Seismicity and Seismic Hazard in the Dominican Republic

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Abstract

The Dominican Republic occupies two-thirds of the island of Hispaniola which is located in the Caribbean-North American plate boundary zone. In the past 500 years, the island has been shaken by large earthquakes, the most recent occurring in 1946 and causing widespread destruction. Since the establishment of a telemetred seismic network in 1979, a great amount of microseismic activity has been detected in the north coast area, in the internal faults and also in the south coast area. The Dominican Republic, with an area of about 48,000 Km^2 and a population of seven million people, is one of the countries with the highest seismic risks in the Caribbean.

Introduction

The Dominican Republic is located on the Island of Hispaniola, which it shares with the Republic of Haiti. The island, which is the second largest in the Caribbean, is located in the Caribbean-North American plate boundary zone. It is traversed by three mountain ranges whose trend is approximately parallel to that of the plate boundary and two of which extend into both countries. They are:

(i) The Cordillera Septentrional, which coincides extensively with the north coast of the Dominican Republic,
(ii) The Cordillera Central with Pico Duarte whose elevation is more than 3,000 metres,
(iii) The Sierra de Bahoruco in the south.

The presence of these mountain systems, in addition to the many active geological faults, on the Island (Figure 1) is evidence of intense historical and contemporary tectonic activity.

In June 1986, the Jet Propulsion Laboratory (JPL) of Pasadena, California, USA, organized and executed a series of extended geodetic base line measurements using global positioning systems (GPS) for the purpose of measuring the relative motion between the two tectonic plates (North American and Caribbean). Of the six stations which they installed, three were in the Dominican Republic, one in Puerto Rico, one on Grand Turk Island and one in Guantanamo, Cuba.

It was concluded from the results of the observations made at these stations that there are significant differences concerning the exact rate and direction of strike-slip motion between the existing plate motion models for this boundary. Figure 2 shows the two relative motions. The plate motion in this area suggests either 2 or nearly 4 cm/yr of relative motion. The models disagree on whether that motion is purely strike-slip or whether a component of convergence exists between the plates. The extreme topographic relief and large gravity anomalies along parts of this boundary testify to the importance of compressional deformation in this complex plate boundary zone. Whether this is due to actual plate convergence or to local and regional changes in the trend of a predominantly strike-slip boundary is not clear.

Prentice et al. (1993) carried out a paleoseismicity study in the Cibao Valley and indicate that "it has been at least 430 years and probably 730 years since the last ground-rupturing earthquake on this segment of the Septentrional Fault". This evidence, coupled

