A COMPARISON OF THE VEGETATIONAL FEATURES OF TWO DESERT MOUNTAIN RANGES
Author(s): FORREST SHREVE
Source: *The Plant World,* Vol. 22, No. 10 (OCTOBER, 1919), pp. 291-307
Published by: Wiley on behalf of the Ecological Society of America
Stable URL: http://www.jstor.org/stable/43477648
Accessed: 03-08-2017 21:09 UTC

A COMPARISON OF THE VEGETATIONAL FEATURES OF TWO DESERT MOUNTAIN RANGES

FORREST SHREVE

The Desert Laboratory, Tucson, Arizona

In southeastern Arizona and southwestern New Mexico there are a number of forested mountains which are separated from one another by desert plains and valleys. The irregular plateau upon which these mountains stand is a portion of the continental divide, draining westward into the Gila River and eastward into the Rio Grande. The greater part of the so-called plateau lies between 3000 and 5000 feet in elevation, being in fact the lowest part of the continental divide between northern Canada and the Isthmus of Tehuantepec.[1] None of the mountains exceed a length of 25 miles, but many of them lie in broken chains, usually running in a NNW-SSE direction and connected by low hills or narrow passes. Immediately south of the group of mountains under consideration lies the northern end of the Sierra Madre Occidental, which forms the boundary between the states of Sonora and Chihuahua, and north of the group are the White Mountains and the Mogollon Mesa, which form the southern edge of the Colorado Plateau. Far to the northeast lies the southernmost portion of the Rocky Mountains, in northern New Mexico.

It is only on the mountains which exceed 7000 feet in elevation that forested areas are to be found, although lesser elevations are frequently occupied by low or open woodland. The principal mountains in the group under consideration are: Baboquivari, Santa Catalina, El Rincon, Santa Rita, Huachuca, Pinaleno, Chiricahua, Las Animas and San Luis. Among the

[1] The Southern Pacific Railroad crosses the continental divide near Separ, New Mexico, at 4502 feet, and the El Paso and Southwestern Railroad crosses it near Vista, New Mexico, at 4679 feet.

less heavily forested mountains are the Whetstone, Mule, Swisshelm, Dragoon, Galiuro, Dos Cabezas, Peloncillo and Big Hatchet ranges. The highest of these mountains is the Pinaleno range, which lies near the left bank of the Gila River at Safford, Arizona, culminating in Mt. Graham at 10,550 feet.[2]

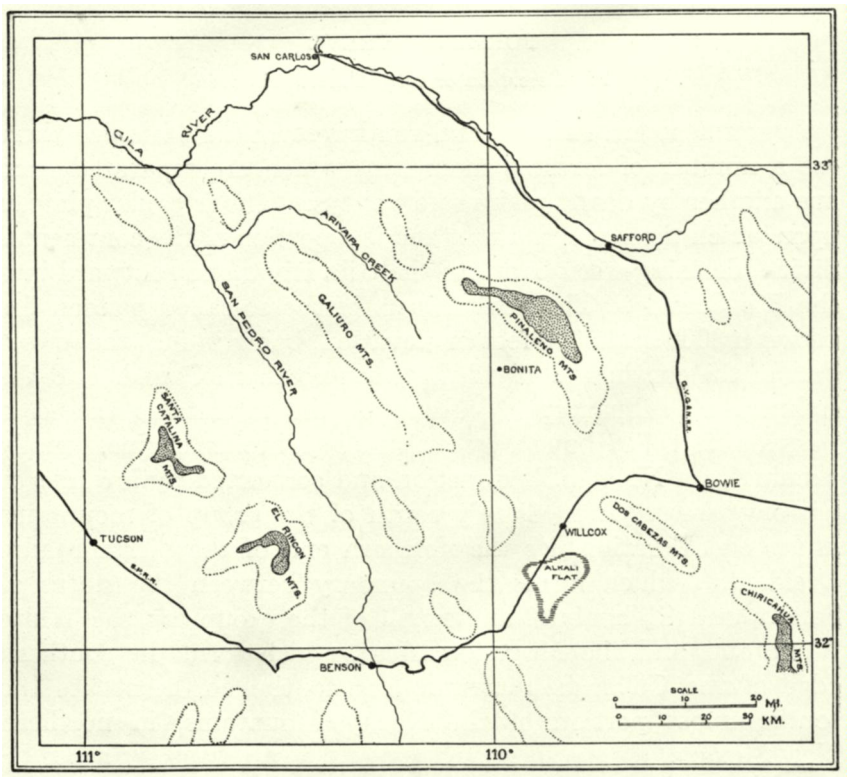

Fig. 1. Map showing the location of the Pinaleno and Santa Catalina Mountains and adjacent ranges.

