SECTION 5
SUBSOIL CONDITIONS IN METROPOLITAN MEXICO CITY AND CHARACTERISTICS OF THE 1985 MICHOACAN EARTHQUAKE

In this section, geological and soil information for the Mexico City region is presented. Specifically, soil types as well as soil zonation for the metropolitan area are described. Information about subsoil topography (i.e. depth of hard deposits) as well as the distribution of site response periods are also presented. Finally, characteristics of the 1985 Michoacan earthquake of interest to lifeline earthquake engineers are discussed.

5.1 Subsoil Conditions

Metropolitan Mexico City is located in a closed basin surrounded by mountains of volcanic origin. Through geological time, the basin became a lake where volcanic ashes were deposited and decomposed into a lacustive clay. This lake eventually dried exposing lake bed soils of unusual mechanical characteristics well recognized in the soil mechanics literature. Detailed characteristics of the different geological materials found in the area are presented by Marsal [5] and Margal and Mazari, [6]. However, for engineering purposes, subsoil conditions in the valley have been grouped in three zones as shown in figure 5-1. These zones are;

a. The Hill Zone; located in the hilly areas around the bed lake and formed basically of volcanic rocks, dense sand and silts.

b. The Transition Zone; located between the Hill and Lake Zones and formed of a shallow layer of clay founded on volcanic rock formations dipping toward the center of the lake.

c. The Lake Zone; located in the lakebed and consisting primarily of soft lacustrine clays, with some clayey siltly sands and medium dense clayey sands all of alluvial origin. Typical statigraphy in this zone is shown in figure 5-2 which was developed from borehole data. The profiles are along sections AA and BB of figure 5-1.