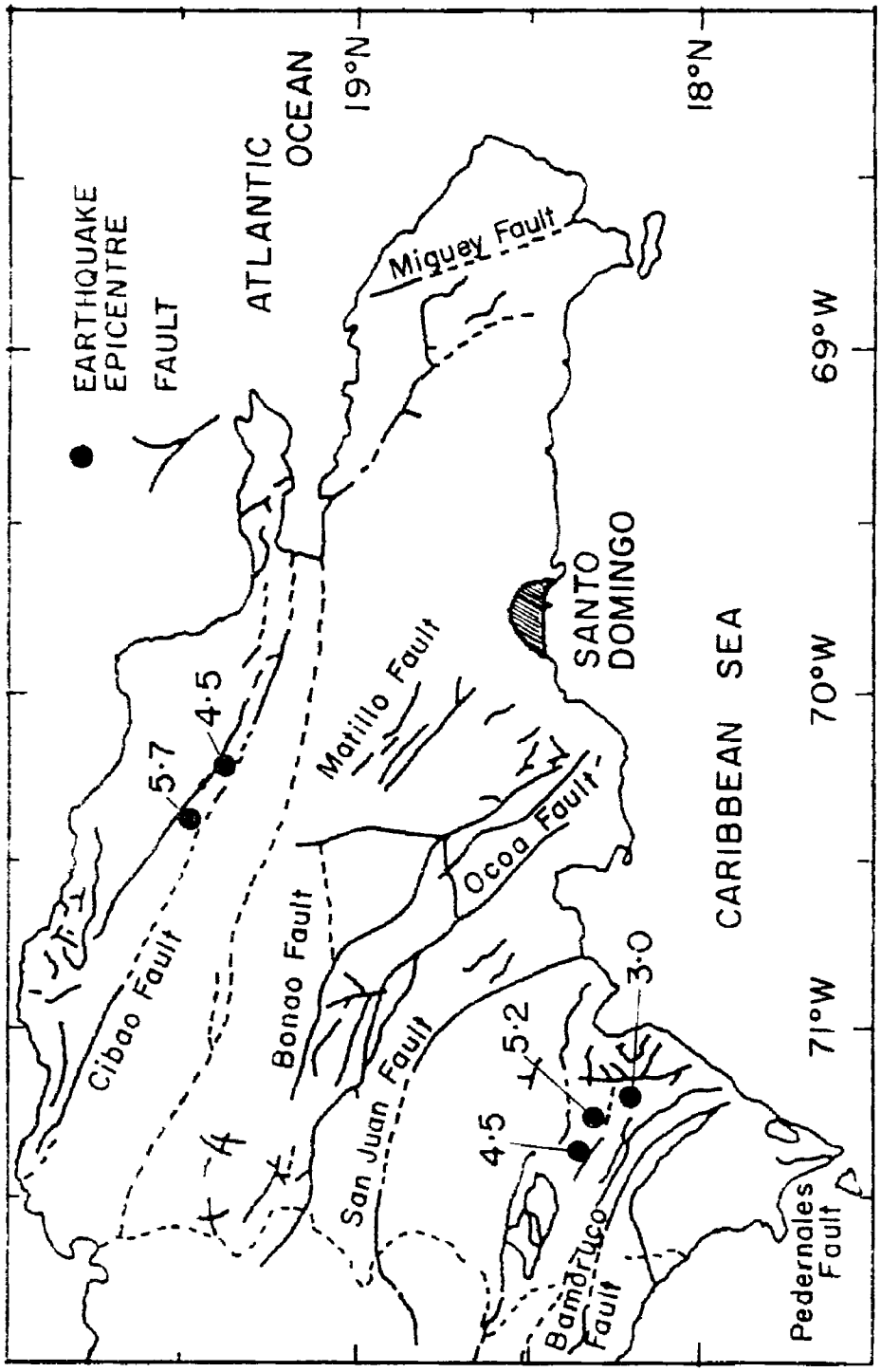

FIGURE 1: Structural features in the Dominican Republic

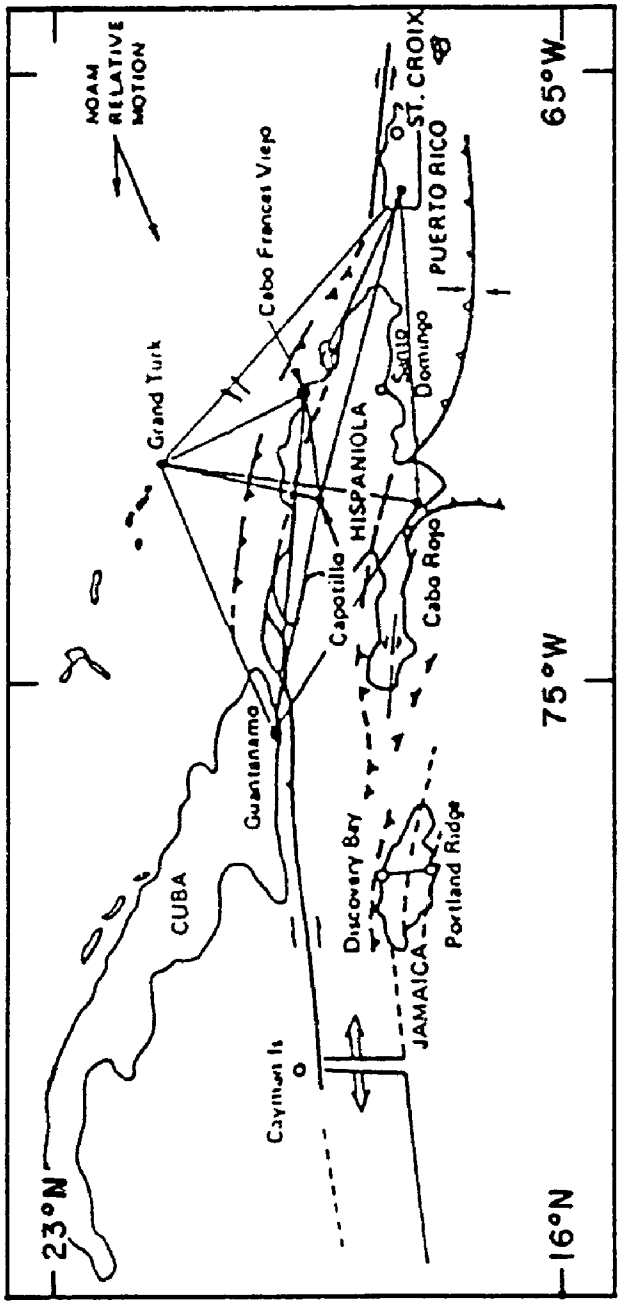

FIGURE 2: Results of GPS measurements showing the directions of relative motion between the Caribbean and North American plates

with the occurrence of an earthquake of magnitude 5.7 in 1993 indicates that the Island is a potential source of high tectonic activity.

