CASE STUDY 3H – CÔTE D'EMERAUDE, FR. (Brittany)

Case study area: Côte d'Emeraude, Brittany, France

Main geomorphological types: Rocky cliffs, sandy beaches, dunes, islets and estuaries.

Main coastal change processes: Coastal erosion, cliff instability, beach change.

Primary resources used: Art and archaeology.

Summary: The study area comprises extensive cliff lines, sandy dunes and beaches which are subject to erosion and instability. Archaeological records and artistic depictions have enabled us to see the rate and scale of this erosion over the last millennium. The palaeoenvironmental and archaeological records demonstrated these changes, particularly from the Iron Age period.

Recommendations: Coastal managers should use these resources when predicting future rates of erosion, they provide hundreds of years' worth of data to assist in the understanding of the rate of change. Further work into historic maps and charts is recommended as this can provide even more detail particularly from the 19th Century.

Coastal managers face an ongoing battle to moderate impacts from the sea in the face of a changing climate and pressures from human use of the coastal zone. The challenges that lie ahead are forecast to increase while resources are being forced to go further.

This case study report is part of the Arch-Manche project, which quantifies the value of under-used coastal indicators that can be applied as tools to inform long term patterns of coastal change. In addition, it provides instruments to communicate past change effectively, model areas under threat and interpret progressive coastal trends.

The Côte d'Emeraude area is one of four case studies within the Brittany area of France. This case study report introduces the study area and why it was chosen as part of the project. This report presents the results of the detailed art study. No specific archaeological or palaeoenvironmental field work has been carried out, however, former archaeological field studies have provided data regarding the coastal evolution in this area. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. Further details about the project methodology applied can be found in Section 2.

Within the Côte d'Emeraude area, the archaeological and palaeoenvironmental resource and the available art resource have been researched, scored and analysed. The extents of the detailed study areas are shown in Figure 3H1 below. The area considered for archaeology and palaeoenvironment has been selected to provide a representative range of types of evidence across a range of periods spanning from Palaeolithic through to more modern coastal heritage. The art, photograph and map case study area encompasses a broader stretch of the coastline to reflect the various coastal morphologies and features which have been depicted over time.

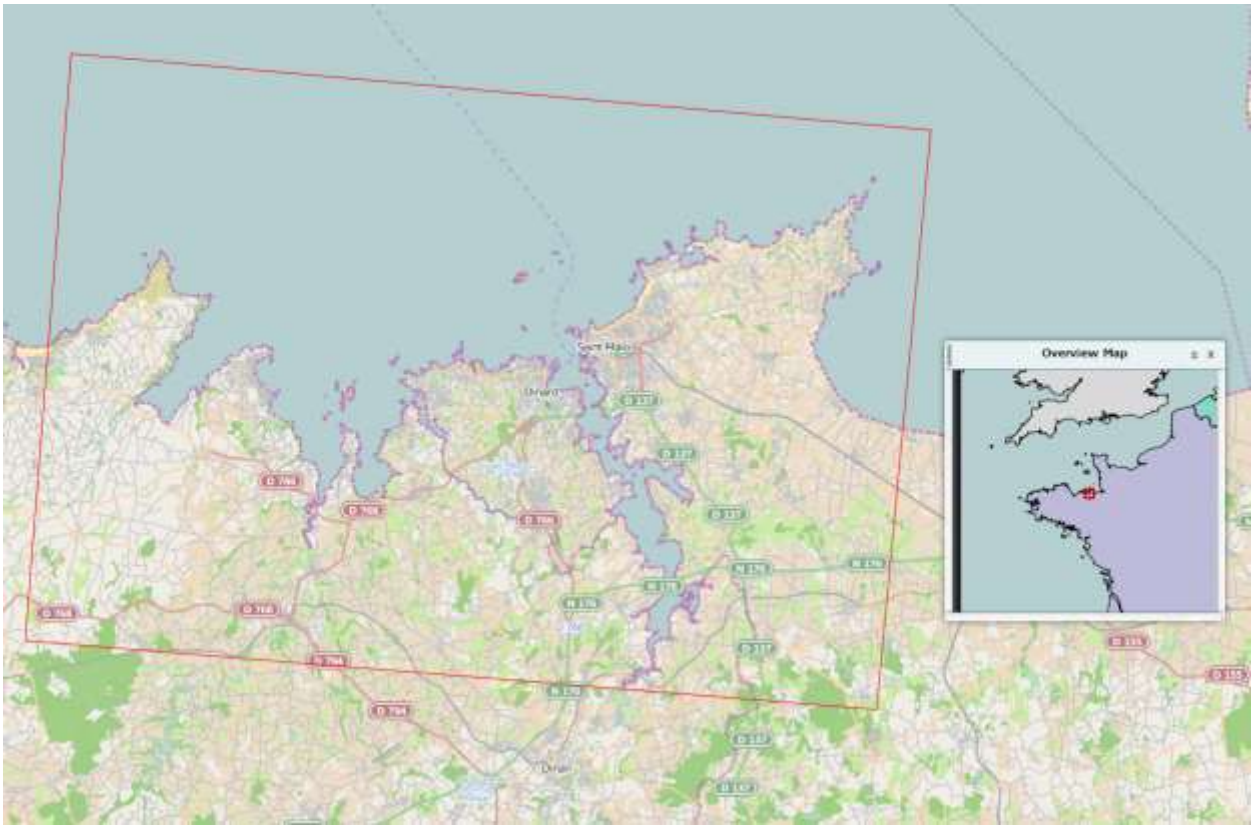

Figure 3H1. Map of the Côte d'Emeraude study area.

3H.1 Introduction to the Cote d'Emeraude Study Area

In Northern Brittany, the "Côte d'Emeraude" is located on two departments: Ille-et-Vilaine (with Cancale at its eastern limit) and Côtes d'Armor (Cap Fréhel being the western limit), and represents just under 100 km of coastline. The name 'Côte d'Emeraude' is quite recent, dating to the end of the 19th century it corresponds to a tourist area without any proper cultural or political identity. Located along the English Channel, the Côte d'Emeraude comprises numerous bays and capes as well as peninsulas, islands and islets, in addition to important geographical features such as the Rance and Arguenon rivers estuaries.

Tourism has developed very quickly in this area since the middle of the 19th century, with various coastal constructions such as dykes, embankments, roads and buildings having created an 'artificial' coastline. The economy of this area mainly relies on tourism, with an important demographic development along the coastal belt. Beyond the buildings occupied by inhabitants, there are many secondary residences and establishments dedicated to tourist activities such as hotels, a casino and spa. This tourist economy is based on the coast and the attaction o fhte maritime environment. In spite of the attempts to manage the position of the coastline with dykes and embankments, it is important to remember that the shoreline has changed. Sedimentary and climatic changes have played a great part in these changes, as well as storms.

Recently, new mesures have been taken to protect populations and installations, mainly after the Xynthia storm (in 2010), when the prescription of a Risk Prevention Plan – Marine Submersion (PPR-SM) has been set up for all the coastal parishes (Collective, 2009 and 2013), governed by the Environemental code (since 1995). Frequenlty, coastal protection structures are damaged during storms due to a combination of waves, high tides and a storm, e.g. in 1905

when the Saint-Malo dike was partly damaged. Nowadays, private structures along the Saint-Malo dike are regularly damaged by climatic events.

3H.1.1 Geomorphology of the Area

This section outlines the key geological and geomorphological features and processes of the study area. These factors have a significant impact on the on-going changes to the coastline and associated sites, deposits and features preserved related to the archaeological and heritage resource, in addition to being depicted through a range of art sources.

Geological History

The geology widely explains the shapes, structures and landscapes of the coastal areas. Since the formation of the geological features, the erosion and the long term resistance (several millions years) have underpinned the present landscapes. Erosion acts differently according to the geomorphology (cliffs, beaches) and the bedrock material (limestone, granite). Within the general geology of the area, there are metamorphic rocks to the east (from Cancale to Saint-Jacut), Precambrian sediments [top of Earth-590 Ma] (Saint-Jacut Fort La Latte) and magmatic cadomian rocks and Paleozoic sediments (Fort La Latte in Cape Frehel) (Graviou 2012: 14-18; Plaine and Jegouzo 2012: 14-17; Le Goff *et al*., 2009, Cogné *et al.,* 1980).

One of the main geological features in this area is the Massif of Saint-Malo (Jonin 2008 : 50-53), which is ‘cut’ by the Rance river estuary. The Massif de Saint-Malo has a ‘*metamorphic continuum*’ from micaschist and gneisses green schist features (south) to anatectic granites (north) through the rocks of amphibolite 'facies', which makes this zone, among other things, of major interest within geology education. Originally it was silty or more sandstone, rich in alumina, sometimes more calcium, the base of the sedimentary pile lying north in the current part migmatitic. All these sediments of Brioverian lower age (590-600 million years? were affected by metamorphism ‘Low Pressure - High Temperature’, within the Cadomian chain, around 540 million years ago. They also recorded several episodes of deformation, probably three, more or less easily identifiable on the outcrop or that are deducible from regional measures of 'schistosity' or foliation.

Geomorphologic Processes and Human Intervention

The sedimentary superficial deposits of the northern coast of Brittany, between cap Fréhel and Saint-Malo, were recently studied using side-scan sonar data, sediment analysis of subtidal and tidal facies, and morphological analysis of intertidal and shallow-water areas (Bonnot-Courtois *et al*. 2002). The tidal range in this area reaches 14 metres during high spring tides, giving rise to strong tidal hydrodynamics. The intertidal sedimentary deposits have a complex distribution linked to the wide range of coastal geomorphology.

The subtidal zone is dominated by coarse-grained deposits, which are the main offshore sediments. Grain-size progressively decreases until close to the shore where sandy sediments overly the bedrock. The superficial sand cover in places shows various bed forms at water depths of 5 to 15 metres. The coastal zone is characterised by numerous rocky outcrops and very coarse grained sediments distributed widely over the mapped area; it is an abrasion platform that evolves under very high hydrodynamic conditions and consequently has a poorly developed sedimentary prism.

The shoreline of the coast has undergone many changes. In the eastern part, strong tides (among the largest in Europe) have caused long term landscape change, eroding cliffs and bringing sediment into bays. Climatic events such as storms and tidal waves have an undeniable impact, they can alter the coastline either temporarily or in the long term (storms can

fill bays). More than 40% of the erosion is caused by storms and marine activities such as wave action or flooding of low-lying areas (Hénaff *et al* 2007). This change in the coastline may cause changes in human activities (fishing, sailing).

The erosion is exacerbated by humans, with actions such as the modification of river banks, aggregate extraction in river beds and sea drainage of coastal marshes, and planting work impeding natural transit of sediment. The construction of beach frontages, followed by the building of sea defences against erosion, often accelerate erosion. The extraction of sand near sea sedimentary shores further accentuates this erosion.

In the Rance river estuary, the building of the Rance Tidal Power Station in 1966 (which takes advantage of the huge tide potential) had a great impact on the estuary and river landscape and activities; the dam provides electricity to the surrounding cities but deeply impacted the sediment budget of the river and of the estuary. Indeed, there are significant sediment supplies with artificial immobilisation of several hours of sea water upriver, promoting sedimentation of fine particles. Then, there is a silting of the Rance, with an extension of mudflats (accumulation of up to 3m). This brings various consequences: reducing the width of the channel (which decreases the flexibility for use by ships), modification of wildlife since some fish only reproduce in the sand. The estuary of the Rance River is now entirely shaped by human actions (Bréhier *et al*. 2009-2010).

In order to protect the main tourist coastal cities, such as Saint-Malo, against erosion, numerous dykes have been built along the coasts, even when some geomorphologists had pointed out that such structures may speed the erosive and sedimentary processes. During the early 19th century, the northern coast of the municipalities of Saint- Malo and Paramé consisted of dunes occupied by windmills and industries. The first works to build a dyke were achieved in 1854 in the municipality of Saint-Malo at the east end of the furrow between the wedge and the Piperie mill belonging to MM. Challah and Le François. In 1856, M. Palmié completed a defensive wall 270 meters long, continuing from the first dike (called "*dike Tourou*"), to protect its lime kilns and other industries. In 1853, a violent storm seriously damaged the existing defenses. In October 1856, the government approved the draft continuation of the dyke, increasing its length to 449 meters. The work of the "Dunes dykes" was completed in 1858. After several additions and recognising the importance of the dyke to the emerging tourist seaside resort of Paramé, the Société des Bains de Mer decided to fill the gap of 3 meters from the dike Lemoine to align it with the dike Dunes. Stairs were built in 1887 for access to the beach. Benches were installed by 1900, street lights in 1909. To protect the new villas, the dam was repaired in 1887 by the State. In 1903, the project to repair the dam Lemoine to the rear of the Hoguette was achieved through management. The dam in its current state extends over 900 meters between the wedge and the Piperie Rochebonne and has been fully built or rebuilt by the state between 1854 and 1905 (Figure 3H2).

