Natural hazards in the French West Indies : an overall view

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NATURAL HAZARDS IN THE FRENCH WEST INDIES: AN OVERALL VIEW

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Abstract

The aim of this paper is to give an overall view of the natural hazards and risks affecting the French West Indies. These are mainly connected with hurricanes, volcanic eruptions and earthquakes which have caused several deaths and seriously weakened the local economy during the last three centuries. First of all the geological and geographical conditions which determine the natural predisposition of the French West Indies to geophysical and atmospheric hazards are described. Then the risk for the population is taken into account, both in terms of the direct effects of the above mentioned hazards and of the side-effects, that is tidal waves, floods and mass movements. Finally the economic and social impact of natural disasters on the French West Indies and the difficulties arising in risk mitigation are shown.

Key words: natural hazards, risk mitigation, French West Indies.

Riassunto

Lo scopo di questo lavoro è di fornire un quadro generale delle pericolosità e dei rischi naturali che interessano le Indie Francesi Occidentali. Questi sono principalmente connessi con uragani, eruzioni vulcaniche e terremoti che, nel corso degli ultimi tre secoli, hanno causato parecchi decessi e seriamente indebolito l'economia locale. Vengono dapprima descritte le condizioni geologiche e geografiche che determinano la naturale predisposizione delle Indie Francesi Occidentali a pericolosità di tipo sia endogeno che esogeno. Viene poi considerato il rischio per la popolazione, sia in termini di effetti diretti dei fenomeni sopra citati, che i termini di effetti marginali dovuti allo sviluppo di maremoti, alluvioni e frane. Infine viene considerato l'impatto sul tessuto sociale ed economico dei disastri di origine naturale nelle Indie Francesi Occidentali e le difficoltà che insorgono nella mitigazione del rischio.

Termini chiave: pericolosità naturali, mitigazione del rischio, Indie Francesi Occidentali.

1. INTRODUCTION

The French West Indies have a long experience of natural disasters. In effect, the natural context means that their island territories are exposed to many of the most dangerous natural risks such as hurricanes, volcanic eruptions and earthquakes. Over the last three centuries natural disasters have caused the death of several tens of thousands of people and the cost to the economy has been considerable; this has weakened the societies affected and retarded their development. Almost all of the oldest human establishments have been affected by one or more of these risks in the course of their history. In spite of this, little effort has been made to limit the consequences of these disasters and those which have been made have often been shown to be insufficient or inadequate.

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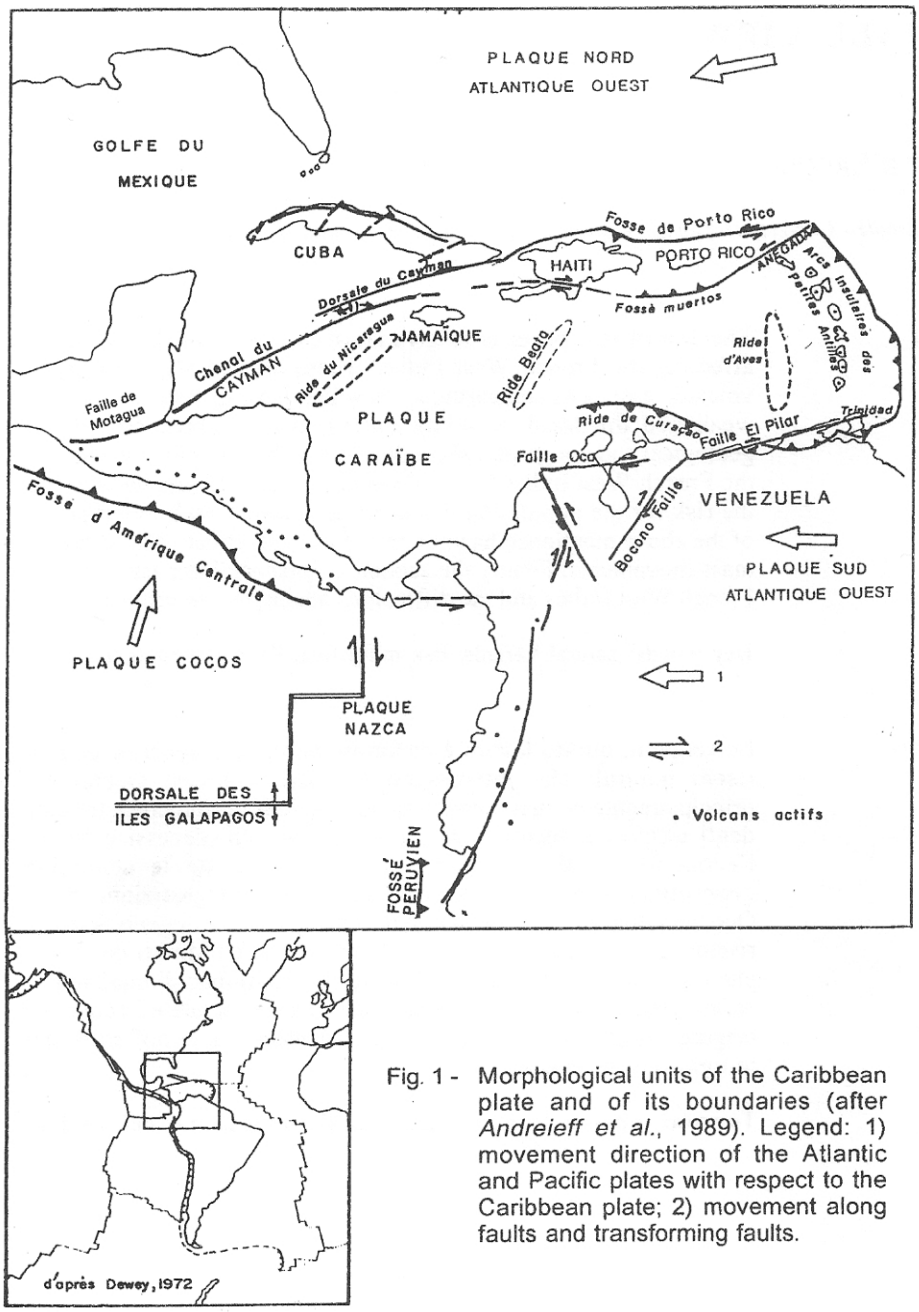

Fig. 1 - Morphological units of the Caribbean plate and of its boundaries (after *Andreieff et al.*, 1989). Legend: 1) movement direction of the Atlantic and Pacific plates with respect to the Caribbean plate; 2) movement along faults and transforming faults.

2. NATURAL PREDISPOSITION OF THE FRENCH WEST INDIES TO GEOPHYSICAL AND ATMOSPHERIC HAZARDS

2.1 Earthquakes and volcanic risks

The French West Indies are in a particularly unstable zone of the earth's crust arising from the clash of tectonic plates. With the exception of Cuba the islands of the French West Indies are part of the Caribbean plate wedged between the West Atlantic plate and the Cocos plate of the East Pacific (Figs. 1 and 2) The boundaries of this plate are complex and even now we have relatively little detailed knowledge of them. The limits comprise two subduction zones, these being occidental (the Cocos Plate subduction under Central America) and oriental (the

West Atlantic subduction under the Caribbean area, from Tobago to the Anegada passage to the south of the Virgin Islands, at the east of the insular arc of the Lesser Antilles). It has long been suggested that the northern and southern limits (from the Greater Antilles to Guatemala and from Colombia to Venezuela respectively) are zones which form a single system of transforming faults, but which have proved to be much more complex in detail.

