ALPINE FLORA OF SAN FRANCISCO MOUNTAIN, ARIZONA

Elbert L. Little, Jr.[1]

San Francisco Mountain, known locally as the San Francisco Peaks, is the highest point in Arizona and has the state's only definitely alpine area. The disjunct alpine flora of this isolated volcanic cone is, therefore, of special interest. Forty-nine species of alpine vascular plants, including four not recorded previously for the state and several others found nowhere else in Arizona, are represented in a spare-time collection made here by the author in 1938.

Although many botanists have visited San Francisco Mountain during the past half century, there has been no previous attempt to assemble a complete collection of the alpine flora or to prepare a description of the vegetation above the timberline. The author was stationed nearby at Fort Valley Experimental Forest, a branch of the Southwestern Forest and Range Experiment Station about nine miles northwest of Flagstaff. From this convenient base he made nine collecting trips to summits of the highest peaks during the growing season from June to September 1938, besides one trip in 1937 and two in 1939.

Geology and Geography

This eroded volcano (text fig. 1) is situated about ten miles north of Flagstaff, Coconino County, northern Arizona (mostly in T. 22 and 23 N., R. 7 E., Gila and Salt River Meridian, centering near latitude 35° 20′ N., longitude 111° 40′ W.). From a high timbered plateau within Coconino National Forest about 7000 feet above sea level, it rises abruptly more than a mile to a maximum elevation of 12,655 feet and forms a prominent landmark visible many miles from all directions.

A summary of the geology and geography of San Francisco Mountain, taken mainly from Robinson's (18) monograph, will serve as a background for the discussion of the alpine plants. The area was at no great height above the sea when volcanic activity in the form of lava flows began in the Pliocene epoch. In early Pleistocene, San Francisco Mountain with four smaller volcanoes was formed from about 38 cubic miles of lava and rose about 8800 feet above the plain. Afterwards the region was raised to its present height above sea level, and nearly four hundred small basaltic cinder cones were formed.

Since the volcano became extinct San Francisco Mountain has lost by erosion about three thousand feet or more than one-third

[1] Associate forest ecologist, Southwestern Forest and Range Experiment Station, which is maintained at Tucson, Arizona, by the Forest Service, United States Department of Agriculture.

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of its height but only about eight per cent of its volume. No trace of the former crater is left. A large interior valley, called the Inner Basin, was formed on the northeast side and was occupied by a glacier nearly two miles long probably in the late Wisconsin stage. This station was thought to be the southernmost for Pleistocene glaciation in the United States until evidence of glaciation was found a few years ago in the White Mountains of southern New Mexico; Pleistocene glaciation occurred also farther south than San Francisco Mountain on San Gorgonio Peak, southern California. As a result of erosion San Francisco Mountain (text fig. 1; pl. 5, fig. 1) now has the shape of a hollow, truncated cone about twelve miles or less in diameter at the base,

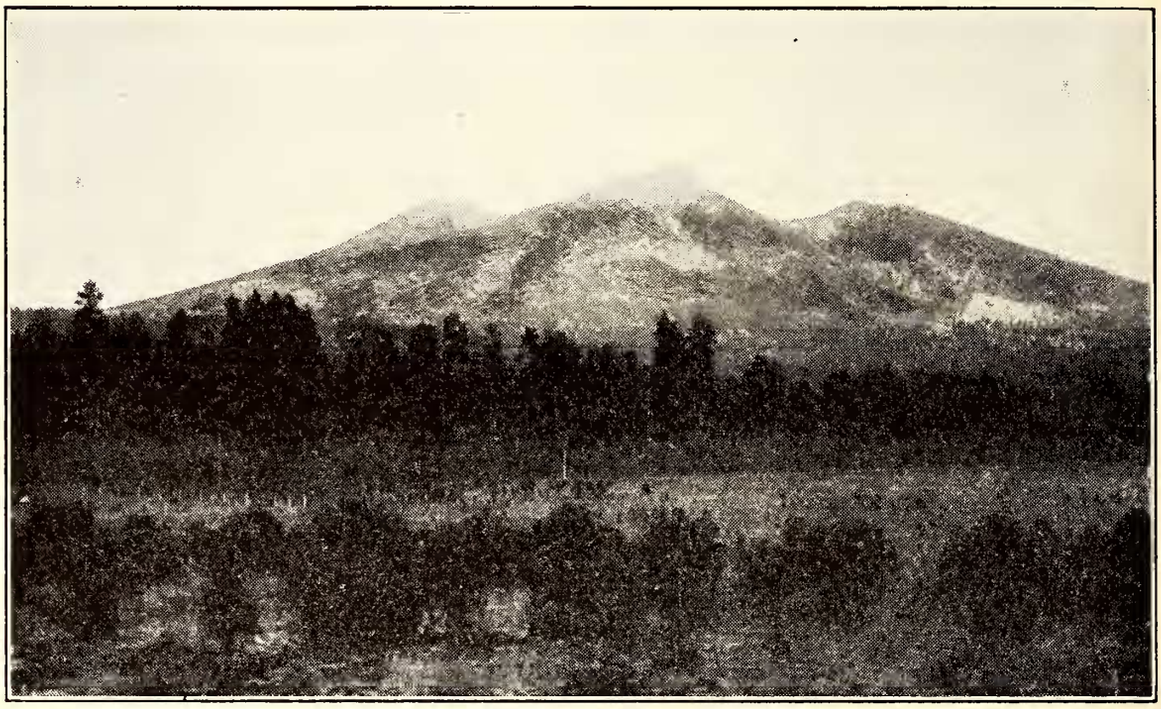

Fig. 1. San Francisco Mountain, as viewed from Fort Valley Experimental Forest on the southwest, is a symmetrical, eroded volcanic cone. Its three highest peaks are Humphreys Peak (left), Agassiz Peak (center) and Fremont Peak (right).

