.e., isolated outcrops, formations, and structure. Cuyler (1931) investigated the use of vegetation as an indicator of geologic formations in central Texas and found it a valuable aid. Although he stated that his method cannot necessarily be used in all parts of the country, he was sure that ". . . in many places valuable results in mapping geologic structure can be obtained by the use of plants as indices of geologic formations" (p. 78).

In most cases in the Swisshelm Mountains it is difficult to correlate vegetative differences with different geologic formations. Several formations occur in the limestone portion of the study area, but vegetation has been useful in differentiating only one with reasonable accuracy. This formation belongs to the Naco Group and differs in part from the other formations in its classic content. The Earp Formation contains more than 50% clastics and the Horquilla Formation, which is in the same group, less than 50%. The Earp Formation is commonly represented by dense communities of sandpaper bush (*Mortonia scabrella*). This does not mean that *Mortonia* does not occur on any other formation, but that it is associated more abundantly with the more clastic Earp

Formation. It grows on this substratum on all slope aspects whereas on other formations it is, in the first place, less dense, and secondly, more frequent only on their north facing slopes. An isolated outcrop of the Earp Formation limestone can be easily differentiated from the Horquilla Formation near the north central edge of the study area by an abundance of _Mortonia_ inhabiting the Earp limestone (Fig. 2). Two rounded hills of the Earp Formation near the center of the study area also support sandpaper bush in almost pure stands (Fig. 12).

With the use of indicator species, isolated outcrops of material differing in lithology from surrounding rock type can often be noticed at a distance by marked differences in species types. With the use of cliffrose (_Cowania mexicana_) as an indicator, the writer was able to identify two unmapped limestone outcrops located within the rhyolitic portion of the study area (Fig. 2). Furthermore, contacts between differing rock types can be recognized when the species characteristic of each lithologic feature are known. The occurrence of _Mortonia,_ for example, stops abruptly at the non-basic alluvium near the center of the study area (Fig. 12). The presence of _Cowania_ and _Ceanothus_ near the south central portion of the area revealed the contact between limestone and igneous parent material which supports an _Agave_-grass association.

A sill of diorite porphyry occurring in the extreme southern center of the area has been described and mapped by Loring (1947). A stand of oak and juniper coincide almost exactly with the extent of this instrusive igneous sheet. Although the oaks do not indicate diorite porphyry necessarily, their occurrence in a dominantly limestone area is at least indicative of a change in rock types even though the sill is partially covered by alluvium. Oaks were also found to inhabit the higher portions of peaks capped by quartzite and granite in the western portion of the study area, whereas they were absent from limestone peaks.

Vegetative indicators of geologic structure are less evident in the Swisshelms, although their use in other localities has been quite successful. Cuyler (1931) in central Texas has used plants to identify faults, anticlines, and synclines in addition to contacts. A narrow band of conspicuous vegetation, chiefly composed of Acacia vernicosa, follows what appears to be a fault zone in the western center of the study area. It is possible that enough water may be available along the fault plane to create desirable habitat conditions for this vegetation, or it may be growing in response to better textural qualities of the substratum along this zone. In addition, differences in vegetation densities coinciding with less resistant beds in the limestone protion of the study area often produce a slightly banded appearance on these ridges.

With more comprehensive sampling and analysis of vegetation and more detailed maps of geologic formations and structure in the area, it seems possible that more relationships between vegetation and formations and structure might be discovered. Present available information seems to provide evidence that vegetation does indicate some geologic features in the study area as well as lithology.

CHAPTER 11

SUMMARY AND CONCLUSIONS

Complexity of vegetative patterns and diverse lithology in the northern Swisshelm Mountains, Arizona, attracted me to investigate the relationship of vegetation to rock types in the area.

