CARACAS, VENEZUELA EARTHQUAKE OF

JULY 29, 1967

Soil Engineering and Engineering Geology Observations

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ABSTRACT

On Saturday, July 29, 1967, at approximately 8:05 p.m. (Caracas time), the Northern Coast of Venezuela, in the Caracas region, was struck by a damaging earthquake. The epicenter was located approximately 50 kilometers northwest of Caracas. The Richter Magnitude was between 6.3 and 6.5. The depth of focus was estimated to be 10 to 15 kilometers. No strong records of acceleration or duration of strong shaking are available as the strong motion instrument located in Caracas did not function. However, based on data from recordings at local radio and television stations, the duration of strong shaking was approximately 20 to 30 seconds. This earthquake was notable for the extensive damage to modern high rise, earthquake resistant buildings. There were several areas or pockets of intensified damage in the city of Caracas and in the small coastal town of Caraballeda on the Caribbean shoreline. Life loss and property damage were comparatively great in these two pockets of damage. The damage patterns were to some degree unexpected, considering the moderate size of the earthquake. However, the preliminary information suggests that the predominating element that caused the heavy damage in localized areas was the underlying soil and geological conditions.

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SEISMOLOGY

At about 8:05 p.m. the city of Caracas and surrounding area suffered an earthquake with an approximate duration of 35 seconds which resulted in a loss of at least 230 human lives in Caracas and on the coast and great property damage. There was a certain confusion as to the initial information of the earthquake; duration and intensity of shaking, location of the focus and epicenter, and the Richter magnitude. There was a selective form of destruction in the Caracas Valley as well as along the coast especially the region of the real estate developments of Tanaguarena and Caribe where undoubtedly the intensity of ground motion was greater.

Data received from the Cajigal Observatory in Caracas located the epicenter at the following coordinates: longitude 67° 25' W., latitude 11° 00' N., and distance to the Caracas Observatory, 62 kilometers. Depth of focus 28 ± 3 kilometers. According to the Cajigal Observatory the duration of greatest intensity was of 20 seconds, the magnitude was of 6.3 on the Richter Scale. The intensity on the modified Mercalli Scale was of VI - VII in Caracas and VIII or more at Los Palos Grandes and Caraballeda. Information received from the U.S. Coast and Geodetic Survey regarding the details of the earthquake are as follows: Epicenter location at longitude 67.3° W., latitude 10.6° N., with a probable error of + 19 kilometers. Depth of focus estimated 10 to 15 kilometers. Richter Magnitude 6.5. Both the Cajigal and USC & GS epicenters are shown on Figure 1.

Seismicity of Venezuela

The general high seismicity of Venezuela is apparent, both from evidence of the historic earthquake records and from evidence of active "earthquake faults" that traverse Veneluela, especially the Caracas region. Noteworthy destructive historic earthquakes that have struck Caracas are as follows: June 11, 1641, earthquake destroyed most of Caracas; October 21, 1766, damage in Caracas; March 26, 1812, earthquake destroyed Caracas killing 10,000 in Caracas and 16,000 in other cities in Venezuela; October 29, 1900, earthquake damaged many homes in Caracas killing at least 140 people.

Active earthquake faults near Caracas include the San Sebastian fault zone (probably an extension of the Bocono fault) located along the coastline north of Caracas and the Avila fault located at the foot of the steep mountain range north of the Caracas Valley. The general geology and fault systems of Northern Venezuela are shown on Figures 1 and 3.

GEOGRAPHY

Sierra Avila

The branch of the Coast Cordillera, located between the Caribbean Sea and the Valley of Caracas, has been named Sierra Avila. Along this range, maximum heights are encountered such as the Caracas Saddle with heights of 2,640 meters and Naiguata Peak with a height of 2,765 meters.

The mountain slopes facing north are quite steep and rugged and are crossed by numerous streams of very abrupt falls with V-shaped stream beds and short runs, varying between 5 and 9 kilometers; these are torrential type streams with strong erosive action which cause extensive washout of material.

The coastline in front (north) of Sierra Avila, is practically straight and with an east-west orientation, following a system of faults. In this zone the coast is deep and practically reaches the foothills of the mountains, there being only two relatively level spaces formed by debris cones (alluvial fans) among which the most important ones are those of Caraballeda and Tanaguarena, exactly in the coastal zone where the greatest damage occurred during the earthquake.

The slopes toward the southern part of Sierra Avila, which serve as the northern limit to the city of Caracas, are very steep and are distinguished by a high angle normal fault (Avila fault) which generally traverses from east to west at the foot of the range. A series of steep streams with V-shaped beds and numerous falls and rapids, flow towards the City of Caraca finally flowing into the Guaire River.

The Sierra Avila is still in its youthful stage, as there have been found along the coastline and in some of the valleys terraces indicating various periods of uplift. A phenomenon which geologically is still continuing.

Caracas Valley

The Caracas Valley is long and narrow, controlled by the Guaire River and its main tributaries the Valle River. Some stream channels have served as urban centers to the city as is the case with Baruta Creek which flows from the south and the Caraota Creek on the north.

The total length of the Valley of Caracas between Antimano and Petare is approximately 25 kilometers, with a maximum width of 4 kilometers north-south. The average height above sea level is 900 meters.

The Valley of Caracas is a structural valley owing its existence to the Avila fault lying towards the southern slope of Avila Sierra. Throughout the length of the foothills of the mountains there may be found a series of alluvial foothill-cones which are gradually mixed with the alluvial sedimenxs of the Guaire River. Originally, the Guaire River may have run close to the fault zone. and nearly parallel to it, but the rapid deposition of the foothill cones has forced the river to the southern part of the valley.

Towards Petare the river crosses to the south and the alluvial valley changes into a narrow gorge cut into the rock, which has served as control level of the alluvial deposits of the Valley of Caracas.