two miles in diameter at the top, and one mile high. Its slope is about 20 degrees at the top and gradually becomes less towards the base. The irregular rim forms a knife-edge divide between the outer slope and the Inner Basin. Along this crest line, which is continuous except on the northeast, are six peaks above 11,000 feet in elevation. The three highest, projecting above the timber line, are: Humphreys Peak, elevation 12,655 feet, on the northwest; Agassiz Peak, elevation 12,384 feet, on the southwest; and Fremont Peak, elevation 11,984 feet, on the south.

Previous Botanical Investigations

No references to alpine plants of San Francisco Mountain were found in reports of the United States Government exploring and surveying expeditions, though this mountain lay on the

route of several. In the United States National Herbarium are specimens of alpine plants collected on San Francisco Mountain by the following early collectors in the years indicated: E. Palmer, 1869; H. H. Rusby, 1883; M. E. Jones, 1884; Mr. and Mrs. J. G. Lemmon, 1884; E. L. Greene, 1889; F. H. Knowlton, 1889; D. T. MacDougal, 1891, 1898; J. W. Toumey, 1892; E. O. Wooton, 1892; C. A. Purpus, 1900; J. B. Leiberg, 1901; G. A. Pearson, 1908–1909. The Forest Service herbarium at Fort Valley Experimental Forest has specimens of about 25 alpine species collected by G. A. Pearson and others.

Hoffman (9) in 1877 noted that the timberline was irregular, approaching to within one thousand feet of the summit on the eastern side and five hundred feet on the western. Rusby (19) wrote in 1889 that at the summit grow only lichens and that the alpine flora, of which he named 6 species, begins one or two hundred feet below. This statement, perhaps the source of a similar one by Harshberger (8, p. 583), is not strictly correct. In a list of Arizona plants collected by E. A. Mearns, Britton (2) in 1889 mentioned 23 species from San Francisco Mountain, including about 6 occurring above timberline. The first meteorological studies in the alpine zone of San Francisco Mountain were made by D. T. MacDougal in August 1898, (3, p. 43–45).

There have been four detailed studies of the vegetation of San Francisco Mountain and vicinity from different viewpoints. First of these and the only one to include the alpine zone was Merriam's (13) biological survey in 1889. A timber survey of the forests of this area was made by Leiberg, Rixon, and Dodwell (11) in 1901 and 1902. Pearson's (16) detailed study of the forest types of San Francisco Mountain included measurement of environmental factors from 1917 to 1919 at five climatic stations in different zones from the base to the timberline. Hanson (7) in 1922 and 1923 conducted a similar series of climatic stations in his research on the vegetation of the four lower zones at the base of this mountain. The more recent summaries of Arizona vegetation by Nichol (15) and others contributed no additional information on alpine plants.

San Francisco Mountain is of special historical interest to biologists because it was here in 1889 that Merriam (13) made one of the first thorough investigations of the plant and animal life of a western locality and worked out his life zones or climatic zones. From the alpine zone, above 11,500 feet, on the "bleak and storm-beaten summit" of San Francisco Mountain, Merriam listed 20 species of vascular plants. He recognized also the subalpine or timberline zone, a narrow belt at an elevation of 10,500 to 11,500 feet, where the trees became stunted and prostrate, and included a list of 16 species attaining their maximum development here. Later, when he proposed his explanation of temperature control of the geographic distribution of animals and plants, Merriam (14) omitted the subalpine zone, which does not appear

to be distinct ecologically, and did not separate it from the Hudsonian or spruce zone.

Merriam's two lists totaling 34 species comprise the only detailed published study of alpine and timberline plants of San Francisco Mountain. This collection, which was made by F. H. Knowlton and deposited in the United States National Herbarium, contains specimens of a few other alpine species not mentioned by Merriam. *Corallorhiza maculata* (listed as *C. multiflora*) was recorded from timberline zone apparently through error, as the altitude mentioned on the label (*Knowlton 106*) is 10,000 feet. The author has collected specimens of all the others in Merriam's two lists except *Sagina saginoides* (*S. Linnaei*).

Discussion

Alpine areas above timberline on San Francisco Mountain occupy about two square miles, nearly all located on the slopes of Humphreys and Agassiz peaks (pl. 5, fig. 1). As here limited the alpine zone is that above the highest wind timber, "krummholz," or dwarf tree species (pl. 5, fig. 2). On this mountain such alpine scrub is represented by Engelmann spruce (*Picea Engelmanni* Parry) and bristlecone pine (*Pinus aristata* Engelm.). Though roads go about half-way up the mountain on four sides, the rocky alpine summits must be reached on foot.