Seismic History

From the discovery of the Island on December 10, 1492, until the present, the historical records indicate that strong earthquakes have occurred, some of which have had significant impact on the history of our country.

On May 2, 1562, an extremely strong earthquake was felt over the entire Island and completely destroyed the original City of Santiago (presently the second largest City in the country) as well as the original city of La Vega. These two cities are now located elsewhere and today the ruins of the original cities are available for inspection.

History books indicate the impact of these earthquakes on the economic and social life from colonial to present days. These earthquakes accelerated the process of migration of the original inhabitants from the Island to the continent.

Table 1 is a summary of earthquakes which generated effects consistent with intensities greater than IV on the Mercalli-Cancani-Sieberg scale. There have been 61 earthquakes stronger than intensity IV and 23 stronger than intensity VII and 10 stronger than intensity IX since 1551. This shows that during a 100-year interval, approximately 3 earthquakes exceed intensity IX, important information from the point of view of seismic risk and earthquake engineering.

Table 1: Intensity (Mercalli-Cancani-Sieberg Scale)

TIME	I≥IV	I≥VII	I≥IX
155>	3	2	2
165>	22	7	3
175>	26	10	3
1851-1911	19	4	2
TOTAL	61	23	10

The Earthquake of August 4, 1946

This earthquake is very important for the evaluation of seismic hazard on the Island. It is the strongest earthquake that has occurred so far during the 20th century and is well-documented. Consequently, it is used for reference in engineering design.

This earthquake occurred on August 4, 1946, at 1.30 p.m. with a magnitude of 8.1 on the Richter scale. It was felt at distances of more than 300 km from its epicentre located in the eastern part of the Samana Peninsula (19.2 ^{o}N, 68.8 ^{o}W). The greatest damage occurred in the Cibao Valley in the cities of San Francisco de Macorís y Moca, approximately 170 km from the epicentre. This is due to alluvial deposits of the valley and the fact that the principal cities are located within the Septentrional fault system. At the same time, cities located closer to the epicentre such as Samana and El Seibo suffered less damage. A tsunami encroached several kilometres into a village on the north coast destroying its houses and causing more than 100 deaths.

The city of Santo Domingo, located approximately 160 km from the epicentre, did not suffer great damage, just cracking of its buildings as well as the bridge over Rio Isabela. One of the explanations for this is the presence of reef limestone beneath the city.

Figure 3 is a map showing the epicentre of the main shock and several of its aftershocks. One of the aftershocks, of magnitude 7 on the Richter scale, occurred 4 days after the principal shock. Shocks strong enough to be felt by people continued for more than a month and created national panic because of the inexperience of the people. As a

