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Prévention des risques d'érosion et de submersion littoraux: la connaissance du risque, les études d'impact en vue des travaux de protection

Prevention of coastal erosion and submersion risks: knowledge of the risk, impact studies with a view to protection works

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QUATERNARY SLOPE FORMATIONS BETWEEN TROUVILLE AND HONFLEUR.

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Between Trouville and Honfleur (Fig.1), the upper third of the slope is a rounded cornice formed in the Cenomanian chalk over a height of more than 50 metres and lined irregularly with a quaternary slope deposit, made of a mixture of fragments resulting from frost-fracturing and weathering of the chalk and of eolian loam. In the more gentle slope (10 to 12 %) which follows on from it down to the shoreline, the higher Oxfordian and Kimmeridgian marls and the Albian sands and clays are concealed everywhere by Quaternary formations several metres thick which have collapsed or slipped. At the bottom of the slope, 2 to 3 metres above the high water line, these formations are eroded, giving rise to a small "debris" cliff . The random observation of these formations and the superficial morphological risks of their recent movements formed the basis for the Zermos map of Trouville.

THE QUATERNARY FORMATIONS OF THE SLOPE

Nature of the formations :

They are, firstly, **chalk blocks** which have collapsed or slipped from the cornice and are generally more voluminous in the intermediate section of the slope (over 100 metres long) than close to the shore (a few dozen metres). They consist of chalk belonging to the "glauconiticy chalk" level of the lower Cenomanian. It is a yellowish sandy or gritty chalk, always glauconitic, featuring large chert beds, jointed, cracked, sometimes decarbonated, very often weathered and taking on the appearance of a very plastic greenish clay. The chalk always rests on several metres of glauconitic clays and sands, the blocks having slipped along with their "cushion" of clayey sands. At the water's edge, one can see small blocks of Kimmeridgian marls dipping towards the top of the slope and standing almost vertical as a result of pressure from the unconformable Quaternary formations (particularly blocks of chalk).

Secondly, they are **eolian deposits** (loess) and periglacial formations of the debris type. The loess deposits come from the Seine estuary, which was very open at the time of the last Quaternary glaciations. They are sandy, with chalk granules, very calcareous (25 to 30 % CaCo3), with traces of occidation or marmorosis ; having been reworked by run-off, they have a slightly laminated structure. The **periglacial debris** inserted between these loess deposits consists of frost-fractures chips of chert and flint and chalk nodules enbedded in more or less sandy (chalk)

