The High Normandy Chalk Cliffs: An Inspiring Geomorphosite for Painters and Novelists

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Abstract

The High Normandy coast specificity relies on the existence of remarkable landforms, such as white chalk cliffs and pebble beaches. Due to the low mechanical strength of chalk, these cliffs are very susceptible to erosion, and the rapid cliff retreat (~20 cm/year) threatens homes located inconveniently at the top of the cliff. Because of cumulative factors (exposure to strong west wind, beach sedimentary crisis, low altimetry of valleys), this study area of the eastern English Channel is also particularly sensitive to storm flooding. Moreover, the High Normandy cliffs, with their imposing verticality, their whiteness varying in tone with the ever-changing light and tide and their ghostly shapes, exerted also a powerful attraction to painters and novelists. One of the most famous chalk cliffs known in High Normandy, and probably in France, is Etretat. This site is remarkable because of its geological features and its very low rates of cliff erosion at a historical scale (few cm/year). The touristic site of Etretat, which has been affected by the fashion of sea bathing of the nineteenth century, has inspired painters. French writers, such as Guy de Maupassant and André Gide, also fell in love with the site, not to mention Maurice Leblanc, father of the “gentleman burglar”, Arsène Lupin, who hid the treasure of the kings of France in the “hollow stack”.

Keywords

Chalk cliff • Coastal erosion • High Normandy • Etretat • Geomorphosite

4.1 Introduction

The High Normandy coast is characterised by imposing chalk cliffs with flint bands, 70 m high on average, overlooking gravel beaches and shore platforms, themselves derived from the cliff retreat. These cliffs are interspersed by deep valleys either drained or dried (*valleuses*), which are the only links between the sea and the inland. This is why coastal communities and their activities are preferentially located in these low areas, though liable to flooding. Due to its morphostructural characteristics (chalk cliffs highly susceptible to weathering), its orientation to the disturbed atmospheric westerly flux and important urbanisation at elevation often lower than high water level of spring tides, the High Normandy coast is particularly vulnerable to natural hazards, namely, storm surge and coastline erosion. The cliff retreat is fast (average 20 cm/year on average between 1966 and 1995), though not uniform. These scarps, located at the north-west end of the Paris Basin, are carved in the Upper Cretaceous chalk, the homogeneity of which is only apparent. Due to tectonic deformations perpendicular to the coastline, various geological strata are outcropping. These lithostratigraphic characteristics determine differences in cliff morphology with contrasted erosion rates.

The cliffs of Normandy, with their imposing verticality, their whiteness varying in tone with the ever-changing light

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Fig. 4.1 Chalk cliff, shore platform, groyne, gravel beach and valley of Scie (Pourville-sur-Mer) (Photo S. Costa)

and tide and their ghostly shapes, exerted a powerful attraction for painters of the nineteenth century. From Camille Corot to Gustave Courbet, with a special mention for the impressionist painter Claude Monet, they have given us representations of Yport, Dieppe and Etretat. As this site, although daily harassed by the sea, the “Aval Arch” (compared by Maupassant to an elephant dipping its trunk into the sea) has not been eroded and reduced since Claude Monet’s time (painter of a “series” that represented it under various lighting conditions at different times of day).

Writers have been also inspired by these white walls and pebble/gravel beaches. Thus, Alphonse Karr (1808–1890) said, “if I had to show a friend the sea for the first time, it is Etretat I would choose”. Similarly, Guy de Maupassant presented one of the arches of Etretat, the Manneporte, “like a vault through which a ship could pass”.

Here below, we present the morphological and landscape characteristics of this coastline that are related to the regional geology. These geological characteristics also explain the terms and rates of shore evolution which undergoes much erosion. Finally, we will focus on the exceptional site of Etretat that attracted geomorphologists, painters, writers and tourists fascinated by the geology and landscape of its remarkable arches, cave and stack.

4.2 Geographical and Geological Setting

Over 120 km of shoreline, between Cap d’Antifer and Le Tréport, we can observe an original coast, characterised by chalk cliffs and gravel beaches (Figs. 4.1 and 4.2). Averaging approximately 70 m in height, they do not exceed 40 m at Cap d’Ailly (Fig. 4.4, cf. infra), but 105 m at Antifer and 101 m at Le Tréport.

Geologically, this area corresponds to the north-west termination of the Paris Basin (Fig. 4.3a). The plateau of High Normandy and Picardy, and therefore its cliff, is formed of Upper Cretaceous chalk (Cenomanian to Campanian) more or less rich in flints (Cavelier et al. 1979; Mégnien and Mégnien 1980; Mortimore and Pomerol 1987; Juignet

