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MORPHOLOGICAL INVESTIGATIONS OF THE SLIDING AREAS ALONG THE COAST OF PAYS D'AUGE, NEAR VILLERVILLE, NORMANDY, FRANCE

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ABSTRACT

A recent landslide on the Normandy coast at Villerville is investigated. Site investigation shows the complexity of the landslide morphology, comprising principally multiple rotational slides in Kimmeridge marls. The triggering mechanism for the major slide which occurred in December 1981 was thought to have been a severe ground frost causing a build-up of pore pressures. However, this paper casts doubts on that as the possible cause and emphasizes the need for further instrumentation of the site.

INTRODUCTION

Along the coast of Normandy, for at least two or three centuries, two areas have been periodically affected by landslides, these being a western area located near Port-en-Bessin, and on the eastern side, the area located between Trouville and Honfleur. In this second area, a very spectacular slide took place during late December 1981 and early January 1982, on each side of Villerville. Following this destructive event (several houses were completely destroyed) we undertook the following research:

- An historical investigation, using written reports in papers and archives.
- The study and mapping of superficial formations covering the sedimentary *in situ* rocks, along and down the slope.
- The measurement of ground surface displacements for two years.

THE LANDSLIDE OF JANUARY 1982 IN VILLERVILLE

Villerville is a small seaside resort, not far from and east of Deauville. The landslide took place over a period of about 30 days. The first cracks, in the houses located along the Trouville to Honfleur road, appeared on December 15th. The landslide accelerated from December 25th. onwards, with a climax from January 13th. to January 14th., 1982.

In the mid-slope locations a lot of secondary parallel and transversal cracks occurred, elongated from south-west to north-east. Sometimes open more than one metre, these cracks resulted from significant tensile stress. A rejuvenation and lengthening of