Calciphile and calciphobe species were identified in the field and their reliability tested along a traverse crossing various lithologic types. A measure of their effectiveness based on the degree to which calciphile and calciphobe species in one area correspond to related plants found to have lithologic preferences in other localities was made and a list of species compiled containing what were considered to be apparent indicator species of rock type. These species were then analyzed from the standpoint of their validity on different slope aspects and on alluvial materials derived from the various parent rocks in the area. Examination of the soil properties correlating with distributions of indicator species was also undertaken. Finally, correlation between vegetation structure and geologic substrata was investigated and the usefulness of calciphile and calciphobe species in indicating geologic features examined.

The following woody species are considered as being both reliable indicators of substratum in the northern Swisshelm Mountains, Arizona and sufficiently common in the study area to be useful: Of limestone, *Ceanothus Greggii*, *Condalia spathulata*, *Cowania mexicana*, *Dalea formosa*, *Mortonia scabrella*, *Parthenium incanum*, and *Quercus pungens*; of rhyolite, *Quercus Toumeyi*

It must be remembered in doing ecological work, however, that numerous environmental variables are present in any given location and more often than not, their interrelation rather than their isolated effects are the controlling factors influencing predominant patterns. When the woody vegetation of the northern Swisshelm Mountains is subjected to ecological investigation, several general statements concerning its distribution can be made:

1. Based on preferences for calcareous or igneous substratum a list of twenty calciphiles and calciphobes out of thirty-seven woody species encountered along a traverse was compiled. Twenty, however, was a larger number of species than could be labeled actual indicators of lithology because of the intervention of other environmental factors influencing certain species. Six of the thirty-seven woody species appeared to be adapted to both types of lithologic material and were labeled ambiguous.

2. In general, calciphile species tended to be more reliable indicators of rock type than calciphobe species and, in terms of sampled occurrences, sandpaper bush (Mortonia scabrella), a calciphile, was the most reliable indicator of substratum in the study area. As a group, calciphiles had a high fidelity on limestone occurring eighty-seven times on that substratum compared with only eleven occurrences on other rock types. Calciphobe species occurred twenty-four times on rhyolite and eleven times on limestone and silicified limestone, showing somewhat less fideltiy to a particular substratum than was demonstrated by calciphiles. A measure of effectiveness was gained by comparing local calciphile and calciphobe species with those other investigators have found in varying localities. Fourteen of twenty calciphile and calciphobe species in the Swisshelm Mountains were noted by other investigators as exhibiting similar indications in various localities, and seven of these were noted by more than one investigator. Based on having at least one species comparison in another area, twelve of the calciphiles in the Swisshelms can be considered as demonstrating a preference for calcareous substratum in southern Arizona. Only generic relationships were comparable for regions outside Arizona, with the exception of Chihuahua, Mexico.

3. With the exception of Emory oak, calciphile and calciphobe species did not lose their validity with changes in slope aspect, although there was a marked concentration of certain species on preferred slopes within each type.

4. Soil analyses from the rock types pointed to a better correlation between the chemical properties of the soil and the distribution of calciphiles and calciphobes than between the physical properties of the soil and their distribution. However, the influences of both chemical and physical properties of the soil are suggested. There is a strong correlation between higher pH and Ca plus Mg and calciphiles on the various lithosols. One vegetation type (chaparral) seems to correlate well with textural properties of the soil.

5. Composition and texture of alluvium and colluvium are closely related to distance from parent rock, and are either basic or acidic depending upon source of material. Seven of ten calciphile and calciphobe species occurring on alluvium along a traverse were found to correlate well with basic and non-basic alluvial deposits respectively. Although there is some evidence of mixing and overlapping of various sediments in a few locations, the majority of the species tended to retain their values as indicators of sources of alluvium. Several species, not included as

calciphiles or calciphobes, were found to exhibit strong preferences for more mesic habitats along intermittent stream courses in the area.

6. Vegetation types as well as flora differ distinctly from one substratum to another. When the structural forms of the vegetation types are considered from the standpoint of their relative abundance on various lithologic substrata, certain correlations between the substratum and the type of vegetal structure it supports are apparent, for example, trees and grass on rhyolite and shrubs on limestone. It seems reasonable to presume that certain factors of the substratum are involved in influencing the physiognomy of the vegetation.

