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The Boca del Tocuyo earthquake of April 30, 1989 in Venezuela

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ABSTRACT: On april 30, 1989 a 5,7 earthquake occurred in the Caribbean Sea, near the town of Boca del Tocuyo in Venezuela. The earthquake was part of abnormal activity in that area and was felt in a great many cities in the central and western part of the country and caused liquefaction in some towns near the epicenter. The maximum intensity assigned was VII for the areas where liquefaction did not occur, and IX for the specific areas where it did. There were no accelerograph records, but the maximun ground accelerations that took place were estimated on the basis of intensities. This paper presents the seismological data and provides an evaluation of the damages found. The main conclusions concerning this event are: a) The damage caused by this earthquake was due mainly to liquefaction; b) Most of the damage in areas where liquefaction did not occur was due to bad quality construction.

1 INTRODUCTION

On April 26, 1989, abnormal seismic activity began in the Caribbean Sea, east of the town of Boca del Tocuyo. This activity was of the so-called seismic storm type, and 2,000 seismic events were recorded from that date until June 29, 1989 by the Morrocoy station, which is part of the Seismological Station Network of the Venezuelan Foundation for Seismological Research (FUNVISIS).

The most important earthquake occurred on April 30, 1989, with a magnitude of 5.7 and an epicenter in the Caribbean Sea some 20 km. east of Boca del Tocuyo. This earthquake was felt in several cities in the central and western part of the country.

One remarkable characteristic of this earthquake was the fact that it caused liquefaction in Boca del Tocuyo, Tocuyo de la Costa and Chichiriviche, located some 20 km. from the epicenter. The earthquake caused damage mainly in one story houses, churches, schools, in a water tank and in two residential buildings in Boca del Tocuyo, Tocuyo de la Costa, San Juan de Los Cayos, Chichiriviche and Tucacas.

The earthquake did not cause any injuries or deaths. 150 persons were left homeless in Boca del Tocuyo and Tocuyo de La Costa.

2 SEISMOLOGICAL DATA

FUNVISIS' Seismological Station Network began detecting abnormal seismic activity in the Caribbean Sea, some 20 km. east of the town of Boca del Tocuyo, in Falcón State, Venezuela, on April 26, 1989, and recorded some 2,000 seismic events, up until June 29, 1989, at the Morrocoy station, the one that is closest to the epicenter (Figure 1). According to FUNVISIS (1989), of these events, 2 had a magnitude of 5 or more, 4 a magnitude of 4 or more, and 46 a magnitude of 3 or more. The strongest earthquake (mb = 5.7) occurred on April 30, 1989 at 4h 22' 53.4" local time (8h 22' 53.4" GMT) and was located at 11.102 N and 68.179 W, with a focal depth of 11 km.

3 INTENSITY STUDY

To perform the intensity study, 230 surveys were done at 40 locations in the central and western part of the country, within a radius of 180 km. from the epicenter.

The intensity distribution, using Brazee's Modified Mercalli Scale (1978), is outlined in Figure 2, which shows that the highest intensity assigned was VII, for the towns of Boca del Tocuyo, San Juan de los Cayos, Chichiriviche and Tocuyo de la Costa (Falcón State). In the Caracas Metropolitan Area (Federal District), more than 150 km. from the epicenter, the