Coastal evolution is sometimes said to be forced by storms, sometimes by average meteorological conditions; this point has been documented by geomorphologic studies (Regnauld *et al*., 2010), especially on the Verger Bay site. The exact role of very strong storms is therefore a widely debated issue. On the northern coast of Brittany, a site located in the eastern part of the Côte d'Emeraude, Verger Bay, has been surveyed for the last 20 years and has evolved under the control of human management, long periods of calm weather and three large storms. The weight of each of these agents on coastal evolution has been examined. Their respective impact is highly variable in time and in space, thus making it very difficult to understand coastal behavior with a simple conceptual model of forcing, controls and resilience.

These notions do not have the same meaning depending on where they are applied but storms appear as the main forcing agent on a large extent of the studied coastline.

Figure 3H2. The Saint-Malo/Paramé dyke after the 1905 storm (ancient postcard H.L.M ed.)

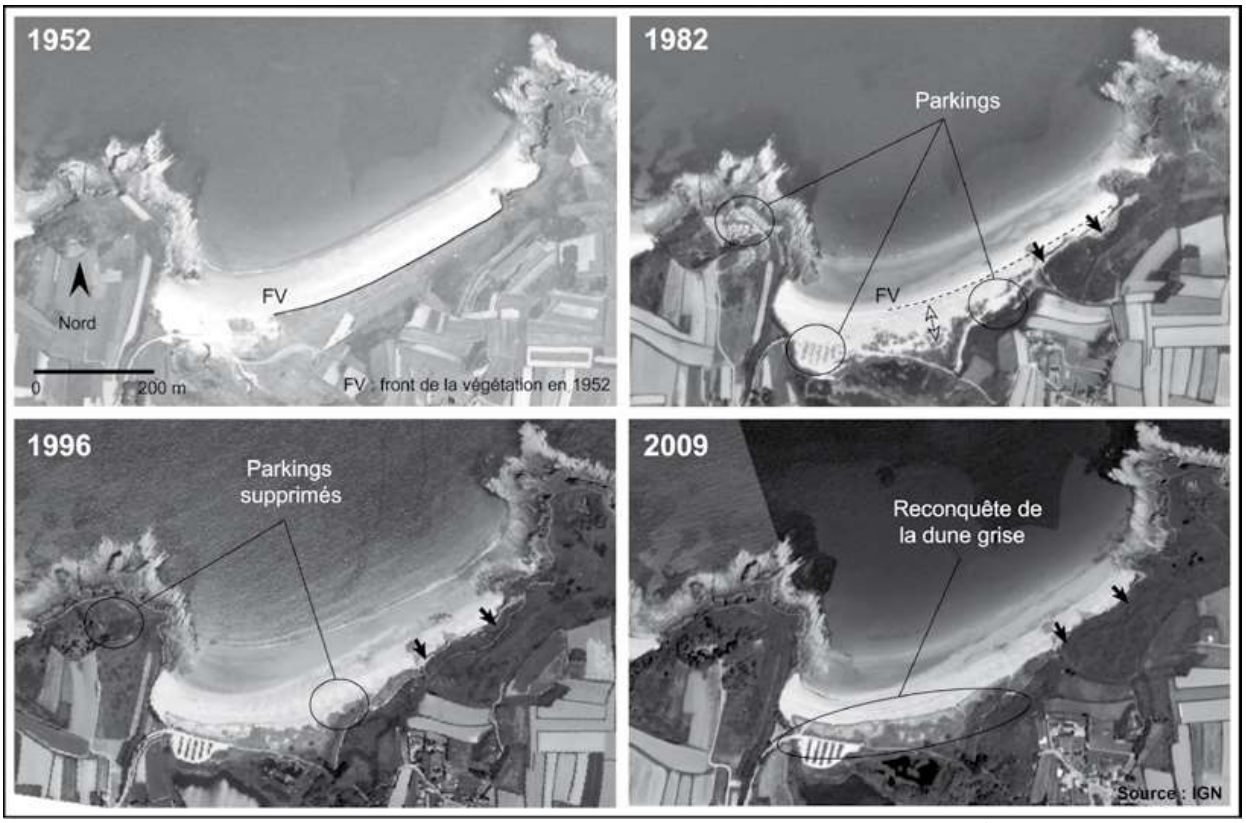

Figure 3H3. Evolution of the Verger Bay case study site, based on IGN (Institut Géographique National) air photos, showing the coastline changes and the main natural and anthropic causes (building then removal of the car parks) (after Regnauld et al., 2010)

In northern Brittany, an important geomorphological response to Holocene sea level rise has been the development of coastal dunes with associated lagoons and marshes. At Verger Bay (Figure 3H3), a marsh has formed behind a dune system which has been developing *in situ* for the last 4000 years. The litho-stratigraphy of the marsh comprises extensive peat formation, with sands, silts and occasional sand lenses, the latter probably associated with storm surges. The sequence dates from 10,320±120 BP. After 3000 BP, flood episodes on the marsh are more common, while the upper marsh deposits can be correlated with the recent period of dune building. Prehistoric artefacts (remains of cooking implements) have been found on a cliff to the east of the marsh and are buried by wash over deposits, which indicate a sudden abandonment of a settlement possibly due to a storm surge soon after 2460±80 BP. Surge levels are proposed as a controlling factor on dune crest elevation (Regnauld *et al*., 1996).

3H.1.2 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for Project

The archaeological and palaeoenvironmental data has been obtained from the Atlas des Patrimoine (Culture Ministry), available online (http://atlas.patrimoines.culture.fr/atlas/trunk/), and from the databases of scientific research groups: AMARAI (Association Manche Atlantique pour la Recherche archéologique dans les Îles) and CeRAA (Centre regional d'Archéologie d'Alet, Saint-Malo). Extensive documentation was also provided by the Archéosciences laboratory of the Rennes1 University, which is a component of the federative research group Unité Mixte de Recherche 6566 du CNRS- CReAAH (Centre de Recherche en Archéologie, Archéosciences, Histoire). Another important resource centre for historical periods is the 'Society of archaeology and History of the Saint-Malo area'; dedicated to maritime history, and especially shipwreck studies, the ADRAMAR (Association pour le Développement de la Recherche en Archéologie MARitime) provide an important documentary set, now available online (Atlas Ponant et Atlas des 2 mers: http://adramar.fr/atlas/). Several books concerning the history of the region have been consulted and used (Giot *et al*., 1995 and 1998; see also References Section 3H.7 below), as an abundance of historical literature exists for this region, due to the richness of its past history and stimulated by the importance of the tourist industry.

3H.1.3. Summary of the Archaeology and History of the Côte d'Emeraude Study Area

The archaeological and palaeoenvironmental study area is quite well known, thanks to the research carried out by two research groups:

- The 'Centre Régional d'Archéologie d'Alet' (Ce.R.A.A. created in 1974) which enabled the discovery, excavation and study of several major archaeological sites in this area, situated on the coast as well as inland; and
- The 'Association Manche Atlantique pour la Recherche Archéologique dans les Iles' (AMARAI, created in 1988) is more specifically focused on coastal and island archaeology.

Numerous archaeological sites are known in this area, but many of them have been damaged or destroyed along the coasts, due to various reasons: natural erosion, climatic events, or anthropic pressure. WWII had a particular impact as the city of Saint-Malo and the surrounding area was considered as a strategic area; the Atlantic Wall was built along with numerous concrete structures built on places where archaeological remains had been formerly foun. Many archaeological sites also suffered from bombing, e.g. on Cézembre island where a famous pre-roman settlement was destroyed in 1944.

Early Prehistory (Palaeolithic and Mesolithic)

Some Paleolithic sites are currently on the foreshore, showing the rise in sea level since their construction (e.g. Port-Briac Cancale). Paleolithic sites have existed on the islets and islands of the Côte d'Emeraude, however, some of them were destroyed by military structures, particularly during WWII (an example being the Grand Bé site (Saint-Malo) where bunkers were built). Many islets and islands are accessible at low tide, especially between Dinard and Saint-Malo. The presence of archaeological remains on these sites, suggest that with the rise in sea level, many other remains are now submerged or missing (source: CeRAA - Centre Régional d'Archéologie d'Alet).

The Gastines site at Saint-Marc-en-Poulet (Ille-et-Vilaine), on the western bank of the river Rance, lies on the beach. It consists of an open camp dated from the middle Palaeolithic period, located near a rocky cliff. The site provided evidence of lithic industry (flint), but no bone remains or charcoals were preserved. No anthropic structure was visible and the archaeological interpretation is only based on the lithic industry. However, the main part of the site has probably been destroyed by erosion (Monnier 1988).

At present, there has not been any archaeological excavation of any Mesolthic sites in the area, however, some prehistoric layers containing microlithic flint remains have been identified through fieldwalking surveys. The Mesolithic layer at the la Varde peninsula is associated with a contemporary fishtrap, making this site one of the most significant in the area.

Later Prehistory (Neolithic, Bronze Age and Iron Age)

These periods are illustrated by several archaeological sites. On Verger Beach (Cancale), an important shell midden at la Moulière is included in the small sandy cliff and has been seriously eroded by the waves and the pedestrian path leading to the beach. According to the radiocarbon dating, the site was occupied between the early Bronze Age and the early Iron Age. Next to this, a metal age layer has been found on the beach, characterised through ceramic sherds (Cocaign *et al.* 1996 : 71-81).

For the Iron Age, the main site is the coastal cliff castle of Alet (Saint-Servan), located on the right side of the Rance river mouth, and studied since the 1970's, with an intensive excavation program (Langouët, 1996: 31, 34). It consists of a pre-Roman town, densely settled and largely focused on commercial activities as a port of trade (*Reginca*) which was closely linked to Hengistbury Head (Dorset, UK). This pre-Roman town is located at a strategic crossing point for river, land and maritime routes, the exchange networks and long distance trading are illustrated by the numerous finds of goods coming from the Mediterranean area as well as from across the English Channel.

Roman Period

Even if the city of Alet had been partly abandoned after a great fire c. 20-25 A.D., the site was still occupied during the Roman period (Figure 3H4); at the lower edge of the city, some port installations have been found in the tidal and underwater area, including a basin and a wooden pump used to supply fresh water to the ships which were moored at the quay. Intensive underwater excavations in the estuary enabled the port to be located. The main landscape changes since the Roman period date to the 4th century when the topography was transformed by breaking through the alluvial bank, which was isolating Solidor Bay from the sea (Langouët, 1996). Such environmental changes explain the discovery of a Roman cemetery at the foot of the Solidor tower, during the building of a new quay in the 19th century.

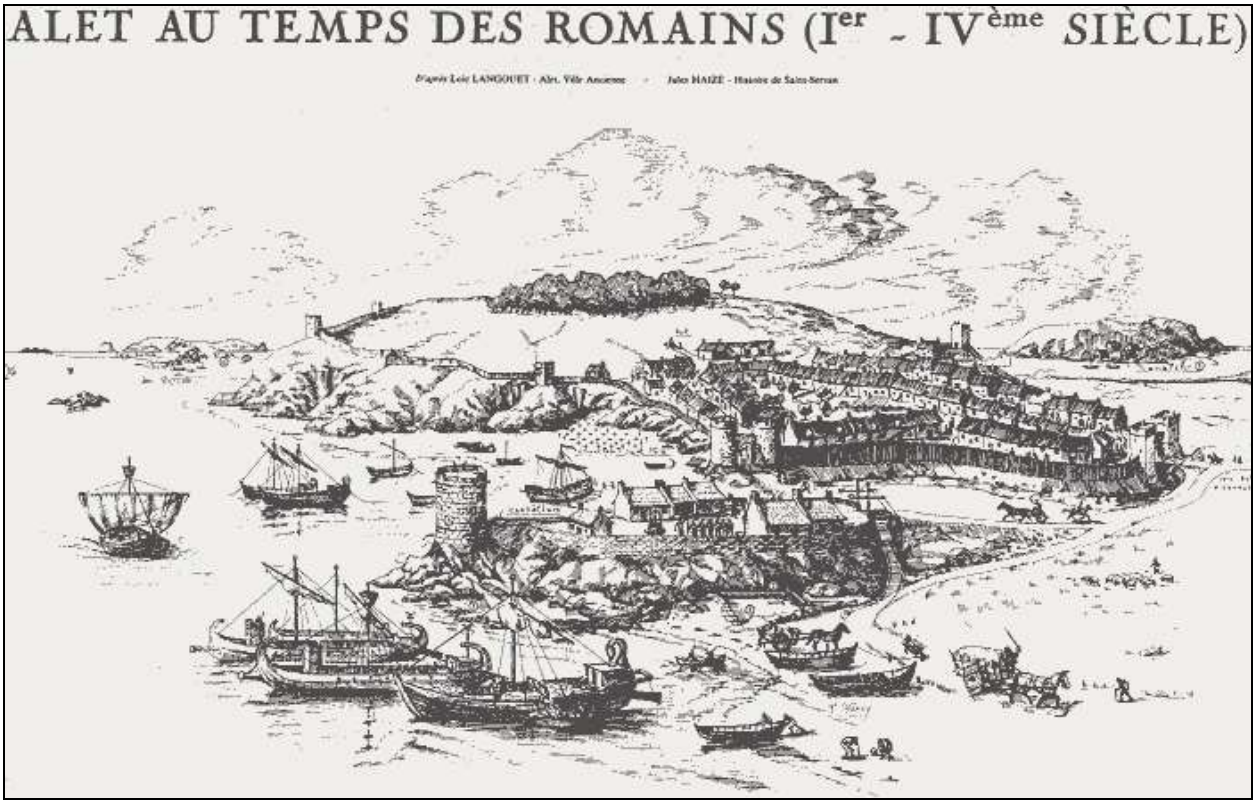

Figure 3H4. The Alet (Saint-Servan, Saint-Malo) castellum and harbour, during the Roman period (after Langouët and Haizé).

