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The Chalk karst of Normandy, France: reconstruction of Quaternary landscape evolution along the Seine River and the coastline of the Pays de Caux.

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Caves in the Upper Cretaceous Chalk limestone are generally rare, but more common in the Normandy (France), with several hundred recorded sites (Rodet, 1992). Most occur in the Seine valley and along the Pays de Caux coastline. Few caves are several km long with active streamways; others are relict systems, sometimes preserved up to 90m asl. Many caves are infilled with sediment, sometimes totally and often display a paragenetic morphology. The sediments include reworked loessic material, clay, sand and flint derived from Palaeogene and Quaternary Clay-with-Flint and loess deposits that overlie the Chalk. The Normandy chalk limestone was always used as a natural resource for building construction, liming of agricultural fields and water exploitation. The Chalk exploitation created long manmade galleries in the Caumont quarry (50 km) which is presently subject to collapse processes. Relict caves near the plateau de Caux are generally connected to the surface through dissolution sinkholes leading to suffusion process and surface subsidence. The recent evolution of caves is closely related to natural hazards in the Normandy karst landscape.
From a speleogenesis perspective, the spatial and vertical distribution of caves suggest a link between cave elevation, Chalk stratigraphy and the Seine river' incision. To better constrain the speleogenetic context, high resolution stratigraphy, detailed topographical analysis and age dating was used to understand the Quaternary evolution of the multi-level cave system along the Seine valley. Detailed stratigraphical logs derived from laser scans combined with palaeontological sampling suggest that cave development may be associated with particular inception horizons within the Chalk sequence (hardgrounds, sheet flints, marl seams), in particular the Light Point hardground/Shoreham marl level (Hoyez, 2008) at the top of the Lewes Nodular Chalk/base Seaford Chalk formations. The sediment infilling into caves attest to significant sediment inputs during various stages in the Quaternary. The studied caves along the Seine valley include: Caumont (15 m asl), Funiculaire (40 m asl), Mont Pivin (70 m asl) and Roche Percée (80 m asl) caves. Although previously partially dated (Rodet, 1992), they were recently reinvestigated to help constrain the timing of sediment infilling into the caves and to derive a minimal model age for the cave development related to the incision of the Seine River. The River Seine has a very well-developed terrace system corresponding to seven incision stages covered by periglacial alluvial formations (Lautridou, 1983; Lecolle, 1989), but less well-dated. Along the Somme Basin adjacent to the Seine river, the highest terraces dated are up to 95 m asl. These terraces record valley incision that began at $\sim$1 Ma (Antoine et al., 2007), with several terraces dated by absolute ages and archeological findings. Recent palaeomagnetic data from the studied cave showed both normal and reversed polarity from the Funiculaire cave whereas higher-level caves showed normal polarity and may fall in the Jaramillo normal period (0.9-1.06 Ma). Having normal and reversed sediments in the Funiculaire cave appears to be in accordance with the nearest dated alluvial terrace (600 $\pm$90 ka; $\sim$40m asl) in the Somme catchment (Antoine et al., 2007).