or at higher elevations within its drainage basin.

In the specific example of zone W-1 the moderately high influx of pine pollen to Lake Washington sediments suggests a pine forest nearby (*28*). The contemporaneous lignin record, however, indicates that this woodland probably did not extend upstream of the lake, where herbaceous flowering plants apparently predominated. This suggested vegetation pattern for zone W-1 may have been transitional to those of later periods when regional vegetation and vegetation within the upstream drainage basin were similar, resulting in more consistent sedimentary lignin and pollen records.

In conclusion, it is clear that lignin does not reflect genus-level changes in vegetation that can be characteristic of paleoenvironmental conditions. However, as indicated by our results for zone W-1, the lignin chemical analyses may under some circumstances detect classes and distributions of local vegetation that are not evident from pollen remains. Determinations of lignin compositions in lake sediments, in association with pollen analyses, may provide complementary indicators of paleovegetation.

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8. Lake Washington (elevation 6.4 m) is 29 by 3 km and up to 65 m deep; it drains an area of about 300 km^2 directly east of the lake. The core was collected at 47°40.4'N and 122°13.4'W with the cooperation of the captain and crew of the R.V. *Thompson*, D. Morrison and A. van Geen.
9. Pollen percentages were calculated from tallies of 500 to 600 grains mounted in silicone oil. Influx values were determined by counting the proportion of exotic grains added and applying ^{14}C ages to calculate sedimentation rates [L. J. Maher, *Rev. Paleobot. Palynol.* **32**, 153 (1981)].
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Eruption of El Chichón Volcano, Chiapas, Mexico, 28 March to 7 April 1982

Abstract. *El Chichón volcano erupted at 2322 hours on 28 March 1982 after being dormant during historic times. Three major eruptions of tephra occurred between that date and 7 April, discharging approximately 0.3 cubic kilometer of andesitic pyroclastic material. The initial eruption produced crystal-rich tephra of higher silica and alkali content than the lithic pyroclastic materials of the second and third eruptions. The initial tephra consists of primarily juvenile materials, whereas the later eruptions produced both lithic and juvenile fractions.*

The volcano El Chichón, located in the southeastern state of Chiapas, Mexico, initiated a series of major tephra eruptions at 2322 hours on 28 March 1982. The late Pliocene or early Pleistocene stratovolcano, which lies on the east end of the Mexican neovolcanic zone in the modern Chiapacean Volcanic Arc (*1*), historically had been inactive, displaying only solfataric activity (*2*).

Chiapas marks the juncture of the American, Cocos, and Caribbean plates. Current volcanic activity in the area is attributed to continued subduction of the Cocos plate beneath southeastern Mexico (Fig. 1) (*1*).

During the first 10 days of activity approximately 0.3 km^3 of tephra was ejected in three major eruptions, causing 187 confirmed deaths and leaving 60,000 people homeless (*3*). No lava flow was reported, but pyroclastic flows and

Table 1. Chemical analysis of tephra and dome material, El Chichón. The data for tephra ejected between 28 March and 2 April represent 12 samples; the 3 to 7 April data represent 22 samples. Values are percentages by weight. N.D., not determined.

Compound	28 March to 2 April		3 to 7 April		Andesite dome	Standard deviation	Mean standard error
	Mean	Range	Mean	Range			
SiO_2	59.3	54.9 to 62.2	56.4	53.8 to 60.2	58.2	±0.6	±0.13
TiO_2	0.7	0.6 to 0.8	0.8	0.7 to 0.9	0.8	±0.2	±0.01
Al_2O_3	17.3	16.8 to 17.8	17.3	16.6 to 18.5	16.8	±0.7	±0.10
FeO*	5.4	4.8 to 5.6	6.3	5.2 to 10.3	6.5	±0.1	±0.01
MnO	0.1	0.1 to 0.2	0.1	0.1 to 0.2	0.2	±0.1	±0.00
MgO	1.8	1.2 to 2.8	2.2	1.8 to 3.3	2.1	±0.8	±0.16
CaO	6.2	6.0 to 8.0	6.9	5.8 to 8.8	7.5	±0.4	±0.01
Na_2O	4.5	3.5 to 6.0	4.2	3.6 to 5.2	4.2	±0.7	±0.19
K_2O	3.1	2.0 to 3.6	2.9	1.8 to 3.5	2.4	±0.2	±0.01
P_2O_5	0.1	0.0 to 0.1	0.1	0.0 to 0.1	0.1	±0.1	±0.01
LOI†	1.4	1.1 to 1.4	1.3	0.3 to 1.5	N.D.		
Total	99.9		98.6		98.8		

*Includes total Fe. †Loss on ignition.

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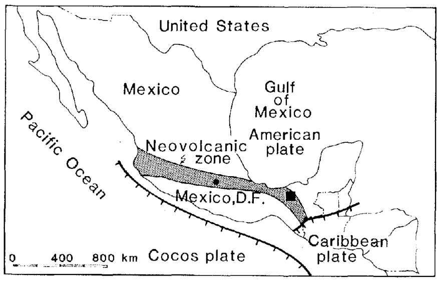

Fig. 1. Index map showing the location of El Chichón (black square, which is also the area shown in Fig. 2).

surges were noted during the April eruptions (*4*).

