LANDSLIDES AND MUDFLOWS IN A YOUNG VOLCANIC HAWAIIAN TYPE STRUCTURE

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A. STRUCTURAL AND CLIMATIC CONDITIONS OF DEVELOPMENT

In the Mascarene group, the emerged part of Reunion Island was built since barely two million years from fluid basalt lava flows and ash layers emitted by two volcanoes whose structure and relief are very similar to the Hawaiian archipelago's youngest constructions.

Still active, younger Piton de la Fournaise (alt. exceeding 2300 m) raises on the southwestern part of older Piton des Neiges (alt. exceeding 3000 m). Both volcanoes give its almost rounded shape to the island whose area does not exceed 1000 square miles (2500 square km).

Striking erosion forms are mainly the result of the sharp topographic contrasts and of general directions suggested by faulting. (Fig. 1).

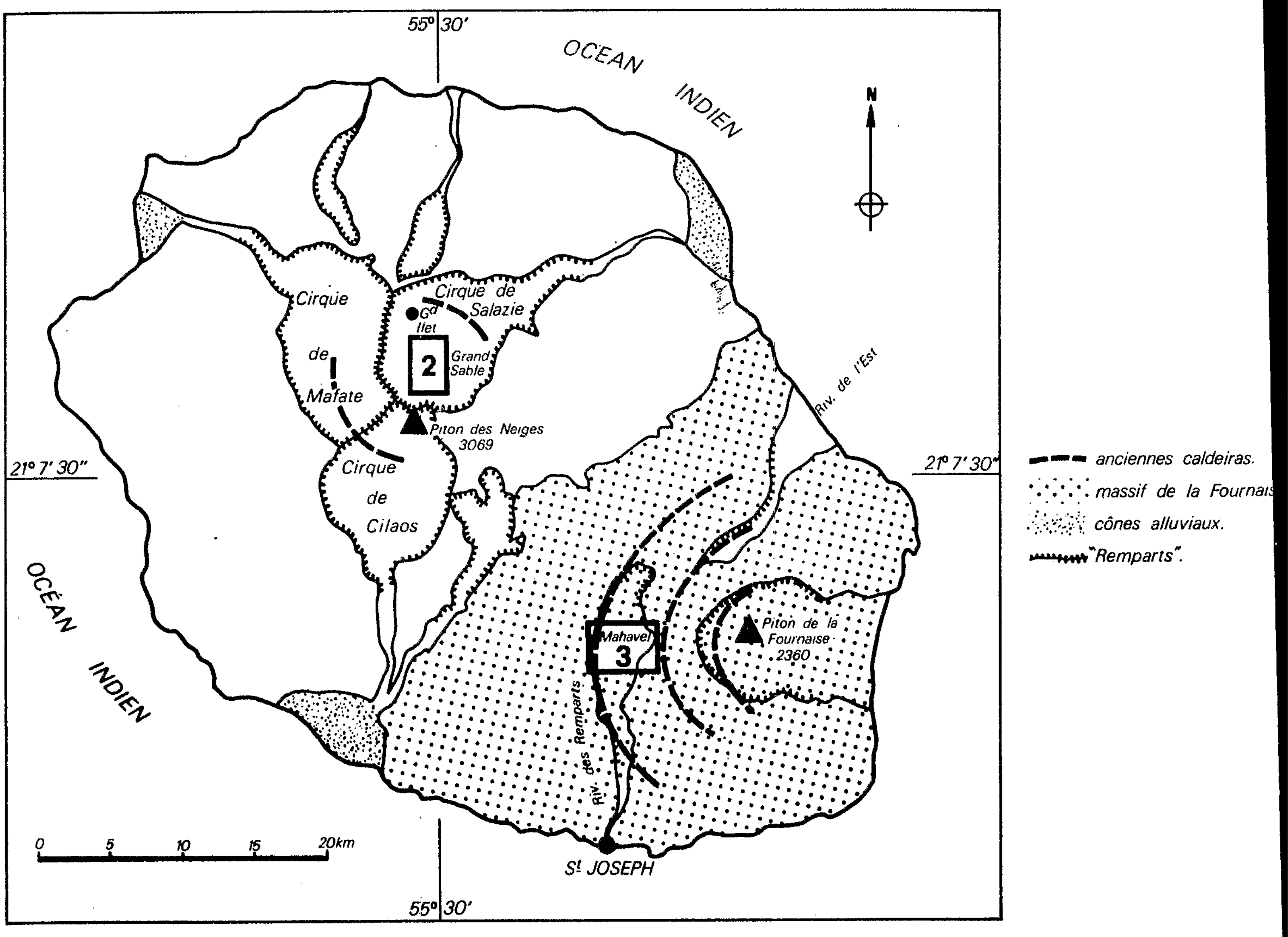

Fig. 1: LA RÉUNION — Structure générale et grandes formes de l érosion.

Three huge amphitheaters or cirques as they are locally known were hollowed out on the northeastern, northwestern and southwestern part of the Piton des Neiges since less than 20,000 years. Their bottom is partly filled up with detritic and clastic material issued from the impressive and steep slopes surrounding them. (Angular slopes up to 70 degrees--height between 500 and more than 1000 m). These slopes are known as Remparts (outer walls, ramparts). Parts of late lava flows poured down from the former summit of the volcanic construction are also present. Gullies and ravines (locally known as ravines) often delimit patches of flat land known as ilets (small islands), most of which were lately occupied at the beginning of the 19th Century by poor white colonists who could not afford buying slaves and expensive coastal land to cultivate sugar cane. Since then, hamlets and even small villages still exist on the ilets of the cirques and in the bottom of the main deep valleys of Piton de la Fournaise (Riviere de l'Est and Riviere des Remparts). Cirque de Salazie and cirque de Cilaos still retain the largest population in this kind of settlement, which nevertheless represent only a minority (a few thousand people) of a whole population (550,000 inhabitants) mainly living in coastal settlements. (Pl. 1-2). Favored by the topography and the structure, erosion is still exaggerated by heavy rains seasonally reinforced by torrential rainfall of hurricanes. Even the sheltered excavations of cirques record more than 3500 m/m per year (average) on windward and 2300 m/m on leeward. Intensity and importance of hurricane's rains may be striking: During the last very serious hurricane which hit the island in 1980, more than 5000 m/m of rainfall were recorded in several altitude locations. Grand Ilet station, (cirque de Salazie), at an altitude of 1110 m, recorded more than 5240 m/m during the same period, the record for 24 hours being 1742 m/m.