GEOLOGY

System of Faults

In Venezuela there is a system of geological faults, which are responsible for the greatest part of the earthquakes occurring in Venezuela. One of the most important faults, not only because of its extension, but also because of its activity, is the great Bocono fault. It extends from the Southern Andes to the Caribbean, follows approximately the direction of the Andean Cordillera, and continues across the Coast Cordillera until it enters the Caribbean Sea where it is known as the Caribbean or San Sebastian fault, passing a few kilometers to the north of the coast. See Figures 1 and 3. This system of faults has had several periods of activity from the Cretaceous up to the present time. A number of systems of minor faults are related to this principal system produced by subsequent adjustments. The most destructive earthquake associated with the Bocono fault zone occurred in 1812, with an approximate intensity of X MCS; it affected Caracas, Yaracuy, Barquisimeto, and Merida and is reported to have taken more than 25,000 human lives.

A fault that has had no known activity in historic time is the great transcurrent dextral fault of Oca, to the south of the Goajira Peninsula, which passes between the Gulf of Venezuela and the Lake of Maracaibo, extending to the east passing through the south of the State of Falcon, where its principal movement is vertical; this fault is found northeast of the Bocono fault. Figure 3. Northwest of Maracaibo the Oca fault cuts recent shorelines, indicating its geologically recent activity.

To the east of the Bocono fault, the El Pilar system of faults, is to be found, situated between the Gulf of Venezuela and the Lake of Maracaibo which continues to the east passing to the south of the mountain system to the north of Trinidad; this system of faults in terms of earthquake activity is next in importance to that of Bocono. The movements in this system have caused the earthquakes which have occurred in the past at the Araya-Paria Peninsula, Cumana and in the Islands of Margarita and Cubagua, and to the north of Trinidad.

Geological Aspects of the Valley of Caracas

Lithology

The rocks which surround the Valley of Caracas are metamorphic, belonging to the Caracas Group of Cretaceous age, represented in the north flank by gneiss micaceous feldspathic schist which are hard, compact, foliated, folded, and crossed by quartz veins and aplite dikes. To a lesser degree there are amphibolites, serpentinized, peridotites, serpentines, calcareous, graphitic schists, and green schists.

On the southern flank and in the subsoil of the Guaire River bed, the rocks are represented by calcareous schists, graphitic schists and sericitic schists, mixed with thin lens of limestone, micaceous quartz schists, marble limestone and gneissoid rock to a lesser proportion. These rocks are hard when fresh, finely foliated injected with silica and intensely folded, sheared and fractured but they weather easily.

The metamorphic rocks of the Caracas Valley are covered by residual and alluvial soils of diverse thicknesses and alluvial debris cones of which more will be said later.

STRUCTURE

The The Sierra Avila, composed essentially of gneisses and schists, is bounded on the north and south by fault zones. In detail, its structure is very complex. The principal folds appearing in the Dengo map (1951) are: the Junquito anticline, the Cementerio syncline and the Baruta anticline. These folds are symetric structures whose axes have a general direction N. 60 to 70 E. The Sierra Avila is considered on a whole as an anticlinal structure, modified by subsequent faulting.

TYPICAL CONDITIONS OF THE SUBSOIL OF THE CARACAS VALLEY

The subsoil of the Caracas Valley is quite erratic, due to the geological and topographical conditions of the valley. In the zones located to the south of Guaire River, the prevailing material is residual soil resulting from the decomposition on the site of the bedrock (schists); in the areas occupied by the residual soils, the most important residential zones in the south and east sides of Caracas have developed.

In general, these soils are composed of micaceous sand and silt and clay from medium to high plasticity, and soft decomposed schists. The thickness of the latter is quite variable, from just a few centimeters to more than twenty or thirty meters. In some hills the schists are nearly on the surface, but these, due to their high degree of weathering, are considered as a soil of hard consistency.

On the banks of the Guaire and Valle River, there are alluvial sediments, whose thickness towards the south is generally small as the river often is to be found eroding on rock. But towards the north the thickness is quite large.

These soils are also quite variable, generally composed of granular materials deposited in a lenticular and erratic manner, and there may be found silt, sandy silt, silty clay, silty sand, nearly clean sand, sandy gravel, and silty gravel.

There are streams that when emptying into the Guaire River form small valleys; one of the most important is Baruta Creek which empties to the south and east of Caracas, and has formed an ample zone of alluvial sedimentation, whose characteristics are similar to the alluvial sedimentation of the Guaire River.

Towards the northern part of the Guaire River, the characteristics of the soil change completely; at some places there may be found the alluvial sediments of the river, but climbing towards the skirt of the Avila, residual soils may be found whose formation is the same as that of the Sierra. Micaceous elements may be frequently encountered in these soils, with small fragments of gneiss which have been caused by the erosion and weathering of the rock.

The alluvial cones of the longer streams descending from the Avila result in a sedimentation even much more erratic, as there may be found from very fine plastic soil, to rocks measuring more than 1 meter in diameter, mixed with clayey, sandy, and silty gravel. Sometimes these boulders are to be found superficially and others several meters underground. On these debris cones have been constructed the real estate developments of San Bernardino, Altamira, Los Palos Grandes, Sebucan and Los Chorros.

