Timberline is the most conspicuous and uniform vegetational boundary along the vast slopes of Iztaccihuatl and Popocatepetl. Its position marks the upper altitudinal limit of one dominant species, *Pinus hartwegii* Lindl. At the same time it delimits the lower edge of the alpine vegetation, which is generally considered to occur only above timberline (cf. Van Steenis 1934). Data on the elevations and positions of the timberlines of Iztaccihuatl and Popocatepetl have been obtained through use of photogrammetric and statistical methods as part of a taxonomic, ecological, and phytogeographic study of the alpine floras of Mexico and Guatemala.

Accurate determinations of the elevations of timberlines are desirable for several reasons. (1) Such data contribute to the understanding of the distribution and tolerance ranges of individual species. (2) The elevations of timberlines must be accurately known to facilitate understanding of factors controlling their positions. (3) Since timberlines delimit alpine from subalpine areas, knowledge of their elevations is necessary when comparisons are made among alpine floras of different mountains. (4) Should climatic fluctuations alter the elevation of timberline, the magnitude of change could be determined only if the previous elevation were accurately known. (5) Precise data are required for comparative studies of the elevations of timberlines throughout the world. For example, Troll (1961) and Daubenmire (1954) have shown that the elevation of timberline rises gradually from the poles toward the equator to about 25° or 30° lat, where it levels off; near the equator it may even dip slightly. The location of Iztaccihuatl and Popocatepetl at about 19°N lat makes accurate data on the elevation of their timberlines important to such studies.

Inaccuracies in the determinations of elevations of timberlines have resulted for at least three reasons. (1) Bench marks are often not available to permit accurate calibration of altimeters. (2) Timberlines may vary widely in elevation in local areas, making it difficult to distinguish an average elevation. (3) Different aspects of timberline have been measured; i.e., some investigators consider the upper edge of continuous forest to be timberline while others recognize it as the altitude of the highest tree, and still others accept a midpoint between these extremes.

The terms "timberline" or "límite de la vegetación arbórea" have not been precisely defined for Iztaccihuatl and Popocatepetl by previous authors. Recent papers by Troll (1959, 1961), however, indicate that in Mexico the forest line (*Waldgrenze*) occurs at 4,000 m and timberline (*Baumgrenze*) at 4,200 m. In the present study the word "timberline" denotes the boundary between subalpine forest and alpine meadow (forest line *sensu* Troll). The elevation of this boundary varies within certain limits which are expressed statistically in Table I. The maximum altitudinal limit of *Pinus hartwegii* (timberline *sensu* Troll) is most accurately indicated by the upper confidence limits (for randomly chosen elevations).

Elevations have been reported several times previously for the timberline of Popocatepetl but the Iztaccihuatl timberline has received relatively little attention. Most measurements have been made with barometric altimeters. According to Farrington (1897) the limit of trees on the northwest side of Popocatepetl was found at 3,639 m by Sonneschmidt in 1770, at 3,823 m on the south-southwest side by Glennie in 1827, at 3,980 m on the east side by Dollfus in 1865, and at 4,030 m on the north side by Aguilera and Ordoñez in 1894. Sonntag (1859) provided one of the most reliable early reports of the elevation of timberline on Popocatepetl. He noted that it occurred about 400 ft above Rancho Tlamacas on the north side of the cone, at nearly 13,200 ft of absolute height. This elevation coincides closely with the present position of timberline in relation to the former Rancho. Felix and Lenk (1890) stated that timberline was 50-80 m higher than Rancho Tlamacas. They included an excellent photograph taken


THE TIMBERLINES OF IZTACCIHUATL AND POPOCATEPETL, MEXICO

JOHN H. BEAMAN

Department of Botany and Plant Pathology, Michigan State University, East Lansing, Michigan

from Cerro Tlamacas which shows much of the timberline on the north side of Popocatepetl. Heilprin (1892) recorded an elevation of 13,160 ft (presumably near Tlamacas) for timberline on Popocatepetl and indicated that this was about 100 ft lower than the point at which the last pines on Iztaccihuatl were encountered. An elevation of 4,000 m was given for the timberline of Iztaccihuatl by Felix and Lenk (1890). On the basis of these early reports, it seems probable that in the 19th century the timberlines were in about the same position as they are at present.

