CASE STUDY 3I – TRÉGOR & NORTHERN FINISTÈRE

Case study area: Trégor and Northern Finistère, Brittany, France

Main geomorphological types: Soft cliffs, shingle and sandy beaches, shingle spits, creeks, estuaries and dunes.

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

Primary resources used: Archaeology, Palaeoenvironment, Art.

Summary: The study area comprises extensive cliff lines which are subject to erosion and instability. Extensive archaeological and palaeoenvironmental investigations have enabled us to retrace precisely the evolution of settlement in relation to coastal changes, especially in the bay of Lannion area, from early prehistory up to modern times. Artistic depictions, numerous photos and charts have provided further data concerning the rate and scale of erosion and coastal change over the last few hundred years.

Recommendations: The scientific observations should make coastal managers aware of the consequences of future sand and aggregate extraction, which is planed offshore in the bay of Lannion in the near future. These observations highlight the potential of analysing past changes (especially through geo-archaeological evidence), in order to evaluate the impact of current management decisions. This is especially important when considering the soft rocks or sedimentary features of the coastal areas, which are vulnerable and very sensitive to any change, either of climatic or anthropic origin.

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.

Trégor - North Finistère is one of four Brittany case study areas and represents the largest one in terms of geographical extent. This case study report introduces the study area and why it was chosen as part of the project, the results of the archaeological and palaeoenvironmental study are then presented along with the results of the art study. The analysis of these results and the potential for demonstrating the scale and rate of sea level change are then presented. Further details of the project methodology are in Section 2.

Within the Trégor and North Finistère 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 3I.1 and 3I.2 below. Within the case study area, a more limited zone is considered for archaeology and palaeoenvironment, i.e. western Trégor (bay of Lannion); it has been selected to provide a representative set of types of evidence across a range of periods spanning from the Palaeolithic through to more modern coastal heritage, which is further illustrated by recent field work results. 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, including not only Trégor and the bay of Lannion (Côtes d'Armor) but also the whole northern part of the Finistère department.

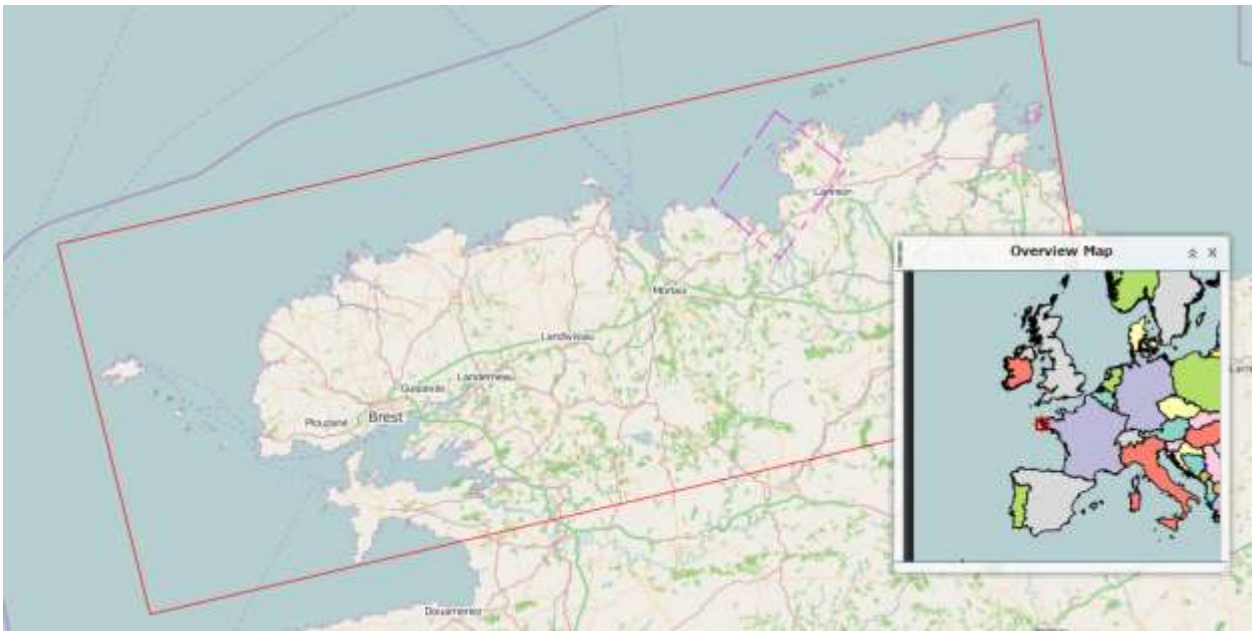

Figure 3I.1. Map of the Trégor- North Finistère study area, the dotted line represents the extent of the archaeological study area.

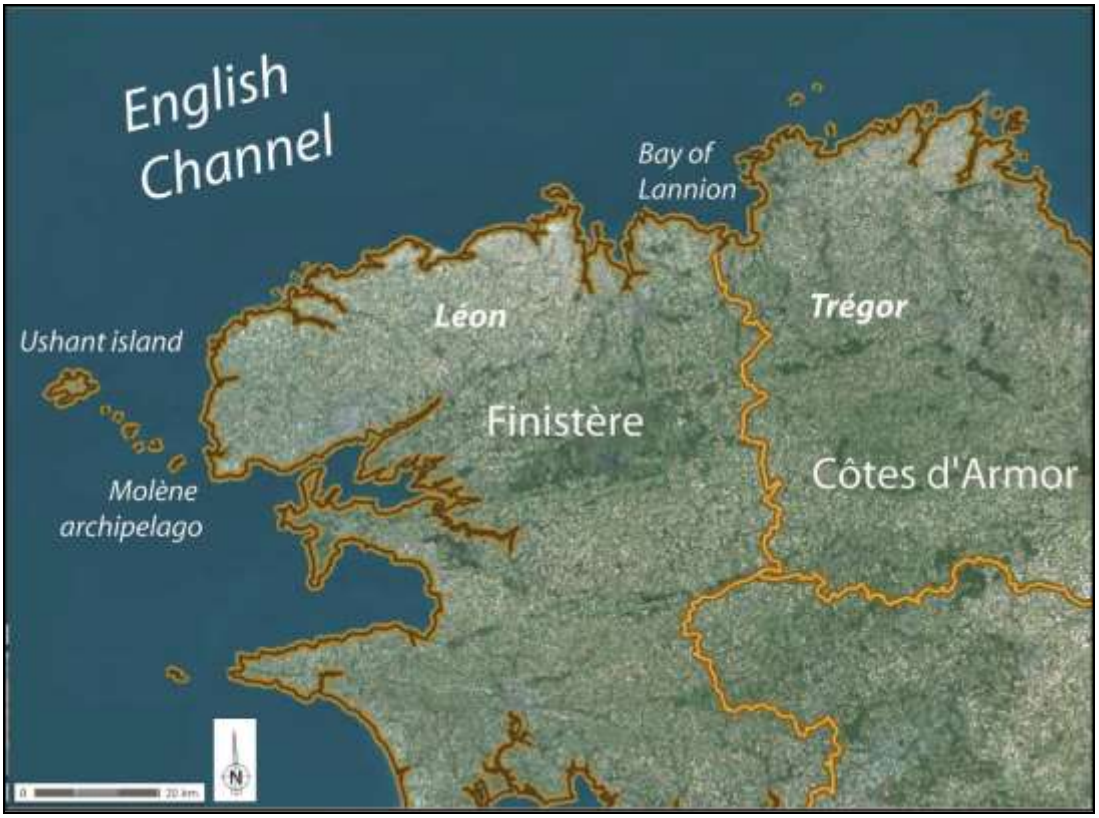

Figure 3I.2. Map of the Trégor- North Finistère study area, with present administrative limits and main zones mentioned in the text.

3I.1. Introduction to the Trégor and North Finistère Study Area

The Trégor and North Finistère areas are located in the north western part of the armorican massif, and peninsula of Brittany. The present administrative entities are departments of Côtes d'Armor and Finistère, the last one being the more western of Brittany, as indicated in the origins of its name. Some historical areas have been defined according to religious divisions, such as the ancient bishop's territories and cultural zones (Trégor, Léon). Then, for example, the Trégor area is located astride both departments (Finistère and Côtes d'Armor).

The area covered by the case study measures around 150km, within this the coastline has many indentations as rias and bays, numerous islands and islets, meaning the measured distance is closer to 300km. The coastline of Trégor and North Finistère has been developed progressively over the last millennium, as shown by the archaeological and palaeoenvironmental data (Bizien-Jaglin *et al*., 2002, Batt & Giot, 1980). The area has diverse landscapes, which alternate between sandy bays, small islands and rocky promontories. Some areas are densely populated such as seaside stations (e.g. St Michel-en-Grèves) and towns (Lannion, Morlaix), with other areas dominated by large sandy dunes (Léon area) or protected wild zones which are free of human coastal settlements (e.g. some islets of the Molène archipelago).

The case study demonstrates the role of natural phenomena and human pressures on the coastal evolution. Several coastal engineers have been carrying out recent work in the Trégor-Nord Finistère area (Cariolet, 2011; Hénaff *et al*. 2013), meaning coastal risk problems have been taken into account. At a local scale coastal managers have often asked scientists to help them in their decisions regarding land use planning and development proposals, even if the conclusions and advice were also often ignored. In recent centuries and decades the most usual response to protection of property and assets has been the construction of coastal sea walls and flood defences, for example in the Bay of St Michel-en-Grèves.

3I.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.

This case study area comprises two main areas, with the bay of Lannion (belonging to the Northern armorican domain) of Cadomian origin (structured between 2000 and 540 My) and the Léon area, of Hercynian origins (Augris and Simplet 2011).

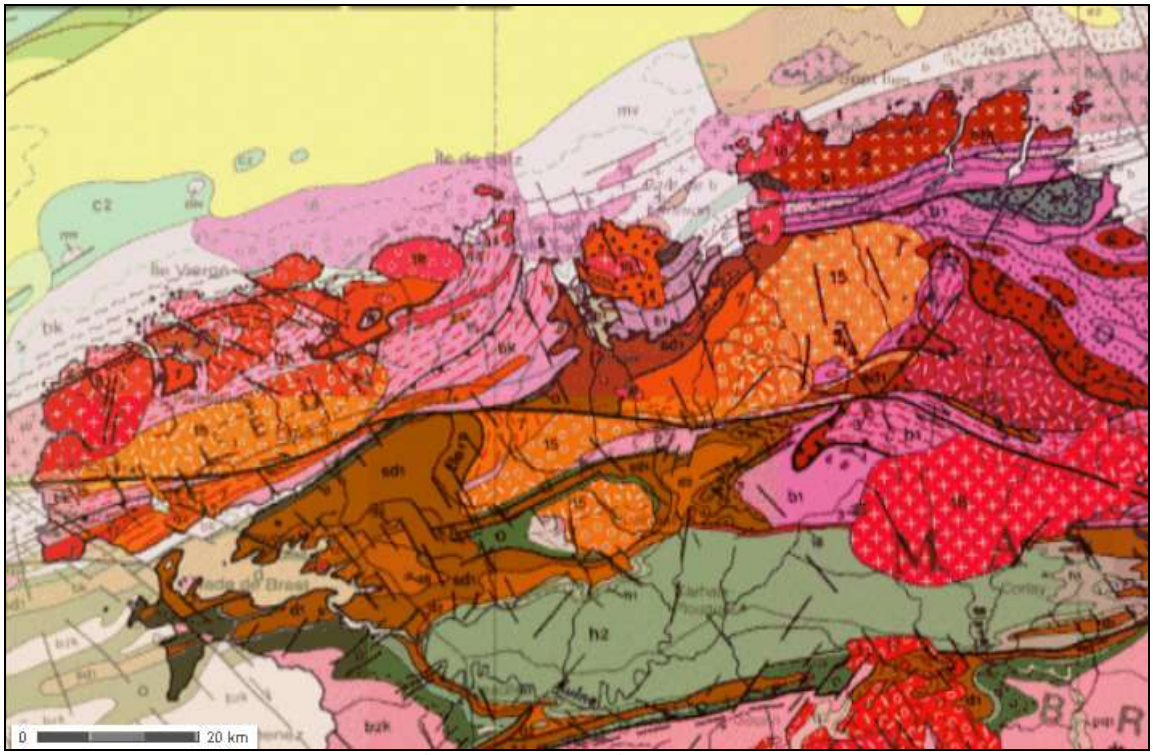

Figure 3I.3. Geological map of the Trégor-North Finistère study area (after BRGM, source Geoportail, IGN).

Geological History

In the Trégor (Port Blessed Trébeurden and Moulin de la Rive), you can see the relics of the oldest rocks of France (Figure. 3I.3). They are exposed in a limited and fragmented way, so that it is difficult to trace their history. At nearly 2 billion years old, they are hardly more than memories in the rock record.

For 650 million years, major tectonic phenomena have twice agitated Brittany, conjuring mountain ranges equivalent to the Himalayas. In the Trégor and North Finistère area, it is the Cadomian chain that is situated in the north of the region (Guingamp, Bay of Saint- Brieuc) and the Hercynian chain.

Over the past 65 million years, the Armorican massif was regularly transformed by the neighboring tectonic episodes and, depending on sea level changes; the seas covered intermittently entire parts of the Armorican massif. Periods of intense erosion in hot and humid climates have followed as well as phases of sedimentary deposits more or less marine.

Finally, it is the Quaternary era (starting overall 2 million years ago) which gives the final shaping to the current landscape of the region. It is punctuated by large glacial and interglacial periods, when most terraces and associated alluvial deposits were developed (Augris and Simplet, 2011) (Figure 3I.4).

Geomorphologic Processes and Human Intervention

The coastal morphology of the Bay of Lannion shows a succession of cliffs and sandy beaches. In its western part, between the Primel cape and Beg an Fry, the coastline of the bay looks like a massive step forward, slightly indented at the mouth by small streams bordered by the highest cliffs of North Finistère which overlook a foreshore that is sometimes very narrow.

To the east of Locquirec, cliffs lower while the foreshore widens (Douron estuary, Saint-Michel foreshore). From St-Michel-en-Grève, the shoreline, previously oriented in an east-west direction forks and turns to a more southern direction. It comprises cliffs one hundred meters in height, between the tip and Locquémeau Beg ar Forn, deeply cut by rivers, including the Léguer also called Lannion river. All rivers discharging into the bay take a course perpendicular to the coastline and could limit small lithological units of the base.

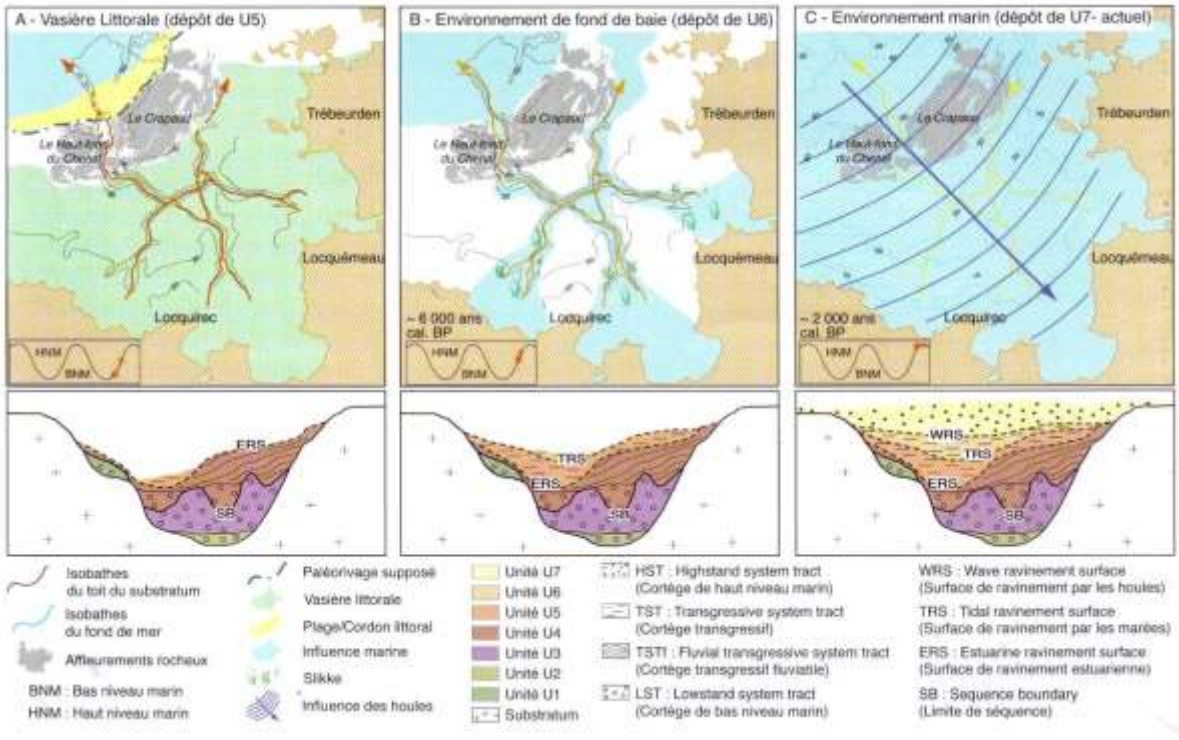

Figure 3I.4. Mapping of the Bay de Lannion channels, fill deposits laid down during the last sea level rise (transgression flandrienne) (after Augris and Simplet 2011).

Located in the heart of the Bay of Lannion, the Léguer estuary cuts the granite massif of Trédrez, consisting of coarse-grained porphyritic granite, which has areas of greater or less fine texture (Auvray and Lefort 1971). This granite is characterised by very numerous rifts, grouped into two sets arranged more or less at right angles and with vertical dips, and a third set of a much less steeply dipping from 10° to 20° only west/northwest. Along the upper foreshore, these rifts facilitate a natural breakdown in rectangular large blocks which, under the prolonged effect of the swell, were processed into pebbles of various sizes. These geological details are important later for architectural observations of the fish traps on both sides of Léguer. The river follows in a east-west trajectory, perpendicular to the coast line which is north-south oriented in this part of the Bay of Lannion.

This coast forms steep cliffs, the height of which reaches 100 meters, between Locquémeau and Ber ar Forn, these are deeply cut by rivers and in particular the Léguer. This topographic configuration is a constraint in terms of the population's access to the resources of the sea, but also provides downwind slopes for the development of wooded areas, the importance of which will be analyzed further.

The current mean sea level in the Bay of Lannion is 5 m above the hydrographic zero, which corresponds to the largest astronomical half tidal range (Augris and Simplet 2011). Even though the tidal range may not be as large as on the Channel coast, the range is sufficiently powerful in the bay of Lannion to justify the development of numerous fish weirs which take advantage of the hydrodynamic flow of the tides.

The economy of the Breton coast has come to rely heavily upon tourism, and this is illustrated in several parts of this study area. This in turn brings about the construction of specific infrastructure, especially yachting harbours (e.g. Trébeurden) and hydrotherapy centres (Trégastel) (Le Dû 1993). For the past few decades, the increase in projects has lead to an inbalance between supply and demand, noticeably the change of the landscape, and considerable spacial conflicts (see Trébeurden harbour). The strict application of the littoral law (1986) is in opposition to financial interest pressures and elected representative ambitions, supported by decentralization. Human intervention is especially noticeable in the tourist destinations of the Trégor area (Perros-Guirec, Trégastel, Trébeurden) as well as in some towns of Northern Finistère (Locquirec, Roscoff, etc). The main transformations are linked to the building of structures (basins, quays), protection dikes, fishing and sailing ports. In some areas (Pleumeur-Bodou and Guissény), new constructions are dedicated to the protection of the coastline against the natural erosion: embankments, breakwaters, moles (Figure 3I.5) which generally have a great impact on the coastal geomorphology.

Figure 3I.5. The Trébeurden new sailing harbour, built in the 1990' (source: http://portdeprimel.fr/).

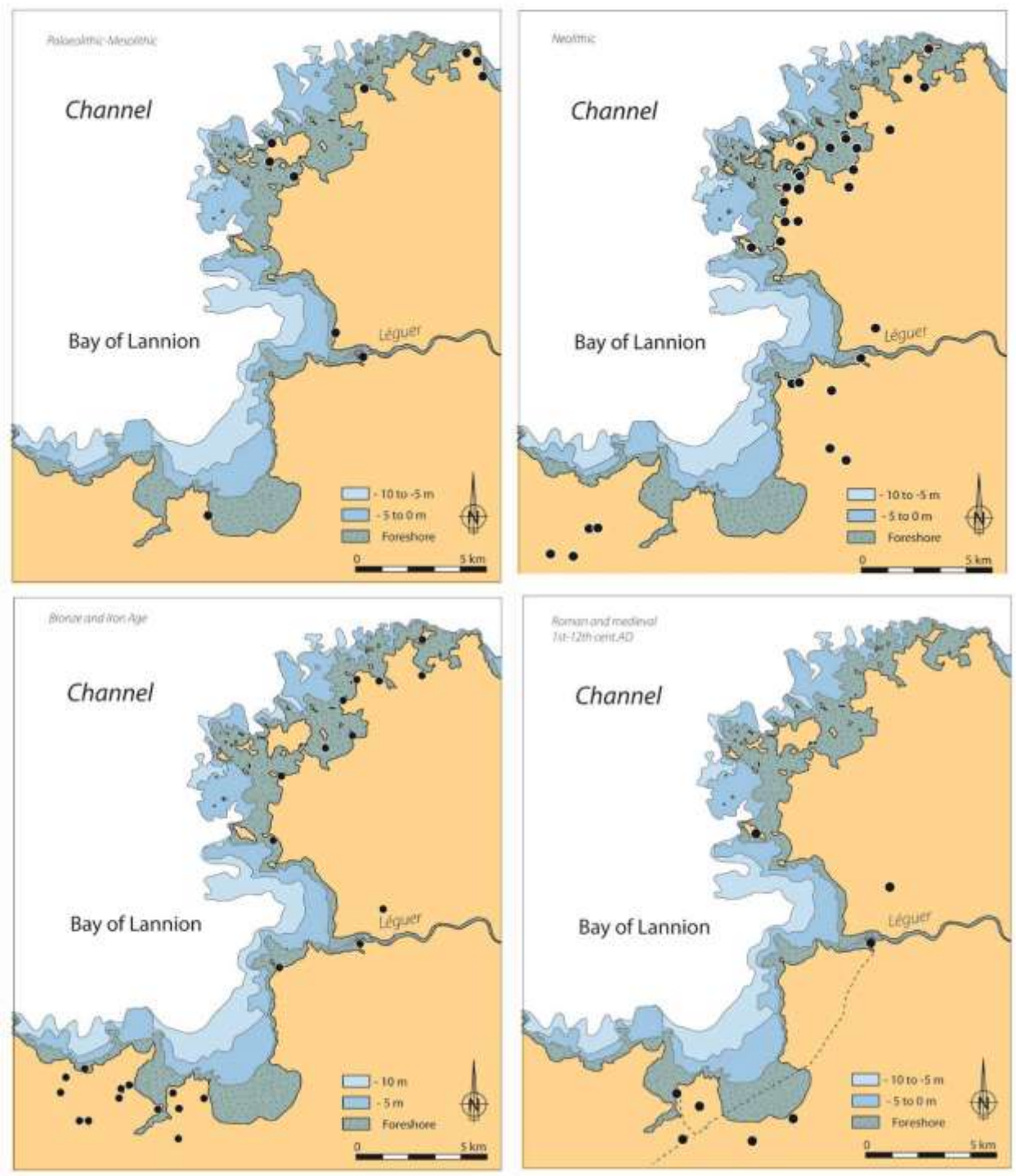

Figure 3I.6. Mapping of the archaeological sites of the area (from Palaeolithic up to Middle Ages) (doc. L. Quesnel and L. Langouët).

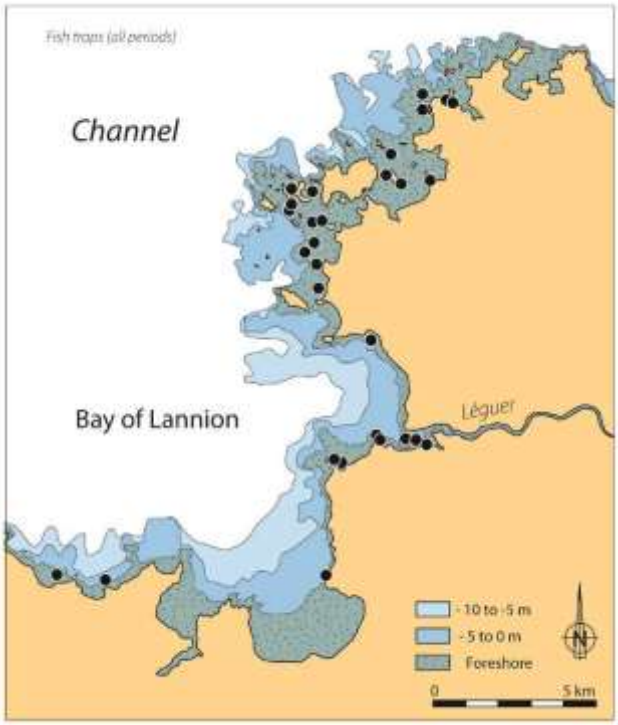

Figure 3I.7. Mapping of the archaeological remains of fish traps (all periods) in the case study area (doc. L. Quesnel and L. Langouët).

3I.1.2 Summary of the Archaeology and History of the Northern Finistère and Trégor Case Study Area

The western part of the study area is very rich in archaeology, (Giot 1987, Giot *et al.* 1998, Sparfel & Pailler 2009) detail of this is developed further through the photographic analysis outlined below. The archaeological and palaeoenvironmental study area focuses on the Léguer estuary area, extending from Pleumeur-Bodou in the north to Locquirec in the south (Figures 3I.6. and 3I.7). The coastline of the case study area consists of the estuary of the River Léguer, where the largest concentration of fish traps are found, including the Petit Taureau fish trap. Their position which is dependant on sea level is the best example in this area demonstrating sea level rise and is the reason why the study area was chosen.

The Léguer estuary is immediately surrounded by cliffs up to 60 m above sea level. The erosion of the cliff is not a major issue, as it consists of granite rocks. On the other hand, the changes in the coastline are important in the bay of Saint-Michel-en-Grève and have rapidly changed in the last three centuries, as can be seen from historical maps. The study area also encompasses the Ile Grande zone in the north which is surrounded by marshes, where is possible to find archaeological sites. In this zone, changes of the coastline were provoked by human activity in the last two centuries, especially with the exploitation of granite quarries. In the entire area, the island archaeology has been particularly dynamic during the past few decades (Le Bihan and Villard, 2007 & 2010; Daire, 2009).

Early Prehistory (Palaeolithic and Mesolithic)

Evidence for the Pleistocene period in the Léguer estuary area includes mainly worked flints dated from the Upper Palaeolithic, when the sea level is considered to be 10m lower than the current level. This material has been found in the intertidal zone around the Ile Grande, several quartz tools were also found in this area, as the quartz veins are common around the Bay of

Saint-Michel-en-Grève, and all along the cliffs of Beg Léguer. As flint is not naturally present in this area, the flint artefacts were made from flint pebble tools carried to the area by the sea.

Many sites dated from the Middle and Upper Palaeolithic have been identified in this area associated with Pleistocene loams (Giot *et al.,* 1998) but no archaeological excavation has taken place. The Palaeolithic evidence in the Léguer estuary area consists of sporadic finds of hand axes and worked flints picked up from the beach. The most important concentration of worked flints was recovered from the beach of Runigou in Trébeurden (Giot *et al.,* 1998).

Later Prehistory (Neolithic, Bronze Age and Iron Age)

The evidence of Neolithic peoples around the Léguer estuary is notable. The main feature of this period is an intense concentration of burial graves and standing stones in the Ile Grande area at the summit of the islands, especially in places with an important visual connection, such as Ile d'Aval, Ile Grande and Enez Vihan (Marchat & Le Brozec, 1991: 42). During this period, the sea level is considered to be 5-7m lower than the current level, and the foreshore archaeological remains of this period are the best evidence of sea level rise all along the coast of Brittany. The Neolithic habitat would be placed in lower areas, nowadays flooded and only accessible at low tide as some the flint tools found in the intertidal zone of Kervegan could be dated from this period. The abundance of standing stones, nowadays located on the shore, such as Prajou, Run ar Gam and Toenno in Trébeurden are a good example of the sea level rise (Figure 3I.8).