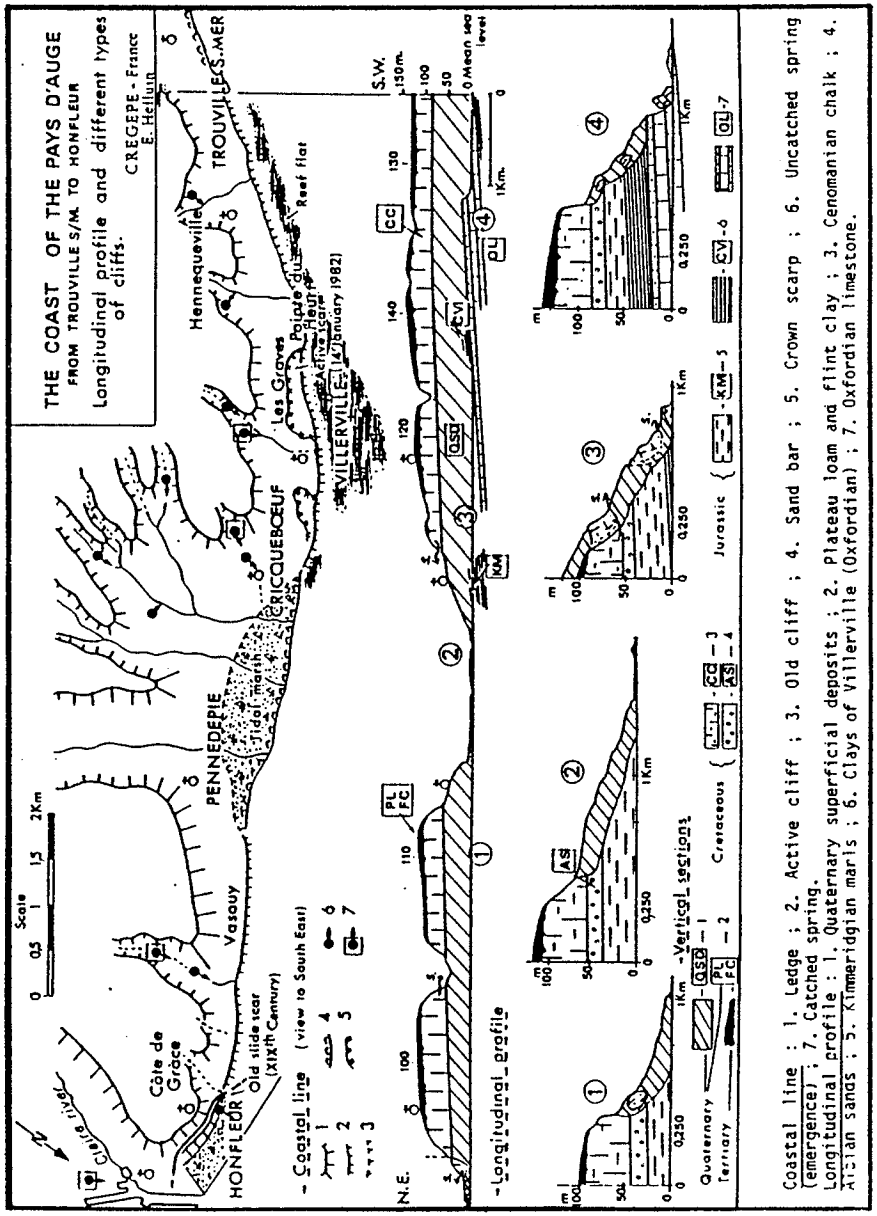

Fig. 1 Geomorphology of the Pays d'Auge cliffs

or loamy (loess) matrix. Its appearance varies greatly according to its location on the slope and the changes in its form: one goes very quickly from chalky debris pressed against the wall of a chalk block to a stratified formation of the "head" type with rough cherts graded and tilted forwards. Having accumulated from the foot of the cornice, they are mainly found at the front of the blocks, where they have been trapped and where they may be 2 to 3 metres thick. In addition to these clearly defined formations there are materials of varying types and sizes embedded in a clay matrix resulting from solifluction. These soliflucted formations are observed at the surface, where they form a thin layer covering the chalk blocks and loess deposits. Their presence under the chalk blocks is unlikely, despite the highly glauconitic clay masses which we have been able to see in the bench under the marl panels and the intumescences which appeared on the foreshore at the time of the January 1982 landslide.

Development of quaternary formations Tentative chronostratigraphy

Along the slope, although the sections provided by the recent landslide are not very deep, they are enlightening. The most comprehensive observations can be carried out on the coastal cliff just below Villerville.

Section I lies close to the property known as "Aigue-Marine", where the cliff reaches a height of + 18 metres NGF. Oriented N 50°, this section cuts across the formations of the Villerville valley, which are visible at this point over a length of more than 50 metres and a height of over 10 metres.

Section I starts at + 5 m NGF. It comprises three lithostratographic units (fig. 2.I) from bottom to top :

I : gravel and non-calcareous loams ;
II : likewise, carbonated ;
III : complex rough head.

Units II and III represent the same cycle, which may be placed in the Weichselian.

On the one hand, the head is not chalky enough to be compared with Saalian head. On the other, given that its matrix is not composed of eolian loam deposits, it is difficult to place it at the very start of the upper pleniglacial period. A more likely theory is that it is old Weichselian head, perhaps the equivalent of the brown head of Port-Racine, the underlying loess having possible been deposited at the beginning of the glacial period. The traces of pedogenesis might be due to interstadial periods of warming. The lower decarbonated unit could be related to an older cycle, perhaps Saalian. Further up the valley, the head becomes a very chalky gravel overlain by very thick calcareous loess.