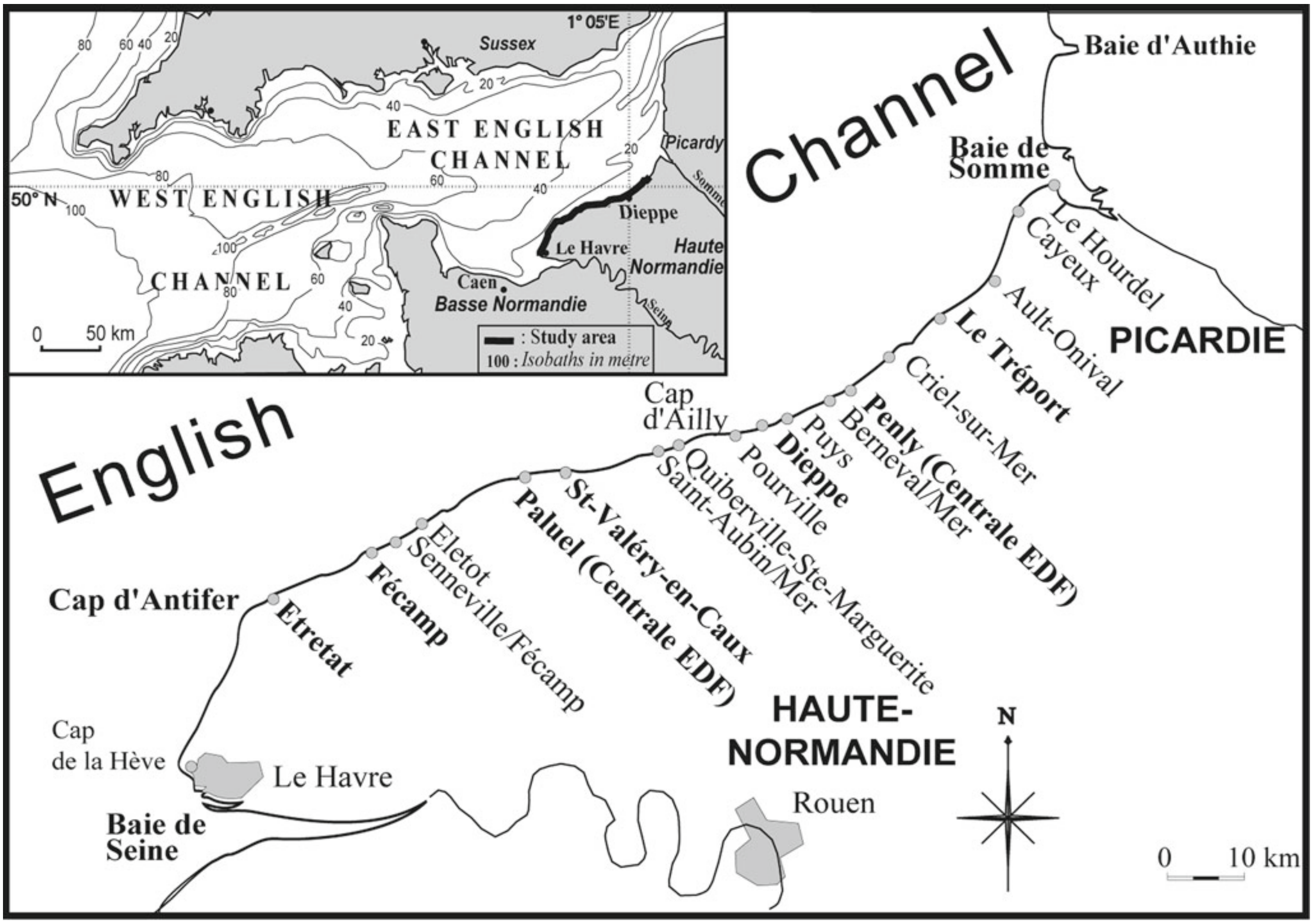

Fig. 4.2 Study area

and Breton 1992; Laignel 1997). Residual formations with flint and Quaternary loess are also deposited on this karstified chalk.

During the Upper Cretaceous (97–70 Ma), an important sea level rise caused flooding of the entire Paris Basin by the "sea chalk", which deposited the imposing chalky layers. It was a shallow, epicontinental sea, in which were deposited large amounts of microorganisms producing calcareous tests that gave rise to thick chalk strata. This lime-rich sedimentary rock is white or greyish, soft and friable and porous hence permeable. Its main component is calcium carbonate (90 % $CaCO_3$). It is formed mainly by an aggregate of coccoliths (skeletal remains of coccolithophores, 1–10 μm in diameter) and often contains planktonic foraminifera that swarmed in the Cretaceous seas. Other microorganisms have concentrated silica in their skeleton (diatoms, radiolarians, sponges, etc.) to generate interbedded bands of flint. The silica content in seawater originally comes from the weathering of silicate minerals constituting the continental crust and was fed by rivers or by wind (dust). This silica can also come from oceanic volcanoes (lithogenic silica) or phytoliths (mainland biogenic silica). Oxygenated and cooling waters are major factors in the formation of flint. The hypothesis most often used to explain the rhythmicity of flint bands in the cliffs is based on climatic variations due to astronomical forcing (Milankovitch cycles): the precipitation of silica would have taken place during a cold period, with the development of upwelling currents being felt up to the edge of the continental shelf and the surrounding epicontinental sea.