Figure 3I.8. A Neolithic of Bronze Age standing stone nowadays located in the tidal area, at Toenno (Trébeurden) (cl. L. Langouet).

Within the area, Neolithic flints have been found in the estuary area of Léguer. Five polished stone axes made from dolerite axes were recovered in the site of Yaudet during excavations (Cunliffe & Galliou, 2005: 31) and another polished axe was found dredged from the estuary of Léguer (Giot,1958).

The main evidence for the Bronze Age and Iron Age in this area is the site of Yaudet. The excavations were carried out by Barry Cunliffe and Patrick Galliou from the Institute of Archaeology, University of Oxford and the 'Centre de recherche bretonne et celtique, Université de Bretagne Occidentale', they began in 1991 and continued until 2002 (Cunliffe & Galliou, 2004, 2005, 2007). The site may have been defended in the Late Bronze Age, but the massive rampart was built in the Late Iron Age. Dredging in the estuary of the Léguer close to Le Yaudet has also recovered three bronze swords (Briard, 1971). The swords dated from Early Bronze Age or beginning of the Middle Bronze Age (c.1500 BC) to the end of the Late Bronze Age (c.800 BC) were ritually deposited in marshland fringing the river over a period of time when the mean sea level was several metres lower than it is at present. A lack of Bronze Age structures is an issue in the whole region and this period is mainly documented by funeral monuments, such as those discovered within the shore near the pointe of Sehar (Locquémeau-Trédrez) (Daire, 2011: 143) or by objects, especially weapons, frequently found in rivers bed or estuaries (see below). In the Léguer estuary area, the main evidence of Iron Age settlements is the Yaudet promontory and the Moulin de la Rive habitat, the last one being buried under a thick dune level, where a huge number of pottery sherds were recovered after the erosion of the cliff (Giot *et al*., 1986).

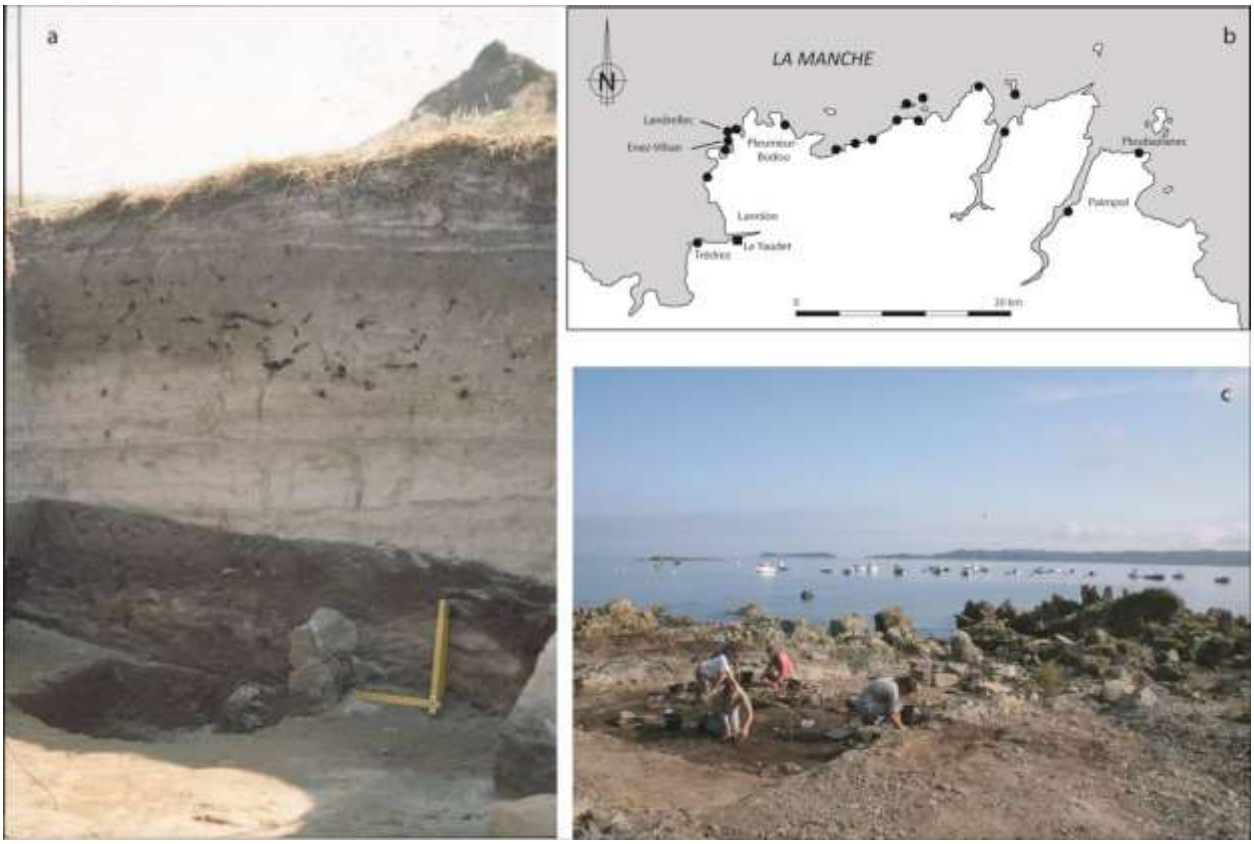

Figure 3I.9. Iron Age salt production in the Trégor area. a: Sandy dunes formed above the Iron Age archaeological level, Landrellec. b: Distribution of the Late Iron Age salt workshops in the area. c: Excavation in progress on the Dossen Rouz site, in 2009 (doc. M.Y. Daire).

The archaeological evidence in the Late Iron Age, when the sea-level was about 2 meters lower, shows an important coastal occupation with considerable salt working and fishing activity within the Léguer estuary area. The whole Trégor area shows a dense network of salt workshops sharing the same technology and producing salt in large quantities for an export market (Figure 3I.9). The excavation of the salt working site of Dossen Rouz took place in 2009

(Daire, 2011), after the Xynthia storm in 2008 eroded the Sehar peninsula, forcing a rescue archaeological project to protect the site (Figure 3I.9.c). At this point, during one night, the coastline retreated 9 meters! Another salt working site was identified within the cliff of Landrellec due to the erosion of the cliff after a storm in 1990, an excavation took place and some well preserved structures were identified, a big excavated kiln and a series of five pits (Daire & Le Brozec, 1990). Another contemporary salt workshop (2nd-1st cent. BC), featuring the same architecture and inner organisation, has been excavated on Enez Vihan island (Daire *et al.,* 2001). The excavation of the Iron Age site of Yaudet promontory, which is one of the major sites of this area (Figure 3I.10), has shown intense occupation in this period with the construction three ramparts within the first century BC (Cunliffe & Galliou, 2005). Another fortification, possibly going back to the Iron Age has been identified in the Dourven cape, only 1 km downstream from Yaudet; no excavation has taken place but is possible to see several ramparts made with stones (Daire, 2011: 129). The Yaudet settlement was placed within an important network of exchange between the Atlantic coast of Gaul to the Gironde and beyond, and northwards across the Channel to the south coast of Britain stretching from Devon to Hampshire, from the second century BC until the first century AD.

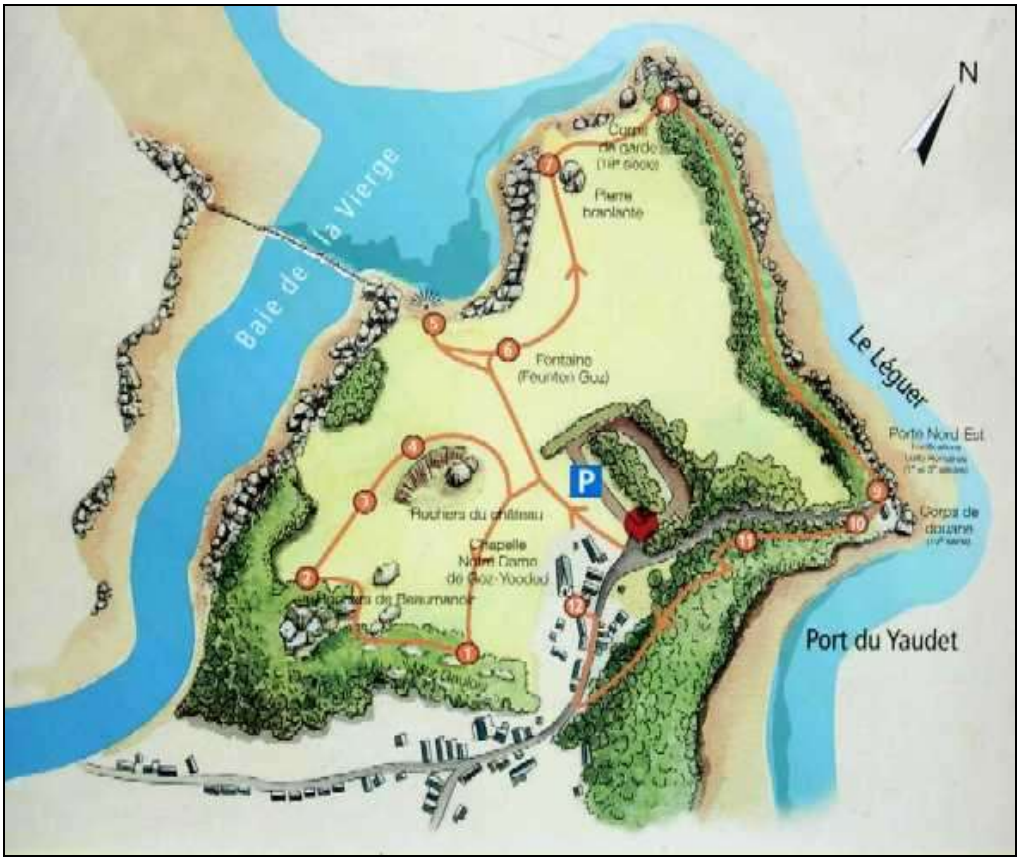

Figure 3I.10. The Yaudet fortified promontory and surrounding maritime installations (source: http://bro-plistin.pagesperso-orange.fr/)

Roman Period

After the Caesarian campaign against the Armorican tribes in 56 BC, a period of constant revolts of the tribes occurred, and the later rampart of the site of Yaudet would represent either a response to the subsequent events of the conquest period or a resurgence of native resistance. After the defeat, the occupation continued uninterrupted well into the first century AD, when new towns were established under the Augustan settlement (Corseul and Carhaix),

these changed the economic dynamics and the maritime oppida became marginal. The site of Yaudet was then only occupied in the Upper Plateau by a small community and during the third century would be a military installation.

In the late Roman period several Roman towns of Armorica were defended by walls, and the fortification of Yaudet shows its important location on a maritime promontory protecting the estuary (Figure 3I.10), as it was also the case of Alet (Saint-Malo) and Brest. There is little evidence of activity in the first half of the fourth century but by around AD 400 the site was again in active use and has been occupied ever since.

Roman villas are not uncommon in the study area and an important coastal settlement was identified around the Bay of St-Michel-en-Grève (Figure 3I.11). The most important was the construction of a roman villa near the Douron estuary; some remains of the villa were discovered, but the bathhouse was well preserved covered by dunes. The bathhouse was built in the 1st century AD and later converted into a house and partially demolished. The site was abandoned during the 3rd century AD and covered then by dunes. An excavation took place in 1981 and 1982 after a first dig by Colonel Pérès until 1938 (Bardel, 1984). Another roman villa was identified under the cemetery of St-Michel-en-Grève parish where after a big tempest, some roman structures were discovered. A protective wall was built then in 1869 in order to defend it against the tidal bore.

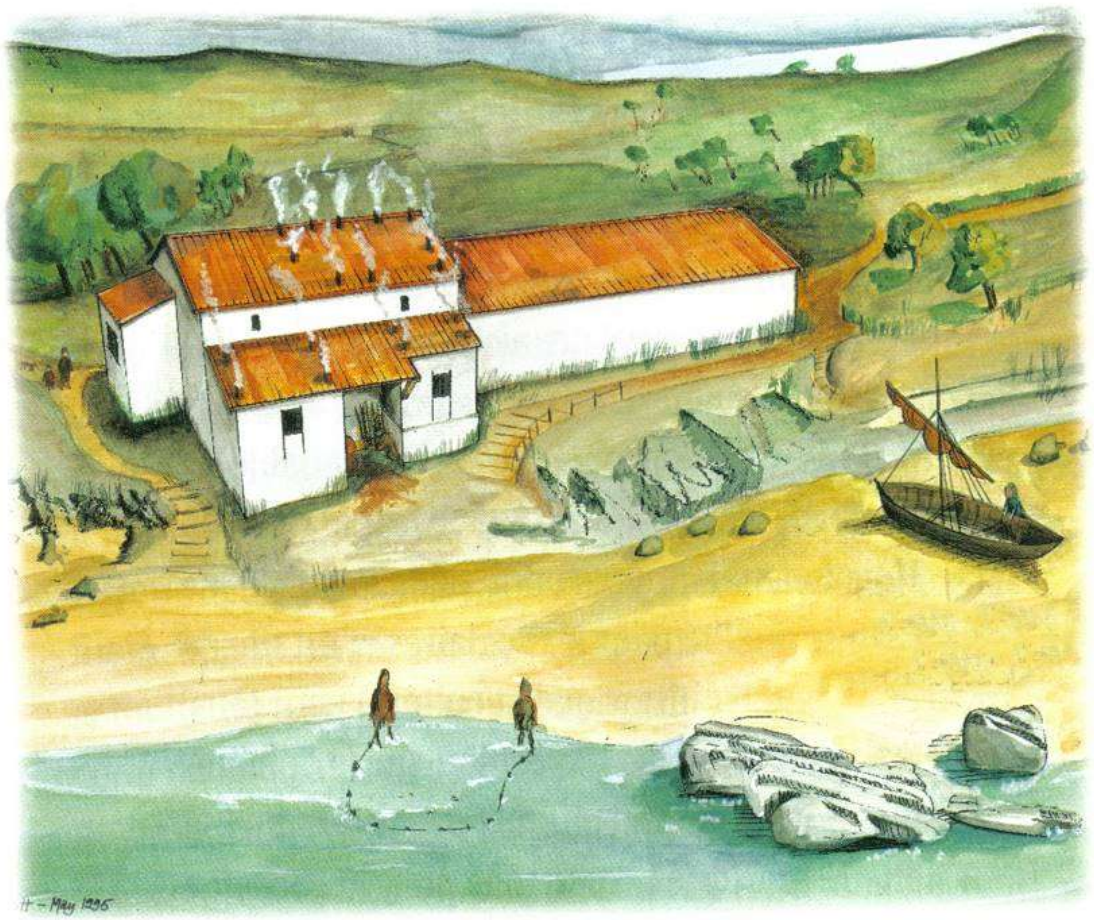

Figure 3I.11. Reconstitution of the roman bathhouse of Plestin-les-Grèves, Hogolo (drawing by M. Batt, after Bardel 1984).

A road was built in the Roman period between the oppidum of Yaudet and the town of Saint Michel en Grève. The name of "voie romaine" (roman road) is still preserved in the city of St Michel en Grève, as a 'fossil' of the roman road (see below in both Art and Maps and Charts analysis). After the town, the road crosses the beach of St-Michel-en-Grève towards the Saint-Efflam area. At the time of construction, the sea level was lower and the path was never flooded by the tide, it was also protected from the sea by a shingle barrier. This road has traditionally been an important route of communication between the towns of Lannion and Morlaix and it was in use until at least the 18th century.

Medieval Period (500AD – 1485AD)

For the early Medieval period there is a lack of significant activity in the late 4th or early 5th century in this area. The known archaeological record from 380-550AD is almost non-existent, except from the site of Yaudet, the headland which was occupied throughout the 5th and into the 6th century. The archaeological remains of Yaudet between c.AD 380 and 550 are of potential relevance to the lively debate surrounding the supposed large-scale emigration of communities from Britain in the 5th century and their settlement in Armorica.

The main coastal activity for this period would be fishing (see below) and the estuary exploitation around a monastic establishment founded during the 6th century on the Yaudet promontory. This monastic community was also responsible for the construction a dam built of massive blocks, the Baie de la Vierge fish trap. The construction of the Petit Taureau fish trap in the Léguer estuary is probably related to the community of Yaudet, with an early medieval construction phase around 615AD (see below for the detailed study).

Between the 9th and the 10th centuries, the whole area suffered sporadic raids, mainly from Viking enclaves settled along the Seine, which continued until the middle of the tenth century. The Yaudet monastery was probably attacked but there is no archaeological evidence of destruction. Anyway, the constant raids and the Viking invasions provoked a progressive abandonment of coastal habitat. In the bay of Saint-Michel the sea level rose and a cross, the Croix de Mi-Lieu, was placed as a landmark for pilgrims and travellers.

In the high medieval period, the Léguer estuary area is dominated by the town of Lannion, 6 km upriver, which became the port-of-entry and had a better location than the Yaudet promontory. It was also protected by attacks from the sea, and it has a privileged location on an important route node that made Lannion an important commercial point. On the other hand, the Yaudet site became more and more isolated, located off of the commercial routes.

Post-Medieval Period (1485 AD – 1900 AD)

A significant element of archaeological record within the Post-Medieval period includes the construction of coastal military defences in order to protect the population and the ports from attack. A key feature is the construction of a path along the coastline of Brittany which was created for watching of the ships for customs purposes. This is now a coastal path used for pedestrians and visiting tourists. The position of batteries and guardhouses along the coast in strategic positions is mainly reflected in historic maps dated from the 18th century.

Between the 19th and the 20th century the coast has suffered intense granite quarry exploitation, especially the Granite Rose area between Trébeurden and Perros-Guirec (Figure 3I.12). The quality of this granite and the particular colour was the main reason for the intense exploitation that provoked important changes in the coastline and the destruction of archaeological sites. The fishing industry and the building of the harbour of Trébeurden, Plestin or Trégastel was also an important issue for the local economy.

Modern

During WWI and the inter-war period, the main coastal activity was tourist related. The beaches of Trébeurden and St-Michel-en-Grève became a major tourist destination in France. The main impact of sea level change was the construction of the railway between Lannion and Morlaix along the coastline of Saint-Michel (Figure 3I.13).

The majority of sites from the 20th Century comprise WWII defence systems with the construction of the Atlantic Wall by the German army. A defensive system was placed within the shore of Plestin-les-Grèves, in front of Villa les Dunes, as a part of the Atlantic Wall. It consists of one casemate and four blockhouses partly buried in the sand; it was partly destroyed after the war. The main area controled by the German army was Saint-Michel bay, as it was a probable disembarkation zone, during this period the Cross of Mi-Lieu was destroyed by target practice.

Figure 3I.12. Remains of the granite quarry activity in the Trégor area (Enez Vihan, Pleumeur-Bodou) (ph. M.Y.Daire).

Figure 3I.13. Early 20th century promotion of Plestin-les-Grèves seaside station (source: the passion-metrique.net).

3I.1.3 Archaeological, Palaeoenvironmental and Coastal Heritage Resources Consulted for Project

The archaeological and palaeoenvironmental data has been obtained from the *AMARAI* Database, the *Atlas des Patrimoines*, the *Splashcos* Database and the *Inventaire du Patrimoine des Côtes d'Armor,* further information about the data collected for the project is available below. Several books were also used, either general (Giot *et al.,* 1995; Collective, 1992), or thematic (Monnier 1981), or local (Boutouiller, 2002; Apegit annual bulletins 1986-1996).

Several archaeological projects have been carried out in this area over the last twenty years. The longest research project was the Yaudet excavations undertaken annually between 1991 and 2002, the main interest was the Iron Age period but the excavations showed that the promontory had been in use almost continually since the Neolithic period. The scientific report was published in three volumes (Cunliffe & Galliou, 2004, 2005, 2007), the first one presents a background study of previous research and volumes 2 and 3 form the detailed report of the excavations from the Neolithic to the present day, and include a useful general overview of the archaeology around the Yaudet site for every chronological period.

Another archaeological project was the study of fish traps from the Mesolithic to modern period along the Brittany coast coordinated by Loïc Langouët and Marie-Yvane Daire, since 2006 (Daire & Langouët 2008, 2010). Over 750 fish traps were identified in Brittany, but Servel-Lannion was chosen for the Arch-Manche project because of its richness and diversity of heritage from various periods. The description of the works carried out in 2012 and 2013 are detailed below. The last archaeological research project in this area to be considered is the study of Iron Age salt working sites conducted by M.Y. Daire, as several sites were identified and three of them were excavated (Landrellec, Enez Vihan and Dossen Rouz) generally after a

big storm event. The salt working sites, once located within the Iron Age coastal belt, are nowadays strongly affected by erosion and are particularly illustrative of coastal changes.

Alongside this, another research project was the *Inventaire de Patrimoine des Côtes- d'Armor* funded by the department of Côtes-d'Armor, the region of Brittany and the Ministry of Culture of France between 2002 and 2011. The main objective was to create an inventory of coastal heritage for use in coastal management and supporting tourist information (http://archives.cotesdarmor.fr/). The programme includes a compilation of archaeological evidence, historical maps, ancient photographs and architectural heritage in 49 coastal towns.

A database on submerged prehistoric sites has recently been constituted, as the French contribution to the international Splascos Atlas (in progress); it was a main resource for prehistoric sites in addition to the archaeological inventories of the Atlas des Patrimoines (http://atlas.patrimoines.culture.fr/atlas/trunk/) and especially the AMARAI Database, which provided the most detailed and updated information about archaeological sites in Brittany, especially island and coastal sites.

3I.1.4 Art History of the Area

This section presents the background to artistic representations within the area including key schools of artists and individual artists. This provides the background to the broader consideration of individual artworks within the study area. The coastal region of Northern Finistère and Trégor was not very frequently depicted in comparison to the tourist region of Cote d'Emeraude or Cornouailles which were a major source of inspiration for artists from all over the world and where the Pont-Aven School of painters was created in the nineteenth century. Fortunately, some pioneers of photographic techniques represented numerous parts of this case study area. Photographers produced photographic images for postcards which provide visual records of areas where tourism developed on the coast.

The art study area extends for a distance of 260 km along the coast from Paimpol in Côtes-d'Armor, eastwards and then westwards to Crozon in Finistère. The area formerly selected for the analysis of archaeological records has been enlarged to a wider territory for the art study, especially in a western direction, in order to gather a sufficient set of illustrations, and include some important study sites, such a those of the Léon coastal area.

As in the other case study areas, the approach for the coastal study sites aimed to:

- Demonstrate the role that historical works of art (oil paintings, watercolours and prints) and especially photos, can play in terms of supporting understanding of long-term coastal change;
- Assist understanding of the chronology of coastal change in Northern Finistère and Trégor; and
- Provide examples of those artists' works which form reliable records of coastal conditions at the time they were painted.

Art Resource

The main resources used for the paintings of the area included some illustrated books which provided a wealth of paintings and watercolour drawings (Delouche 2003), but the main resource was the Joconde online database. The Culture ministry database 'Joconde' is the gateway to the collections held by museums and public galleries in France. The cataloge contains nearly 500,000 records of objects of any kind (archeology, fine arts, ethnology, history, science and technology etc) enhanced by thematic sections, zooms and virtual exhibitions.

Joconde is the result of an ongoing partnership between the office of the digital broadcasting service, collections of museums in France and the participating museums.

The most prominent figure for art in this area is Henri Rivière. Henri Rivière (1864–1951) was a French artist and designer best known for his creation of a form of shadow play at the Chat Noir cabaret, and for his post-Impressionist illustrations of Breton landscapes. Rivière first visited Brittany in 1884, spending most of his summers there until 1916. Together with bustling Parisian life, rural Brittany constituted the majority of the subjects of his landscape works, between 1890 and 1894. He also made colour woodcuts (studies of waves), strongly influenced by the vogue for Japonism at the time (Collective, 2008).

Another important artist is Emmanuel Lansyer (1835-1893), considered as one of the best landscape artists of his time, with Corot; his work includes more than 1,500 paintings, including many Breton landscapes (Delouche, 2003).

3I.1.5 Art Resources Consulted for the Project

For the Northern Finistère and Trégor area, the art approach benefited from the academic work (Master2) led in the Rennes 2 University by E. Motte (Motte 2013). The theme of the dissertation was: '*Representation and Evolution of the Shoreline: What do regional paintings 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 covering the case study area.

The main source for photographs was the collection available in the Archéosciences Laboratory (University of Rennes) (ICARE, http://ntarcheo2.univ-rennes1.fr/icare/). Several books have recently highlighted the importance of pioneer photographers in the region, these provided important contextual information for our research (Croix *et al*., 2011; Prod'homme, 2012; Biet and Bouze, 2010).

One of the most informative maps and charts used within this case study area was the '*Carte des Ingénieurs géographes du Roy*' (18th century), which provides very accurate details especially along the coasts. At a local scale, a very detailed example is the 'Cadastre Napoléonien' (19th century) which provides a view of the limits of private and public properties, buildings and fields, sometimes with additional information.

3I.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 (Collective, 2009).

3I.2.1 Review of Key Contributors to Coastal Change

The question of coastal changes due to the effects of sea level rise has recently been revised by P. Stéphan for north western Brittany (Stéphan, 2011) (Figure 3I.14). The lithostratigraphy and biostratigraphy of three back-barrier sediment sequences in the Bay of Brest are examined to reconstruct the Holocene sea level history in the western part of Brittany. A saltmarsh foraminifera-based transfer function is used to assess palaeo-sea level positions with a precision of ± 0,51 m. The transfer function is applied to foraminiferal assemblages from four cores, providing 16 new sea level index points from western Brittany. Our data suggests a relative stability of relative sea level between 6250 and 5500 cal. yr BP, followed by a period of sea-level rise (about 2 mm/yr) between 5500 and 3200 cal.yr BP. A decrease of relative sea level with a magnitude of 2 m is suspected between 3200 and 2800 cal.yr BP. After 2800 cal.yr

BP, a new period of sea level rise is recorded, slowing until today. These results are in agreement with the curve of Morzadec- Kerfourn (1974) from the northwestern part of Brittany. However, the period of relative sea level fall around 3000 cal.yr BP is questioned. Although this regression phase is recorded in the North Sea and in parts of the English Channel, this event is recognised neither along the other French coasts, nor along the south western coast of England.

In addition to natural causes of coastal change, several recent publications have underlined the impact of human interventions on coastal areas. An illustration is provided here with Vougot beach (Guissény, north coast of Finistère) which has been subject to a recent geomorphologic study (Suanez *et al.,* 2010). It is a massive drifting sand body approximately 250 to 400 m wide and 2 km long. This dune, with a southwest to northeast position, protects a vast polder area which was disconnected from the sea by a dike construction in 1834. For several decades the eastern part of this dune experienced erosion mainly due to the construction of an artificial jetty in 1974 (Curnic jetty), which entirely modified the hydrodynamics and sedimentation processes. In order to determine the actual trend of evolution, the advance rate, and the resultant sand drift that is occurring, a survey of the dune was achieved between 2004 and 2009 (Figure 3I.15). The results show that the speed of dune retreat has increased in the last decades, and confirm the fact that the Curnic jetty is constantly interrupting the sand drift inducing an increase in sediment loss from the Vougot beach/dune system.