CONDITIONS OF THE SUBSOIL IN THE PALOS GRANDES AND ALTAMIRA ZONE

Los Palos Grandes and Altamira are located in the eastern section of the city; the sedimentary deposits at this place are quite deep. After the earthquake, some drilling was done extending to a depth of 115 meters without having reached bedrock. The composition is of a granular texture with silty lenses and layers of pebbles or of boulders. The distribution of the soils in this zone is quite erratic and irregular, which may be explained by the type of deposition that has occurred. Borings were made with the standard penetration test, with widely varying results due to the presence of pebbles and of small rock fragments which at times give very high and distorted values. However, in predominantly sandy zones, the tests indicated a rather low compactness. In the profile in Figure No. 4, of one of the most affected zones, located between two of the collapsed buildings (San Jose and Neveri), we may observe in the first place very fine sandy silt slightly micaceous and mixed with fragments of micaceous quartz schists; clayish silts with fine micaceous sand slight fragments of quartz, and clayish silt, slightly sandy in which may be seen a low plasticity. These materials are generally of a yellowish brown color and are mixed with layers of silty sands with fragments of gravel and nearly clean sands.

Of interest are the layers of gneiss boulders, with some slightly sandy weathered micaceous quartz schists. These boulders are found in a mold of fine micaceous silty sand resulting from the change in the gneiss itself. In some places these layers of boulders reach a thickness of 7 meters thick. At times it is possible to correlate these layers, but in other cases they are found forming isolated strata in an erratic manner.

We are also able to observe the presence of some clayish lenses of from medium to high plasticity with some elements of quartz and with sandy zones, also thick gravel sand very slightly silty and micaceous, mixed with quartz fragments of up to 3 centimeters in diameter.

CONDITIONS OF THE SUBSOIL IN THE COASTAL ZONE

In our reference to the general geology, mention was made of the characteristics of the soils in the foothills of the coast. Lacking a more specific knowledge of these soils, we shall not describe them, but will only refer to the zone suffering the greatest damage and some zones known to the authors.

In the area where the Port of La Guaira is located thicknesses of up to 20 meters have been determined, formed by the deposition of the material carried down from the hills. In this zone there are boulders of hard gneiss of up to 1 meter in diameter interbedded with silty clean sand, with a fairly high water level, controlled by the sea level.

In the area where the Mansion Charaima and Macuto Sheraton Hotel buildings are located (Caraballeda and Tanaguarena), two types of deposition may be described: first a deposition of materials carried down from the mountains, which are characterized by their production of sandy material having silt, clay and fragments of gneiss, as well as by the presence of gneiss boulders, which are deeply buried and have the characteristic yellowed brown color (See Figure No. 5). Above these is a typical lagoon deposition formed by interbedded layers of micaceous elastic silt, greasy to the touch with organic decomposing matter; and silty sand with organic matter. Sea shells and peat strata are frequently found. These materials are from dark grey to black in color, with a high mica content.

DAMAGE TO THE BUILDINGS

The damage pattern to buildings in Caracas was very complex. Extremely damaged buildings and others barely damaged are located, in many cases, alongside each other; there is even the case of the Palace Corvin Building, made up of two similar sections, one of which was completely destroyed. the other remaining standing with some structural damage.

Immediately after the earthquake, the Ministry of Public Works made a survey of all the damaged buildings and those in which the owners had doubts as to their having been affected by the earthquake. An investigation was made covering approximately 8,000 buildings and houses, with 32 plans prepared indicating the buildings damaged in Caracas. The results of this investigation indicated that there were 1,802 buildings damaged in the Caracas Valley, as shown in the Table No. 1.

Based on the plans prepared by the Ministry of Public Works and on personal observations, damaged buildings were classified according to the numter of stories and damage that might have occurred in the structure and architecture. This covered a total of 1,253 buildings of which 20% suffered structural damage and 80% suffered architectural damage.

The heavily damaged buildings were scattered throughout the city. A careful analysis revealed some small concentrations among which it is interesting to mention the Los Palos Grandes Zone, where the map of damage shows four buildings that suffered total collapse and several extremely damaged buildings within a radius of approximately 500 meters, as shown on Figure No. 6. It was established that the greatest damage occurred in the Los Palos Grandes and El Paraiso zones and in some zones in thd neighborhood of the Valle River and towards Roosevelt Avenue.

An inspection of the fallen and seriously damaged buildings in the Caracas metropolitan area leads to the conclusion that all the damage was structural with no faulting or slumping in the foundations. Only in the zone where the Macuto Sheraton Hotel is located, was there any movement in the soil, as evidenced by a fissure at the beach.

In the Guigue region, near Lake Valencia, 96 kilometers from Caracas, some landsliding in the subsoil occurred. The landsliding observed there seems to have been caused by a typical phenomenon of liquefaction of saturated loose sands.

Damage to the Coastal Zone

The zone suffering the heaviest damage on the coast was the beach area surrounding the Lagoon at Caraballeda, north of Sierra Avila. On the zone bordering the Lagoon, three three-story buildings were totally destroyed, the top four stories of the Mansion Charaima collapsed and fell to the south and the Macuto Sheraton Hotel suffered considerable damage.

In the zone adjoiring Caraballeda several modern houses suffered so much damage that it was necessary to completely demolish them; all the paraboloides of the service station collapsed and nearly all the elevated water tanks of the houses which were supported by only one column fell.

We do not have available a complete census of damage to this zone, but some of the buildings of thd Naiguata Bathing Resort, located 15 kilometers to the east, suffered damage of certain importance.

Relation Between the Damage and the Conditions of the Subsoil

A map was prepared showing the location of the damaged buildings and the thickness of the sediments, through which it was possible to establish that a certain relation existed between the thickness of the alluvial and colluvial sediments, and the damage to the buildings. Los Palos Grandes where the thickness of the granular material exceed 114 meters, suffered the greatest damage; likewise towards the zones near the Guaire and Valle River, great damage was also suffered. On the other hand, the entire zone to the south of the Guaire River, lying on rocky material or residual soil, suffered practically no damage. A comparison between Los Palos Grandes and zones such as Colinas de Bello Monte and Colinas de Santa Monica where there are great concentrations of high building shows very little structural damage; the only damage being architectural.