Medieval Period (500AD – 1485AD)

During the Medieval period several castles and fortresses are built at various strategic points on the coast. At the foot of Mont Garo (Saint-Suliac), the 'Viking' camp named 'Gardaine' provides a good illustration of sea level evolution and coastal changes (Figure 3H5). Located in the river Rance estuary and probably built after the 10th century AD, this earth camp is currently partly submerged. Since the building of the Rance Tidal Power Station in 1966, the amount of sediments deposited around the site increased, which is now more easily reachable on foot. This camp was originally a defensive installation, consisting of several lines of wooden posts. During the 19th century the site was damaged and some parts of the banks were destroyed, allowing sea water to invade the inner part of the enclosure. Among the various materials found in the camp are animal bones and iron weapons. The strategic position offers some landing possibilities, as well as control of the fluvial and maritime circulation of ships. Located next to the Châteauneuf-d'Ille-et-Vilaine isthmus, the only way to cross the marshes and gain access to the Clos-Poulet area, the Gardaine camp is also likely to have played a role in controlling land transportation and movement (Langouët 1991).

Figure 3H5. The "Viking camp" of Gardaine, Saint-Suliac (cl. L. Langouët).

Another site from the later medieval period is Fort Lalatte (Plévenon), this military construction was built around the mid 14th century AD, with significant later additions, particularly in the 17th century. It is one of the best examples of coastal medieval fortification with its main fortified tower still preserved. Located on a cape, this fort is linked to the control of the Bay of la Fresnaye (and then of the Saint-Malo port). Other fortified sites include the Chêne vert castle (Plouër-sur-Rance), built on the remains of a medieval fortress (13th-15th centuries) along the Rance river. The Guildo castle (Créhen) is built on a rocky promontory dominating the Arguenon river estuary. The remaining visible structures date from the 14th-15th centuries, however, according to the results of archaeological excavations, the first occupation of the site goes back to the Iron Age.

Several chapels and churches have been built along the coastline during the medieval period, e.g. on the Cézembre island, where a chapel was built during the early 15th century, dedicated to saint Brandan. Later on, a monastery existed on the same island.

In the Rance river estuary, there is a tide mill which consists of a dam and associated channels which utilize the tidal movement of sea water to create energy to run the mill. While millers used this natural energy to grind grain, the process of the installation of dikes changed the sedimentation of the estuaries. Many of these mills date from the late Middle Ages to the Modern period, but most of them were abandoned during the 20th century.

Post-Medieval Period (1485AD – 1901AD)

A significant feature of the Post-Medieval period in this case study area is the building of coastal military defences, most of them belonging to the group known under the general name of ‘Vauban’ fortifications, which generally lie over former structures: islets of Petit Bé, la Conchée, Harbour, Cézembre island, off the city of Saint-Malo and the Alet fortification, are all dedicated to the protection of Saint-Malo.

In addition, numerous shipwrecks line the bay of Saint-Malo and reflect the rich maritime history of the city (Feige 2005). From 1590–1593, Saint-Malo declared itself to be an independent republic. Saint-Malo became notorious as the home of the corsairs, French privateers and sometimes pirates. The corsairs of Saint-Malo not only forced English ships passing up the Channel to pay tribute, but also brought wealth from further afield. Jacques Cartier, who sailed the Saint Lawrence River and visited the sites of Quebec City and Montreal – and is thus credited as discovering Canada - lived in and sailed from Saint-Malo. The maritime and military history of Saint-Malo is one of the richest of the region.

In the 19th century, the reputation of Saint-Malo and, more generally speaking, the Côte d'Emeraude area, is basde on the development of seaside resorts, particularly since 1830. This lead to the development of the marina, dykes, and paths along the coast and on the beaches. These port and tourist developments often caused a reduction of erosion on the nearby beaches. Due to these developments, traditional human activities on the foreshore such as seaweed farming, collecting sand, and sea life collection disappeared progressively in favour of the tourist economy. For example the ancient fishing port of Dinard became exclusively a beach resort and a sailing port.

The natural landscape has been totally modified, not only by the building of numerous holiday houses, but also by the planting of exotic and imported trees such as acacias, Chinese palm trees, and cedar from Atlas. Some promenades are arranged along the water side, such as in Saint-Malo where there was a path from as early as 1767; the promenades often reused former coastal control paths.

There is a regional tradition of the exploitation of marine products along the coasts, especially with fish traps (Langouët and Daire, 2009, for more details, see the Trégor case study (Section 3I)) and fishing remains an important economic resource for local communities. The exploitation of seaweeds developed with industrial use of soda (especially in gall industry), and is currently marked by the remains of dedicated kilns. The exploitation of clay along the coast (e.g. Sillon beach in Saint-Malo) is linked to industrial activities such as pipe productions, which were then sold locally and also overseas.

Most of the cities of the Côte d'Emeraude area have an economy based on marine fishing (fish and crustaceans) and coastal collection of seafood at low tide. Saint-Malo also developed wider trading activity, with the building of dedicated structures (harbours, ports areas) and shipyards which evolved, mainly since the 16th century, linked with colonial trade and offshore fishing.

Modern

Since the middle of 19th century the emergence of tourist resorts is closely linked to the birth and development of the national railway networks (Clairay and Vincent 2008). Once the preserve of the aristocrats, visiting the seaside for enjoyment and health became more widely available to the population from the mid 1930s (Delignon, s.d.), and fuelled the need for coastal structures such as promenades, hotels and spas. New eating habits emerged with a growth in demand for seafood; oysters farms, some of them exiting since the 16th century, rapidly developed, especially in Cancale bay and the Arguenon estuary, and are still very productive.

The majority of sites from the 20th Century comprise WWI and WWII defence systems. The construction of the Atlantic Wall along the coast, in the 1940s, had various consequences. Concrete military installations along the shore included bunkers, batteries, guns etc, many of which were situated in strategic areas, transformed the coastal landscape. However, the destruction of these installations during the Liberation (through blasting and disassembly, e.g.

bombing of Cézembre island, Cardin 2003-2004) also caused the complete destruction of archaeological and historical sites.

Figure.3H6. Saint-Servan harbour in the early 20th century (cl. Gauthier).

3H.1.4 Art History of the Area

This section presents the background to artistic representations within the area including key schools and individual artists. This provides the background to the broader consideration of individual artworks within the study area. In this area, the priority has been given to the analysis of art works as there is extensive documentation available to illustrate historical changes within the coastal landscape. The analysis includes paintings, watercolours, engravings, photos and ancient postcards.

The variety and richness of the types of coast in the area has attracted artists which have created large numbers of depictions (paintings, prints, watercolours, photos etc), especially since the nineteenth century, which was marked by the rise of seaside tourism especially along the Côte d'Emeraude.

Introduction

The art study area extends for a distance of a bit less than 50km, from Cancale in the east to the cap Fréhel in the west. The approach for the coastal study site aimed to demonstrate the role that historical works of art (oil paintings, watercolours, and prints) can provide in terms of supporting understanding of long-term coastal change and assist in understanding of the chronology of coastal change in the Côte d'Emeraude. A number of examples are provided of those artists' works which form reliable records of coastal conditions at the time they were painted.

Literature Review

The coastline of Côte d'Emeraude benefits from a rich landscape art heritage, closely linked to the touristic history of the area during the 19th century. Some of the most notable specialists in

the study of the history of Breton paintings and painters are D. Delouche (Delouche 1996 and 2003) and A. Cariou (Cariou, 2011), who have considered the tradition of general landscape representations inland as well as along the coasts. Recently, some authors drew attention to the pictures of humid zones, which are currently under the attention of ecologists (Goeldner-Gianella *et al*. 2011), especially in the coastal area.

Cotes d'Emeraude Art Resource

The main are collections are located in regional museums such as Musée des Beaux Arts de Rennes, and local art galleries such as the Musée Yvonne Jean-Haffen (Dinan), the Musée Mathurin Méheut (Lamballe), as well as private art galleries which are especially numerous in the city of Dinard. However, concerning this specific area (Côte d'Emeraude), the main resources for researches were illustrated books, with a wealth of paintings and drawings that form the largest number of illustrations of the study area coastline.

The most prominent artistic figure is Eugène Louis Gabriel Isabey (1803-1886) who was a French painter, draftsman, and printmaker (Leribault, 2012). Born in Paris, the son of Jean-Baptiste Isabey, a painter as well, Eugène Isabey studied and worked at the Louvre Museum. Early in his career his paintings consisted of mostly watercolor landscapes. In 1820, he travelled to Normandy and Britain painting land and seascapes, especially in the Côte d'Emeraude area (Figure 3H7). After 1830, he switched to narrative and historical painting. He was later selected to become one of Louis-Philippe's court painters.

Another important artist is Emmanuel Lansyer (1835-1893), considered as one of the best landscape painters of his time, with Corot; his work includes more than 1,500 paintings, including many Breton landscapes with numerous views of Saint-Malo and the Ellé river. Lansyer settled in Douarnenez during his summer holidays which helped draw other artists to the town during the late 19th century.

Figure 3H7. The Grand Bé island, at low tide, Saint-Malo (watercolour by E.L. Isabey, c. 1820). Source Joconde, Ministère de la Culture. http://www.culture.gouv.fr/public/mistral/joconde_fr.

3H.1.5. Cote d'Emeraude Art Resources Consulted for the Project

For the Côte d'Emeraude area, the art ranking and analysis benefited from an academic study (Master2) led in the Rennes 2 University (Motte 2013), under the direction of H. Regnauld, with help from M.-Y. Daire and R. McInnes. The theme of the dissertation was: *Representation and Evolution of the Shoreline: What do regional paintings can teach us about the Breton coastal environment*? In order to establish the art resource available for this study, it was necessary to review the topographical paintings, drawings and prints held by the principal national, region

and local collections. The analysis has questioned the scientific value of iconography when it is used as a source for understanding the evolution of coastal landscape. From a corpus of ancient illustrations representing shorelines in Brittany, a study of coastal change during the last centuries is proposed. The points from which the artists were painting were relocated and photographs taken. A comparison of the two images allowed an assessment of the exactness of the work of art as an objective source of knowledge. Then detailed study of the images highlights specific landscape changes, which are recorded through a consistent methodology. A synthesis of results is compared with other available historical data enabling conclusions over whether a set of paintings provide accurate representations of landscape changes in Brittany. This research work aimed to exploit these representations as a source of scientific information able to increase knowledge about physical evolution of the coastline, particularly offering an approach over a longer period than it is possible with visual materials traditionally used in geography such as photographs and satellite images.

3H.2 Current Environmental Impacts/ Threats and Coastal Management Approach

This section considers the current environmental impacts and threats along the coastline and reviews the current coastal management issues and approaches.

3H.2.1. Review of Key Contributors to Coastal Change

Along the coasts of Côte d'Emeraude the natural erosion combines with a strong anthropic pressure. The coastal evolution of this area can be explained by a combination of several factors:

- There are many human developments, especially around the major tourist cities where buildings have changed the shoreline (e.g. port of Saint- Malo), land has been reclaimed from the sea and new dykes have modified the sedimentation process.
- Significant weather events (storms, tidal waves) can set back the coastline for a few hours or permanently mark the landscape.
- Natural erosion can be hastened by human activities (especially intensive agriculture).
- Exotic plantations near the coast of trees that are not normally suitable for this type of land (due to wind, rain, salt); e.g. intensive plantation of pine trees along the coasts proves to be disastrous as under the trees secondary short vegetation disappears; consequently the land becomes vulnerable to rain water streaming and erodes much faster.
- Intensification of coastal occupation leads to a strong urban pressure (economic attractiveness), pressure from tourism (with mass tourism, camping, etc), and the development of many activities (aquaculture, seaweed exploitation, biochemistry, etc) which require infrastructure.
- A particular example in this area is the use and extraction of silica sand and gravel in the Gulf of Saint-Malo which can change the seabed. These human activities change the coastline, impacting sediment exchange and current sediment levels.