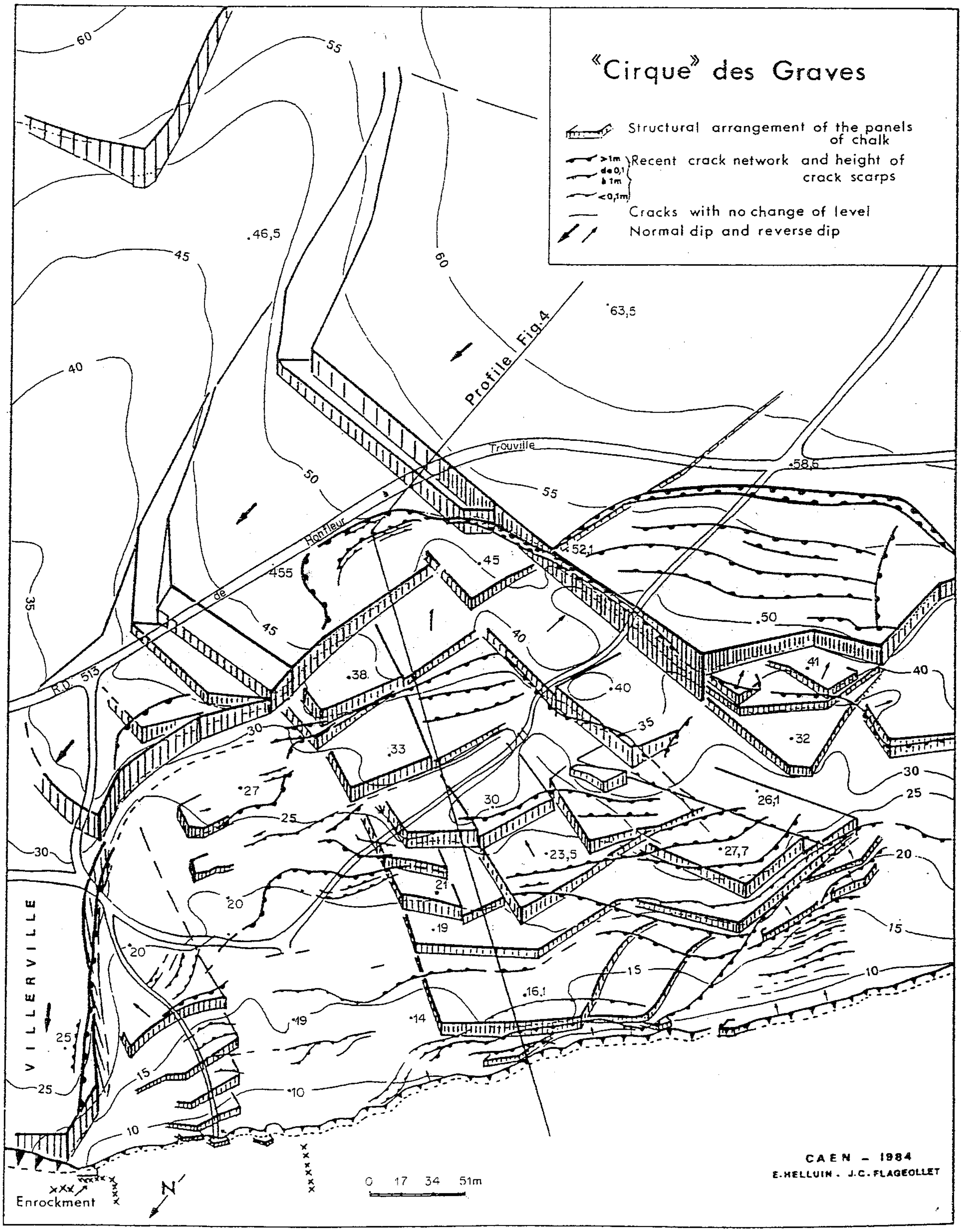

Fig.1 Morpho-structural diagram of the slope.

the main fault scarp making up the head slip occurred. This main fault reached 1500m in length, from the western edge of Villerville to the Point du Heurt, cutting the 513 road from Trouville to Honfleur in two points, and is now the up-slope boundary of a cirque-shaped unstable area called "cirque des Graves" (Fig.1). In front of the main scarp and inside the modified area a lot of reverse cracks and backward collapses denote that this is a composite landslide, with both superficial and deep movements.

At the foot of the slope several push ridges appeared. These extended as far as the beach, where the ridges were destroyed by the sea each high tide, but reappeared at every low tide. Under the beach sand in the main ridge (Fig.2) vertically straightened clays and marls, lenses of glauconitic sands, pieces of chalk, and silt and flint pockets were all visible.

Fig.2. The main push ridge which raised the strand of the beach of Villerville, January 23rd., 1982.

The areas affected by these sliding phenomena are located on each side of Villerville, and have the shape of an amphitheatre. Along the western part of this amphitheatre the ground has been removed from the 513 road to the beach of Villerville, a distance of 400 metres. Villerville itself has been saved, due to a stone wall sea defence and its location at the end of a valley, excavated in Kimmeridgian marls, and overlain with head and loess which are resistant to sliding phenomena.

The prolongation of the sliding phenomena. After January 1982, the sliding reduced in speed, but did not stop. In June 1982, a network of displacement indicators was installed along some cracks and down