It is interesting to note that the apartment buildings constructed by the Banco Obrero (Workers' Bank), known locally as superblocks, located in the 23 de Enero sector in the Catia district, founded on residual or schistic soils, suffered very little damage. It was also noted that the Alta Vista zone, also located in Catia, where the buildings are known to have a series of construction defects, suffered very little damage.

In the Caraballeda zone, as shown in the geologic profile of the subsoil in Figure No. 5, there is a thick, irregular deposit. The location of the buildings most affected around the lagoon and the fissure that appeared at the beach leads us to think that the conditions of the subsoil had a pronounced effect on the collapse of the structures; unfortunately, at the time we prepared this paper we did not have available the data on geophysical measurements on which to establish more precise comparisons.

It is believed that at Caraballeda, the intensity of ground motion was greater and that oscillations, especially at the Mansion Charaima, must have been very great, leads to the assumption that the effect of the earthquake was to extend the deformation of the higher stories, that is, the whip effect

CONCLUSIONS

The city of Caracas has many modern, earthquake-resistant buildings, (mostly reinforced concrete) some of which were badly damaged by the earthquake. The heavy damage was concentrated in relatively small areas and varied depending upon the type of building and the underlying soil and geologic conditions.

Because of localized areas of poor soil conditions in Northern Venezuela, such as the areas surrounding Lake Valencia, a complete understanding of the subsurface conditions must be obtained prior to further development. Also more accurate and precise location of active faults should be made so that possible future damage from faulting can be avoided.

The Caracas earthquake of July 29, 1967, even though of moderate magnitude, may prove to be one of the world's more significant because of the detailed data available which can and should be used to influence future earthquake-resistant design and construction throughout the world. The sub surface geologic and soil conditions obviously played an important role in the damage; therefore, it presents a unique opportunity to study the influence of subsurface conditions on the damage to different types of structures.

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TABLE 1

DAMAGE OF BUILDINGS

	I	II	III	IV	V	TOTAL
Minor	-	230	29	1.040	5	1.304
Major	-	65	18	140	4	227
Serious	-	31	5	210	5	251
Collapse	-	8	2	10	-	20
Total	-	334	54	1.400	14	1.802

I. Buildings with metal structure

II. Buildings with concrete structure

III. Modern houses or villas transmitting the load to the foundation through bearing columns or walls interlocking with concrete or steel elements.