Coastal evolution is sometimes said to be forced by storms, sometimes by average meteorological conditions; this point has been documented by geomorphological studies (Regnauld *et al*., 2010), especially at the Verger bay site (see below). The exact role of very strong storms is therefore a widely debated issue. On the northern coast of Brittany, a site located in the eastern part of the Côte d'Emeraude, Verger bay, has been surveyed for the last 20 years and has evolved under the control of human management and the impacts of long periods of calm weather and of three large storms. The weight of each of these agents on coastal evolution has been examined. Their respective impact is highly variable in time and in space, thus making it very difficult to understand coastal behavior with a simple conceptual

model of actions, controls and resilience. The coastal response to each of the actions is not the same in different areas, however, storms appear to be the main shaping force on a large extent of the studied coastline.

3H.2.2 Summary of Current Coastal Management Approach

Coastal risk management is a responsibility of coastal local authorities in partnership with the the regional and national environmental agencies. The Natura 2000 (EU, ratified by French government in 1996 ; Ministère de l'Ecologie, Cartographie de l'Inventaire National du Patrimoine Naturel) protects several zones in the Côte d'Emeraude area, such as the Arguenon estuary, Saint-Malo and Dinard archipelagos, the Cap Fréhel, the coastline between Cancale and Paramé, and the Rance river estuary with the islets of Notre-Dame et Chevret. This legal control tool limits human building and structures, taking account of two key features: birds and natural habitats. The main goal of this network is to maintain or to bring back a stable situation, favorable to the preservation of natural habitats, especially for wild fauna or plants recognised as of community interest.

In the Côte d'Emeraude area (Figure 3H8), the Conservatoire du Littoral owns several properties: Verger bay, Besnard islet, des Landes island, and several capes: la Varde, le Décollé, Meinga and Nick. In these areas access is limited (and forbidden during bird nesting season), the paths have been marked out in order to keep large areas of land free of human presence (stamping) and to favor the progress of natural formations (e.g. dunes).

The Rance estuary is protected as a 'Zone Naturelle d'Intérêt Ecologique, Faunistique et Floristique', meaning that no structures can be built in this area (thanks to a law adopted in 1982 and reinforced in 1983; Inventaire National du Patrimoine Naturel, Cartographie de l'Inventaire National du Patrimoine Naturel). The 'ZNIEFF' consists of an inventory plan of the natural and scientific resource, describing and identifying the zones of high biological potential.

In the wake of the Xynthia storm in 2010, the building of new houses is not permitted in the eastern part of Côte d'Emeraude (Saint-Malo, Cancale, Saint-Coulomb) if the soil level is equal or lower than the sea level (urbaplu). The general councils of Côtes d'Armor and Ille-et-Vilaine departments have bought some areas, in order to manage and protect them in cooperation with European structures.

Some additional rules concern important areas for the protection of wild birds (EU since 1979), or the creation of regional nature parks, e.g. the 'Rance Côte d'Emeraude park' (since 2008) for the preservation of natural maritime and coastal heritage.

Figure 3H8. Map of the Côte d'Emeraude study area, featuring the protected zones (after Geoportail, 2013).

3H.3 Ranking Artistic Depictions

The ranking systems developed for artworks, historic photographs, maps and sea charts were applied to each of the selected depictions, the results are described in more detail below.

3H.3.1 Art Ranking

Compared with the state of the art on the other side of the English Channel, and referring to R. McInnes works within the UK case study areas, for the French side there was a slight adaption of the methodology to make it applicable specifically to the Brittany coast (type of coast and different artistic tradition).

The art approach benefited from the academic work of E. Motte (Motte 2013). Research on the painters of the Emerald Coast region used the database of the Ministry of Culture. Here, we mainly considered Eugène Isabey (1803-1886), who represented many landscapes of Brittany and Normandy, and Théophile Busnel (1843-1908) who was an illustrator, including work for newspapers. It is also important to highlight Felix Benoit as one of the most accurate artists for the depiction of the coasts, as he produced very fine and precise engravings of several areas of the Côte d'Emeraude.

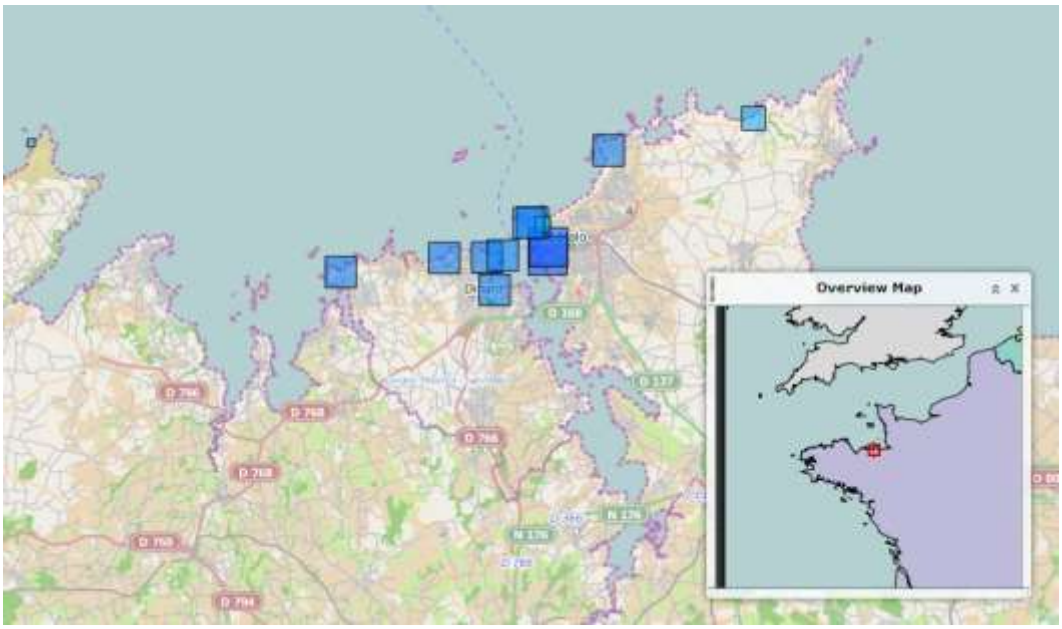

Figure 3H9. Location of art images (paintings) in the Côte d'Emeraude case study area.

The development of the ranking system is described in Section 2. By entering the data on artwork type, medium, subject matter, time period and other parameters, the database was then able to calculate the ranking scores for ten works of art from the case study site.

Artists tended to represent either the landscape as it is or from a certain perception providing their interpretation. They mostly focussed on the Rance river estuary, i.e. Saint-Malo and Dinard areas (Figure 3H9), which were the main attractive zones popular with tourists. Analysis of the accuracy of artists reveals that most 'liberties' taken with depictions involve changes to forms and proportions. However, the paintings generally give good indications of the geomorphology and vegetation.

The highest ranking, a painting by E. L. Isabey, scores 74; he was one of the most accurate painters for the visual depiction of coastal landscapes. However, due to the cohesion of the painters' styles, all the scores reach a (more or less) medium rank, without great difference between the total values. The main category of artwork consists of watercolours, which generally permit more nuances within views and perceptions. Due to different backgrounds and techniques, the works of artistis do not reveal the same sensitivities. E. Isabey willingly represents landscapes while T. Busnel depicts characters.

Table 3H1 include the 13 paintings reaching the highest scores. A more detailed explanation of some case study sites and the interpretation of the individual artworks is provided below.

ID No	Location	Artist	Date	Score type	Score style	Score environment	Total Score
113	Baie de Dinard	Eugène Isabey	1864	Water-colour	Topographical	Detailed view	66
118	Baie de Saint-Servan (Saint-Malo)	Eugène Isabey	1850	Water-colour	Topographical	Detailed view	74
109	Fort Duguesclin (Saint-Coulomb)	Théophile Busnel	1913	Chromolitho-graphie	Picturesque	General view	55
	Saint-Enogat	Eugène	1850	Water-	Topographical	General view	59

114	(Dinard)	Isabey		colour			
119	Plage de Saint-Servan (Saint-Malo)	Eugène Isabey	1850	Water-colour	Topographical	Detailed view	74
110	Remparts de Saint-Malo	Eugène Isabey	1870	Water-colour	Topographical	General view	66
115	Baie de Saint-Enogat (Dinard)	Eugène Isabey	1850	Water-colour	Topographical	General view	59
111	La Grande porte de Saint-Malo	Unknown	1820	Oil	Picturesque	Detailed view	48
116	Baie de Saint-Malo	Eugène Isabey	1850	Water-colour	Topographical	General view	59
117	Le Grand Bé (Saint-Malo)	Eugène Isabey	1864	Water-colour	Topographical	General view	59
258	Port Hue Beach (Dinard)	Alexandre Nozal	End of the 19th cent.	Water-colour	Topographical	General view	59
259	Pointe du Moulinet (Dinard)	Duroy-Bateau	1850-60	Drawing	Picturesque	Detailed view	59
260	Cap Fréhel (Plévenon)	Felix Benoit	1865	Engraving	Picturesque	General view	29

Table 3H1. Top art ranking results for the Côte d'Emeraude study area.

3H3.2 Historic Photograph Ranking

The historic photograph resource, particularly of old postcards, available dating from the 19th century onwards is very rich for the study area, mainly due to its popularity for tourism. The photograph ranking system was applied to images primarily chosen from locations along the coastline where historic paintings and archaeological sites were also known. Hundreds of historic images exist for this stretch of coastline, it should be noted that this study was not intended to be exhaustive, it aimed to highlight the potential for historic photos to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums and galleries, as well as private collections has the potential to provide many more.

The majority of photos assessed were of heritage views, containing features which can be identified today, the oldest photo assessed was taken in 1853. For the Côte d'Emeraude area, where available photos were very numerous it was necessary to select the most informative ones relating to coastal change. The photographs reaching a total score of 100 were selected as being the most representative for the assessment of coastal change or illustrating the presence of heritage sites along the seashore. In this area, archaeological heritage is scarcely represented within photos. Geological features are illustrated by L. Collin, who was a geologist of the Rennes University during the first half of the 20th century.

For this case study area, 317 photos were selected. The existence of such an important set of pictures is clearly linked to the touristic attraction of the region. This goes in parallel with the development of the tourist postcard tradition.

Figure 3H10. Location of historic photos in the the Cote d'Emeraude case study area

The most ancient photos date from the mid 19th century (1853), with the majority dating from the first quarter of the 20th century, a period when photography became more widely available to the population. These pictures generally depict the most popular tourist places, either wild landscapes such as Grouin Cape near Cancale, Cape Fréhel in Plévenon, or places of interest (grottos, historical monuments, castles, churches); but the main interest is generally the seaside resorts (Saint-Malo, Dinard, Saint-Lunaire). Thanks to this photography, it is possible to follow the landscape evolution of some places of the Côte d'Emeraude, revealing diverse changes and infrastructures (dykes, quays, etc).

The largest available photographic documentation is through the tourist postcards of the late 19th and early 20th centuries. The postcards have at two distinct objectives:

- to witness that the tourist wwas really 'there', which is why they often represent a hotel, a spa, a castle, a garden, etc; and
- to show the beauty of natural landscapes.

Many of these postcards picture the former situation of some places, before constructions on or arrangement of the shore through harbour installation, etc. These examples can often help in the reconstruction of coastal changes during the last decades and across the century.

Most of the postcards concern seaside resorts and cities (around 200). They inform us about the coastal arrangement along the coastline, and on the threats due to anthropic pressure and climatic events (e.g. the photos showing the destruction of the Paramé-Saint-Malo dyke in 1905 when a storm combined with high tides). Some ancient photos of the fortified city of Saint-Malo *intra-muros* (within the walls) exist, dating from 1853, showing the city before the harbour arrangement of the 20th century and the construction of pools and quays, at a time when the enclosed town was only reachable at low tide.

Sometimes, the photos help to rediscover some structures that no longer exist, e.g. lobster basins, formerly situated between the beach and Fort National. Some ancient postcards picture places where access is now impossible (forbidden), e.g. Cézembre island, where due to the bombing during the WWII it is still dangerous even now.

Img_ uid	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
135	Saint-Malo Intra-muros	1853	Medium		Poor	55
136	Saint-Malo Intra-Muros	1853	Medium		Poor	55
180	Fort National (Saint-Malo)	1952	High		Good	100
181	Le Chêne Vert (Plouër-sur-Rance)	1900-1925	High		Good	100
186	Le château du Guildo (Créhen)	1900-1925	High		Good	100
411	Cap Fréhel (Plévenon)	1900-1930	Poor		Good	55
660	Cale de l'épi (Cancale)	1900-1925	High		Good	100
671	Pointe du Grouin (Cancale)	1900-1925		High	Good	100
701	Moulin du Lupin (Saint-Coulomb)	1900-1920	High		Good	100
708	Le Hâvre (Saint-Malo)	1900-1905	High		Good	100
724	Digue après le raz-de-marée (Saint-Malo)	1905	High		Good	100
744	Cale de Dinan (Saint-Malo)	1900-1923	Medium		Good	100
750	L'île Cézembre (Saint-Malo)	1900-1925		Medium	Good	77
756	Parcs à homards (Saint-Malo)	1900-1925	High		Good	100
760	Débarcadère du Petit Bé (Saint-Malo)	1900-1925	Medium		Good	55
779	Rocher Bizeux (Saint-Malo)	1900-1925		Medium	Good	100
781	Hôtel Victoria (Saint-Malo)	1900-1925	High		Good	77
793	Pointe de la Malouine (Dinard)	1900-1911	High		Good	77
794	Pointe du Moulinet (Dinard)	1900-1925		High	Good	100
795	Plage de Saint-Enogat	1900-1925	Medium		Good	100
855	Digue de la Banche (Saint-Jacut-de-la-Mer)	1900-1902	High		Good	77
871	Pointe de la Garde (Saint-Cast-le-Guildo)	1900-1925		High	Good	100
884	Le Bec Rond (Saint-Cast-le-Guildo)	1900-1925		Medium	Good	77
902	Le fort Lalatte (Plévenon)	1900-1925	Medium		Good	55

Table 3H2. Top ranking photographs within the Cote d'Emeraude case study area.