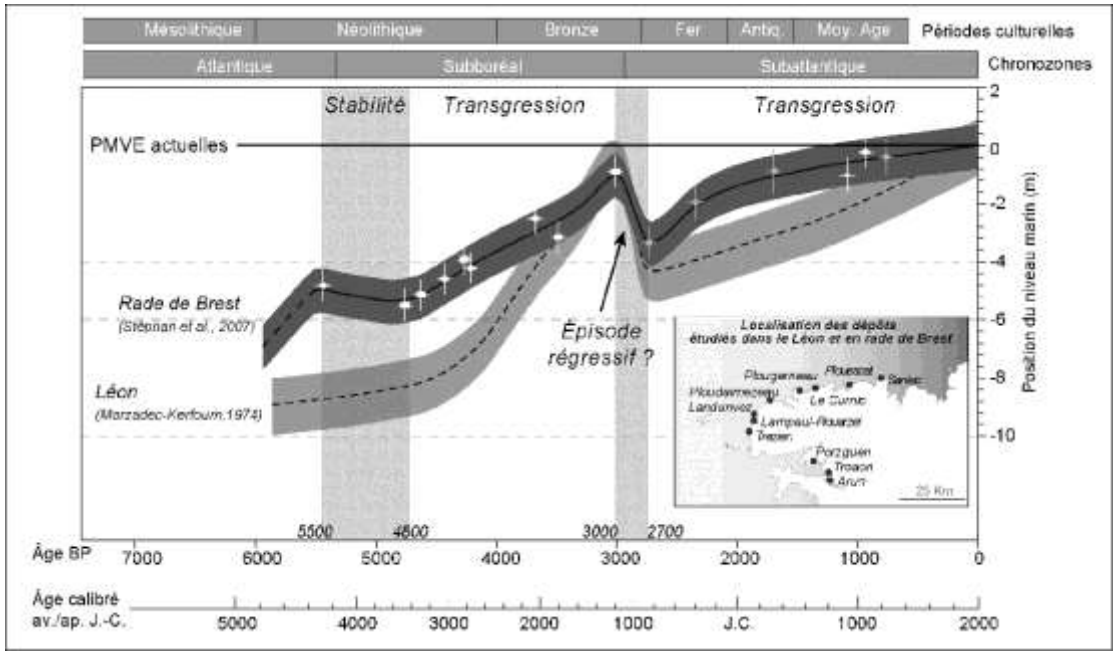

Figure 3I.14. Curves for the Holocene sea level variations (highest sping tides (PMVE)) in the North Finistère Léon area, calculated (after Stéphan in Sparfel & Pailler, 2009: 10).

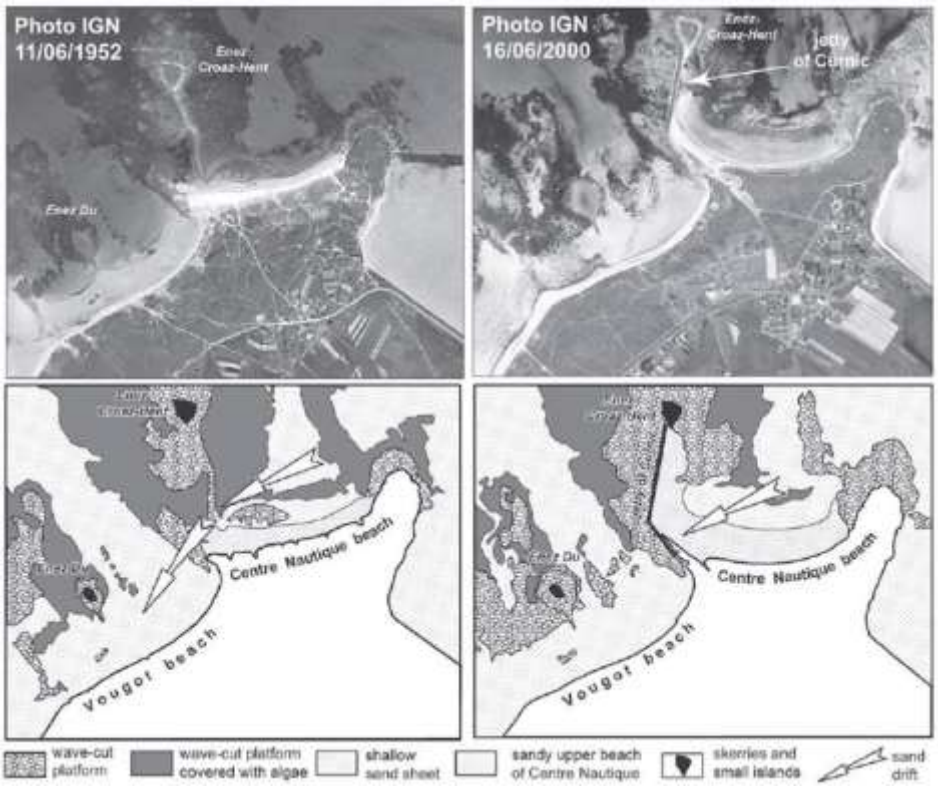

Figure 3I.15.Comparison of 1952 and 2000 aerial photographs illustrating the accretion of the Guissény (Northern Finistère) beach due to the building of the Curnic jetty in 1974. The east-to-west sand drift is generated by wave diffraction around Enez Croaz-Hent island (after Suanez et al., 2010).

3I.2.2 Summary of Current Coastal Management Approach

Coastal risk management is a responsibility of coastal local authorities (i.e towns, departments) in partnership with regional and national institutions (Conservatoire du Littoral, Maritime Affairs, Culture Ministry) (Merckelbagh, 2009). Scientific assessments of coast change and management have been carried out within the framework of several geomorphological studies, generally in response to requests by local managers. These studies showed that uncombined planning policies could produce particularly detrimental effects impacting geosystem functioning 'irreversibly'. Elected representatives and coastal populations settled in coastal areas are concerned with the acceleration of the retreat of dunes and coastal ridges. The scientists raise issues of coastal protection against marine damage and, to this effect proposals were made by researchers to the elected representatives (Figure 3I.16).

According to our current knowledge of the natural environment, several sites of interest are inventoried in the Country TRÉGOR - GOELO:

- 60 Natural Areas of Ecological Interest, Flora and Fauna (SSSI) type 1, a total area of 5,170 ha comprising marine environments, coasts, land (islands, dunes, estuaries, mudflats, rocky coasts, forests, ponds, marshes, moors)
- Protected sites of the country include one Nature Reserve (the Sept-Îles archipelago) and three Special Protection Areas (SPAs); 32 sites are classified under the 1930 Act.
- Management systems in place consist of 6 Sites of Community Interest in the Natura 2000 network.

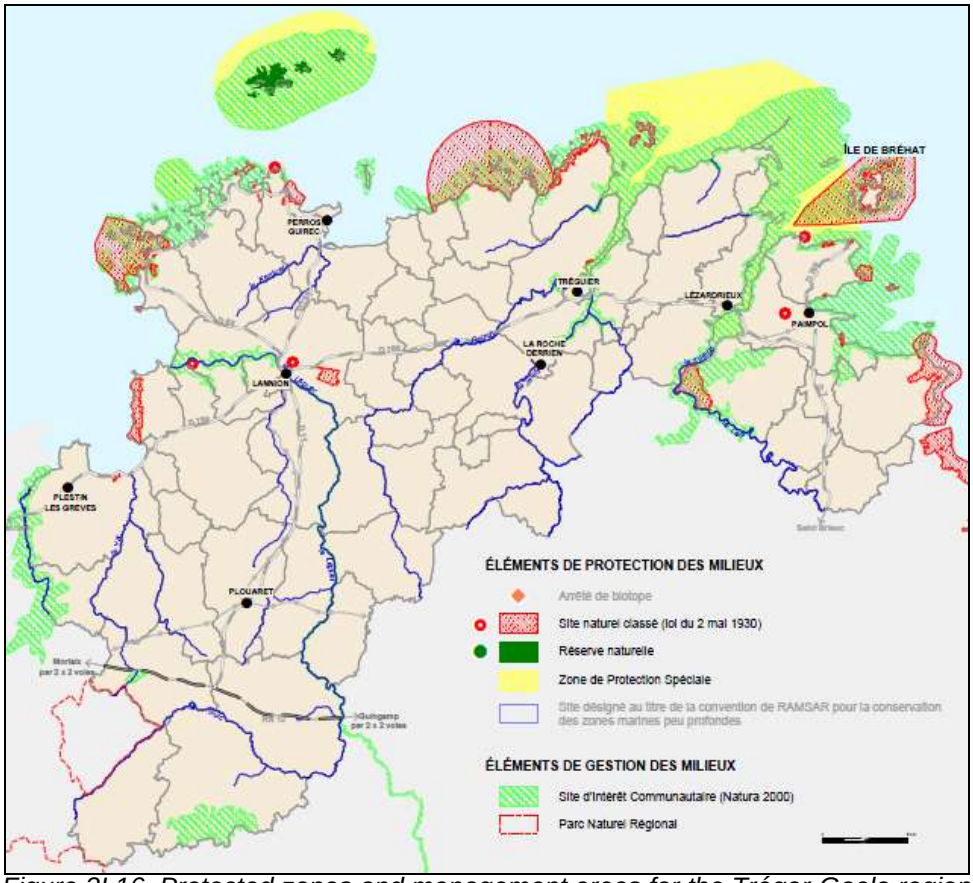

Figure 3I.16. Protected zones and management areas for the Trégor-Goelo region (source: www.bretagne.developpement-durable.gouv.fr/).

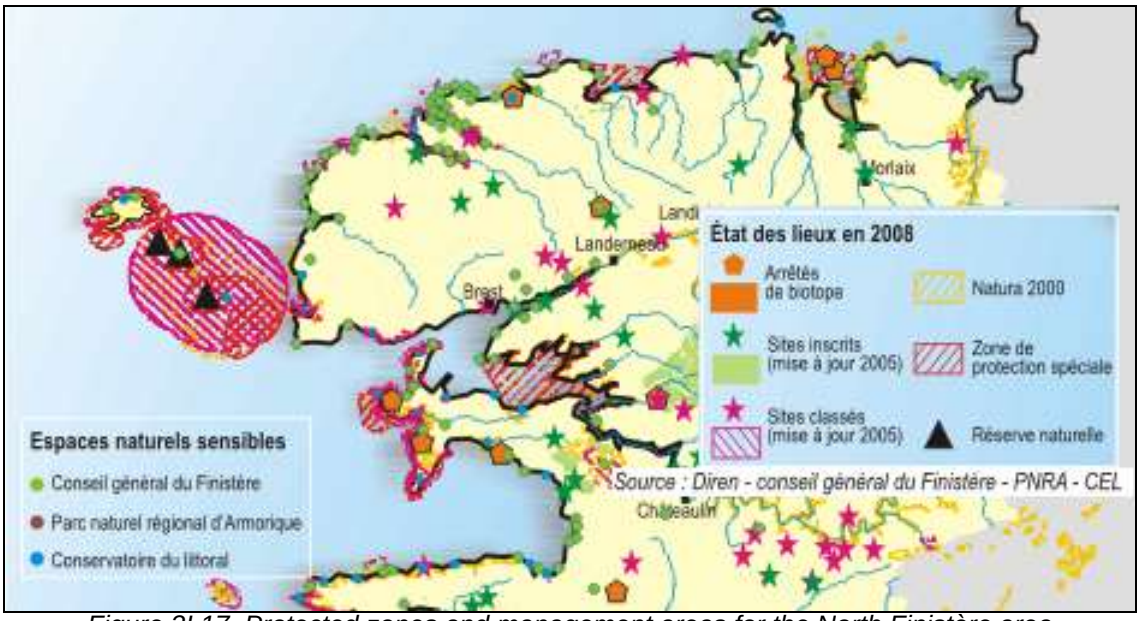

Figure 3I.17. Protected zones and management areas for the North Finistère area (source: www.bretagne.developpement-durable.gouv.fr/).

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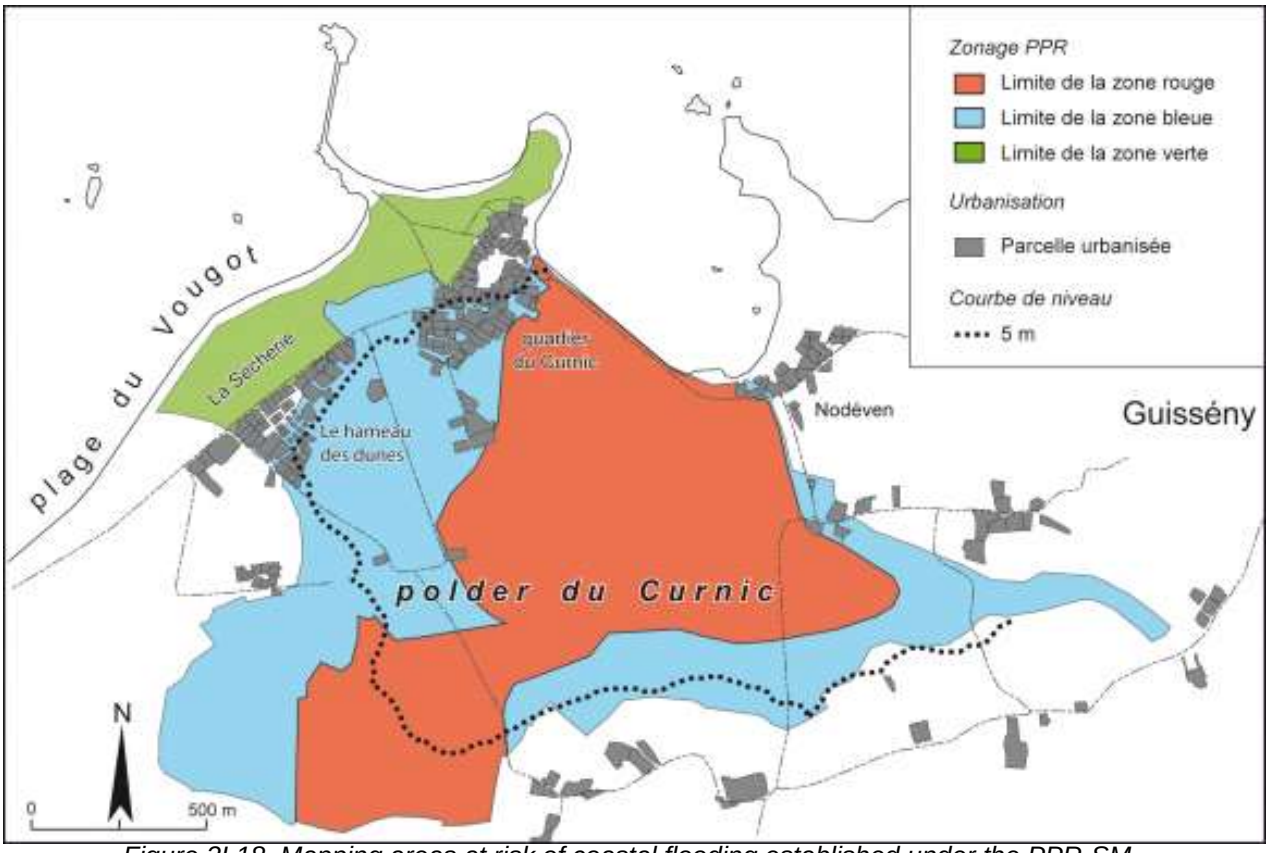

Figure 3I.18. Mapping areas at risk of coastal flooding established under the PPR-SM for the municipality of Guissény (after Cariolet et al., 2012).

In Northern Finistère there are numerous protected areas, as shown on the Figure 3I.17 (www.bretagne.developpement-durable.gouv.fr/). Risks threatening coastal areas within this case study, are of different natures: coastal erosion, flooding and, in some areas, anthropic pressure (tourism, pollution), as shown for example in the Curnic area (Figure 3I.18).

3I.3. Archaeological and Palaeoenvironmental Ranking

This section outlines the results of the archaeological and palaeoenvironmental ranking from the Trégor and north eastern Finistère study area, followed by a discussion of the results. The ranking methodology applied is detailed in Section 2.

The ranking results have benefited from detailed research carried out in the area, especially linked with the excavations and environmental study of the Servel-Lannion fish traps and their surroundings, i.e. the Léguer estuary (Langouët *et al.* 2012, Langouët and Bernard, 2012). Another area of interest was located around the St-Michel-en-Grèves bay, were an important settlement dating back to the Roman period has been recently studied and restored.

3I.3.1. Results of the Archaeological and Palaeoenvironmental Ranking

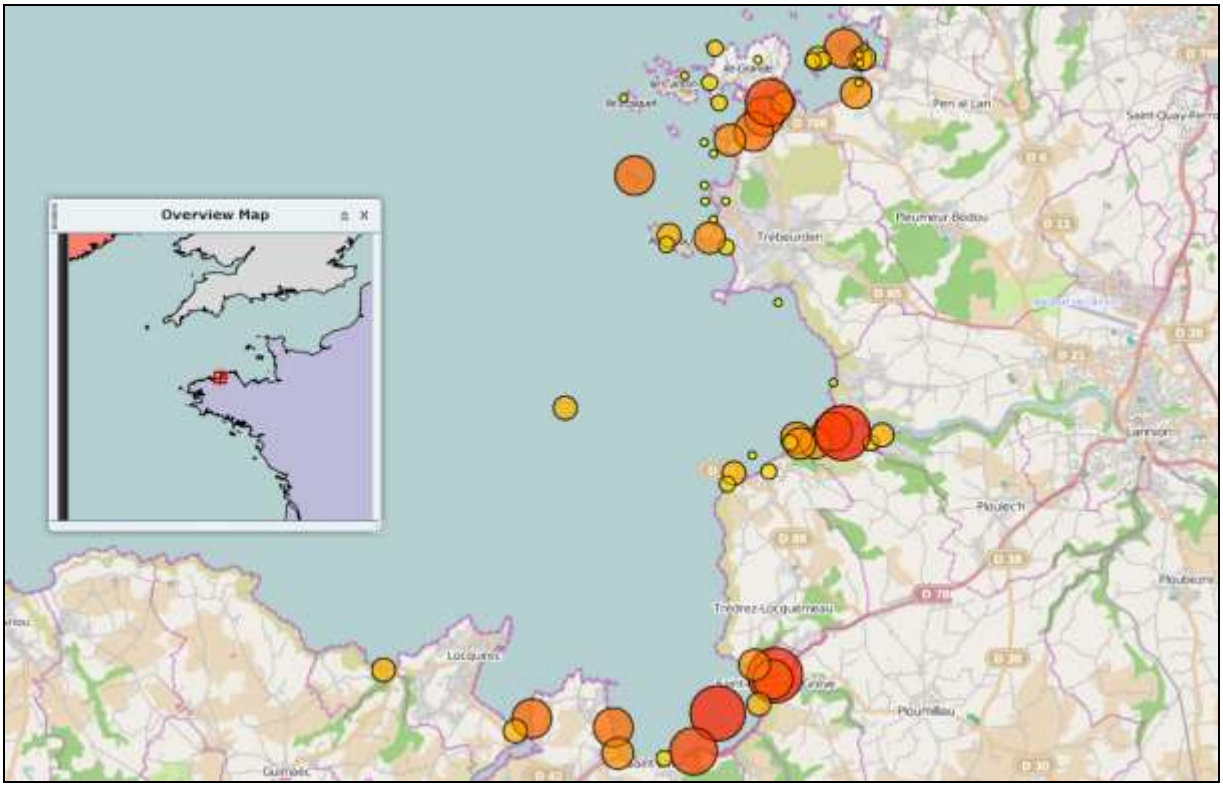

Figure 3I.19. Map showing the distribution of ranked archaeological sites within the Trégor and North-Eastern Finistère study area.

Within the Léguer estuary study area data was obtained from the AMARAI Database, the *Atlas des Patrimoine* of the Ministery of Culture, the SPLASHCOS Database and the Inventaire du Patrimoine des Côtes d'Armor of the Region of Brittany. Where sites ranked highly further research was then required in order to understand the full nature and extent of the site. Each data set went through a process of cleaning, in order to prevent the duplication of sites; this process is detailed further in the Methodology Section 2. A total of 62 sites and records were assessed.

The highest ranking sites (Figure 3I.19) are listed in the table below (Table 3I.1), the total score has been normalised to give each site a score out of 100.

APE uid	Site Name	Site Type	Period	Score – Sea Level	Score – Environmental	Score – Temporal Continuity	Total Score	Coastal Context
361	SAINT-MICHEL-EN-GREVE – Croix de Mi-Lieu	Monument	Medieval	High	High	High	100	Inter tidal
700	SAINT-MICHEL-EN-GREVE - Roman road	Other find spot	Roman	High	High	High	100	Inter tidal
457	LANNION - Petit Taureau	Marine Installation	Medieval	High	High	High	100	Inter tidal
687	PLESTIN-LES-GREVES - Railway	Monument	Inter-war	High	High	Medium	88	Above HW
686	TREBEURDEN - Enclosure	Other find spot	Medieval	High	Medium	High	88	Coastal
360	PLESTIN-LES-GREVES - Hogolo	Monument	Roman	Medium	High	Medium	77	Above HW

363	PLESTIN-LES-GREVES - Palaeolithic soil	Monument	Palaeolithic	High	Medium	Medium	77	Above HW
467	SAINT-MICHEL-EN-GREVE - Eglise	Monument	Medieval	Medium	Medium	High	77	Above HW
520	LANNION - Corps de garde	Marine Installation	Medieval	Medium	Medium	High	77	Inter tidal
439	TREBEURDEN - Ile Molene	Other find spot	Iron Age	Medium	High	Medium	77	Inter tidal
371	TREBEURDEN – Runigou	Other find spot	Palaeolithic	Medium	High	Medium	77	Inter tidal
373	TREBEURDEN - Menhir Run-ar-Gam	Monument	Neolithic	Medium	Medium	High	77	Coastal
403	PLEUMEUR-BODOU - Enez An Erc'h	Other find spot	Palaeolithic	Medium	High	Medium	77	Coastal
695	PLEUMEUR-BODOU - Beg Crec'h ar Men	Other find spot	Iron Age	Medium	Medium	Medium	66	Coastal
689	PLEUMEUR-BODOU - Landrellec	Other find spot	Iron Age	Medium	Medium	Medium	66	Inter tidal
417	PLEMEUR-BODOU - Keryvon dolmen	Monument	Neolithic	Medium	Medium	Medium	66	Coastal HW
369	TREBEURDEN - Menhir Toenno	Monument	Neolithic	High	Medium	Low	66	Inter tidal
696	TREBEURDEN – Trozoul	Monument	Iron Age	Medium	Medium	Medium	66	Above HW
449	PLOULEC'H - Poull Mad Dogan	Marine Installation	Medieval	Medium	Medium	Medium	66	Inter tidal
516	TREDREZ-LOCQUEMEAU - Plage de Kirio B	Marine Installation	Medieval	Medium	Medium	Medium	66	Inter tidal
515	TREDREZ-LOCQUEMEAU - Plage de Kirio A	Marine Installation	Medieval	Medium	Medium	Medium	66	Inter tidal
739	SAINT-MICHEL-EN-GREVE - Toull ar Vilin	Buried Landsurface	Modern	Medium	Medium	Medium	66	Above HW
514	PLESTIN-LES-GREVES - Saint Efflam	Monument	Medieval	Medium	Medium	Medium	66	Coastal

Table 3I.1. Top archaeology and palaeoenvironement ranking results within the Trégor – North Finistère case study area.

Ranks for sea level change

	High	Medium	Low
Number of sites	8	30	24

Ranks for environmental change

	High	Medium	Low
Number of sites	6	28	28

Ranks for temporal continuity

	High	Medium	Low
Number of sites	10	18	34

Table 3I.2. Detail of archaeology and palaeoenvironemental site ranking results for each category.

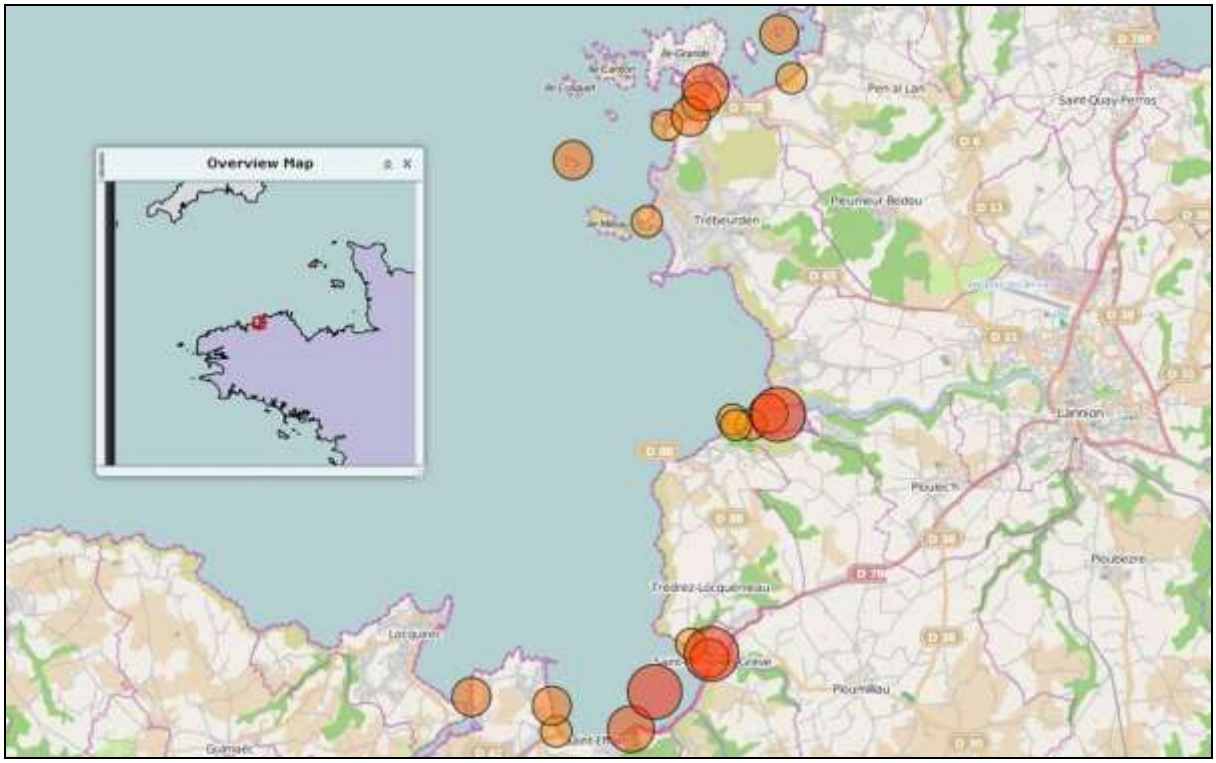

Figure 3I.20. Map showing the distribution of the highest scores sites within the Trégor and North-Eastern Finistère study area.

3I.3.2 Discussion of the Ranking Results

The table of highest ranking archaeological and palaeoenvironmental sites is dominated by medieval and prehistoric monuments. The estuary of the River Léguer is dominated by the fish traps within the intertidal zone, and it represents one of the biggest concentrations of fish traps on the coast of Brittany. The chronology of the fish traps depend on their position within the estuary, which is why they are important for demonstrating landscape evolution. The level and dates of the Servel-Lannion fish traps and others in the area provide valuable evidence of coastal and sea level change. In addition to the archaeological works carried out on the Petit Taureau fish trap, (which included and dating of several different phases), the analytical studies done in the intertidal zone help to reconstruct the environment of the estuary and its geomorphological changes from prehistoric times.

Alongside the fish traps, prehistoric monuments are also represented with in the high ranking sites. Examples include Neolithic monuments, burial graves and standing stones in the area around the Ile Grande, in the north of the Léguer estuary. Their current coastal position is one of the best sources of evidence of sea level rise in Brittany, as they were originally located several kilometres inland in an elevated position above the coast, with an important visual connection. The menhirs of Toenno (Figure 3I.8), are the best sample of sea level rise in this area. Unfortunately, no recent archaeological excavations have taken place on this site, the burial graves were mainly excavated at the beginning of the 20th century, and no further analytical studies of the monuments have been completed. At the same time, prehistoric finds of worked flints have not been subject to a research project and are mainly isolated finds.

The bay of St-Michel-en-Grève is the last area where we can find highest ranking sites. The long term and continued occupation of the bay, from Palaeolithic to modern times, enables the development of modelling of coastal change. Rises of sea level within the bay were visible in the

18th century when the road that used to cross the beach from at least roman times was abandoned due to the danger of the tides flooding the path. Dredging and herding activities were responsible for coastal changes in modern times, as the dunes visible at least during the 17th century suddenly disappeared due to human impact. Over the last two centuries, several embankments were necessary to protect the coastline, the road and the railway. They also had a purpose for tourists, as the bay became a major draw for visitors to the coast of Brittany, who needed transport to the area in addition to protection from the waves.

The intense quarry exploitation of granite sources provides information on coastal change over the last two centuries. This activity provoked not only the disappearance of archaeological sites but also a direct impact on the coastline, especially the islands around the Ile Grande. Other sites which scored lower, because they do not have temporal continuity, but still have the potential to provide information on coastal change were the salt working sites. The sites of Dossen Rouz, Landrellec, Trozoul, Beg Crec'h ar Men or Enez Vihan provide information of coastline change and due to their fragility they are very sensitive to the coastal erosion.

Several megalithic remains from the Neolithic period are considered further through the photo ranking analysis. These sites are now within the tidal area and illustrate sea level rise and coastal change more generally since the Neolithic period.