Timberline is somewhat irregular and extends nearly one thousand feet higher up the southern and western exposures than the northern and eastern. In ravines on north-facing slopes finger-like areas of alpine vegetation reach down to lower levels. Typical alpine vegetation may occur in protected areas while trees grow on exposed ridges above. Besides the obvious effects of direction of slope and topography, drifting of winter snows is partly responsible for the irregularity of the timberline. After winter storms white clouds of snow are blown off Humphreys Peak into the Inner Basin. The best development of alpine meadows is at an elevation slightly below 11,500 feet at the extreme upper end of the Inner Basin where the deeper snow drifts do not disappear until midsummer. At one place here an alpine meadow merges laterally into a subalpine meadow.

Environmental factors. Climatic and edaphic factors affecting the alpine vegetation here probably are similar to those of other exposed western peaks. Coville and MacDougal (3) noted that air temperature at the summit of Agassiz Peak had less daily

Explanation of the Figures

Plate 5. Alpine Zone of San Francisco Mountain, Arizona. Fig. 1. View from Fremont Peak northwest across the Inner Basin, showing treeless alpine summits of Agassiz Peak (left) and Humphreys Peak (right). Fig. 2. Wind-swept, dwarf Engelmann spruce (*Picea Engelmanni*) at timberline ridge on west side of Agassiz Peak. Alpine rock field or lichen association in background. Pearson's timberline climatic station was nearby. Fig. 3. Alpine meadow association, in which the dominant species, *Geum turbinatum,* forms mats of vegetation on a rocky slope.

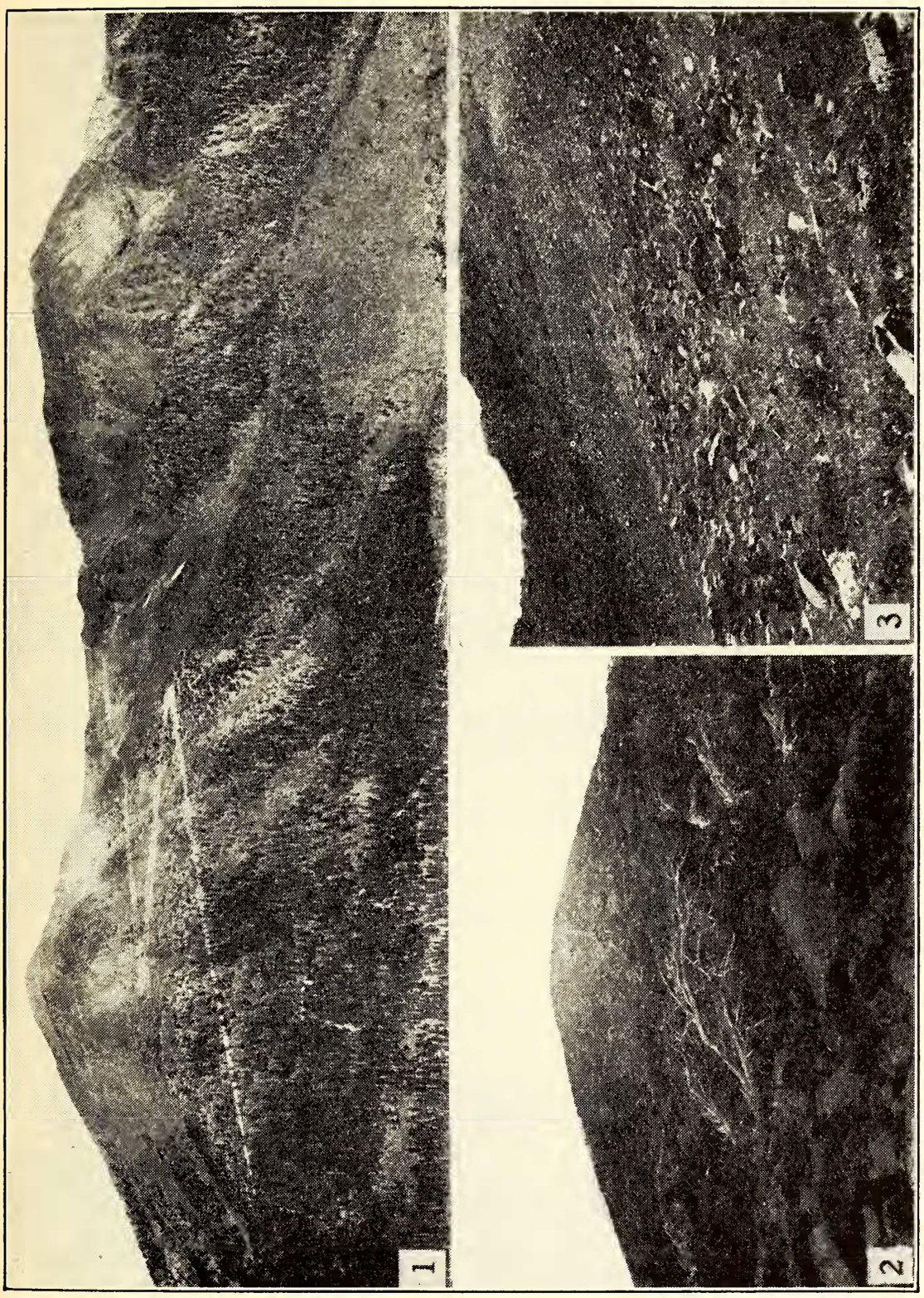

PLATE 5. ALPINE ZONE OF SAN FRANCISCO MOUNTAIN, ARIZONA

variation than that at lower altitudes but found a greater difference between temperature of soil and air at the top than at lower levels.