In spite of the general permeability of the structure, which accounts for the lack of run-off in most of the younger part of the island, the average flow of the main rivers may be multiplied by 400 or 500 during the ensuing floods. All these factors are highly favorable to the occurence of an extensive range of catastrophic soil movements which actually are one of the prominent features of the erosional processes in Reunion Island.

B. TYPES AND EXAMPLES OF LANDSLIDES

Depending on the nature of the material involved and on the size of the phenomenon, several types of movements are known, from the classical landslide started by the rotational slipping process into a deep clayey material, to the mudflow, through the rock avalanche.

It seems easier for our purpose to establish them into two main families: The superficial and narrowly localized landslides and the deep ones, involving large amounts of material. During or following periods of heavy rains, slopes stability may be locally broken by the weight of water percolated into a permeable layer, or the regression erosion of a spring suddenly reactivated. Superficial landslides so triggered on generally steep slopes pull down the soil and the vegetation with an increasing momentum and efficiency as the mass runs downwards. This case is very commonly met. (Pl. 3-4).

Important to huge landslides involving sometimes quasi instantly the movement of several ten million cubic meters of material are more impressive but fortunately not so frequent. Yet it is clear that a significant part of the amphitheaters and of the major valleys was formed from such events. Clastic material of slides often dammed the rivers, the dams being later broken by floods, then mudflows spreading the elements of former landslides downstream and sometimes down to the entrance of the gorge by which each cirque is open towards the coast. Numerous outliers of such sequences may be observed. The island has been settled since barely more than three centuries, but even during this short period of time, and most probably under a present climate less aggressive than under some past quaternary episodes, several hugh landslides have been observed. With population increase, this hazard has even proved to be a danger not only for economic activities but for man, too. The characteristics of three big landslides are summarized hereunder.