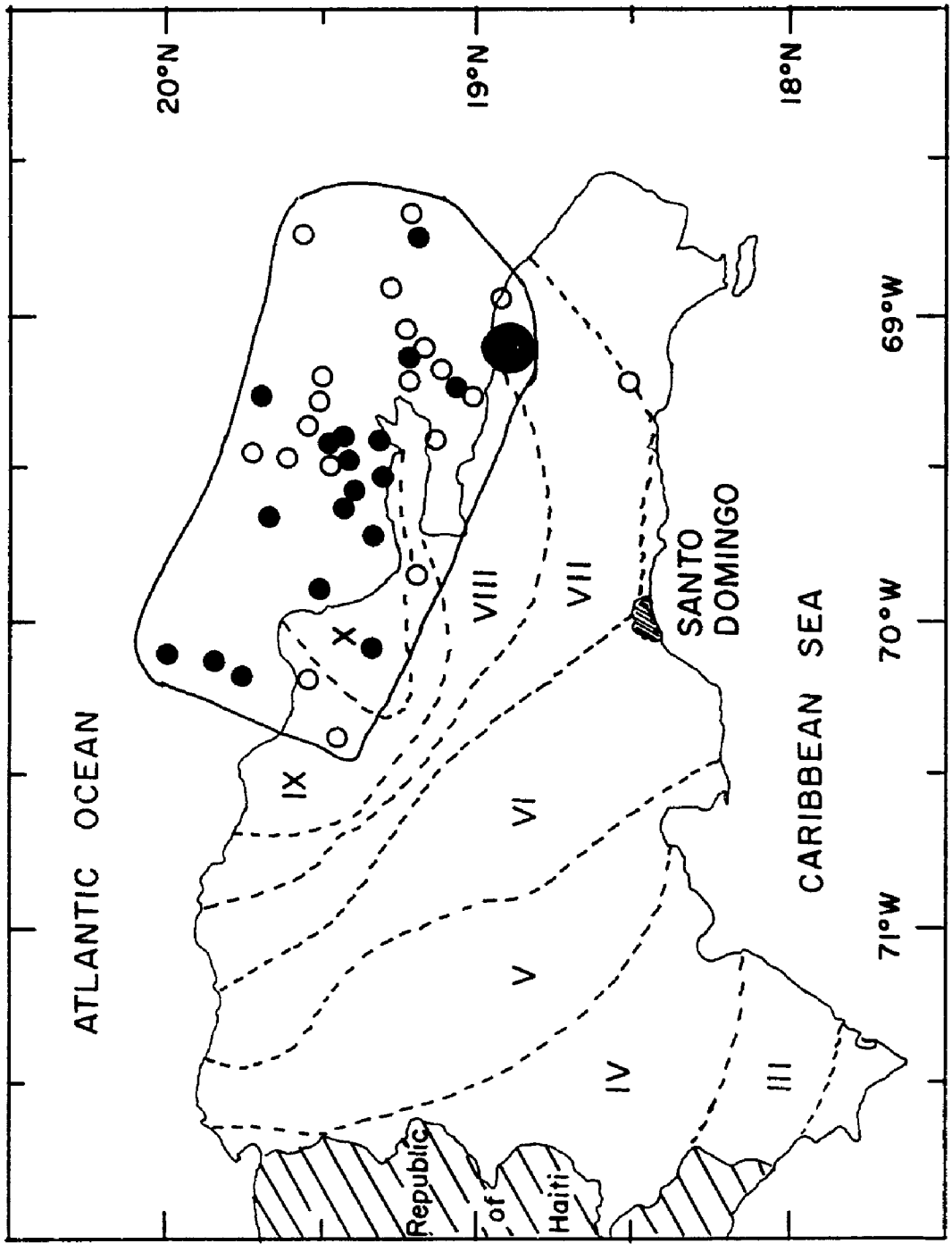

FIGURE 3: Location of the earthquake of August 4, 1946 and some major aftershocks

result, there was a mass exodus of people from the north coast to the interior of the Cibao Valley that paralysed the economy and provoked government intervention.

We now know that the Cibao Valley is the most active zone in the entire country and has the highest probabilities of suffering from a strong earthquake.

This earthquake and its aftershocks seem to define the zone where the subduction process of the North American Plate and the Caribbean Plate ends and where the transform fault begins.

Seismic Activity in 1987

In 1987, we began work with the National Seismic Network with a total of 15 telemetered stations (Figure 4) and presented a strong program of seismic observation for the entire island. From July to September, there were two simultaneous swarms on the north coast which generated an earthquake of magnitude 5.7, with its epicentre (19.23 ^{o}N, 67.48 ^{o}W) near the town of Villa Vasquez at a depth of 10 km. After this shock, another followed with a magnitude of 4.5 that caused much panic among the people. The earthquakes felt in this zone continued for more than 15 days (Figure 5). The principal earthquake caused the primary school, as well as other government buildings, to crack.

The majority of buildings in this region are single-storey wooden houses with zinc roofs, which explains the little damage observed.

However, the most important factor was that on this same day, we were able to warn the Civil Defence of a possible earthquake several hours before it occurred.

Seismic Hazard and Development

It has been observed that the Island has been shaken by strong earthquakes that have reached an intensity of more than IX on the Mercalli scale and during an epoch the Dominican Republic was almost depopulated.

During the first 9 months of 1993, 4 earthquakes have occurred which have generated effects consistent with intensities greater than V. The last one of these occurred on August 19 in the Ocoa fault with its epicentre 40 km from the City of Santo Domingo where it was strongly felt. The earthquakes associated with this fault are easily felt in Santo Domingo.

At present, the Dominican Republic has a population of approximately 7 million people distributed in an area of 18,000 square miles with one of the highest densities of population in the Americas, about 389 persons per square mile. If we consider that 80% of the people live in the cities, we discover that the situation has changed significantly since the earthquake of 1946 when the population was approximately 2 million and 80% rural.