The movement of tectonic plates is the cause of the earthquakes and volcanic activity in the French West Indies. Earthquake activity is considerable over all at the periphery of the Caribbean plate (Fig. 3), while volcanic activity particularly affects the subduction zones.

The seismic foci of the Greater Antilles is localised throughout the length of the fosses and faults occurring between the Motague fault, which cuts Guatemala in two, and the Anegada fault, which is the junction between the Greater Antilles and the northern extremity of the insular arc of the Lesser Antilles. In this arc the foci are localised down to a depth of 200 km in the Benioff zone, the plane of obliquity of which is near 60° under the arc of the Antilles. A distinction should be drawn between superficial intracrustal earthquakes and those associated with subduction (Fig. 4). The foci of the latter may be superficial (less than 40 km in depth) and are located east of the arc along the fosse of the Lesser Antilles. The foci are deeper and deeper from east to west and occur progressively to the perpendicular of the volcanic islands. They give rise to the most violent and destructive earthquakes. The probability of such earthquakes occurring is relatively small as compared with those which characterise other subduction zones (in particular the West Caribbean subduction zone which affects Central America or that which stretches along Andean America). Furthermore, the southern end of the arc is less active than its northern end. The relative overall infrequency of this type of phenomenon (statistically, it appears that everyone in the region will experience a major earthquake at least once in his lifetime), together with its particularly destructive nature, makes it a great potential danger to the French West Indies.

The East Caribbean subduction also engenders intense volcanic activity. The volcanoes in the Lesser Antilles are fed by magmas of high viscosity (in large part andesitic volcanic activity). They can therefore give rise to very explosive eruptions. The eruptions of the Soufrière in Saint Vincent and the Montagne Pelée in Martinique in 1902 are particularly significant. Not all the eruptions are explosive, however, particularly when the gas content of the magma is insufficient; this was the case, for example, in the 1971 eruption of the Soufrière of Saint Vincent, which was of a largely effusive nature (creating a dome of andesitic basalt). Nevertheless, the volcanoes in the French West Indies are particularly dangerous, above all when we remember that the eruption of the Montagne Pelée in May 1902, which cost 29.000 lives, was judged by the experts as being of moderate or even modest size as compared with others which had affected the insular arcs (Krakatoa in 1883, Katmai in 1912 or even Bezimiannyi in 1956). But the Montagne Pelée also experienced cataclysmic eruptions more than 20.000 years ago, one being the same type as that of Mount Saint Helens in 1980. The probability that such events will recur in centuries to come is very low but not entirely non-existent.

In addition to the Montagne Pelée, the Soufrière of Saint Vincent and the Soufrière of Guadeloupe constitute a permanent threat (Fig. 5). It is always possible that they could be reactivated (especially the Mont Misery at St-Kitts, which is very close to the Saint Vincent Soufrière and the

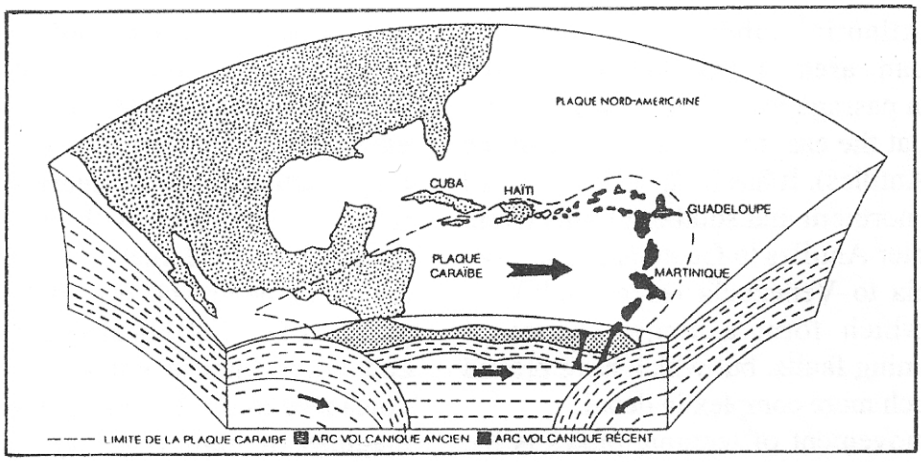

Fig. 2 - Boundaries of the Caribbean plate (after BRGM).

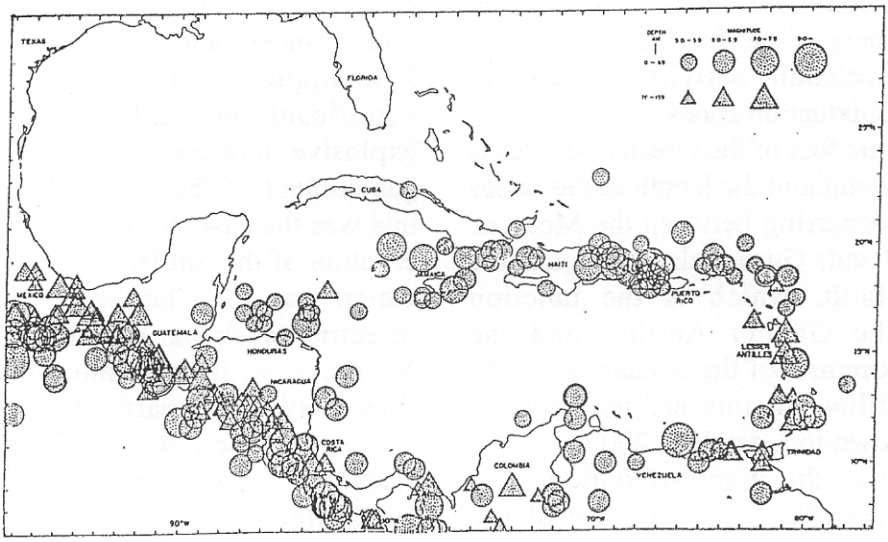

Fig. 3 - Epicentre of the earthquakes registered in the Caribbean area between 1898 and 1952 (Richter magnitude≥ 5,0) (after *Tomblin*, 1992).

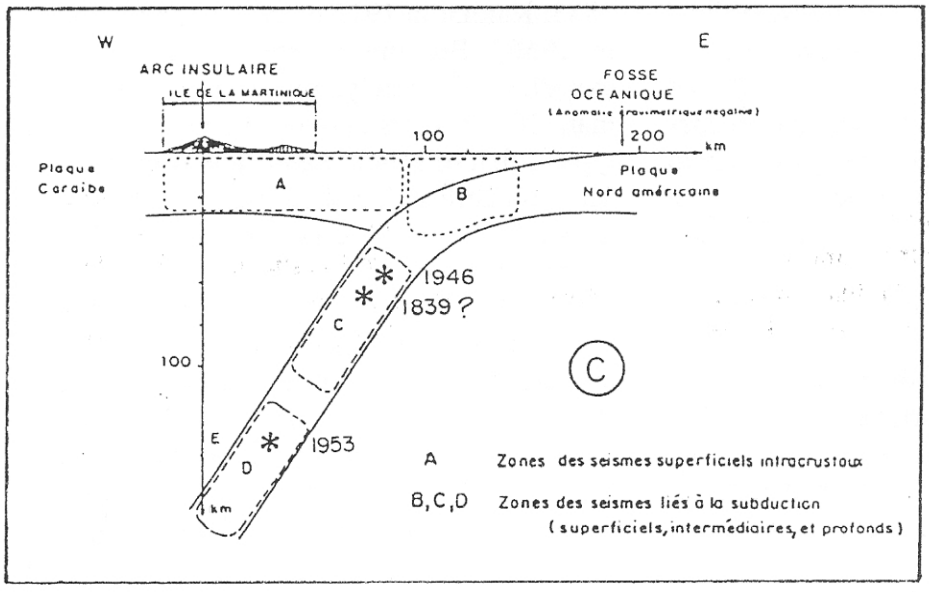

Fig. 4 - Vertical E-W profile of the subduction of the eastern Caribbean area at the latitude of Martinique (after BRGM).

