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MICROZONING STUDIES IN THE MAULE REGION,CHILE

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Abstract

The region of Maule, which is located between parallels 34°40'S and 36°15'S with an area of 30302 Km^2, lies within a seismic gap. This study covers the nine main cities and towns wich include about 50% of the population and dwellings of the region.

The purpose of this study is to carry out an evaluation of soil for fundation. A high porcentage of houses and public buildings, within this region are made of adobe. This is why it is necessary to evaluate the risk and the quality of the soil for future expansion of the cities and towns of the region.

Microzoning results, mainly evaluate by microseismic refraction experiments, wich yield values for longitudinal and traverse wave, geology information and underwater level.

The results shown on isovelocity curves of the second layer and isopach line of the first layer of the cities of Curicó, Molina, Talca, San Javier, Linares, Parral, Cauquenes, Contitución and San Clemente, which show a good correlation with the former given parameter.

The cities which are located on the Central Valley show mean velocity of V_p=1200-1800 m/s and V_s=530-910 m/s with a deph of 2.5-3.5 m which correspond to gravel deposit of the Central Valley. The velocity of the city of San Clemente V_p=940 m/s, V_s=395 m/s correspond to power fine clays. Talca is composed by gravel and volcanic asch and the correspondent transition zone, shows V_p=1700 m/s, V_s=850 m/s y V_p=790-1600 m/s, V_s=305 m/s respectively. The transition zone is not well defined to the geophysical information. By the way the volcanic asch zone shows a great dispersion of values of velocity and thickness of the correspondent layer. Constitución, the last city shows a great dispersion of values of V_p and V_s and of the thickness of the correspondent layers.

Generally the Region of Maule show very good soil for fundation, considering the second determined strata. In this way the first strata must be taken away. The thickness of this strata varies from 1.5 to 3.5 m.

Introduction

Many method have been used to microzonic areas of interest: Akamatsu et al (1995) made a microzonation earthquake Algermissen et al., 1976, is making probabilistic studies to estimate the maximum acceleration. In the case of strong ground motion records as they represent the real target events are the most reliable (e.g. Tuleker and King, 1984; Lermo et al., 1988). In addition examples can be given using nuclear explotion (Rogers et al., 1984) quarry blast, vibration (Atakan 1991) and signal such a tremors from commuter trains (Nakamura 1989).

In general all the methods give a partial knowledgement of the seismic zonation or microzonation as in Chile, where cities like Valdivia, Concepción, Talcahuano, Santiago, Taltal, Tocopilla, Coquimbo, La Serena, Viña del Mar, San Antonio, Valparaíso and Arica have been maimly leaded to the buildings damage according to the MSK intensity scale, geological information and other particular studies.

Geological Setting

The areas comprised in this study are constituted by the Central Valley and the Coast Range. The first is constituted by Quaternary sediments. These sediments are mainly present in the Central Valley and in the adjoining valley. The Central Valley is a morpho-tectonic unity characterized by strong deposits of sediments. These deposits have few to high consolidation and are principally composed by laharic deposit and Alluvial sediments of pleistocene and recent age.

The second formation is constituted by mountain chains which border up the east zone of the Central Valley and are composed by volcanic-continental formation of the Central Range stratified and folded of the Tertiary to Pleistocene age. These rocks are run through by intrusive rock borders, that constitute dikes, mantle lodes and volcanic necks.

Analisys of the results

Seismic experiments were distributed among the most important cities and some village of the Maule Region in an attempts to make the samples as representative as possible Table I summarizes the collected data and figures 3 to 11 show the cities with the distribution of the seismic experiments, the isovelocity curves of the 2nd layer and isopach line of the 1st layer.