Today, the strategy for the development of the country has been changed to multi-storied buildings and large dams. The wooden houses have been substituted by concrete blocks with concrete roofs.

Knowing the seismic history of the country and observing the building characteristics just mentioned, it is necessary to conclude that the investigation of the seismic risk must be one of the fundamental variables that should be considered in the development of our country.

Conclusions

It is evident that the study of the seismic hazard and the seismic risk in the Dominican Republic must become greater and more profound in an accelerated and systematic manner.

Until now the investigations have been sporadic and isolated. To avoid disaster the approach needs to be changed. Our principal problem is not how little we have, but how easy it is to loose what we have. We must, therefore, establish an extensive system of communication for exchange of information and experiences throughout the Caribbean.

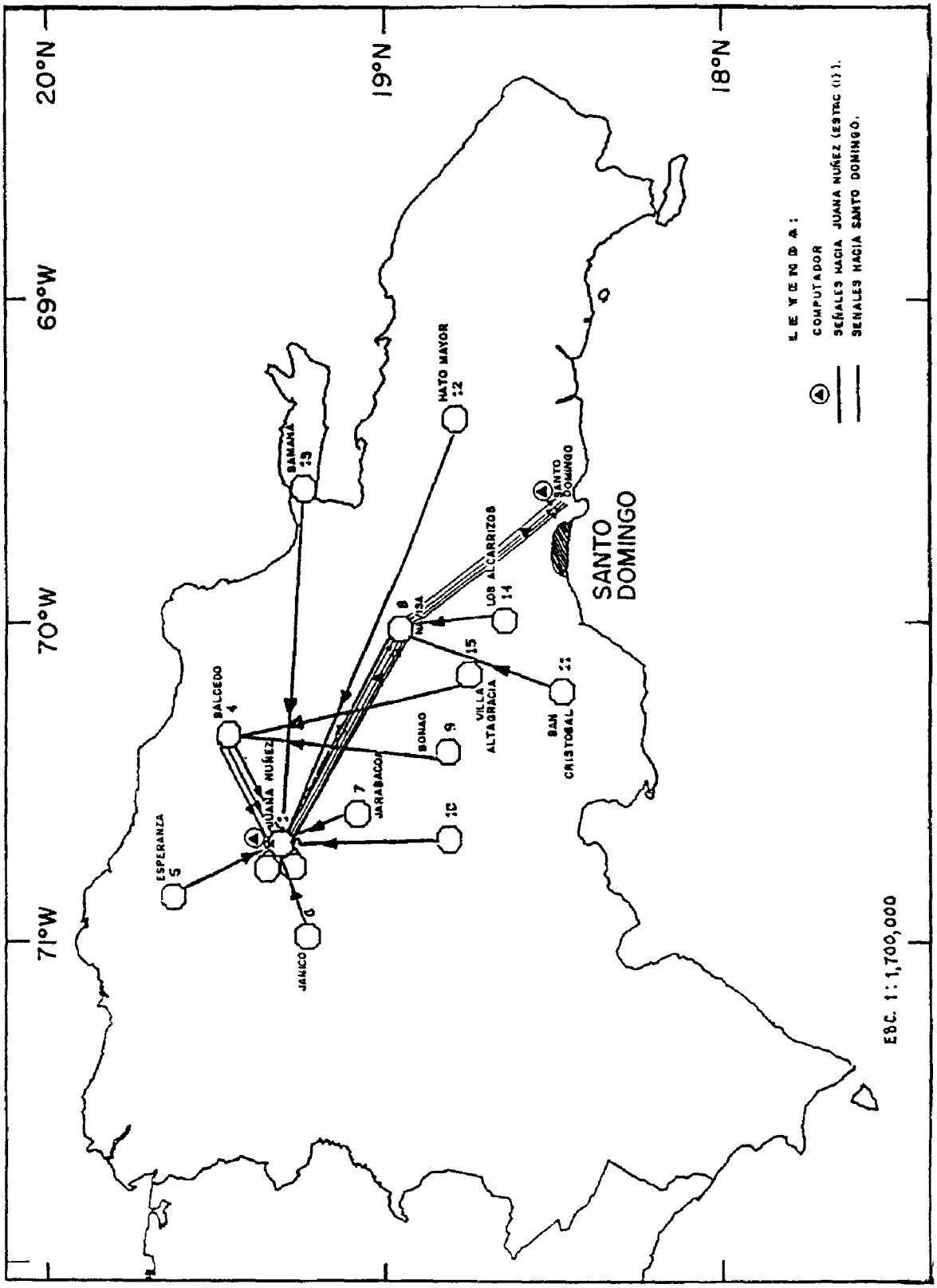

FIGURE 4: The Dominican Republic National Seismic Network in 1985

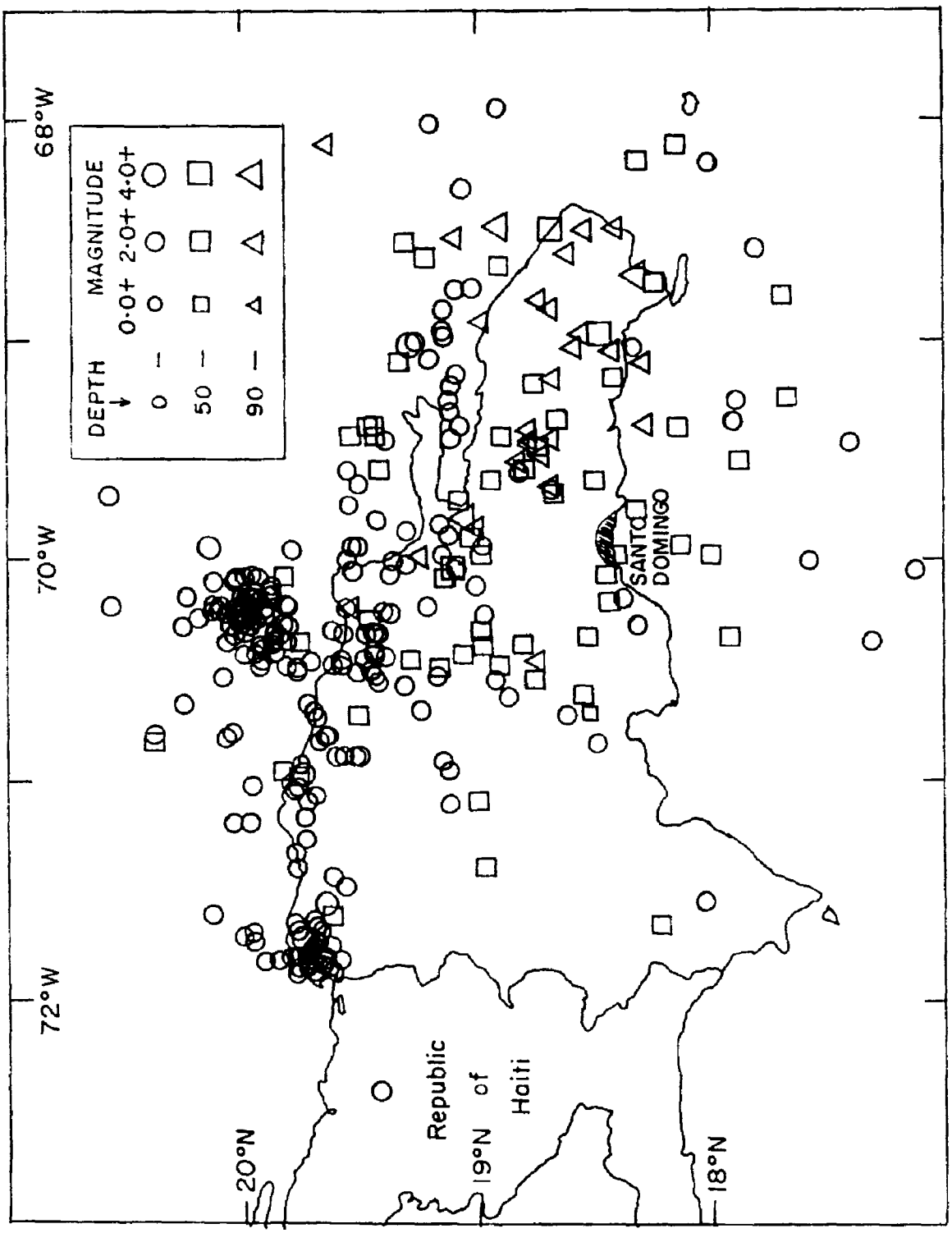

FIGURE 5: Seismicity in the Dominican Republic Area. July – September, 1987

References

Prentice, C.S., Mann, P., Taylor, F.W., Burr, G. and Valastro, S. (1993). Paleoseismicity of the North American - Caribbean boundary (Septentrional fault), Dominican Republic. Geology, 21: 49-52.