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# Assessment of seismic hazard in the islands of Guadeloupe and Martinique (Antilles)

P. Godefroy, E. Leroi, P. Mouroux & B. Sauret
*BRGM-Marseille, France*

Ch. Paulin & J. Ph. Rançon
*BRGM-Antilles, Pointe-à-Pitre, Guadeloupe Island, France*

ABSTRACT: During the past three centuries, the Islands of Guadeloupe and Martinique were severely affected by earthquakes in 1839, 1843, 1851, 1897, 1946 (Fig. 1). A general evaluation of the seismic hazard was carried from 1986 to 1990, which led to a geotechnical zonation of both islands and a microzonation of their two capitals, with practical recommendations for the planning of construction.

## INTRODUCTION

The 16 March 1985 earthquake ($M_s$ = 6.0, epicentre north of the island of Montserrat) was moderately felt in Guadeloupe, especially in Basse-Terre and the capital Pointe-à-Pitre, but it served to remind that a major earthquake can strike the Lesser Antilles at any time. After all, the event of 8/02/1843 (intensity IX MSK) had killed 1500 people in Pointe-à-Pitre and the earthquake of 11/01/1839 reached an intensity of VIII-IX MSK at Fort-de-France on Martinique. The public authorities thus started planning the necessary actions to reduce seismic risk. General seismic hazard was evaluated for the entire archipelago of Guadeloupe, including the islands of Saint-Barthelemy and Saint-Martin, and for Martinique. This study led, among other points, to:

1. A seismotectonic synthesis.
2. Identification and characterization of the seismic sources and related seismic ground motions.
3. The zonation of different types of landslides, liquefaction phenomena, etc., at scale 1:100,000 for all islands.
4. Seismic microzonation at 1:5000 for Pointe-à-Pitre (Guadeloupe) and at 1:10,000 for Fort-de-France.
5. Practical conclusions and recommendations for development planning and construction purposes.

An example of the work performed in Guadeloupe is presented hereafter.

## THE SEISMOTECTONIC SYNTHESIS

### Geodynamic setting of Lesser Antilles Arc

The eastern Caribbean, where the two islands are located, overlies an active plate margin. Subduction of the American Plate below the Caribbean Plate takes place in an ESE direction, with a rate of convergence of about 2 cm/y and a dip of the subduction plane of about 50° near Guadeloupe and about 60° near Martinique. This subduction is seen as the cause of the tectonic and seismic activity in the region, and of its volcanism.

The characteristics of this subduction seem to justify a relatively moderate seismic activity in comparison with other subduction areas. Strong subduction earthquakes are rare and have a maximum magnitude of 7.5 to 8.0 (Godefroy et al., 1990).

### The structural and neotectonic framework

Guadeloupe and Martinique, and their continental slopes, have a typical structural configuration of horsts and grabens on land, and submarine valleys and highs, all being controlled by normal faults. Several of these major faults show post-Miocene to Recent syn-sedimentary movements that affect the coastal morphology of the islands, some of which were proven to be younger than 120,000 years.

Microtectonic work indicates a general system of radial extension that has been active since at least Late Quaternary time. This implies that normal movements along the active faults will be the most likely source of seismic shocks. Certain of these faults directly affect the major towns of Point-à-Pitre & Fort-de-France.

Seismicity

Historical macro-seismic data provide three centuries of information on the two islands. For the period before the 20th Century, the characteristics of major earthquakes can only be estimated. Reliable data are available for the period after 1950 and especially since local monitoring networks were set up in 1973.

The maximum intensities of major earthquakes plainly justify the fact that seismic risk is taken into account on the basis of deterministic hazard evaluation. On average, one or two shocks are felt each year, and every century at least two shocks occur with an intensity of over VII (causing significant damage to buildings).

Most of the earthquakes felt on the islands are of distant origin, but local seismicity exists as well, caused by nearby and superficial sources, as shown by historical data. Two destructive earthquakes, on 16/05/1851 ($I_o$ = VII) and 29/04/1897 ($I_o$ = VIII), can be related to local sources that are very close to the main towns on Guadeloupe. The careful study of seismicity on the two islands, placed in its geodynamic context, has led to the identification of three main types of seismic source on Guadeloupe, which must be considered for a reliable evaluation of the hazard.

IDENTIFICATION OF THE SEISMIC SOURCES ON GUADELOUPE

See table, as well as Figure 2.

REFERENCE SEISMIC MOTIONS AND (MACRO) ZONATION OF GUADELOUPE

The zonation that is associated with the application of French building regulations for earthquake-prone areas (AFPS, 1990), for constructions at "normal risk", ranks all of the islands of Martinique and Guadeloupe in the same zone III, which is assumed to be exposed to strong seismicity.