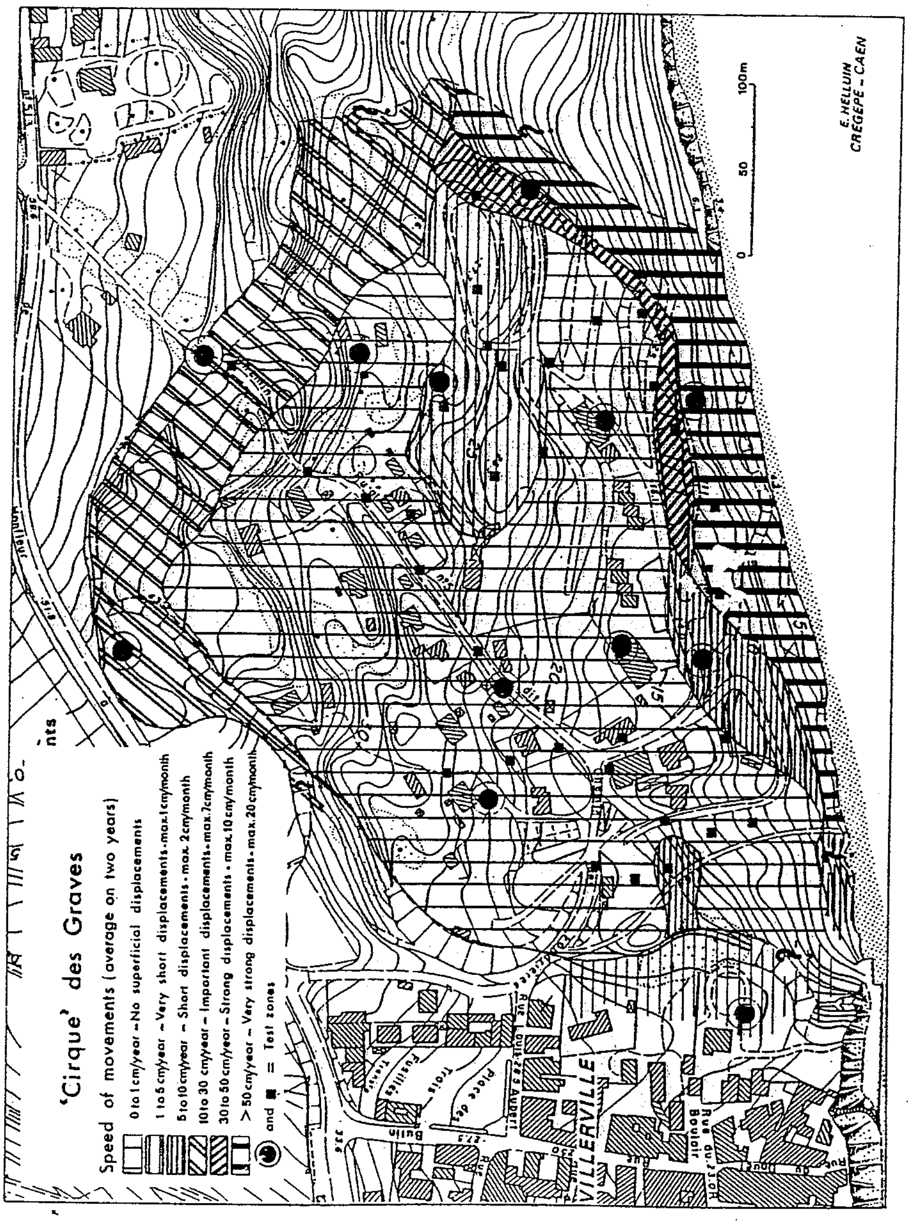

Fig.3. Zoning of superficial ground displacements, 1982 and 1983.