3I.4 Art, Historic Photos, Maps and Charts Ranking

The ranking systems developed for artworks, historic photographs, maps and sea charts are outlined within Section 2. The ranking systems were applied to a range of selected artworks, some of them being described in more detail below.

3I.4.1 Ranking Artistic Depictions

Research identified eight exhibiting artists who painted on the coastline of Northern Finistère and Trégor between 1770 and 1920 and fifteen paintings were considered (Table 3I.3). By entering data on artwork type, medium, subject matter, time period and other parameters into the the project database it was then possible to calculate the ranking scores for fourteen works of art from the Northern Finistère and Trégor art case study site. The highest ranking artworks, usually gaining 60 points are detailed oil paintings and watercolour drawings, lithographs and steel engravings from the second half of the nineteenth century. These are followed by watercolour drawings from the mid-nineteenth century that were painted by impressionist and postimpressionist artists, the main artist in this period was Henri Rivière who had a house in Ploubazlanec in the Trieux estuary and was fascinated with the coasts of Brittany.

Artists tended to paint attractive or dramatic coastal locations as well as shipping subjects. Marine representations have always been an important subject, especially between the 18th and the 19th century. From the mid 19th century the coast of this region and of Brittany was painted by impressionist or postimpressionist artists. Their aim was not a detailed representation of marine erosion or geomorphological aspects, but a personal point of view. The interest in painting the coast at different periods provides evidence of change over time.

Figure 3I.21. The Loguivy harbour while low tide by Henri Rivière, 1905 (Musée d'Art et d'Histoire de Saint-Brieuc)

The result is that many of the sites of key geomorphological and coastal risk management interest have been painted by artists particularly during the nineteenth century. Even if located at the eastern limit of our study area, the River Trieux estuary painted by Henri Rivière (Figure 3I.21) and also by Paul Sébillot illustrates how art can inform us of long-term coastal change.

These differing coastal landforms and processes and their impacts on coastal residents, assets and infrastructure could not have been easily matched to the most informative works of art without the provision of the ranking system. The ranking system has identified ten study locations, at each at least one artwork has been examined in more detail (see Table 3I.3).

A more detailed explanation of some selected sites and the interpretation of the individual artworks are provided below. The assigning of scores to each artwork suggested names of those artists who had depicted different aspects of the Northern Finistère and Trégor coast across the timeline 1770-1920. These artists include Paul Sébillot (1843-1918), Emmanuel Lansyer (1835-1893), Nicolas Ozanne (1728-1811), Louis Nicolas van Blarenberg (1716-1794), Théodore Gudin (1802-1880), Henri Rivière (1864-1951), Théophile Busnel (1882-1908) and Jules Coignet (1798-1860). These artists can be relied upon in terms of the accuracy of their depictions of the Northern Finistère and Trégor coastline.

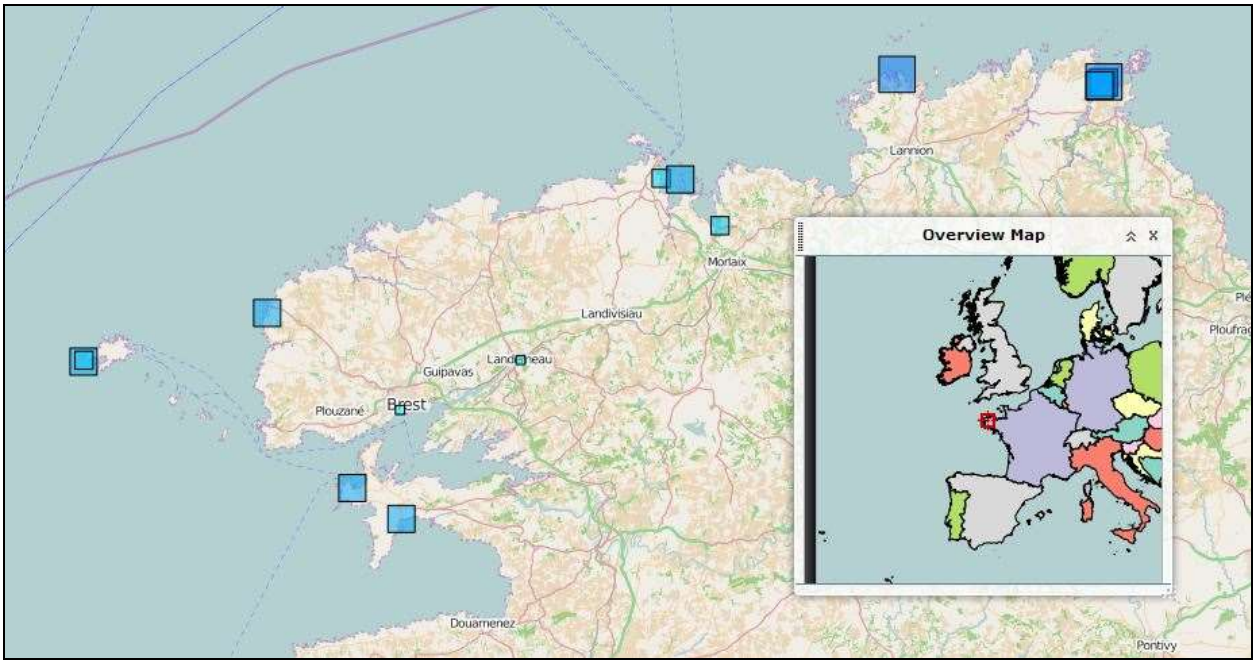

Figure 3I.22. Location of art images within the Trégor – North Finistère case study.

Study No.	Location	Artist	Date	Score type	Sco-re pe-riod	Sco-re style	Sco re heri - tage	Score envi-ron.	Total Score
1	Embouchure du Trieux, Loguivy	Paul Sébillot	1879	Oil	Mid	Topog.		Det. View	62
2	Bréhat, Loguivy	Henri Rivière	1905	Water-colour	Late	Topog.		Gen.l View	55
3	Embouchure du Trieux, Loguivy	Henri Rivière	1905	Water-colour	Late	Topog.		Gen.Vie w	55
4	Embouchure du Trieux, Loguivy	Henri Rivière	1908	Water-colour	Late	Topog.		Gen. View	55
5	Saint Guirec, Trégastel	Théophile Busnel	1890	Water-colour	Late	Pictu.		Gen.Vie w	62
6	Ile Callot, Carantec	Emmanuel Lansyer	1893	Oil	Late	Topog.		Gen.Vie w	51
7	Porspoder	Théophile Busnel	1893	Water-colour	Late	Pictu.		Gen.Vie w	55
8	Le Teucer, Ouessant	Emmanuel Lansyer	1885	Oil	Late	Marine		Det. View	55
9	Port de Camaret	Théodore Gudin	1830	Oil	Earl y	Topog.		Det. View	55
10	Morgat	Henri Rivière	1907	Water-colour	Late	Topog.		Gen. View	55
11	Rivière près du Dourduff	Emmanuel Lansyer	1874	Oil	Late	Topog.		Gen. View	40
12	Batteries du port de Brest	Louis Nicolas Van Blarenberghe		Watercol our	Earl y	Pictu.		Gen. View	37

Table 3I.3. Top art ranking results within the Trégor – North Finistère case study.

3.4.2 Ranking Historic Photographs

A total of 443 historic photos (and photographic postcards) were assessed as part of the project, images were primarily chosen from locations along the coastline where historic paintings and

archaeological sites were also known. The photographs were collected and then scored using the methodology outlined in Section 2 (Figure 3I.23).

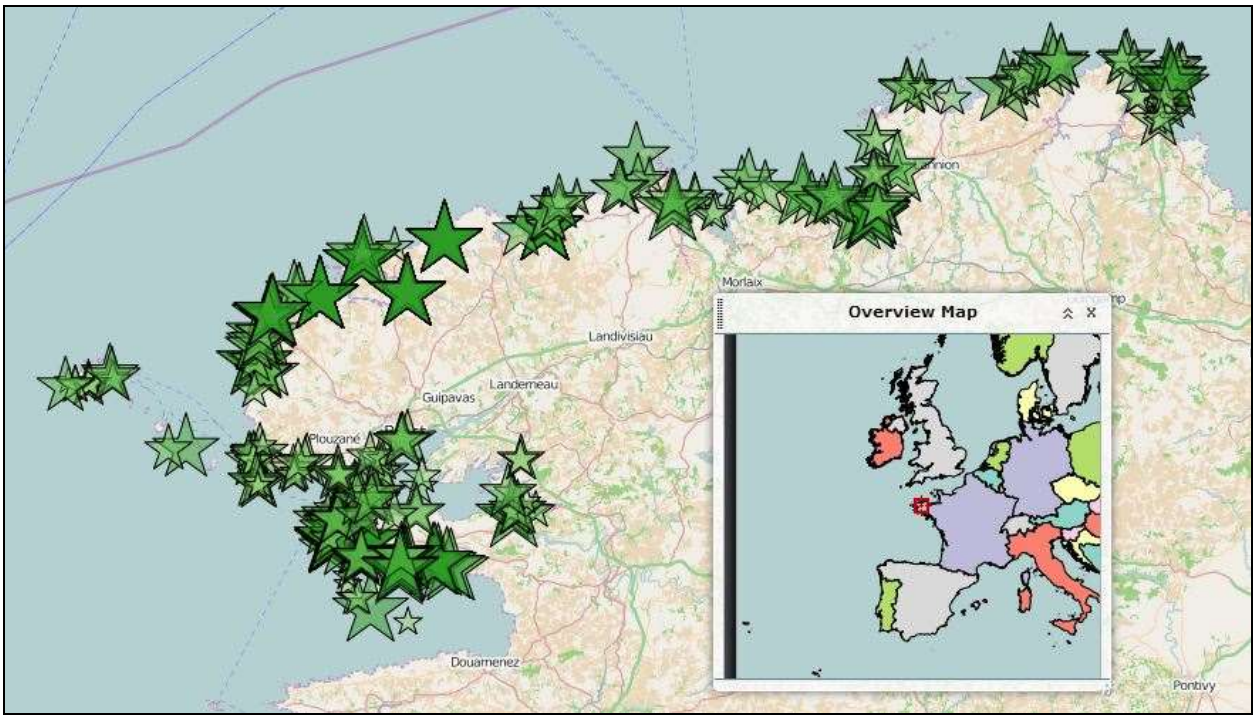

Figure 3I.23 Location of historic photos in the Trégor – North Finistère case study area.

Hundreds of historic images exist for this stretch of coastline, it should be noted that this study is not intended to be exhaustive, it simply aims 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 table below (Table 3I.4) outlines the results of the ranking, note that photographs were scored as either a heritage view or a non heritage view. The majority of photos assessed were of heritage views, containing features which can be identified today, the oldest photo assessed was taken around 1900; amongst the 443 selected photos for this area, most of them date from the first quarter of 20th century. Unfortunately, the name of the photographers is seldom known and most of them remain anonymous. Photos scoring c.100 and those showing archaeological sites or megatlithic monuments located on the foreshore on in dunes were selected as they have the most potential to illustrate coastal changes and especially sea level rise.

Figure 3I.24. View of the pointe du Toulinguet (Finistère) geology, around 1910 (© Labo Archéosciences UMR 6566 CReAAH).

The distribution of photographs is quite unequal as many depict areas of tourist interest or coastal towns. For example where are few tourist views of the Molène archipelago, this is fortunately counterbalanced by the fact that some pioneer prehistorians had a great interest in the study of the megalithic monuments in this archipelago.

Some places are very well represented, e.g. the Crozon peninsula (Finistère) or the Bréhat archipelago, for tourist or scientific purposes. For example, serveral geologists such as L. Collin were early interested in the Crozon peninsula and its remarkable sites (Pen Hir, Tas de Pois, Dinan bay, Toulinguet cape, Morgat grottos) (Figure 3I.24).

For this area, a lot of archaeological and geological ancient views are available; these views generally illustrate not only the coastal changes but also cultural heritage elements, some of them having disappeared since that time. For example, on Melon island (Porspoder) the great standing stones represented on the A. Devoir photos have been totally destroyed in 1942 (Figure 3I.25) (Daire & Lefeuvre, 2001). Another example is the ‘Pont Crac'h’ in Plouguerneau, corresponding to a very old (Roman or Iron Age) ford built to facilitate the crossing of the Aber Wrac'h river; this site, reached and regularly damaged by the sea at high tides, was rebuilt in 2008 (Figure 3I.26).

Id	Title	Year	Score Heritage View	Score Non Heritage View	Physical Image State	Total Score
58	Yaudet-Chapel & Leguer estuary	1910-1920	Medium		Good	100
60	La croix de Mi-Lieue	1900-1945	High		Good	100
65	Pare-lames (Plestin)	1918	High		Good	100
146	Menosach (Plouguerneau)	1900-1910	High		Good	100
154	Allée couverte de Kernic (Plouescat)	1900-1910	High		Good	100
164	Menhir de Men Ozach (Plouguerneau)	1900-1930	High		Good	77
165	Allée couverte de Lerret (Kerlouan)	1900-1930	High		Good	100
198	Pont du Crac'h (Plouguerneau)	1900-1930	High		Good	100
229	Grand Menhir (Porspoder)	1900-1923	High		Good	100
231	Grand Menhir (Porspoder)	1900-1923	High		Good	100
268	Allée couverte du Ribl (Lampaul-Ploudalmézeau)	1900-1930	High		Good	100
342	Falaise Est de Portz Naye (Camaret-sur-Mer)	1900-1930		High	Good	100
357	Pointe du Toulinguet (Camaret-sur-Mer)	1900-1930		High	Good	100
381	Anse de Kervenny (Plouguerneau)	1900-1930	High		Good	100
385	Le château de Dinan (Crozon)	1900-1930		High	Good	100
408	Tombe de Roch Glas (Penvenan)	1958	High		Good	100
421	Pointe du Grand Grouin (Camaret-sur-Mer)	1900-1930		High	Good	100
498	La jetée de Pempoul (Saint-Pol-de-Léon)	1900-1925	High		Good	100
521	Oratoire Saint-Guirec (Perros-Guirec)	1900-1925	Medium		Good	77
633	Moulin du Birlot (Bréhat)	1900-1925	High		Good	100

Table 3I.4. Top photo ranking results within the Trégor – North Finistère case study.

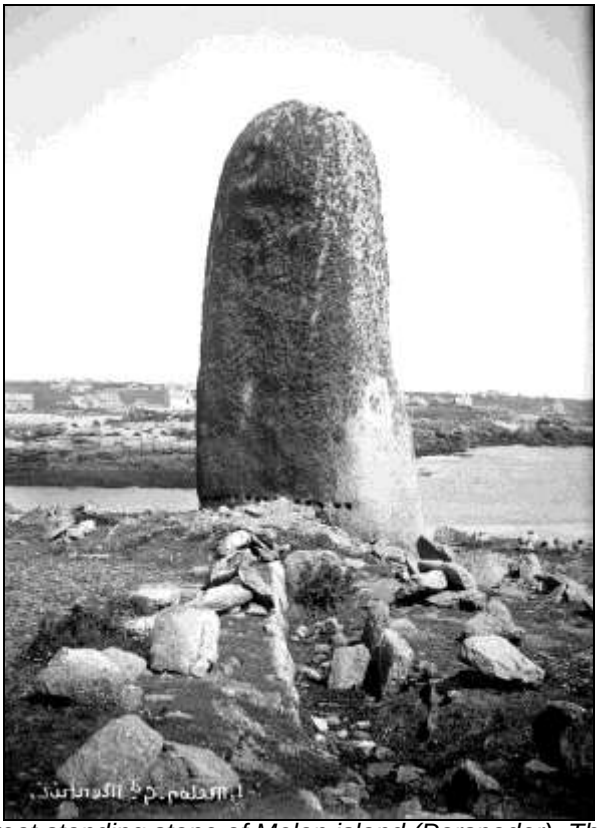

Figure 3I.25. View of the great standing stone of Melon island (Porspoder). This menhir was bombed and destroyed in 1942 (© Labo Archéosciences UMR 6566 CReAAH).

Figure 3I.26. View of the pre-Roman ford of Pont Crac'h (Aber Wrac'h) which was totally rebuilt in 2008. (© Labo Archéosciences UMR 6566 CReAAH).

Most of the pioneer 'antiquarians' were interested in the question of the sea level changes, and tried to study and illustrate the phenomena in the region of Brittany, through remarkable case study sites. Examples include the Neolithic passage graves of Lerret (Kerlouan) and Kernic (Plouescat), the Neolithic or Bronze Age of Menosach (Plouguerneau), and the Metal Age cist tombs of Penvénan which were long protected by dunes but totally disappeared in the 1970's. The position of all these monuments in the tidal area provides accurate data on sea level rise and coastal changes, as all these monuments were ereted in times when the coastal landscape was very different. The megaliths were obviously situated out of reach of the sea. Coastal changes mean that the main dunes of Northern Finistère are thought to be formed after the Bronze Age (Guilcher & Hallégouët 1991, Hallégouët 1971, 1978 and 1981).

Certain postcards picture coastal sites including submerged or tidal monuments, such as the Saint-Guirec oratory in Perros-Guirec, built between the 11th and 12th centuries, and nowadays submerged at high tide, or the "Mi-Lieue" cross at Saint-Michel-en-Grève (destroyed during WWII and rebuilt in 1993). Some of these photos are of historical interest, especially those featuring Brest bay, as this area has been intensively militarised over several centuries, changing radically since WWII. Following the destruction and bombing during the war, a lot of new structures have appeared in this area: enlargement of Brest harbour means that the Brest roman castle is no longer on sea edge, changes and construction work on Longue island which is now devoted to a nuclear submarine base, means public access is forbidden.

Some of these photos clearly show the impact of modern construction work such as at Sainte-Anne beach at Saint-Pol-de-Léon, were the natural pebble bar was transformed into a road in 1968.

3I.4.3 Ranking Maps and Charts

Several historical maps exist of the Northern Finistère and Trégor coastline, some of them dating back the end of the 17th century. 33 maps were assessed as part of the project (Figure 3I.27) using the methodology outlined in Section 2. 19 maps correspond to the whole case study area of Northern Finistère and 14 maps correspond to the specific area of Trégor and the estuary of the River Léguer. It should be noted that this study did not intend to be exhaustive, it simply aimed to highlight the potential for historic maps and charts to provide information on coastal change. A brief search of resources available online was carried out, although further research online, in museums, libraries and galleries, as well as private collections has the potential to provide many more. The focus of this project was on the bay of Saint-Michel-en-Grève where the evolution of the coastline over the last three centuries is depicted. The maps were assessed and digitised to create map regressions of the coastline, this was later combined with other data sources (see below).

A total of 33 maps and charts were assessed and scored within this case study area (Table 3I.4). Most of those ranked are marine charts, which are closely linked to trade and military purposes. They generally depict ports, anchorage bays, and also reefs and rocks, and the main markers for seafaring and coastal sailing.

Notable military points along the coast are highlighted on the maps especially during wars (17th and 18th centuries), e.g. the Brest bay fortifications (the Mingan or Bertheaume forts, the Espagnols cape fortifications) while during the 19th century, the maritime data includes features useful for offshore fishing and navigation, such as the depth of the seabed, stream orientations or the nature of the seabed.

Land maps include very detailed documents such as the Napoleaonian 'cadastral plans' (19th century). Some charts concentrate on the presenation of the archaeological and megalithic record; they mainly concern the Molène archipelago (six maps) and provide information on the monuments and landscapes which have been subject to change or disappearance.

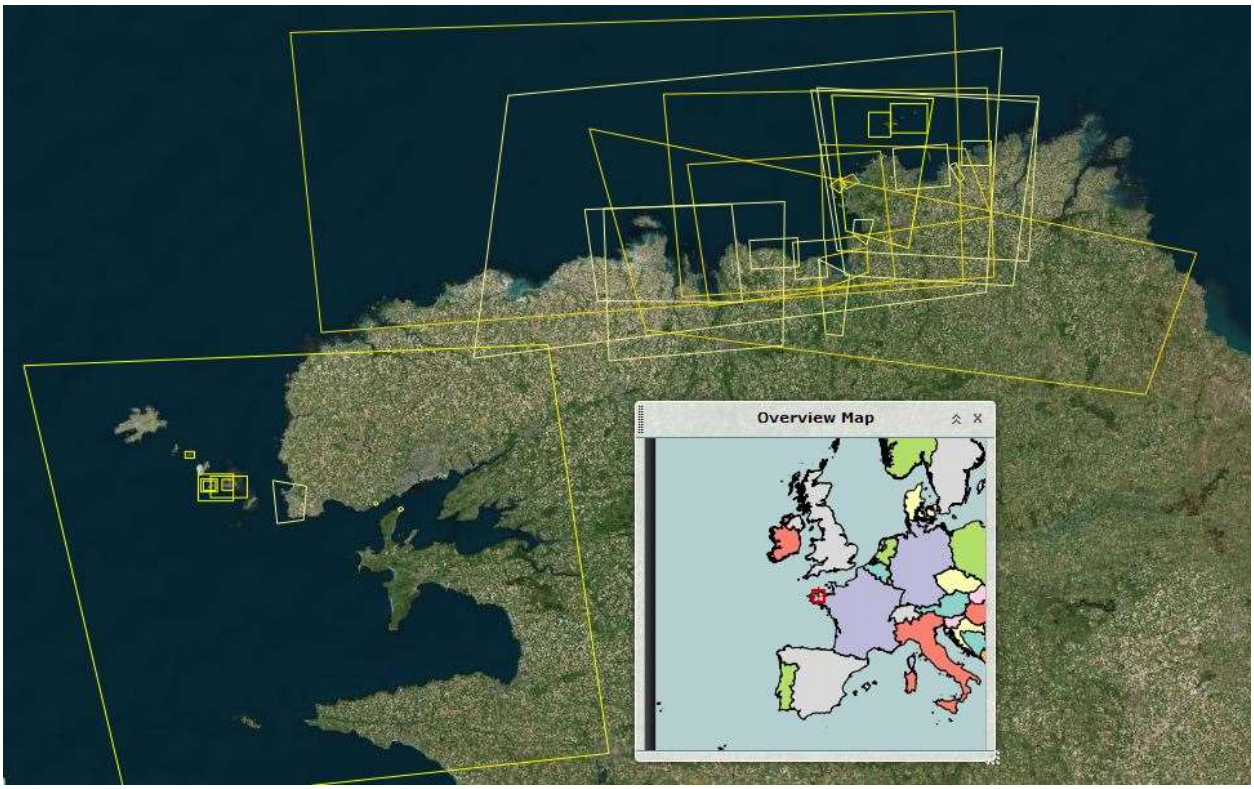

Figure 3I.27. Location of the maps assessed along the Trégor and Finistère coastline.

MAP _uid	Title	Year	Score Chrono-metric Accuracy	Score Topo-graphic Accuracy	Score Detail in non-coastal area	Score Geometric Accuracy
38	Plan cadastral parcellaire de la commune de Plestin	1814	60	30.55	100	100
39	Carte des ingénieurs du Roi – Léguer	1770	73.33	50	66.66	50
40	Carte des Ingénieurs du Roi – Baie de Saint-Michel	1771	73.33	50	66.66	66.66
41	Costes de France sur l'Océan et sur la Mer Mediterranée, coste de Bretagne	1690	73.33	50	33.33	33.33
42	Cadastre Pleumeur-Bodou Section A1	1826	20	16.66	66.66	83.33
43	Cadastre Ile Grande Pleumeur-Bodou	1826	73.33	50	66.66	66.66
44	Carte de France Lannion	1835	73.33	50	66.66	66.66
46	Carte géologique du Finistère	1844	73.33	38.88	33.33	66.66
47	Carte d'une partie de la côte du Nord de Bretagne	1754	73.33	41.66	0	83.33
48	Coste de Bretagne depuis les Sept Isles jusqu'à l'isle Molene et Lanion	1764	20	16.66	33.33	66.66
49	Carte particulière des costes de Bretagne qui comprend Morlaix Saint Paul de Leon les Sept Isles et l'Isle de Bas	1693	73.33	20.83	33.33	66.66
50	Carte de la côte de Lannion	1735	73.33	20.83	33.33	33.33

51	Embouchure rivière de Lannion	1756	20	20.83	33.33	50
52	Capitainerie de Lannion	1710	73.33	25	33.33	33.33
60	Ile Quéménès et son Lédénes	Unknown	13.33	16.66	66.66	66.66
61	Ile Trielen et l'île aux Chrétiens	Unknown	13.33	16.66	66.66	83.33
69	Perros-Guirec	Unknown	6.66	25	100	50
73	Saint-Jean-du-Doigt	Unknown	6.66	20.83	100	50
74	Locquirec	Unknown	6.66	20.83	100	50
75	Les Sept îles	Unknown	6.66	16.66	0	50
76	Les Sept îles	Unknown	6.66	16.66	0	66.66
77	Ile de Balanec	1962	13.33	16.66	33.33	83.33
78	Ile de Quéménès	Unknown	13.33	16.66	33.33	50
79	Ile de Trielen	Unknown	13.33	16.66	33.33	66.66
80	Ile de Trielen	Unknown	13.33	16.66	33.33	66.66
92	Plan particulier depuis Saint Mathieu jusqu'à Blanc-Sablon	1756	73.33	20.83	33.33	50
94	Carte particulière des côtes de Bretagne : Contenant les environs de la rade de Brest	1756	73.33	16.66	33.33	83.33
95	Plan des batteries haute et basse de la pointe des Espagnols	1695	73.33	33.33	66.66	100
96	Plan du fort de Mingan établi en 1688, comprenant les deux batteries, haute et basse	1754	73.33	25	33.33	83.33
106	Batterie de Trelevern; Port Blanc	1756	73.33	27.77	33.33	50
118	Costes de Bretagne [le Diben – Plouescat]	1740	73.33	27.77	33.33	66.66
119	Carte particulière de la baye de Morlaix	1754	66.66	33.33	66.66	83.3
142	Tréguier Port-Blanc	1771-1785	0	33.33	66.66	50

Table 3I.5. Top results for map ranking within the Trégor – North Finistère case study.

3I.5 FIELD RESEARCH STUDIES

Archaeological and palaeoenvironmental fieldwork were carried out for case study area of Western Trégor, this section outlines the field studies undertaken and the main results.

3I.5.1 Key Research Questions

The research questions to be answered through this approach were to determine the potential of archaeological and environmental data to inform on long term coastal changes in the Western Trégor area. Regional coastal changes were to be addressed on a multi-millennial timescale, with a focus on some specific periods, especially the Middle Ages.

3I.5.2 Approach to Information Gathering and Fieldwork

The program within the bay of Lannion study area comprised detailed field work (2011, 2012 and 2013) combined with desk based studies and analysis (radiocarbon dating combined with dendrochronology). Various kinds of documentation have been used, as well aerial photos, ancient maps and charts and historic documentation, in order to retrace the environmental and human history of this site. The fieldwork comprised several excavation campaigns on the foreshore and regular surveys (by foot and with a drone).

3I.5.3 Archaeology Field Data Gathering Results

The selected sites in the case study area have provided a lot of information illustrating the coastal evolution in the bay of Lannion, with a special focus on the Léguer estuary, and a very detailed study of the Servel-Lannion fish weir installations, which provided accurate evidence of change.

Archaeological data sources have been used for sites close to the banks of the estuary, this includes a Neolithic passage grave (which no longer exists) on the foreshore of Ploulec'h (Marchat and Le Brozec 1991). The Yaudet promontory cliff castle offers a broad chronological sequence site, with human occupation spanning mainly from the Iron Age to the Middle Ages (Cunliffe and Galliou 2004, 2005 and 2007). The archaeological objects found in the sand dredged from the estuary primarily reflect the Neolithic and Bronze Age cultures and, with less certainty, the Middle Ages. The fishing installations in the estuary cover the widest chronological scope, and are the subject of study and more accurate calibrations of chronology.

I1. Fish weirs of the Léguer estuary, bay of Lannion

Since 2007, the collective research program on the ‘foreshore fish traps of Brittany’ revealed the existence of 750 structures (Daire & Langouët, 2008 and 2010). Approximately 90% of structures are stone dams, several of them are today under the 0m Marine Level because of Holocene transgression, indicating their relative ancient age. The Bay of Lannion fish weirs have been subject to an extensive research program since 2011.