Major tectonic deformations in NW-SE directions result in the outcrop of various strata from the Upper Cretaceous (Fig. 4.3b). The majority of cliffs are formed by Senonian white chalk rich in flints (Coniacian, Santonian and locally Campanian). However, this apparent homogeneity hides more complex details. Turonian chalk comprising clay, greyish to whitish, with little or no flint, protrudes near Antifer, Etretat, Fécamp and Le Tréport where it reaches its maximum extension at Penly. Locally, Cenomanian chalk protrudes too. These are heterogeneous, sometimes rich in detrital components (clay and quartz), and can be glauconitic or nodular. A 10 m thick cover of sandy, clayish sediment of Palaeogene age can be found on the cliff top at Cap d'Ailly, at Sotteville and at Bois de Cise (Bignot 1962). In detail, the lithostratigraphy of chalk is more complex (Mortimore 2001; Hoyez 2008).

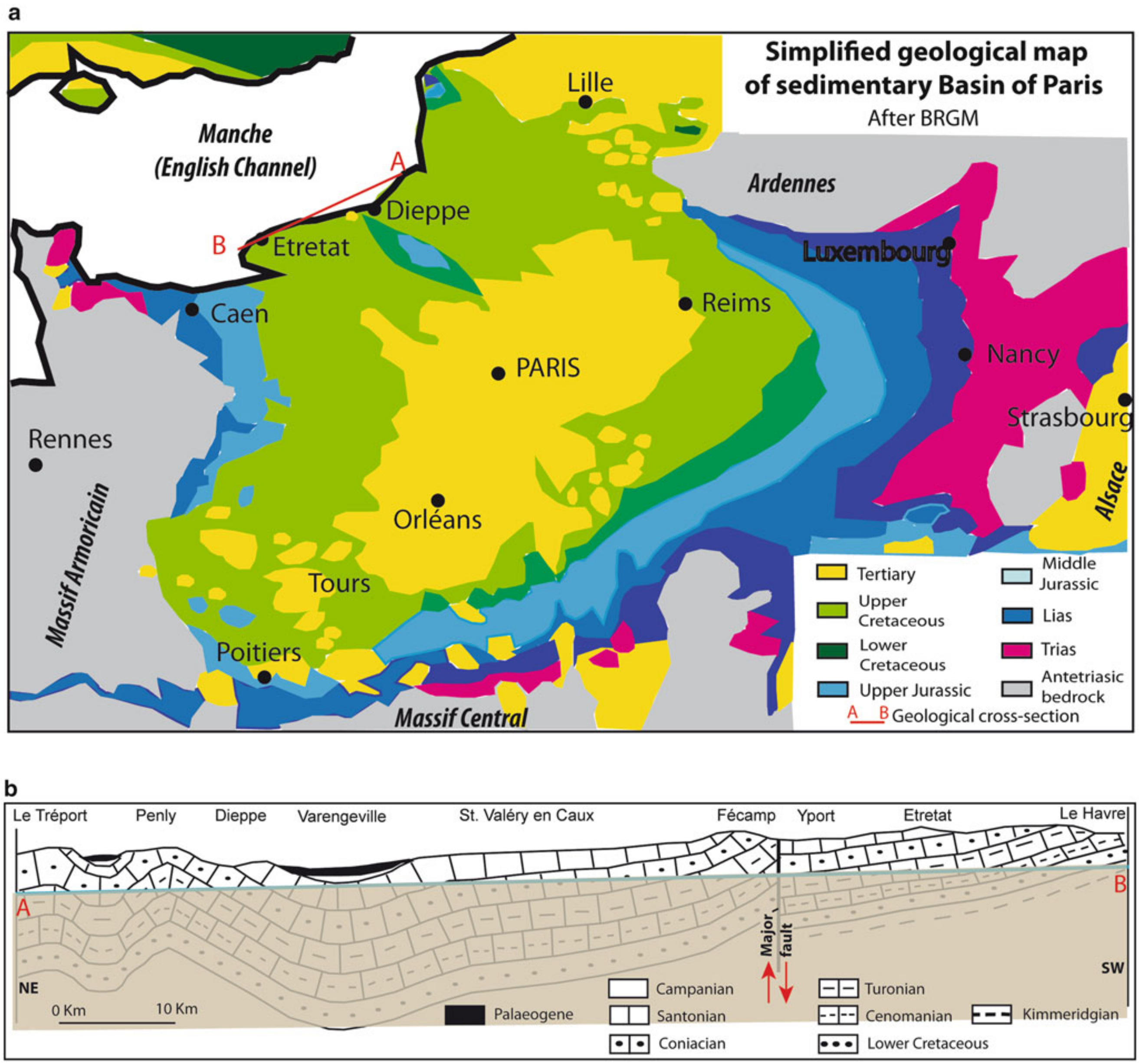

Fig. 4.3 (**a**) Simplified geological map of sedimentary basin of Paris (after BRGM); (**b**) geological cross section of the coast between Le Havre and Le Tréport (Costa 1997)

Because of their different structural characteristics, weathering of chalk layers does not proceed uniformly, and, hence, the various chalk strata correspond with different types of cliff morphology with contrasting rates of evolution. Three main types of cliff are recognised (Fig. 4.4): "simple cliffs" cut in Senonian chalks are stretching for approximately 70 km around the coastline; "resistant pedestal" cliffs correspond to a resistant outcrop, generally the Turonian layer; and lastly, the "complex cliffs", in particular around Cap d'Ailly, mainly consist of sand and clay layers—the cliff foot is cut in the Santonian chalks, which are then covered by the non-cohesive Tertiary sediments.