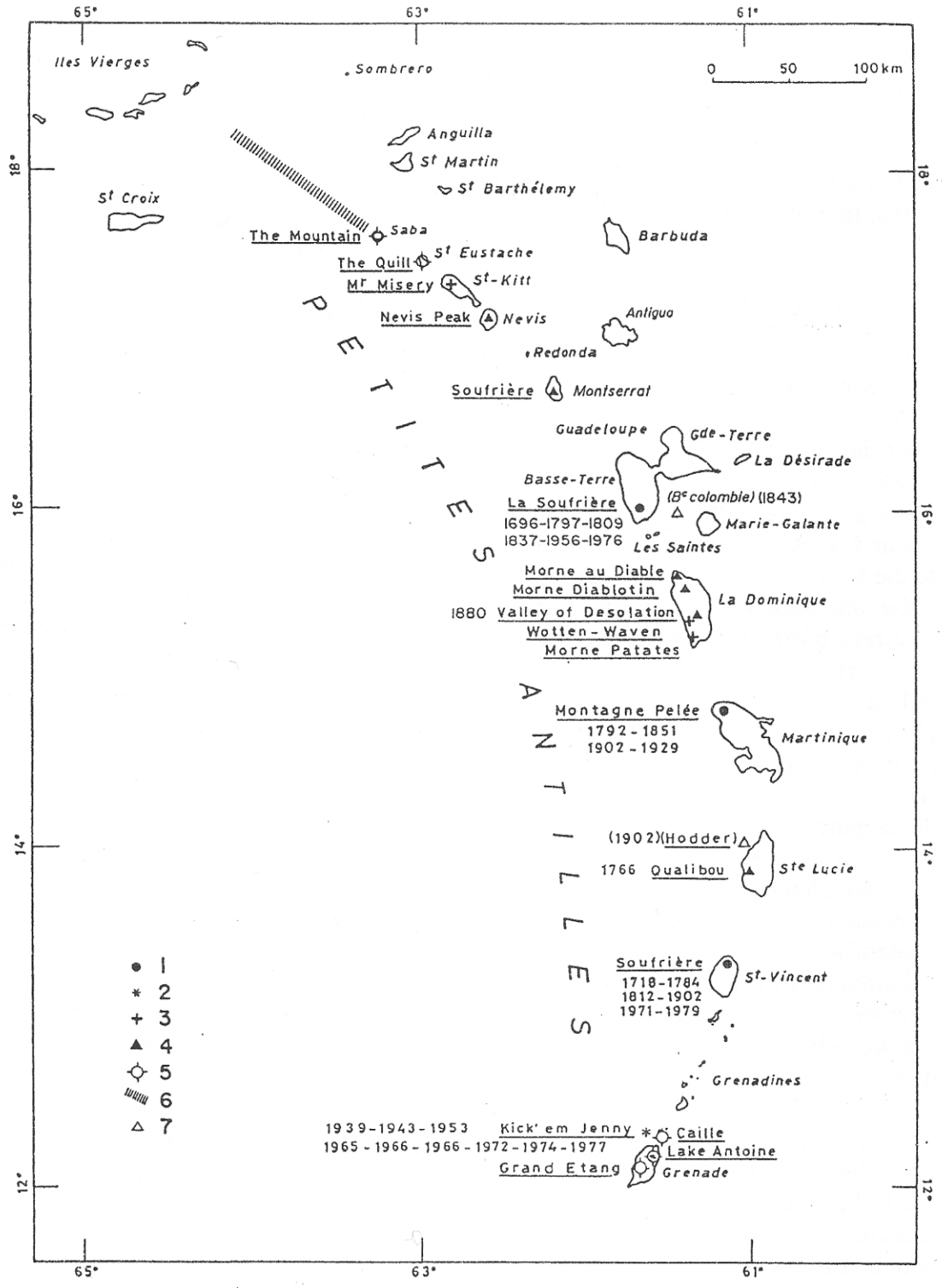

Fig. 5 - Localisation of the active and recent volcanoes of the Lesser Antilles (after BRGM: notes accompanying the geological map of the volcanic massif of the Soufrière, Guadeloupe; scale 1:20.000). Legend: 1) active volcano with dates of historic eruptions; 2) active sub-marine volcano with dates of historic eruptions; 3) volcano without known eruptions whose re-activation is expected to occur; 4) volcano with continuous slow magmatic activity or extinct, but subject to explosive activity of phreatic origin; 5) recently extinct volcano; 6) northern sub-marine segment of the internal volcanic arc extinct for three millions years; 7) site where a possible sub-marine eruption has been indicated (date in brackets), but where no volcano actually exists.

volcanoes in the south of the Dominican Republic) and the submarine volcano Kick'em Jenny, to the north of Grenada, should not be long in emerging. Since its last eruptions in 1977 and 1988 are only 150 m from the surface!

2.2 Cyclone risks

Hurricanes (or tropical cyclones) are very deep atmospheric depressions accompanied by violent winds, torrential rain and, whilst over the sea and before reaching land, by swells and hurricane waves. These phenomena are particularly destructive to life and property. Because of their situation to the west of the Atlantic the French West Indies are frequently affected by hurricanes. In effect, during the winter season (July to October) disturbances of African or East Atlantic origin move from east to west above the ocean, at the same time reinforcing the unstable base of the trade winds (Fig. 6). At this time the development of disturbances is provoked by a warm oceanic surface and a very disturbed climate over West Africa. The risk of cyclones is at its greatest in August and September.

Fortunately the hurricanes which develop over the Atlantic do not necessarily cross the arc. They may keep to an exclusively maritime course if their trajectory is inflected early. Furthermore, the disturbances which occur at some distance from the African coast do not necessarily reach the force of a hurricane close to the islands, or they give rise to hurricanes which are relatively weaker. The most powerful hurricanes, the trajectories of which are not deviated, do cross the Lesser Antilles (Fig. 7). Thereafter, they either travel north, affecting the Greater West Indies and the North American continent or they cross the Caribbean sea to reach the Central American Isthmus and the Gulf of Mexico. The South Caribbean, on the whole, is less frequently affected (Fig. 9).

Some hurricanes even start in the Caribbean sea, which is particularly warm during the winter season. They travel north and only affect the Greater Antilles, the Bahamas and the American continent.