Regarding the distribution, the whole case study area is covered by ancient photographs and postcards. But the highest scores (Table 3H2) seem to be linked either to the existence of a seaside tourist resort (Saint-Malo, Dinard) or to some wild landscapes, e.g. Fréhel cape.

The Table 3H2 outlines the results of the ranking; note that photographs were ranked as either a heritage view or a non heritage view. Not all the photos are equal in quality and in their informative ability. Some show very large areas of landscape in a general view which does not provide much detail on the geomorphology, but can show the general state of the landscape in a given time. In the Côte d'Emeraude area, the photographs generally feature large views.

3H3.3 Maps/Charts Ranking

Several historical maps exist of the coastline, with dating back over 400 years. These maps were assessed as part of the project using the methodology outlined in Section 2. The study of maps in this case study area was not exhaustive, it aimed to highlight the potential for historic maps and charts to provide information on coastal change.

Most of the ancient maps that we know of for the Côte d'Emeraude area were drawn for marine purpose. They are related in particular to trade, but also to military defenses. They often depict harbours, shelters, watering places, but also marine features such as anchorages, rocks and major landmarks for navigation (e.g. coastal shipping). Defensive points along the coast are highlighted on the maps, particularly during the wars (e.g 17th and 18th century, with St-Malo) and periods of major offshore sailing (especially in the 19th century). Shipping information is focused on the depth of the seas, currents or the nature of the seabed (Collectif 1992). Finally, with the establishment of the Napoleonic "cadastre" (19th century mapping based on registering property), the plots are shown in more accurate maps and include the coastline.

Figure 3H11. Map of Saint-Malo "island" (1758) featuring the limits of low and high tides and the limited access to the fortified city. Source : gallica.bnf.fr/Bibliothèque NAtionale de France. http://gallica.bnf.fr/ark:/12148/btv1b53016834n

The focus of this documentary research was on the baie de Saint-Malo but the majority of maps consulted depicted the whole Brittany region. The maps were gereally obtained in a digitised format and were later combined with all other data sources. However, as the maps and charts studied for the Côte d'Emeraude area were not very numerous (only 6 were ranked – detailed in Table 3H3), so the interpretation of the rankings is based on a limited dataset.

MAP_uid	Title	Year	Score Chronometric Accuracy	Score Topographic Accuracy	Score Detail in non-coastal area	Score Geometric Accuracy
88	Carte particulière des côtes de Bretagne : Depuis Granville jusqu'au cap Fréhel	1756	73.33	25	66.66	83.33
89	Plan du terrain au dessus du moulin du Boschet	1756	100	50	100	100
101	Carte de la rade de Saint-Malo et d'une partie de la rivière de Dinan	1600	73.33	38.88	33.33	66.66
93	Saint-Malo	16th / 17th	20	50	33.33	66.66
102	Plan du port de Saint-Malo tel qu'il paroit de mer basse	1754	66.66	27.77	33.33	66.66
100	Carte particulière des entrées du port de S. Malo, et de la riviere de Dinan. Comme elle paroissent aux plus basses marées des equinoxes	17th	20	36.11	33.33	50

Table 3H3. Top ranking maps within the Cote d'Emeraude case study area.

3H.4. Art Field and Research Studies

No dedicated archaeological or palaeoenvironmental fieldwork was carried out within the Côte d'Emeraude case study area as the available documentation on the historic resource was already detailed enough to analysis of some sites. However, field studies were undertaken in support of the art research, demonstrating the need for studies related to the different evidence types (paintings, photos and maps).

In addition to natural evolution, due to the tourist activity in this area, some parts of the coastline or this area have been severely transformed during the last century. For example, in the Saint-Briac area, as shown in the paintings of the great painters of the late 19th century and contemporary photographs, the coast, before the establishment of resorts, was devoid of trees. It was the new summer residents who planted all kinds of plant species to embellish the site.

3H.4.1 Key Research Questions

The research questions to be answered through the art representations, maps and photos concerned:

- the visualisation of coastal changes in a selected area
- the time scale and rhythms of the changes; and
- the process and origins of the coastal transformation.

All these questions aim to contribute to a better understanding of the issues and help put forward solutions to the managers of the coastal areas.

3H.4.2 Approach to Information Gathering and Fieldwork

Where possible, fieldwork has been undertaken to assess the informative value of paintings, maps and photos illustrating coastal changes. The sites selected for fieldwork were: the medieval Château du Guildo, Saint-Malo town and harbour, the Moulinet cape on Dinard, the Port Hue beach in Saint-Briac and the Fréhel Cape.

3H.4.3 Art Field Data Gathering Results

Five sites were selected for more detailed analysis, these are presented below.

H1. Château du Guildo (Figure 3H12)

Location

The Guildo castle is located in the western part of the Côte d'Emeraude, in the mouth of the Arguenon estuary, Créhen town (Côtes d'Armor).

Why was the study site selected?

The photos (postcards) feature historic buildings threatened by coastline retreat.
Ruins of an ancient castle which originated in the 12th century are shown. This building has a number of developments until the 14th century. As the castle is pictured several times in photos and paintings it was possible to analyse the coastline evolution of this specific place during the period of the 18th - 21st centuries.

Geomorphologic setting

The castle occupies a rocky outcrop consisting of mica schist and crossed by a bench of dolerite, bordered to the north and west by the Arguenon.
The views (postcards, upper part of the Figure 3H12) show how close the sea water comes to the castle, revealing a probable sea level rise since the time of its building. The comparison between the Blin painting (Figure. 3H12 lower left) and a recent photo taken from the same angle (Figure.3H12 lower right) show a sedimentary accretion process (with the development of silty vegetation) at the foot of the castle.

How the site can inform coastal risk management?

The images show that the castle is exposed to high tides (as demonstrated by sea weeds beneath the walls). It is certainly much closer to the shore than when it was inhabited. The analysis of the documents gives potential information on coastline retreat during historic periods.

Figure 3H12. Various views (postcards) and painting of the Guildo castle (ancient postcards, painting from Lille Musée de Beaux-Arts and photo after Feiss-Jehel 2011).

Key coastal risk management issues for the location

The archaeological investigations and restoration of the castle recently gave an opportunity to underline the threats to the coastal heritage in this area. The local authorities (Créhen parish and Côtes d'Armor department) have been fully informed and are now aware about this situation.

Chateau du Guildo Castle - Ranking score achieved: 100

H2. Saint-Malo harbour, ancient map (Figure 3H13).

Location
Saint-Malo city and harbour is located on the northern coast of Brittany, Ille-et-Vilaine department, and is situated on the right side of the Rance river estuary.

Why was the study site selected?
This site has been selected as representative for the impact of anthropic pressures and urbanization on the coasts.

Geomorphological settings
Saint-Malo city and harbour are located in the middle of the Massif de Saint-Malo, a '*metamorphic continuum*' cut by the Rance river estuary. The site was originally composed of several islands, some of them being now artificially connected to the main land (e.g. Saint-Malo island), maritime and estuarine bays, and sandy slopes combining with rocky cliffs (e.g. Alet/Saint-Servan). In this area, the tidal range, which is the largest in Europe, reaches 14 metres, it means that the shoreline has been shaped by the tides and the sea.

How the site can inform coastal risk management?
The site of Saint-Malo reveals a long history of managing risk from the sea. The architectural history of the city reveals building of dykes along the most exposed part (le "Sillon") that started in the early 17th century. During the following centuries, the dykes were extended or rebuilt several times, while they were regularly damaged by storms, and the local authorities are aware of this.

Key coastal risk management issues for the location
Comparing the views in Figure 3H13, it can be seen that the main risk to be managed is pressure from human development. Some areas of land around the harbour, which were wild and free of constructions during the 16th-17th century are now densely settled.

Saint-Malo ancient Maps - Ranking Score achieved: 20 to 66

Figure 3H13 . Saint-Malo, ancient map (16-17th century) (Source : gallica.bnf.fr/Bibliothèque Nationale de France) and present view (cl. G. Cazade, Le Pays Malouin).

H3. Dinard city, Pointe du Moulinet by Duroy Bateau 1850-60 (Figure 3H14).

Location
Dinard is a town located on the northern coast of Brittany, Ille-et-Vilaine department, and is situated on the left side of the Rance river estuary, west of Saint-Malo.

Why was the study site selected?
Dinard is a typical seaside resort, with an economy which has been based on tourism for a long time and is reflected in features such as beaches, hotels, spa and casino. The evolution of the represents an important issue here due to the touristic economy and for local inhabitants who have houses along the seashore.

Geomorphological settings
Dinard settles on a rocky promontory, dominating the Channel on its northern sea side and a more protected façade on its eastern side, turned to the Rance river and facing Saint-Malo harbour. Here, rocky coats sections alternate with large sandy beaches.

How the site can inform coastal risk management?
The comparison of the pictures (Figure 3H14) shows that the site is subject to natural erosion which causes a retreat of the coastline, even in rocky parts.

Key coastal risk management issues for the location
Taking into account the density for habitation along the coastline, the major risk inferred by erosion concerns the more exposed private and public buildings.

Dinard City Painting - Ranking score achieved: 59

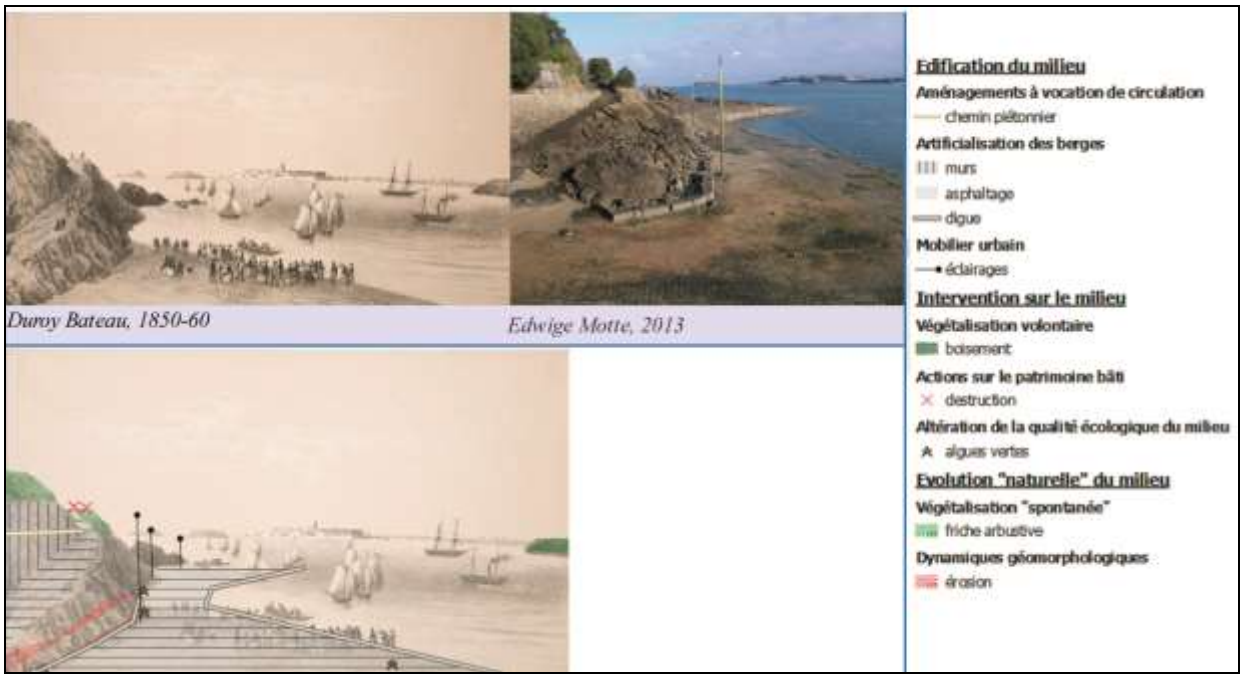

Figure 3H14. The town of Dinard, view of Saint-Malo since the Moulinet cape, (after Motte, 2013).