TABLA I

	1st Layer			2nd Layer			3rd Layer			Intensity		Level
	V_p [m/s]	V_s [m/s]	Thick. [m]	V_p [m/s]	V_s [m/s]	Thick. [m]	V_p [m/s]	V_s [m/s]	Thick. [m]	R-RF Bob	M-M K	underground water
San Clemente												
Profile 1	925	394	>13							X	VIII-IX	>10 m
2	780	370	4-5	950	400	>11				X	VIII-IX	>10 m
3	740	260	>2.0	930	395	>13				X	VIII-IX	>10 m
Constitución												
Profile 1	615	227	4.0	1150	510	7.0	2103	1040	>12	X	VIII	>2 m
2	450	170	3.0	760	312	6.0	1850	840	>18	X	VIII	>2 m
3	588	206	3.5	1140	520	3.0	1550		>17	X	VIII	>2 m
4	440	150	4.5	1390	630	> 9				X	VIII	>2 m
5	750	265	1.0	1200	572	>15				X	VIII	
6	250-400	115	1.5	1190	570	5.0	1700	850	>15	X	VIII	>2 m
7	700	255	2.0	1324	575	>12				X	VIII	
8	600	205	2.5	1135	520	4.0	1600		>15	X	VIII	>2 m
Molina												
Profile 1	500	160	0.5	2130	1065	>13				VIII-IX	VIII	>4 m
2	1200	390	3.0	2310	1175	>12				VIII-IX	VIII	>4 m
3	1600	530	3.0	2500	1260	>13				VIII-IX	VIII	>4 m
4	1200	535	3.0	2120	1060	>14				VIII-IX	VIII	>4 m
5	1100	440	3.0	2200	1170	>13				VIII-IX	VIII	>4 m
Linares												
Profile 1	700	255	2.0	1250	550	5.0	1870	915	>12.0	VIII-IX	VIII	8 - 15m
2	500-780	~240	3.0	1900	965	>14.0				VIII-IX	VIII	8 - 15m
3	830	330	2.5	1800	890	>12.0				VIII-IX	VIII	8 - 15m
4	500-1000	~345	2.0-5.0	1815	910	>12.0				VIII-IX	VIII	8 - 15m
5	764	260	2.5	1600	755	>12.0				VIII-IX	VIII	8 - 15m
6	550	190	1.5	2160	1080	>12.0				VIII-IX	VIII	8 - 15m
7	430	150	0.7	770	350	4.0	2250	1160	>13.0	VIII-IX	VIII	8 - 15m
8	360	105	2.8	2140	1060	>14.0				VIII-IX	VIII	8 - 15m