After several season's work in the Santa Catalina Mountains the writer became interested in making an examination of the Pinaleno range with a view to comparing the general vegetational and floristic features of the two. A comparison of these moun-

[2] This range is locally known as the Graham Mountains, through a careless use of the name of the highest peak as a designation for the entire range.

tains is made more simple than might be the case by the fact that they are both in a relatively initial stage of physiographic development, are both built chiefly of gneiss and both lie in a WNW–ESE position. It is possible, therefore, to compare the vegetation at the same elevations in the two mountains with a minimum of complicating features,[3] and to determine the influence of the greater altitude of the Pinaleno range in affecting the character of its vegetation and flora. In making such a comparison it is necessary to take into account the universal influence of slope exposure, and also the influence on vertical distribution which is invariably exerted by the elevation of the surrounding country.

The Pinaleno Mountains may be pictured as a series of rolling areas surrounded on all sides by steep ridges and narrow cañons, falling away to the flood plain of the Gila on the northeast and to the Bonita, or Sulphur Spring, valley on the southwest. The length of the range is about 28 miles if we disregard the chain of foot-hills that stretches southward toward the Dos Cabezas range. Some of the most salient physical features of the mountain are determined by the fact that on its northeastern side its drainages reach the Gila at elevations of about 2600 feet, and on the southwest side its streams fall to the Bonita valley at only 5000 feet. On the side of the mountain facing the Gila River steep alluvial fans, or bajadas,[4] have been deposited. All of the large streams have cut through these bajadas so that their upper courses now lie through rocky cañons with V-shaped bottoms and their lower courses through shallow cañons in the outwash material, with broadly U-shaped bottoms. A section of one of the bajadas cut parallel to the face of the mountain would exhibit a level top with pronounced edges and sides falling away in parabolic curves. The average distance from the Gila River to the true base of the mountain is about 6 miles. The longest

[3] The vertical limits of species and of vegetations are different on mountains of different mineralogical character. In general, desert species reach higher elevations on volcanics than on gneiss and the highest elevations on limestone.

[4] This Spanish word, which has been quite generally adopted into the vocabulary of physiographic terms, should be pronounced *bahátha*.

of the bajada slopes extend to within 3 miles of the river, and in many cases their slender ends have been cut away from the main bajada, now appearing as elliptica hills with steep sides and flat tops, which still show an inclination accordant with that of the main bajada (see fig. 2). The inclination of the bajada surfaces is such that the innermost portions, next the mountain, are about 1000 feet higher than the ends nearest the river. The gradient of the streams as they follow the interbajadal valleys is much less than this. The line of contact between the true base of the mountain and the summits of the

Fig. 2. Looking toward the Gila River from the northeastern base of the Pinaleno Mountains, showing the dissected bajada at the right, and in the center a hill of bajadal origin.

bajadas is now almost invariably occupied by shallow drainageways of relatively recent origin, or in a few cases is occupied by a major streamway.

On the southwestern side of the mountain the largest streams reach the plain and quickly disappear, with almost no evidences of the history of the enormous amount of deposition that must have been taking place. There is abundant evidence that these streams have frequently changed their courses in the immediate vicinity of the mouths of their cañons, but the boulder-strewn

deltas over which this vacillation has taken place are only very slightly elevated above the adjacent plain.