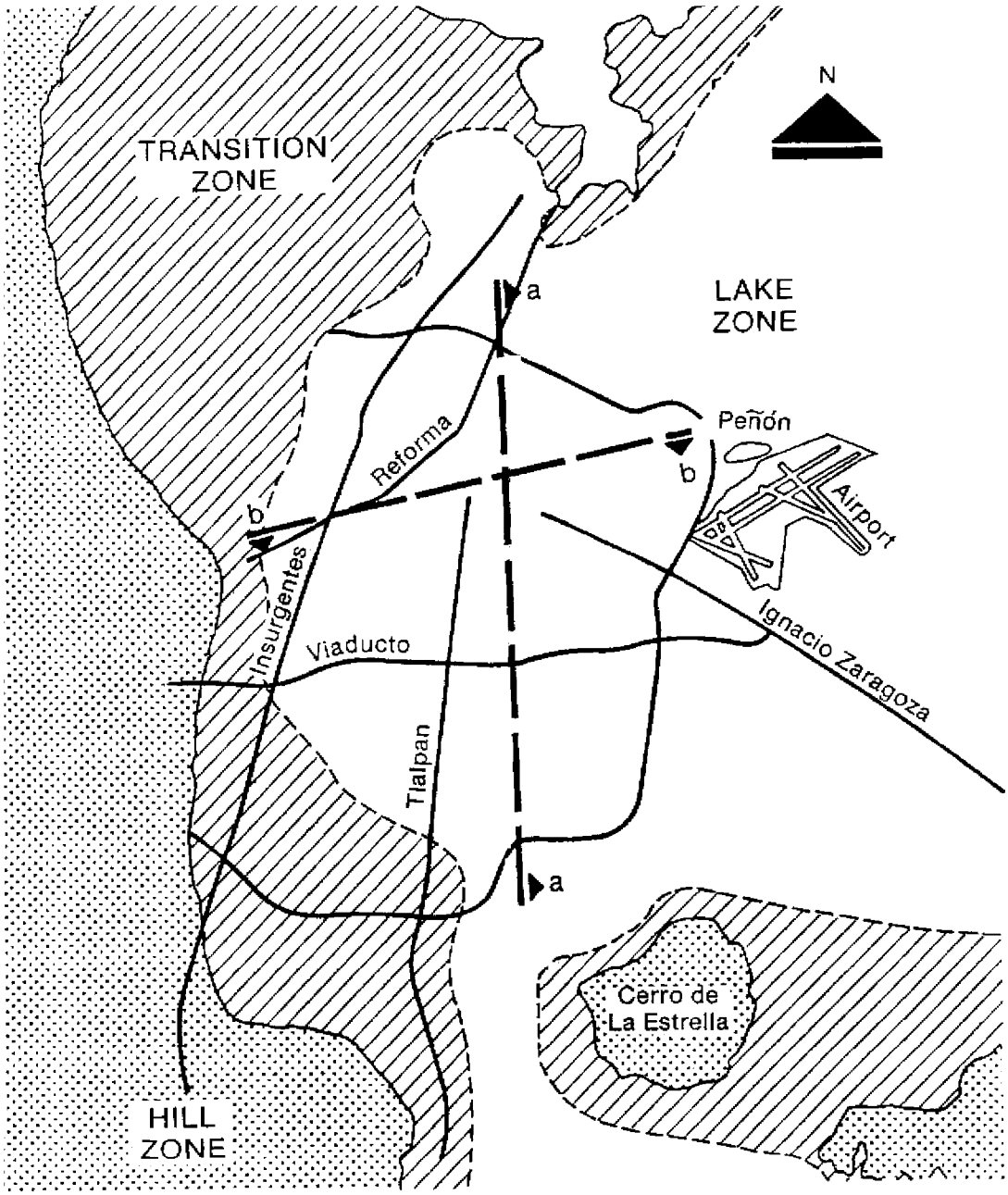

FIGURE 5-1 Soil Zones For Metropolitan Mexico City

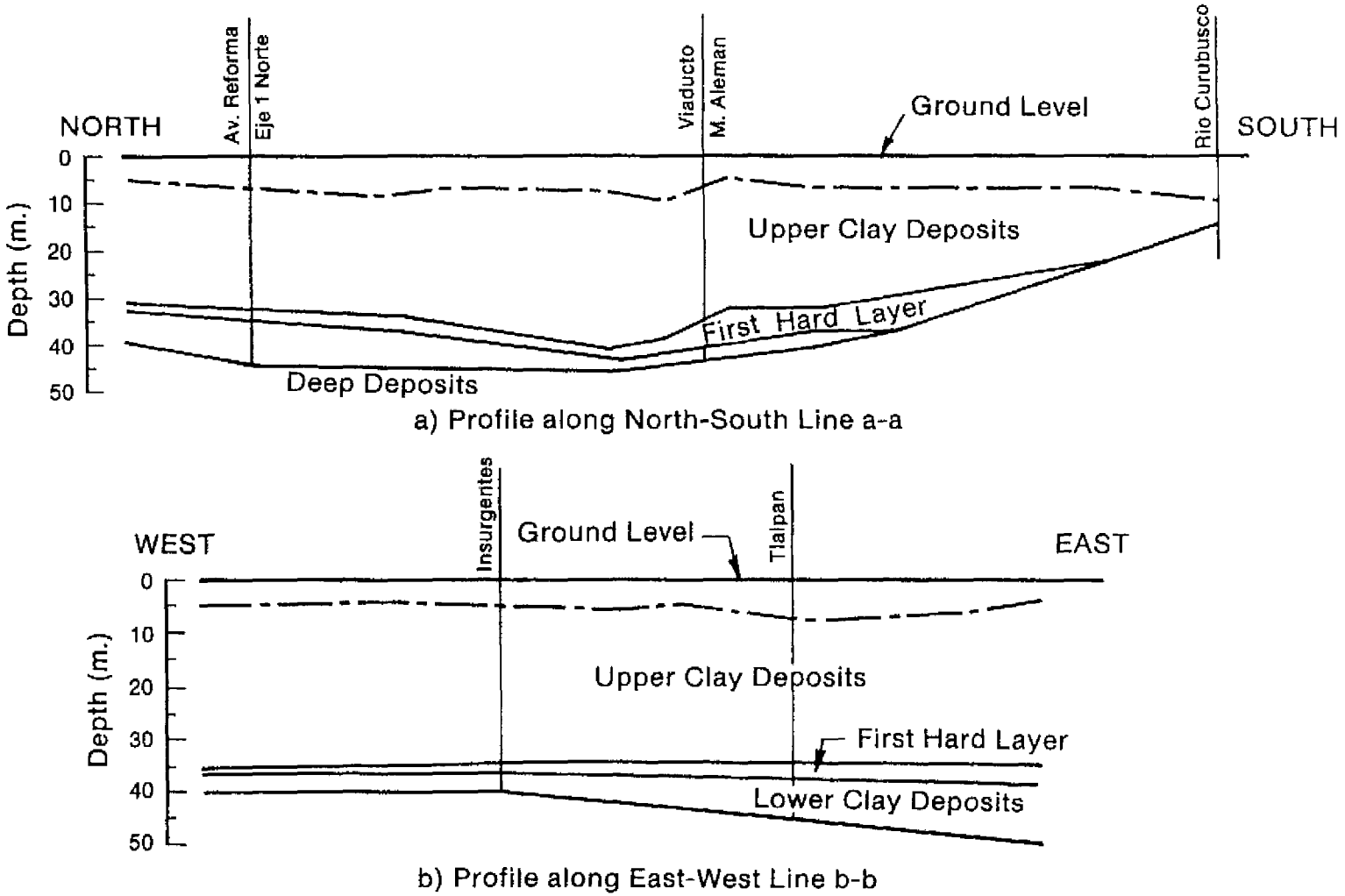

FIGURE 5-2 Soil Profiles For Metropolitan Mexico City

Figure 5-3 depicts the lines of equal depth in meters to the deep deposits. After the September 1985 earthquake, an extensive soil exploration program coupled with microtremor measurements was initiated, [7]. Figure 5-4 shows lines of equal site response period. As one would expect, there is a tendency for deeper sites to have longer periods. However when figures 5-3 and 5-4 are compared there is a lack of a one to one correlation between site period and depth to the deep deposits. As will be discussed in Section 6, most of the distribution pipeline damage occurred in the Lake Zone particularly at locations with site response period of two seconds or larger and with depths to the deep deposit of 30m to 70m. Seismic damage to aqueducts (large diameter transmission mains) occurred only in 'delegaciones' Thahuac and Xochimilco which are located in the southeast part of the city. This part of the city is in the Transition and Lake Zones south of the Cerro de la Estralla (Hill of the Star) and the Cerro de Sta. Catarina (Hill of St. Catarina) and is not heavily urbanized. Local soil conditions along the main main acqueducts in the southeastern part of the city have been reconstructed from available sources [8]. It was observed that the near surface shear wave velocities range from 30 to 50 m/sec in the Lake Zone and were typically about 100 m/sec in the transition zone.

5.2 Characteristics of the Earthquake Motions

The Michoacan Earthquake of September 19, 1985, one of the most destructive in this century, originated about 400 km southwest of Mexico City as shown in figure 5-6. The earthquake was generated at a depth of about 18 km in a subduction zone where the Cocos Plate subducts the North American Plate, as shown in figure 5-7. It consisted of two subevents, with the second initiating about 26 seconds after the first.

The epicentral area had been widely recognized as one with a high probability of earthquake occurrence. As a result, the instrumental information was extensive with numerous records in the epicentral area as well as at different locations in the Valley of Mexico.

In the Valley of Mexico (ie, Metropolitan Mexico City), the recorded ground motions are considered to be fairly unusual due to long period