Parral					
Profile 1	545 190 4.0	1700 800>12.0		VIII-IX VII-VIII	7 - 10m
2	445 148 3.5	1500 745>17.0		VIII-IX VII-VIII	7 - 10m
3	770-1040-392 4.5-7.1	1650 770>12.0		VIII-IX VII-VIII	7 - 10m
4	460 165 3.5	1180 530 5.0	1900 965>12	VIII-IX VII-VIII	7 - 10m
5	375 ~ 115 1.7	915 392 2.5-7.0	1417 645>12	VIII-IX VII-VIII	7 - 10m
6	380 ~ 115 2.0	1035 427 4.0-7.5	1660 770>13	VIII-IX VII-VIII	7 - 10m
7	710 225 2.5	1050 430 3.0	1650 768>12	VIII-IX VII-VIII	7 - 10m
Cauquenes					
Profile 1	445 148 0.5-2.0	565 180 2.5-4.5	750 265>17	VIII-IX VII-VIII	2 - 7m
2	870-1200-425 2.5-4.0	1700 830>15		VIII-IX VII-VIII	2 - 7m
3	660 250 5.0	1725 850>15		VIII-IX VII-VIII	2 - 7m
4	985 415 4.0-7.0	1625 813>17		VIII-IX VII-VIII	2 - 7m
5	763 320 1.5-9.5	1385 628>18		VIII-IX VII-VIII	2 - 7m
6	630 215 3.0	2177 1085>12		VIII-IX VII-VIII	2 - 7m
7	910 392 4.0	1440 655>15.0		VIII-IX VII-VIII	2 - 7m
Talca					
Profile 1	430 140 4.0	1900 965>11		X VIII-IX	>8 m
2	690 250 4.5	2090 1070>10		X VIII-IX	>8 m
3	740 300 2.5	1620 760>12			>6 m
4	650 245 2.0	830 370 6.0	1660 775>8	X VIII-IX	>8 m
5	700 257 2.5	1700 850>12		X VIII-IX	>8 m
6	1260 550 6.0	2150 1050>10		X VIII-IX	>8 m
7	1180 530 5.5	1800 890>12		X VIII-IX	>5 m
8	1055 425 2.5	1225 535>13		X VIII-IX	>6 m
9	300 140 1.0	617 291 3.0	1880 714>12	X VIII-IX	>6 m
10	680 250 3.4	1680 780>16		X VIII-IX	>8 m
11	825 330 5.9	1520 685>17		X IX	>8 m
12	390 125 2.0	790 305 5	1825 895>13	X IX	>8 m
13	1130 515 4.0	1770 864>15			>5 m
San Javier					
Profile 1	580 200 5.0	1360 600 5.0	2345 1180>20	X VIII-IX	~4.0
2	680 265 3.0	1780 870 5.0	2490 1250>18	X VIII-IX	~4.0
3	440 160 1.0	1260 555 7.0	1780 870>15	X VIII-IX	~4.0
4	660 260 3.0	1430 650>18		X VIII-IX	~4.0
5	360 105 1.0	1190 530 5-11	2140 1050>6-13	X VIII-IX	~4.0
6	600 220 1.0	1060 430 3.0	2280 1170>17	X VIII-IX	~4.0
Curicó					
Profile 1	600 220 4.0	1770 864>12		VIII-IX VIII	>6 m
2	605 225 4.0	1900 965>12		VIII-IX VIII	>6 m
3	720 250 3.0	1720 800>14		VIII-IX VIII	>8 m
4	800 360 3.5	1750 860>13		VIII-IX VIII	>8 m
5	860 357 5.0	2150 1050>14		VIII-IX VIII	>8 m
6	890 360 5.0	1800 890>15		VIII-IX VIII	>8 m
7	550 190 4.0	2160 1080>16		VIII-IX VIII	>8 m
8	980 415 3.0	1910 960>17		VIII-IX VIII	>8 m
9	1030 425 3.5	2075 1060>16		VIII-IX VIII	>8 m
Putu					
Profile 1	440 160 4.0	1100 440 6.0	1643 765>18	VIII-IX VIII	>2 m
Pencahue					
Profile 1	300 105 7.0	1400 645>19		IX-X VIII-IX	>8 m
Pelarco					
Profile 1	450 155 2.0	1070 435 8.0	2000 1200>15	IX-X VIII-IX	>4 m
Empedrado					
Profile 1	500 150 1.0	650 245 3.5	800 335>18	IX-X VIII	>10 m
Villa Alegre					
Profile 1	200 0.5	330 2.5	1800 890>18	IX-X VIII	>4 m
2	414 4.0	1680 180 9.0	2770 >14	IX-X VIII	>4 m
3	400 3.0	2030 >15		IX-X VIII	>4 m

Considering the parameters of the seismic zonation mentioned before and the geomorphological location two well defined zones can be distinguished, they are:

-Central Valley zone located to the east of the Coast Range where are the cities of Curicó , Molina, Talca, San Clemente, San Javier, Linares and Parral and the towns of Pelarco and Villa Alegre.

-Coast Range zone where are Constitución and Cauquenes and the towns of Putu, Pencahue and Empedrado.

The soil of the Central Valley are mainly composed by recent gravel depositation with different degrees of consolidation, that velocity vary between V_p=1000 m/s, V_s=345 m/s and V_p=2570 m/s, V_s=1260 m/s, with a vegetal and fine soil cover with thickness which vary among outcrop and 6 metres.

This zone show 3 exceptions that are San Clemente, a part of the city of Talca and Parral. San Clemente shows low velocities (V_p=740 m/s, V_s=260 m/s and V_p=950 m/s, V_s=400 m/s) in comparison to characteristic gravel velocity. The thickness of the two strata, which seem to be of the same material, reach 13 meter depth.