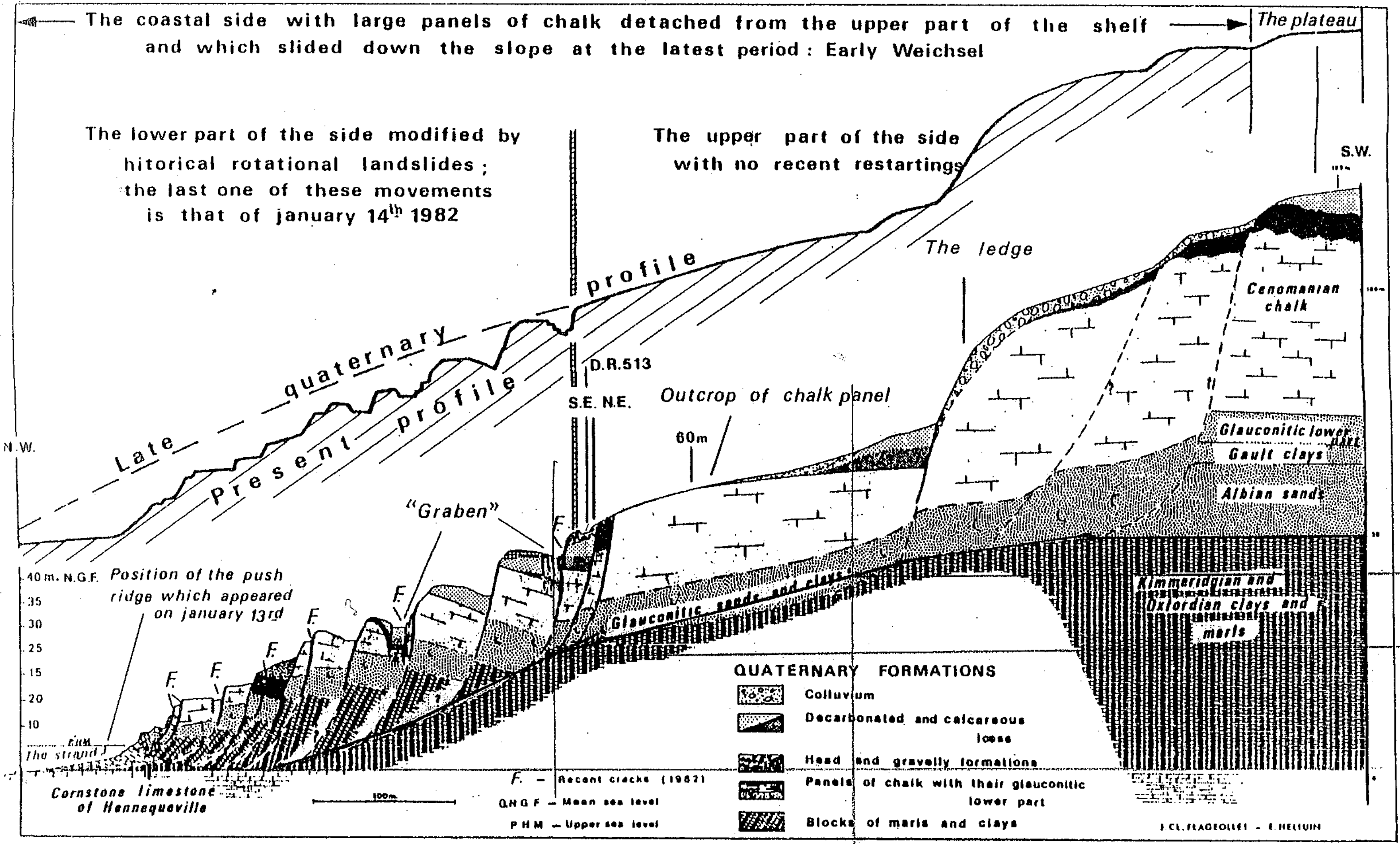

Fig.4. Geological profile of the Villerville slide in 1984.