7. Indicator species as well as other calciphiles and calciphobes were found useful for indicating such geologic features as contacts between lithologic types, a fault zone, and isolated outcrops of material differing in lithology from surrounding rock types. With more detailed knowledge of relationships between flora and the substratum, differentiation of geologic formations based on floristic differences is conceivable.

APPENDIX A

WOODY SPECIES COMMON TO THE STUDY AREA

Scientific Name	Family	Common Name
Acacia constricta	Leguminosae	white-thorn
Acacia constricta vernicosa	Leguminosae	
Agave Palmeri	Amaryllidaceae	century plant
Agave Parryi	Amaryllidaceae	
Arctostaphylos pungens	Ericaceae	point-leaf manzanita
Atriplex canescens	Chenopodiaceae	four-wing salt bush
Baccharis glutinosa	Compositae	seep-willow, batamote
Baccharis sarothoides	Compositae	desert broom
Brickellia californica	Compositae	pachaba
Brickellia venosa	Compositae	
Calliandra eriophylla	Leguminosae	false mesquite
Cercocarpus breviflorus	Rosaceae	mountain mahogany
Ceanothus Greggii	Thamnaceae	
Chilopsis linearis	Bignoniaceae	desert willow
Chrysothamnus nauseosis	Compositae	rabbit-bush
Clematis ligusticifolia	Ranunculaceae	virgin's bower
Condalia spathulata	Rhamnaceae	squaw-bush
Cowania mexicana	Rosaceae	cliff-rose

Scientific Name	Family	Common Name
Dalea formosa	Leguminosae	pea-bush, indigo bush
Dasylirion Wheeleri	Liliaceae	sotol
Ephedra trifurca	Ephedraceae	Mexican tea
Eriogonum Wrightii	Polygonaceae	wild-buckwheat
Erythrina flabelliformis	Leguminoseae	coral bean
Eurotia lanata	Chenopodiaceae	winter-fat
Eysenhardtia polystachia	Leguminosae	kidneywood
Fallugia paradoxa	Rosaceae	Apache-plume
Flourensia cernua	Compositae	tar-bush
Fouquieria splendens	Fouquieriaceae	ocotillo
Garrya Wrightii	Cornaceae	silk-tassel
Gutierrezia lucida	Compositae	snakeweed
Haplopappus laricifolius	Compositae	turpentine-bush
Juniperus deppeana	Cupressaceae	alligator juniper
Juniperus monosperma	Cupresaceae	one-seed juniper
Larrea tridentata	Zygophyllaceae	creosote-bush
Lippia Wrightii	Verbenaceae	
Mammillaria Spp.	Cactaceae	fishhook cactus
Mimosa biuncifera	Leguminosae	wait-a-bit
Mortonia scabrella	Celastraceae	sandpaper bush
Nolina microcarpa	Liliaceae	beargrass
Opuntia Spp.	Cactaceae	prickly pear and cholla

Scientific Name	Family	Common Name
Parthenium incanum	Compositae	mariola
Pinus cembroides	Pinaceae	Mexican pinyon
Prosopis juliflora	Leguminosae	mesquite
Quercus arizonica	Fagaceae	Arizona white oak
Quercus Emoryi	Fagaceae	Emory oak
Quercus oblongifolia	Fagaceae	Mexican blue oak
Quercus pungens	Fagaceae	
Quercus Toumeyi	Fagaceae	Toumey oak
Quercus turbinella	Fagaceae	shrub live oak
Rhus choriophylla	Anacardiaceae	sumac
Rhus microphylla	Anacardiaceae	littleleaf sumac
Rhus trilobata	Anacardiaceae	skunk-bush
Sapindus Saponaria	Sapindaceae	soapberry
Selloa glutinosa	Compositae	
Vitis arizonica	Viticeae	canyon grape
Yucca Schottii	Liliaceae	mountain yucca
Zinnia pumila	Compositae	