According to available data (Araneda et al., 1991) the materials found in San Clemente constituted regular consolidated clay given that fact there wouldn't be any concordance with the geology described by Thiele (1995).

Talca is funded over volcanic ashes and recent gravel depositation, but also exists a transition zone noticed by geology, which is not seen on the seismic waves analysis.

In the 1st layer, volcanic ashes show velocity of V_p=390 m/s, V_s=125 m/s to V_p=825 m/s, V_s=330 m/s with. Thickness of 2 to 6 meters.

The 2nd layer show velocity very similar to the gravel ones V_p=2090 m/s, V_s=1070 m/s to V_p=1520 m/s, V_s=685 m/s. By the way,the elastic behaviour of the volcanic ashes seems to be very different to the seismic answer. Astroza y Monge (1992) in order to check the values given by Medvedev, determined the average increment for the quaternary deposits comparing the isoseismals on rocks with the intensities obtained in 88 cities and villages located in the damaged area of the earthquake of Valparaíso on March 3, 1995.

Geologic unit	Number of data	Increment of intensity intensity respect to rock
Vocanic pumicite ashes	19	1.5 - 2.5

The transition zone which is marked by geology is not seen on the velocity analisis.
Parral also shows 2 kinds of soil: volcanic pumicite ashes with similar characteristics to the ones found in Talca and early alluvial fan deposit.

The towns of Villa Alegre and Pelarco show the same soil characteristics of the Central Valley, a thin soil cover over a strong gravel strata.

In the Coast Range zone, soils have different origins: early alluvial deposit (Cauquenes) over an irregular topography with irregular velocities and thickness likes it is shown on Table 1. The important fact with this city is that the old alluvial deposits show the same characteristic of the Central Valley, only experiments # 1 shows a big difference (1st layer V_p=445 m/s, V_s=148 m/s; 2nd layer V_p=565 m/s and V_s=180 m/s).

Sand and gravel deposits of different ages (Constitución). These sediments mainly consists on non-homogeneous sandy fluvial deposits as shown by the measured velocity and strata. The city is located on the border of the Maule river in a plain with a slight slope to the north. Generally, the velocity of the 1st layer are quite low V_p=750 m/s, V_s=345 m/s with variable thickness among 1 to 4.5 m.

The second and third layer are, in some cases, probably affected by the ground water level due to they present relative high velocities, although it is not common on sand V_p=1135 m/s, V_s=520 m/s to V_p=2103 m/s, V_s=1040 m/s.

Putu, Pencahue and Empedrado villages are componed by sand thick layer of clay and a thick layer of clay, respectively Araneda,Avendaño (1995).

Conclusion

Soil microzoning technology seems appropiate for this study, since there is a solid correlation between velocities and type of soils stablished through geological observation. The foundation soils found in the

Maule Region can be clasified in the following way:

Velocity V_p(m/s)	V_s(m/s)	Geology Formation	Ground wat. lev. m	Q
1200-2500	500-1260	gravel	> 6	I
1000-1200	400- 500	gravel	> 6	II
>1000				III

Vegetal and thin soil can be considered as I very good II regular III deficient IV bad.
Although volcanic ashes have high velocities V_p=2090 m/s, V_s=1070 m/s to V_p=1520 m/s V_s=685 m/s, should be considered on type II but objectly.

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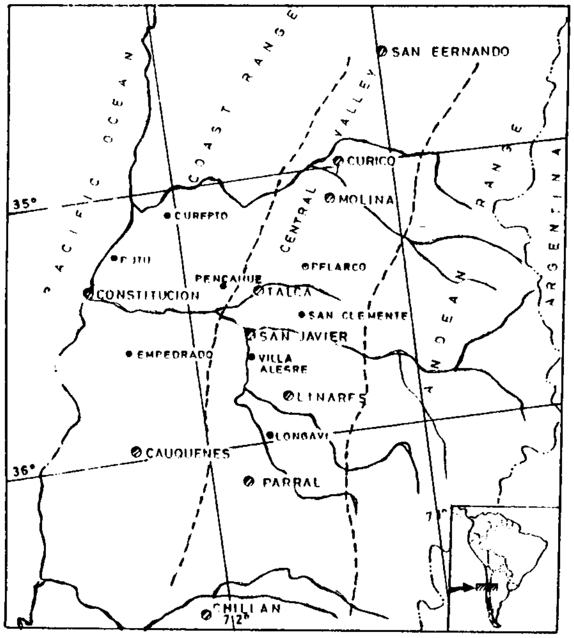