Identification of earthquake sources and determination of associated reference movements, as resulting from the present study, have led to further subdivision of

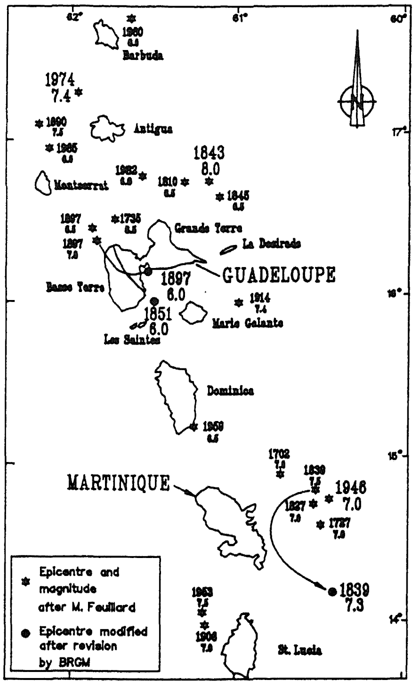


Figure 1: Location of the most likely historical epicentre areas with highest estimated magnitudes, felt in Guadeloupe and Martinique (from: Feuillard, 1984)

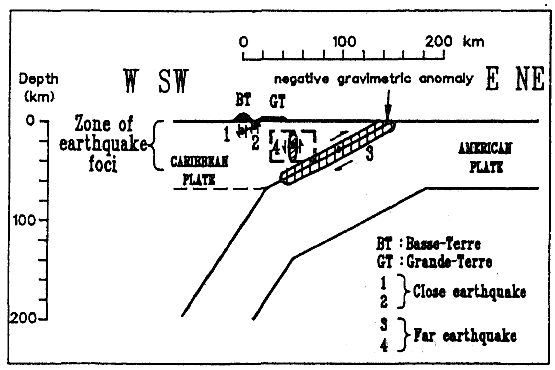


Figure 2: Schematic location of seismic sources selected for Guadeloupe

this zone (Fig. 2). This is based on the use of response spectra representative of the specifics of these sources (Fig. 3). The fact that nearby sources, which until recently were ignored, now are taken into account, is a major step forward.

GEOTECHNICAL ZONATION AT SCALE 1:100,000

This zonation considers all ground movements that could be triggered by an

| | 'NEARBY' SOURCES | | 'FAR' SOURCES | |
|---|---|---|---|---|
| Reference earthquake | 29 April 1897 | 16 May 1851 | 8 February 1843 | 8 October 1974 |
| Magnitude | 5.5 ± 0.5 | 5.5 ± 0.5 | 7.5 to 8.0 | 7.5 |
| Focal depth | 5 km ± 3 km | 10 km ± 5 km | 30 km (average value compared to the size of the failure area) | 40 km at start of failure, 25 km at its centre |
| Inferred max. intensity (MSK) | VIII | VII | IX | IX |
| Source mechanism | normal fault | normal fault | reverse fault | normal fault |
| Location; possible association with a fault | intraplate Caribbean (IC) Gosier fault, etc. | IC, Mateliane-Capesterre fault, etc. | thrusting between Caribb. and Am. pl., between Barracuda and Tiburon ridges | IC, continuation of subd. Tiburon ridge; Desirade escarpment, etc. |
| Min. focal distance | 5 km | 5 km | 50 km | 25 km |
| Seismic moment (dyne x cm) | $5 \times 10^{24}$-$10^{25}$ | $5 \times 10^{24}$-$10^{25}$ | $10^{27}$ to $10^{28}$ | $2.5 \times 10^{26}$ to $10^{27}$ |
| Failure surface | 10 to 30 km² | 15 to 30 km² | 3000 to 10,000km² | 2000 km² |
| Max. failure length | 5 to 8 km | 5 to 8 km | 80 to 140 km | 60 km |
| Average dislocation | 15 to 70 cm | 15 to 70 cm | 2.5 to 10 m | 1 to 4 m |