In the absence of other instrumental records in the alpine zone, it may be of interest to summarize comparable data from Pearson's (16) timberline station (pl. 5, fig. 2) from 1917 to 1919 to indicate the climatic conditions under which the alpine plants are growing. During these three years the frostless period here, from June to September, varied between 101 and 113 days. Mean air temperature for the period from June to September was 47.9 degrees. Because of temperature inversion, or cold air drainage, night temperatures at timberline were little if any colder than at lower altitudes, but the days were decidedly colder. Annual precipitation at Pearson's timberline station was slightly higher than at lower zones, totaling 28.03 inches in 1917, 37.74 inches in 1918, and 52.05 inches in 1919. The P/E ratio, or precipitation divided by evaporation, for the interval from June to September was .812. Wind movement on the exposed ridge at timberline was relatively high.

During the winter months from November or December to March or April San Francisco Mountain has a white cap of snow, which buries and protects the dormant alpine vegetation. In April and May the snow melts in most places above timberline, exposing the dark-colored rock. However, on shaded slopes and areas of deep drifts, large snow banks remain until early July. In 1938 the last small patch of snow melted in the latter part of August. Frequent thunderstorms of cold rain occur in the summer rainy season from July to September. The first light winter snow in the alpine area usually falls early in October.

Above timberline soils are poorly developed and the slopes are largely covered with angular blocks or boulders of andesite and pyroxene dacite. Wind, frost action, and erosion all retard the formation and accumulation of soils on the steep slopes and make the establishment of vegetation difficult. Soil pockets occur in crevices, and in places spreading mats of vegetation hold the shallow soils and help to form more.

Plant associations. The alpine vegetation of San Francisco Mountain is poorly developed and the alpine flora impoverished, in comparison with alpine vegetation and flora of larger, higher mountains. Only two plant associations are distinguished here, the alpine rock field or lichen association and the alpine meadow or *Geum turbinatum* association. In the xerosere the former association gradually merges into and is succeeded by the latter, which is the climax. As no streams, lakes, or permanent snow drifts are present, there is no hydrosere.

In contrast, Cox (4) described on James Peak, elevation 13,260 feet, in Colorado, a much richer alpine vegetation. The alpine meadow, or *Geum turbinatum* association of San Francisco Mountain corresponds with the dry meadow associations on

James Peak, where *Carex rupestris* and *Geum turbinatum* are dominant. On James Peak, however, the dry meadow is succeeded by a climax alpine meadow association in which *Elyna Bellardi,* a species not found on San Francisco Mountain, is dominant. The various communities in hydroseres from wet stony areas, stream and lake margins, and snow drifts through scrub, moor, and wet meadow types to the climax alpine meadow of James Peak all are absent from San Francisco Mountain.

Alpine rock field. The alpine rock field or lichen association occupies most of the mountain summit of San Francisco Mountain, including exposed peaks and ridges (pl. 5, fig. 2). However, some unstable rock slides are almost without plants. This association is characterized by lichens, principally crustose and foliose, on the rock outcrops with vascular plants scattered among the boulders wherever there is sufficient soil. Even on the highest, exposed peaks a few seed plants can be found. Probably the most abundantly represented species or dominant species is the crustose lichen *Rhizocarpon geographicum* (L.) Lam. & DC. (determination verified by Dr. Carroll W. Dodge). Two species of foliose lichens, of which specimens were collected here previously for the Forest Service by F. W. Haasis and J. O. Veatch and determined by G. K. Merrill, are *Lecanora rubina* (Vill.) Ach. and *Parmelia conspersa* (Ehrh.) Ach. Mosses are less common than lichens and are found in crevices and to a lesser extent on boulders. *Hypnum revolutum* (Mitt.) Lindb. is characteristic of the shaded soil pockets. The moss species most commonly represented on dry outcrops is *Grimmia Doniana* Sm., which, according to Edwin B. Bartram who determined the two mosses, may be the first record for the state. The only alpine pteridophyte, *Cystopteris fragilis,* is commonly distributed in crevices.

The number of species of flowering plants represented in the alpine rock field is high and includes nearly all occurring above timberline. Of these the mat-forming pioneer species of the alpine meadow, *Geum turbinatum,* is most conspicuously represented. Five characteristic species of Caryophyllaceae here are *Arenaria Fendleri, A. sajanensis, A. verna, Cerastium Beeringianum,* and *Silene acaulis.* Three species of grasses commonly represented are *Festuca ovina* var. *brachyphylla, Poa rupicola,* and *Trisetum spicatum. Carex bella* is the sedge species most commonly represented, and *Luzula spicata* the typical rush. Other characteristic species in the rock field include *Polemonium confertum, Solidago ciliosa, Thlaspi Fendleri,* and *Pseudocymopterus montanus.* Typical pioneer species on rock slides are *Geum turbinatum, Primula Parryi, Senecio franciscanus,* and *Arenaria saxosa.* In shaded crevices and cliffs *Heuchera versicolor* f. *pumila* and *Oxyria digyna* are commonly represented.