As compared with other parts of the world, such as the Indian Ocean and the North-West Pacific, the probability of a hurricane's occurring is lower than in the Atlantic space. Nevertheless, 120 or more cyclones have crossed the Eastern Caribbean since 1871, i.e. an average of one a year. In some years several have struck, for example in 1963 (Edith, Flora, Helena). Moreover, if the frequency seems to have diminished slightly since 1960, the hurricanes in recent decades have been particularly devastating (among them David, Frederic, Allen, Gilbert, Hugo). Finally, the most powerful hurricanes such as the super-typhoons of the Pacific, with winds reaching more than 230 km/h (and 120 km/h is already regarded as hurricane strength), pass through the French West Indies as frequently as through other, more cyclogenetic regions, such as the North-West Pacific, i.e. about once a century.

2.3 Inferred risks

Disaster risks in the French West Indies are not only connected with the direct effects of geophysical or violent atmospheric phenomena, but also with their side-effects (tidal waves, floods, mass movements etc.). The extension of the coasts, the often-mountainous reliefs and poorly consolidated land are some of the conditions which favour their development.

Phreatic or phreatomagmatic eruptions may involve the formation of lahars along the gorges leading from volcanoes. These mudflows and block flows pour into the sea and could be the cause of small tidal waves. This was the case in Martinique along the Roxelane (lahars) and at Saint-Pierre (tidal

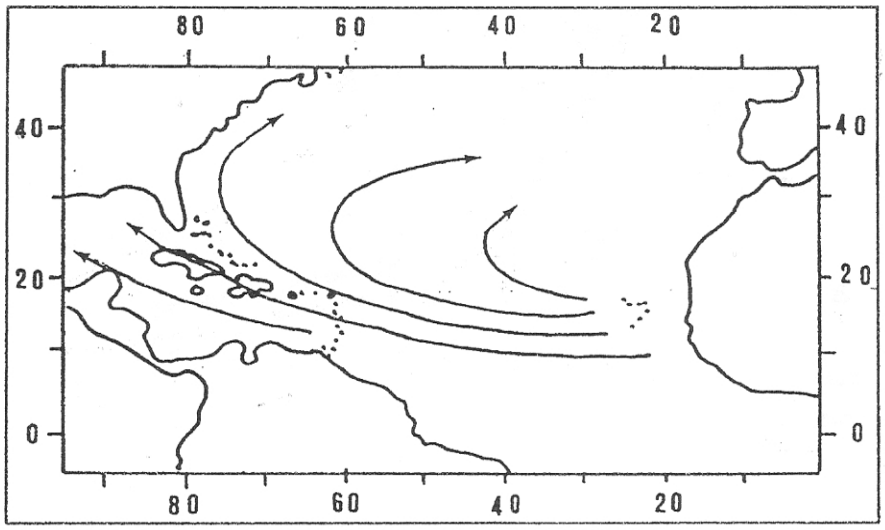

Fig. 6 - Average trajectories of storms and hurricanes in the north Atlantic and in the Caribbean area (after *Pagney*, 1992).

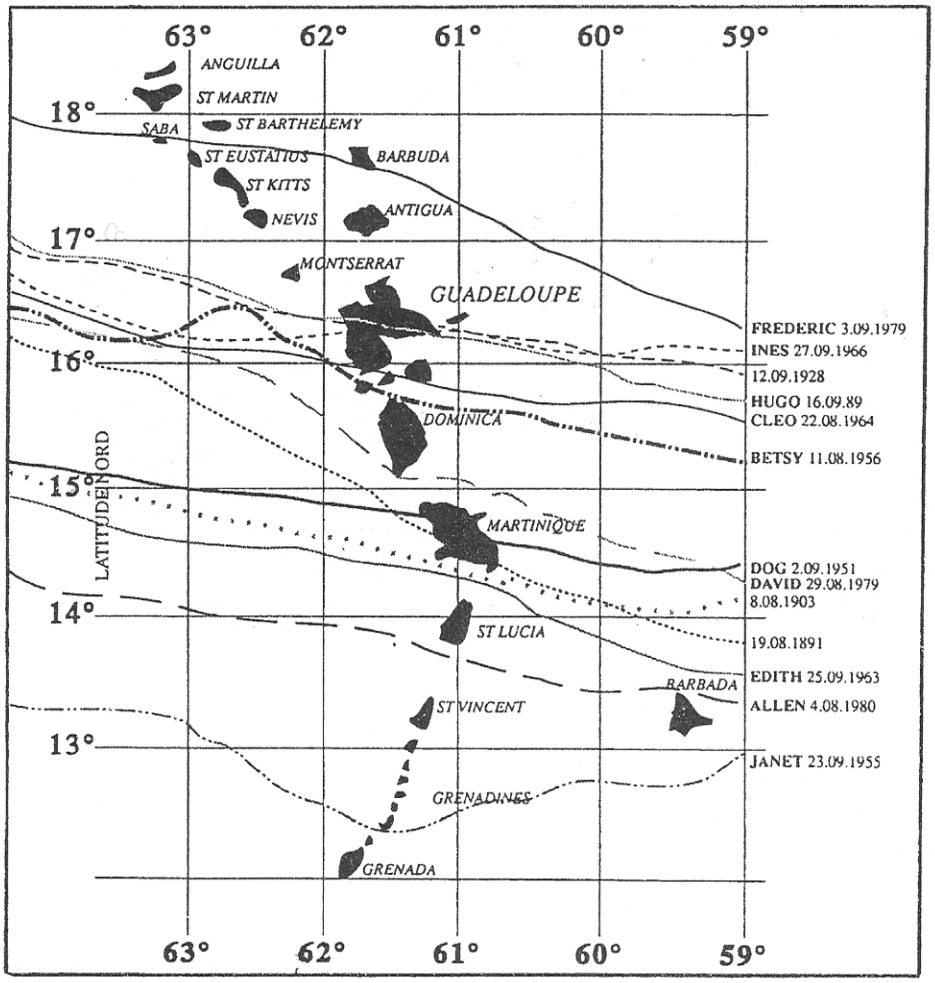

Fig. 7 - Cyclone trajectory in the Lesser Antilles (1891-1989) (after *Services Météorologique Interrégional Antilles-Guyane de la Martinique*, 1992).