On the slope, small blocks of chalk are incorporated into the head, but the large chalk blocks are covered by head and loess. They slope gently towards the bottom of the valley. Two conclusions may be drawn from this : the chalk

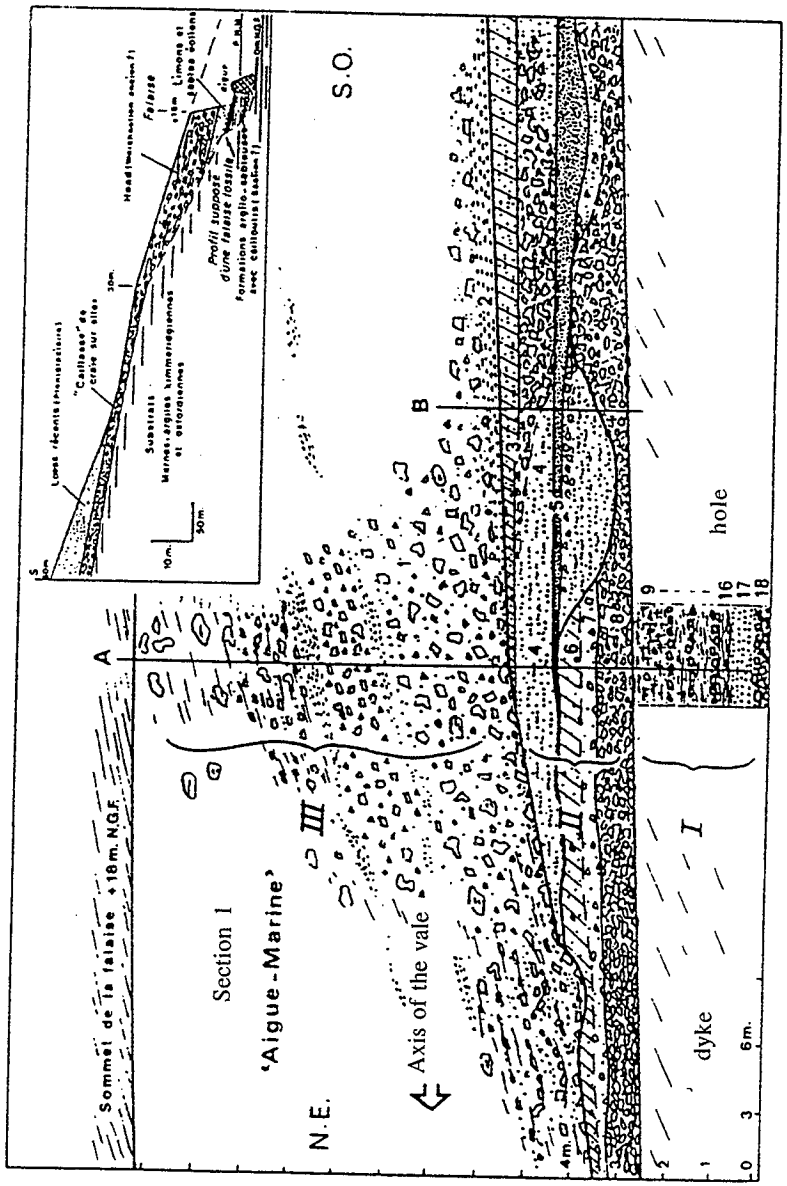

Fig. 2 - 1 Section in the debris cliff at Villerville

blocks were formed **at the beginning of a Quaternary cold period**, during which they slid down on the clay sands. The sequence of events might have been as follows : destabilisation of the cornice due to tapping of water logged Albian sands ; break-up of blocks set in motion by flowage of the underlying glauconitic clays, the chalk blocks thus sliding down to the bottom of the slope and breaking up in the process ; slippage was facilitated by the disappearance of forest cover and the high humidity at the start of the cold period ; the initial profile of the slope was smoothed down ; the gap in the cornice at the top of the Villerville valley accounts for the almost complete absence of chalk blocks along the centre line of this valley, which is filled mainly with loess deposits ; the downward movement of the main chalk blocks had largely been completed when the last loess was deposited and when frost-fracturing of the chalky cornice produced the debris which formed the head. It is possible, however, that small blocks slid down at a later stage and were incorporated into the formations.

Section II (Chemin des Graves, near the RN 513) corresponds to the northern wall of a fissure which lowered the level of the land by three to four metres over more than 300 metres during the landslide of 1982. The fault occurred at the edge of a shelf-like