Location

The bay de Lannion is located in the Western part of the Trégor area (Côtes d'Armor department). The Léguer river flows east to west, crossing Lannion town and ending in a wide estuary bordered by steep wooded slopes (Figure 3I.28).

Why was the study site selected?

This area has been selected for the richness of the available data illustrating the coastal changes along the Channel. The estuary of the Léguer had multiple installations of fish trap dams. Since 2011 there has been an active research program studying the complex of the Petit Taureau-Lannion Servel, which has witnessed several development phases. The complexity of

the archaeological phasing of the site led to the analysis of data in relation to the geographical context of the whole estuary Léguer. This provides information for a more comprehensive study of palaeoenvironmental conditions and ancient fish weirs in connection with coastal settlements. Indeed, this estuary is marked by the presence of several coastal fortified sites (cliff castles) sucha as Dourven (and perhaps also the Beg Léguer cape), the chronology of which remains to be clarified. The major site of Yaudet to Ploulec'h experienced a long period of human occupation, from the Late Prehistory up to the Middle Ages, as shown by the excavation program developed on the site for several years (Cunliffe and Galliou 2004, 2005, 2007).

The Léguer estuary comprises several fish weirs dating from various periods (Table 3I.1). Beyond the regional context and numerous fish trap remains presented above (Daire and Langouët 2008, 2010), it is interesting to note that the Léguer river is today considered as having higher numbers of fish, especially salmon, within the Côtes d'Armor department (Landre 1975).

The fish weirs of the Léguer estuary have probably benefited from this rich fish resource over time; additionally, the capture technique, based on wooden traps or stone dams is particularly well adapted to an estuarine environment, where marine and fluvial streams can be very strong, especially in the area surrounding the Yaudet promontory. Thanks to the field and lab research, these fish weirs have been characterised according to their architecture and their installation (Daire and Langouët, 2011a & 2011b; Langouët *et al.,* 2012a & 2012b and 2013).

In addition to the study of the fish weirs, since the 1950's the dredging upstream and downstream of Beg Léguer and Yaudet have provided interesting archaeological finds, the chronology of which goes from the Neolithic up to the Middle Ages, with the Bronze Age period being well represented (Giot 1969, Langouët *et al*., 2012a). These finds are linked to the presence of peat layers stratified between sandy levels. Most of the objects were found during the sand sieving on the Lannion harbour quays. Fortunately, the investigations by P.R. Giot during this period could provide precise indications about the sedimentary context and the geographic origins of the objects.

From the Neolithic period (U6 unit), we can identify two complete hafted stone axes, one of them having lost its stone part a moment after its discovery (Giot, 1958 & 1960). These objects probably come from the peat layers indentified at the bottom of the stratigraphic sequence (see below). The Bronze Age is represented by several objects, discovered about 1 km upstream, in a place of a ford probably in use during metal ages and historical times (Giot, 1967: 336-337; Briard, 1971; Mélin, 2011). This set of swords, dredged from this point of the Léguer estuary probably reveals a very important Bronze Age deposit close to the ford.

Later periods are less well represented. Despite the existence of the major settlement on the Yaudet promontory, mainly settled during the Iron Age and Roman period, the contemporary finds are scarce in the waters of the estuary. Coming from the sandy level, a small amount of pottery can be attributed the last stages of the Late Iron Age (3rd-2nd cent. BC). Coming from the same place, human bones (skulls), Roman and medieval pottery and querns (pre-Roman or Roman) were also mentioned (Langouët *et al*., 2012b).

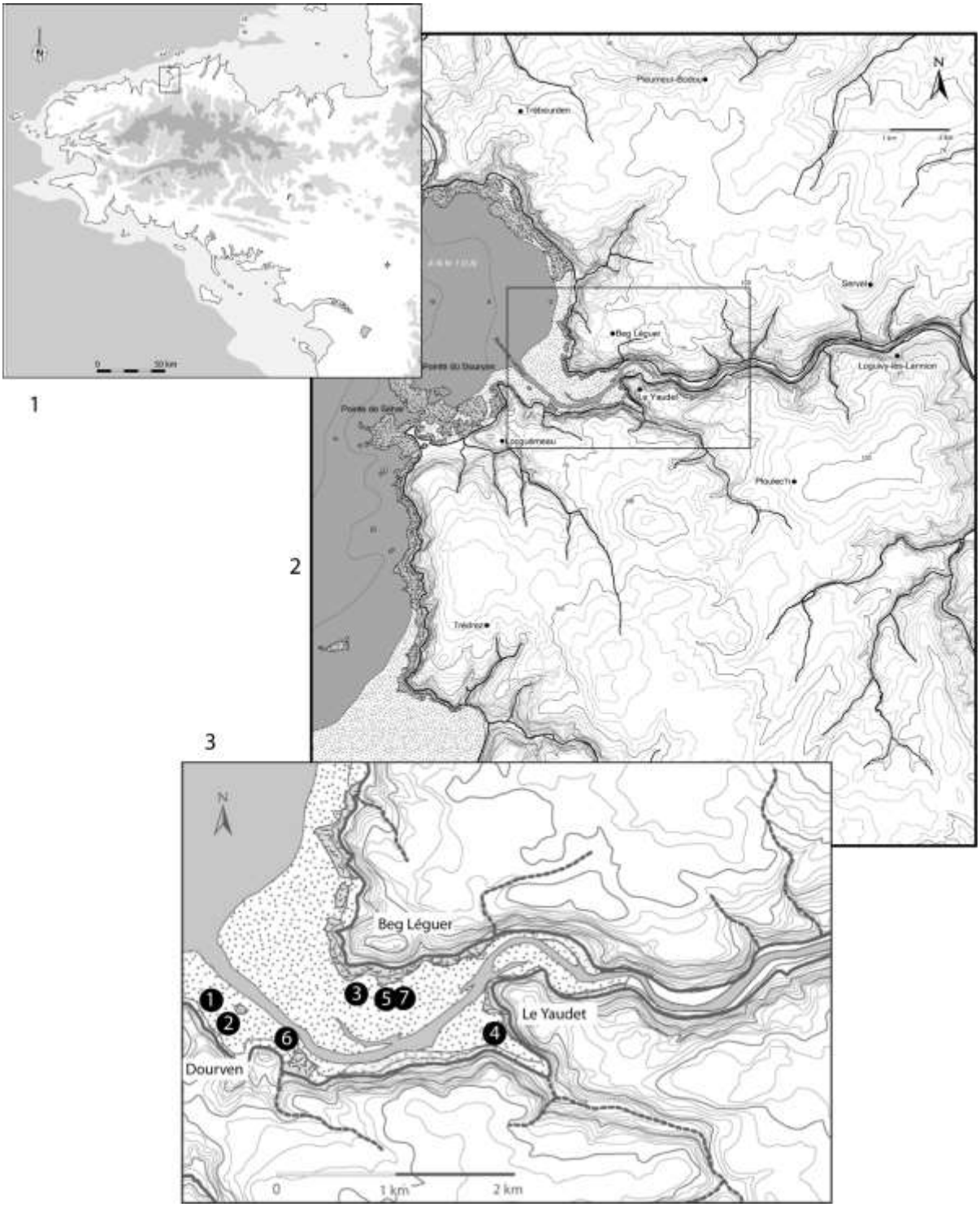

Figure 3I.28.Location of the Bay of Lannion and Léguer estuary (1 and 2) and distribution of the fish weirs in the estuary (3) (doc. L. Langouët and L. Quesnel).

Geomorphological setting

A map published in 1995 (Pinot 1995), based on aerial photographs shows the situation of the Léguer estuary in 1952 before sand extraction (n°1, Figure 3I.29). At this time, the Léguer flood

drained away thanks to five channels visible near Servel point; nowadays, only one channel remains, drawn by the sand extraction near the Poull Mad Dogan point.

The sedimentary story of the Léguer estuary is partly accessible in the wider framework of the Lannion bay study, with two corings extracted in 1979 in this zone (Augris & Simplet, 2011: 80-83). Geologists have distinguished, amongst several layers, a level called U6, rich in organic materials and especially peat remains. It is interpreted as an estuarine deposit typical of the back foreshore of a bay (slikke), able to fill in the ancient channels. The radiocarbon dating of the organic materials gave, for U6 level, a date c. 6000 y cal BP (about between 4300 and 3000 BC). A layer above (U7) was composed of sands of various grains sizes; it is typical of marine conditions, formed by the transformation of sediments due to the action of waves. Layer U7 is dated around 2300 y cal BP (about 400 to 200 BC). This confirms that, during the Iron Age, the sediments deposition process was subject to waves and swells and Lannion bay was open to the maritime environment (Augris & Simplet, 2011: 80-83).

Additional data was collected during the 1960's, during the time when the sand of the estuary was intensively exploited, and following the discovery of a Neolithic hafted stone axe then others archaeological objects. P. R. Giot conducted a thorough investigation with operators of sand dredgers, especially those working in the surroundings of the Yaudet cliff castle; he could then obtain quite precise indications of the stratigraphy and collect some samples for radiocarbon dating and pollen analysis.

The stratigraphy was observed in two points of the estuary, corresponding to places of archaeological finds discoveries. The ‘big hole’ located between the Yaudet promontory and Beg Hent quay, at 100 m from the present southern shore) (n°1, Figure 3I.30), has shown (from top to bottom):

- a sandy/silty level (modern);
- then a layer composed of coarse reddish sand from the river, several meters thick (almost completely exploited); and
- a peat level, thin and foliated.

From this area come the human bones, medieval ceramics and two axe' antler hafts. The more recent objects probably originated from the red sand level as the prehistoric finds certainly come from the peat layers. A radiocarbon date was gained for the peat layer: 3075 + 110 BP, i.e. 1303 +140 cal BC (GIF 819), the transition between middle and late Bronze Age (Giot, 1969).

The ‘gué aux épées’ (Swords ford) is the second observation point; located about 1 km upstream from the previous one, in a probable ford location used in various times, this area provided a set of bronze weapons. The stratigraphy has shown (from top to bottom (Figure 3I.31)) :

- a sandy/silty level (modern);
- a coarse grey sandy level;
- a black thin peat layer (20 cm thick);
- a coarse sandy level, 2 to 4 meters thick depending on the location;
- a deposit composed of a blending of peat and clay, 30 cm thick; and
- a dense gravel level at the bottom.

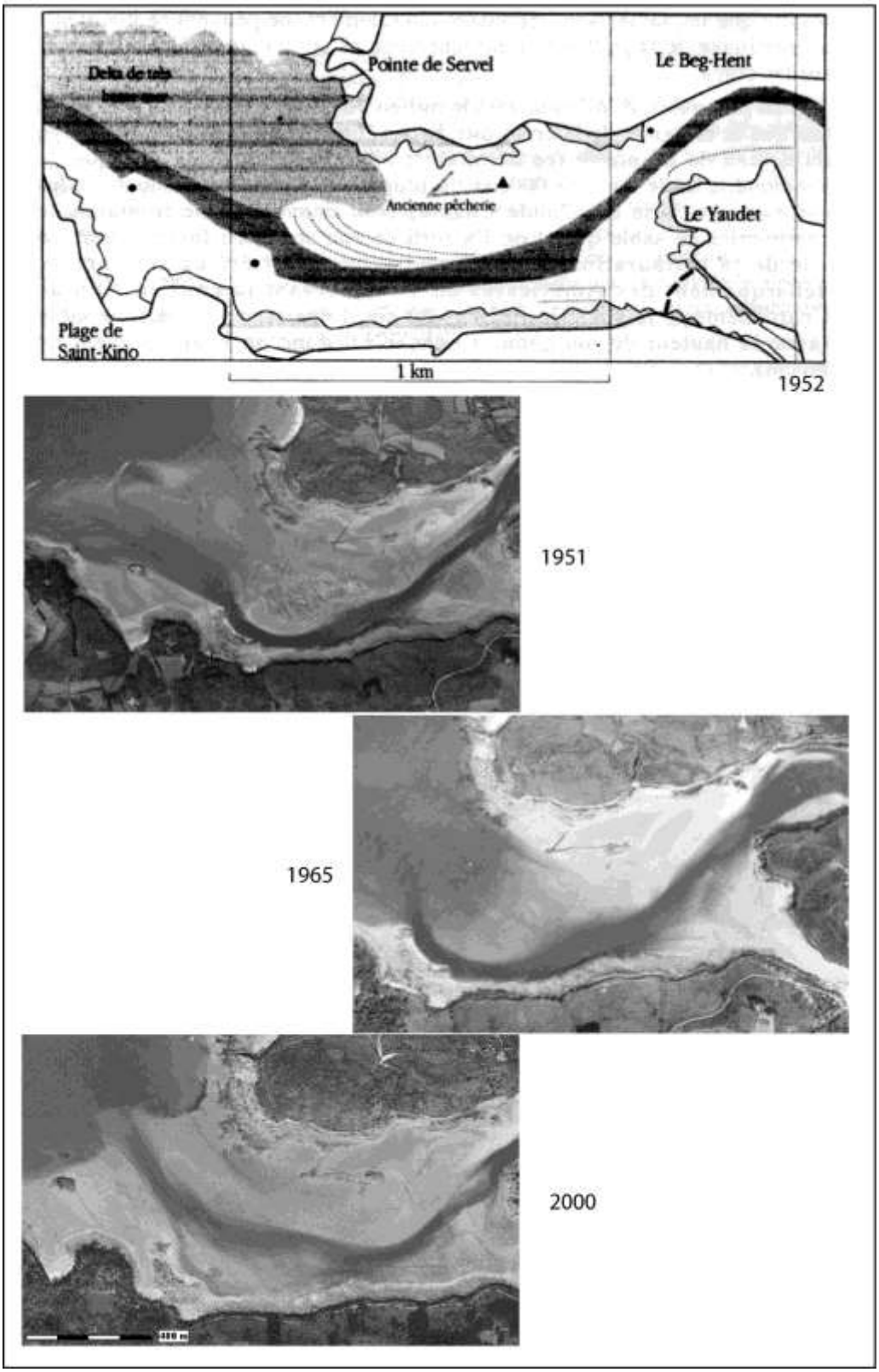

Figure 3I.29. Recent evolution of the Léguer estuary and flood channels, due to the intensive sand extractions (after Pinot 1995 and IGN, Langouët et al.. 2012).

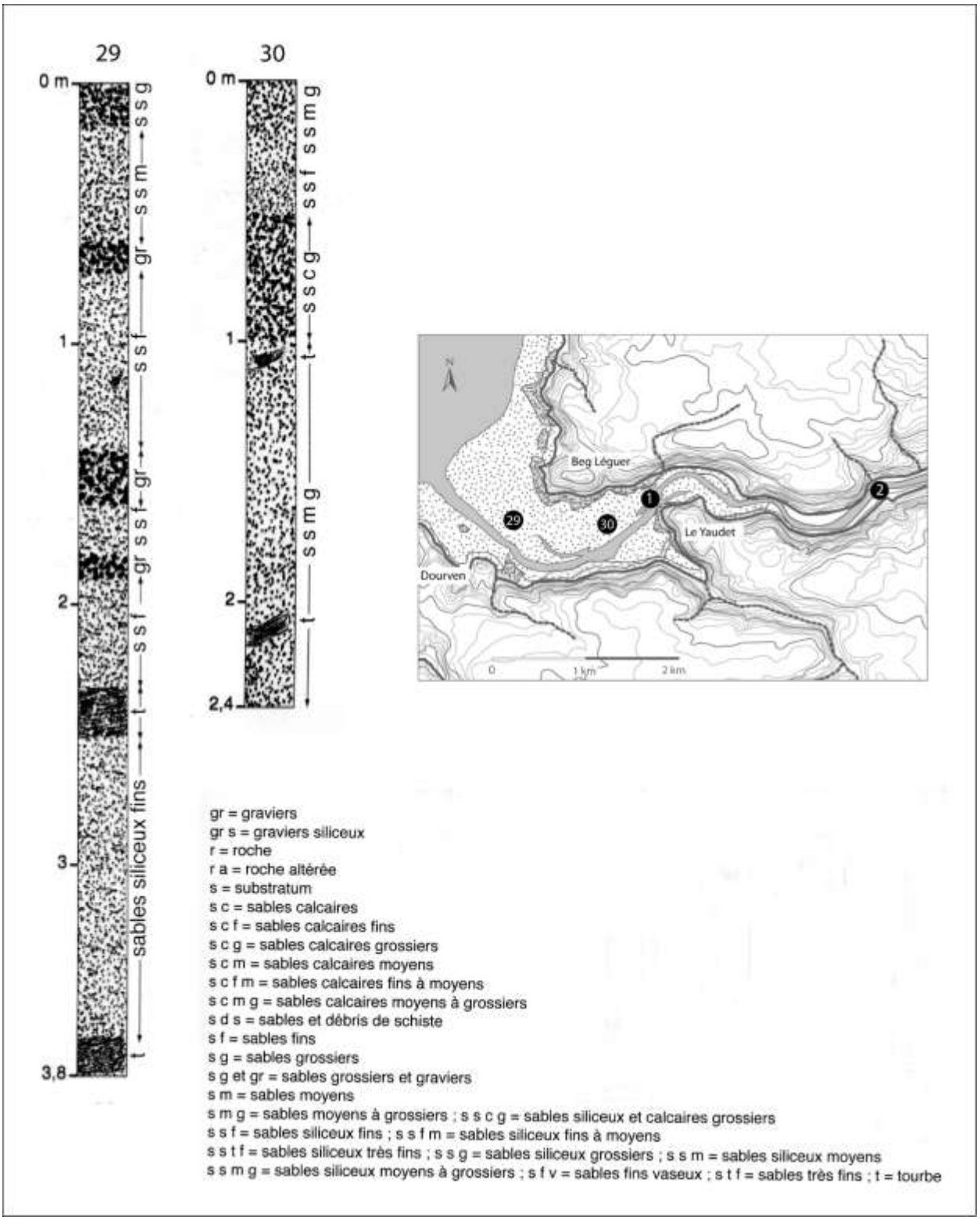

Figure 3I.30. Location and geomorphological characteristics of the cores carried out in the Léguer estuary (after Augris and Simplet, 2011, revised by Langouët et al., 2012).

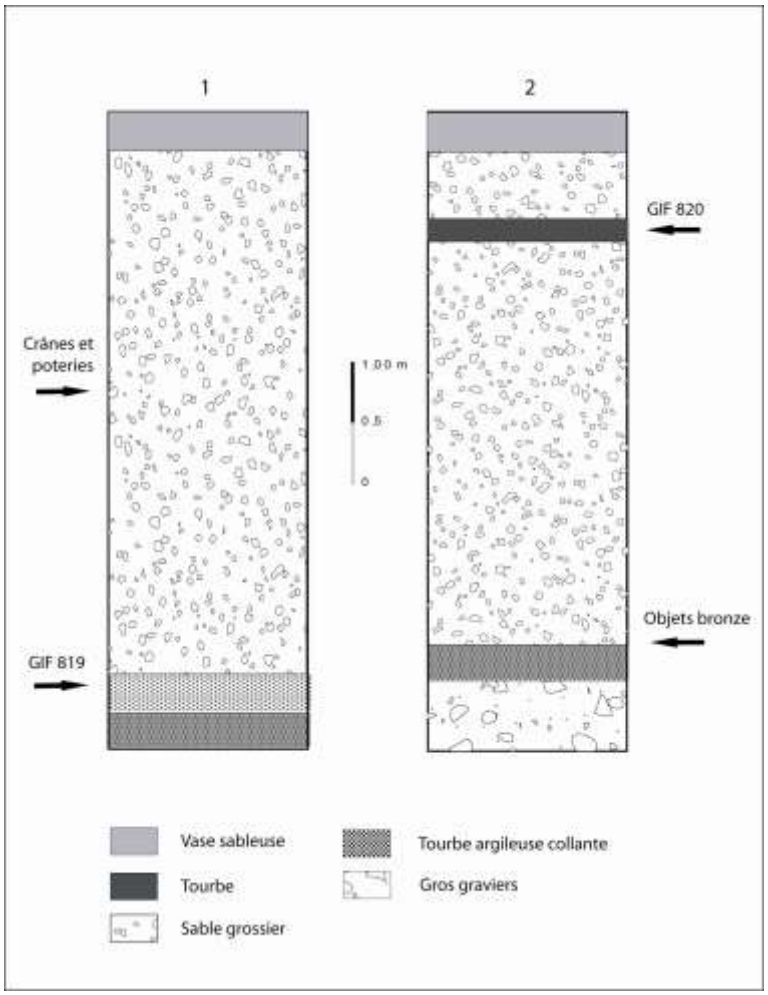

Figure 3I.31. Detailed stratigraphic reconstruction in the place of the 'Big Hole' sand extraction with location of the radiocarbon dating samples (after Giot 1969 and Langouët et al., 2012).

According to eyewitnesses, this part of the estuary was totally dry some years earlier, but the red sand exploitation reactivated the flooding of the channel. A second radiocarbon date has been gained for a peat sample from this area, the result of which is 1600 + 105 BP, i.e. 435 + 115 cal AD (GIF 820); this gives another illustration of the occupancy of the estuary, during the Roman or early Medieval periods.

The stratigraphy described above is comparable with the one observed during the excavations carried out on the Petit-Taureau fish weirs (see below): a brown coarse sandy level, rich in marine small shells appeared about 30 cm below the current soil surface; on this level were laid the big wooden installations of the dam from the early Middle Ages, as well as the plants layer and the stone installations at the base of the earlier building stage (phase D) (Langouët *et al.,* 2012b).

Key coastal risk management issues

The maritime façade of the Bay of Lannion is subject to intensive erosion, accelerated by sudden climatic events such as storms. One good example has been provided by the archaeological study of the Locquémeau-Dossen Rouz Iron Age site, which was excavated in 2009 following the big storm of February 2008 (Daire, 2011); during one single night, the coast lines retreated 9 m, causing extensive damage not only on the archaeological site but also in

the tourist area and port installation (the sailing school was destroyed) and on the natural features (pebbles bar).

The main risk of anthropic origin in this area is the industrial project of marine aggregate and sand extraction in the Bay of Lannion, initiated in the 2000's by the Lafarge and Italcimenti concrete production group. Geomorphologists (IFREMER) and environmental defense groups (Le Peuple des Dunes) tried then to make coastal managers aware of the consequences of offshore extraction in the coastal area (http://lepeupledesdunes.com/IMG/pdf/tour.pdf and http://www.lemonde.fr/idees/article/2013/10/04/attention-a-la-destruction-de-la-baie-de-lannion_3489862_3232.html.

How can the sites inform coastal risk management?

The complete study of the fish weirs and especially the level or height at which they were constructed makes it possible to provide precise indications of the local sea level variation and coastal evolution in past times, this helps future coastal management, by understanding the processes and providing precise measurements. These fish weirs are presented below in chronological order, the evaluation of which results from the detailed study carried out since 2011 in the Léguer estuary (Table 3I.6 and Figure 3I.32).

N°	Site	Nb (m)	δ(BMME) (m)	Chronology
1	Trédrez, Dourven-A	0,40 ± 0,2	3,7 ± 0,1	Bronze Age
2	Trédrez, Dourven-B	0,70 ± 0,2	3,4 ± 0,1	Bronze Age
3	Servel, Corps de Garde	1,70±0,10	2,4 ± 0,1	Iron Age
4	Ploulec'h, Anse de la Vierge	2,38 ± 0,1	1,7 ± 0,2	Roman-early MA
5	Servel, Petit-Taureau (D)	2,45 ± 0,05	1,6 ± 0,1	650 AD
6	Ploulec'h, Poull Mad Dogan	2,80 ± 0,3	1,3 ± 0,3	early MA
7	Servel, Petit-Taureau (A)	2,90 ± 0,1	1,2±0,1	Late 15th cent. AD

Table 3I.6.Fish weir heights and dating proposals for their building, according to the variation of the PHBMME (Lowest Neap Tide level). The n° refers to the map, Figure 3I.32 (after Langouët et al. 2012).

Located at the eastern foot of the Dourven promontory, two ancient fish weirs have been dated from the Bronze Age, according to their level of construction compared to the sea level variation curves:

- a dam of a "V" shape (Daire and Langouët 2010: 12); the topographic level of its base is (Nb) is +0,40 ± 0,2 m/0 SHOM;
- another dam, also of «V» shape (n°2), the level of its base is Nb is +0,70 ± 0,20 m/0 SHOM.

On the opposite bank of the estuary, a fish weir of «V» shape is located at the foot of the Beg Léguer promontory (n°3). The level of its base is (Nb) is +1,70 ± 0,10 m/0 SHOM. The dam of the Vierge bay, (n°4), at the southern foot of the Yaudet promontory, is quite difficult to date in the way that the 1970's excavations have seriously disturbed the archaeological layers in the sluice area. The map (Figure 3I.13) shows the existene of two sluices; the level of the base of the dam and of one of the sluices is +2,38 ± 0,20 m/0 SHOM. Another dam, with a curved shape, situated between the Poull Mad Dogan conning-tower and the left site of the estuary (n°6), has a level of +2,80 ± 0,30 m/0 SHOM at the base of the wall.

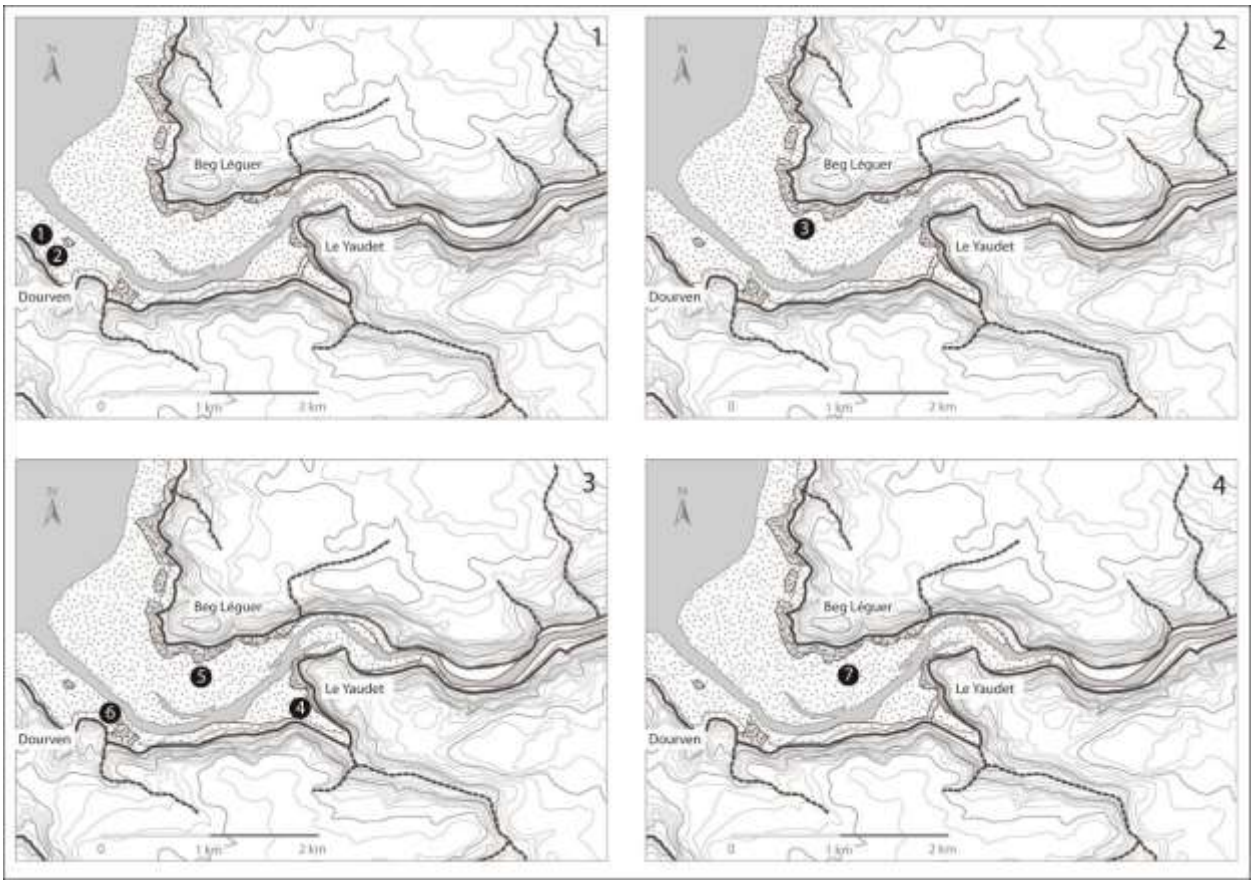

Figure 3I.32. Mapping of the Léguer estuary fish traps, according to their building date evaluation. 1: Bronze Age (2000 BC-800 BC), 2: Iron Age (800-50 BC), 3: Roman and Early Middle Ages (1st cent. BC-7th cent. BC), 4: Middle Ages (10th cent. AD and later) (doc. L. Langouët).

