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Inshore analyse of the morphostructural evolution of the coastal cliffs of Bessin, Basse-Normandie, France

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The cliffs' retreat is a major issue for the management of coastal territories. Two coastal areas in "Calvados" and "Pays de Caux", French Normandy, are studied by the University of Caen for several years, and more recently assisted by the University of Lausanne.

The studied section of the cliffs of Bessin is about 4.3 km long and lies between the World War II artillery batteries of Longues-sur-Mer and Arromanches-les-Bains. The site's lithology is mainly made of two formations: the limestones of Bessin that lie on top of the marls of Port. On the coastline, the cliff's height varies between 10 and 75 meters above sea level. The marl formation acts like an aquitard, as it is semi-impermeable. Therefore, more or less important water outflows are observable at the point of contact between the marls and the limestones.

First, the study aims to create an up to date geomorphological map as well as a kinematic classification of the existing instabilities of the different cliff's profiles. This part is realized with on site field measurements. We observe several profiles depending on the type of cliff studied: sinking of limestone panels due to creeping marls at the base, overhang limestone formation, wave-cut notch, detachment, tilt, rotational slide, superficial separation etc. These several behaviours depend on the cliff's exposure to the Channel sea and weathering factors, morphology, presence of pebble beach etc. The coastline section is thus classified depending on the different morphological types observed, which influence the stability and erosion rates. Principal morphological types here are: overhang limestone formation near Cape Manvieux, creeping marls near le Chaos and graben near le Bouffay.

Then, the cliffs' condition is compared to the diachronic analyse of the shoreline evolution supported by different photographic documents. This part of the study allows to refine the spatiotemporal occurrence of the different ground movements. However, cliffs'retreat evolves in successive leaps and bounds. Thus, results won't be significant if there aren't long period observations. Therefore, the documents used consist of orthophotos and oblique aerial pictures that cover a period from 1947 to 2009. This step shows higher retreat velocity in marls (0.15-0.2 m/yr) substratum than in limestones (0.05-0.1 m/yr).

Finally, we also focused on a complex landslide that happened in May 2013 near Cape Manvieux. We aim to reconstruct the kinematic and to determine the mass volume that has moved. For that purpose, a terrestrial LiDAR (Optech Ilris-3D ER) acquisition of the instability was performed in July 2013. The 3D point cloud allows a quite precise estimation of involved volume. Moreover, LiDAR data and field observations let us think that the current state of the instability was created by multiple events and is a complex mix of creeping marls and toppling of limestone destabilised by a back subvertical discontinuity which is parallel to the coastline.

In conclusion, the studies on morphostructural evolution of the cliffs with geomorphological field studies and LiDAR acquisition lead to a better comprehension of coastline retreat in Normandy.