The plain at Bonita is a portion of the Sulphur Spring Valley, which has a total length of about 100 miles (in the United States), a width of 10 to 25 miles, and lies wholly above 4000 feet. The central part of this valley is a bolson, or enclosed basin, draining into an extensive alkali flat, which is crossed by the Southern Pacific Railroad between Willcox and Cochise, Arizona. The southern portion of the valley is drained by the Whitewater Draw and the northern portion by Arivaipa Creek, a tributary of the San Pedro, which is in turn a tributary of the Gila. The Arivaipa is a small stream fed only by storm waters, and its upper course lies through an alluvial valley from one to two miles in width. This valley is sharply separated from the older and higher level of the Sulphur Spring Valley by a low scarp. Although the Arivaipa is thus seen to be working in the direction of the ultimate tapping of the Willcox bolson, it is nevertheless doing so at an extremely slow rate because of the small volume of its flood waters. The great difference which has been described as existing between the basal topography of the two sides of the Pinaleno Mountains is undoubtedly due in great measure to the presence of the strong drainage of the Gila on the one side and the weak drainage of the Arivaipa on the other, if we disregard the original structural characteristics of the region.

VEGETATION

The larger features of the vertical distribution of vegetation in the Pinaleno Mountains are similar to those that have been described by the writer for the Santa Catalina Mountains,[5] The outstanding features of dissimilarity between the two mountains are due to the greater altitude of the former (by 1400 feet), and to the fact that the cañons of the former are more sharply cut and better watered. The higher elevation results in extended areas of forest of a type which is only spar-

[5] Shreve, Forrest. The vegetation of a Desert Mountain Range as Conditioned by Climatic Factors. Carnegie Inst. Wash. Pub. 217, 1915.

ingly represented at the highest altitudes in the Santa Catalinas. The rugged topography of the Pinaleno range and the numerous constant streams bring about a sharper contrast between the vegetation of cañons and slopes at lower and middle altitudes than is the case in the Santa Catalinas. The evergreen scrub of lower altitudes is carried to high elevations on the steep south slopes and the mesophytic vegetation is carried to low elevations along the constant streams of the larger cañons. This sort of interdigitation of the lowland and mountain vegetation is conspicuous in all desert mountains, but its amplitude is greater in the Pinaleno Mountains than in any of the smaller neighboring ranges.

The narrow belt of desert which lies between the Gila River and the eastern base of the Pinaleno Mountains is characterized mainly by *Covillea tridentata*, *Atriplex polycarpa* and *Lycium gracilipes*. The commonest representatives of the cacti are *Opuntia stanlyi*, a low form with club-shaped joints, and *O. engelmannii*, an erect platyopuntia with very large joints. The simple vegetation of the desert floor becomes somewhat richer on entering the interbajadal valleys, where *Prosopis*, *Atriplex canescens* and *Isocoma wrightii* are the most abundant plants. *Opuntia spinosior*, *O. engelmannii* and *O. macrocentra* are the only common representatives of the cacti in these valleys and on their gravelly sides. In habitats of this character at elevations only 800 feet lower in other parts of southern Arizona there is a strong representation of such striking cacti as *Carnegiea* and *Opuntia bigelovii* and a series of desert shrubs and perennials confined to lower elevations.

The tops of the largest bajadas lie between 4000 and 5000 feet, sloping upward at a gradient of slightly less than 500 feet to the mile. The extremely coarse material of which they are built is revealed by their gravel soil and numerous rounded boulders of 1 to 4 feet in diameter. The southern crests of the bajadas are thickly clothed with the common species of *Opuntia* and with *Fouquieria*, while the tops are very scantily covered with *Prosopis* and *Yucca radiosa*, and with a very open summer carpet of *Hilaria cenchroides*, *Eragrostis lugens*, *Aristida scheidiana*,

the omnipresent *Gutierrezia gracilis* and other herbaceous plants. On the portions of the bajadas nearest the mountain and on the north-facing slopes at 4800 to 5200 feet the shrubbery becomes more abundant, being open on the level and forming closed thickets on the slopes. The characteristic shrub is *Quercus grisea*, and almost equally common are *Ceanothus greggii*, *Cercocarpus paucidentatus*, the semi-succulent *Nolina* and the suffrutescent *Artemisia ludoviciana*. Less frequent are *Juniperus monosperma*, *Garrya wrightii*, *Arctostaphylos pungens* and *Agave parryi*.

Fig. 3. Slopes of Frye Cañon, on the northeast face of the Pinaleno Mountains, howing encinal with scattered individuals of *Pinus chihuahuana*.