GEOGRAPHY AND GEOLOGY

Iztaccihuatl (5,284 m) and Popocatepetl (5,452 m) are respectively the third and second highest mountains in Mexico and rank sixth and fifth on the North American Continent (Fig. 1). They are the two southernmost peaks in a short north-south range, the Sierra Nevada, which separates the Valleys of Mexico and Puebla (see Fig. 2, insert). Popocatepetl is almost perfectly conical, while Iztaccihuatl has a north-south elongation of about 10 km. The latter in profile suggests a white-blanketed woman (hence the Nahuatl name Iztaccihuatl, white woman). The summits of both mountains project more than 3,000 m above the surrounding valleys. The Paso de Cortes (3,680 m) is the lowest part of a saddle separating the two mountains; it is 84 km by road southeast of Mexico City.

Both Iztaccihuatl and Popocatepetl have been the subjects of considerable geological investigation. They are near the middle of a volcanic zone which crosses Mexico between lat 18° and 22° N. This zone coincides with the Clarion and San Andres faults (Lorenzo 1959). Iztaccihuatl is much older than Popocatepetl, dating back probably to the Miocene (Robles Ramos 1944, White 1951). The young Pleistocene cone of Popocatepetl is constructed over the older Nexpayantla volcano which may also extend back to the Miocene (White 1951). Iztaccihuatl apparently has been inactive since the early Pleistocene but Popocatepetl (which means smoking mountain in the Nahuatl language) erupted most recently in 1920-21. The principal rock of Iztaccihuatl is a gray amphibole-andesite. The cone of Popocatepetl, in which lava flows are interbedded with layered volcanic rocks, is a grayish-black hyper-
sthene-andesite (Farrington 1897, White 1951). Much of the surface of both mountains is mantled by black, sandy ash which is considerably weathered on Iztaccihuatl but little altered on Popocatépetl. The “perpetual snow” of Popocatépetl is a firm field on the northern and western upper slopes (White 1954). Most of the summit of Iztaccihuatl is capped by nine small glaciers (Lorenzo 1959). Great lateral moraines, probably of Wisconsin age, occur at 3,100-3,500 m in valleys on the west side of Iztaccihuatl; additional moraines are found at higher elevations, especially between 4,270-4,450 m (White 1956).

**CLIMATE**

In the Valleys of Mexico and Puebla the summers are wet and pleasantly cool and the winters dry and cool. At higher elevations on the mountains temperatures become progressively lower and precipitation increases. The latter reaches a maximum considerably below the summits, however, and then diminishes upward. According to White (1951) the maximum precipitation on the north side of Popocatépetl occurs at about 3,500 m.

Comparative climatic data from above and below timberline might contribute much to the understanding of environmental factors controlling the elevation of timberline but such data apparently do not exist. The most extensive climatic records were obtained in 1942 by Robles Ramos (1944) at Hueyatlaco on the west side of Iztaccihuatl at 3,551 m elevation. The average of the mean monthly temperatures at this station was 7.7° C. The average of the maximum monthly temperatures was 16.6° C, and the average of the minimum monthly temperatures was 0.6° C. The highest temperature of 20.5° C occurred in May and the lowest of −2.6° C in March. The highest mean monthly temperatures of 9.0-9.2° C were in April, May, and June, and the lowest of 6.1-6.2° C in December and January. Frosts occurred in every month except May and June but were most frequent from October through March.

Total precipitation at Hueyatlaco in 1942 was 1,368.7 mm. The wettest months, which each received between 186.4 and 296.5 mm, were June through September and November. Precipitation exceeding 0.1 mm occurred almost every day from June through September. The driest months, having between 6.1 and 40.9 mm precipitation, were January through April, October, and December. Snow fell only during November (2 times), December (11 times), and January (2 times). At higher elevations snows come at any time during the year. White (1951) has noted that above 4,300 m on Popocatépetl snow is the usual form of precipitation during June, July, and August. Hail is also common in the summer. The summer storms are of the orographic, convective type, with high winds and much lightning. The early mornings are usually clear, but after about 9 AM cumulus clouds begin to build up, first on Iztaccihuatl, and later on Popocatépetl (White 1951). Precipitation sometimes begins in the morning but more frequently comes in the afternoon. Storms may end in the afternoon or last into the night. Occasionally during the summer there are periods of several days which are continuously cloudy with light rain falling most of the time. During the dry winter months completely cloudy days are rare.