Figure 1

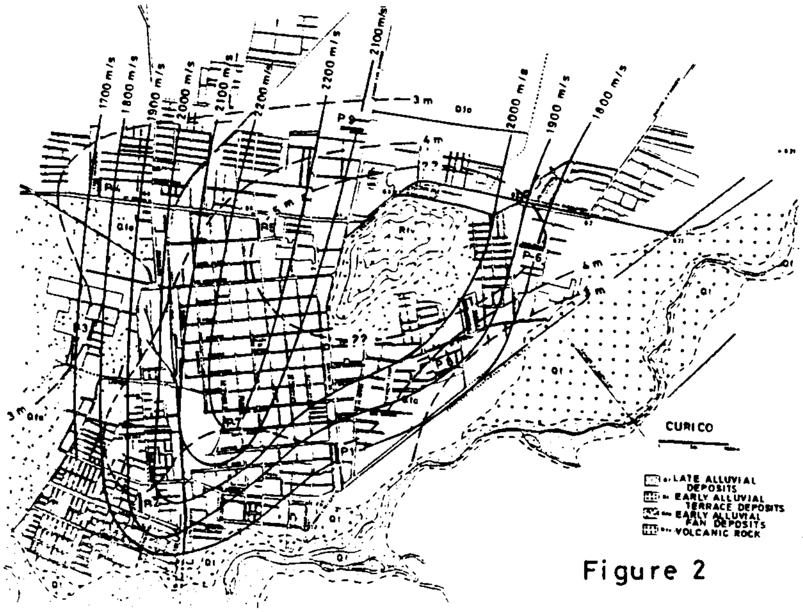
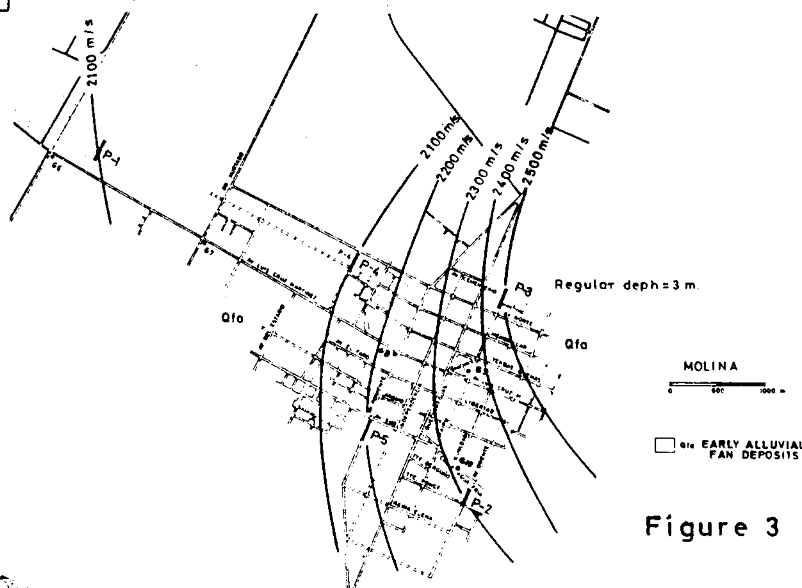