At the altitude of the uppermost portions of the bajadas it will be found that the interbajadal valleys and the cañons of the mountains itself are heavily wooded with evergreen oaks, with *Juglans major* and *Platanus occidentalis* along the streams. At elevations as low as 5500 feet, and near the banks of constant streams, it is possible to find numerous shrubs and other plants characteristic of higher altitudes, such as *Robinia neomexicana*, *Quercus submollis*, *Alnus oblongifolia*, *Ceanothus integerrimus* and *Salix* sp.

After reaching the slopes of the mountain proper we find a typical encinal[6] in which *Quercus emoryi* and *Q. arizonica* occur along with the components of the scrub just mentioned. Communities of this general composition occupy the south-facing slopes up to 7000 feet, and a scrub of similar appearance clothes the steepest slopes of southern outlook to elevations of slightly more than 8000 feet. *Cercocarpus* and *Robinia* are among the few shrubs that range throughout the vertical extension of the encinal and its high-altitude analogue. Above 7000 feet this shrubby vegetation is made up chiefly of *Quercus reticulata*, *Q. submollis*, *Q. hypoleuca* and *Ceanothus fendleri*. At its highest limit it is sometimes found to merge into young thickets of *Populus tremuloides*.

On the southwestern side of the Pinaleno Mountains the vegetation is much more simple in its distributional features, owing to the greater simplicity of the topography. The grassland of the Bonita valley becomes very open as it is followed up the slopes immediately adjacent to the base of the mountain, and *Yucca radiosa* is the most conspicuous of the woody plants, with *Opuntia spinosior* and *Prosopis* playing a secondary rôle. Open encinal covers the lowest slopes of the mountain, here somewhat more than 5000 feet in elevation, and descends in many places onto the gentle alluvial aprons over which the principal streams find their way to the plain. The courses of the largest streams, as those from Grant, Goudy and Jesus cañons, can be traced from a distance by their trees. These are chiefly *Quercus emoryi*, *Fraxinus velutina*, *Platanus occidentalis* and *Juglans major*. Near Fort Grant a running stream ten feet wide may be found at all seasons of the year, shaded by its fringing grove of trees. On following this stream down the very gentle slope toward Bonita the amount of water is found to become rapidly less and the riparian grove to become more and more open. Within less than two miles from the mouth of the cañon the water has vanished and the dry streamway has

[6] Encinal is an open or closed community in which evergreen oaks are dominant. From the Spanish *encina*, evergreen oak; *encinal*, evergreen oak forest. (Pronounced with accent on the last syllable.)

a marginal growth of *Yucca*. The large triangular area which receives this natural and continuous sub-irrigation from the waters of Grant and Goudy cañons has been the seat of successful agricultural operations from the earliest settlement of Arizona.

The extent of pine forest in the Pinaleno Mountains is not so great as might be expected from the size and altitude of the range, owing to the extremely steep and rocky character of the slopes that lie at favorable altitudes for the pines. The total area of forest is about 56 square miles, if we comprise the encinal and brushland that lies above the normal lower limits for the

Fig. 4. A park on the main ridge of the Pinaleno Mountains at 9200 feet surrounded by forest of *Pinus ponderosa*. The park is chiefly occupied by *Dugaldea hoopesii*.

pine. The total area of the mountain lying above 8000 feet is slightly over 35 square miles, and this is almost completely covered with forest.[7] Out of the 21 square miles of forest or potential forest below 8000 feet it is doubtful if the pines occupy more than 8 to 10 square miles, whereas they occupy scarcely more than this much of the heavily forested area above 8000 feet, where other trees are dominant.

[7] I am indebted to Mr. T. T. Swift, Supervisor of the Crook National Forest for the loan of maps of the Pinaleno Mountains from which these computations of area were made.

On the northeast face of the mountain the pines are first encountered at about 6800 feet, while on the southwest face there are very few groves below 7600 feet. This difference is partly due to slope exposure and partly to the well-known influence which is exerted on the vertical distribution of mountain vegetation by the elevation of the basal plain or valley. Extensive areas between 7000 and 8500 feet are occupied by oak scrub, with groves of pines only in the most favorable situations.