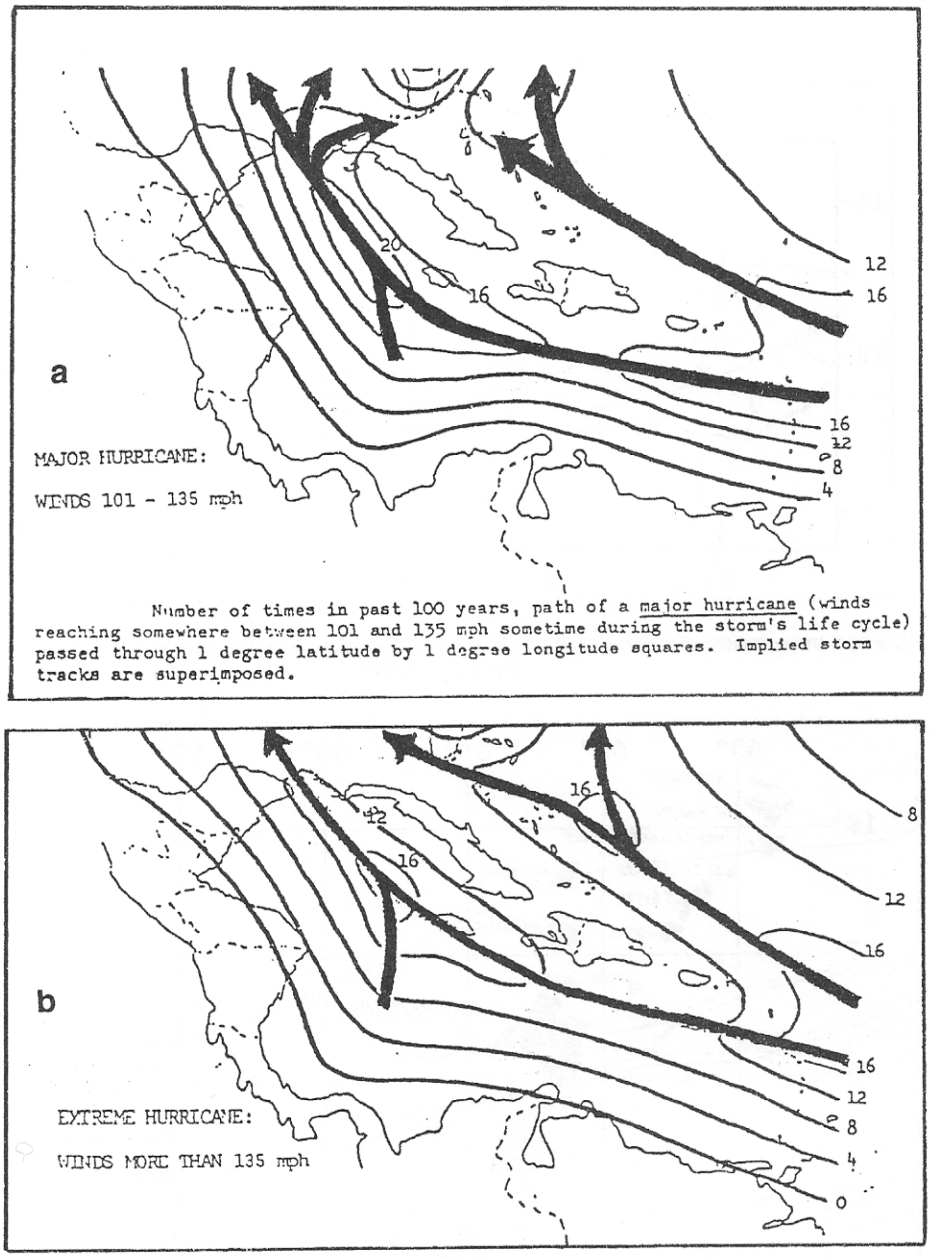

Fig. 8 - Hurricane damage frequency in the Caribbean over a period of one hundred years (after *Friedman*, 1973 in *Tomblin*, 1992; modified); a) winds 101-135 mph; b) winds > 135 mph.

wave) a few days before the fatal eruption of 1902.

Stronger tidal waves are sometimes caused by submarine volcanic eruptions or by earthquakes (for example, the earthquakes in Jamaica in 1692 and Puerto Rico in 1918).

Earthquakes may also be the cause of particularly formidable liquefaction phenomena. Sandy or limestone soils, loose and humid, liquefy and will no longer bear the weight of construction. Sometimes they pile up as a result of a flushing phenomenon. Many islands in the West Indies experience these phenomena, in particular on beaches, river banks and sectors formerly given over to mangroves, which have now been replanted and which have become more and more urbanised. This phenomenon occurred at Port Royal in

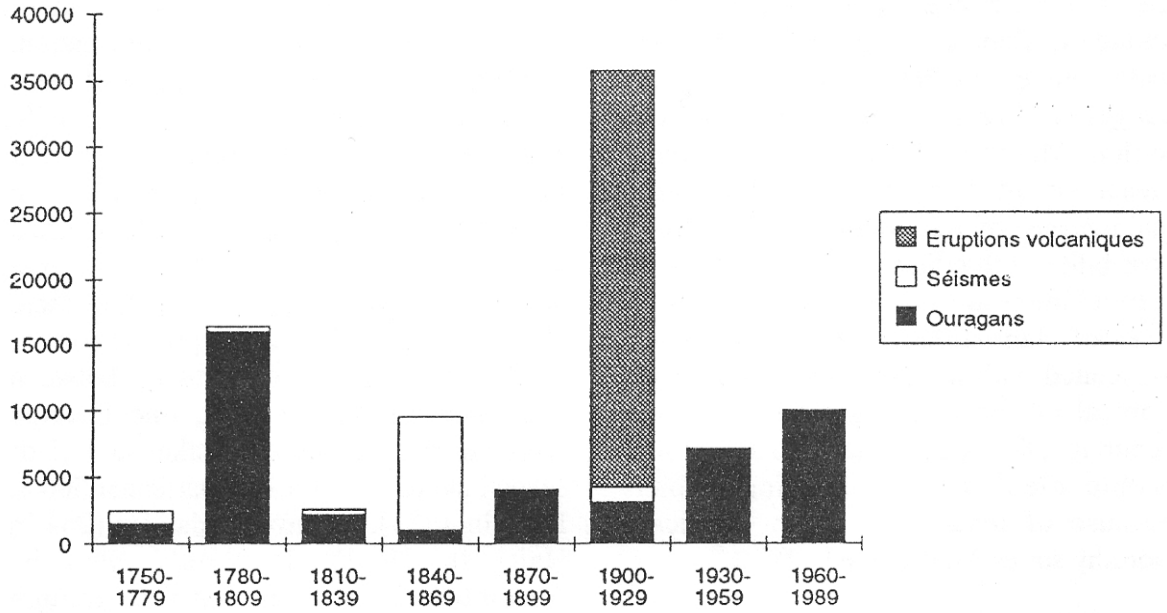

Fig. 9 - Evolution of the number of casualties due to natural disasters in the Antilles since 1750 (subdivision of casualties with respect to the type of disaster) (after *Tomblin*, 1992; *Collymore et al.*, 1993).

Jamaica in 1692. In Martinique a large part of the Lamentin plain and several sectors of Fort-de-France (such as the Terres Sainville quarter) could also experience it if there is a major earthquake.

Mass movements (landslides, rockfalls etc.) could also accompany an earthquake because of the mountainous relief on many islands and because of unreasonable human occupation in these high-risk areas. The East Jamaican earthquake of 13 January 1993 gave rise to sizeable landslides, though it was a relatively modest 5,3 on the Richter scale (VII being the maximum intensity).

Extremely violent and destructive winds are not the only feature of tropical cyclones; there are also cyclonic swells and storm waves which threaten the whole coastal installation (and the coasts are the most densely populated areas of the French West Indies). In 1989 the rise in sea level because of storm tides was of the order of 3,2 m in the north of Grande-Terre in Guadeloupe when Hurricane Hugo passed. On the south-east coast of St-Lucie cyclone Allen (1980) provoked a storm tide the *surcôte* of which was estimated at 4,5 m. In extreme cases this could be more than 7 m.

Tropical cyclones also give rise to an increase in rainfall, large or small, depending on the case, but always above average. In regions crossed by the eye of the hurricane there are often more than 100 mm of rain in 24 hours and it can even be as high as several hundreds mm, particularly in mountainous regions on slopes exposed to the weather. In August 1979, 350 mm of rain fell in 24 hours on the east slope of the Montagne Pelée when Cyclone David passed. With Dorothy in August 1970 700 mm was recorded locally in a single day on the eastern bluffs in Martinique.