Alpine meadow. The alpine meadow or *Geum turbinatum* climax association is developed on the more favorable sites, such

as at the upper end of the Inner Basin and ravines not far above timberline (pl. 5, fig. 3). However, the area occupied is only a small fraction of the alpine zone. Plants of the dominant species, *Geum turbinatum,* start as pioneers on rocky slopes and especially at the bases of rock slides. They spread vegetatively by creeping stems to form compact mats in which soil is built up and other plants become established to form an almost solid mantle of vegetation. If any species of vascular plants may be said to be abundantly represented above timberline, it is this. Other mat-forming species here include *Potentilla Sibbaldi* and *Silene acaulis.*

Most of the species listed under rock fields are commonly represented also in meadows. The following species of grasses and sedges are typical: *Festuca ovina* var. *brachyphylla, Trisetum spicatum, Carex bella, C. albo-nigra,* and *C. ebenea.* Other species of meadows include *Luzula spicata, Arenaria sajanensis, Cerastium Beeringianum,* and *Solidago ciliosa.* Scattered or rare in alpine meadows are individuals of the following species not observed elsewhere above timberline: *Phleum alpinum, Poa reflexa, Gentiana barbellata, G. monantha, Pedicularis Parryi, Veronica Wormskjoldii,* and *Erigeron simplex.*

Mosses of several species are present in alpine meadows but are not common. Liverworts of a single species, *Lophozia porphyroleuca* (Nees) Schiffn. (determination by Dr. A. W. Evans), were found above timberline. Not reported previously from Arizona, this species is represented sparingly in alpine meadows and more commonly in the subalpine forest.

This climax association is slowly spreading through mat formation by the dominant species, and all degrees of intermediate stages between rock field and meadow can be observed. The two associations sometimes are mixed together, for example near the bases of steep slopes where large boulders which have rolled down from above have a vegetation of lichens though surrounded by a climax meadow.

Above timberline growth begins in June, or possibly earlier on southern and western exposures. By the middle of June plants of the following species are in flower: *Thlaspi Fendleri, Geum turbinatum, Pseudocymopterus montanus,* and *Polemonium confertum.* Most of the alpine species blossom in July and August. Among the last species to begin flowering, in August and September, are *Gentiana barbellata, Erigeron simplex, Senecio franciscanus,* and *Solidago ciliosa.* Plants of *Geum turbinatum* continue to flower throughout the summer. By the first of October even the last late flowers have been killed by frosts and the vegetation has become dormant for the winter.

Geographic Distribution of Species. Four species of vascular plants found by the author on San Francisco Mountain apparently are here first recorded for the state with corresponding extensions of range. All have a northern distribution and reach their southern limits on this and similar mountain summits. The

alpines are *Juncus Drummondii, Erigeron compositus,* and *Erigeron simplex.* More unusual is *Botrychium lanceolatum,* a subalpine pteridophyte reaching the timberline. This circumboreal species has been recorded previously from only three western states, Washington, Wyoming, and Colorado. As the author (12) has noted, the station on San Francisco Mountain is the southernmost reported in North America and nearly four hundred miles southwest of the nearest known localities in central Colorado. A few other alpine species here have been found nowhere else in Arizona, but some occur also on Arizona's second highest mountain, Thomas or "Baldy" Peak, elevation 11,470 feet, in the White Mountains one hundred and fifty miles southeast.

Merriam (13) observed that many of the species above timberline on San Francisco Mountain are arctic-alpine circumpolar species widely distributed in arctic regions of North America and Eurasia, such as Alaska, Hudson Bay, Greenland, Spitzbergen, and Siberia, and extend far south on summits of such high mountain ranges, as the Sierra Nevada, Rocky Mountains, Alps, and Himalayas. However, after an interval of fifty years, there are fewer species in common with these more distant points, owing to increased knowledge and probably also to a trend toward a narrower concept of the species. As a result of such changes and of corrections in nomenclature, only one-half of the 34 species listed by Merriam (13) as occurring in the alpine and timberline zones now bear the same names.

The occurrence of disjunct arctic-alpine plants on San Francisco Mountain was explained by Merriam according to the present interpretation, that of migration southward during the glacial period and the ascension of mountain peaks as the temperature became warmer. He concluded that, as these species could not have reached here afterwards, the volcano could not be of more recent origin than the glacial period.

Rydberg (20) classified the alpine flora of the Rocky Mountains into ten groups according to geographical distribution, while Holm (10) in a detailed analysis of the alpine flora of Colorado distinguished four elements as to origin. The 49 alpine species of San Francisco Mountain fall into five more or less natural groups, according to their ranges as given in floras and manuals and in the phytogeographical treatises by Rydberg (20) and Holm (10). These groups are listed below with the abbreviations used in the list of species, the number of species in each, and the percentage of species in each.

	Number of species	Per cent
Arctic-alpine circumpolar species (CP)	15	30.6
North American arctic-alpine species (NA)	5	10.2
Rocky Mountain alpine species (RM)	24	49.0
Southwestern species (SW)	3	6.1
Endemic species (EN)	2	4.1

Thus, the relationships of the alpine flora of San Francisco Mountain are quite definitely northern with the floras of arctic and alpine regions. The 15 arctic-alpine circumpolar species, almost one-third of the total, are widely distributed in arctic regions in North America and Eurasia and on alpine mountain summits at lower latitudes. Two of these, *Arenaria sajanensis* and *Stellaria umbellata,* are recorded from Siberia but not from Europe, while the rest are listed from both Europe and Asia. A few have even wider distribution. *Cystopteris fragilis* is almost cosmopolitan and ranges to tropical America. *Phleum alpinum* and *Trisetum spicatum* are found also in alpine South America.