A shore platform is cut into the chalk at the foot of the cliffs. The seaward slope is gentle (1° maximum at Antifer). This wide shore platform (150–300 m) is covered on its landward margin by a thin gravel beach.

During the Miocene, the uplift of the High Normandy plateau has been initiated, as a consequence of the Alpine orogeny (marine sands (from Redonian transgression) trapped in karst formations (at Valmont) above 120 m; Cavelier et al. 1979; Mégnien and Mégnien 1980). This uplift of about 150 m led to the formation of coastal cliffs, to progressive entrenching of streams in connection to jointing and the individualisation of the Seine course from

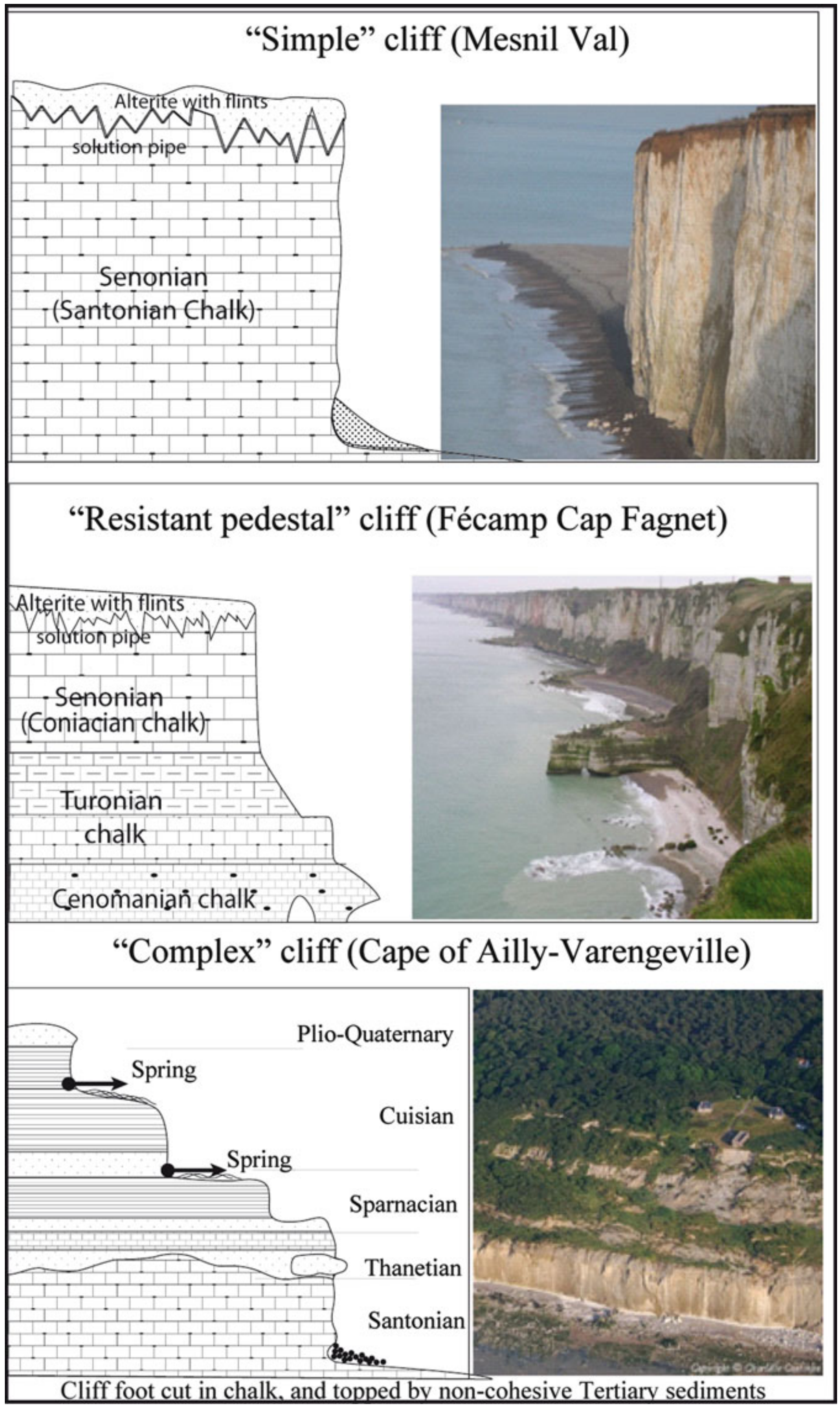

Fig. 4.4 Types of High Normandy cliffs according to stratigraphy (Costa 1997)

that of the Loire. At the same time, the water table fall increased the dislocation of chalk and led to karst formation. Glacial periods caused the lowering of sea level, and during the last one, the Würm glaciation (−30,000 years), the ice sheet reached the middle of British Isles and the northern of Europe. In this climatic context, the channel dried up completely and crossed by large rivers flowing into the Atlantic far beyond the present-day coastline (Paleo-Seine, Somme, Thames, Meuse, Scheldt, Rhine, etc.). During this low sea level, the cliffs were not the vertical and white walls that we know today, but the landscape looked like the banks of the Seine today, namely, sides covered by head deposits and framed by deeply incised valleys.