Grand Sable's landslide occurred on 11.25.1875 in the southwestern part of cirque de Salazie. Tiers, already depressed under the level of the top crest of Piton des Neiges fell, most probably because of the drawing off of downstream thermal springs. The landslide was channelled on a distance of two kilometers between altitudes 1800 and 900 M. by a small valley. It was stopped by a detritic hill which was partly destroyed (Piton de Grand Sable) and dammed temporarily another valley (Riviere des Fleurs Jaunes) from which its channel was a tributary. Material was about 40 to 50 meters thick and the volume was estimated, depending on authors, between 20 and more than 70 million cubic meters. Witnesses said that the flow took no more than 2 to 3 minutes to reach its final location. Boulders were thrown on the surface of an ilet more than 100 meters above the bottom of the valley des Fleurs Jaunes and earth shaking triggered a few minor landslides downstream. Sixty-two people were killed, buried with their houses (Fig. 2).

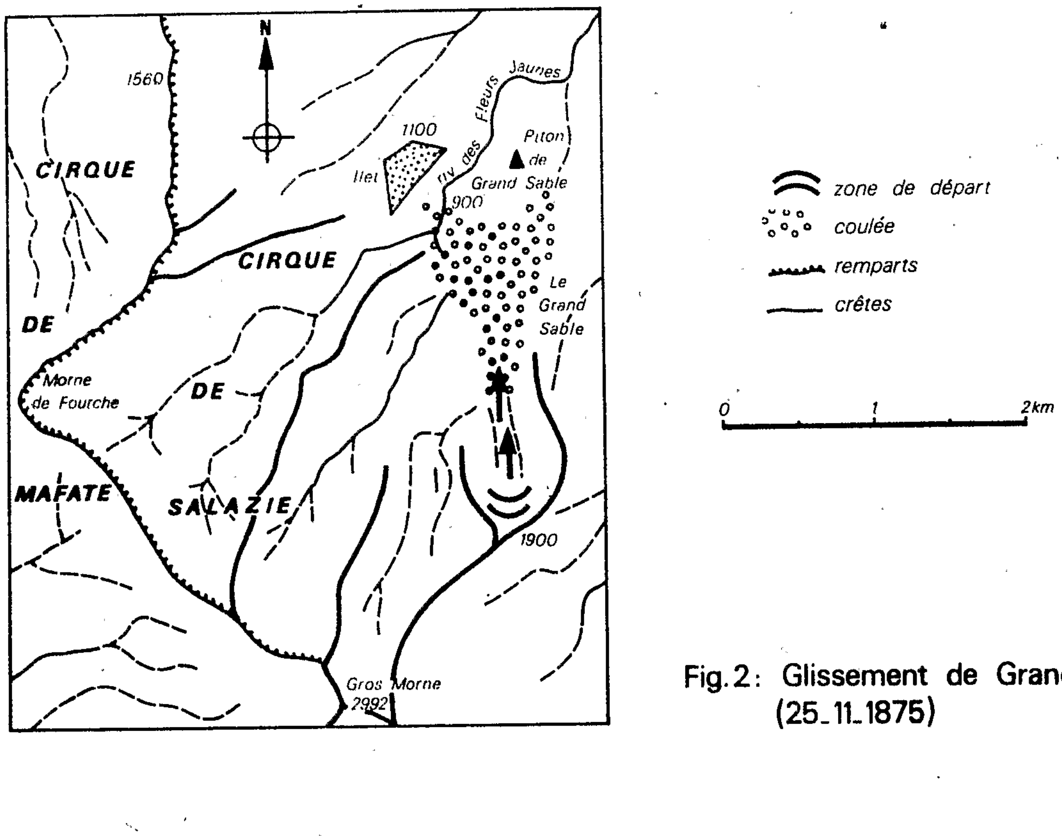

Fig. 2: Glissement de Grand Sable. (25.11.1875)

Bras de Mahavel's landslide took place on 05.06.1965, after a period of continuous rainfall in April, at the end of the rainy season. Material came from the edge of the catchment area of a tributary of the Riviere des Remparts. Structure and dip favored drawing off in an highly permeable surrounding of young volcanic material. Deep cracks were noticed later beyond the edge of the catchment zone.