IV. Old houses with mud or adobe walls, the greater part located in the central part of the city.

V. Old churches, chapels, etc.

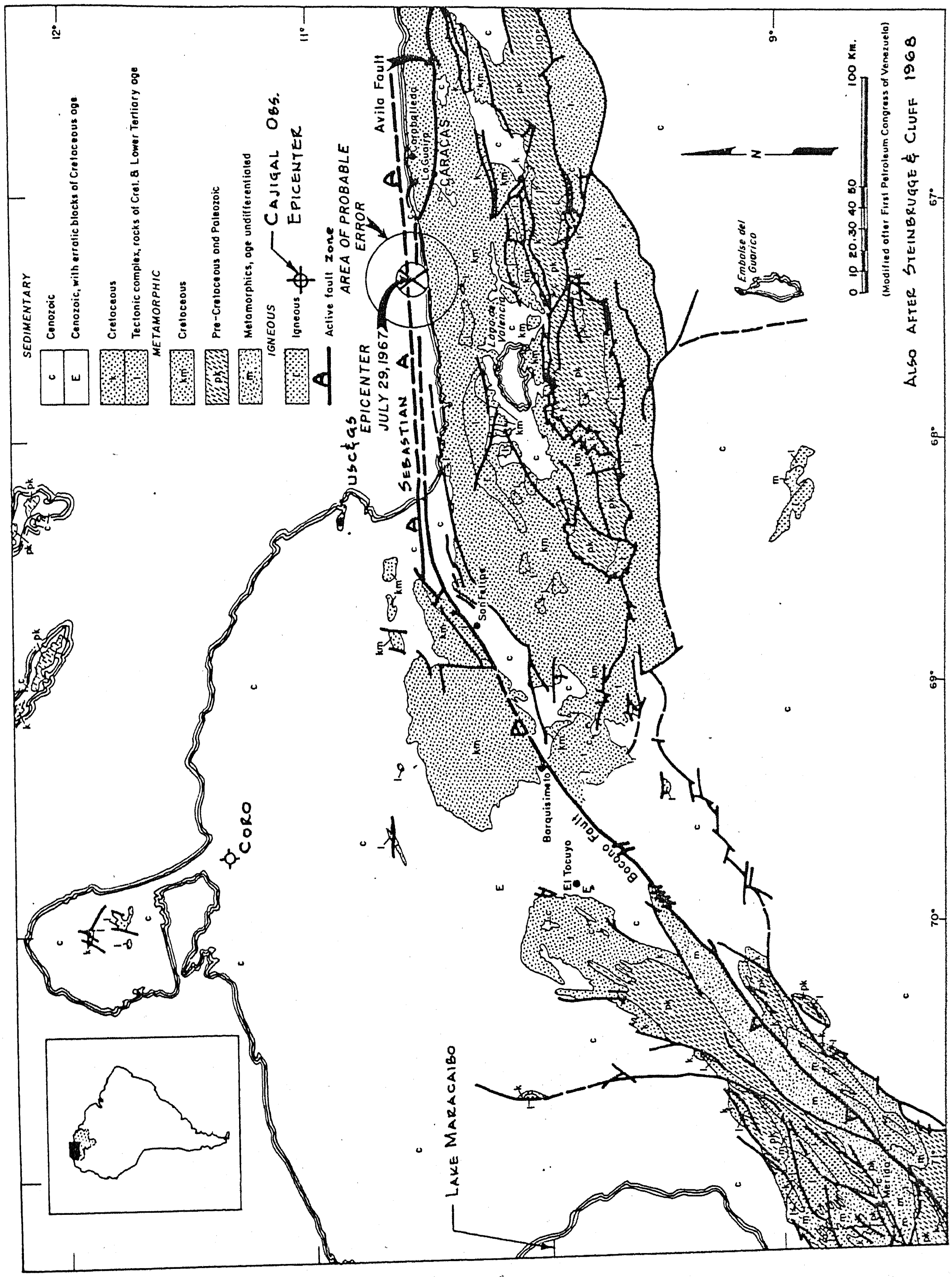

SEDIMENTARY
Cenozoic
Cenozoic, with erratic blocks of Cretaceous age
Cretaceous
Tectonic complex, rocks of Cret. & Lower Tertiary age
METAMORPHIC
Cretaceous
Pre-Cretaceous and Paleozoic
Metamorphics, age undifferentiated
IGNEOUS
Igneous
Active fault zone
CAJIGAL OBS.
EPICENTER