The strong rains give rise to serious flooding when there are tropical waves or heavy local storms, which become formidable in a tropical storm period (in 1993 the tropical storm Cindy caused considerable damage in Martinique, particularly in the mountainous northern area). They are often disastrous when a cyclone passes. The mountainous zones are

most frequently subject to flooding because the slopes are steep and rainfall is more abundant than on the plains, but the watercourses on the plain are also very dangerous, particularly at the mountain outlet. Moreover, the frequent under-measurement and the very inadequate maintenance of watercourses increases the possibility of flooding.

In addition to flooding there is also the risk of landslides, which are often associated with the passage of storms and tropical cyclones, though they may also occur in other circumstances. Forty four people died or were missing, mostly because of landslides, when Hurricane Dorothy struck Martinique in 1970.

3. The economic and social impact of natural disasters on the French West Indies

3.1 Direct consequences

The French West Indies have paid a heavy price for natural disasters over recent centuries. The tables showing the main earthquakes, volcanic eruptions and cyclones (Tabs. 1 to 3 and Fig. 9). Figure 9 and Tables 1 to 3, showing the most significant earthquakes, volcanic eruptions and cyclones speak for themselves. The worst disasters of each type recorded have caused several thousand deaths (29.000 people died in the eruption of the Montagne Pelée in May 1902, 15.600 died in the hurricane of 1780 and 5.500 in the earthquake of 1842) and the material and economic loss is in the region of several billion dollars at today's evaluation.

The list of major historical events in the West Indies indicate that hurricanes are responsible for some 44.000 deaths, volcanic eruptions for almost 32.000 and earthquakes more than 15.000.

In addition to these figures, we must add the several thousand victims of less serious events which are not recorded and of those for which there is little or no information. This brings the numbers of victims of these three natural hazards to around 100.000. This figure would be much higher if it included all hazards, in particular the associated drought and famine which killed several thousand people in the seventeenth and eighteenth centuries (for example, there were 5.200 deaths in a population of 36.400 in Antigua and Barbados between 1883 and 1885). Flooding unconnected with hurricanes has also taken a toll of several hundred victims (in particular 500 in Haiti in 1983), as have landslides (264 in Haiti in 1954). It should also be remembered that epidemics, though different in nature, have also been disastrous. Cholera killed 40.000 in Jamaica in 1850-1851 and 20.000 in Barbados in 1854.

The loss of life is also accompanied by physical injury and psychological damage to those who have lost everything (the Haitians who survived the earthquake of 1842), to the homeless (80.000 in the Dominican Republic after Hurricane David in 1979) and to those evacuated (75.000 in Guadeloupe in 1976 when the Soufrière was reactivated). The material and economic loss was also considerable. Some quarters of Pointe-à-Pitre were totally demolished by the 1843 earthquake, 60% of the real estate in the Dominican Republic was destroyed or seriously damaged by Hurricane David in 1979 and the town of Saint-Pierre disappeared in 1902, to mention only a few of the more striking examples. Public building was also affected; 80% of Jamaican schools were unusable after Hurricane Gilbert in 1988 and the infrastructure (particularly roads, bridges and electricity) is always badly damaged after an earthquake or a hurricane. Agriculture, a key sector in the economy of most of the islands, has suffered

Tab. 1 - Main cyclone disasters which have affected the Antilles since the 18th century after *Tomblin*, 1992; *Collymore et al.*, 1993).

PRINCIPALES ILES CONCERNEES	NOM	DATE	NOMBRE DE VICTIMES	PERTES ECONOMIQUES (en millions de dollars)
JAMAIQUE		1722	400	
CUBA		1768	1000	
MARTINIQUE		1766	440	
ST-KITTS		1772	Plusieurs	
BARBADE MARTINIQUE EN MER (flotte espagnole) JAMAIQUE		1780	4326 9000 2000 300	
DOMINIQUE		1806	Beaucoup	
BARBADE		1831	2000	
DOMINIQUE		1834	200	
CUBA		1846	Quelques centaines	
ST-THOMAS		1867	Des centaines	
BARBADE		1888	Une centaine	
MARTINIQUE		1891	700	
ST-VINCENT		1898	300	
PORTO RICO		1899	3000	
JAMAIQUE		1903	207	
HAITI		1909	116	
JAMAIQUE		1912	142	
HAITI		1915	1600	
PORTO RICO		1918	116	
MONTSERRAT ANTIGUA ET BARBUDA		1924	45	
CUBA		1926	600	
PORTO RICO GUADELOUPE		1928	300 1200	
REPUBLIQUE DOMINICAINE		1930	2000	
CUBA		1932	2500	
HAITI		1935	2150	
JAMAIQUE		1951	104	56
BARBADE ST-VINCENT	JANET	1955	179	
BAHAMAS CUBA REPUBLIQUE DOMINICAINE HAITI JAMAIQUE TRINIDAD ET TOBAGO	FLORA	1963	7175	784
BAHAMAS CUBA REPUBLIQUE DOMINICAINE HAITI GUADELOUPE	INEZ	1966	593	129
MARTINIQUE	DOROTHY	1970	44	
DOMINIQUE REPUBLIQUE DOMINICAINE	DAVID	1979	1440	195
HAITI JAMAIQUE STE-LUCIE ST-VINCENT	ALLEN	1980	315	208
REPUBLIQUE DOMINICAINE HAITI JAMAIQUE	GILBERT	1988	453	1092
DOMINIQUE GUADELOUPE MONTSERRAT ST-KITTS	HUGO	1989	21	Au moins 1000

Tab. 2 - Main earthquake-induced disasters which have affected the Antilles since the 17th century (after *Tomblin*, 1992; *Collymore et al.*, 1993).

ILES CONCERNEES	DATE	OBSERVATIONS
REP. DOMINICAINE	1691	Ville d'Azua détruite
JAMAIQUE	1692	Environ 5000 morts dont 3000 de fièvre jaune. Les 3/4 des maisons de Fort-Royal (3000) détruites: effet des secousses et phénomène de liquefaction. La baie de St. Ann's a été affectée par un tsunami.
GUADELOUPE	1735	
HAITI	1751	Ville de Port-au-Prince détruite
REP. DOMINICAINE	1751	Toutes les maisons d'Azua détruites
HAITI	1770	250 morts. Port-au-Prince, Leogane, très affectés
ANTIGUA ET BARBUDA	1785	Séisme très violent, beaucoup de dégâts
CUBA	1788	Ville de Santiago détruite
MARTINIQUE	1839	Plus de 300 morts. Destruction quasi totale des habitations de Fort-de-France
REP.DOMINICAINE	1842	300 morts. Destruction de Santiago
HAITI	1842	5200 morts. Cap Haitien détruit
GUADELOUPE	1843	Plus de 3000 morts. Dégâts très importants à Pointe-à-Pitre, certains quartiers totalement rasés.
ANTIGUA ET BARBUDA	1843	Quelques dizaines de victimes. Dégâts très importants (toutes les maisons en pierre de Barbuda détruites, cathédrale St John très endommagée, etc.).
JAMAIQUE	1907	Un millier de morts sur les 48000 habitants de Kingston, plusieurs d'entre eux dans l'incendie qui a suivi le séisme. Environ 10000 sans-abris.
PORTO RICO	1918	Plus de 100 victimes. Tsunami ayant accompagné le séisme
REP. DOMINICAINE	1946	75 morts, 20000 sans-abris
ANTIGUA	1974	Pas de victimes, mais d'importants dégâts
JAMAIQUE	1993	1 mort. De nombreuses habitations, individuelles ou immeubles ont connu des dommages structuraux principalement à Kingston, St Andrew et St Thomas. Toits effondrés, murs fissurés.