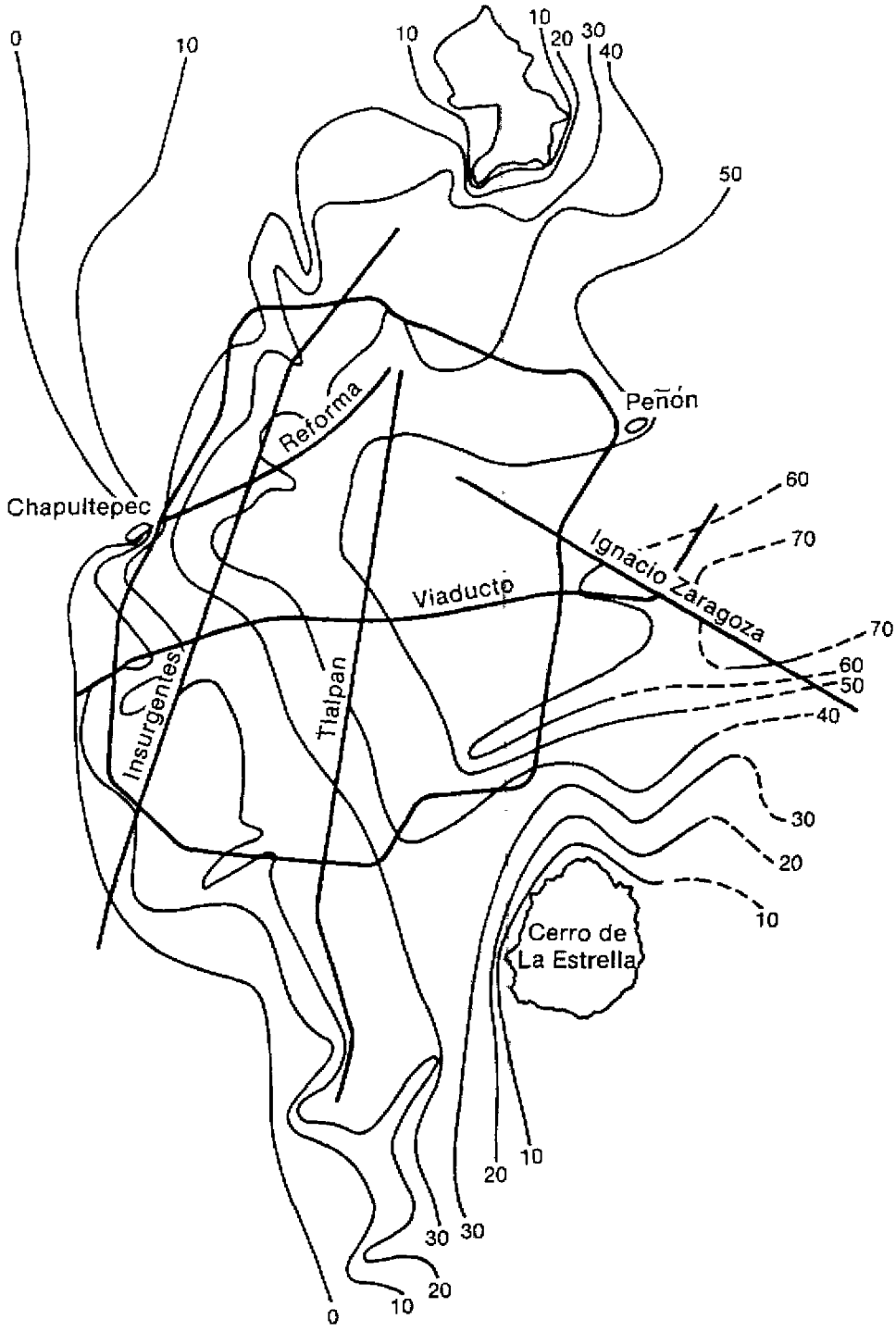

FIGURE 5-3 Lines Of Equal Depth To Deep Deposits (In Meters)