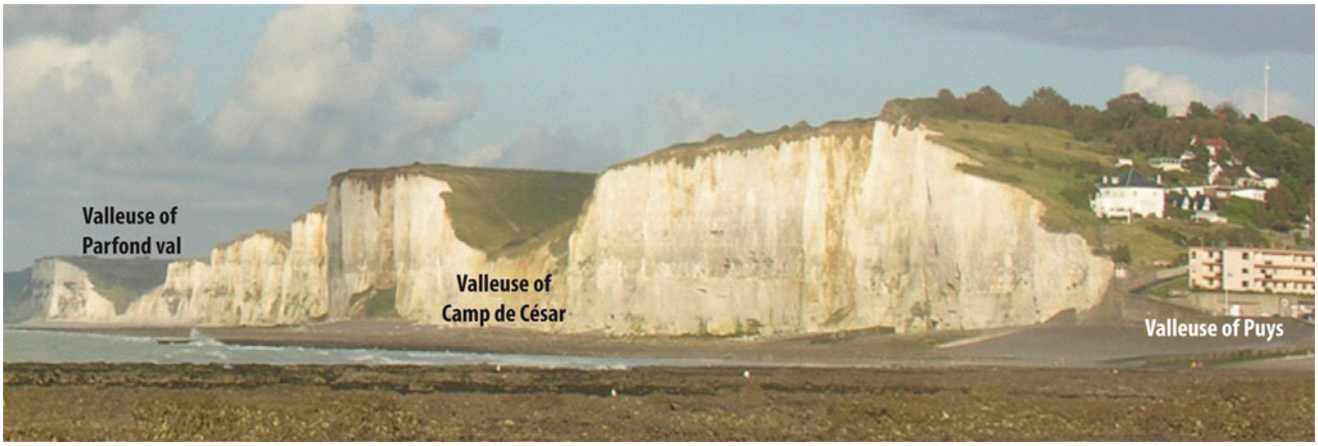

Fig. 4.5 Three hanging valleys above shoreline (valleuses): Puys (with houses), Camp de César and Parfond-Val (Photo S. Costa)

After the end of the last glaciation (−18,000 years), the sea level rose up to nearly 100 m (Flandrian transgression) to reach the foot of the coastal side (5–6,000 years ago) and remove the limbs and loose debris. At this time, the chalk cliffs were reactivated, vertical arches were created and hanging valleys overlooking the shoreline (*valleuses*) were formed. These are dry valleys perched atop the cliffs. They result from the competition between a slow digging of the river (which has seeped into the ground) and the rapid retreat of cliffs (Fig. 4.5).

Among the best known *valleuses* are those near Varengeville-sur-Mer, which host the park of Moutiers. The presence of deposits of sand, clay and sandstone of Tertiary age in the *valleuses* and their sheltered position from the disturbed westerly flow favour biodiversity as testified by the renowned flora park of the *Bois des Moutiers*. This park, which displays luxuriant rhododendrons, azaleas and camellias growing on acid soils, was inspired from the eighteenth-century British gardens, with the contribution of the famous British landscape designer Gertrude Jekyll.

Another characteristic of the Varengeville area is the existence of dwellings (*Manoir d'Ango*) and a church, built in the seventeenth century in local materials, such as red and white clay bricks, flints and sandstones. This church, threatened by cliff erosion, has a choir bathed in blue light reflected by the stained glass windows, partly created by the artist Georges Braque, whose grave is now located in the "sailor cemetery" adjoining the church.

The numerous dry and drained valleys perpendicular to the shoreline are protected by a gravel beach that is often thick (due to the presence of jetties and groynes) and 30–100 m wide. These valleys, the only connection between sea and inland, represent also the lowest parts along the cliffs: their elevation is not higher than the highest high tide level and makes these zones very fragile. Yet, it is in these low coastal areas that are affected by storm surge that the population and their activities are concentrated (Fig. 4.6).

4.3 Chalk Cliffs Affected by Rapid Retreat

Photogrammetric analyses were carried out to quantify the retreat of chalk cliffs. The 1966 and 1995 vertical aerial photographic surveys (1:10,000) from the French National Geographic Institute have been used (Costa et al. 2001, 2004). The mean retreat rate of the entire shoreline under study is approximately 6 m between 1966 and 1995, which yields a rate of 0.21 m/year. This average rate, however, masks a very high spatial variability of cliff retreat (Fig. 4.7). In fact, the analysis allows three distinctive areas to be distinguished: (1) an area of low retreat rate (0.8–0.13 m/year) between Antifer and Fécamp, (2) an area of moderate retreat rate (approximately 0.19 m/year) between Fécamp and Saint-Valéry-en-Caux and between Dieppe and Le Tréport and (3) an area of rapid retreat (0.21–0.28 m/year) between Saint-Valéry-en-Caux and Dieppe (Costa et al. 2001, 2004).