The topographic levels measured at the foot of the dam walls or in the sluice (Nb) provide a general idea of their dating, according to the hypothesis that the builders have probably taken into account the best efficiency of the dam, in terms of fish catching and of accessibility, at each low tide, whatever the tidal range. In this hypothesis, the level Nb of the dam theoretically corresponds to the ancient level of the Lowest Neap Tide level (PHBMME). This level is currently calculated linked with the local maximum tide range (MM): (PHMEME)act = 0,416*MM.

We can measure the Nb level for several fish traps of the Léguer estuary (Table 3I.6). The difference between Nb and the current (PHBMME)act gives, with a certain precision, and evaluation of δ(PHBMME), variation of the sea level since the time the dam was built (Daire & Langouët, 2010).

A quick analysis of the fish weir locations in relation to chronology shows the following general tendency: the older fish weirs are located in the current maritime zone at the mouth of the estuary and over time they were progressively installed further upstream, in more protected areas. This evolution goes in parallel with the terrestrial settlements and occupation evidence is located in the vicinity or the fishing installations. The new data obtained on the Petit Taureau fish weirs illustrates the relationship between humans and the environment during the Middle Ages (Langouët *et al.,* 2012b).

We must also take into account the sea level rise which, over the period being considered reaches several meters in this area; indeed, a fish weir dam stops being efficient when it becomes no longer reachable while low tide. The sea level rise has consequences, not only on the accessibility of the dam by the people, but also on the efficiency of the trap as the fish can escape from it if the water level is too high. This process could have combined with sediment filling phenomena within some of the dams which have 'trapped' the sand thereby raising the soil level within the fish weir, meaning the trap looses its efficiency for catching fish.

On the another hand, the sediment accumulations which progressively moved the flow channels could have impacted the fish circulation, providing an additional reason to move the location of some of the dams. Hence, the abandonment or displacement of fish traps can by explained by a combination of both processes – sediment accumulation and changes in fish movement patterns.

The scientific studies have underlined the importance of sand extraction of the mid 20th century on the transformation of the geomorphology of the estuary, providing historical evidence of the impact of such industrial exploitation. This impact is particularly visible on the fish trap remains, the visibility and conservation of which are a good indicator of the sediment budget evolution (see below).

Fish weirs of the Léguer estuary ranking score achieved: 100

I2. Servel-Lannion Petit Taureau Fish Trap

Location
The Petit-Taureau set of fish weir dams is located on the maritime territory of Servel-Lannion town (Côtes d'Armor department) and is located in the mouth of the Léguer river estuary (n°5 and 7 Figure 3I.32 above).

Why was the study site selected?
Within the general context of the Léguer estuary (and its fish weir remains, see above), the site has been selected because of its ability to provide environmental and archaeological data, regarding coastal changes, and the opportunity to carry out a complete field study. Previous to the fieldwork, the aerial photography analysis indicated the existence of several successive dams at this location, making it a high potential for chronological evolution (Figure 3I.37). This site has been subject to intensive field work in 2011, 2012 and 2013 (excavation and sampling) as well as a full analysis program (radiocarbon dating, dendrology, dendrochonology), providing the first references for tidal archaeology in Brittany (Daire *et al.* 2011a, Langouët *et al.* 2012b, 2013).

The research program including the Petit Taureau fishtrap dams and the other traps of the Léguer river estuary, could not be undertaken withoug studying their sedimentary environment. This is important for taking into account the processes that lead to the construction and shifting of successive dams, as well the historical context and relationships with settlements as the "natural" evolution of the fluvial-marine environment. On the other hand, if the environmental changes dictated the position of the building of walls/dams, it is also probable that the presence of dams had an impact on the flow of sediment and submarine river channels.

Research and expertise clarified the chronology of the various dams that have succeeded at the Petit Taureau (Figure 3I.33). The stony phase is the most visible on aerial photographs, but came after structures made from wood and wattle, established in 615 AD. The D1 dam had

succeeded a previous wooden trap whose remains, found below the D1 dam, were dated by radiocarbon to between 580 and 660 AD.

Figure 3I.33. Aerial viw of the Petit Taureau fish weir showing a cumulative view of the various building stages (taken from a drone, doc M. Mahéo and L. Langouët).

Two lines of stones (B and C) were identified as the remains of walls associated with wooden structures made of vertical posts and wattle branches. The probable oldest dam B (600-660 AD) was quickly destroyed and replaced by the longer D1 dam. It seems that the fish trap in the D1 stage did not last long, despite a fairly complex technology. It was quickly replaced by another wattle installation bearing on the petit Taureau rocky amount and a small rock to the west.

D1 dam had associated wooden posts and stones (big pebbles) collected from the top of the beach. It was replaced by a dam C (660-730 AD), the same technology as that used for dam B, but built with bigger posts. D2 dam could correspond to a blockage of the remains of D1 in order to prevent its components interfering with the operation of the dam C.

Although the precision of radiocarbon dating does not distinguish them chronologically, it is likely that during the 11th-12th centuries AD, at least one wattle installation (with two arms) was set up and probably went through two phases. The synthesis of radiocarbon dating can demonstrate a medieval stage with two lines of wattle that had been identified and dated: 1037-1220 AD (Ly- 8874) and from 1026 to 1162 AD (Ly- 8875). Equally, in the east-west part of phase A building, two lines of wattle were found and dated: 1040-1100 or 1120-1140 AD and 1160-1260 AD.

The building of the phase A stone walls goes back at least to the second half of the 15th century (Clément 2011), when the wattle phase was replaced by the dam with ‘squared’ stones, which were accurately described in texts of the 17th century.

Geomorphological setting

Various specialists and observations have been used to create a better understanding of the potential of Petit-Taureau site in terms of geo-archaeology (Langouët *et al*. 2012a) (for the geomorphological features, see above).

The fish weirs of the Léguer estuary, and especially the Petit-Taureau dams, seem to play, over time, a game of 'hide and seek', as their visual detection varies from one period to another; this phenomenon is especially demonstrated in the photo-interpretation of aerial photographs available for a period between the 1950s and today (Figure 3I.34). We tried to analyse the causes of this phenomenon in a wider geographical framework for the entire mouth of the Léguer estuary.

The analysis of the aerial photos taken since 1952 shows, on the site of the Petit Taureau, a process of sediment thinning down, which reveals at least four architectural phases of the fish trap building (Daire and Langouët, 2011: 6-8) (Figure 3I.33). The explanation of this phenomenon is closely related to the recent history of the Léguer estuary, occupied by sandy-muddy sediments, combining alluvial river flows and input wind and marine (Pinot, 1991 and 1995).

Since the 1950s, the sediments of the downstream Léguer estuary have been intensively exploited, the materials being used by construction companies of the Lannion and Finistère areas, to rebuild the towns and buildings bombed during WWII. In total, approximately 2.5 million m^3 of sand were extracted from the estuary; the digging of the delta created a channel under the promontory of Yaudet and caused the migration of sand in the direction of the mouth estuary, then the foreshore level lowered (approximately 1 m) (Pinot, 1995: 109-111). This phenomenon not only explains the appearance of the remains of several fish traps on both sides of the estuary (Daire and Langouët, 2011a and 2011c), especially after 1977, but is at the origin of archaeological discoveries, documenting the human settlements in the area (see below).

Key coastal risk management issues for the frontage

We have highlighted in the previous section the general risks threatening the whole bay of Lannion and the estuary, as well the natural threats (coastal retreat due to erosion and storms) and the anthropic ones (offshore sand extraction in the bay of Lannion).

At the more restricted scale of the archaeological remains (dams), one risk is due to the local economy, as this area is devoted to shell collecting by professional. As we could see during our fieldwork campaigns, harvesting the shore generally requires removing stones and then destroying or modifyomg the ancient dams, with effects on the landscapes.

How the site can inform coastal risk management

The four successive dams of the Petit Taureau fish weir are located on the right side of the estuary, at the foot of a natural promontory (Beg Léguer). Recent fieldworks demonstrated the existence of four architectural phases, the wooden construction alternating with stone dams. Field excavation and desk based archives research permitted the dating of the various phases.

Thanks to the combination of radiocarbon and dendrological analyses, we can now assess that the oldest phase of construction (phase D) goes back to the early 7th cent. AD (Langouët *et al.,* 2012b). On the other hand, the recent study of the post medieval archives, concerning the latest stage of construction of the Petit Taureau fish weir, helped to find documents dating back to the

second half of the fifteenth century (Clément, 2011). For this building phase, the level of the dam base is +2,90 ± 0,1 m/0 SHOM.

The construction of several dams during the centuries (Figures 3I.36 and 3I.37) indicates that it was probably necessary to rebuild the fish trap several times. For some stages, this can be due to problems in the conservation of raw materials (wood); but, for some others, we suspect that the impact of the dams on sediments flow and flooding channels location have obliged the local people to clean the installations, change the orientations of modify the general shape of the traps. The architectural history of the Petit-Taureau fish weir, and more generally on the maritime installations in the Léguer estuary, seem to be closely linked with the environmental evolution of the area.

As demonstrated above, a regular observation and monitoring of the archaeological remains inform us on the coastal evolution and transformation of the estuary.

Petit Taureau fish trap ranking score achieved: 100

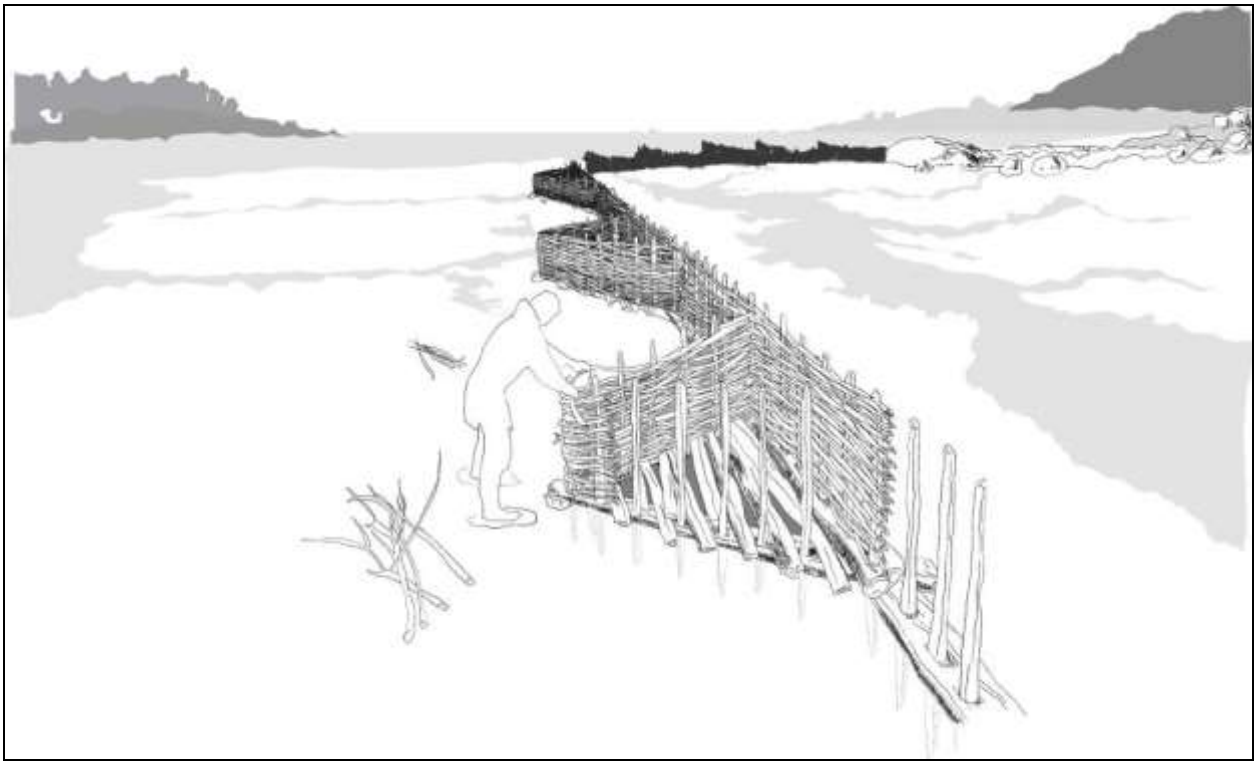

Figure 3I.34. Drawing proposing a reconstitution of the D1 dams' building phase (Petit Taureau fish trap, Servel Lannion) (doc. V. Bernard, CNRS).

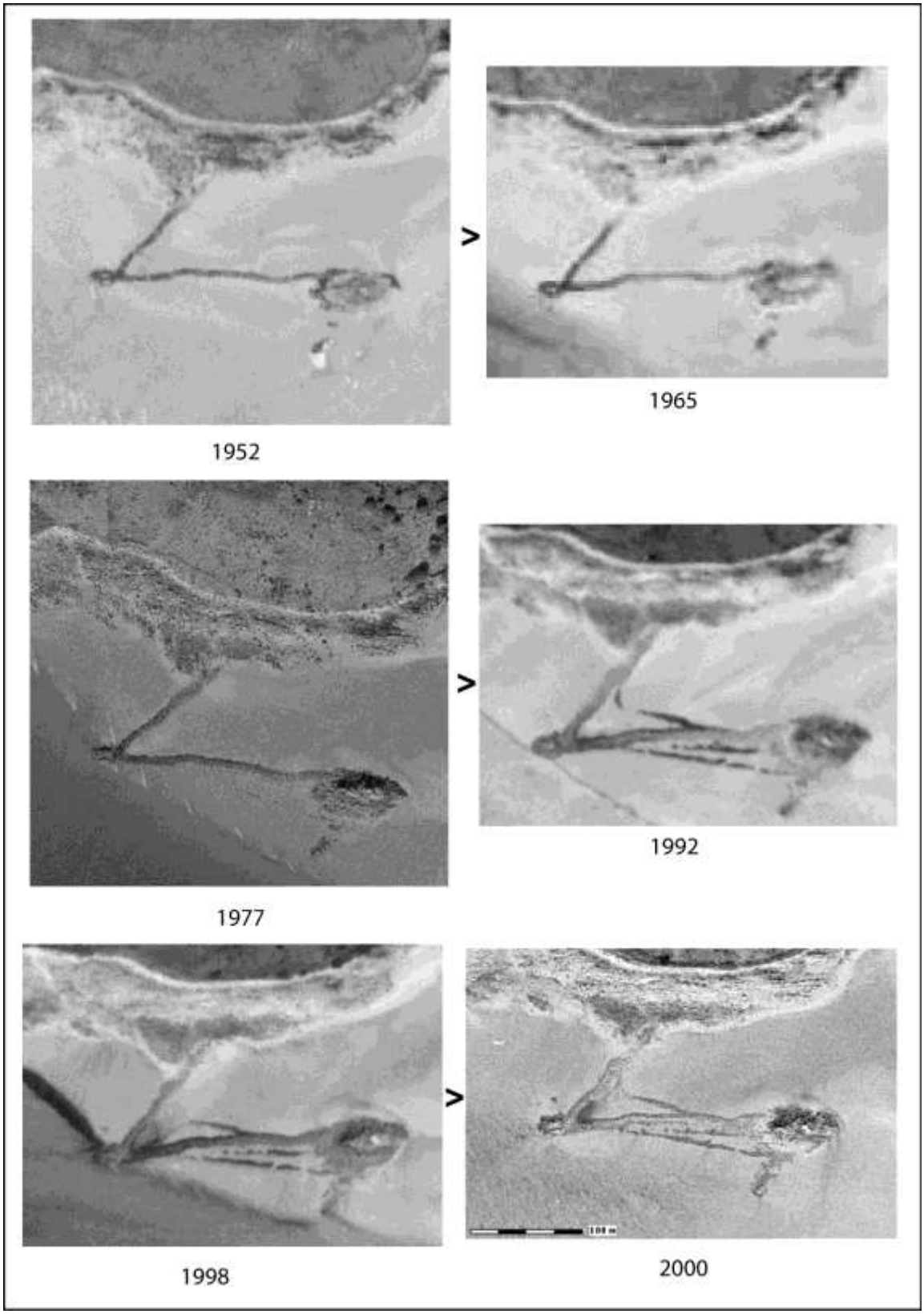

Figure 3I.35. Evolution of the visibility on the Petit-Taureau (Servel-Lannion) fish-traps, as a consequence of the sand extraction in the estuary and recent sedimentary evolution in the Léguer estuary (IGN photos, after Langouët et al. 2012).

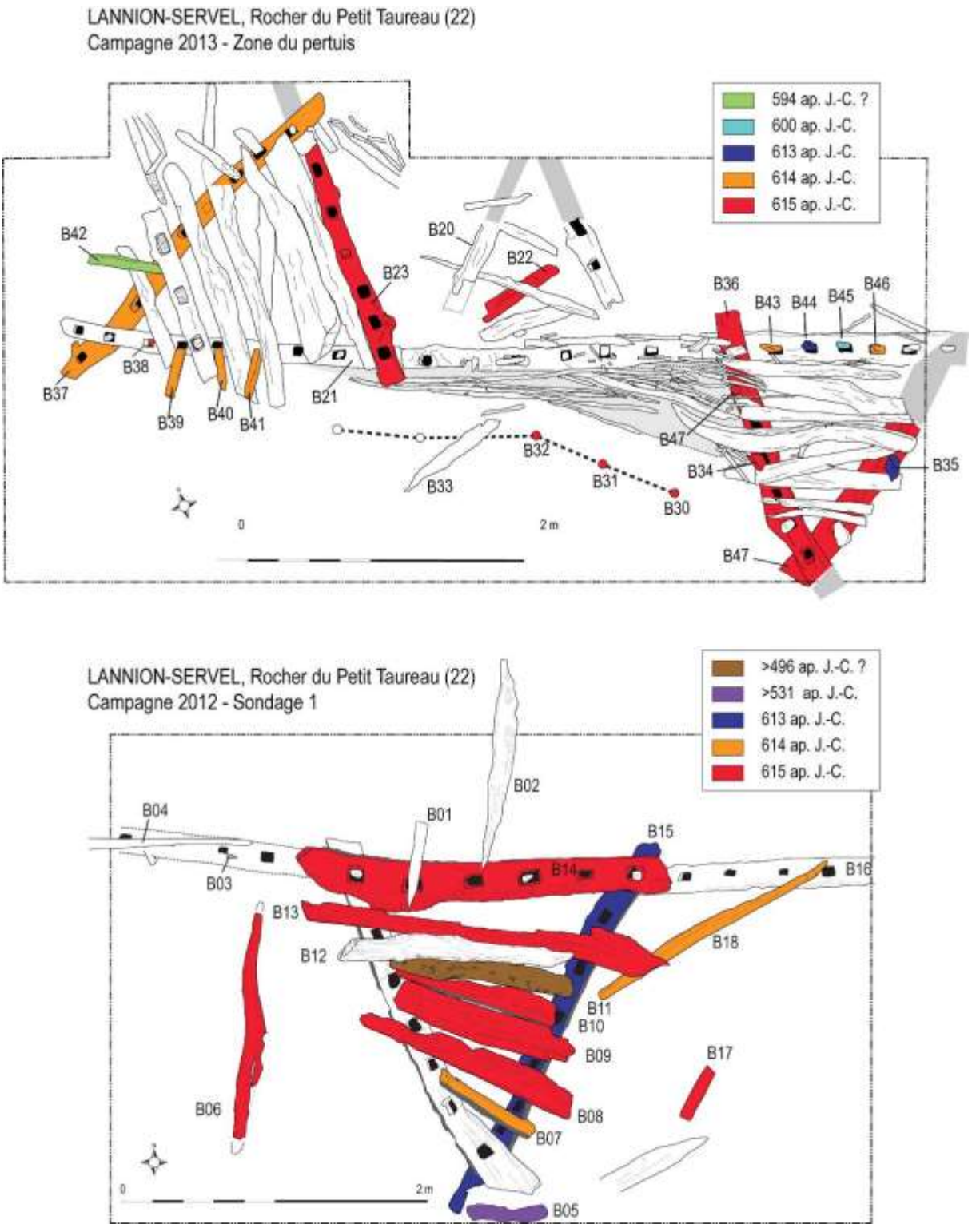

Figure 3I.36. Mapping of the wooden installation of the Petit Taureau fish trap and distribution of the dendrology dating (doc. V. Bernard, CNRS).

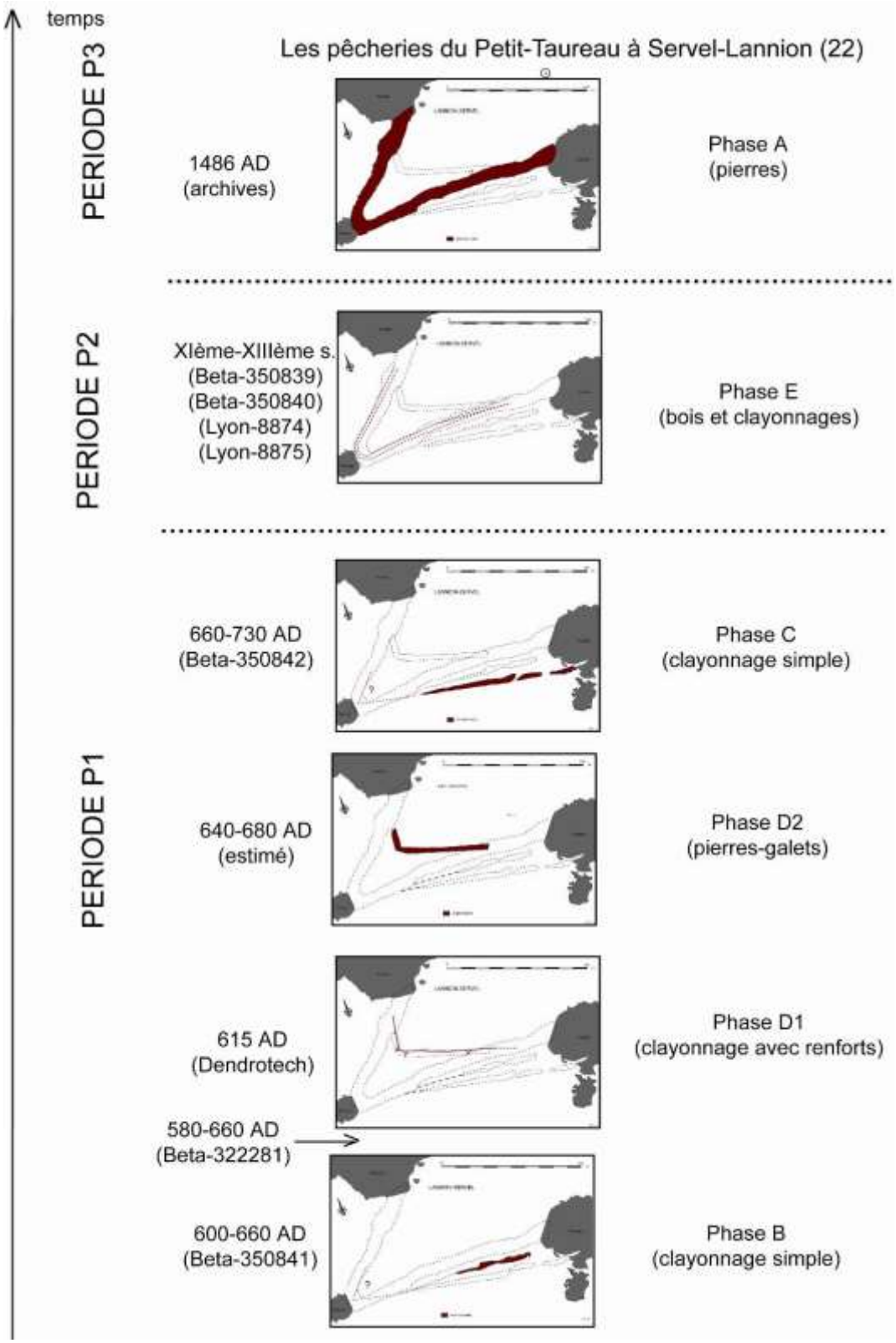

Figure 3I.37. Evolution and phases of dams' construction, Petit-Taureau fish weir (Servel-Lannion) (after Langouët et al., 2013).

3I.6 Art Studies

The case study area has been been depicted within a range of artistic media: paintings, photos, maps and charts. For each type of artistic material, field studies helped in the analysis of the informative value of the pictures as illustrations of coastal changes in the North Finistère and Trégor area.

The art approach benefited from the academic work led by E. Motte (Motte, 2013) in the Rennes 2 university. This work included consulting several art books and online resources (e.g. Joconde database). Ancient postcards used for the project were available either in private collections or though online resources; the main source of the ancient photos illustrating this coastal area was the collection of the Archéosciences laboratory (University of Rennes, ICARE project).

3I.6.1 Approach to Information Gathering and Fieldwork

Concerning art, the academic work of E. Motte partly consisted of a comparison of the paintings or artistic representations with the real current landscape, based measuring the detail of geomorphological changes (Motte 2013).

Sites represented on ancient photos were also subject to a field approach, comparing the current situation with the one pictured in the late 19th century and the early 20th century; in this approach, when possible, several photos of various dates, taken from different angles have generally been compared.

Historical maps in this area have been compared with present examples and with historical satellite images in order to assess the conditions of the coastline and changes that may have taken place over time. The IGN Database provides a huge collection of aerial views of Brittany from 1947, which have been compared with the aerial views of Brittany provided by GeoBretagne.

3.6.2 Art Field Data Gathering Results

The selected sites in the Northern Finistère and Trégor case study area were chosen to reflect coastline changes and human impact. The fieldwork element has been largely visual in terms of identifying the location of the paintings and making judgments, on site, of the role that art can fulfill as a qualitative or quantitative tool to support coastal risk management.

Either one particular map has been assessed, or a sequence of maps of the same area in order to examine changes over time. These have been reviewed against data from field observations. This helps establish a chronology of coastal change through the eighteenth and twentieth centuries.

I3. "Grandes roches au pied du sémaphore", by E. Lansyer, 1884

Location

Ushant island is located in the extreme western part of the study area, facing the Finistère coast. The painting represents a rocky cliff located on the northern coast of the island.

Why was the study site selected?

This site has been selected as representative of the wild landscapes of the northern coast of Brittany, which is less often pictured than some tourist areas, except by some painters such as E. Lansyer.

Geomorphological setting
The painting represents the typical granite and rocky landscape of Northern Finistère, with cliffs and rocky shores, without beaches.

Key coastal risk management issues for the frontage
Study of this painting shows the main risk threatening this part of Ushant island is erosion, as it appears very active at the foot of the rocky areas, subject to rain and sea water streaming, which damage the small vegetation which otherwise maintain the top soil levels (Figure 3I.38).

Figure 3I.38. Ushant, "Grands rochers près du Sémaphore", by E. Lansyer, 1884, analysis of the painting by E. Motte (after Motte 2013).

How the artwork can inform coastal risk management
E. Motte's work has underlined the fact that the painter (E. Lansyer) has taken some liberties considering the real landscape, e.g. narrowing or exaggeration of some distances. However,

some parts of this painting provide realistic representations of several features, such as the general shape of the rocks, the vegetation cover of the slope in the first stage (Figure 3I.38). As mentioned above, the erosive process on this sensitive formation can be noticed when comparing with the current field reality.

Where can the original artwork be viewed? In Saint-Brieuc fine arts museum.

"Grandes Roches…" Ranking score achieved: 51

I4. "Rivière près du Dourduff", by E. Lansyer, 1874

Location
The painting represents the mouth of the Dourduff river, in the bay of Morlaix (Northern Finistère) (Figure 3I.39).

Why was the study site selected?
This site has been selected as representative of the bay of Morlaix landscape; it is typical of quite densely settled tourist areas of the Trégor region.

In a comparative point of view, it seemed interesting to compare two different landscapes of the same case study area, comparing this view of the bay of Morlaix with the one of Ushant Island, presented above, especially as both of them were painted by the same artist.