Although the Hueyatlaco climatic data were taken about 500 m below timberline on Iztaccihuatl, they are still suggestive of the general climatic regime at timberline. A very important difference is evident between the climate of this area and climates at timberline at more northern latitudes. Winter temperatures on Iztaccihuatl and Popocatépetl are not much colder than summer temperatures. In contrast, winter temperatures at timberline in such areas as the Rocky Mountains are extremely low. Snow at timberline on Iztaccihuatl and Popocatépetl is infrequent and of short duration. Great quantities of snow and ice accumulate during the winter at timberlines to the north. Climatic differences between high and low latitudes and their relationship to timberlines have been discussed by Troll (1959). In view of such differences, it is remarkable that there are similarities in timberlines at low and high latitudes.

**MATERIALS AND METHODS**

Elevations and positions of the timberlines are based on two topographic maps, 14Q-h (107) Iztaccihuatl and 14Q-h (123) Popocatépetl (scale, 1:25,000; contour interval, 10 m) published in 1954 and 1956, respectively, by the Departamento Cartográfico Militar of the Secretaría de la Defensa Nacional, México, D. F., México. The Iztaccihuatl map covers the west side of Iztaccihuatl; the Popocatépetl map includes the northwest side of Popocatépetl and all of the Paso de Cortes. The maps are marked with a military grid (indicated by tick marks in Figs. 2-4) to facilitate location of specific points. Figures 2-4 were traced directly from the maps after the timberlines had been placed on them by the method outlined below.

The Iztaccihuatl timberline (Fig. 2) was mapped mostly along the west side of the mountain from the farthest point in a northeastern direc-
tion permitted by the map to an arbitrary stopping point directly west of Cerro Amacuilecatl (Pies). The timberline on Milpulco ridge was not included. The Popocatépetl timberline (Fig. 3) was mapped over all of the area permitted by the map, except that timberline on the Yoloxochitl ridge was not included. The forest-meadow boundary in the Paso de Cortes (Fig. 4) was mapped to the north edge of the Popocatépetl map (open meadow is continuous from the Paso de Cortes to the south side of Iztaccihuatl). Three other topographic maps which will cover the remaining portions of the mountains are as yet unpublished.

The timberlines were interpreted from vertical aerial photographs, numbers 28-41 and 52-62 of Levantamiento del Estado de México, No. 1230, made in December 1955 by the Cia. Mexicana Aerofoto, S. A., México, D. F., México.

Radial line triangulation (cf. Spurr 1960) was used to relocate a series of photographic points on the base maps. Timberlines were then transferred to the maps by means of an Abrams Instrument Corporation “Sketchmaster,” which utilizes a semitransparent mirror system to visually superimpose the photographic image on the map. Timberline as seen on the photographs was sketched on the maps within triangles formed by three neighboring points common to photograph and map.
Relatively little subjective judgment was involved in mapping. On Iztaccihuatl and in the Paso de Cortes the boundary between forest and meadow is clearly evident in the aerial photographs. Small islands of trees above the continuous forest were not drawn or measured. Similarly, meadows below continuous forest were not included. Delimitation of timberline on Popocatepetl was complicated by two factors. (1) An extremely deep, almost vertical-walled valley (Barranca de Nexpayantla) cuts through timberline on the northwest side, causing heavy shadows and extreme relief in short distances. Timberline in this area was difficult to delineate accurately. (2) On the west side of the cone vast deposits of relatively new, unconsolidated volcanic ash occur at timberline. Trees are scattered over much of the ash deposit but do not form continuous forest. Timberline in this area was considered to correspond to the upper maximum limit of trees; some large, sparsely forested areas occur below timberline.

After the timberlines had been drawn on the maps their elevations at any location were evident from the contour lines. Samples of elevations at 100 randomly selected points on each of the timberlines were obtained as follows. The maps, with the timberlines transcribed on them, were enlarged five times with a Saltzman projector to facilitate accurate measurements of distances along the timberlines with a Keuffel and Esser Map Measure. One hundred points at random distances (obtained from a random numbers table) from a starting point were measured with the map measure and marked on the enlarged timberlines. The random points were transferred to the original maps by reduction with the projector. The elevations of all points were determined from the contour lines. Computations were then made of the means, medians, standard deviations, coefficients of skewness, and confidence limits. Confidence limits were computed from the Pearson Type III probability distribution (Carver 1950).