The 5 North American arctic-alpine species have a distribution from Greenland to Alaska, or slightly narrower, and southward on high western mountains but are not listed from Eurasia. The 24 Rocky Mountain alpine species occur in high mountains generally from Montana south to Colorado and Utah and on the highest peaks of New Mexico and Arizona. Some of these are found also in somewhat lower zones. Three southwestern species are confined to New Mexico and Arizona or slightly beyond and apparently have migrated up to the alpine area from lower zones, where they are more typical.

Only two alpine species, *Senecio franciscanus* Greene (5, p. 19–20), and an undescribed species of *Pedicularis,* are endemic to San Francisco Mountain, and neither furnishes a clue as to routes of migration. In his monograph Greenman (6, p. 29–30) listed only 6 collections of *Senecio franciscanus,* all from this mountain. Though *Senecio* is well represented in alpine regions with several species confined to Colorado, the species apparently most closely related to *S. franciscanus* are distributed nearby at lower zones in the same area. The undescribed species of *Pedicularis* is an endemic closely related to the widely ranging species, *P. Parryi* A. Gray. Several other alpine plants here have been proposed as new species, but these have been reduced to synonymy, with the exception of one or two retained as varieties of other species. However, a large number of endemic species is not to be expected on a geologically young volcanic cone.

Most of the alpine species of San Francisco Mountain are found also below timberline, especially in subalpine meadows. The following commonly represented species, as well as a few others, are confined to the alpine zone here: *Arenaria sajanensis, Silene acaulis, Polemonium confertum,* and *Senecio franciscanus.* A few, such as *Arenaria Fendleri* and *Thlaspi Fendleri,* are equally characteristic of the western yellow pine zone at the base of the mountain.

By comparing the alpine flora of San Francisco Mountain with similar plant lists from other southwestern peaks, it should be possible to trace the probable routes of the arctic-alpine plants in migrating to this newly formed volcano. Bailey's (1, p. 51–53) list of 60 characteristic species of the arctic-alpine zone in New

Mexico indicates a much richer alpine flora in the Sangre de Cristo Range at the southern end of the Rocky Mountains more than three hundred miles eastward. The nearest alpine peaks of the main Rocky Mountains are in Colorado about two hundred and fifty miles northeast. Thirty-eight of the 50 alpine species on San Francisco Mountain are included in Cox's (4) list of 196 alpine species on James Peak, Colorado. The high plateau of Arizona, on which San Francisco Mountain is located, is almost continuous with alpine summits in southern Utah two hundred miles northward and connects on the southeast with the White Mountains one hundred and fifty miles distant and with mountains in western New Mexico.

Raunkiaer's Life-forms. The 48 alpine species of seed plants on San Francisco Mountain were grouped also according to Raunkiaer's (17) life-forms. Phanerophytes are absent above timberline, and only four life-forms are represented. Most of the species (40) are perennial herbs classed as hemicryptophytes. The remaining 8 are listed below according to life-form. The 5 species of chamaephytes are: *Geum turbinatum,* the abundantly represented, mat-forming species; *Silene acaulis,* a typical cushion species; *Arenaria sajanensis, Saxifraga caespitosa* subsp. *exaratoides* var. *Lemmonii,* and *Potentilla Sibbaldi.* The single cryptophyte or geophyte species is *Senecio franciscanus,* which is especially successful on rock slides because of its creeping rhizomes. There are only 2 species of therophytes or annual herbs, *Androsace septentrionalis* var. *subumbellata* and *Gentiana monantha.*

As others have noted, the distinction between chamaephytes and hemicryptophytes is not sharp, and a few of the species classed as the latter might as well have been called chamaephytes. At any rate, the prevailing life-form here is that of low perennial herbs with rosettes and stems which, often retaining bases of old leaves, elongate slightly each year.

The biological spectrum of the alpine zone of San Francisco Mountain and Raunkiaer's revised normal spectrum are compared below, with percentages of species under each life-form. The slightly higher percentage of chamaephytes above that of the normal spectrum indicates a cold climate intermediate between the temperate hemicryptophytic climate and the chamaephytic climate of arctic regions.

	Raunkiaer's revised normal spectrum Per cent	Alpine zone of San Francisco Mountain Per cent
Phanerophytes	46	0
Chamaephytes	9	10.4
Hemicryptophytes	26	83.3
Cryptophytes	6	2.1
Therophytes	13	4.2

List of Alpine Species

This study is limited to the vascular plants above timberline on San Francisco Mountain. All species normally found at some distance above the irregular line of the last stunted individuals of tree species were included, regardless of their occurrence in other zones. As it was sometimes difficult to determine whether a species should be classed as alpine, a partial list of subalpine species reaching the timber line or slightly beyond is included as evidence that these species were not overlooked. For example, the shrubby species *Juniperus communis* var. *sibirica* and *Ribes montigenum,* which occur in protected rocky situations slightly above the highest spruces and pines, are not typically alpine.