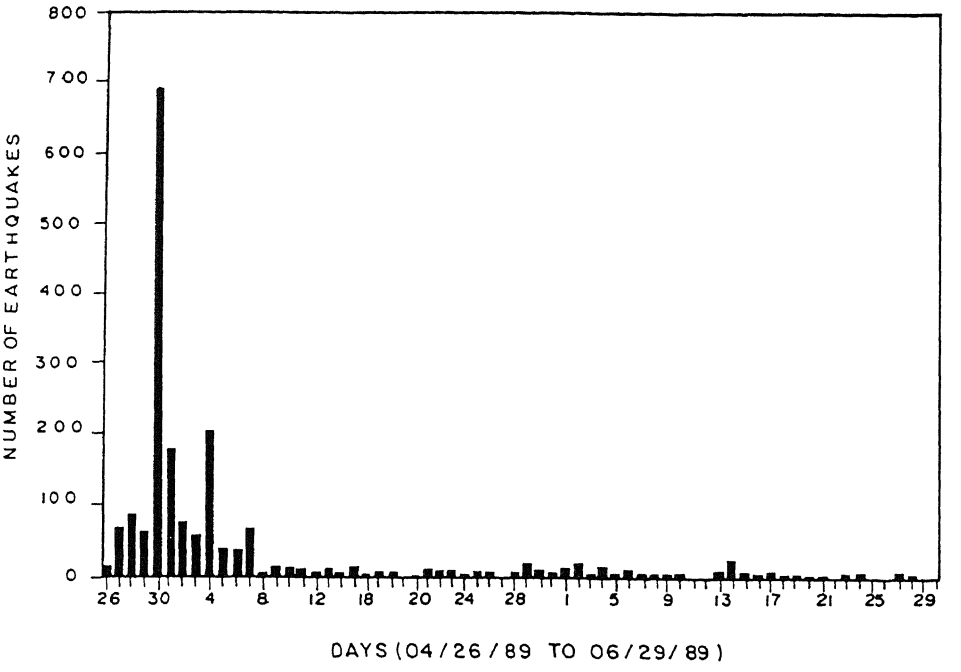

FIGURE 1. RECORDED EARTHQUAKES AT MORROCOY STATION

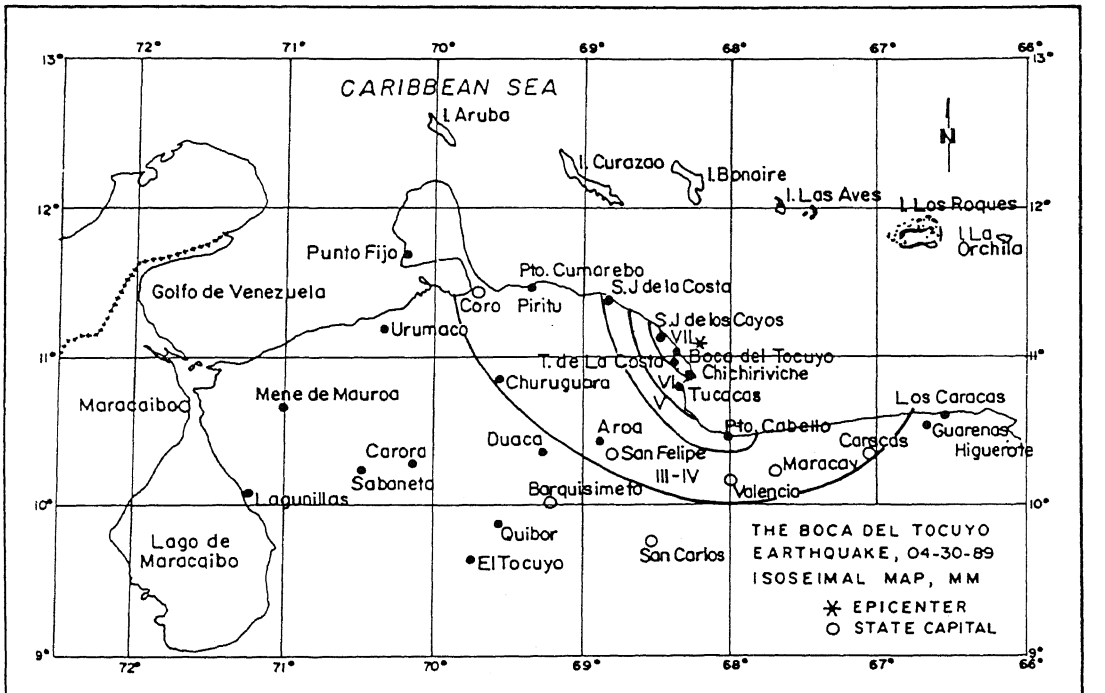

FIGURE 2

intensity was III. In the areas located near the Caribbean Sea and/or along the Tocuyo River in the towns of Boca del Tocuyo, Tocuyo de La Costa and Chichiriviche, liquefaction was found. Those specific sites were therefore assigned an intensity of IX on Brazee's Modified Mercalli Scale (1978).

One interesting detail shown by this study of intensities was that the predominant direction of the movement was northeast to southwest, and it was found that it was felt more intensely towards the southeast.

4 MAXIMUM GROUND ACCELERATION

There were no accelerograph records of this event; the maximum ground accelerations were estimated, however, based on the intensities assigned using the Coulter et al. (1973) correlation between acceleration and intensity for intermediate soils. According to that correlation maximum acceleration is between 0.13g and 0.19g for areas where the intensity was VII, which is consonant with the damage found; for the localized sites with an intensity of IX where liquefaction occurred, the maximum acceleration was between 0.55g and 0.85g, which are high values for a moderate earthquake; this confirms the Coulter et al. study (1973), which states that the correlation is not very reliable at intensities above VIII.