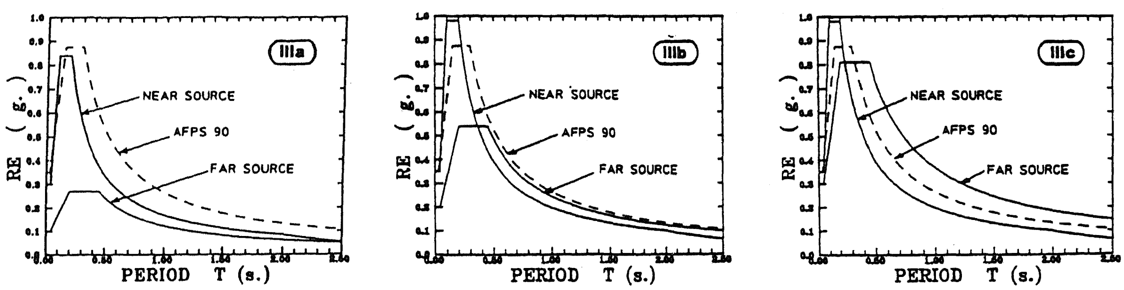


**Figure 3: Proposed horizontal elastic response spectra (5%) for Guadeloupe. Comparison with AFPS-90 recommendations**

earthquake, as well as vulnerable areas (towns, roads, etc.) on the islands.

Four hazard levels were defined for the following phenomena: landslides, damming up, rock falls and liquefaction. Combining these hazards leads to a multi-criteria map that not only comprises four hazard levels, but also the vulnerable areas. Such zonation indicates the priorities for microzonation studies at a larger scale, as well as the impact on infrastructure.

## SEISMIC MICROZONATION AT SCALES 1:5000 TO 1:10,000

Large-scale zonation was based on the methodology described by Bard et al. (1991), for the towns of Pointe-à-Pitre (1:5,000) and Fort-de-France (1:10,000). The principal results obtained for the first town, in Guadeloupe, are as follows:

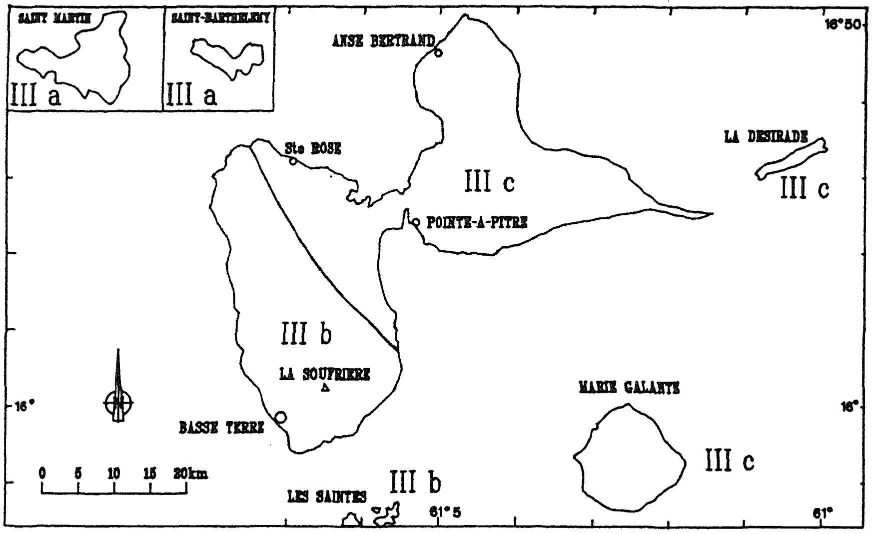


Figure 4: Regional seismic zonation of Guadeloupe

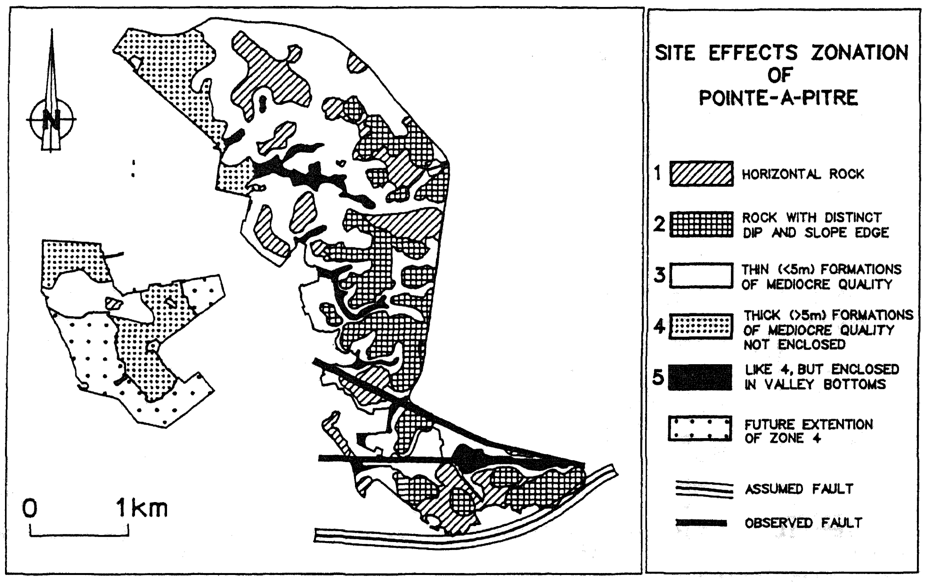


Figure 5: Zonation of Guadeloupe at scale 1:100,000 Multicriteria risk map

## Geological and geotechnical data

Low limestone hills, on the east side of town, disappear westward under a mangrove swamp that was partially filled in for development purposes. Between rock and rubble occurs a level of plastic clays, as well as the compressible muddy-peaty and sandy substrate of the mangroves.