The material of the landslide was heterogeneous, yet very wet ash, scoria and clay dominated and were mixed with blocks, often bigger than one cubic meter. The flow took also a very short time to went down on a distance of about 4 km from around 2000 - 23000 m. to less than 700 m. in the bottom of the Riviere des Remparts. Vegetation was destroyed up to more than 100 m. above the bottom of the Bras de Mahavel on the slopes near the junction with the main river. Here again, the tributary valley channelled the flow which dammed the main valley. The dam was 40 to 50 m. high, its width exceeding locally 500 m. The volume of the landslide was estimated between 20 and 50 million cubic meters. As there was no settlement in the junction zone of the two valleys but only ilets upstream and downstream in the Riviere des Remparts, there were no casualties. A channel was dug out in the upper part of the dam, which was closely watched to ensure the security of the little town of Saint-Joseph, built on the coast at the river's mouth. Yet underground run off proved to be so important that only a short lived lake was formed behind the dam (Fig. 3).

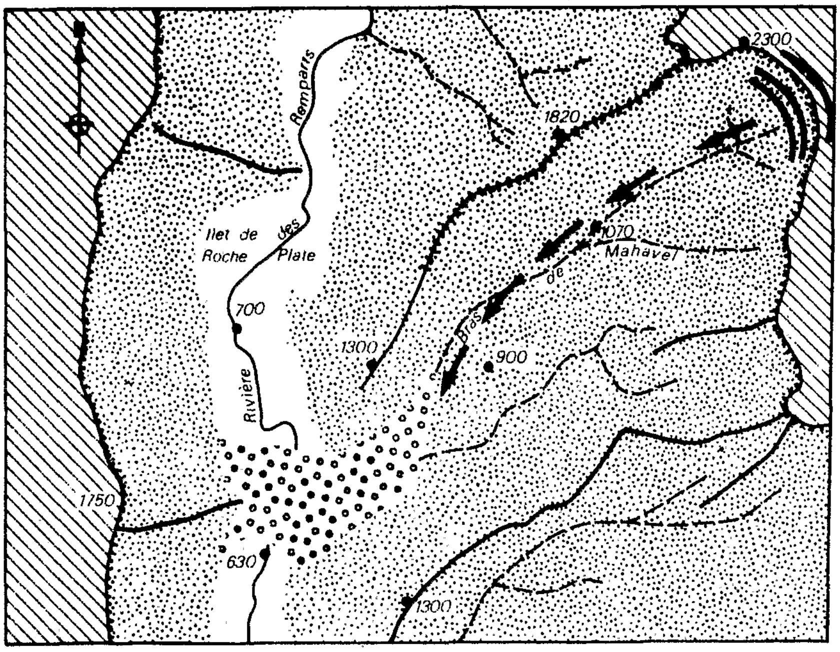

Fig. 3: Glissement du bras de Mahavel. (6-05-1965)

During the very serious hurricane Hyacinthe, which recently hit Reunion Island (01-15/29-1980) more than half of the 25 deaths were caused by landslides. Ten people were killed in the western part of cirque de Salazie, near Grand Ilet Village. A landslide, involving clastic material and channelled by a gully, moved on 1 km. between altitudes 850 and 650 m. High impregnation by heavy rains (exceeding 5000 m/m in 12 days) and the presence of an underground sill dipping downstream seem enough to explain the triggering. The landslide took place at the end of the rains brought by the hurricane (01.28. 1980) (Humbert, Pasquet, & Stieljes, 1981).

C. PREPAREDNESS AND MITIGATION

After hurricane Hyacinthe, the French Bureau de Recherches Geologiques et Minieres (BRGM), National Geological Service, prepared detailed maps of the different "Geological risks" for the two cirques of Salazie and Cilaos where landslide hazard is the most obvious for local populations.

Maps are at the scale of 1:25000 and show risk zones for each physiographic unit in the cirques:

- Remparts and their edge
- Main inlets
- Isolated prominent summits of the bottom or the rim of cirques
- Valley bottoms

For each subdivision of these units, where risks have been represented according to the geomorphological maps symbols are given in addition:

- An historical record of the striking known phenomenons
- The detailed list of geological risks (rockfalls, landslides, subsidences, earth falls, gullying)
- Recommendations and priorities for mitigation.