5 LIQUEFACTION

The most outstanding characteristic of this earthquake was the liquefaction of the soil in Boca del Tocuyo, Tocuyo de La Costa and Chichiriviche, on the eastern coast of Falcón State (Figure 3).

The areas where liquefaction occurred in Boca del Tocuyo are close to the sea and along the banks of the Tocuyo River; in Tocuyo de la Costa, they were along the Tocuyo River, and in Chichiriviche it occurred near to the coast line.

In the test soil bores made by De Santis et al. (1990), it was found that the liquefation ocurred between 0.20m and 4.00m of depth, in a sedimentary environment associated with abandoned meanders and fluvial-deltaic deposits with sand and silt; a typical geothecnic profile from a zone where liquefaction ocurred is the following: from 0 to 4.00m fine grey loose sand; from 4.00 to 8.00m medium dense fine grey sand; from 8.00 to 11.00m clayey sand loose to medium and from 11.00 to 15.00m medium dense fine sand.

The effects of liquefaction were found on the surface, as the injection of sand along ground fissures, ground fracturing and isolated sand cones.

It's important to mention that there is not knowledge about earthquakes that have caused liquefation in the zone before.

6 DAMAGE ASSESSMENT

Most of the damage was found in one- family houses located in the areas where liquefaction occurred in Boca del Tocuyo and Tocuyo de la Costa. In addition to the houses damaged, churches and school buildings, a water storage tank and two residential buildings also showed damage.

6.1 Houses

120 cases of houses with damage ranging from slight to serious were reported. Most of the damaged houses were built reinforced concrete columns and transverse beams, and smaller longitudinal wooden beams supporting a lightweight roof. The most common damage consisted of cracks in the clay-block walls due to differential settlement brought about by the loss of load carrying capacity of the ground due to liquefaction (Figure 4a). In the case of the houses in areas not affected by liquefaction, the damage was due to lack of anchoring between the walls of the houses, corrosion of the steel reinforcement and poor construction quality.

6.2 Churches

Two churches were damaged. The first, built more than 20 years ago, had a lightweight roof supported by small wooden beams which were held up, in turn, by concrete columns and the perimeter walls. The damage consisted of a fallen parapet from the main facade, due to lack of anchoring, and the failure of three of the wooden beams that held up the roof (Figure 4b).

The second church was built more than 30 years ago, and consists of a central nave and a bell tower that is separate from the central nave. The nave structure consist of two longitudinal frames resting on 6 reinforced concrete columns, and a lightweight roof supported by steel beams. The damage in this church consisted of cracks in some columns, beams and in the masonry partitions.

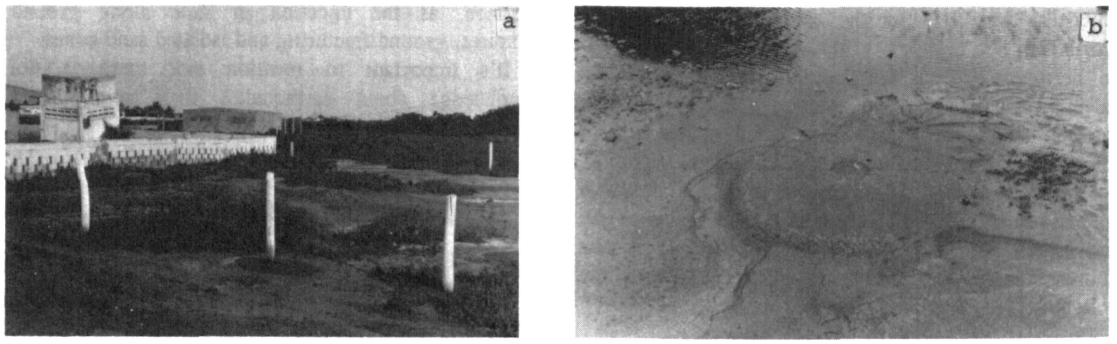

Figure 3 Liquefaction effects at Boca del Tocuyo. a) Settelement of water tank and sand boil; b) Sand boil detail