The geotechnical data concerning these four types of substrate were analysed from a very large number of pre-existing boreholes and tests.

## Site effects

These were considered according to one- and two-dimensional models (the GEFDYN software (Modaressi et al, 1991), which gave five zones (Fig. 6):

1. horizontal rock;

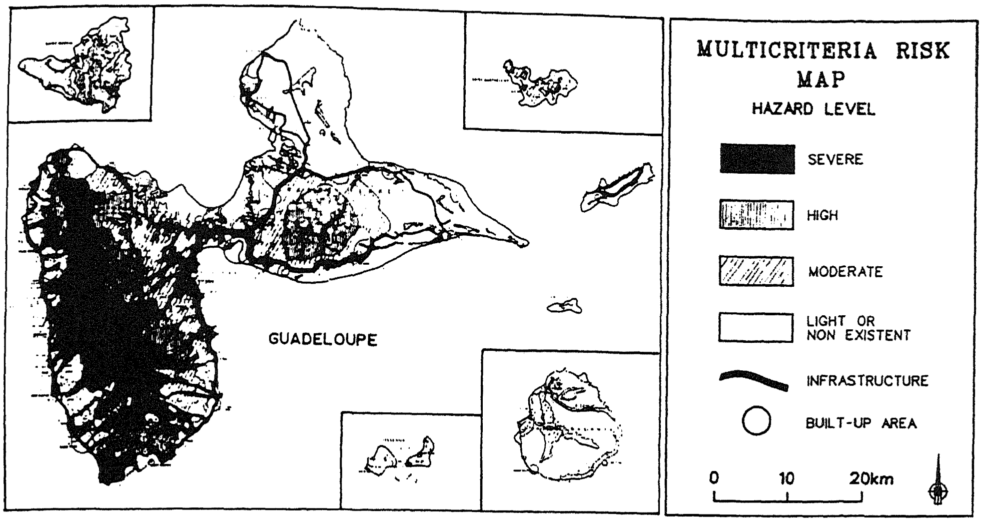


Figure 6: Microzonation of Pointe-à-Pitre at scale 1:5000. Map of faults and site effects (for zones, see text)

2. rock with distinct dip and slope edge;
3. thin (<5 m) formations of mediocre quality;
4. thick (>5 m) formations of the same quality, not enclosed;
5. formations of the same quality, but enclosed in valley bottoms.

For each of these zones, the 'δ(T)' coefficient of the PS 69/82 rules is varied as a function of the own period of the structure. It can thus be taken as a site coefficient, and also integrates the effects of a 'nearby' source; e.g. for zone 4: maximum 'δ(T)' = 1.6, for a period 'T' of 0.4-0.7 seconds.

### Induced effects

Liquefaction is the phenomenon that will cause greatest damage in Pointe-à-Pitre. Four hazard levels were retained, level 4 corresponding to little-compacted sandy ground, such as hydraulic landfill. For landslides, only the limestone-cliff edges present a hazard of level 4.

### Effects due to active surface faults

Independently of the effects of 'nearby' sources considered for site effects, an active fault can cause surface failure that could damage a construction. Known faults, such as the Gosier fault in south Pointe-à-Pitre, were mapped as a 50 m wide strip. Conform AFPS 90 regulations, "except in case of absolute necessity" no construction should take place near such faults. A further refinement is that all construction at 'special risk' must be forbidden, and that for buildings at 'normal risk' it is recommended to avoid construction of, in order of priority, Class C (hospitals, etc.) and then Class B (buildings open to the public).

## CONCLUSIONS

The general study of seismic hazard on the islands of Guadeloupe and Martinique, should lead, among other items, to:

- better understanding of seismic risk by local decision makers and the public;
- improvements in the quality of development work and construction, especially of dwellings, thanks to the creation of 'Pilot Centre';
- installation of a network of sensitive accelerometers, for better definition of seismic sources and their effects;
- better organization of first-aid and assistance in case of an earthquake.

## ACKNOWLEDGEMENTS

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