H4. Saint-Briac, Port Hue beach by A. Nozal (end of the 19th century) (Figure 3H15).

Location
Saint-Briac is a small seaside town, located at the present limit between Côtes d'Armor and Ille-et-Vilaine departments. Its territory is limited to the west by the Frémur river. The Port Hue beach is facing to the north.

Why was the study site selected?
The site has been selected because, despite of the tourist development of the town, it has long benefited from coastal management measures, especially the wild parts of its territory.

Geomorphological settings
The Saint-Briac territory shows a diversity of features, with large sandy beaches alternating with rocky sections, e.g. the Garde Guérin cape. This painting shows the Port Hue beach, in the foreground and the Garde Guérin cliff castle in the background.

How the site can inform coastal risk management?
This site shows interesting evolutional features of the coast: first, we notice that some elements of the “built” heritage (houses on the Garde Guérin cape, and bath cabins) have recently been dismantled, due coastal management decisions. Due to the protection measures recently taken, some wooden barriers, "ganivelles" have been installed in order to prevent from people from walking over the site, and to promote stabilisation, then progression, of the dunes (Figure3H15).

Key coastal risk management issues for the location
The coast line of Saint-Briac is located in a Natura 2000 protection area. Nevertheless, the natural erosive process is very active in some parts.

Saint-Briac Painting - Ranking score achieved: 59

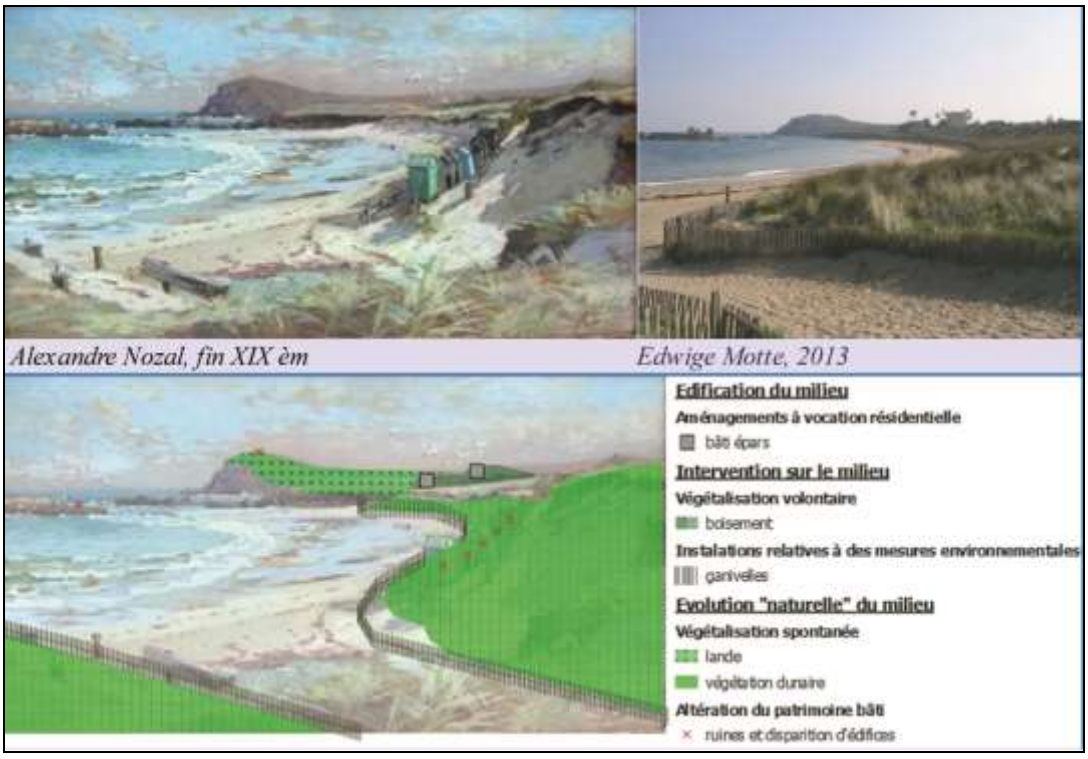

Figure 3H15. Saint-Briac, Port Hue beach (after Motte, 2013).

H5. Cap Fréhel by F. Benoist, 1865.

Location

Cape Fréhel is a peninsula in Côtes-d'Armor, in northern Brittany, France which extends off the Côte d'Émeraude into the Golfe de Saint-Malo. The Cape is located 8.5 km from the town centre of Fréhel, although, administratively, it is located within the territory of the commune of Plévenon.

Why was the study site selected?

Overlooking the sea for more than 70 meters, the shale cliffs and pink sandstone of Cape Fréhel offer one of the most beautiful views of Brittany. It is considered one of the greatest tourist sites of interest in the Côte d'Emeraude.

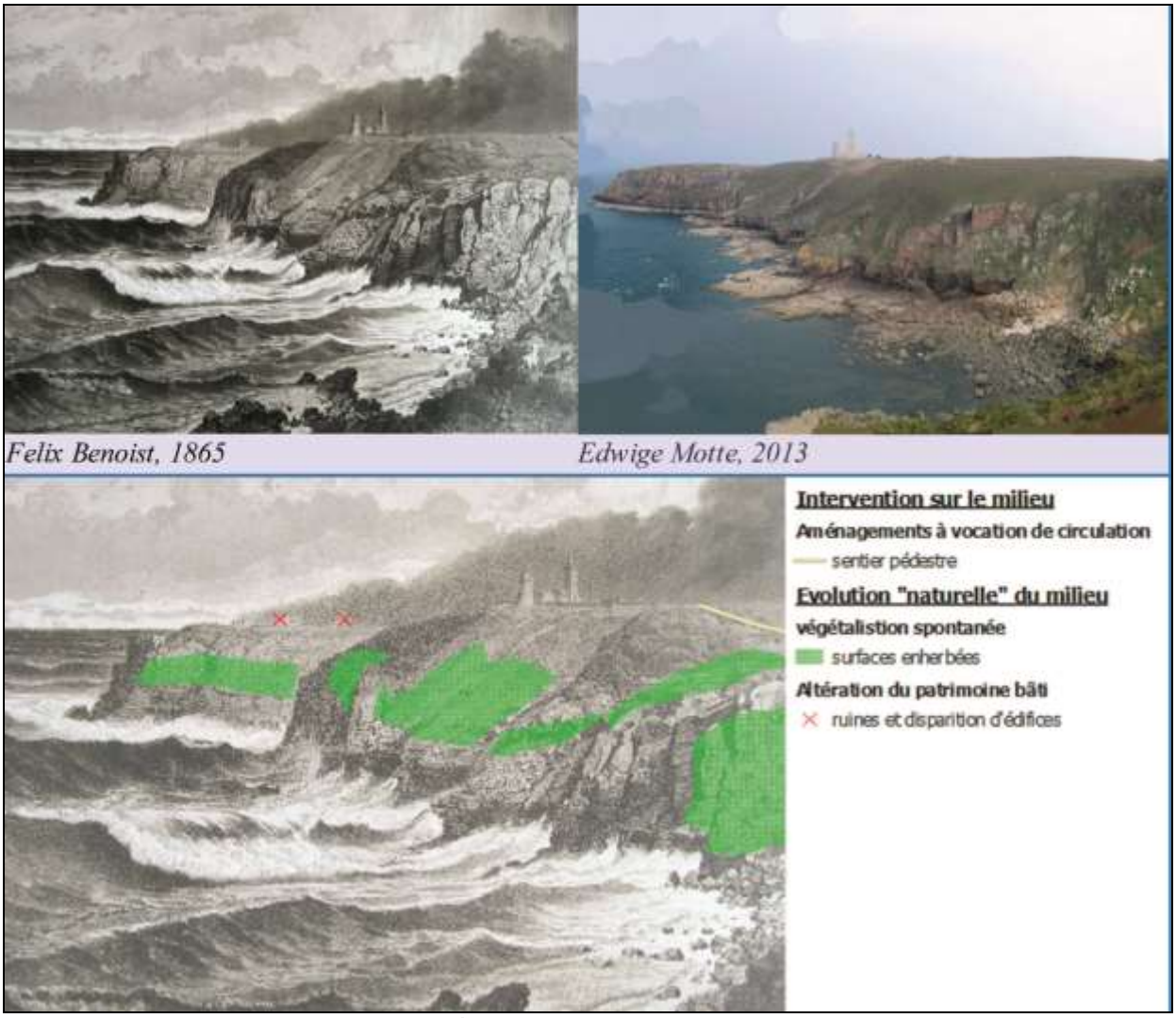

Figure 3H16. Cap Fréhel, yesterday and today (after Motte, 2013).

Geomorphological settings
The peninsula is surrounded mainly by cliffs which make it difficult to access via sea. The whole of the undulating terrain is covered in moorland and marshes which make it difficult to construct any structure on the site.

How the site can inform coastal risk management?
No towns or villages are situated on the peninsula, however, there are some located at the tip of it. As shown on E. Motte documents (Figure 3H16), some ancient buildings have been dismantled and only the two lighthouses, one from the 17th century and the other one from 1950, have been preserved as elements of the historic heritage.

Key coastal risk management issues for the location
This exceptional site is currently an ornithological reserve. Cap Fréhel is a good example of a remarkable site where it is possible to manage tourist activities with nature preservation.

Cap Fréhel painting - Ranking score achieved: 29

3H.5 Analysis

The Cote d'Emeraude study area provides evidences of the coastal changes occurring due to natural forces and human actions as revealed by historic paintings, photos, and maps, illustrating the rate and scale of this change over the last few hundred years. This section considers the most informative and reliable data gathered from this study area for contributing to understanding of the scale and pace of coastal change.

The Côte d'Emeraude area study has combined the use of paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve our understanding of coastal change. In this case study area there are several illustrations of long term effects of erosion, however, focus is particularly drown to short term transformations due to:

- Several sections of this area having been subject to intensive coastal occupation and tourist development since the 18th century, leading to dense coastal constructions (seaside resorts, private and public buildings, etc), some of them (e.g. the Saint-Malo dikes) completely transforming the coastline; and
- Many sites in this area are currently covered by protection measures (e.g. as natural or bird reserves) and we can then analyse the efficiency of the coastal management.

3H.5.1 Archaeology, Heritage and Palaeoenvironmental Features

Although archaeological fieldwork was not carried out within this study area, available data from sites was used to investigate changes. Some Palaeolithic layers and late prehistoric settlements give ideas of coastal changes, mainly the rise in sea level, but these often lack precise dating. The available data for the Saint-Servan Alet site, in the Sain-Malo area, is examined as it provides a good example of combining documentation for maximum analysis. Within the framework of the Arch-Manche project, it was possible to improve knowledge for the Mesolithic period, as it was less studied in this area.

Within a inventory of the ancient fish traps of Brittany (Daire and Langouët, 2008 and 2010), L. Langouët spotted a stone dam on several aerial views (IGN,Google Earth) with a length of 67 m between two rocky mounts called Petit Daviers and Frand Daviers (Figure 3H17). It was already visible in views of 1952. This site has been chosen due to the fact that this fish trap is no longer reachable on foot, which means it is probably a very old structure, used at times when the sea

level was a bit lower. An underwater survey was conducted on this structure in order to gather more precise data.