Figure 2



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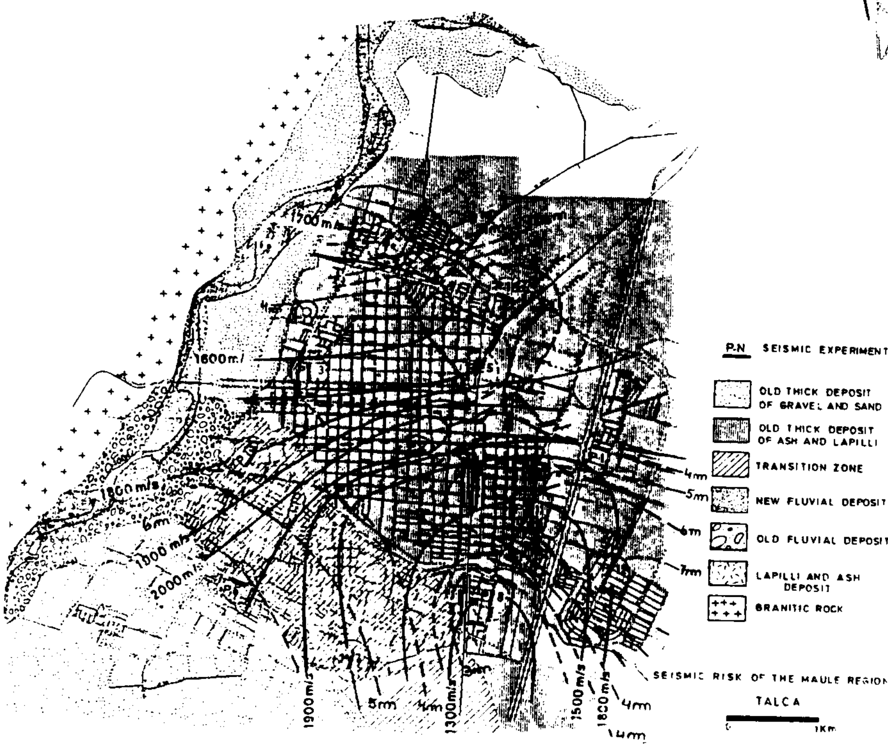

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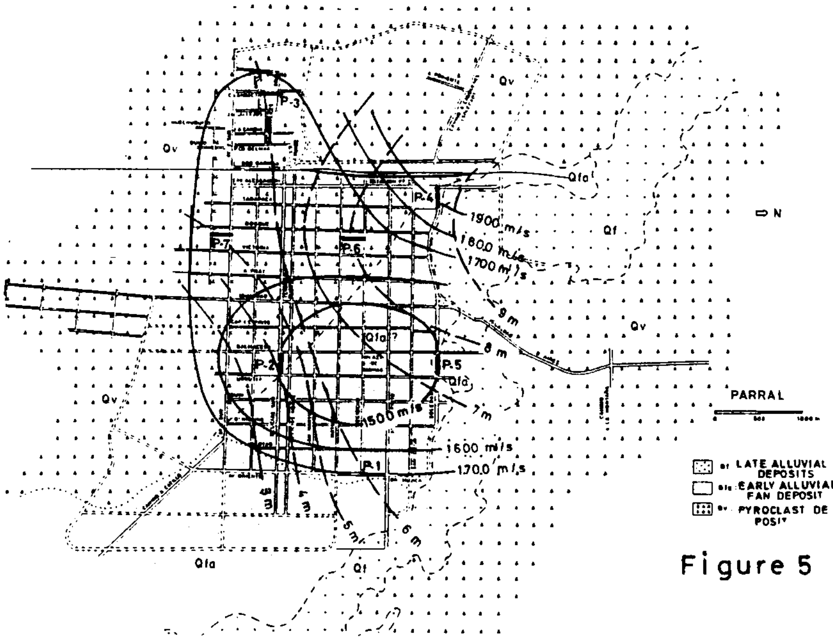