BRGM more generally recommends:

- To reinforce watching during heavy rain periods in settled zones identified as "high risk zones"
- To improve vegetation cover in all vulnerable zones, wherever possible
- To better adapt public equipment (roads, telephone, etc.) to what should be considered as a permanent risk, only aggravated during "climatic crises" (hurricanes).

Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) tries, in a paralled direction, to compute the balance of natural hazards in the French overseas Departements and Territories as a whole. This study will be partly done for the Pacific Territories, in cooperation with the regional project of East West Center (Pacific Islands Development Program) on natural hazards preparedness and mitigation in the South Pacific countries.

This research program involves integrated mapping of the zones of risk for different hazards, based on historical records, and including equipments, resources and productions indexes, and population location, for a better mitigation approach and consequently a better integration of hazards into regional planning.

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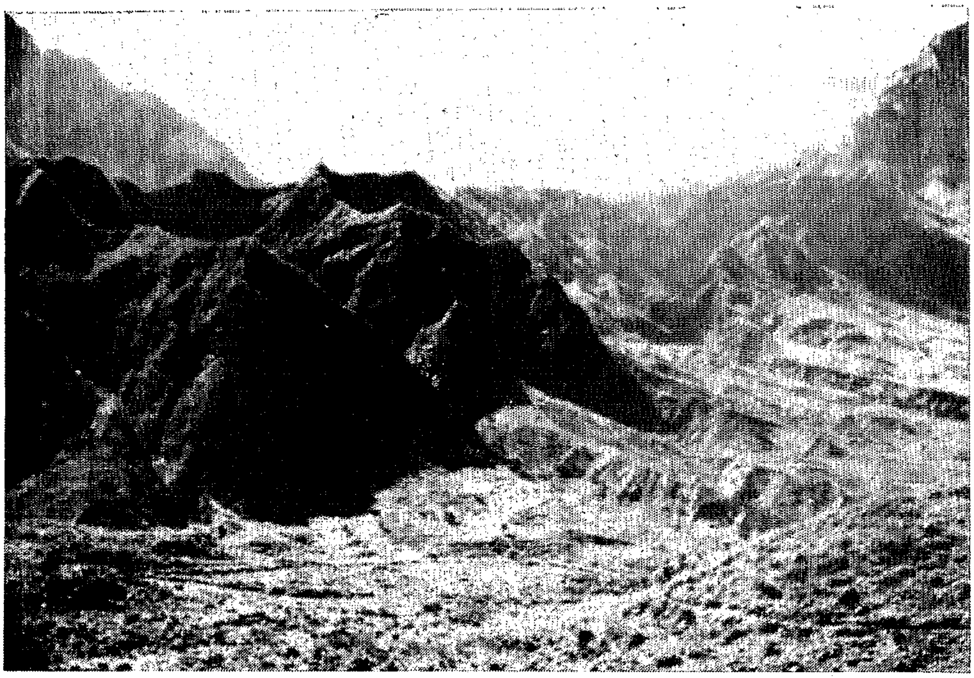
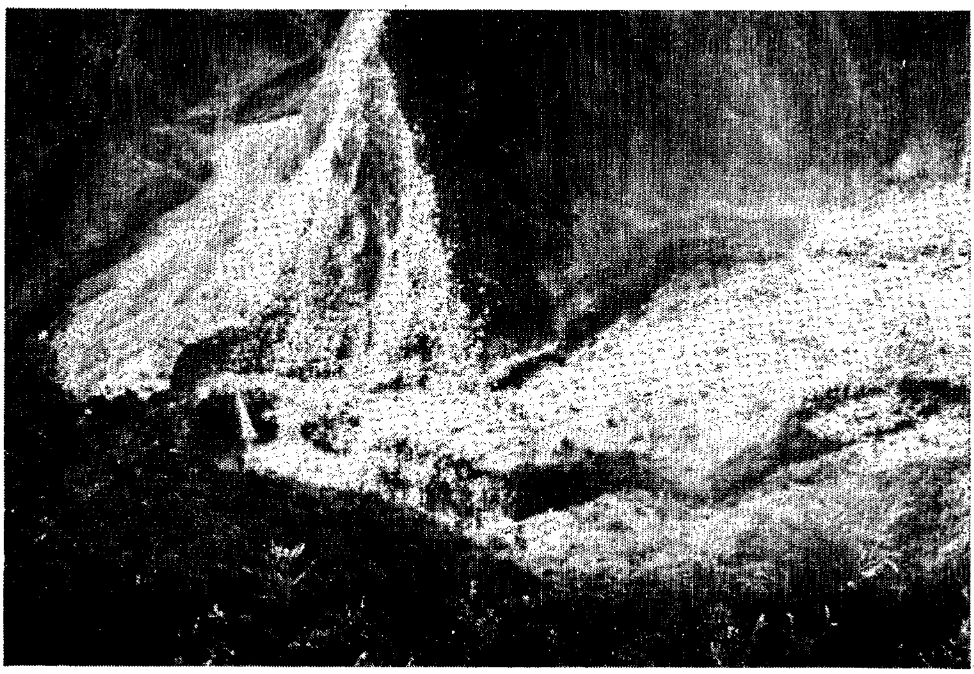
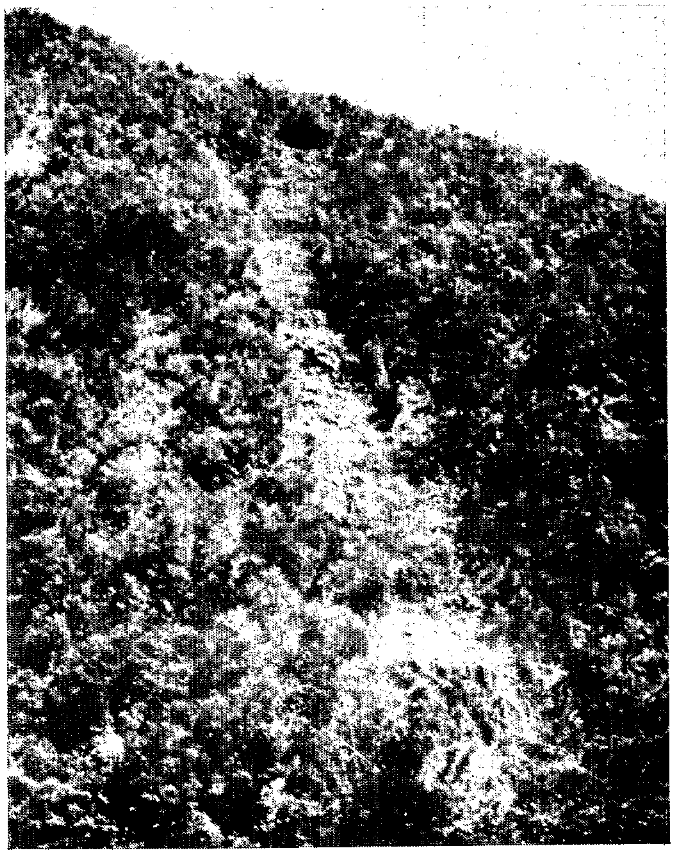
Humbert, M., Pasquet, R., & Stieljes, L. (1981) Les risques Geologiques dans les cirques de Salazie et de Cilaos. (Ile de la Reunion). GRGM, Rapport 81 Sng - 543 Reu. 97 p. + cartes.



1. Reunion Island : Type of landscape in the "cirques" (cirque de Mafate). Depressed tiers in front of surrounding "Remparts" and detritic filling of the bottom are deeply dissected.