In naming the specimens the author wishes to acknowledge the valuable assistance of several specialists. The author made determinations at the herbarium of the Field Station of the Bureau of Plant Industry at Sacaton, Arizona, and at the United States National Herbarium. Specimens of certain groups were further checked by the following specialists: Pteridophyta by Dr. Wm. R. Maxon, Gramineae by Dr. J. R. Swallen and Prof. J. J. Thornber, *Carex* by J. W. Stacey, *Juncus* by Dr. F. J. Hermann, *Ranunculus* by Dr. Lyman Benson, and Compositae by Dr. S. F. Blake. Determinations of all the remaining specimens have kindly been checked by Dr. T. H. Kearney. Nomenclature is that of the forthcoming Flora of Arizona, by T. H. Kearney and R. H. Peebles. The names thus are in accord with the International Rules of Botanical Nomenclature and are conservative.

Duplicate sets of the author's specimens have been deposited in the United States National Herbarium, herbarium of the University of Arizona, herbarium of the Sacaton (Arizona) Field Station, and herbaria of the Forest Service at the following localities: Washington, D. C.; Albuquerque, New Mexico; Southwestern Forest and Range Experiment Station at Tucson, Arizona, and Fort Valley Experimental Forest near Flagstaff, Arizona.

The 49 alpine species of vascular plants of San Francisco Mountain, including a single pteridophyte and 48 species of flowering plants, are grouped into 35 genera and 17 families. Specimens of two additional species were undeterminable. Largest families are Caryophyllaceae (a family well represented at northern points and high elevations) with 8 species, Compositae with 7, and Gramineae with 6 species. Principal genera are *Arenaria* and *Saxifraga* with 4 species each and *Carex* and *Potentilla* with 3 each. Rydberg (20, p. 92–93) lists from San Francisco Mountain an additional species, *Lloydia serotina* (L.) Sweet, which is omitted here because no herbarium specimen from Arizona could be located. The species are listed below with brief notes on habitat and abundance. Geographic distribution or range is abbreviated as explained above.

Polypodiaceae

Cystopteris fragilis (L.) Bernh. Crevices, alpine rock fields; common. CP.

Gramineae

Agropyron Scribneri Vasey. Loose rocks and gravel, alpine rock fields; scattered. The weak stems spread out in all directions over the rocks. RM.

Festuca ovina L. var. brachyphylla (Schult.) Piper. Alpine meadows and rock fields; common. CP.

Phleum alpinum L. Alpine zone, confined to climax alpine meadows; rare. CP.

Poa reflexa Vasey & Scribn. Alpine zone, in meadows; rare. RM.

Poa rupicola Nash. Alpine meadows and rock fields; common. RM.

Trisetum spicatum (L.) Richt. Alpine rock fields and meadows; common. CP.

Cyperaceae

Carex albo-nigra Mackenzie. Alpine rock fields and meadows; common. RM.

Carex bella L. H. Bailey. Alpine rock fields and meadows; the most commonly represented species of *Carex*. Flowers from June to September. RM.

Carex ebenea Rydb. Alpine rock fields and meadows; common. RM.

Juncaceae

Juncus Drummondii E. Meyer. This species, previously unrecorded for Arizona, was to be expected here, as it ranges from Alaska south in mountains to New Mexico and California. Rare in one alpine meadow at the upper end of the Inner Basin and commoner in nearby subalpine meadows. RM.

Luzula spicata (L.) DC. Alpine meadows and rock fields; common. CP.

Polygonaceae

Oxyria digyna (L.) Hill. Shaded rock crevices of alpine zone; uncommon. CP.

Caryophyllaceae

Arenaria Fendleri A. Gray. Typical of lower elevations, a depauperate alpine form common in alpine rock fields. RM.

Arenaria sajanensis Willd. Alpine rock fields and meadows; common. CP.

Arenaria saxosa A. Gray. Rock slides in alpine zone but more characteristic of lower zones; common. SW.

Arenaria verna L. Alpine rock fields and meadows; common. Nearly all the plants are densely glandular pubescent, but rarely glabrous plants are found. CP.

Cerastium Beeringianum Schlecht. & Cham. Alpine rock fields; very common. NA.

Sagina saginoides (L.) Britton. Alpine zone (*Knowlton 134*, U. S. National Herbarium); rare. Not collected by the author. CP.

Silene acaulis L. Alpine meadows and rock fields; commonly forming cushions or mats. CP.

Stellaria umbellata Turcz. Alpine rock crevices and meadows; uncommon. CP.

Ranunculaceae

Ranunculus inamoenus Greene var. alpeophilus (A. Nels.) L. Benson and var. subaffinis (A. Gray) L. Benson. Var. *subaffinis* is endemic to San Francisco Mountain. Alpine meadows and in mats of other plants; rare and scattered. RM.

Ranunculus sp. Alpine meadows and in mats of other plants; rare and scattered. An apetalous plant. Perhaps a reduced form of *R. pedatifidus* J. E. Smith, which sometimes lacks petals.

Cruciferae

Draba aurea Vahl var. aureiformis (Rydb.) Schulz. Alpine rock fields; common. NA.

Draba crassifolia Graham. Alpine meadows; rare. NA.

Thlaspi Fendleri A. Gray. Alpine rock fields and meadows; common. SW.

Crassulaceae

Sedum rhodanthum A. Gray. Alpine meadows and rock fields; common. RM.

Saxifragaceae

Heuchera versicolor Greene f. pumila Rosend. *et al.* Alpine rock ledges and crevices and also in alpine meadows; common. SW.

Saxifraga caespitosa L. var. Lemmonii Engler & Irmscher. Forming mats on alpine ledges and rock fields and occasionally in alpine meadows; not common. CP.