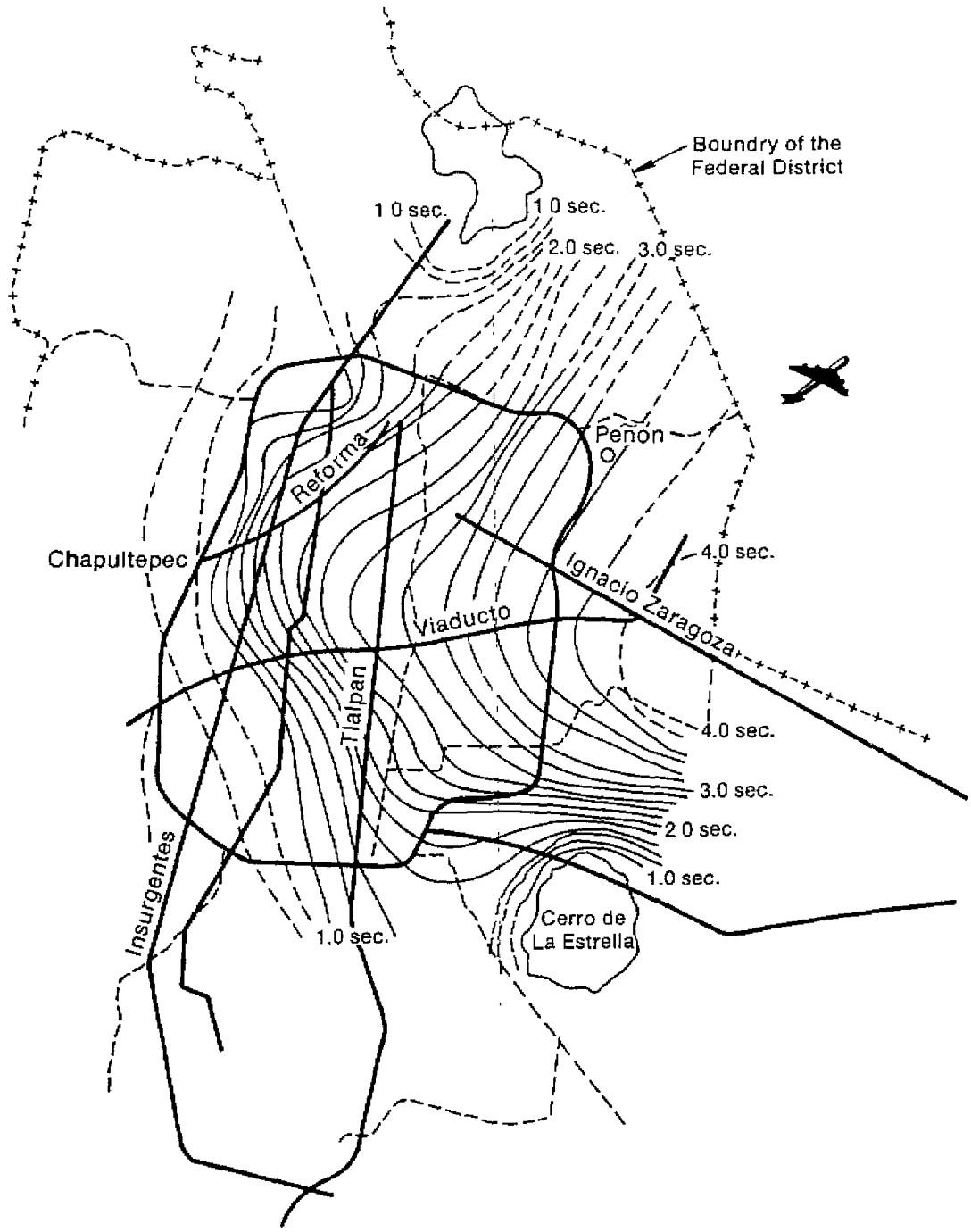

FIGURE 5-4 Lines Of Equal Site Response Period (In Seconds)