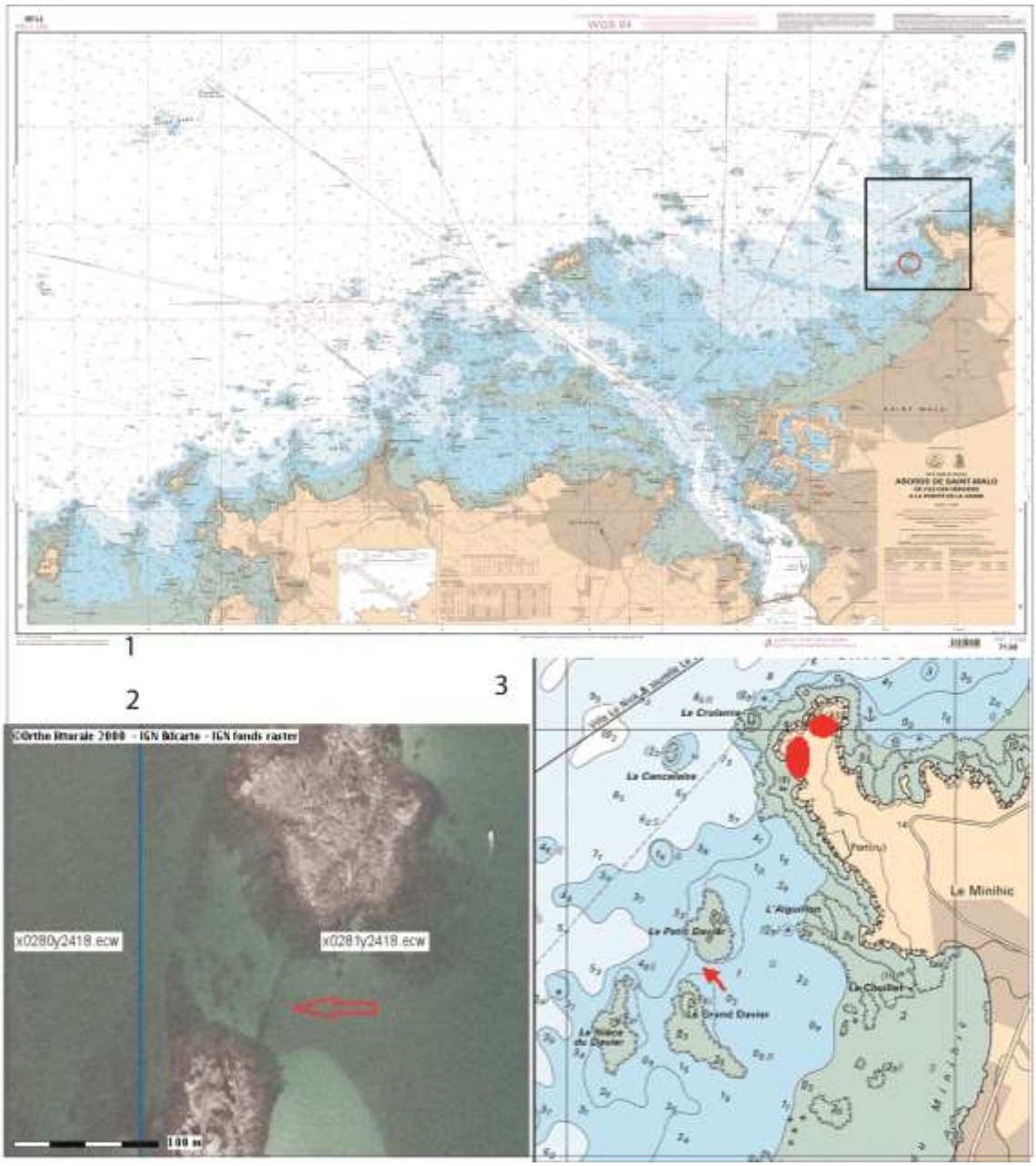

Figure 3H17. Saint-Malo, location of the Mesolithic site on the La Varde cape and of the underwater fishtrap on Marine map from SHOM (1 and 2) and dams of the fish trap visible on the aerial view (2) (source Geoportail, IGN) (doc. L. Langouët).

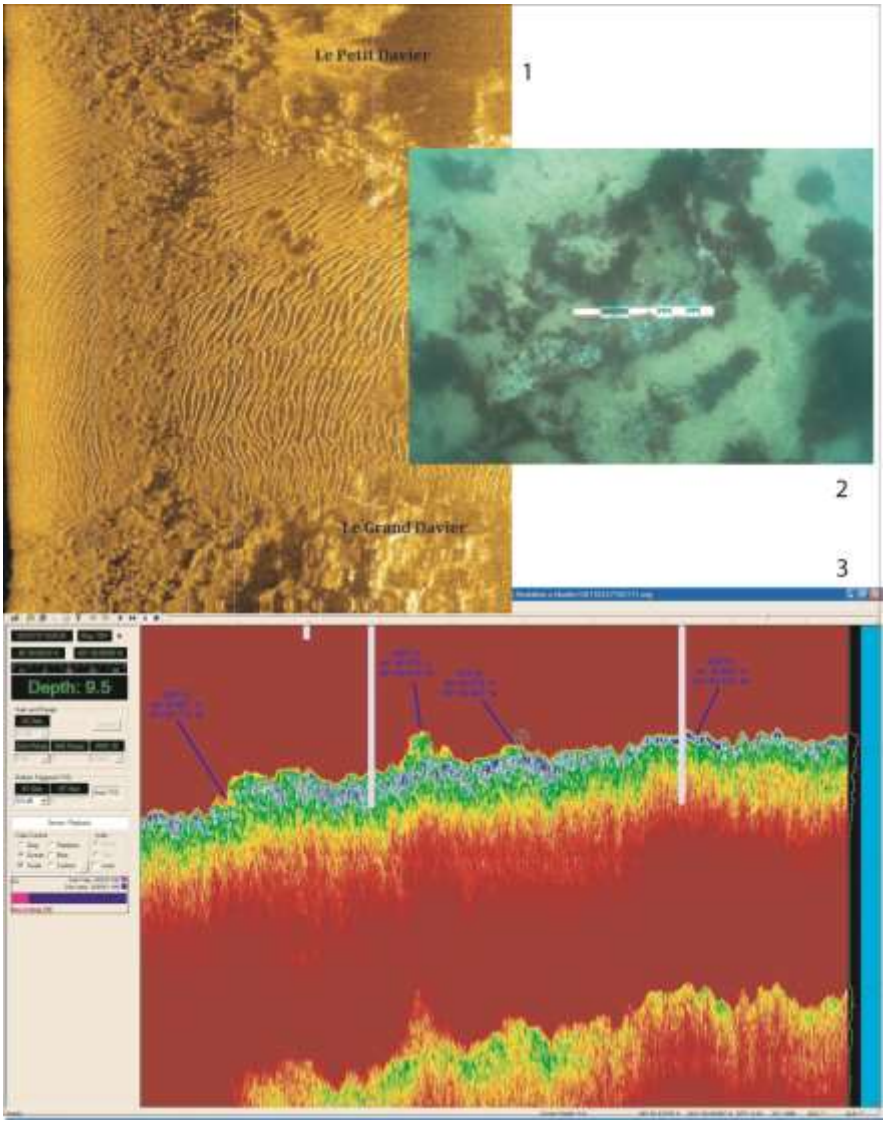

Figure 3H18. Saint-Malo, underwater survey views of the Daviers fihtrap. 1: Sidescan sonar mapping © Adramar. 2: Diving survey showing special arrangement of the stones, possibly the sluice © N. Job/Adramar. 3: Stratabox profile (27_SBP 10_21_11.seg) mapping the starting point of the southern wall of the fishtrap. © Adramar.

Following the Adramar work on this site (Le Ru 2013), a review of data obtained with a side-scan sonar and sediment penetrator (Figure 3H18) was undertaken. The stone structure, located between the Grand and Petit Daviers, is interpreted as an old dam. Seaweeds attached to stones, facilitated the overall detection of the weir on the aerial views of the IGN (Figure 3H17, n°2). It is well adapted to the concavity reflux stream between rocks, which represents a positive identification element. Side-scan sonar surveys have demonstrated the presence of an organised set of stones, and allowed the hypothesis that it could be a geological feature to be discounted. The dam, even if very damaged, is identifiable on the side-scan sonar documents (Figure 3H17, n°1).

Diver verification enabled visual observation of the northern part of the dam. When the stones were sufficiently high above the sandy bottom, the height of the dam remains ranged between 0.10 and 0.4 metres. The width of the dispersal of the stones is between 4.5 and 5 metres. As

an access track was not observed by the divers, it is not possible to find the height of the dam when in use (Daire & Langouët, 2010: 28).

The sediment penetrator and dives could not inform on the nature of the geological substrate (sand mixed with stones or sand on shallow rocky bottom?). It is therefore difficult to assess the likely buried part of the dam. The sediment penetrator also showed that in its southern part (see SPB 15), the dam seems to have a relief and a significant vertical rock removal compared to the sandy bottom. The dives have confirmed the presence of granite blocks on the path of the dam. No organisation of architectural order was observed. In the explored areas, the height of stones compared to sandy bottom was 0.20 m maximum. A special arrangement was noticed, it could be the remains of a sluice, according to the provision of some stones (Figure 3H17, n°2).

The level of the sandy bottom near the dam was estimated on the maps (-1.90 m / 0 SHOM) but more precisely measured during the dives. The average values of the sandy bottom in contact with the dam indicate the value -2.15 M / 0 SHOM (plus or minus 10 cm). These measurements have been analysed regarding the regional curves and data related to sea level changes. According to the position of the fishtrap, it indicates a local rise of sea level (lower level of small tides = LLST) estimated to c. 7.70 metres. Such a change indicates that the Daviers fishtrap was built and used in the Mesolithic period.

In the cape of Varde in Saint-Malo, two deposits dating from the Middle Mesolithic (circa 8200-7600 BP) (Kayser 1991) have yielded abundant stone tools; the first study involved nearly 5,000 waste knapping fragments and over 190 tools made of various stones (Kayser 1991). The distance between both sites (the fishtrap and layers) is about 750 m; from the La Varde cape, there is a direct view to the Daviers fishtrap.

3H.5.2 Artistic Depictions

Following the research and location of a large number of artistic images of the coastline of the study area it was possible to rank their relative importance in terms of their value in informing on long-term coastal change. The art case study area was extensive. The ranking system directed research to the higher potential locations, usually where detailed artworks were available, often painted in watercolour or printed as aquatint or steel plate engravings.

We must emphasise that the paintings and prints available for the study area have been the subject of critical analysis (see the academic work by E. Motte, 2013). Indeed, painters and artists sometimes took liberties with reality when representing landscapes, this varied depending on the school of painting, and on the personality of the painters. A critical look at the results provides several lessons about the informative value of this media. In general, the comparison for each site between the realism of the representation and the current situation justifies the use of art as a source of geographic information. Identifying when the objectivity of representations had been influenced by the view or ‘fantasy’ of the artist aided analysis.

Observations show that only a quarter of iconographic representations used for this work (Motte, 2013) include examples where the artist has taken obvious liberties within the depiction. Most works appear to be relatively accurate depictions of a geogrphical area at a particular time. This result is significant in that it highlights in the predominance of an accurate rendering of reality in this type of media, legitimising its use as a source of scientific information.

In terms of the most helpful artworks for comparing coastal change, engravings, lithographs, and prints appear more objective because they are mostly political documentary productions or

works with territorial and geographical meanings. Often their artistic meaning is less important than the record they provide in a legal-political and topographical sense (Motte, 2013).

The paintings often look more subjective, because they are essentially artistic works with sensitive and aesthetic meanings, considered as an artistic genre of landscape painting beyond mere rendering of reality. This difference is very well illustrated through the case study considered above: the engraving of the Cape Fréhel brings a very detailed view, allowing an accurate analysis of the local changes, whereas the paintings of Saint-Briac beach give a much more general idea of the coastal evolution.

3H.5.3 Combined Resources

As demonstrated above, the comparison between maps, drawings, and historic or archaeological data is the most relevant approach to illustrate coastal changes and understand the process and rhythms of this evolution. Each of the resources listed above can provide detailed information about past environments and the position of the coastline, through combining these resources it is possible to provide more accurate information not just from one time period but over a longer term, this can inform the rate, scale and pace of coastal change along the coastline. The data can not only provide quantitative information on coastline position, but can also provide qualitative information that can assist in illustrating coastal changes to a large audience. For example, it is possible to illustrate the 'long term' coastal changes and provide a 2D synthesis on the La Varde cape site (Saint-Malo); the Figure 3H19 shows the Mesolithic landscape (8000-6000 BC), with a lower sea level which uncovered a large foreshore; this allowed the exploitation of the Daviers fish weir, by the inhabitants of the La Varde cape, which was settled at this period.

The academic work carried out by E. Motte (2013) started to explore a novel approach to landscape evolution, taking as reference supports pictorial representations and ancient maps, compared with geography and geomorphologic features. The study established a methodology adapted for sites in Brittany and for the regional iconographic traditions, it has involved two complementary approaches: the construction of a 'rationalized' interpretive look of the iconography, and the invention of a system to extract and record graphically the information revealed by the diachronic study of comparative images. The application of this approach to illustrations of various types of coast has enabled the establishment of an inventory of many natural and anthropic changes. The comparison of these changes with knowledge from scientific literature is positive and validates the overall approach. However, the study of a larger collection is required to enable more localised and eventually more thematic analysis. Further targeted studies could be undertaken on images which include the same scale of area represented – either an opened-up or narrowed panorama - for maximum comparison.

The results of the combination of art and geomorphological approaches provides information on two levels. Firstly reviewing how art works can be used for scientific purposes rather than subjective reflections of a view. Secondly how the record of changes demonstrated through comparison with the modern situation can enrich knowledge of coastal evolution over centuries. The observations reflect the breadth and variety of changes on the coast for over a century. Considering all the studied sites, a summary of results is presented. Major landscape evolution features observed within artworks are coherent with the facts identified by the literature on the subject. This allows a conclusion that the collection of works of art provide an accurate description of landscape changes in Brittany, especially along the Côte d'Emeraude which is one of the best documented areas of the Breton region.