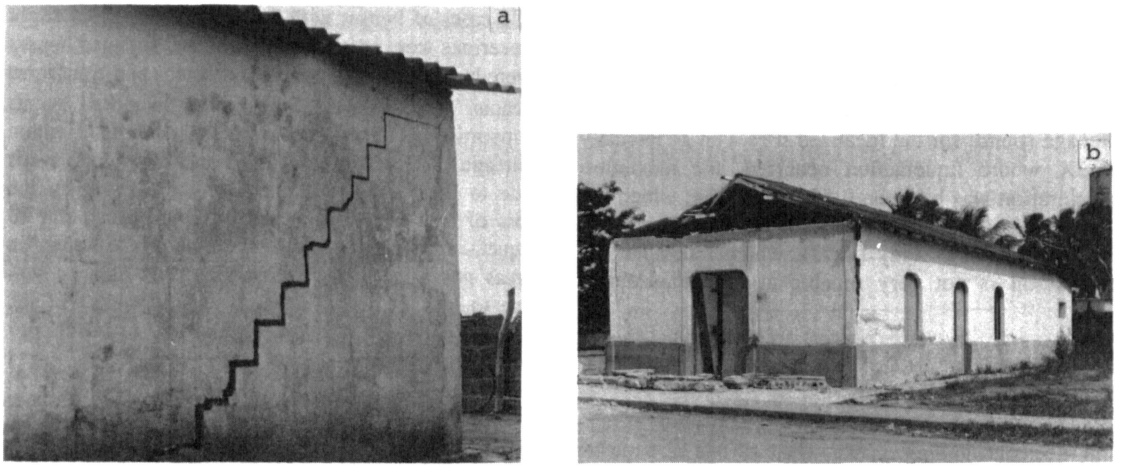

Figure 4 Damage in typical constructions of the area. a) Cracking due to settlement; note light roof; b) Fallen parts of church front

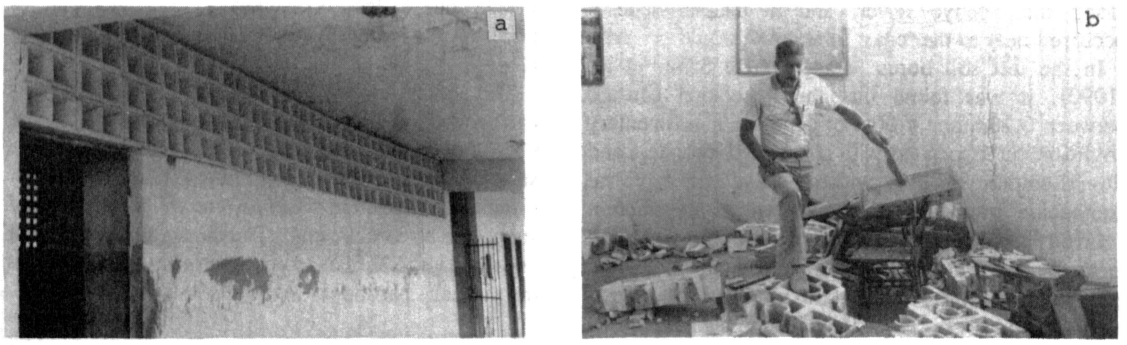

Figure 5 Ventilacion blocks in partition walls at Tocuyo de La Costa school. a) Displaced; b) Fallen in room class

6.3 School buildings

Damage occurred in two 2-story reinforced concrete school buildings. The damage consisted of longitudinal and vertical cracks in the masonry partitions, gaps between the columns and the walls and some fallen ventilation blocks due to lack of anchorage and maintenance (Figure 5).

6.4 Water tank

This 120,000 liter reinforced concrete water tank, which was empty when the earthquake occurred, showed 3 cracks caused by flexure covering half the perimeter of the circular hollow column 2.80 m. in diameter and 15 m. high that supported the tank.

6.5 Residential buildings

There are very few tall buildings in the towns near the epicenter; two of them, however, showed considerable damage to the masonry partitions at several levels.

7 CONCLUSIONS

The conclusions of this event are the following:

The damage caused by this earthquake was due mostly to the liquefaction that occurred.

Most of the damage found in areas where liquefaction did not occur, was due to faulty construction and lack of maintenance.

The liquefation ocurred between 0.20 m and 4.00 m in the depth in the zone conformed by abandoned meanders and fluvial-deltaic deposits.

The greatest intensity assigned on the basis of the damage found was VII; however, as liquefaction occurred in some specific areas, an intensity of IX was assigned to these areas. The maximum mean acceleration was estimated at between 0.13 and 0.19g for the areas with an intensity of VII, which is consonant with the damage found; however, for the areas with an intensity IX the estimated acceleration values (between 0.55 and 0.85g) are high for an earthquake of this characteristics.

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