**Discussion**

*Descriptions of the timberlines*

Data on the elevations of the timberlines of Iztaccihuatl and Popocatepetl and the forest-meadow boundary in the Paso de Cortes are summarized in Table I. The nearly constant elevation of the timberline on Iztaccihuatl is evident from the low standard deviation and the narrow confidence limits. This uniformity is also apparent in Fig. 2 where timberline and the 4,000-m contour line can be seen to closely parallel each other. Minor variations in elevation are usually correlated with local topographic features (Fig. 1). Maximum elevations are attained on ridges, while minimum elevations occur in depressions. The density of *Pinus hartwegii* at timberline is only slightly less than at lower elevations, although at the upper edge of the forest small patches of trees are often interspersed with meadow (Fig. 5). The trees are rarely deformed but become smaller at their upper limit. Individual trees and small islands of trees which are found occasionally above timberline almost never

| Table I. Statistical data (in meters) on the elevations of the timberlines of Iztaccihuatl and Popocatepetl and the forest-meadow boundary in the Paso de Cortes. |
|---|---|---|---|
| Item | Iztaccihuatl | Popocatepetl | Paso de Cortes |
| Mean elevation | 4,020 | 3,911 | 3,725 |
| Median elevation | 4,001 | 3,909 | 3,719 |
| Standard deviation | 49 | 82 | 82 |
| Coefficient of skewness | -0.17 | 0.07 | 0.30 |

* Confidence limits for randomly chosen elevations give the percentage (99% or 99%) of timberline that can be expected to occur within the range of elevations indicated. Confidence limits for the population means were obtained by the standard method in which they had a specified chance (99% or 99%) of including the population means before the elevations were sampled.

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**Fig. 5.** Vertical aerial view of a segment of timberline on the west side of Iztaccihuatl, December 1955. Alpine area is at right, with subalpine forest to the left. Photo by Cia. Mexicana Aerofoto, S. A.
occur higher than the maximum limit of continuous forest.

The timberline of Popocatépetl, with a mean elevation 109 m lower than that of Iztaccíhuatl, also differs from the latter in having nearly twice as great a standard deviation. It tends to follow the 3,900-m contour (Fig. 3) but there are conspicuous deviations. Timberline on the north side of Popocatépetl is fairly similar to that on Iztaccíhuatl although the average elevation is slightly lower. In the Barranca de Nespayantla, on the northwest side, variations in elevation apparently are caused by steep slopes and cliffs. On the west side extensive volcanic ash deposits probably are responsible for lowering timberline to an average elevation of about 3,850 m, and the density of the pine forest is much reduced. In part of this area timberline follows the line of contact between old and new ash deposits (Fig. 6). Trees occur on the lower, older ash which has been dissected by erosion. They have not invaded the newer, undissected deposit which has encroached on the older material from above.

The forest-meadow boundary in the Paso de Cortes has not been called a timberline for several reasons. On the south side of the Paso de Cortes the meadow is bounded by forest from above (Fig. 4). The mean elevation of this line is nearly 200 m lower than that of the timberline on Popocatépetl and almost 300 m lower than the mean elevation of the Iztaccíhuatl timberline. Although there are no extremely irregular topographic features or large areas of unstabilized volcanic ash in the Paso de Cortes, the standard deviation is as great as that for the timberline on Popocatépetl. Furthermore, the dominant species in the Paso de Cortes meadow are not the same as those immediately above timberline on Iztaccíhuatl and Popocatépetl (Beaman, in press). The forest-meadow boundary in the Paso de Cortes is therefore not a timberline. The meadow is subalpine rather than alpine. As it extends to higher elevations on the south side of Iztaccíhuatl, it gradually becomes alpine, and the forest-meadow boundary grades into timberline. In aerial photographs the forest-meadow boundary is more sharply defined than the two timberlines. Trees adjacent to the subalpine meadow are mostly larger and the stands denser than those at timberline on Iztaccíhuatl and Popocatépetl.

Evidently the meadow in the Paso de Cortes has been present for a long time. In his ascent of Popocatépetl in 1896, Farrington (1897) noted that after about a 2-hour ride through woods he came to a series of well-marked plateaus with long stretches of dry grass "dotted here and there with stunted pines." This area is unmistakably

**Fig. 6.** Vertical aerial view of a segment of timberline on the west side of Popocatépetl, December 1955. More recent, undissected volcanic ash deposit to the right is above timberline. Older, dissected ash to the left is sparsely forested with *Pinus hartwegii*. Photo by Cia. Mexicana Aerofoto, S. A.