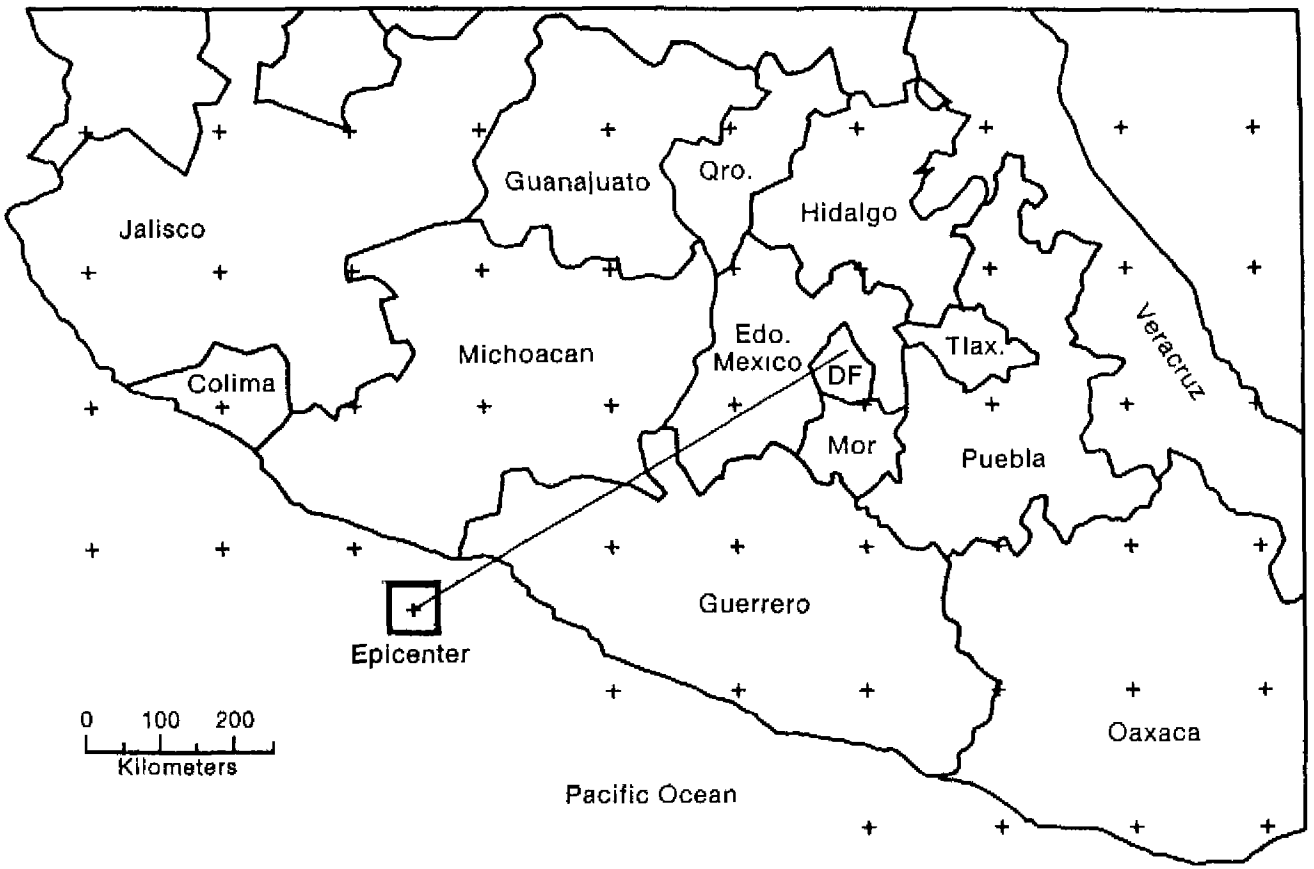

FIGURE 5-5 Epicenter Location For Michoacan Earthquake

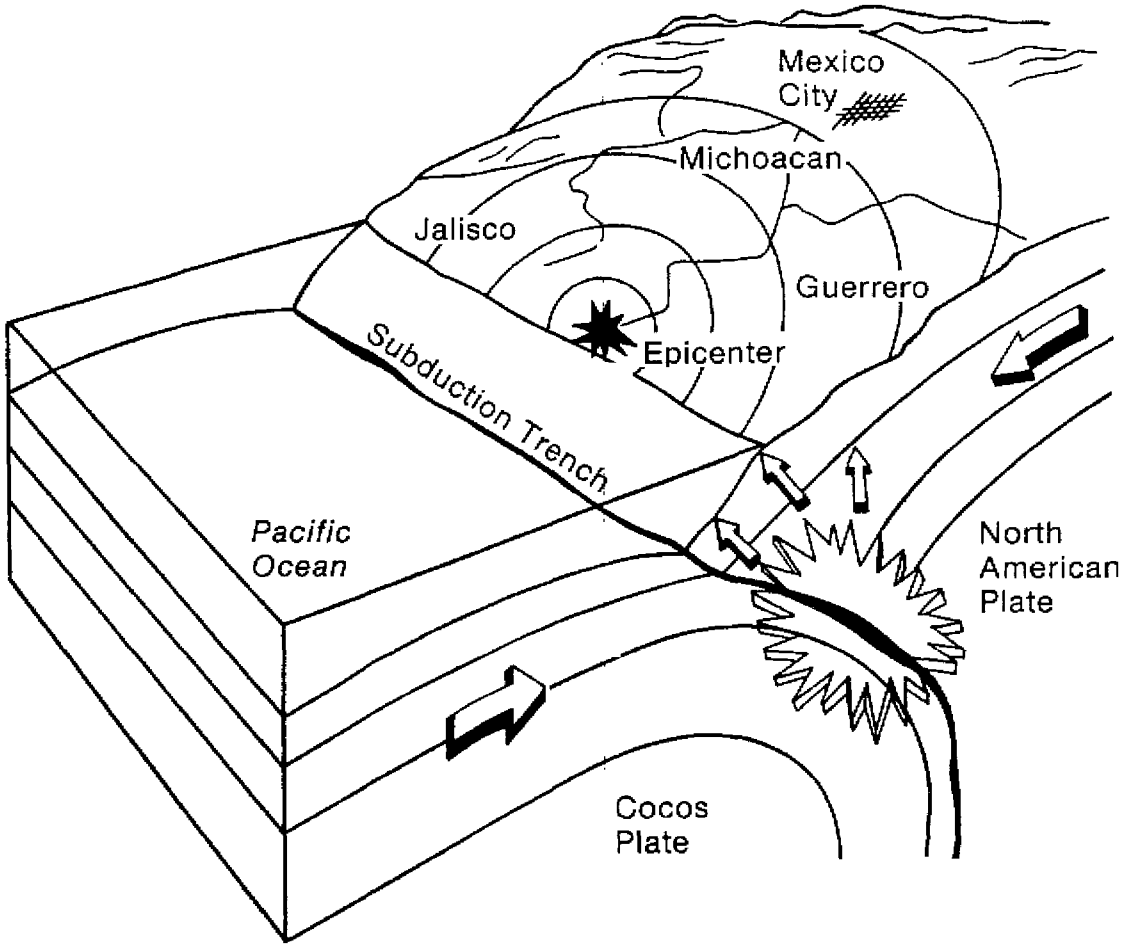

FIGURE 5-6 Movement Of Plates

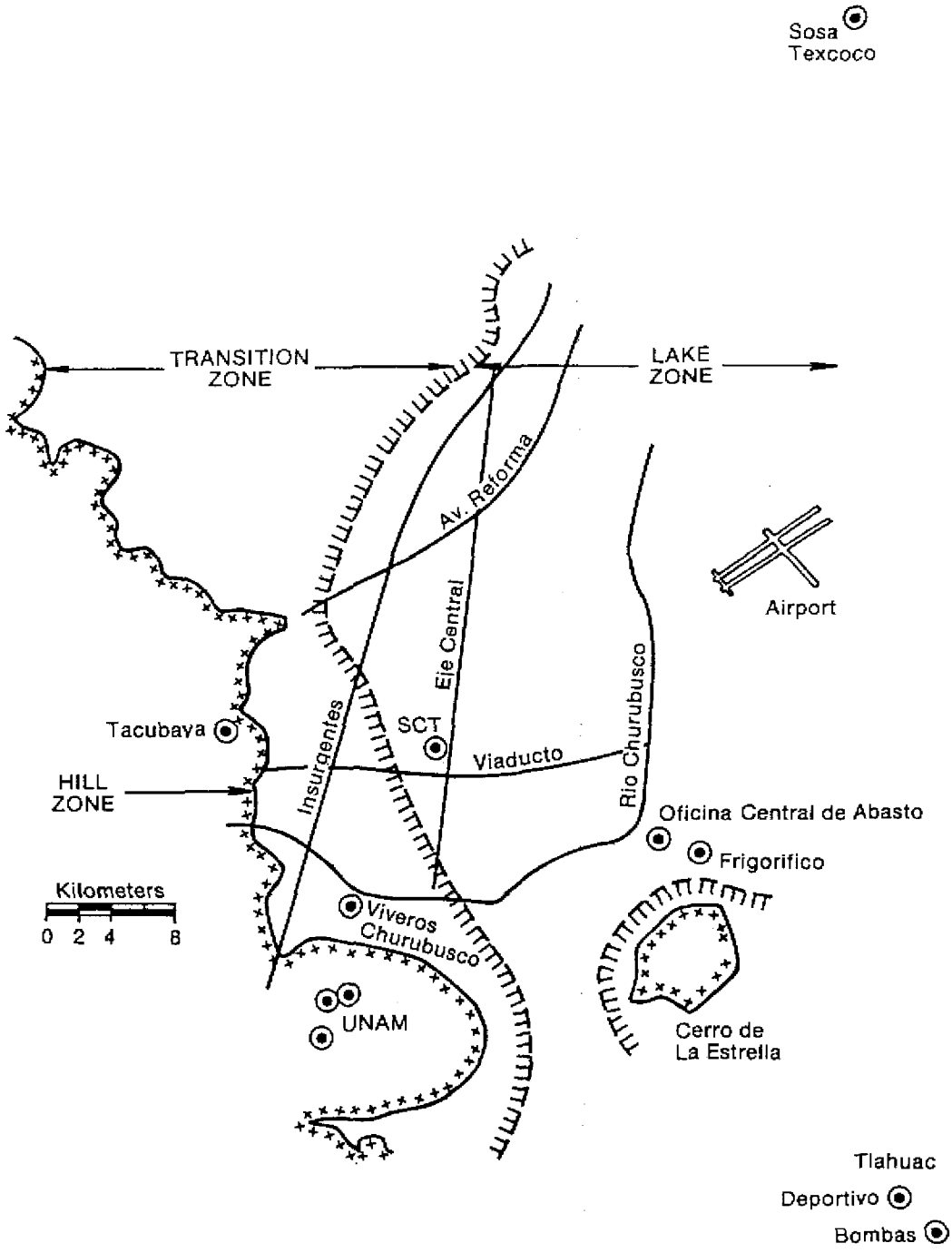

FIGURE 5-7 Location Of Strong Motion Instruments In The Valley Of Mexico

frequency content and large amplification in the Lake Zone. Figure 5-7 shows the location of the recording stations in the Valley of Mexico. Table 5-I presents the peak ground acceleration, velocity and displacement for both horizontal components at each of the Valley of Mexico stations. Table 5-II lists the average values for the peak horizontal ground parameter in the Hill, Transition and Lake Zones respectively. Note that the acceleration in the Lake Zone is roughly three times that for Hill Zone, while the Lake Zone velocities and displacements are roughly four times the Hill Zone values.