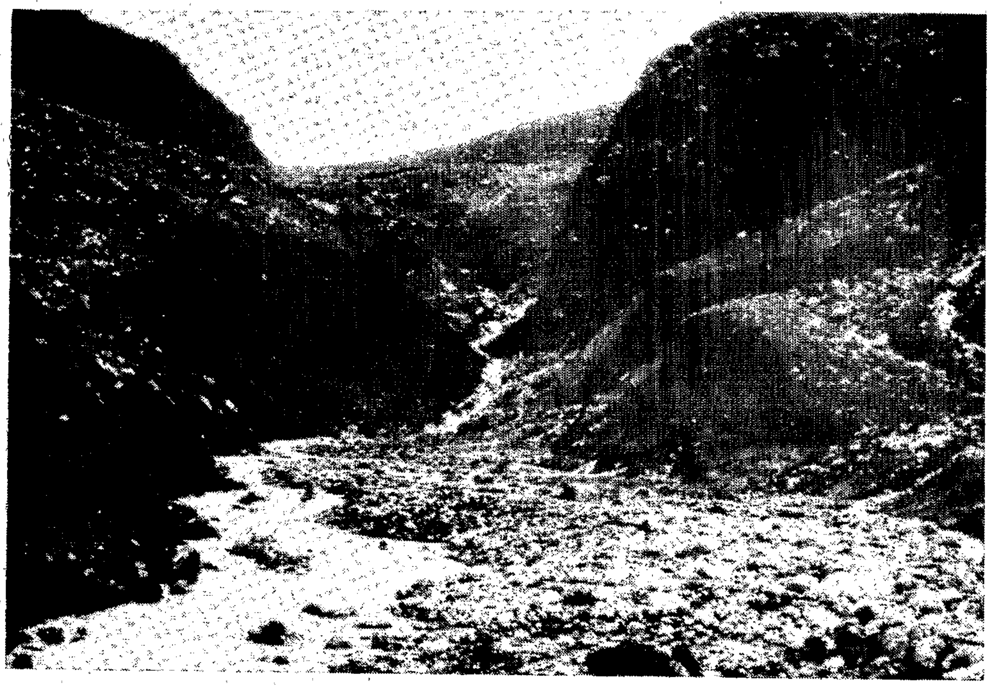
2. Reunion Island : Type of landscape in one of the main deep valleys. An "Ilet" and its settlement in the bottom.



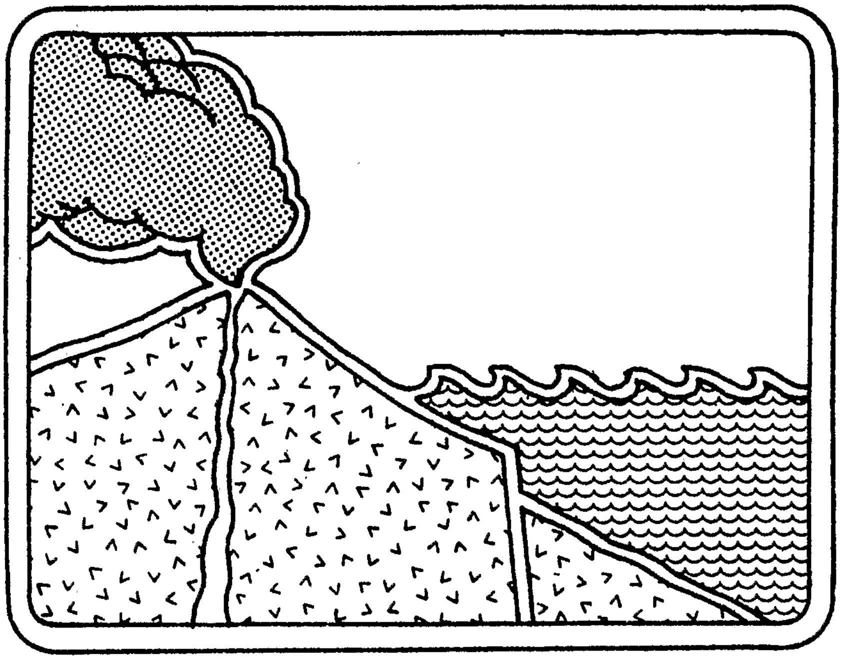
3. Réunion Island : Superficial landslide on a steep slope.

4. Reunion Island : Downstream part of the same landslide showing the vegetation pulled down.

5. Reunion Island : Huge deep landslide of the Bras de Mahavel (05.06.1965). General view, looking upstream, of the landslide which came from right hand and dammed the Riviere des Rempart's valley.



6. Reunion Island : Close view of the central part of the dam resulting from the Bras de Mahavel's landslide. Looking upstream.



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