APPENDIX B

LINE TRAVERSE DATA

	Alluvium				Rhyolite	
Species	Pos.	Neg.	Ls	Sil. Ls	Dark	Light
	12	16	44	10	22	3
Acacia constricta	2	1	1	-	4	-
Acacia vernicosa	-	-	6	2	1	-
Agave Palmeri	1	-	3	-	2	-
Agave Parryi	-	1	11	3	4	-
Arctostaphylos pungens	-	-	-	-	-	2
Calliandra eriophylla	1	-	3	-	-	-
Cercocarpus breviflorus	-	-	1	-	-	-
Opuntia Spp. (Cholla)	-	5	2	2	4	-
Condalia spathulata	4	-	4	-	-	-
Cowania mexicana	-	-	2	-	-	-
Dalea formosa	2	-	4	-	-	-
Dasylirion Wheeleri	-	-	6	1	-	-
Ephedra trifurca	1	2	-	-	-	-
Eysenhardtia polystachia	-	-	1	2	-	-
Fallugia paradoxa	-	-	-	-	-	-
Fouquieria splendens	-	-	12	1	-	-
Garrya Wrightii	-	-	-	-	-	1

	Alluvium				Rhyolite	
Species	Pos.	Neg.	Ls	Sil. Ls	Dark	Light
Grass Spp.	1	1	-	-	-	-
Juniperus deppeana	-	-	1	-	-	-
Juniperus monosperma	-	-	2	2	1	1
Larrea tridentata	1	-	-	-	-	-
Lippia Wrightii	-	2	4	3	-	-
Mortonia scabrella	9	-	26	1	-	-
Nolina microcarpa	5	1	16	2	13	2
Opuntia Spp.	2	4	12	3	2	-
Parthenium incanum	-	-	8	-	-	-
Pinus cembroides	-	-	-	-	-	1
Prosopis juliflora	2	16	-	2	10	-
Quercus arizonica	-	-	2	2	1	-
Quercus Emoryi	-	-	1	3	4	2
Quercus oblongifolia	-	-	1	-	-	-
Quercus pungens	-	-	4	-	-	-
Quercus Toumeyi	-	-	-	-	-	2
Rhus choriophylla	-	2	5	1	-	-
Rhus microphylla	3	-	8	2	-	-
Rhus trilobata	-	-	1	-	-	-
Yucca Schottii	-	-	2	-	-	-

APPENDIX C

QUADRAT DATA

QUADRAT 1
Horquilla Formation Limestone

ELEVATION: 5,400 feet

SLOPE GRADIENT: 10°

SLOPE ASPECT: Southeast

SLOPE POSITION: Near top

SOIL: Residual

SPECIES: *Calliandra eriophylla* (1); *Dalea formosa* (1); *Dasylirion Wheeleri* (1); *Fouquieria splendens* (7); *Mortonia scabrella* (2); *Opuntia* Spp. (8); *Parthenium incanum* (2); *Quercus pungens* (1); *Rhus microphylla* (4).

COVERAGE: Discontinuous

QUADRAT 2
Horquilla Formation Limestone

ELEVATION: 5,200 feet

SLOPE GRADIENT: 5°

SLOPE ASPECT: North

SLOPE POSITION: Mid-slope

SOIL: Residual

QUADRAT 2 (Continued)

SPECIES: Agave Palmeri (1); Cowania mexicana (6); Nolina microcarpa (7); Opuntia Spp. (3); Quercus Emoryi (1); Rhus choriophylla (1).

COVERAGE: Discontinuous

QUADRAT 3
Earp Formation Limestone

ELEVATION: 5,250 feet

SLOPE GRADIENT: 5°

SLOPE ASPECT: South

SLOPE POSITION: Mid-slope

SOIL: Residual

SPECIES: Dalea formosa (5); Mortonia scabrella (27); Nolina microcarpa (1); Opuntia Spp. (2); Rhus trilobata (1).