Even within each of these coastal sections, important variations do exist. These sharp variations are linked with the influence of cliff collapses or anthropogenic obstacles, such as harbour arms or major groynes that disrupt the gravel transit from the south-west to the north-east. Then down current from these obstacles, the cliff retreat can be multiplied by 2 or 3. These observations are confirmed by the analysis of the retreat at 50 m intervals (Fig. 4.10).

The identification of three sectors with distinctive retreat rates raises questions about the causes of this spatial distribution of the cliff retreat rates and especially its relation to the outcropping of different chalk strata (Costa 1997; Costa et al. 2004). The sectors with "low"

Fig. 4.6 Storm surges at Etretat in 27–28/02/1990 (Photo S. Costa)

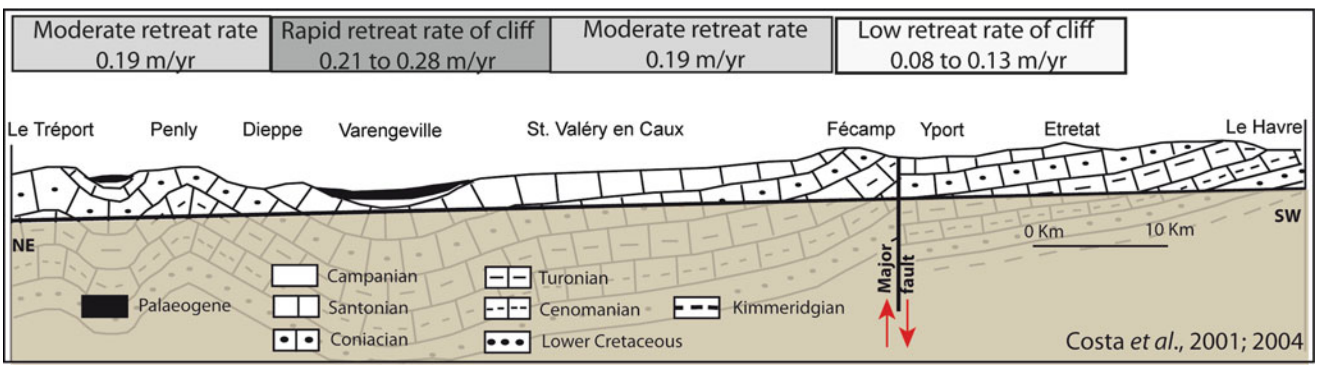

Fig. 4.7 Relationship between chalk rates, cliff retreat and lithology (Costa et al. 2001, 2004)

and "moderate" retreat are affected by infrequent but voluminous rockfalls and correspond to cliff-foot cut into Turonian, Cenomanian and even Coniacian outcrops (Antifer/Fécamp; Fécamp/Saint-Valéry-en-Caux; Dieppe/Le Tréport). By contrast, the rapidly retreating sectors, affected by frequent but less voluminous rockfalls, correspond to Santonian and Campanian outcrops (Saint-Valéry-en-Caux/Dieppe).

4.4 Etretat as a Specific Area: Cave, Arch and Stack, Affected by Very Slow Retreat

The site of Etretat is one of the most famous coastal chalk cliffs in France. The town is settled in a dry valley perpendicular to the shoreline, which is framed by specific cliffs, marked by stacks, caves and arches (Fig. 4.8). This site comprises four principal capes and arches: *la Porte d'Amont* (upstream door), la *Porte d'Aval* (downstream door) with his stack, *la Manneporte* and *la Pointe de la Courtine* (tip of La Courtine).

The Etretat cliffs are chiefly cut in the Coniacian chalk, but the upper Turonian appears locally. Morphological characteristics of the site of Etretat result from specific geological phenomena.

Chalk stratification is affected by pseudo-folds, which suggest that the bedding planes were originally wavy and therefore the seafloor during the Turonian-Coniacian was very irregular. Etretat is one of the most remarkable examples of this phenomenon. In fact, these undulations were induced by ocean currents that formed on the seabed antidunes and megaripples, hectometric wavelength and decametric amplitude on the surface of sludge chalk, hence created the so-called dips that are not in relation with tectonics. This area is also affected by synsedimentary slumping, and hard-ground development is also found, particularly in the Coniacian chalk (Fig. 4.9). These bioturbated nodular chalks, pluricentimetric to metric in thickness, were formed during interruptions of sedimentation (Lasseur 2007). These hard grounds are mechanically resistant, due to their induration/dolomitisation, and they block the water infiltration into the cliff and allow the development of endokarst.

Fig. 4.8 Cave, arch and stacks of Etretat (Photo S. Costa)

Lastly, the flint vertical development locally reaches up to 5 m in thickness. The inverted pear shape, called *paramoudra*, is the most classic; it is a secondary silicification around an axis whose origin is variously interpreted (possibly worm burrow). All these structural characteristics make the cliffs of Etretat more resistant to the development and preservation of endokarstic and exokarstic features such as solution pipes, which are often filled by alterites with flints and Tertiary deposits.