AREA OF PROBABLE ERROR
EPICENTER JULY 29, 1967
SEBASTIAN
Avila Fault
CARACAS
Carabelleda
LaGuaira
Lago de Valencia
Embalse del Guarico
San Felipe
Barquisimeto
El Tocuyo
Bocono Fault
Merida
CORO
LAKE MARACAIBO
0 10 20 30 40 50 100 KM.
(Modified after First Petroleum Congress of Venezuela)
ALSO AFTER STEINBRUGGE & CLUFF 1968
12°
11°
9°
67°
68°
69°
70°

FIGURE: 1

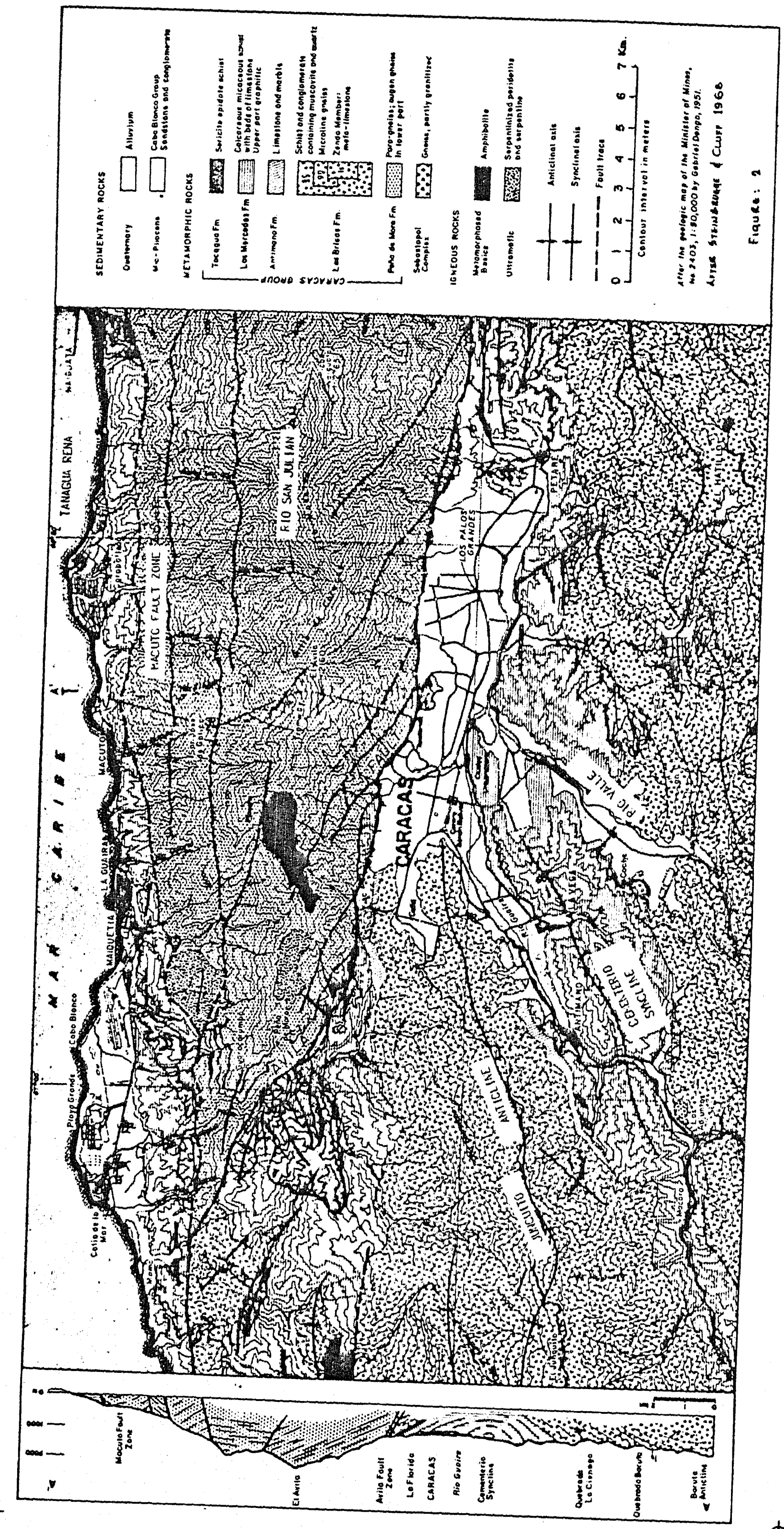
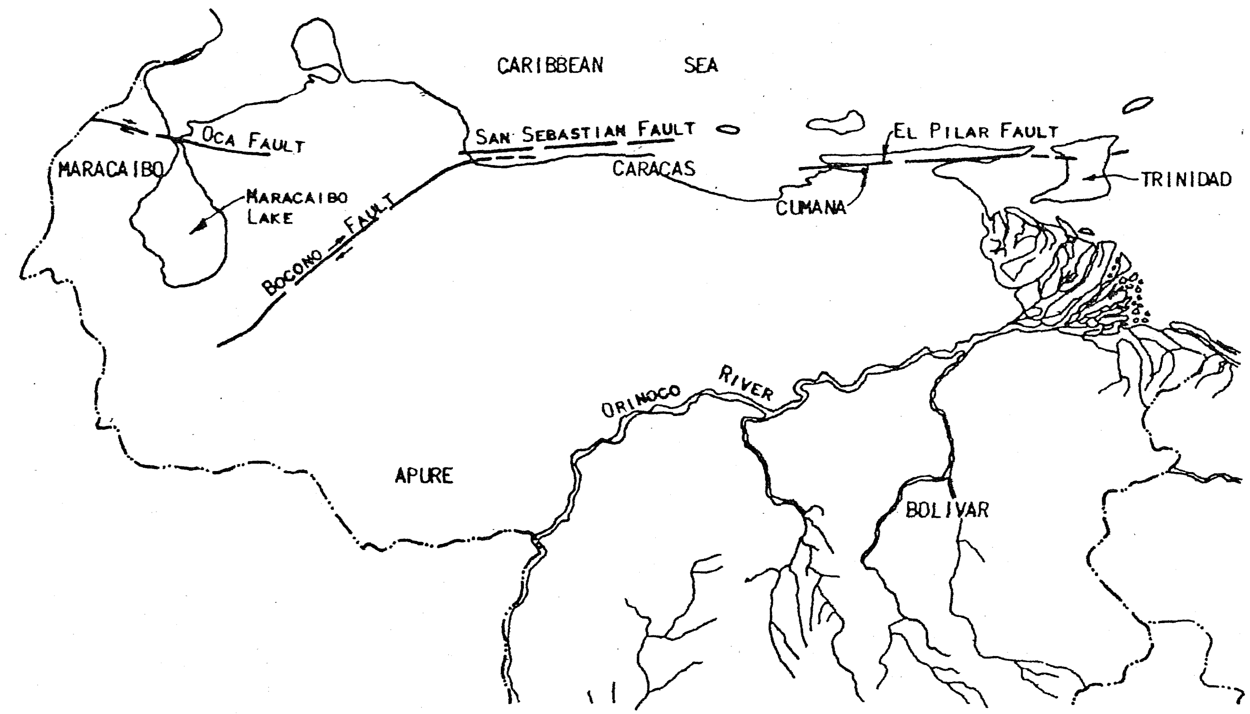