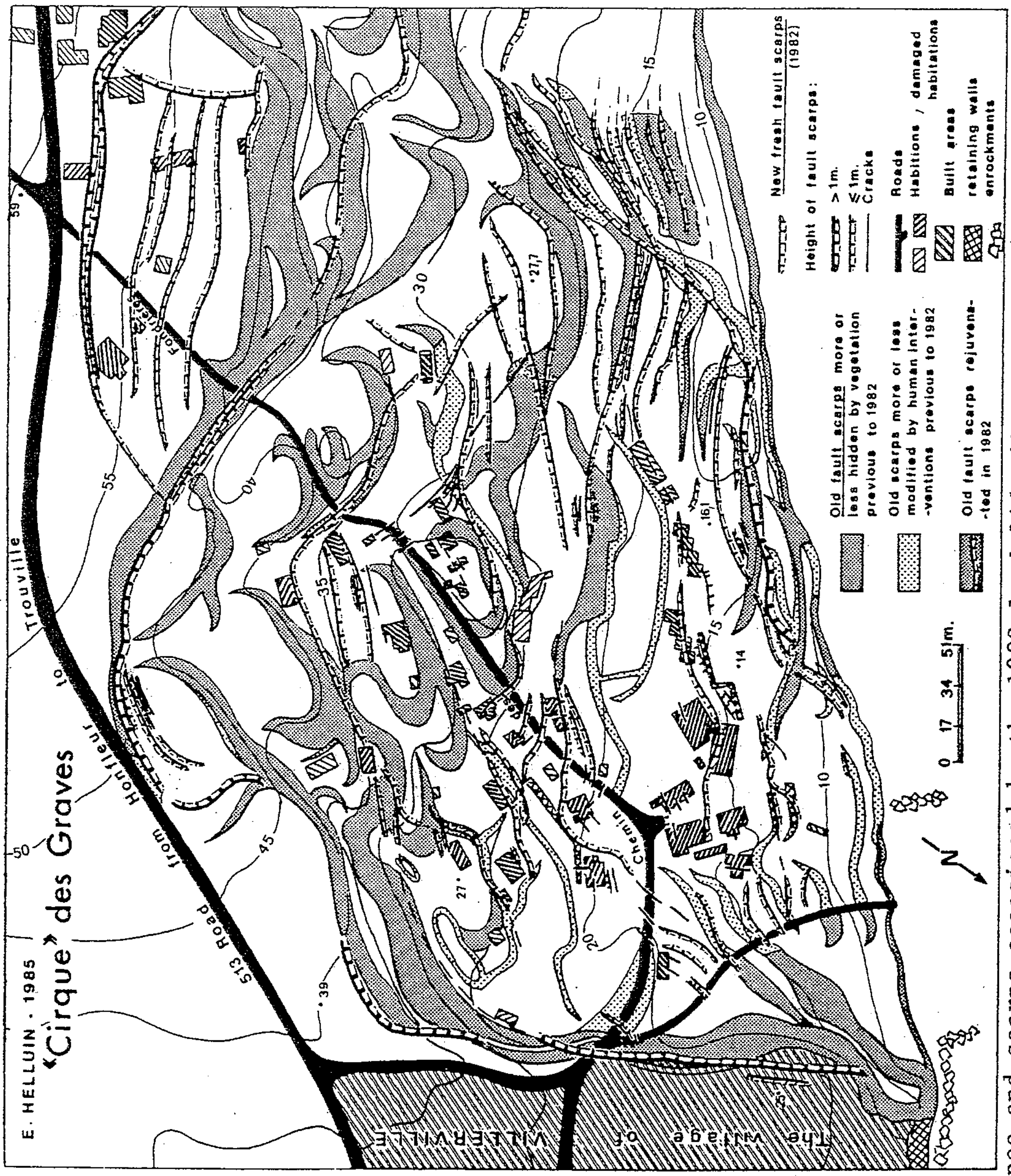

Fig.5 Slopes and scarps occasioned by the 1982 landslide (latest survey February 1984).

the slope. Two years later we were able to indicate the average speed of the superficial displacement for the whole slide (1cm per year) and some important differences of speed of movement within the sliding mass. There are two areas which are very much unstable: the slide head, with movements of about 10 to 30cm/year, and the slide foot, where the average speed of displacement was fastest - more than 50cm/year (Fig.3).

GEOLOGY AND GEOMORPHOLOGY OF THE COASTAL SLOPE

Sedimentary in situ rocks. These are shown in the geological profile of Fig.4. There are, over the edge of the Pays d'Auge plateau a cover of loess, a weathered chalk horizon (flint clay), overlying forty metres or so of Cenomanian chalk with numerous cherts and flints, overlaying glauconitic sands. Gault Clay and Albian glauconitic sands then overlie forty metres or so of Kimmeridgian and Oxfordian marls and clays with more resistant banks of marly limestone and iron concretions.