For many authors, the alignment of the arches and caves would be the result of fracturing parallel to the shore that would have allowed the installation of a karst pipe hollowed out by the sea after the last Holocene marine transgression. The natural evolution of this site, by regressive erosion of the cliffs, will lead gradually to expanding caves, which will form an arch, the top of which will collapse to form a stack. Structural features also explain the low rates of cliff retreat at Etretat that did not seem to have evolved on a historical timescale (Fig. 4.10). The coastal evolution calculated by photogrammetric analysis is about 3–4 cm/year between 1966 and 1995 (of the same order of magnitude as the error margin of the method!) but increases (10–15 cm/year) to the north of la *Porte d'Amont*. This is the lowest retreat rate of the High Normandy chalk coast.

Fig. 4.9 Hard-ground outcrop at the bottom of the cliff at Etretat, foreground right (Photo S. Costa)

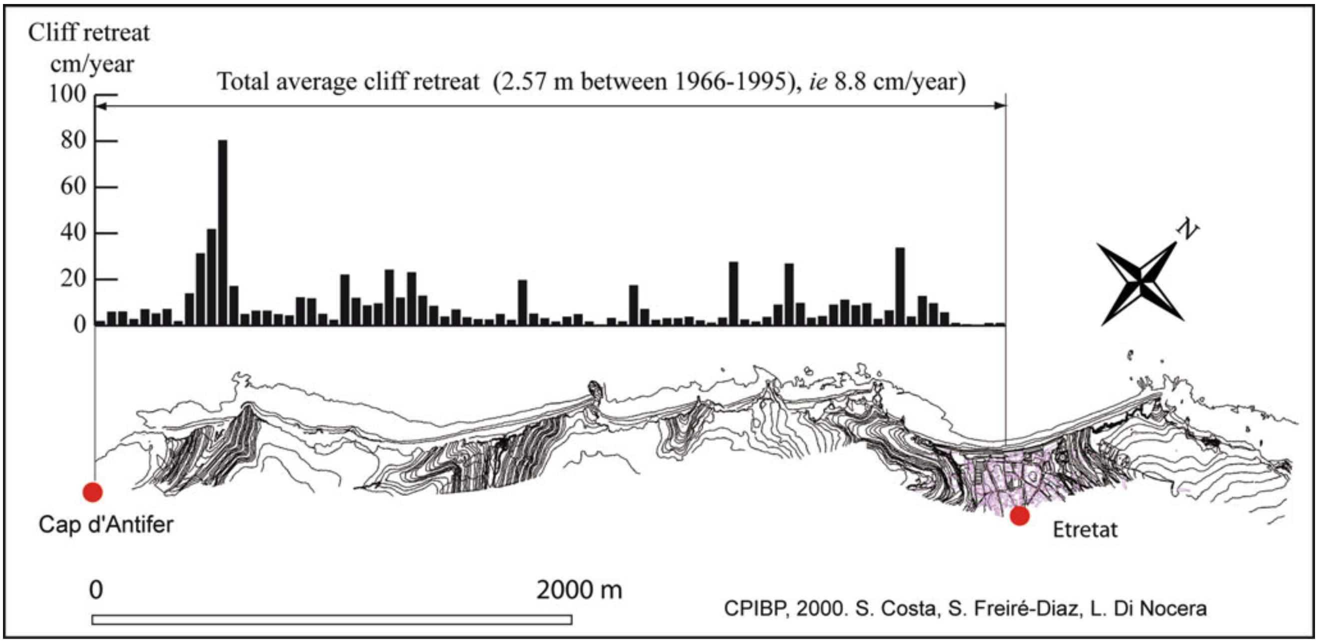

Fig. 4.10 Rates of cliff retreat at Etretat between 1996 and 1995 (Costa et al. 2001, 2004)

4.5 Etretat: A Geomorphosite Exerting Powerful Attraction to Nineteenth-Century Painters and Writers

The cliffs of Normandy, with their imposing verticality, their whiteness varying in tone with the ever-changing light and tide and their ghostly shapes, exerted a powerful attraction to painters of this period. From Gustave Courbet (1819–1877) to Claude Monet (1840–1926), they have given us representations of Yport, Dieppe and Etretat reflecting their fascination with geology. The high hygrometric content of the air explains the colour shades and the quality of the light. The "quest of light" has been the aim of the impressionist painters.

Since 1824, Dieppe and Brighton were connected by paddle steamer, facilitating a meeting point of the arts midway between London and Paris. Whereas the story has often focused on two central personalities, Walter Sickert and Jacques-Emile Blanche, these represented only the nucleus of a much wider artistic community, starting with Bonington and Turner in the earlier 1820s and ending a century later with the important relationship between Ben Nicolson and Georges Braque, who met regularly in Varen-geville. Coastal Normandy played a prominent role in the development of Impressionism during this period: by the late 1860s and early 1870s, the beach was the central character in the scenes depicted by Manet, Monet and Boudin. This new playground for the fashionable holidaymakers provided both subject matters and clients along the *côte d'Albâtre*.

Etretat beach, called "the beach of artists and writers", was the nineteenth-century resort frequented by the "upper class". In 1852, the casino opened, followed by bathing establishments, regatta clubs, tennis and golf. The last decade of the Second Empire (1860–1870) was probably the most brilliant period of this worldly Etretat. The villas made of bricks and flints with slate roofs located on the hillsides are still today witnessing this great time. The above-mentioned low rates of erosion are supported by a variety of paintings on the site of Etretat. They show that the landscape has changed very little since the nineteenth century. In general, the channel and its seashores have been in the middle of an important sequence of the universal history of painting, especially *landscape painting* during the nineteenth century and the first half of the twentieth.