SEDIMENTARY ROCKS
METAMORPHIC ROCKS
IGNEOUS ROCKS
CARACAS GROUP
MAR CARIBE
MACUTO FAULT ZONE
RIO SAN JULIAN
CARACAS
LA GUAIRA
MACUTO
MAIQUETIA
LOS PALOS GRANDES
PETARE
ANTICLINE
SYNCLINE
After the geologic map of the Minister of Mines, no 2405, 1:50,000 by Gabriel Dengo, 1951.
Contour interval in meters

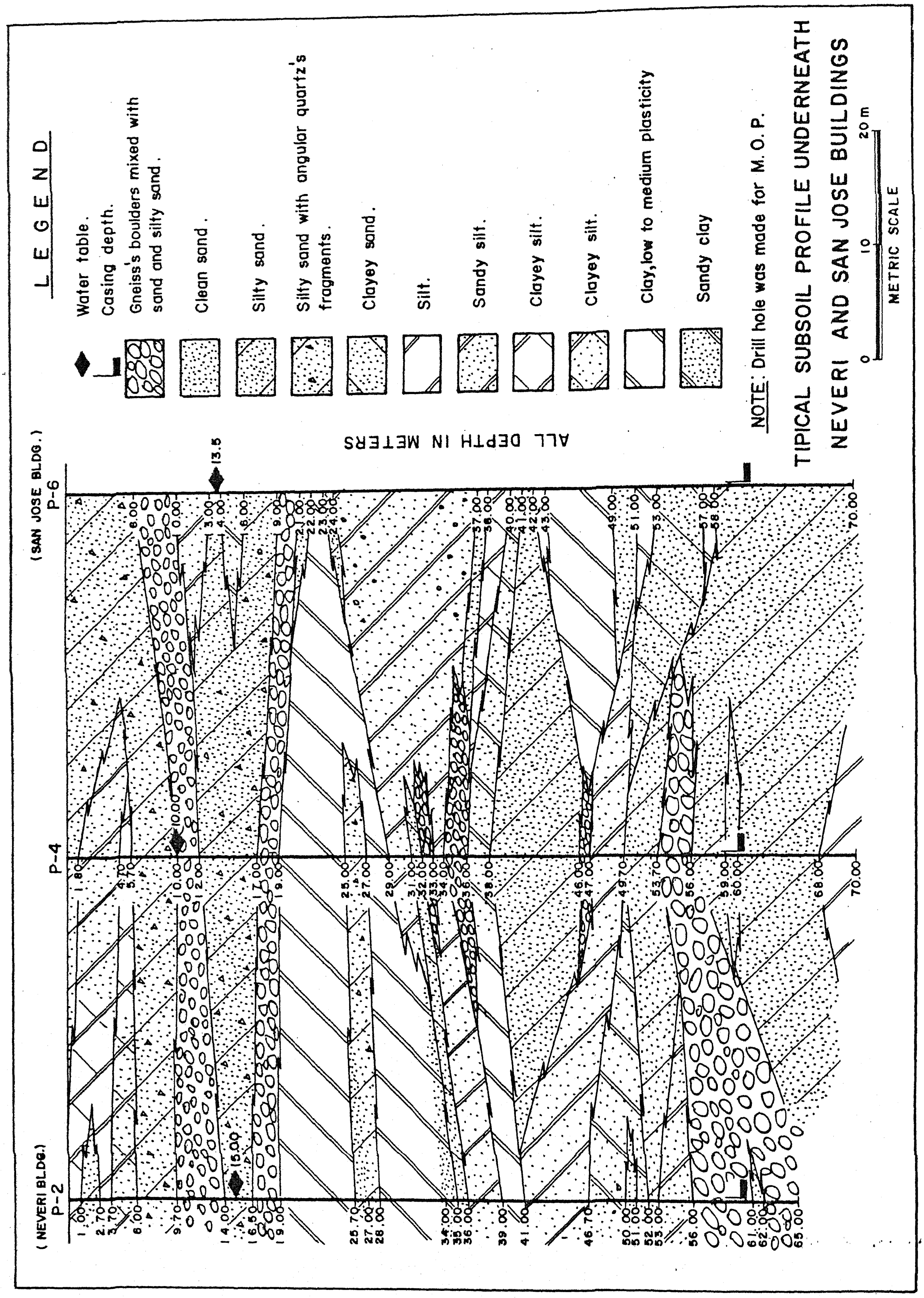
Figure: 2

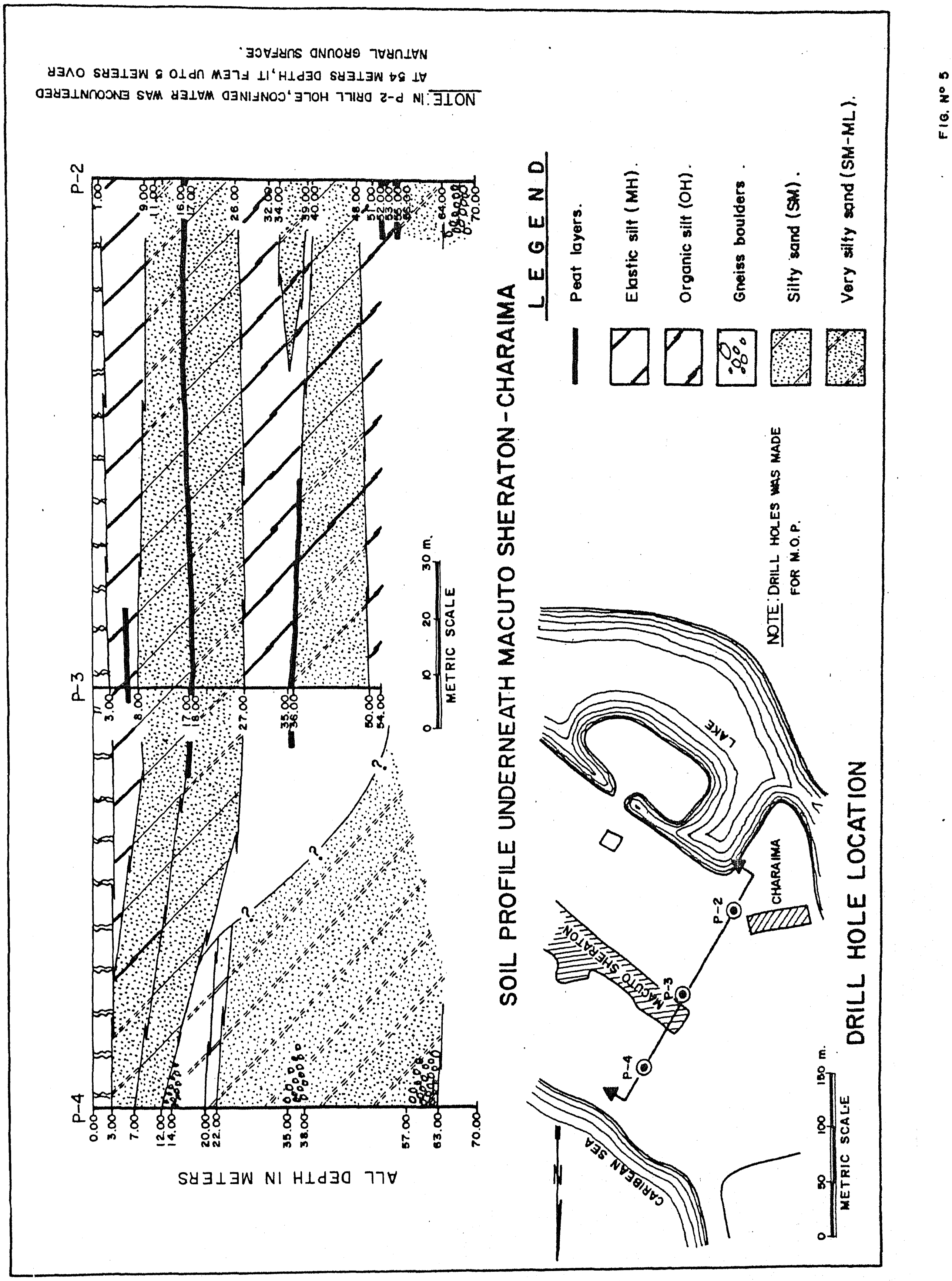


GENERAL MAP OF NORTHEARN VENEZUELA SHOWING MAJOR FAULTS

(SKETCH NOT TO SCALE)

FIG. Nº 3


LEGEND
Water table.
Casing depth.
Gneiss's boulders mixed with sand and silty sand.
Clean sand.
Silty sand.
Silty sand with angular quartz's fragments.
Clayey sand.
Silt.
Sandy silt.
Clayey silt.
Clayey silt.
Clay, low to medium plasticity
Sandy clay
NOTE: Drill hole was made for M. O. P.
TIPICAL SUBSOIL PROFILE UNDERNEATH
NEVERI AND SAN JOSE BUILDINGS
0
10
20 m
METRIC SCALE
ALL DEPTH IN METERS
(NEVERI BLDG.)
P-2
P-4
(SAN JOSE BLDG.)
P-6