Loess
Craie altérée
argiles à silex
Craie du Cenomanien
Sables glauconiel
Marnes
Calcaire marneux

Superficial deposits. The in situ rocks themselves are covered by a thick patch-worked mantle. During their descent, blocks of chalk have been divided into fragments, so those of upper slope areas are sometimes 200m long, whilst those of the slide foot are less than 10m (Fig.4). By comparison with other litho-stratigraphic head units in Normandy, especially on the Cotentin Coast, at Ecalgrain and Port Racine, the déposition of chalk blocks and head date from the early Weichselian to late Weichselian. The two loess beds found in the middle part of the slope can be compared (Flageollet and Helluin, 1984) with recent loess (Pleniglacial) of the Seine Valley (Centre de Gêomorphologie, 1982).

SLIDES AND GEOMORPHOLOGICAL EVOLUTION OF THIS COASTAL SLOPE

Loess and head deposits surround and cover the chalk blocks, so much of the superficial formations were in place on the slope at the end of the Weischselian period, when the slope was stabilized. We do not know exactly when the surface removal took place, for example, at the beginning of the Holocene, or later. But we are sure that several slides are recent, not more than 2 or 3 centuries old: 1808, 1849 (Ballais et al., 1984), 1923, 1928, 1977. This latter was probably one of the most important slides occurring since the 19th Century, with cracks 300m long. But, within living memory, there has not been so important or catastrophic a landslide as that of 1982.

The cirque-shaped area of sliding has spread up-slope and is an example of retro-active erosion. Morphologically, one can distinguish old scarps and cracks, prior to 1982, more or less hidden by vegetation, old scarps rejuvenated in 1982, and new fresh scarps (see Fig.5). Sometimes, fresh scarps follow the outlines of chalk blocks, but, more frequently, they go through the chalk or the head as well. Because of that, and because one could find in January 1982 Kimmeridgian marls in the foot bench, we suppose that the sliding planes intersect the marls at depth (Fig.4), in the form