Figure 5

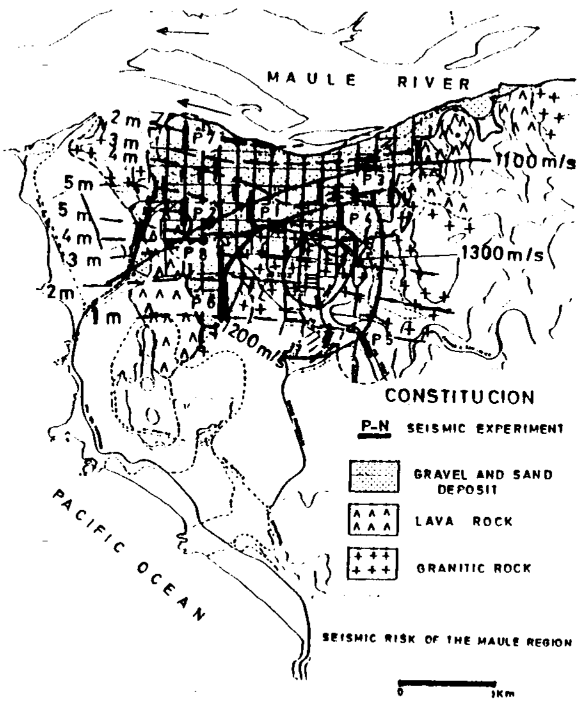
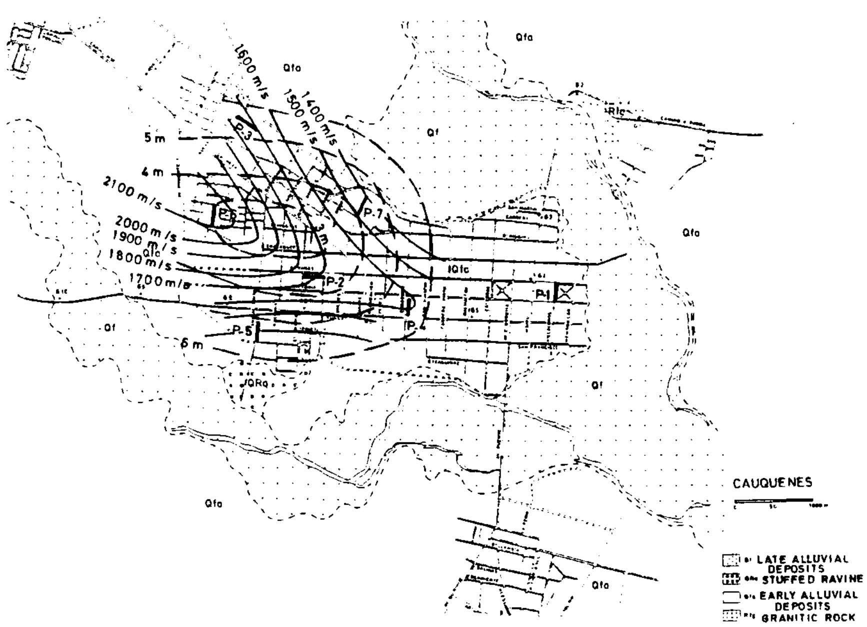


Figure 6

SEISMIC RISK OF THE MAULE REGION



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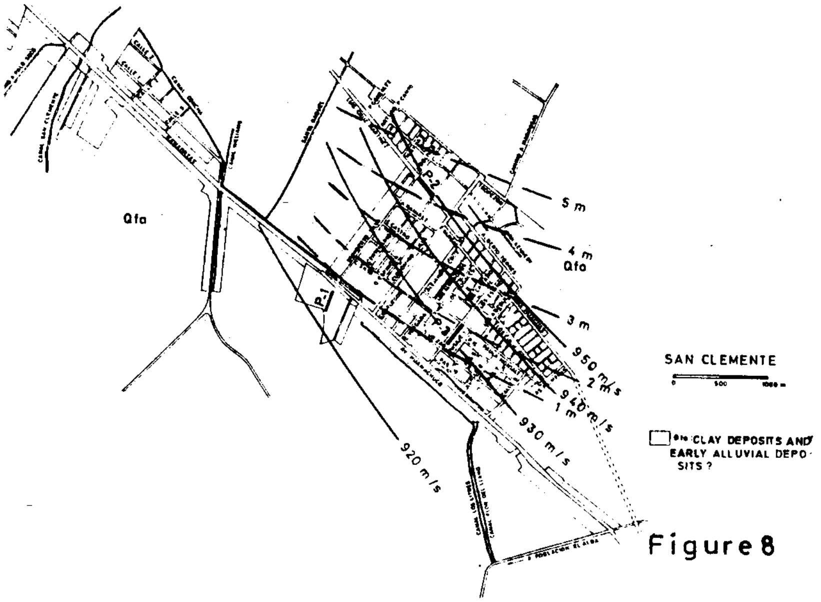