The predominant pine is *Pinus ponderosa*. The closely allied form known as *Pinus arizonica* has not been detected in the

Fig. 5. Forest on a shoulder of the north slopes of Mt. Graham at 10,300 feet. The trees are *Picea engelmannii*, *Pinus strobiformis* and *Abies arizonica*.

Pinaleno Mountains, although in the Santa Catalina range it forms the great bulk of the yellow pine forest, *Pinus ponderosa* being local and infrequent. Above 8600 feet the pines are confined to southern exposures and at about 9500 feet they reach their upper limit. The northern slopes between 8000 and 9500 feet are chiefly occupied by *Pseudotsuga taxifolia*, *Abies concolor* and *Pinus strobiformis*, all trees of general occurrence throughout the high mountains of southern Arizona. On going above 9600 feet these trees become less frequent. The highest elevation is reached by *Pinus strobiformis*, which occurs on dry ridges at 10,300 feet, where its resemblance to *P. flexilis* is very strong.

The low dense forest found on the main ridge and at the summit of Mt. Graham, from 9600 to 10,500 feet is made up of *Picea engelmannii* and *Abies arizonica*. Neither of these trees is found elsewhere in the isolated mountains of southern Arizona except for the occurrence of a small colony of the latter on the north slopes of Mt. Lemmon in the Santa Catalina range. Other woody plants characteristic of the *Picea-Abies* forest are *Salix bonplandiana*, *Populus tremuloides*, *Alnus tenuifolia*, *Symphoricarpus oreophilus*, *Lonicera involucrata*, *Vaccinium scoparium* and *Rubus parviflorus*.

RAINFALL

In the summer of 1917 the writer attempted to secure a series of rainfall readings at 1000-foot intervals on the southwest face of the Pinaleno Mountains, for comparison with a similar series

TABLE 1

Rainfall for the summer of 1917 in inches

	SANTA CATALINAS, JUNE 30 TO SEPTEMBER 30	PINALENOS, JUNE 23 TO SEPTEMBER 23
Tucson (2400 feet)	6.26	
Thatcher (2800 feet)		2.62
3000 feet	6.1	
4000 feet	8.0	
Willcox (4190 feet)		6.07
Bonita (4916 feet)		5.73
5000 feet	7.1	
6000 feet	9.2	12.0
7000 feet	14.0	15.5
8000 feet	15.0	13.6
9000 feet	17.3	12.1

in the Santa Catalinas. Five metal cans were installed from 6000 to 10,000 feet inclusive, with 8 liters capacity and 10 cc. of kerosene to prevent evaporation. The gauges were installed and read on both mountains at such time as to secure the summer rainfall alone (July, August, September). The gauge at 10,000 feet was overturned during the summer and the record lost. The readings for the other stations on the two mountains, together with those for the Weather Bureau stations at adjacent towns are shown in table 1.

It goes without saying that the rainfall record of a single season is of relatively little value, but it has been impossible to continue the observations on the Pinalenos and the data secured are of too great interest to be discarded. The altitudinal curve for the Santa Catalinas (fig. 6) closely approximates the form of the average curve for a ten-year series in that mountain, showing a sharp rise from the base, at 3000 feet, to the first mountain station, at 4000 feet, a drop to the second station, at 5000 feet, and a pronounced rise from 6000 to 7000 feet. There have been several years when the rainfall at 9000 feet on the Santa Cata-

Fig. 6. Canopy of the forest on the summit of Mt. Graham at 10,500 feet. The trees are chiefly *Picea engelmannii*.

linas was less than at 8000 feet, and the question rose as to whether 9000 feet was near the elevation at which the altitudinal increase of rainfall ceases in this region. The aim of securing data from the Pinalenos was (1) to determine whether the altitudinal increase of rainfall has ceased at 10,000 feet; (2) to determine the influence of the higher basal elevation of these mountains in affecting the shape of the curve of altitudinal increase; and (3) to discover whether the lowest station in the forest has here a markedly higher rainfall than the next station below it, as is true in the Santa Catalinas.