Geomorphological setting
The area of the Dourduff river mouth is known under the name 'break of Dourduff'; this geological formation, i.e. the conglomerate containing pebbles of igneous rocks, includes lenses of limestone, containing fossils that have allowed us to date this geological formation back to the strunien (Devonian to Carboniferous passage). The Dourduff river flows to the sea through a wide estuary, of "*aber*" or *ria* type.

Key coastal risk management issues for the frontage
The study of this painting shows the main risks threatening this part of the Dourduff estuary are, on one hand, natural erosion, as it appears very active on the soft rocks and, on the other hand, anthropic pressure with coastal buildings (houses, dike, quay).

How the artwork can inform coastal risk management
E. Motte's work has underlined some features on the painting linked with coastal evolution and risk management (protective structures such as dykes on the left side of the estuary). This is linked to the development of housing and infrastructure in this area: the lack of bridge required the use of a ferry to cross the Dourduff. With the development of the railway, a railway bridge was built (linking Morlaix to Plestin-les-Grèves) in 1921, which was later converted into a road bridge in 1925.

Where can the original artwork be viewed? In the Maison Lansyer (Loches)

"Rivière près du Dourduff" Ranking score achieved: 40

Figure 3I.39. "Rivière près du Dourduff", by E. Lansyer, 1874, analysis of the painting by E. Motte (after Motte 2013).

I5. "Batteries du port de Brest", L.N. Van Blarenberghe, 1770' (Louvre museum)

Location
This painting represents the mouth of Brest harbour, viewed from the royal battery in the 1770's, painted by L.N.Van Blarenberghe (1716-1794) (n°1, Figure 3I.40).

Why was the study site selected?
This painting is an artwork from Louis-Nicolas Van Blarenberghe (1716-1794), a French painter famous for his representations of war and battles (especially during the Austria Succession war, 1745-46). During his travels in various European countries, he painted numerous marine oil paintings. His son was incorporated in the workshop of the Royal Corporation of the Geographers engineers (Versailles). His work is marked by his strong relationship with the aristocracy and several European royal families, who designated him officially as the "battles painter" (1769-1771 and 1978) and painters of the ports and coasts in 1975 (Maillet-Chassagne and Château-Thierry, 2004).

This site has been selected as representative of an ancient historic building set within the natural bay which has been strongly impacted and transformed. Since the time of the painting

changes and transformations have occurred in this area, as shown by the comparison between the 18th century and present day view (Figure 3I.40).

Geomorphological setting
Brest harbour, accessible to larger vessels because of its depth, is a large body of water sheltered from the storms of the Atlantic Ocean through the Roscanvel peninsula that almost closes the harbour, leaving a relatively narrow passage (1.8 km), Brest Channel, between the tip of the "Pointe des Espagnols" and the north side of the harbour. There are several peninuslas that stick up into the bay.

The Rade de Brest topography, both above and below water, corresponds in part to the lower section of the Aulne valley, which was flooded by rising sea levels during the Holocene. Underwater this includes buried channels from rivers which once flowed into the Bay of Brest.

A boat anchorage is shown in the middle of the painting; an ancient map drawn in 1689 (n°3, Figure 3I.40) clearly represents a sandy bar in the middle of the bay, off the Brest castle, which probably corresponds to alluvial deposits of the ancient river channel and meanders, mentioned above.

Key coastal risk management issues for the frontage
The comparison of artistic documents (Figure 3I.40) illustrates humanly induced pressure on the bay of Brest, many of these developments are linked to risks to the town and harbour activities, they are also linked to destruction of natural landscapes, loss of ecosystems and pollution.

How the artwork can inform coastal risk management
Brest Castle, which dates back to the Roman period, and the harbour structures, have deeply transformed the natural landscape of this bay, over the past two millenia. However, on the Van Blarenberghe's painting (n°1, Figure 3I.40), some parts of the landscape still remain without structures around the castle; the comparison with the current situation (n°2, Figure 3I.40), shows the pressure from urbanization and industrial/trade port activities all around the bay which no longer remains ‘natural’.

Where can the original artwork be viewed? The original painting is currently located in the Louvre museum in Paris.

“ Batterie du Port de Brest“ ranking score achieved: 93

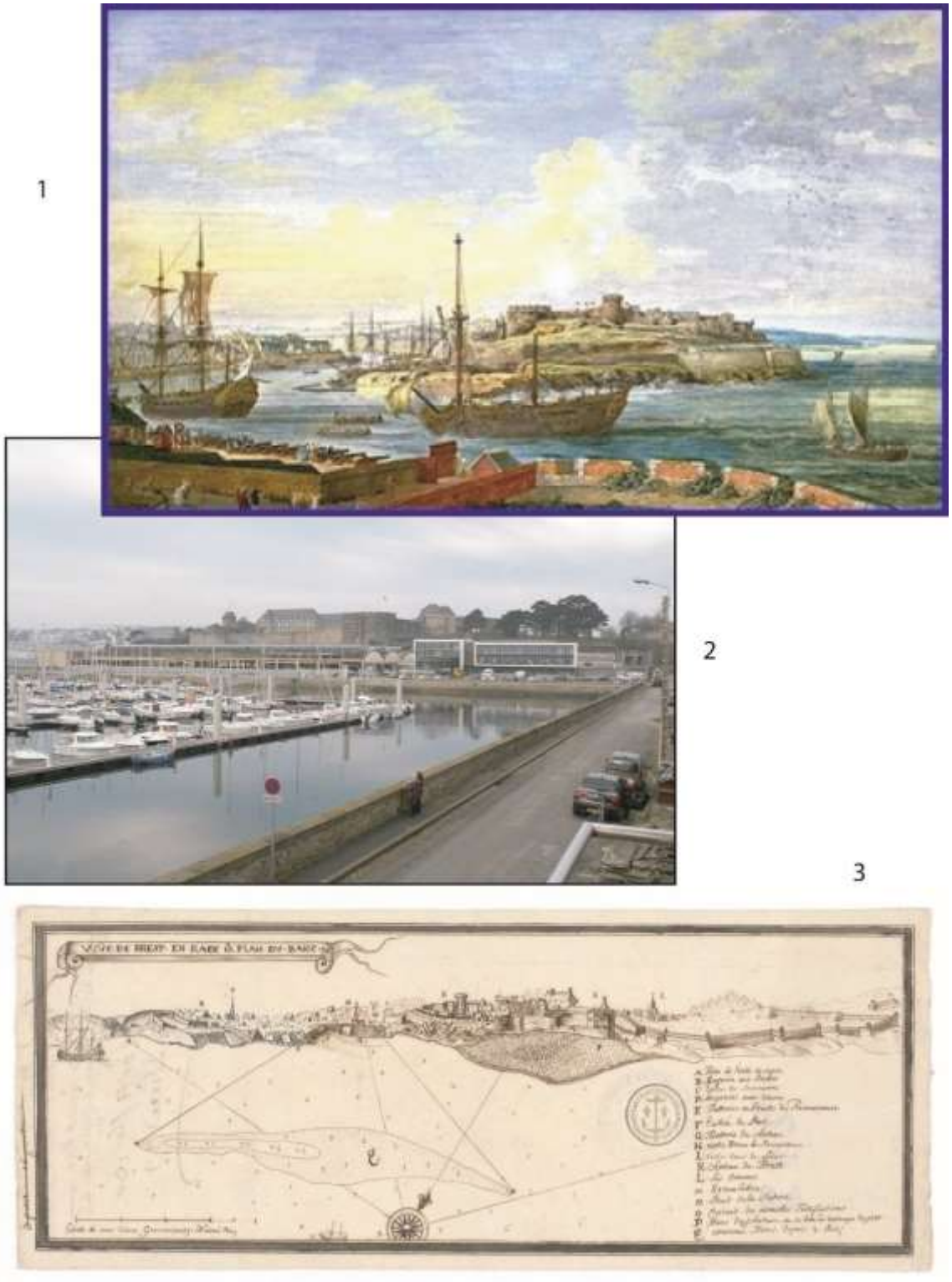

Figure 3I.40. Views of Brest harbour and castle. 1: "Batteries du port de Brest", painting by L.N. Van Blarenberghe, 1770' (Louvre museum); 2: current view of Brest castle and harbour, from the south-east (anonymous, online Immo-ouest.com/medias); 3: map of Brest bay "Ville de Brest, rade et plan du banc", 1689 (SHDMV).

I6. Plouguerneau, Men Ozac'h, by A. Devoir (c. 1910)

Location
The megalithic monument is located in the northern part of the Finistère department, in the tidal belt of the Plouguerneau village.

Why was the study site selected?
The site has been selected as an illustrative example of megalithic monuments which are now situated in the intertidal area (Figure 3I.41); as it was initially erected on the land, the present situation of this 'menhir' is an indicator of the sea level rise during the Holocene period. This monument has been used by the antiquarians and pioneers of archaeological studies, especially A. Devoir who was one of the first people to propose a scientific approach to sea level changes.

Geomorphological setting
The Men Ozach monument is located in a large flat sandy bay, in the estuary of the 'Aber Wrac'h' river, which is a geomorphological feature typical for this area of coast, called the 'Aber Coast'. This coasts belongs to the 'Low Shelf of Léon' formation (northern Finistère), comprising deep indentations and bordered by numerous island and islets; the rocky parts alternate with large sandy beaches. The importance of the tide range in this part of Brittany (c. 8 m) explains the importance of the territory and surfaces cleared of sea water during low tide. As shown on the picture, the small islands are then reachable on foot at low tide.

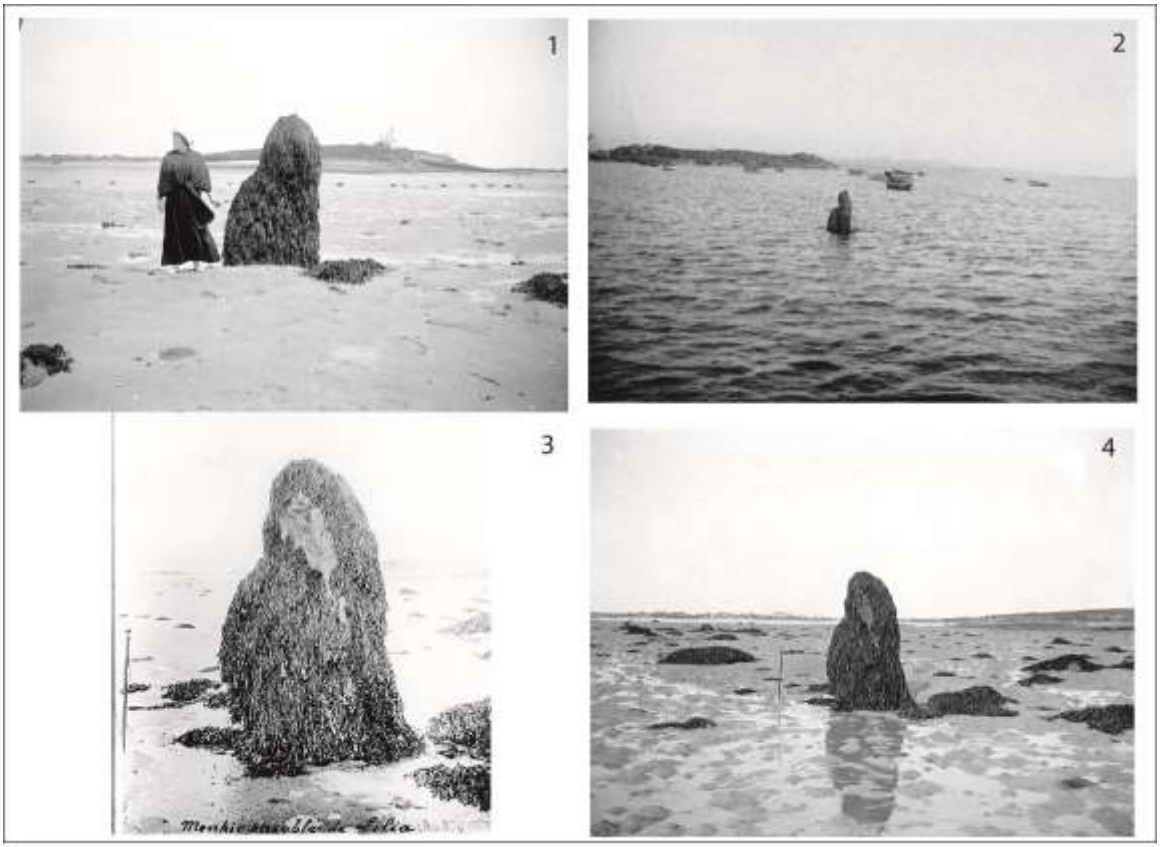

Figure 3I.41. Views of the tidal Men Ozach standing stone (menhir), Plouguerneau (Finistère) (photos by A.; Devoir, early 20th century) © Labo Archéosciences UMR 6566 CReAAH.

Key coastal risk management issues for the frontage
This area is subject to intensive coastal erosion, due to several factors:

- its geographical location, facing the west and exposed to the main storms;
- the tide and waves effects on the soft rocks formations; and
- the human buildings (ports, quays) which can modify locally the sedimentation processes and retain sand.

In addition, the food submersion risk threatens, more or less, some parts of this coastal area.

How the artwork can inform coastal risk management
Among the available pictures of the site (Figure 3I.41), n° 1 has been selected for ranking as it appears to be the most informative, due to the large view showing the landscape around the standing stone and also due to the fact that the lady standing next to the 'menhir' provides a scale for the size of the monument. The photo n°2 shows the monument at high tide and the n°3 details the presence of seaweeds attached to the monuments, both of them proving the current position of the 'menhir' which is regularly (twice a day) submerged by sea water.

Where can the original artwork be viewed?
The original view (glass photographic supports and positive papers) are part of the collection of the Laboratoire Archéosciences (Rennes University).

"Plouguerneau Men Ozach" photo ranking score achieved: 77

Comment: Despite the very high quality of palaeo environmental indications, the ranking score is not maximum due to the fact that menhir (standing stones) monuments are difficult to date with precision, as they are said to be erected from the Neolithic to the Bronze Age period.

I7. Kerlouan, Lerret by A. Devoir (c. 1913)

Location
The megalithic monument of Lerret, a Neolithic passage grave, is located in the northern part of the Finistère department, in the tidal belt of Kerlouan village.

Why was the study site selected?
The site has been selected as an illustrative example of megalithic monuments which are now located in the tidal area (Figure 3I.41); as it was initially erected on the land, the present situation of this megalithic burial is an indicator of sea level rise during the Holocene period. This monument has been considered by the antiquarians and pioneers of archaeological studies as witnessing the Holocene local sea level changes. During its construction, the monument stood on the banks of Quillimadec river, but the water level having risen, it is now regularly found submerged. Now this path is no longer covered by a single slab, which forms an upper chamber of 1.50 meter. Around the monument, traces of occupation were discovered, including a shale ring-disc in 1926, and a flint dagger in 1965. The village of farmers and breeders, where these megalith builders lived, was unearthed nearby in the coastal submerged peat layers of Tressény bay. Excavations have allowed the discovery of houses, stones to grind grain, flint, polished stone axes and Neolithic ceramics. The monument dates back to the period late 4th millenium-3rd millenium BC (Giot *et al.,* 1998, Sparfel & Pailler, 2009).

Geomorphological setting
The Men Ozach monument is located in Tresseny bay, which is an ancient *ria* featuring a deep indentation in the coast of Kerlouan. Just as the menhir described above (which is located 8 km

to the south west), the Kernic monument is located on the 'Aber Coast', belonging to the 'Low Shelf of Léon' formation. The importance of the tide range in this part of Brittany (c. 8 m) explains the scale of intertidal area exposed during low tide. During Prehistoric times, especially the Neolithic period, this area was a coastal plain where megalithic monuments were settled on the top of the small hills, which became islands due to the sea level rise.

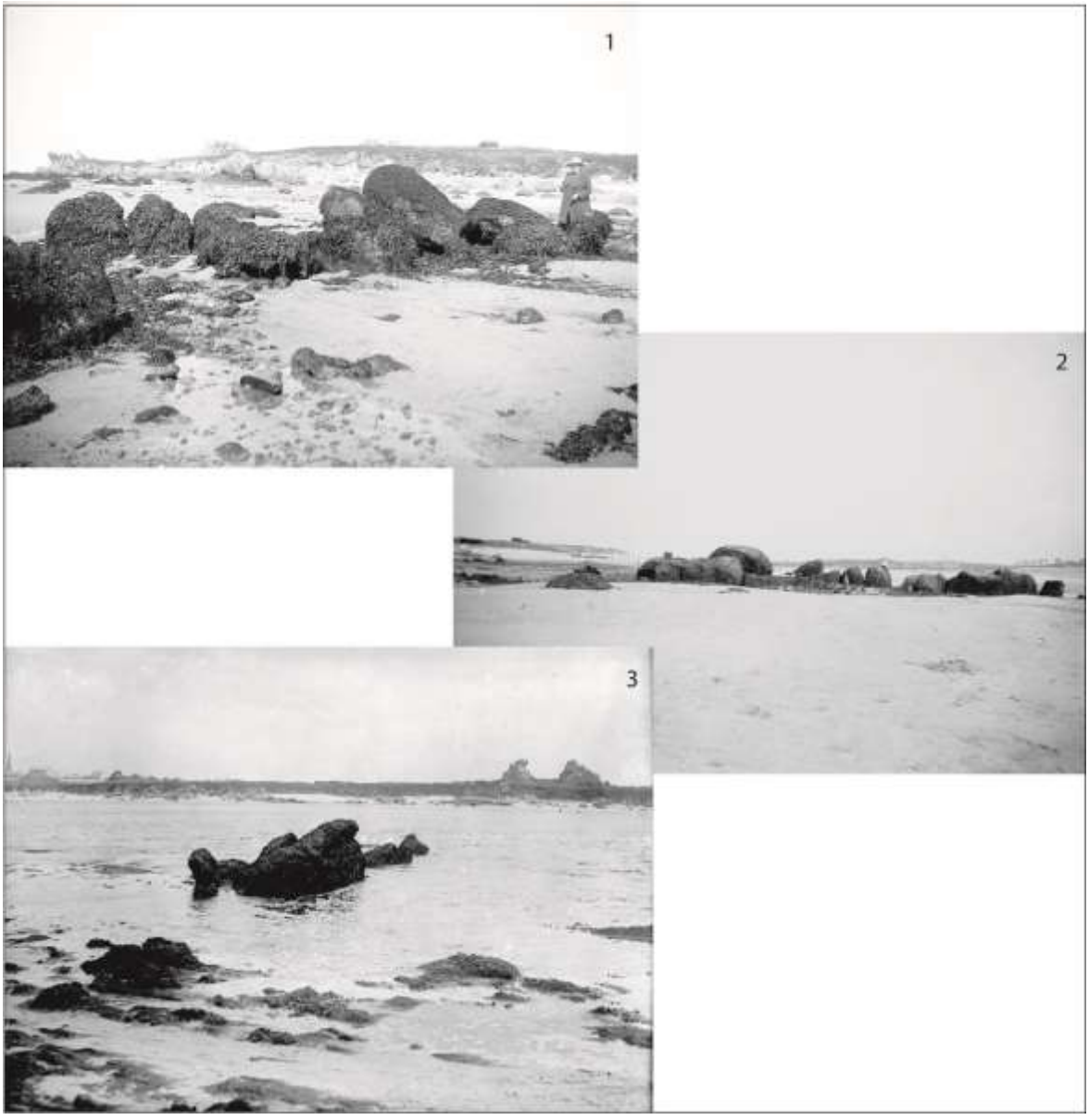

Figure 3I.42. Views of the tidal Neolithic passage of Lerret in Kerlouan village (Finistère) (photos by A. Devoir, 1913) © Labo Archéosciences UMR 6566 CReAAH.

Key coastal risk management issues for the frontage

Similar to the previous study site, this area is subject to intensive coastal erosion, due to several factors:

- its geographical location, facing the west and exposed to the main storms;
- the tide and waves effects on the soft rocks formations; and

- the human buildings (ports, quays) which can modify locally the sedimentation processes and retain sand.

The erosive process is clearly demonstrated by the fact that the monument has been progressively damaged by waves, with a loss of several architectural elements. In addition, the food submersion risk threatens, more or less, some parts of this coastal area.

How the artwork can inform coastal risk management

As shown on the pictures of the Lerret site (Figure 3I.42), the passage grave is regularly covered by sea water at high tide, which is confirmed by the presence of seaweeds stuck to the monuments, both of them proving the current position of the 'menhir' which is regularly (twice a day) submerged by sea water.

Where can the original artwork be viewed?

The original views (glass photographic supports and positive papers) are part of the collection of the Laboratoire Archéosciences (Rennes University).

Kerlouan, Lerret ranking score achieved: 100

I8. Penvenan, Port Blanc, Y. de Bellaing (1936)

Location

The site is located at the beach of Port-Blanc, town of Penvenan, situated in the Trégor region (Côtes d'Armor department). The city of Penvenan is characterised by a strong geographic presence of the sea with outstanding coastal areas, and an archipelago of islands. Two ports recently rearranged as 'Port-Blanc' and Bugueles, demonstrate the importance of these havens for fishing and coastal sailing, today and in the past. Many elements demonstrate the 'maritime dimension' of the town and are of archaeological origin dating back to the Neolithic period. The islands hosted the first occupation by coastal populations from across the Channel, especially the monks and early Chistians since the 6th century.

Why was the study site selected?

This photo represents the megalithic burials discovered in 1935 in the beach of Port-Blanc, locally named ‘Roch Bras’ (Figure 3I.43). The archaeological remains of this site indicate several environmental changes since their building during the Bronze Age (probably during the late 2nd or early 1st millennium BC) (Mazères & de Bellaing, 1936). Several cist stone burials, generally empty, appeared on the beach after storms during the 1930's. These burials were partially destroyed by natural erosion during the 1950's, as mentioned in scientific documentation.

Geomorphological setting

At the local scale, in the surroundings of the archaeological remains, observations mention the ‘old soil’ which contained archaeological remains dating back to the Metal ages, as well as four banks, perpendicular to the foreshore, quite regularly spaced, and fossilized by a sandy dune. This shows that ancient farming structures with field limitations can be traced back to the Bronze Age and early Iron Age.

The archaeological remains provide a date for the development of coastal dunes in this area.

Figure.3I.43. View of the Late Bronze Age or Iron Age burials, discovered in 1936 on the Port-Blanc beach (Roc'h Glas), Penvenan (Côtes d'Armor). Located at the base of sand dunes, partly destroyed by storms (photos by Y. de Bellaing, 1935) © Labo Archéosciences UMR 6566 CReAAH.

Key coastal risk management issues for the frontage
The main risk in this area is erosion that threatens the coastal formations which are mainly composed of soft rocks and sand dunes.

The beach dike of Port-Blanc was built during the 4th quarter of the 20th century (around 1970) (Figure 3I.44). It replaced an old sea defence wall. It is extended by a wall-embankment military defence, built during WWII. A blockhouse completes this defence. The wedges are of recent construction, apart from the wedge Rohanig at the end of the harbour front, which dates from the early 20th century. This protection wall has totally transformed the natural landscape and the coastline along the Port-Blanc bay, which in its current form should be consided 'artificial'.

How the artwork can inform coastal risk management
This archaeological site provides key information on the coastal landscape formation and its evolution:

- the formation of sand dunes and the history of some coastal areas, submitted to regular or episodic sand invasions, during the last three or four millennia; and
- the vulnerability of the sand dune formations facing the regular climatic events (wind, swell) or the sudden ones such as storms which regularly eroded the coastline before the construction of the dike.

Where can the original artwork be viewed? The original photo is part of the collection of the Laboratoire Archéosciences (Rennes University).

Penvenan, Port-Blanc photo ranking score achieved: 100.

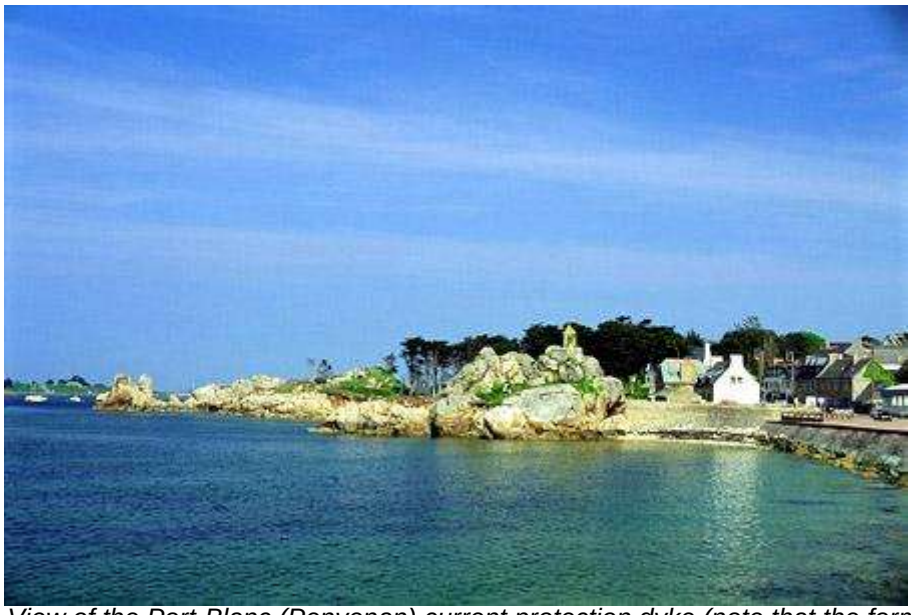

Figure 3I.44. View of the Port-Blanc (Penvenan) current protection dyke (note that the former dune has disappeared) (source jedecouvrelaFrance.com, link http://www.kamaxx.com/jdlf/img/photos/4877_1.jpg).

I9. Carte des Ingénieurs du Roi –St-Michel-en-Grève Bay

Location

The *Carte des Ingénieurs du Roy* was created during the second half of the 18th century with a military purpose, it is one of the first detailed representations of the whole territory of France, in this case the view of the Saint-Michel dates of 1771. The selected section of the charts represents the St-Michel-en-Grèves bay, which is located in the southern part of the bay of Lannion, at the limit between the Finistère and Côtes d'Armor departments (Figure 3I.45).

Why was the study site selected*?*

The Bay of Saint-Michel is especially interesting because it has been depicted with more or less detail in several maps. The oldest representation dates to 1690 and the coastal maps to the 18th and the 19th century, combined with aerial views provide information on coastal and geomorphological changes in this area ove at least three centuries. Besides that, the presence of a path across the beach which is probably of Roman origin and which was in use until the end of the 18th century provides information on sea level change over the long term.

Geomorphological setting

The Bay of Saint-Michel has changed significantly in the last two centuries due to human impact, it consists of a wide sandy beach surrounded by consolidated cliffs in the north and the south of the bay up to 50m; in the east, three streams of water have changed this channel during the 19th century.

Key coastal risk management issues for the frontage

St-Michel-en-Grève bay is threatened by several risks:

- its geographic position infers some peculiar sedimentary processes (accumulation in some parts and erosion in others), due to the marine streams which flow in the bay of Lannion (Augris & Simplet, 2011); and

- as a tourist destination seaside town, the town population and buildings are regularly increasing.

How the artwork can inform coastal risk management

In this area, we can clearly appreciate the environmental changes and the sea level rise, due to the accumulation of sediment and the human effect. In 1771, when the map was created, the route along the bay was still in use and it was protected from the streams Yar and Roscoat thanks to the sand bank that avoided them to pass through and their channel flowed near the city of Saint-Michel. The sand dredged in this area has provoked a progressive sea level rise and the change of the river channel, because the removal of the sank bank meant the river flowed toward the sea. First coastal defenses were created to protect the road and the railway, but this embankment wasnot always enough, and it has suffered during big storms.

Where can the original artwork be viewed?

The original of the document can be viewed in the Vincennes castle (Ministère de la Défense) but the association AMARAI has bought and owns an electronic copy of this document.

Saint-Michel bay map Ranking score achieved: 66.6

Figure 3I.45. Chart featuring the Bay of St-Michel-en-Grèves
(Carte des Ingénieurs géographes du Roy, 1771, doc. Ministère de la Défense, SHDMV).

Figure 3I.46 . Photo of the "Croix de mi-lieue" located along the ancient Roman pathway, which became a pilgrim road during the Middle Ages (author unknown, source: Degemer Mat, lien http://www.st-michel-en-greve.fr/vignettes/patrimoine/croix-de-mi-lieue.jpg).