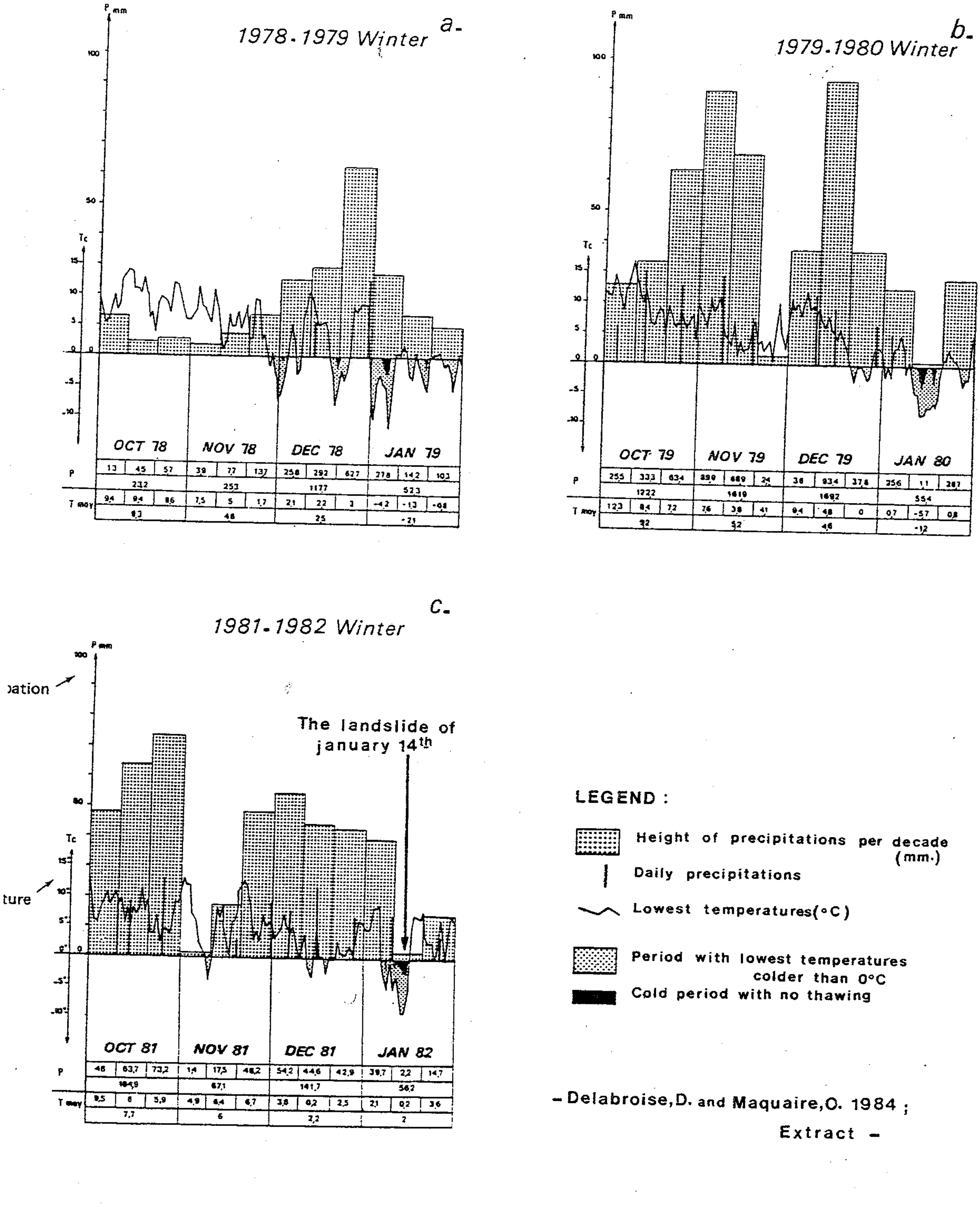

Fig.6. Precipitation - temperature diagrams from October to January, for 1978-80 and 1981-82. (Meteorological station of St. Gatien-des-Bois, Deauville Airport)

of multiple rotational slides (Brunsden, 1971; Hutchinson et al., 1982).

DISCUSSION

After the December 1981 landslide, some geologists gave an explanation of the Villerville slide as being due to a strong frost period lasting ten days (temperatures less than -10°C), followed immediately by a long period of heavy rainfall (195mm). The sudden frost occurred on January 6th., 1982. One supposes that all the springs and seepages stopped, and that, consequently, the quantity of phreatic water and therefore the hydrostatic pressure increased enough to initiate failure.

However attractive it may be, this explanation gives rise to some strong reservations. It is not certain that all springs and seepages were frozen. In the Winter of 1984 in Villerville it was noticed that the water in certain springs kept flowing, under a thin layer of frost. In addition, meteorological conditions were not really very exceptional during the 1981-82 Winter (Fig.6c). This can be seen by comparison of temperature and precipitation data from 15 winter seasons, from 1968 to 1983 (Delabroise and Maquaire, 1984). For example, although the 1979-80 winter presented the same meteorological conditions as those of 1981-82 (Fig.6b), that is 40 days of rain (180mm) coming after ten days of strong frost (temperatures less than -10°C), no perceivable landslide occurred. Similarly, although there were several cold periods and significant precipitation (145.5mm) from December to mid-January, during the 1978-1979 Winter (Fig.6a), no movement was perceived.

Thus, we can conclude that the hypothesised causal relationship with the frost action is not proven. More precise measurements, such as ground temperatures during periods of frost, and other factors, for example the seastorm effects, must be considered. Current investigations are being undertaken in these areas.

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