The answer to the first of these problems was not wholly lost by the failure of the record at 10,000 feet, as the maximum rainfall was registered at 7000 feet and there was a progressive fall up to 9000 feet, this station having nearly the same reading as the one at 6000 feet. In 1917 the rainfall at Bonita, near the

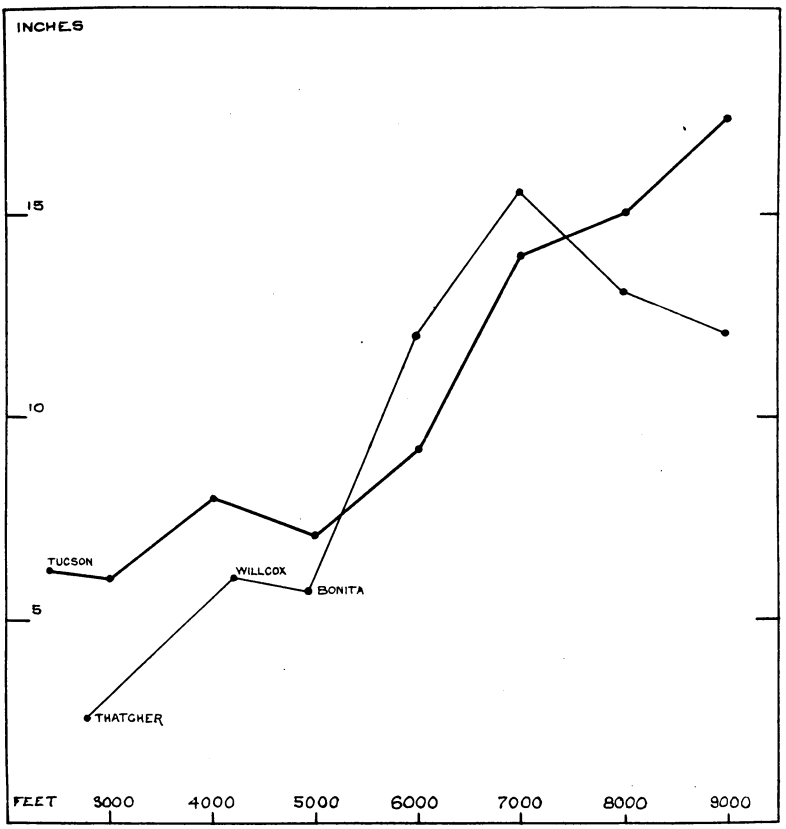

Fig. 7. Graphs showing the relation of altitude to rainfall in the Santa Catalina Mountains (heavy line) and Pinaleno Mountains (light line) for the summer of 1917.

base of the Pinalenos, was slightly less than at Willcox, 35 miles away near the centre of the bolson, although Bonita is nearly 1000 feet higher than Willcox. At the first mountain station, however, the rainfall was more than twice as great as the fall

at Bonita, showing that here, just as in the Santa Catalinas, the first 1000 feet of mountain slope engender a marked rise in the rainfall. The conditions which give the forested elevations of the Santa Catalinas a much higher rainfall than the encinal region appear to be reversed in the Pinalenos, where there is a fall in the precipitation on ascending from the latter vegetation at 7000 feet into the forest at 8000 feet.

The vertical distribution of rainfall in the isolated mountains of the southwest is not only of great theoretical interest to meteorology but is of fundamental importance in connection with our knowledge of their vegetation, and also of practical value to foresters with relation to forest management and the control of fires. Any seasonal records that can be taken will be of great value, as it will obviously be a long time before we can secure data for the entire year at these uninhabited elevations.

FLORA

At the present time the floristic features of the Pinaleno Mountains can be discussed only in a general way. The imperfect knowledge of their flora may be judged by the fact that no plants were collected in them after the visit of J. T. Rothrock, with the Wheeler Expedition in 1874, until the first visit by the writer in 1914. The most prominent differences between the forested elevations of the Pinaleno and Santa Catalina Mountains lie in the existence of a group of subalpine species in the former, for which there are no favorable altitudes in the latter; and in the existence of a few species at lower elevations in the former which have failed to make their way to the latter. The Pinaleno Mountains are also without many of the desert and encinal species of the Santa Catalina Mountains.

The most prominent of the subalpine plants found in the Pinaleno range but absent from the Santa Catalinas are:

Alnus tenuifolia Nutt.
Caltha leptosepala DC.
Campanula parryi Gray
Chimaphila umbellata (L.) Nutt.
Gentiana elegans A. Nels.