I10. Carte des Ingénieurs du Roi – Penvenan, Port Blanc Cove

Location
The chart represents the area of Port-Blanc, town of Penvenan, situated in the Trégor region (Côtes d'Armor department) (Figure 3I.47).

Why was the study site selected?
This beautiful and detailed map covers Port-Blanc area (Penvenan), a place where numerous archaeological remains have been found. The limits of the coast, of the islands, and of the rocky islets are accurate and have been depicted with remarkable attention.
This handmade chart is certainly the first precise marine map of the coastal area from Tréguier to Port Blanc (source: http://www.histoiremaritimebretagnenord.fr/).

Geomorphological setting
The geomorphological setting has been presented for this area in the section above.

Key coastal risk management issues for the frontage
See the above section.

How the artwork can inform coastal risk management

The comparison between this ancient chart and the current landscape features shows how some sections of the coast have changed during the last three centuries.

Where can the original artwork be viewed?
The only version of this map is this original (as it has never been printed) and is preserved in the BNF (Bibliothèque Nationale de France, Division 3-folder 43 of the Marine Hydrographic Service).

Penvenan Port-Blanc cove map ranking score achieved: 50

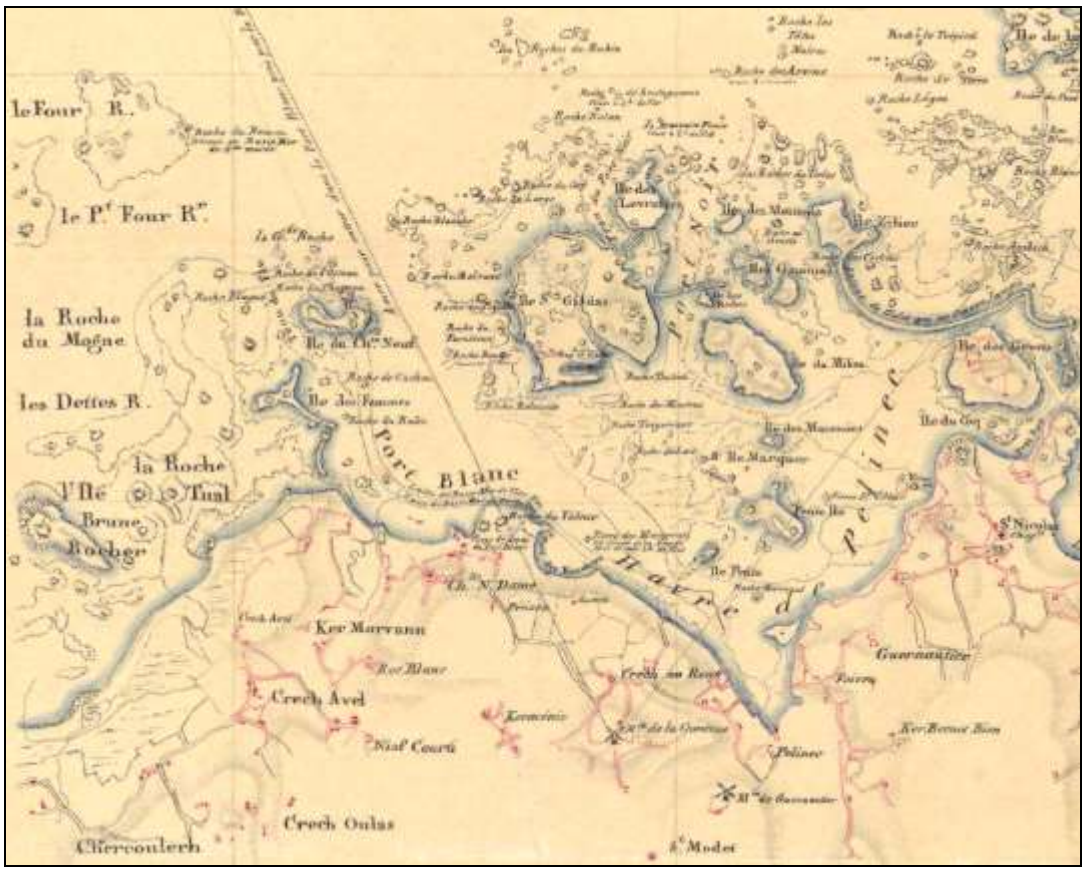

Figure 3I.47. Ancient map 'Tréguier Port-Blanc' (1771-1785) (Source SHM, Ministère de la Défense).

3I.7 Analysis

The Northern-Finistère and Trégor study has combined the use of archaeological and palaeoenvironmental data, paintings, historic photographs, maps and charts in order to demonstrate how these tools can be used to improve understanding of coastal change in the long and short term. The study area contains key elements which have been used for the reconstruction of the ancient (prehistoric) coastal landscapes and the curves featuring Holocene sea level variations. In Brittany, this area is long considered as one of the reference places for palaeoenvironemental reconstructions and this explains the richness of the available documentation (old maps and charts, photos and to a lesser degree, paintings).

Some recent works, either targeting archaeological problems or environment/geomorphology questions, have been applied to this geographic area, where coastal evolution can be studied at various times and spacial scales.

3I.7.1 Archaeology and Heritage Features

The archaeological assessment focussed on the megalithic monuments and archaeological layers, currently located on the tidal shore. The positions of these burials or monuments in a place were they are now regularly submerged clearly indicates that they were settled in a time when the sea level was lower. Numerous archaeological studies and environmental analyses provided accurate data for the building of local sea level curves. For more recent periods (from Metal Ages up to Historical times), the fish trap studies revealed some precise data on environmental changes, as demonstrated for the Léguer estuary and the Petit Taureau fish weir.

It is interesting to note that the study of sea level variations and the search for indicators of coastal change is not a new issue for scientists; indeed, the ancient documentary set of the Archéosciences laboratory (Rennes 1 university) has provided a range of unpublished documents dating from the early 20th century, revealing that several monuments and archaeological sites of the area have provided data for this study (Devoir, unpublished; Giot 1990). The selected sites were mainly megalithic ones, dating from the Neolithic and Bronze Age periods, passage graves, burials and standing stones, such as the one of Men Ozac'h the study of which has been detailed above (Figure 3I.48). For the first time, curves supporting past sea level variation have been proposed.

It is noticeable that such a scientific approach born in Northern Finistère, is due to the presence of numerous archaeological sites located in the tidal foreshore (Figure 3I.49). Later on, in the 1960's, the same sites have been reconsidered, while submerged peat deposits were subject to pollen analyses and radiocarbon dating (Morzadec, 1974), still with the aim of building a precise curve for sea level rise. These works have been recently updated by P. Stéphan, with the use of new scientific approach using lithostratigraphy and biostratigraphy (Stéphan, 2011 & 2012).

As demonstrated by the archaeological surveys, it is also interesting to note that a number of the archaeological sites which have significant potential for holding data to inform on coastal change are themselves likely to be lost through continuing erosion of the coast. This phenomenon is fully illustrated in the framework of the ALeRT project (Archéologie, Littoral et réchauffement terrestre) (Daire *et al*., 2012). This project underlines the vulnerability of the coastal heritage facing various kinds of risks, especially erosion, and highlights the need to gather data from those high and medium scored sites to capitalise on this information before it is lost (for more information, see:http://alert-archeo.org/).

For the Bay of Lannion, ancient sedimentary and stratigraphic observations, though sketchy, are fortunately interspersed with radiocarbon dating and archaeological discoveries, providing chrono-stratigraphic markers. From these observations, we now see that, in the Léguer estuary, due to marine transgression, sedimentation at the bottom of the bay, with levesl of accumulation of organic matter and river sediments, was followed by marine sedimentation. It was during this transition that fish weirs have gradually been installed on both sides of the estuary. The oldest fish traps detected at the mouth of the Léguer estuary go back to the Bronze Age (Dourven at Trédrez) and the Iron Age (Corps de Garde at Servel). The evolution of the implementation of these fish traps and their progressive displacement upstream not only follows the rhythm of a marine transgression in progressive slowdown, but also the very complex sedimentary history of this estuary (Figure 3I.50). If natural factors have largely determined the shaping of banks, human interventions at different periods are also responsible for deep changes in the network of channels of fluvial-marine flows.

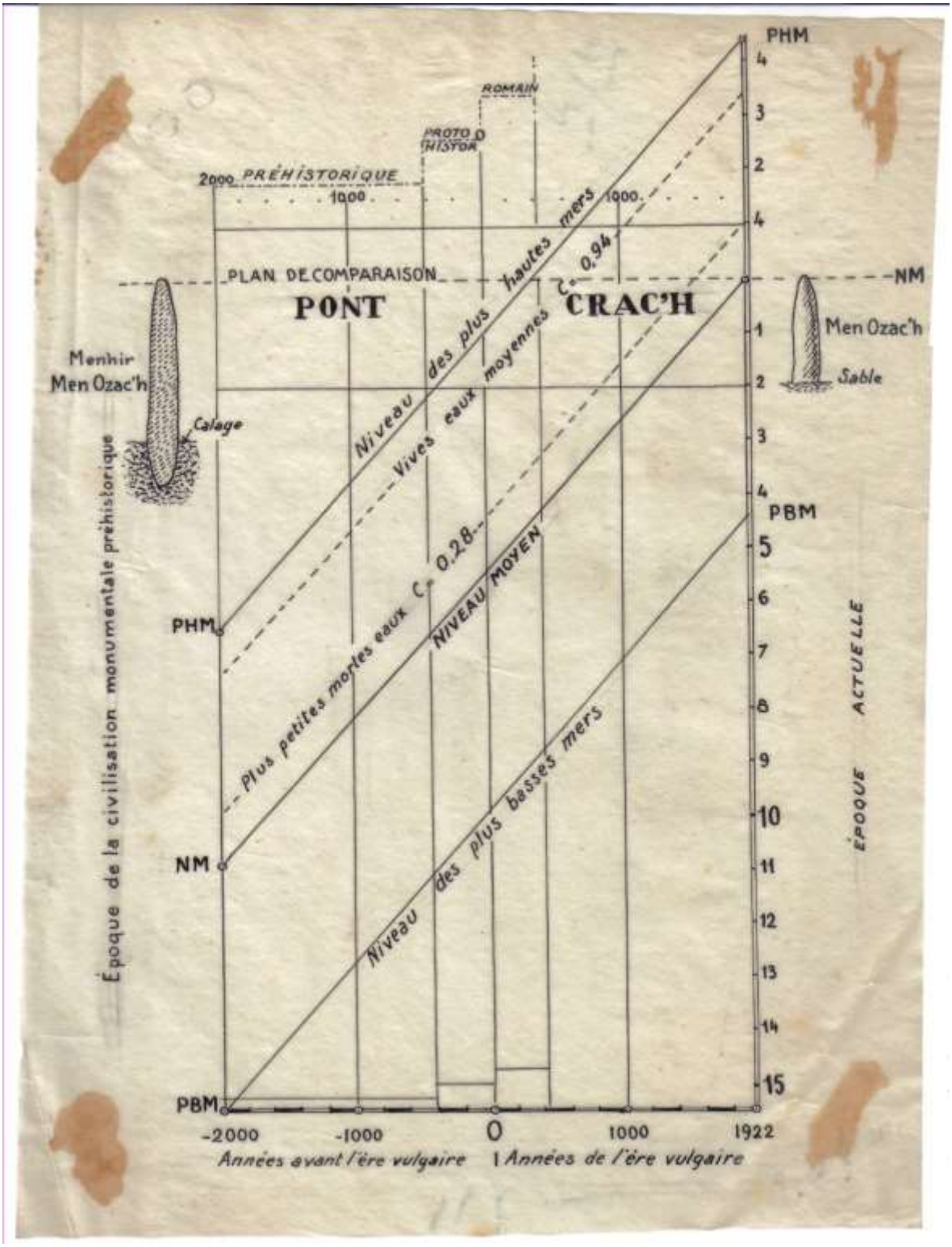

Figure 3I.48. Analysis of the Men Ozach standing stone (Plouguerneau, Finistère) as an indicator of Holocene sea level rise (doc. by A.Devoir, early 20th century) © Labo Archéosciences UMR 6566 CReAAH.

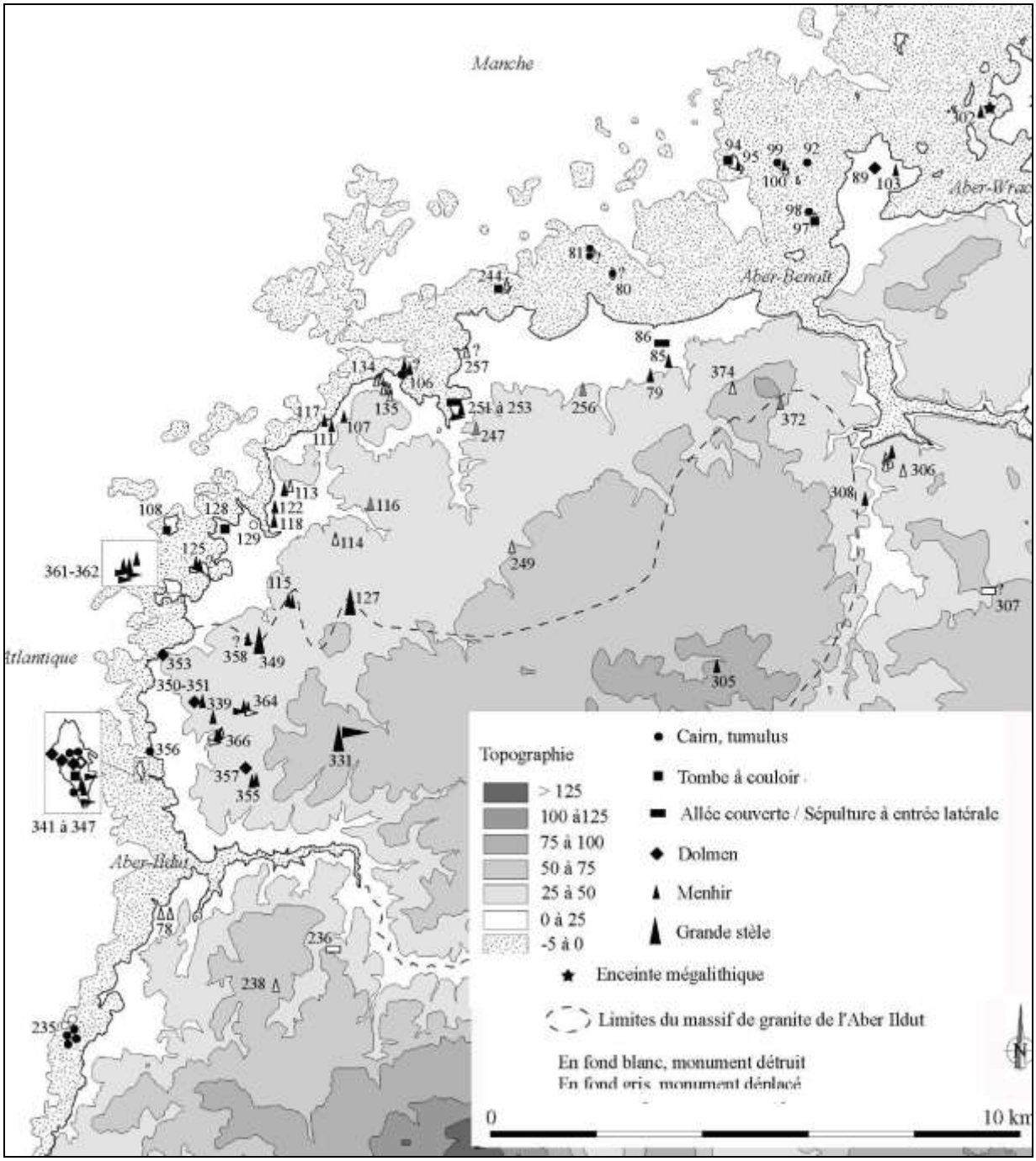

Figure 3I.49. Distribution of the Megalithic monuments (Neolithic and early Bronze Age) in the north west Finistère area, and their position regarding the topographic sea level (after Stéphan in Sparfel & Pailler 2009: 57). The map especially shows (in grey) the probable location of the ancient foreshore (Neolithic), which is currently submerged. This explains why a lot of monuments, formerly settled on the top of small hills, are now located on isolated islands or islets.

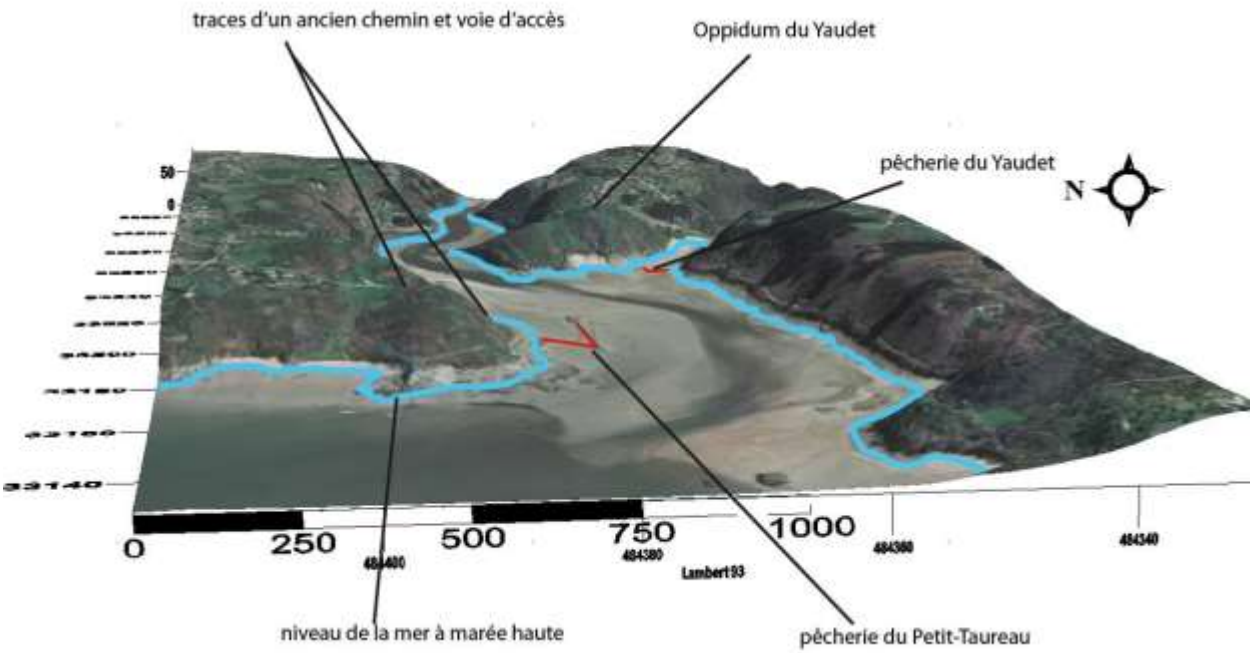

Figure 3I.50. 3D reconstruction of the Léguer estuary during Middle Ages, showing the location of the main fish traps and settlements (after Marie Poignant, Dijon University).

3I.7.2 Artistic Depictions

Following the research and location of a large number of photographic images of the study area coastline it was possible to rank their relative importance in terms of their value on informing on long-term coastal change. Several ancient maps and charts were also used. The art case study area was extensively covered by ancient photos; including taken by the pioneer scientists (collection from the Archéosciences laboratory, ICARE project; López-Romero and Daire, 2013) as well as those used for tourist purpose and edited postcards.

The ranking system directed research to the higher ranking case study locations usually where detailed accurate photos or maps were available as the artworks and especially the paintings were less numerous and illustrative in this area. Then, we selected the most representative photos, generally featuring archaeological sites witnessing sea level rise; in terms of the most helpful photos comparing coastal change, those representing the megalithic monuments of Northern Finistère area have been selected.

As well, the selected high scored ancient charts are those where, for example, beach levels are clearly indicated or where special features (sand bars, dunes) can be measured; a good example is provided by the Saint-Michel-en-Grèves bay.

3I.7.3 Combined Resources

Plouescat is a town in northern Finistère; its coastline is of about 13 km long with a succession of sandy beaches, dunes, and massive blocks of granite. Kernic Cove is a bay where there are extensive mudflats and sandbanks. One of the most famous megalithic monuments of the region stands on the tidal shore of the Kernic beach.

Among all the megalithic monuments of this area, the ‘Guinirvit’ passage grave has been fully excavated in the 1980's. This monument was damaged by the builders of the surrounding port,

as many megalithic blocks were taken for the construction of the quays, mainly used by the seaweeds farmers. The ancient photo, taken at the early 20th century, shows the monument in a better state of preservation than it is today.

The passage grave measures 10 m long and is currently submerged twice a day; this is a good indication of sea level rise, which is locally estimated at 7 m since the Neolithic period. The excavations carried out in 1986 under the direction of the prehistoric antiquities of Brittany enabled evidence of this collective burial and its protective enclosure to be recorded. This research and other studies have uncovered an important set of potsherds and lithic materials: circular flint scrapers or blades, hammers, quartz fragments, polished axes, arrowheads and slag. This monument has been protected as Cultural heritage ('monument historique') since 1960.

The following image (Figure 3I.51) presents various views of the megalithic monument. The ancient photo, (n°1, Figure 3I.51) taken during the very early 20th century, shows the passage grave in an early stage, before the damage by the builders of the quays (n°6, Figure 3I.51).

As for the monuments presented above, these megalithic remains, nowadays located on the tidal foreshore, give an indication of the sea level rise since the Neolithic period, which is evaluated to 7 meters. However, this phenomenon is not the only reason for coastal changes in this area. As is visible when comparing the maps (n°3-5, Figure 3I.51), the sand dunes and river flood channel have changed in shape and location during the last four centuries. On the Cassini map (17th century) as according to the 18th century chart (n°3 & 4, Figure 3I.51), the area of the Curnic bay is only a sandy slope, formed behind a rocky bar that retains the sand and which is cut by the river meanders; as seen on the recent maps (n°4, Figure 3I.51), this area is currently submerged at high tide, probably because of a combination of a slight sea level rise and discharge of sand due to the river flow or to the marine streams.

This area is currently protected, as a natural zone for bird reproduction. The nature curators are aware that the coastal managers for tourism impact on this vulnerable area, especially sailing activity which could damage the sand dunes (http://inpn.mnhn.fr/site/natura2000/FR5312003/).

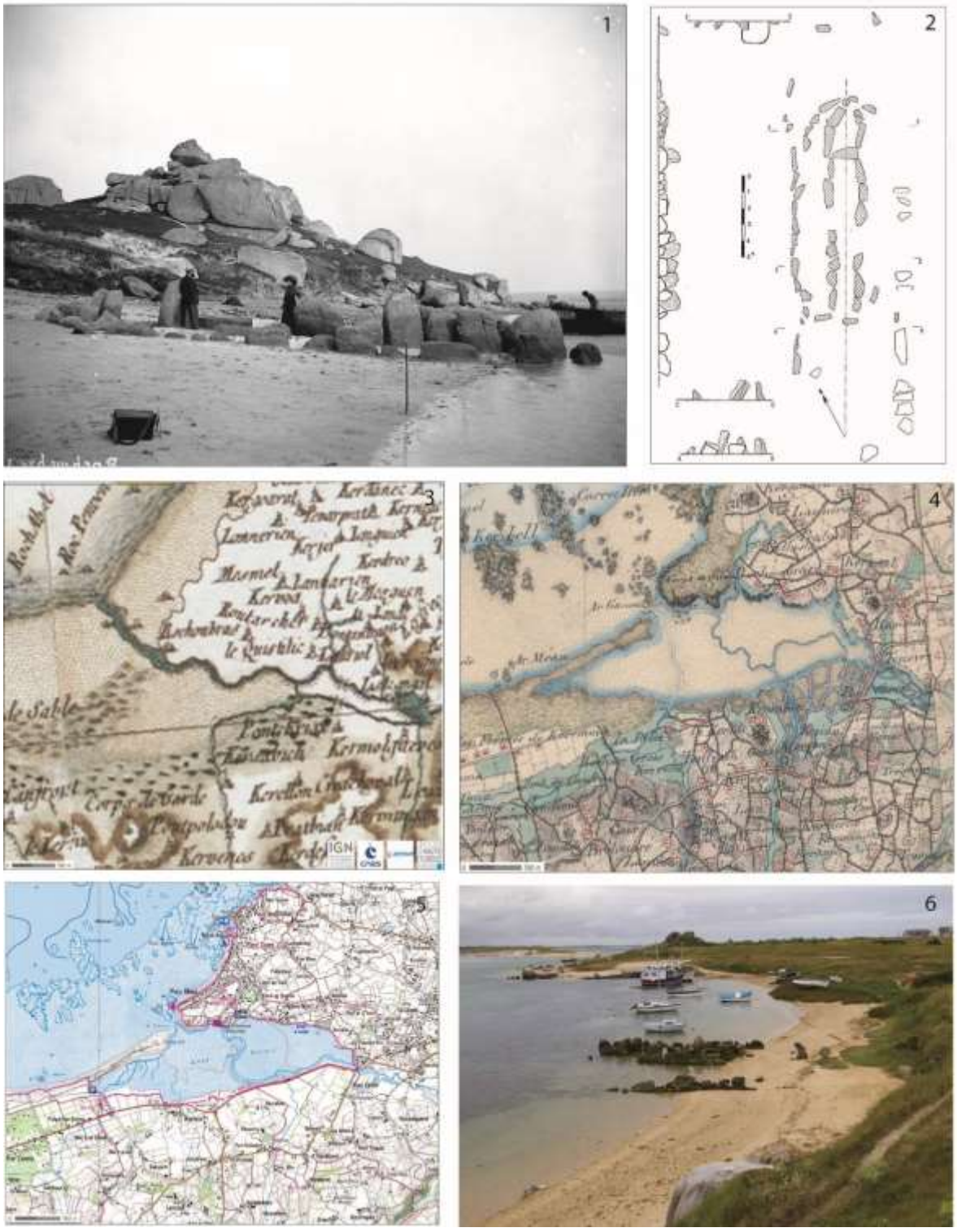

Figure 3I.51. Combination of visual documents of the Neolithic passage grave of the Kernic Bay (Plouescat, Finistère). (1) Early 20th cent. photo of the monument © Labo Archéosciences UMR 6566 CReAAH, (2) Map of the inner part of the megalithic remains (doc. J. L'Helgouac'h, 1965), (3) Cassini chart (17th cent.), (4) "Etat major" chart (1820-1866), (5) Current IGN map (source Géoportail), (6) present day (doc. M. Monros).

3I.8. Conclusions and Recommendations

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 on 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.

In the case of Lannion bay, we can consider that the massive extraction of estuarine sands in the decades 1950-1970 has restored the Léguer estuary a former state, clear of recent alluvium, probably older than what was recorded by J. P. Pinot - the late 18th cent.; this state could be traced back to the Metal Ages if one believes the combination of sediment study, radiocarbon dating and archaeological data. Anyway, the fish weirs of the Léguer estuary provide information on thirty centuries of the history of fishing and peopling of the estuary. Sedimentary data (cores and surveys) and associated dating provide markers, actually quite sketchy in terms of calibration samples on the one hand to the Bronze Age (or Neolithic period) and, secondly, to the Middle Ages.

This observation should make coastal managers aware of the consequences of future sand and aggregate extractions, which are planed offshore in the bay of Lannion int the near future.

In the same way, the complex history of Kernic bay gives an opportunity to underline the benefit gained from analysing the past and especially the geo-archaeological evidence, in order to evaluate the impact of the current managment decisions. This is especially important when considering the soft rocks or sedimentary features of the coastal areas, which are vulnerable and very sensitive to any change, either of climatic or anthropic origin.

This report is a section of the Technical Report for the Archaeology, Art and Coastal Heritage – tools to support coastal management and climate change planning across the Channel Regional Sea (Arch-Manche) Project. To cite this report please use the following:

Olmos, P Martin, C Daire, MY. 2014 Case Study 3I – Tregor and Northern Finistere, France. In Satchell, J & Tidbury, L (eds) *Arch-Manche Technical Report*.

For further information on the project and to access the full Technical Report please go to www.archmanche.hwtma.org.uk/downloads

The project has been part funded by the European Regional Development Fund through the Interreg IVA 2 Seas Programme. This report reflects the authors' views. The INTERREG IVA 2-Seas Programme Authorities are not liable for any use that may be made of the information contained therein.

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