structure corresponding to the back of a huge chalk block tilting towards the West, at the front of which periglacial formations have accumulated. Running from East to West, the fault cuts through chalk; then through increasingly thick head and loess.

The eolian origin of the loams is undeniable, despite very substantial local chalky deposits (sands, silts, granules). The two loess deposits C.7 and C.8 are probably related to the recente (pleniglacial) loess deposits of the Seine valley. The light brown loam (C.6), which is very different from the other two, might be the equivalent of the loam deposited by periglacial solifluction in the early Weichselian and the upper head (C.4) would represent the kesselt level, which is greatly expanded here.

Hence, an examination of the cliff formations and of the Chemin des Graves suggests that the chalk blocks very probably moved down at the very beginning of the Weichselian.

SLOPE FORMATIONS AND LANDSLIDES

Susceptibility of formations to slidding

The loess deposits, which are very often sandy, are fairly permeable and not very susceptible to flowage. Heads with a sandy matrix and frost-fractured cherts or flints bonded together by their irregular shapes are unlinkely to be propelled into motion again. It can be asserted that these formations are not responsible for a resumption of movement on the slope. The same cannot be said of the large chalk blocks whose base contains glauconite and which, in addtion, often rest on green Albian sands. Impregnation with water can lead to subsidence and slippage.

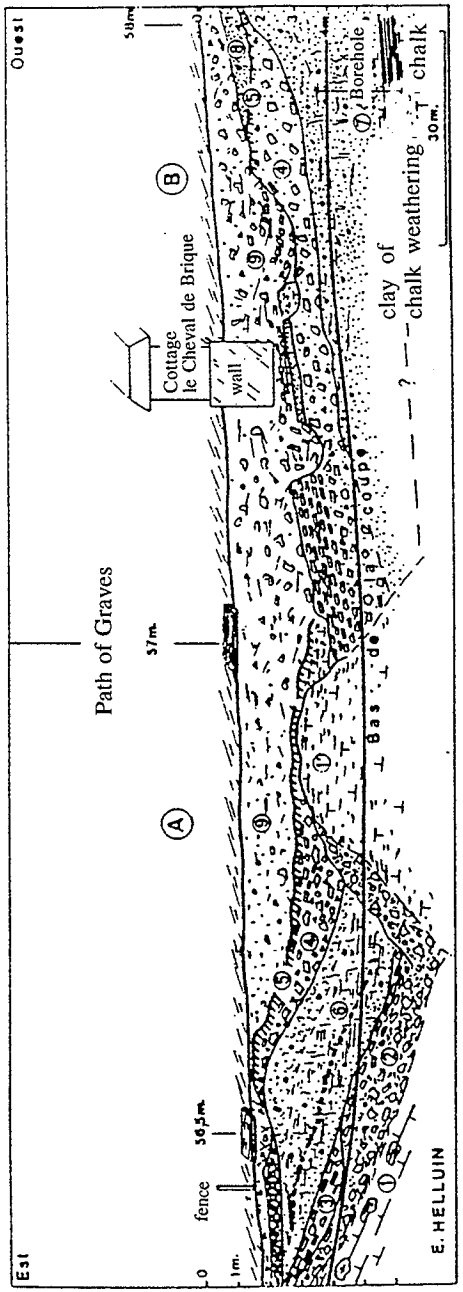

Fig. 2 - 2 Section along a secondary scarp at the " chemin des Graves"