COVERAGE: Continuous

QUADRAT 4
Silicified Limestone

ELEVATION: 5,300 feet

SLOPE GRADIENT: 13°

SLOPE ASPECT: South

SLOPE POSITION: Mid-slope

SOIL: Residual

SPECIES: Agave Parryi (2); Fouquieria splendens (23); Lippia Wrightii (12); Opuntia Spp. (17).

COVERAGE: Discontinuous

QUADRAT 5
Dark Colored Rhyolite

ELEVATION: 5,200 feet

SLOPE GRADIENT: 15°

SLOPE ASPECT: East

SLOPE POSITION: Lower 1/3

SOIL: Residual

SPECIES: Agave Palmeri (2); Agave Parryi (5); Dasylirion Wheeleri (1); Nolina microcarpa (10); Prosopis juliflora (2); and undifferentiated grass cover.

COVERAGE: Sparse

QUADRAT 6
Light Colored Rhyolite

ELEVATION: 5,250 feet

SLOPE GRADIENT: 6°

SLOPE ASPECT: West

SLOPE POSITION: Near top

SOIL: Residual

SPECIES: Arctostaphylos pungens (7); Juniperus monosperma (1); Pinus cembroides (1); Quercus Emoryi (2); Quercus Toumeyi (4); Rhus choriophyllo (2).

COVERAGE: Discontinuous

QUADRAT 7
Rhyolitic Alluvium

ELEVATION: 5,150 feet

SLOPE GRADIENT: Nearly level

SLOPE ASPECT: --

SLOPE POSITION: --

SOIL: Transported--alluvial

SPECIES: *Baccharis sarothoides* (2); *Opuntia* Spp. (cholla) (3); *Prosopis juliflora* (13); Undifferentiated intermittant grass cover.

COVERAGE: Very sparse

QUADRAT 8
Flood Plain Alluvium

ELEVATION: 5,050 feet

SLOPE GRADIENT: Level

SLOPE ASPECT: --

SLOPE POSITION: --

SOIL: Transported--alluvial

SPECIES: *Chrysothamnus nauseosis* (39); Sparse undifferentiated grass cover.

COVERAGE: Continuous

APPENDIX D

LINE TRAVERSE DATA

Species	North 8	South 8	East 22	West 20	Wash 5
Acacia constricta	-	1	2	-	1
Acacia vernicosa	1	1	2	1	2
Agave Palmeri	2	-	3	1	-
Agave Parryi	2	3	6	1	-
Arctostaphylos pungens	-	-	-	2	-
Calliandra eriophylla	-	1	1	1	-
Cercocarpus breviflorus	-	-	-	1	-
Opuntia Spp. (cholla)	1	2	1	2	-
Condalia spathulata	1	-	1	2	1
Cowania mexicana	2	-	-	-	-
Dalea formosa	-	-	1	3	-
Dasylirion Wheeleri	-	1	2	2	-
Ephedra trifurca	-	-	-	-	-
Eysenhardtia polystachia	-	1	2	-	-
Fallugia paradoxa	-	-	-	-	1
Garrya Wrightii	-	-	-	1	2
Grass Spp.	-	-	1	-	-
Juniperus deppeana	1	-	-	-	-
Juniperus monosperma	2	-	1	2	-

Species	North 8	South 8	East 22	West 20	Wash 5
Larrea tridentata	-	-	-	-	-
Lippia Wrightii	1	-	5	1	-
Mortonia scabrella	-	5	7	11	-
Nolina microcarpa	4	3	4	15	1
Opuntia Spp.	2	4	8	-	-
Parthenium incanum	-	-	3	2	-
Pinus cembroides	-	-	-	1	-
Prosopis juliflora	-	-	3	5	-
Quercus arizonica	-	-	-	2	3
Quercus Emoryi	2	-	1	-	-
Quercus oblongifolia	2	-	-	-	-
Quercus pungens	-	1	1	2	-
Quercus Toumeyi	-	-	-	2	-
Rhus choriophylla	2	1	1	-	1
Rhus microphylla	3	2	1	3	2
Rhus trilobata	-	-	-	1	1
Yucca Schottii	-	-	1	1	-