A rough measure of the predominate period of ground motion can be determined by assuming simple harmonic motion. Under this assumption, the predominant period becomes

$$T = 2\pi \frac{D_{max}}{V_{max}} \qquad 5.1$$

where D_{max} and V_{max} are the peak ground displacement and velocity respectively. Using this measure, the predominate periods of ground motion ranged from about 2.5 to 5.5 seconds for the stations in Table 5.I. Note that these strong ground motion predominate periods are somewhat longer than those from microtremor measurement shown in figure 5.4.

TABLE 5-I Maximum Horizontal Acceleration, Velocities And Displacements Recorded In The Valley Of Mexico City - 1985 Michoacan Earthquake

	Site	Orientation	Max Acceleration (gals)	Max Velocity (cm/sec)	Max Displacement (cm)	Soil zones
1	Central de Abastos - Frigorifico	NS	80.6	24.8	15.0	Lake zone
		EW	94.6	37.6	18.9	
2	Central de Abastos - Oficinas	NS	69.2	35.0	25.1	Lake zone
		EW	80.4	41.9	24.6	
3	Cd. Universitaria Laboratorios	NS	28.1	10.2	6.0	Hill zone
		EW	33.5	9.4	7.0	
4	Cd. Universitaria Patio	NS	31.7	10.3	6.2	Hill zone
		EW	34.7	9.4	8.0	
5	Cd. Universitaria Mesa. Vib.	NS	37.4	9.2	6.0	Hill zone
		EW	38.8	11.0	4.0	
6	Tacubaya	NS	34.4	14.3	12.0	Hill zone
		EW	33.2	9.8	8.6	
7	S.C.T.	NS	98.0	38.7	17.4	Lake zone
		EW	168.0	60.5	21.2	
8	Viveros	NS	44.1	11.5	9.1	Transition zone
		EW	42.4	12.2	7.5	
9	Tlahuac Bombas	NS	135.9	64.1	36.6	Lake zone
		EW	106.7	44.6	39.3	
10	Tlahuac Deportivo	NS	117.7	34.9	20.8	Lake zone
		EW	115.6	36.1	22.1	

TABLE 5-II Average Values Of Peak Ground Motion Parameters For The Valley Of Mexico By Zone (1985 Michoacan Earthquake)

Zone	Average Peak Value		
	Acceleration (gals)	Velocity (cm/sec)	Displacement (cm)
Hill	35.4	11.45	8.25
Transition	44.1	12.2	9.1
Lake	119.3	48.0	25.3