Resumption of movement in the Holocene Epoch

A slope with a relatively graded profile due to debris and loess deposits is followed in space and in time by one of chaotic appearance. Morphological surveys show that movements of the slope tend to be located on either side of Villerville, in the Fosses du Macre and the Cirque des Graves. One cannot say exactly in how many stages or over what period the phenomenon took place. When the villas were built at the top of the slope, allowance was made for this phenomenon, but unfortunately, its extent was underestimated. It is in these two areas that one can see blocks of chalk tilted and forming a counterslope and faults which cut through several7different chalk blocks or do not fully coincide with the limits of those blocks. In the low cliff standing a few metres above the beach and rapidly retreating because the sea attacks it and easily removes material, the marls and clays of Villerville are tilted nearly 45°, with an upslope dip. The cornstone limestones of Hennequeville, which are horizontal on the foreshore, also seem to be affected by these reverse slopes.

The resumption of movement has proceeded in stages in the Holocene Epoch, and the small fault scarps which have appeared successively or have been re-opened several times as a result of this have been conceald by the vegetation cover.

REFERENCES

BIGOT A., 1942 : La Basse-Normandie. Esquisse géologique et morphologique. Caen, 125 p. 45 pl., 3 cartes.

CENTRE D'ETUDES TECHNIQUES DE L'EQUIPEMENT. Lab. Rég. de Rouen, 1973. Zone côtière entre Trouville et Honfleur. Etude de glissement de terrain, 22 p.

CENTRE DE GÉOMORPHOLOGIE DU CNRS CAEN, 1979. Table ronde sur les formations de versants hétérogènes. Bull. n° 24, 200 p.

CENTRE DE GÉOMORPHOLOGIE DU CNRS DE CAEN ET DÉPARTEMENT DE GÉOLOGIE DE ROUEN, 1983. Le Quaternaire de Normandie.160 p.

DANGEARD L., 1951 : La Normandie. Géologie régionale de la France. Paris. Hermann, 241 p., 22 fig., 5 cartes, 7 pl., 7 tabl.

ELHAI H., 1963 : La Normandie occidentale entre la Seine et le Golfe Normand-Breton. Bordeaux. Bière, 624p., 136 fig., 31 dépl., 32 pl.h.t.

GUYADER J., 1968 : Le Jurassique supérieur de la Baie de la Seine : Etude stratigraphique et paléontologique. Thèse, Université. Paris, 268 p., 32 fig., 34 pl.

HELLUIN E. et HELLUIN M., 1971 : Les terrains du Pays d'Auge et les travaux d'aménagement - Le Pays d'Auge. Cahier du Département de Géographie de l'Université de Caen, n° 3 - 4, Novembre 1971, p. 23-34.

HUTCHINSON J. et al., 1982 : The geotechnics of coastal cliff stabilisation. London, p. 153-159.

JUIGNET P., 1974 : La transgression crétacée sur la bordure orientale du Massif Armoricain ; Aptien, Albien, Cénomanien de Normandie et du Maine - Le stratotype du Cénomanien, tome 1, 806 p., tome 2, 174 fig.

LAUTRIDOU J.P., 1984 : Le cycle périglaciaire pléistocène en Europe du Nord-Ouest et plus particulièrement en Normandie. CNRS, Caen, 836 p.

LAUTRIDOU J.P., 1968 : Les formations superficielles de Saint-Romain (Pays de Caux). Leur contribution à l'étude morphologique de la région. Faculté des Lettres et Sciences Humaines de l'Université de Caen, 199 p.

MAHIEU J.L. et GUILLOPE P., 1976: Carte Zermos de Trouville. Pont l'Evêque. 1/25.000 BRGM, Paris.