APPENDIX E

SOIL SAMPLE DATA

QUADRAT 1
Horquilla Formation Limestone

DEPTH OF SAMPLING: 5 inches

pH VALUE: 7.82

SOLUBLE SALTS IN SATURATION EXT: 483 parts per million

MAGNESIUM PLUS CALCIUM: 7.4 millequivalents per liter

PERCENT SAND: 52%

PERCENT SILT: 38%

PERCENT CLAY: 10%

QUADRAT 2
Horquilla Formation Limestone

DEPTH OF SAMPLING: 5 inches

pH VALUE: 7.72

SOLUBLE SALTS IN SATURATION EXT: 553 parts per million

MAGNESIUM PLUS CALCIUM: 7.4 millequivalents per liter

PERCENT SAND: 29%

PERCENT SILT: 41%

PERCENT CLAY: 30%

QUADRAT 3
Earp Formation Limestone

DEPTH OF SAMPLING: 5 inches

pH VALUE: 7.9

SOLUBLE SALTS IN SATURATION EXT: 357 parts per million

MAGNESIUM PLUS CALCIUM: 2.8 millequivalents per liter

PERCENT SAND: 24%

PERCENT SILT: 45%

PERCENT CLAY: 31%

QUADRAT 4
Silicified Limestone

DEPTH OF SAMPLING: 5 inches

pH VALUE: 5.1

SOLUBLE SALTS IN SATURATION EXT: 203 parts per million

MAGNESIUM PLUS CALCIUM: 2.2 millequivalents per liter

PERCENT SAND: 22%

PERCENT SILT: 59%

PERCENT CLAY: 19%

QUADRAT 5
Dark Colored Rhyolite

DEPTH OF SAMPLING: 5 inches

pH VALUE: 6.05

SOLUBLE SALTS IN SATURATION EXT: 266 parts per million

MAGNESIUM PLUS CALCIUM: 3.6 millequivalents per liter

PERCENT SAND: 52%

PERCENT SILT: 38%

PERCENT CLAY: 10%

QUADRAT 6
Light Colored Rhyolite

DEPTH OF SAMPLING: 5 inches

pH VALUE: 5.6

SOLUBLE SALTS IN SATURATION EXT: 252 parts per million

MAGNESIUM PLUS CALCIUM: 3.0 millequivalents per liter

PERCENT SAND: 63%

PERCENT SILT: 27%

PERCENT CLAY: 10%

QUADRAT 7
Rhyolitic Alluvium

DEPTH OF SAMPLING: 5 inches

pH VALUE: 6.9

SOLUBLE SALTS IN SATURATION EXT: 385 parts per million

MAGNESIUM PLUS CALCIUM: 4.6 millequivalents per liter

PERCENT SAND: 58%

PERCENT SILT: 31%

PERCENT CLAY: 11%

QUADRAT 8
Flood Plain Alluvium

DEPTH OF SAMPLING: 5 inches

pH VALUE: 7.8

SOLUBLE SALTS IN SATURATION EXT: 315 parts per million

MAGNESIUM PLUS CALCIUM: 4.4 millequivalents per liter

PERCENT SAND: 81%

PERCENT SILT: 13%

PERCENT CLAY: 6%

SOIL SAMPLE A
Calcareous Medium

DEPTH OF SAMPLING: 5 inches

pH VALUE: 7.6

PERCENT SAND: 63%

PERCENT SILT: 18%

PERCENT CLAY: 19%

SOIL SAMPLE B
Non-Calcareous Medium

DEPTH OF SAMPLING: 5 inches

pH VALUE: 5.7

PERCENT SAND: 40%

PERCENT SILT: 34%

PERCENT CLAY: 26%

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