Affected by the fashion of sea bathing of the nineteenth century, the touristic site of Etretat has given us works of painters as Camille Corot (1796–1875) and Gustave Courbet (1819–1877), or Claude Monet (1840–1926) who found inspiration there and contributed to its fame (Fig. 4.11). There were also famous musicians like Jacques Offenbach (1819–1880), who built his house in Etretat and called it "Orpheus in the Underworld", the name of his opera buffa. Similarly, French writers such as Guy de Maupassant (1850–1893) and André Gide (1869–1951) fell in love with the place, not to mention Maurice Leblanc (1864–1941), father of the "gentleman burglar", Arsène Lupin, who hid his treasure in the "hollow stack", 70 m high (Fig. 4.12). In his novel, Maurice Leblanc built the plot around the mystery of the *Aiguille Creuse* (hollow stack) which was assumed to hide the most fabulous treasure ever imagined, transmitted by the kings of France since the time of Julius Caesar.

Fig. 4.11 The cliffs at Etretat Claude Monet 1885. Williamstown. Clark Art Institute, USA (Public Domain)

Fig. 4.12 Cover of L'Aiguille creuse (Hollow stack) by Maurice Leblanc, one of the most famous adventures of Arsène Lupin, the gentleman burglar (© Livraphone Edition, with permission)

4.6 Conclusion

Together with the English coasts of Sussex and Yorkshire, the High Normandy coast is a rare example in Europe of chalk cliffs and cobbly silex beaches. Such coastlines help us to understand the geological history of the sites, such as the modes of chalk deposition (including hard-ground formation during interruptions of sedimentation), the role of ocean currents forming the formation of pseudo-folds on seabed chalks and the influence of the Pyrenean and Alpine orogenies in the tectonic undulations of chalk strata and the preservation of Tertiary sandy clays of Tertiary age in synclinal structures. These various outcrops of differential resistance to erosion explain the existence of cliff profiles and thus the variety of retreat rates. The overall low resistance of chalks explains the rapid erosion that threatens at places coastal communities and their activities. This great wall of chalk also fascinated famous nineteenth-century painters and novelists, who played their part in making these remarkable landscapes famous worldwide. Nowadays, local and regional communities are working together to have the High Normandy coastline added to the World Heritage UNESCO List, in order to make this heritage recognised for its geological, cultural and aesthetical outstanding qualities.

References

Bignot G (1962) Etude sédimentologique et micropaléontologique de l'Eocène du Cap d'Ailly (près de Dieppe-Seine-Maritime). Thèse 3ème cycle, Faculté des Sciences, Université de Paris

Cavelier C, Mégnien C, Pomerol C, Rat P (1979) Le Bassin de Paris. Bulletin d'Information des Géologues du Bassin de Paris 16(4):2–52

Costa S (1997) Dynamique littorale et risques naturels : L'impact des aménagements, des variations du niveau marin et des modifications climatiques entre la Baie de Seine et la Baie de Somme. PhD thesis, University of Paris I – Panthéon Sorbonne, Paris

Costa S, Freiré-Diaz S, Di-Nocera L (2001) Le littoral haut normand et picard: une gestion concertée. Annales de Géographie 618:117–135

Costa S, Delahaye D, Freiré-Diaz S, Davidson R, Di-Nocera L, Plessis E (2004) Quantification by photogrammetric analysis of the Normandy and Picardy rocky coast dynamic (Normandy, France). In: Mortimore RN, Duperret A (eds) Coastal chalk cliff instability. Geological Society, vol 20. Engineering Geology Special Publications, London, pp 139–148

Hoyez B (2008) Falaises du pays de Caux: lithostratigraphie des craies turono-campaniennes. Publications des universités de Rouen et du Havre, Mont-Saint-Aignan

Juignet P, Breton G (1992) Mid-Cretaceous sequence stratigraphy and sedimentary cyclicity in the western Paris Basin. Paleogeography, Paleoclimatology, Paleoecology 91:197–218

Laignel B (1997) Les altérites à silex de l'ouest du Bassin de Paris: caractérisation lithologique, genèse et utilisation potentielle comme granulats. PhD thesis, University of Rouen, Edit. BRGM, Orléans

Lasseur E (2007) La Craie du Bassin de Paris (Cénomanien-Campanien, Crétacé supérieur). Sédimentologie de faciès, stratigraphie séquentielle et géométrie 3D. PhD thesis, University of Rennes 1, Rennes

Mégnien C, Mégnien F (1980) Synthèse géologique du Bassin de Paris. Mémoire du Bureau de Recherches Géologiques et Minière, 3 vol, n° 101, 102, 103

Mortimore RN (2001) Chalk: a stratigraphy for all reasons. Keynote paper. The Scott-Simpson Lecture Proceedings of the Ussher Society 10:105–122

Mortimore RN, Pomerol B (1987) Correlation of the Upper Cretaceous (Upper Cenomanian to Campanian) white chalk in the Anglo-Paris Basin. Proceedings of the Geologist's Association 98:97–143