The first eruptions were characterized by the emission of large amounts of ash, moderate amounts of pumice, and lesser amounts of lithic fragments (*5*). The first phase continued through 2 April, producing a light-gray ash that spread predominantly northeast of the volcano. Thicknesses of 500 mm were measured within 15 km of the volcano, diminishing to 200 mm at 75 km. Approximately 100 mm of fallout materials accumulated in Villahermosa, the capital of the adjacent state of Tabasco.

The second phase consisted of two major eruptions, on 3 April (1933 hours) and 4 April (0536 hours). These eruptions produced a brownish-gray, richly lithic tephra that spread predominantly east of the volcano. At 1030 hours on 4 April, tephra was falling at a rate of 0.33 g/m^2 per second near Teapa, producing almost total darkness and reducing visibility to less than 5 m. By 1230 hours the rate of fallout had decreased to 0.05 g/m^2 per second. On 4 April a number of pyroclastic flows, consisting of hot ash and large pumice blocks, were reported to be moving down the slopes of El Chichón (*3*). Tephra thicknesses of over 400 mm were measured on 5 April near Palenque, 125 km east of the volcano.

Tephra thicknesses were measured and samples collected at 30 sites west, north, and east of the volcano from 3 to 7 April; 23 of the sample locations are shown in Fig. 2. Thirty-four tephra samples from 20 locations north and east of the volcano have been chemically analyzed by nondispersive x-ray fluorescence and atomic absorption methods (Table 1).

The tephra can be divided into two types on the basis of chemical composition. The basal tephra, representing the initial eruptions of 28 March to 2 April, has a lithic content of less than 5 percent and is composed of light-gray materials averaging approximately 59 percent silica. It is overlain by richly lithic tephra, from the 3 and 4 April eruptions, that is light brown to reddish gray and averages about 56 percent silica. Lithic fragments, consisting primarily of reddish-brown hornblende andesite, constitute over 30 percent of the tephra within 30 km of the volcano, but less than 15 percent at distances greater than 80 km. The basal tephra contains higher average concentrations of total Fe, MgO, and CaO and lesser amounts of total alkalis than the pyroclastic materials from the 3 and 4 April eruptions. The content of SiO_2, $K_2O + Na_2O$, and $FeO + MgO$ is graphed in Fig. 3 for each sample analyzed. Although the basal tephra is generally higher in silica and lower in FeO + MgO than that of the later eruptions, a considerable gradation exists between the two types. There are higher concentrations of total Fe and lower concentrations of silica in samples from the 28 March eruptions than in samples from the later eruptions.

The similarity in the concentrations of Ti, Fe, Ca, Na, and Mg oxides of the April tephra and those of a sample from an andesite dome in the crater suggest that the 3 and 4 April eruptions primarily

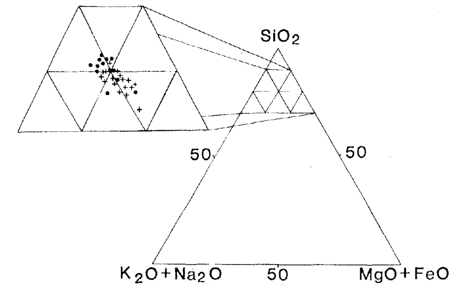

Fig. 3. Graph showing SiO_2, $K_2O + Na_2O$, and MgO + FeO content of tephra from El Chichón (FeO = total Fe). The tephra was ejected between 28 March and 2 April (●) and between 3 and 7 April (+).

involved the fragmentation of preexisting volcanic units of the cone. In addition, the dome rock contains an abundance of reddish-brown oxidized hornblende, which can be identified in the reddish-gray tephra from the later eruptions.

The tephra erupted from El Chichón is calc-alkaline in overall chemical composition and similar to andesitic materials ejected from other volcanoes of the neovolcanic zone (*6*).

In summary, El Chichón volcano began a series of pyroclastic eruptions on 28 March 1982. The first phase of the eruptions, 2 March to 28 April, produced light-gray pumice and ash of andesitic composition and mostly juvenile origin. The second phase, 3 to 7 April, was accompanied by several pyroclastic flows and surges in addition to large amounts of highly lithic fallout. The fallout is mostly reddish-gray ash of more basic composition than that produced from the initial eruptions and represents both juvenile and lithic materials.

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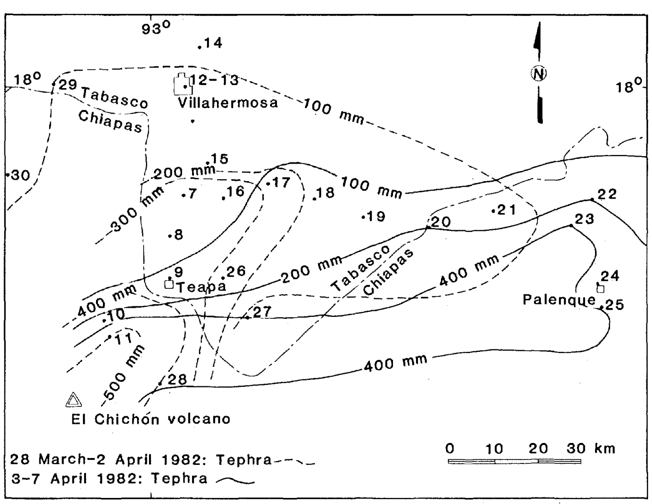

Fig. 2. Tephra accumulation north and east of El Chichón, 28 March to 7 April 1982.

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