SOIL PROFILE UNDERNEATH MACUTO SHERATON - CHARAIMA
P-4
P-3
P-2
ALL DEPTH IN METERS
NOTE: IN P-2 DRILL HOLE, CONFINED WATER WAS ENCOUNTERED AT 54 METERS DEPTH, IT FLEW UPTO 5 METERS OVER NATURAL GROUND SURFACE.
METRIC SCALE
0 10 20 30 m.
LEGEND
Peat layers.
Elastic silt (MH).
Organic silt (OH).
Gneiss boulders.
Silty sand (SM).
Very silty sand (SM-ML).
NOTE: DRILL HOLES WAS MADE FOR M.O.P.
LAKE
CHARAIMA
MACUTO SHERATON
CARIBEAN SEA
METRIC SCALE
0 50 100 150 m.
DRILL HOLE LOCATION
FIG. Nº 5

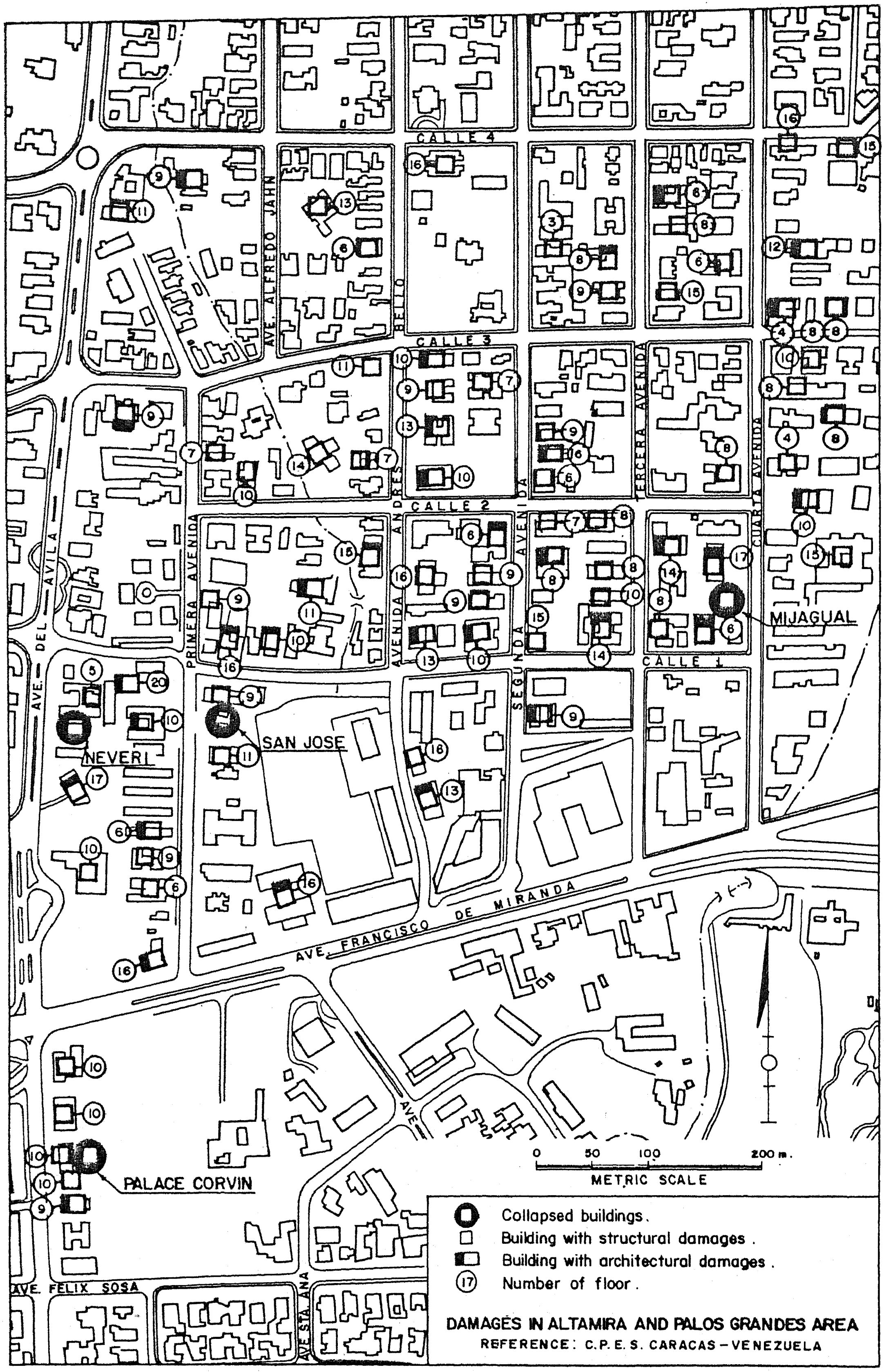

CALLE 4
CALLE 3
CALLE 2
CALLE 1
AVE. ALFREDO JAHN
BELLO
ANDRES
AVENIDA
SEGUNDA AVENIDA
TERCERA AVENIDA
CUARTA AVENIDA
PRIMERA AVENIDA
AVE. DEL AVILA
NEVERI
SAN JOSE
MIJAGUAL
PALACE CORVIN
AVE. FRANCISCO DE MIRANDA
AVE. FELIX SOSA
AVE. STA. ANA
AVE.
0 50 100 200 m.
METRIC SCALE
Collapsed buildings.
Building with structural damages.
Building with architectural damages.
(17) Number of floor.
DAMAGES IN ALTAMIRA AND PALOS GRANDES AREA
REFERENCE: C.P.E.S. CARACAS – VENEZUELA

FIG. Nº 6