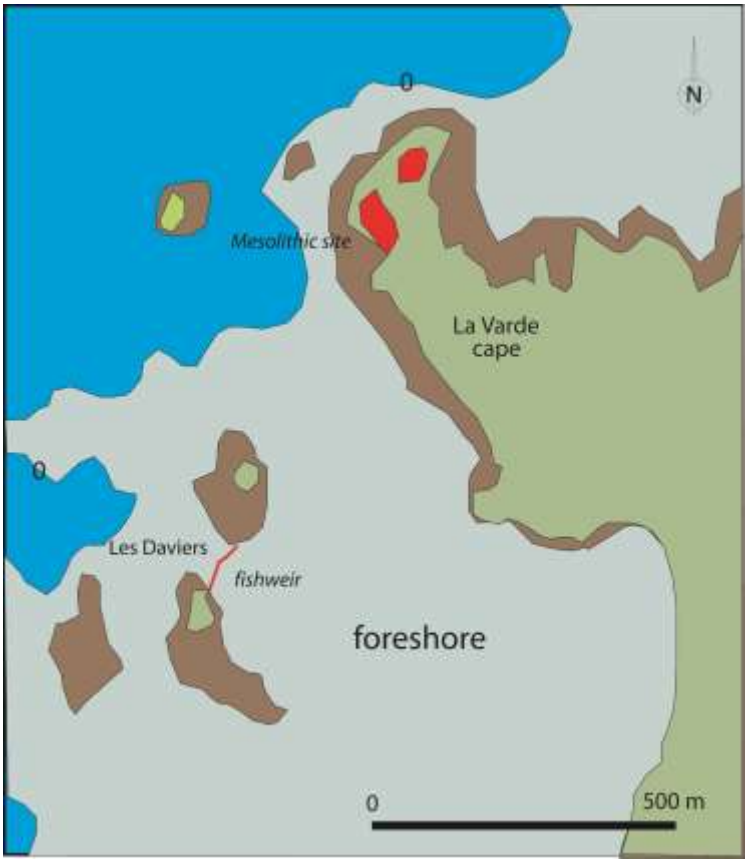

Figure 3H19. Map of the Daviers (Saint-Malo) area during the Mesolithic period (doc. L. Langouët).

As an illustration of the advantage provided by combining resources, the following images (Figures 3H20 and 3H21) show various views the Saint-Servan (Saint-Malo) peninsula, each of them providing elements for comparison as well as data related to coastal changes. The archaeological and palaeoenvironmental data (Figure 3H20), related to the pre-Roman and Roman environment of the Alet peninsula, illustrates the coastal change in this area of the Rance river estuary.

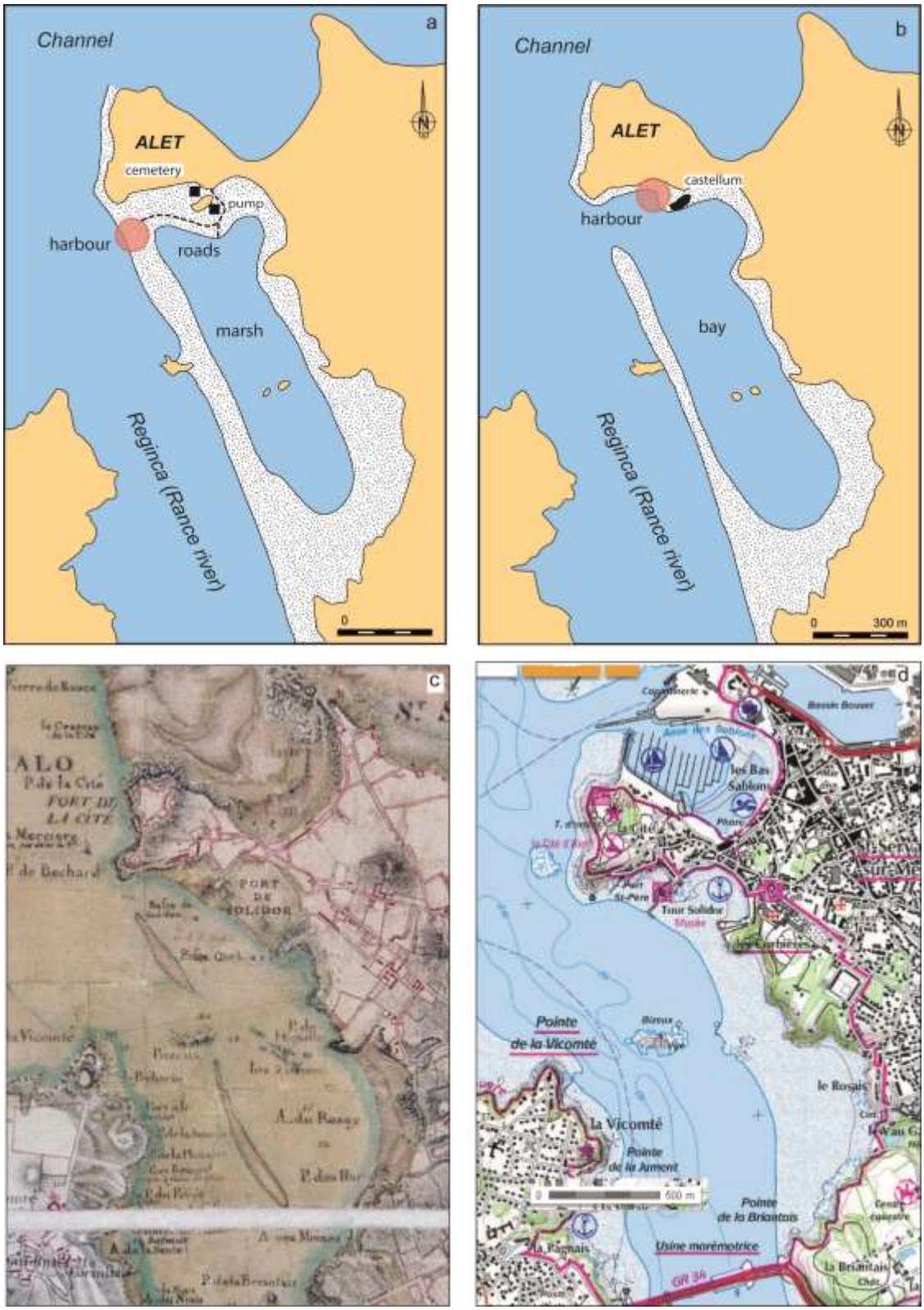

Figure 3H20. Saint-Servan (Alet) promontory and coastal evolution of the ancient harbour: evolution of the topography before (a) and after (b) the 4th century AD, the beak of the alluvial bar caused modification in the use and frequentation of the area. On the ancient map (18th century, Ministère de la Défense, Vincennes) (c) some remains of the alluvial bar still appear. d: 20th cent. view (IGN map).

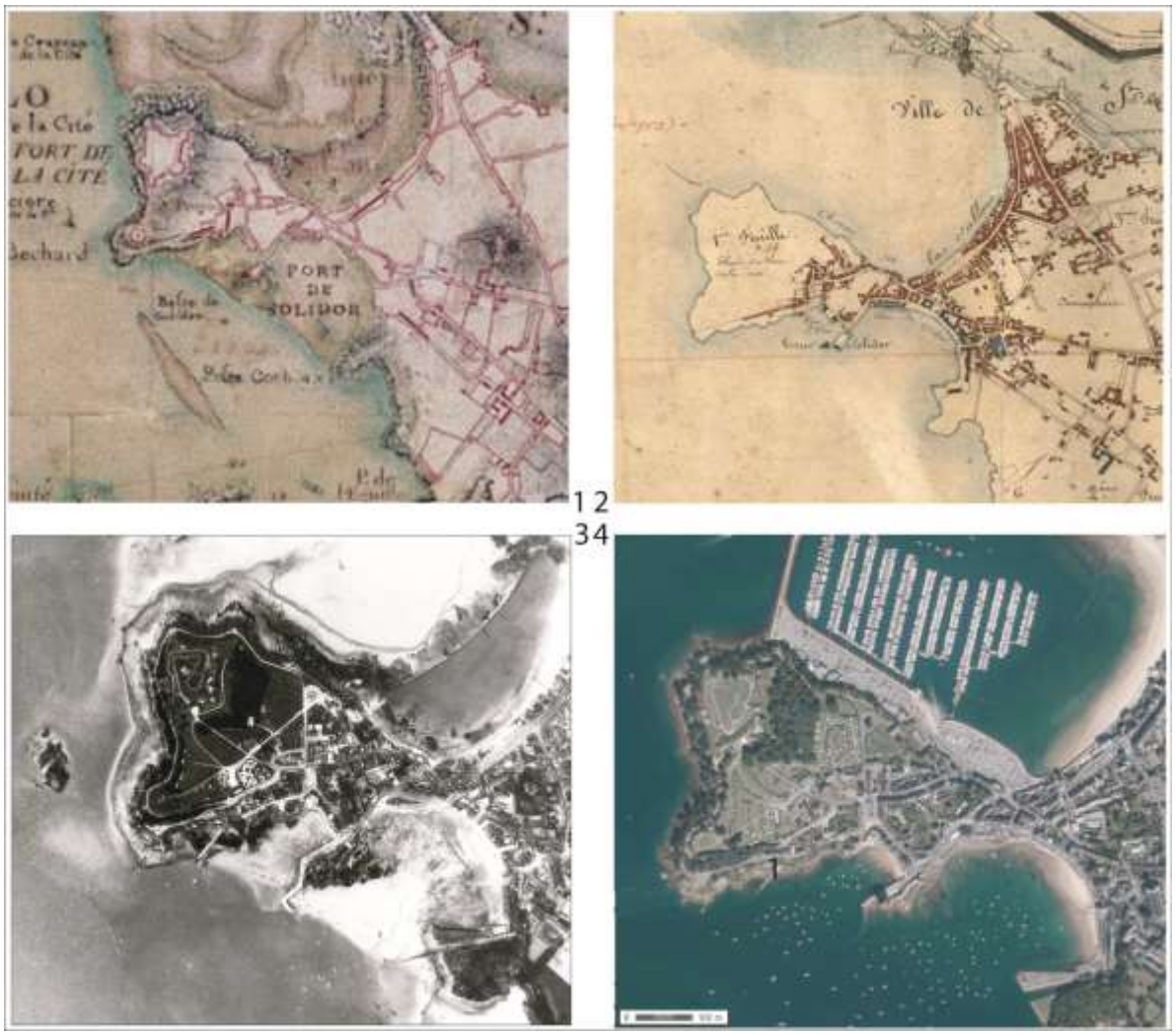

Figure 3H21. Saint-Servan (Alet) promontory and coastal evolution of the ancient harbour. 1. Carte des Ingénieurs Goégraphes du Roi (c. 1785) (Ministère de la Marine). 2. Napoleonian cadastre (1835) (Archives du département d'Ille-et-Vilaine). 3 and 4. Aerial views (1945 and c. 2012) (Geoportail, IGN source).

During the first millennium BC, the current Solidor Bay was protected from the sea by an alluvial bar. A fresh water pumping station has been found during archaeological excavations; it was installed in the cove in the 2nd or 3rd century AD, at a location 4 meters below the current highest water level. At the foot of the tower Solidor, a necropolis was installed during the Gallo-Roman period, probably during the 4th century, in a place that is today a beach. In the Middle Ages, the Alet landing port was installed in the same place. By combining all these paleoenvironmental and archaeological data from excavations conducted in 1960-70, it results in a pattern of evolution of the paleo geographical site. The main reason for these changes is the existence, originally, of an alluvial cordon, protecting land and installations located around a retro coastal marsh from the sea and river water floods.

The breakthrough of this bar could be due either to natural causes (storms and/ or an episode of marine transgression) or human action. Various elements indicate the rupture of the bar in the 4th century AD. The consequences of these changes were initially the invasion of the cove by sea water, then the abandonment of the Roman pumping station and necropolis, and the transfer of the landing harbour of Saint-Père Bay (Langouët, 1996).

During the following centuries, the major modifications of this area are linked to religious and historic events with the building of churches, fortifications (Figure 3H21, 1 and 2) and ramparts (Middle Ages to 17th-18th centuries); during the modern period, the density of habitations and the development of modern sailing harbour installations are visible while comparing the maps and aerial photos; more recently, the building of the Rance Tidal Power Station has had a great impact on the whole estuary and, more precisely, on the Saint-Servan/Alet area.

3H.6 Conclusions and Recommendations

The archaeological and palaeoenvironmental data demonstrate the constant transformation of some parts of the coastline of the Côte d'Emeraude, an area impacted by the highest tidal range in Europe, reaching 14 metres high in the heart of the Norman-Breton Gulf. The estuaries (Rance and Arguenon rivers) have always been intensively settled, as revealed by the density of archaeological sites and the importance of settlements such as Alet/Saint-Malo.

The art and map case studies demonstrate the dynamic nature of the coastal landscapes in the Côte d'Emeraude; together with the photos and paintings they illustrate the tourist and settlement development in this zone since 19th century, these have had a rapid and powerful impact on the coastal landscape.

The Côte d'Emeraude landscape is diverse and comprises various coastal features and situations, however, this area seems to be more threatened by pressures from human structures and developments than by natural erosion or sea level changes. Thanks to the legal tools currently available, some additional natural areas of ecological and tourist interest can be sustainably protected meanwhile some partially urban zones should be seriously monitored.

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