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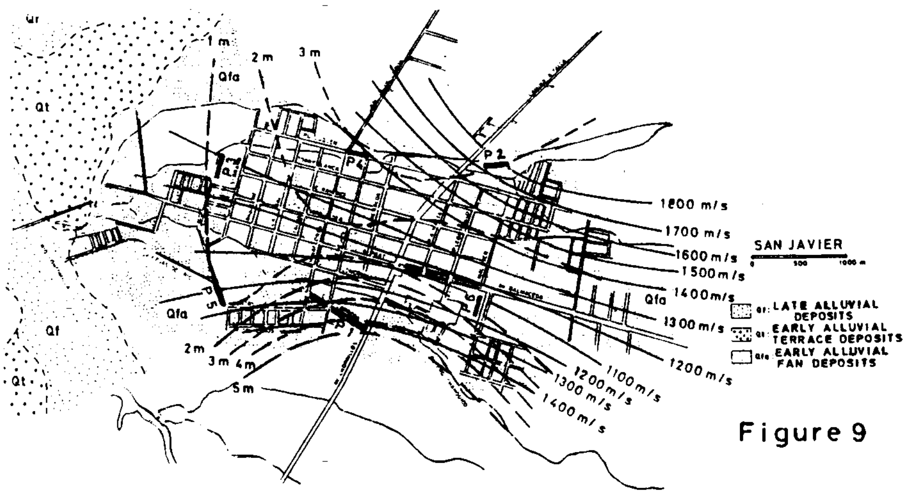

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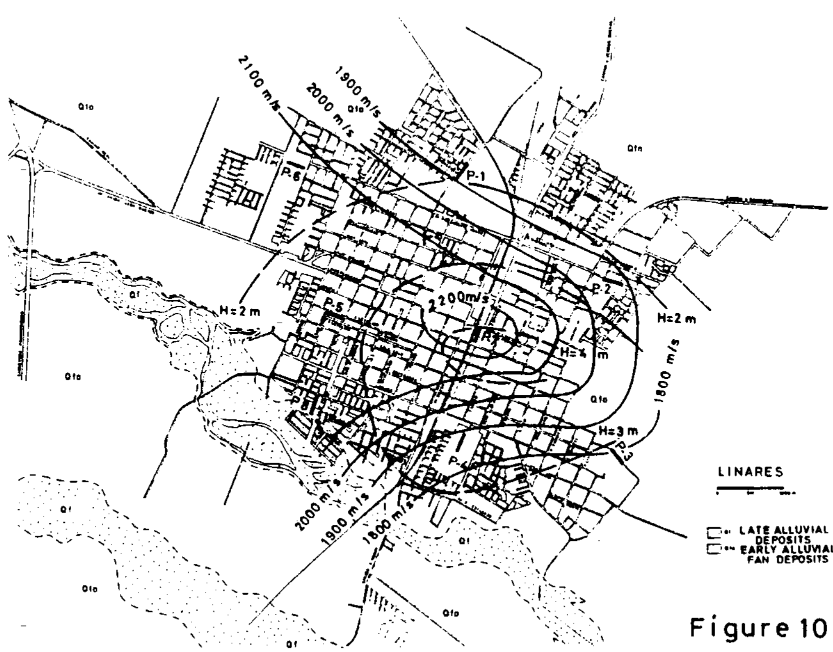

Figure 10