**Fig. 7.** View from the south side of Iztaccíhuatl at 3,750 m, southward across the Paso de Cortes to the north side of Popocatépetl. The dominant grass in the subalpine meadow in the foreground is *Muhlenbergia quadridentata* Kunth.
the Paso de Cortes which still has very much the same appearance (Fig. 7). In discussing Cortes’ march of 1520 into the Valley of Mexico, Prescott (1864, p. 462) wrote, “It was night before the way-worn soldiers reached the bald crest of the sierra,” suggesting that the Paso de Cortes was treeless at the time of the Conquest. Unfortunately neither the letters of Cortes (Folsom 1843) nor the manuscript of Bernal Diaz (Maudslay 1933), who traveled with Cortes, suggests what vegetation was encountered at the highest point on the trail.

**Distribution, reproduction, and growth of Pinus hartwegii**

*Pinus hartwegii* is the dominant tree species at timberline on all high mountains in the Mexican volcanic zone. Possibly it also occurs as far north as Cerro Potosi in Nuevo Leon and south to the high volcanoes of Guatemala, but its counterpart in these areas is currently called *P. rudis* Endl. or *P. montezumae* var. *rudis* (Endl.) Shaw. Heilprin (1892) noted that on the Mexican volcanoes *P. hartwegii* attains a higher elevation than has been recorded for any other pine. It is the only tree occurring above 3,600 m on Iztaccihuatl and Popocatepetl. Its lower altitudinal limit is about 3,100-3,200 m. The only other gymnosperm at or above timberline on the two mountains is *Juniperus monticola* Martinez, which forms small, dense stands suggestive of krummholz. *Pinus hartwegii*, in contrast, is erect and little deformed (Fig. 8), probably because snow and ice accumulation in winter is negligible.

Young plants of *Pinus hartwegii* are rare in both alpine and subalpine meadows of this area.

![Fig. 8. View of timberline on the north side of Nevado de Toluca, about 120 km west of Iztaccihuatl and Popocatepetl. The crown form of *Pinus hartwegii* shown here at timberline is characteristic for this species on all of the high volcanoes in Mexico.](image)

Seedlings were never encountered in meadows in 500 half-square-meter quadrats (100 randomly distributed quadrats per stand in 10- by 100-m stands at 3,700 m in the Paso de Cortes and at 4,000 m and 4,300 m on Iztaccihuatl and Popocatepetl). Pine seedlings occurred with a frequency of 37% in 150 similar quadrats in a forested area near the Paso de Cortes. Although seedlings were not encountered in the sample, it is apparent from Fig. 7 that a few pines have become established in the subalpine meadow.

Radial stem growth was analyzed for eight trees of *Pinus hartwegii* which occurred in the

![Fig. 9. Interior of *Pinus hartwegii* forest at 3,700 m on the northeast side of Paso de Cortes. The dominant grass is *Festuca toluensis* H.B.K.](image)
upper altitudinal range of the species (Table II). Although the data are limited, it is evident that all of the trees grew fairly rapidly. The period of most rapid growth lasted for a short time, averaging only about 30 years. The sample included some of the largest trees in the area (trees 2, 5, and 7), but the maximum age was only 66 years. Thus it appears unlikely that trees of great age, such as those at some timberlines in the western United States, occur at timberline on Iztaccihuatl and Popocatepetl. Stands are probably uneven-aged, but data on age classes are not available. A typical view inside the forest slightly below timberline is shown in Fig. 9.

Environmental factors affecting the elevation of timberline

Although this study was made primarily to determine as precisely as possible the elevations and positions of the timberlines on Iztaccihuatl and Popocatepetl, the data also help to suggest what environmental factors may be important in controlling the timberlines. Daubenmire (1954) has discussed several climatic factors assumed by various authors to affect the elevation of timberline. These include excessive light, light deficiency, carbon dioxide deficiency, snow depth, wind, desiccation during temperature inversions in winter, and heat deficiency. He concludes that heat deficiency may be the most important single factor.

Differences in mean elevations of the timberlines of Iztaccihuatl and Popocatepetl and the forest-meadow boundary in the Paso de Cortes suggest that critical factors influencing their positions are not the same. From the nearly constant elevation of timberline on Iztaccihuatl it appears that the most significant controls are not local. Thus a major role is indicated for some universally occurring climatic factor which is directly correlated with altitude. In connection with the heat-deficiency hypothesis, it should be noted that timberlines apparently coincide with the isotherm of 10°C for the warmest month (cf. Daubenmire 1954). At Hueyatlaco on Iztaccihuatl the highest mean monthly temperature was 9.2°C (Robles Ramos 1944). While these data are inadequate, they seem to support the idea that low temperatures may be critical in determining the Iztaccihuatl timberline.