Saxifraga debilis Engelm. Shallow soils in shaded crevices, alpine rock fields; uncommon. RM.

Saxifraga flagellaris Willd. Mainly in crevices of alpine rock fields; not common. CP.

Saxifraga rhomboidea Greene var. franciscana (Small) Kearney & Peebles. Alpine rock fields and meadows; uncommon and scattered in mats of other plants. Var. *franciscana* perhaps is not worthy of recognition, as it differs only in smaller size and more compact inflorescences. These differences apparently are associated with the alpine habitat. RM.

Rosaceae

Geum turbinatum Rydb. *Sieversia turbinata* (Rydb.) Greene. Dominant in alpine meadows and a pioneer on rocks; by far the most abundantly represented species of flowering plants in the alpine area. RM.

Potentilla concinna Richardson. Alpine rock fields; uncommon. RM.

Potentilla diversifolia Lehm. Alpine rock fields and meadows; not common. RM.

Potentilla Sibbaldi Haller f. (*Sibbaldia procumbens* L.) In mats in alpine meadows and slightly below timberline; common. CP.

Umbelliferae

Pseudocymopterus montanus (A. Gray) Coult. & Rose. In alpine rock fields and also in alpine meadows; common. RM.

Primulaceae

Androsace septentrionalis L. var. subumbellata A. Nels. Alpine rock fields; common. CP.

Primula Parryi A. Gray. Alpine rock fields, including crevices and rock slides, and in meadows; common but scattered. RM.

Gentianaceae

Gentiana barbellata Engelm. Very rare and scattered in alpine meadows but more typical of lower zones. Plants above timberline are inconspicuous until they flower in September. RM.

Gentiana monantha A. Nels. In mats of other plants in alpine meadows; rare. RM.

Polemoniaceae

Polemonium confertum A. Gray. Alpine rock fields and also in meadows; common. RM.

Scrophulariaceae

Pedicularis sp. Rare in climax alpine meadows and common below timberline. Previously referred to *Pedicularis Parryi* A. Gray. However, Dr. Francis W. Pennell, whom I accompanied on a field trip here to collect additional material, is describing the San Francisco Mountain plant as a new, endemic species. EN.

Veronica Wormskjoldii Roem. & Schult. Commoner below timberline, rare in alpine meadows. NA.

Compositae

Antennaria aprica Greene. Alpine rock fields; uncommon. RM.

Antennaria umbrinella Rydb. Alpine rock fields and meadows; uncommon. RM.

Erigeron compositus Pursh. Reported previously from Greenland to Alaska and south to Colorado, Utah, Nevada, and California. Very rare in an alpine meadow and in rock cliffs at timberline. NA.

Erigeron simplex Greene. Previously known from Montana south to Colorado, New Mexico, and California. Though this species typically is radiate, some of the plants here are discoid or

nearly so. Scattered and uncommon in mats of other plants in alpine meadows. RM.

Senecio franciscanus Greene. Endemic to the alpine zone of San Francisco Mountain, where it is commonly represented on rock slides. Discovered in 1884, but the type was collected by Greene in 1889. EN.

Solidago ciliosa Greene. Alpine rock fields and meadows; common. RM.

Taraxacum sp. Possibly a new record for the state, but the scarce material was undeterminable. In mats of other plants in alpine rock fields; very rare.

Partial List of Timberline Species

Specimens of the 24 additional species in this partial list of timberline species were collected by the author in the wind timber or subalpine meadows at timberline or slightly above.

Botrychium lanceolatum (S. G. Gmel.) Angstr.
Woodsia oregana D. C. Eaton
Juniperus communis L. var. sibirica (Burgsd.) Rydb.
Bromus ciliatus L.
Poa Fendleriana (Steud.) Vasey
Poa pratensis L.
Sitanion Hystrix (Nutt.) J. G. Smith
Carex Haydeniana Olney
Carex siccata Dewey
Luzula parviflora (Ehrh.) Desv.
Anemone globosa Nutt.
Aquilegia chrysantha A. Gray
Ribes montigenum McClatchie
Potentilla Hippiana Lehm. var. diffusa Lehm.
Potentilla subviscosa Greene
Rubus strigosus Michx. var. arizonicus (Greene) Kearney & Peebles
Geranium Richardsonii Fisch. & Trautv.
Viola canadensis L.
Epilobium angustifolium L.
Epilobium saximontanum Haussk.
Moneses uniflora (L.) A. Gray
Mertensia franciscana Heller
Penstemon Whippleanus A. Gray
Agoseris purpurea (A. Gray) Greene ?

Summary

San Francisco Mountain, elevation 12,655 feet, is an isolated volcanic cone located about ten miles north of Flagstaff, Coconino County, northern Arizona. The highest point in the state, it has a disjunct alpine flora which is Rocky Mountain alpine and arctic-alpine circumpolar in relationships. Two plant associations are distinguished in the alpine zone here, the alpine rock field or

lichen association on most of the rocky summit and the alpine meadow or *Geum turbinatum* climax association on limited, more favorable sites. Based upon collections by the author in 1938, 49 species of alpine vascular species and 24 additional timberline species are listed with brief notes on habitat and abundance. Four of these are previously unrecorded for the state: *Botrychium lanceolatum* (subalpine at timberline), *Juncus Drummondii, Erigeron compositus,* and *Erigeron simplex.*

Tucson, Arizona,
May, 1940.

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