Ibidium strictum (Rydb.) House
Ligusticum porteri C. & R.
Lonicera involucrata Banks.
Mertensia pratensis Hell.
Oreochrysum parryi (Gray) Rydb.
Pachistima myrsinites (Pursh) Raf.
Pedicularis grayi A. Nels.
Peramium decipiens (Hook.) Piper
Picea engelmanni Parry
Potentilla diversifolia Lehm.
Rubus parviflorus Nutt.

All of these 16 species are found in the mountains of New Mexico and Colorado and 11 of them range northward as far as British Columbia.

A few plants are found in the forested elevations of the Pinaleno range below 9000 feet which are not known from the Santa Catalina Mountains. This group is to be distinguished from the former by the fact that all of its members are growing at elevations which exist in the latter mountains, and they do not therefore appear to depend upon physical conditions which exist only above the altitude of the highest point in the Santa Catalina range.

Berberis repens Lindl.
Ceanothus integerrimus H. & A.
Erysimum wheeleri Rothr.
Galinsoga parviflora var. *semicalva* Gray
Pericome caudata Gray
Rhamnus betulæfolia Greene
Thermopsis pinetorum Greene
Veronica serpyllifolia L.

All of these species are common at their appropriate elevations and in their particular habitats.

A few species are found above 8000 feet in the Pinaleno Mountains which have also been detected in the Santa Catalina range. All of this group are common and widespread in the former and found only in one, two, or in one case in three very restricted localities in the latter. They are:

Abies arizonica Merriam
Acer glabrum Torr.
Artemisia franserioides Greene

Lonicera arizonica Rehd.
Parthenocissus vitacea (Knerr.) Hitchk.
Ptelea angustifolia Benth.
Vaccinium scoparium Leiberg

Each of these lists will undoubtedly be greatly extended by further exploration. To the last of them, however, there attaches an importance which has no relation to its length. Each of the species listed as local in the Santa Catalina range is found in only a small portion of a particular area over which the physical conditions are identical, and over which the species characteristic of that area are found to recur constantly. Each of these seven species is common in the Pinaleno Mountains and found throughout its particular altitude and habitat. It is to be expected that each of them will gradually spread in the Santa Catalinas until all of them are likewise coextensive with a particular set of limiting conditions. We are here brought to face with the entire problem of the manner in which the isolated desert mountains received their plant population. This problem is a large and difficult one, on which the evidence is at present extremely meagre. There seems to be no evidence, however, in favor of such a radical change of climate within the life of these mountains as to have brought about a continuous lowland vegetation like that which is now confined to the mountain summits. In other words we can not think of the forest flora as having been derived by the retreat up the mountains of a forest which formerly occupied the desert valleys. The floristic evidence is against such a view, and is such as to indicate that the isolated mountain forests have secured their plant populations by some means of dispersal across the arid areas which lie between them and the mountain masses to the north-east and the south-east.

The means by which such dispersals took place were undoubtedly numerous, and the rate at which they operated was probably very slow. The limited area of the mountain tops has in itself been an important factor in making this process a slow one. In the Pinaleno Mountains there are 35 square miles above 8000 feet in elevation, in the Chiricahua Mountains 25 square miles and in the Santa Catalinas only 5 square miles. In the last named

range the total length of all the constant streams above 8000 feet is only 1.5 miles. The very moist soil along these streams is the only habitat for over 25 species of plants. Making a generous allowance of 5 feet as the average width of the moist soil along the streams, we have a total of 39,600 square feet, or slightly less than one acre. Even if we hypothecate that most of the dispersal from mountain to mountain has been by the agency of birds, and that the plants growing in moist situations above 8000 feet have been distributed by birds which chiefly frequent that habitat, we have nevertheless a case in which the chances for invasion are rendered extremely poor. This case is scarcely more extreme than others that might be mentioned, and it is cited as bearing on the rate at which invasion by new species has probably been taking place.

The vegetational differences between the several desert mountain ranges are relatively simple, and may be interpreted in terms of the differences in physical conditions which are brought about by differences in altitude, in basal elevation, in character of rock and other features. The floristic differences between them indicate a secular movement of species from the larger and more elevated mountain masses toward the smaller and more isolated ones, with a rapid impoverishment of the flora as the latter are approached.