Tab. 3a - Volcanic eruptions which caused several victims in the Antilles (after *Tomblin*, 1992; *Collymore et al.*, 1993).

ILES CONCERNEES	NOM DU VOLCAN	DATE	NOMBRE DE VICTIMES
SAINT-VINCENT	SOUFRIERE	1812	56
SAINT-VINCENT	SOUFRIERE	07/05/1902	1565
MARTINIQUE	MONTAGNE PELEE	08/05/1902	29000
MARTINIQUE	MONTAGNE PELEE	30/05/1902	1000

Tab. 3b - Other volcanic eruptions in the Antilles since the 18th century (no victims).

ILES CONCERNEES	NOM DU VOLCAN	DATE
SAINT-VINCENT	SOUFRIERE	1718
SAINTE-LUCIE	QUALIBOU	1766
SAINT-VINCENT	SOUFRIERE	1784
MARTINIQUE	MONTAGNE PELEE	1792
GUADELOUPE	SOUFRIERE	1797
SAINT-VINCENT	SOUFRIERE	1812
GUADELOUPE	SOUFRIERE	1837
MARTINIQUE	MONTAGNE PELEE	1851
DOMINIQUE	VALLEY OF DESOLATION	1880
MARTINIQUE	MONTAGNE PELEE	1929
GUADELOUPE	SOUFRIERE	1956
SAINT-VINCENT	SOUFRIERE	1971
GUADELOUPE	SOUFRIERE (1)	1976
GRENADE	KICK'EM JENNY (2)	1977
SAINT-VINCENT	SOUFRIERE (3)	1979

(1) 75000 évacués; (2) Volcan sous-marin, une dizaine d'éruptions au XXº siècle; (3) 22000 évacués

considerably after climatic disasters. The drought from 1945 to 1948 had a disastrous effect on the growing of sugar cane in Antigua; at St-Lucie in 1980 Hurricane Allen decimated 90% of the banana plantations (which corresponds to 80% of the agricultural exports); 100% of the banana sector and two-thirds of the cane sector were affected when Hurricane Hugo passed over Guadeloupe in 1989 and the Jamaican floods of June 1988 caused a loss of 25 million dollars in the agricultural sector.

3.2 The indirect consequences

Over and above these examples and figures, which present only a few facets of the direct consequences of natural disasters in the West Indies, there is the problem of the indirect consequences, in particular those connected with economic development. Like everywhere else in the world, natural disasters are a serious setback to the development of the regions concerned. This is particularly the case when the region is under-developed and there is little land. These conditions are frequent in the West Indies.

With regard to the degree of development, the West Indies are heterogeneous. The gross national product per head ranges from high to very high (more than 8.000 dollars for the British and American Virgin Isles or Martinique (1990 figures) and from low to very low (less than 2.000 dollars in St-Lucie, the Dominican Republic; St-Vincent, Jamaica and Cuba and less than 400 dollars in Haiti). The capacity to bear the shock of disasters is therefore very variable, but we must also take into account other factors, such as political status, which differs considerably; some of the islands are French, British, Dutch or American dependencies.

Provision for the consequences of natural disasters and the quality of the emergency and rehabilitation services can differ appreciably from case to case. The experience of St. Hugo is a clear demonstration of this. Restoration was faster here than in the independent islands because of the scope of the aid offered by their governors, even though most of them received aid from CARICOM (the Caribbean Community, the Common Market of the Anglophone West Indies).

The smallness of the land, characteristic of the islands and particularly of the Lesser Antilles, is another vulnerability factor, as the effect of natural disasters here is proportionally greater than elsewhere. In terms of frequency, these islands are no more subject to natural hazards than neighbouring continental territories. They may even be less subject to certain phenomena such as cyclones, which could bypass the islands without affecting them, while the continental coastlines are not spared. On the other hand, when the islands are struck by the full force of a hurricane or affected by some other hazard of considerable magnitude, a large part, or even the whole of the territory is affected and the economic and social cost of disasters is very soon considerable.

The number of the homeless and of houses destroyed is often very high - 25% of Jamaica's housing was destroyed or seriously damaged when Hurricane Gilbert passed in 1988; 30% was destroyed at St. Lucia (Allen, 1980); Hurricane David destroyed 60% of the housing in the Dominican Republic in 1979, and left 80.000 homeless, i.e. two-thirds of the island's population, and Hugo destroyed 90% of the housing in Montserrat in 1989. Evacuation can be very difficult to organise. In 1979 15% of the population of St. Vincent had to be evacuated when the Soufrière erupted. A fifth of the population was also evacuated in 1976 when the Guadeloupe Soufrière was reactivated. These huge evacuations are a very heavy

burden for the rest of the island community, particularly when there is no help from the governing country, as was the case in St. Vincent.

Very often the smallness of island territory entails very low economic diversification and it is not possible for one sector to ease the losses in another. Economies which are largely agriculturally based are thus extremely vulnerable. The impact of Hurricane David on the economy of the Dominican Republic, for example, was still being felt several years after the event. Agricultural exports collapsed in 1979 and by 1983 national revenue from agriculture and fishing was still lower than it had been in 1978.

Finally the cost of reconstruction is sometimes disproportionate as compared with island revenue. In 1980 the total damage to St. Lucie after Hurricane Allen amounted to almost 90% of its gross national product. Montserrat, with 12.000 inhabitants, was a particularly dramatic case. Losses due to Hugo were estimated at 240 million dollars (not counting the damage to the airport), while the island's gross national product is of the order of 50 million dollars!

The consequences of natural disasters may be heavy for all the West Indian islands, but they are even heavier when the territory is small and politically independent, because they are under-developed and the economy is not sufficiently diversified. Each disaster retards the development of the islands concerned, increases the economic and social differences between islands and in some cases increases the degree of economic dependence on other nations.

4. DIFFICULTIES ON MITIGATING RISKS

The West Indies have a total population of 35 million and each inhabitant can be said to be threatened directly or indirectly by several natural hazards. According to UNDRO, the whole of the West Indian population could be affected by hurricanes and earthquakes, while only 225.000 people are regarded as living with the permanent threat of volcanic activity (890.000 others being directly threatened. The risk to each inhabitant obviously varies, depending on the way in which he is physically exposed to it. Overall, however, it is clear that the risk increases daily, not only because of demographic development (the population has increased by 40% over the last twenty years) but also because of inappropriate practices.

4.1 Practices which neglect the risk factor

4.1.1 Landuser regulations either non-existent or ill-applied

Demographic pressure is expressed in the increasing occupation of marginal land and by landuse which is unreasonable in the face of the potential risks. This problem is illustrated by the development of many West Indian towns on the sea front, on reclaimed land, which is exposed to hurricane waves, tidal waves and liquefaction phenomena. The last two have accompanied the most extensive earthquakes ever experienced in Jamaica (at Port Royal in 1692, at Kingston in 1907, which were also accompanied by a tidal wave). These events have claimed several thousands victims in the past, but what would happen today when the population is much larger and settled on land which is even more exposed? Kingston is a good example of recent urban development on reclaimed land at the sea front, but there are many others: Port-of-Spain, Bridgetown (Barbados), Kingstown (St. Vincent), Pointe-à-Pitre (Guadeloupe), St. John (Antigua) etc.