Minor variations in the elevation of timberline on Iztaccihuatl probably involve environmental factors different from those responsible for its general position. Since the forest boundary usually reaches its maximum elevation on ridges and is lowest in depressions, it is possible that either cold-air drainage or excess soil moisture is critical in the latter areas.

The timberline on Popocatepetl is governed by a complex of factors somewhat different from that on Iztaccihuatl. Irregularities in its position on the northwest and west sides of the mountain apparently are caused by the Barranca de Nexpayantla and large areas of volcanic ash. Ash deposits in particular seem to play an important role in depressing the mean elevation of timberline. The ash is very porous (White 1951). During dry periods it is subject to movement by winds and in heavy rains it is readily eroded. Both the xeric nature of the ash and its instability may restrict the invasion of trees. Furthermore, Eggler (1959) has noted that in volcanic ash of Pari cutin the establishment of plants is probably retarded by mineral nutrient deficiencies. Recent ash deposits, together with climatic factors, are probably responsible for the present position of timberline on Popocatepetl.

Three environmental factors, other than those considered in connection with Iztaccihuatl and Popocatepetl, may be involved in maintaining the large subalpine meadow in the Paso de Cortes. (1) High winds sweep through the area almost constantly. In contrast, the flanks of Iztaccihuatl and Popocatepetl at the same elevations are somewhat protected from winds by the mountain masses. (2) Burning may prevent pine seedlings from becoming established in the meadow. Fires occur in some part of the Paso de Cortes almost every year, and the entire area is probably burned at rather frequent intervals. Large trees in adjacent forest areas are not ordinarily killed by fires. (3) Local residents have utilized the trees for fuel and other purposes. But it might be expected that forests at lower elevations would have been destroyed previous to those in the Paso de Cortes.

Once the meadow became established, whether by natural means or through the influence of man, the invasion of pines probably has been prevented by adverse environmental conditions. The grassy parks or balds of the Rocky Mountains and the Southern Appalachians may be northern counterparts, although Billings and Mark (1957) have suggested that these are ecotonal, occupying positions between the tolerance ranges of different dominant tree species. The meadow in the Paso de Cortes is entirely within the altitudinal range of Pinus hartwegii. Nevertheless, this meadow appears generally comparable to parks and balds elsewhere. The elevation of the Paso de Cortes is only a few hundred meters below the maximum altitudinal limit of the dominant tree species. Be-
cause *P. hartwegii* is already near its climatic tolerance limit, factors such as wind and fire, affecting young plants, may restrict it from the subalpine meadow.

Only tentative conclusions as to what factors are critical in controlling timberline elevations may be drawn from this study. Final solution of the problem must await experimental investigation. It is evident, however, that caution is necessary in the selection of data for use in comparative studies on elevations of timberlines. Comparisons among widely separated mountain systems require data which reflect the primary influence of climate. The figures for Popocatepetl and the Paso de Cortes are not truly representative of the elevation of timberline in Mexico. Only the Iztaccihuatl data are suitable for comparative studies of climatically determined timberline elevations.

**Summary**

Photogrammetric techniques were used to transcribe the timberlines on the west side of Iztaccihuatl, the northwest side of Popocatepetl, and the forest-meadow boundary in the Paso de Cortes to large-scale topographic maps. Elevations at 100 randomly selected points were obtained from each timberline. Mean elevations, median elevations, standard deviations, and confidence limits were computed from these samples. The mean elevations for the timberlines and the forest-meadow boundary are as follows: Iztaccihuatl, 4,020 m; Popocatepetl, 3,911 m; Paso de Cortes, 3,722 m. The latter is not a timberline.

Seedlings of *Pinus hartwegii*, the dominant tree species at timberline, occurred at a relatively high frequency in a pine forest near the Paso de Cortes. They were not observed in alpine and subalpine meadows. Trees at timberline are relatively young and their growth is rapid.

The elevation of timberline on Iztaccihuatl is controlled by climatic factors, with low temperatures probably being critical. The elevation of timberline on Popocatepetl apparently is conditioned by both climatic factors and recent deposits of volcanic ash. Reasons for the occurrence of the subalpine meadow in the Paso de Cortes are not clear, but wind and fire may be involved.

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