The problem is the same on the plains

which can be flooded, on unconsolidated land and on land which slopes too much in regions exposed to volcanic activity. The latter are a more localised threat, but they are far from negligible. If the present-day Saint-Pierre (population 5.000) has little in common with the pre-1902 Saint-Pierre, other West Indian towns have grown appreciably at the foot of dangerous volcanoes (this is particularly true of Basse-Terre, in Guadeloupe, of Roseau in the Dominican Republic and of Plymouth in Montserrat).

This situation is the result of a *laisser-faire* policy, of weakness and deficiencies in the various local authorities with regard to landuse, particularly in the light of reducing the consequences of natural disasters. In some cases, such as the French West Indies, regulations exist but they are not often applied.

4.1.2 Cultivation which is inappropriate to the environment

This is the case in Jamaica, for example, where the Government's efforts to develop the cultivation of coffee have contributed to the decimation of the forest cover, with increasing soil erosion as a consequence. The increase in drought and flooding since the beginning of the 1980s is partly due to this activity. A similar situation is to be found in certain sectors of Barbados or at St. Lucie, where banana cultivation occupies more and more of the island's marginal sectors.

4.1.3 Vulnerable buildings

Building styles and building materials used have a significant effect on vulnerability to earthquakes and hurricanes. The increasingly generalised use of masonry instead of the traditional wood has involved the construction of larger houses and higher buildings. These are perhaps more resistant to cyclones (except for the roofs, which are always a weak point) but they are more vulnerable to earthquakes. The antiseismic building standards, if any, are rarely applied. Very often buildings are erected without consulting an architect, even in islands where the socio-economic level is higher overall.

4.1.4 Deficiencies in crisis management systems

The most recent disasters, in particular that of Hurricane Hugo, revealed the difficulties experienced by the Caribbean islands' local governments in crisis management. This was one of the main conclusions of the international colloquium on natural and technological hazards in the Caribbean, which was held at Fort-de-France in May 1990. Among the weaknesses revealed, there were the incapacity of many local executives to manage an exceptional situation, the lack of real local crisis cells, the difficulty in precisely defining what is needed immediately after the impact and the frequent ineffectiveness of the emergency measures established, because of lack of co-ordination - in a word, the almost total absence of preparation to face emergencies at local level (and sometimes throughout the territory).

4.2 Some explanations of this situation

There are several reasons for these deficiencies in prevention and management policies:

- economic and social reasons (insufficient funds to set up real prevention policies; competition with economic and social preoccupations which may seem more pressing; lack of public housing for poorer people who are often obliged to "squat" illegally on land which had previously been vacant because of the dangers they presented.

- economic reasons again, but this time it is a question of interest (pressure from certain landowners and promoters to prevent their land being classified as risk zones, or, as in the French West Indies, tax concessions on investment, particularly in the building industry, which speeds urban development but makes it difficult for local authorities to control it);
- politics (electoral - natural hazards are rarely a priority - or connected with the lack of agreement between elected representatives in areas where the communal boundaries have no place;
- technical and cultural (such as the difficulty in applying Western-style regulations, which often prove too complex or inappropriate to situations in the West Indies);
- frankly cultural (such as the great reluctance to dissociate the right of ownership from the right to build, demonstrated not only by the population but equally by some elected representatives who sometimes regard the town planning regulations as a luxury for the developed nations).

Over and above these reasons, which limit the effectiveness of any prevention and management policy, there is a further reason the scope of which is no less: the relatively weak perception of the risk and in particular of the danger of earthquakes, which are really the risks with the heaviest consequences in the years to come. Hurricanes are the hazard most likely to occur, as compared with earthquakes and volcanic eruptions. However, while the cost of cyclone disasters increases continually the number of lives lost has diminished appreciably over the last twenty years because of progress in monitoring hurricanes and in predicting their trajectory and speed, by means of radar and satellites. The people of the West Indies are aware of this and an investigation in Martinique indicates clearly that people now fear volcanic eruptions and earthquakes much more than hurricanes. However, even though most people regard these phenomena as particularly destructive, it is nevertheless true that volcanic eruptions are rare on the human scale, so the individual is not induced to take the necessary precautions and the elected representative does not advocate a prevention policy from which he can expect no advantage. This is a serious situation, particularly with regard to the earthquakes which every West Indian resident can expect to experience at least once in his lifetime.

All specialists agree that a major earthquake in the West Indies would be particularly catastrophic. According to the BRGM, a simulation of the major earthquake of 8 February 1843 (more than 3.000 dead at Pointe-à-Pitre) in the present context would result in a death toll of 100.000! Similarly UNDRO estimated in 1979 that the maximum losses in a large-scale event could be 20.000 for a hurricane, 70.000 for a volcanic eruption and 500.000 for an earthquake. This order differs from what we have been able to establish from the maximum number of victims of the known major disasters (Tab. 4). This supports the idea that the nature of the risk to the West Indies has increased and that the death toll of an earthquake is to be feared most, because of the increase in population, the occupation of dangerous land, inappropriate construction and the lack of preparation.

5. CONCLUSION

The foregoing brief analysis of natural hazards aims to demonstrate the double vulnerability of the West Indies to natural hazards. The physical vulnerability is very striking because numerous and varied hazards have occurred in the past and will recur in the future, whether they will be

Tab. 4 - Relationship between the number of casualties and the type of disaster.

	Cyclones	Eruptions volcaniques	Séismes
Total des victimes des principales catastrophes connues aux Antilles	44000 (1)	32000 (2)	15000 (3)
Nombre maximum de victimes connu pour un seul événement	15600 (2)	29000 (1)	5500 (3)
Nombre maximum de victimes prévu pour un seul événement (UNDRO, 1979)	20000 (3)	70000 (2)	500000 (1)

(1) - Numéro d'ordre

hurricanes, earthquakes, volcanic eruptions or other violent natural phenomena. The human vulnerability reaches disturbing proportions, particularly with regard to infrequent but very destructive risks, such as earthquakes. Overall, the West Indies are relatively unprepared for a disaster. However, efforts have been made for several years now to set up a major hazard culture in the Caribbean basin and to develop sound regional structures to deal with potential risks, both with regard to prevention and to crisis management and rehabilitation. The CDERA (Caribbean Disaster Emergency Response Agency) was founded in 1991 for this purpose. For the most part the structure comprises independent members of the Commonwealth but the effective participation of these countries is very varied. The other West Indian islands, whether independent or attached to a political governing country, have their own systems of crisis management. The French West Indies have the same structures as other French departments, the only difference being that the hazards are more frequent and varied and that the human context sometimes makes it difficult for these structures to operate effectively, as they were designed for the French mainland.

Generally speaking, it seems that the efforts made in recent years in some islands relate mainly to crisis management, sometimes to informing the public and to training managers, and much less to medium- or long-term preventive measures (rational management of land, application of building standards). However, the reduction of the consequences of a future disaster depend heavily upon these measures.

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