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Climate variability and storm impacts as major drivers for human coastal marsh withdrawal over the Neolithic period (Southern Brittany, NW France)

A. Fernane [a,b,*], A. Penaud [a], E. Gandouin [b], J. Goslin [c], B. Van Vliet-Lanoë [a], M. Vidal [a]

[a] UMR 6538 Domaines Océaniques, IUEM-UBO, Brest University, UEB, rue Dumont d'Urville, 29280 Plouzané, France
[b] IMBE, UMR 7263 CNRS-IRD-UAPV, Aix-Marseille University, Europôle Méditerranéen de l'Arbois, Pavillon Villemin, BP 80, 13545 Aix-en-Provence Cedex 04, France
[c] UMR 6554 CNRS LETG-Geomer, IUEM-UBO, Brest University, UEB, rue Dumont d'Urville, 29280 Plouzané, France

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ABSTRACT

Relationships between climate variations, vegetation dynamics, and early human activities during the Neolithic have been reconstructed from high-resolution pollen and foraminiferal records obtained from cores retrieved from coastal wetland located in southern Brittany (Guidel, NW France). Our data show that the area around Guidel corresponded to a dense temperate forest locally replaced by riparian forest in the marsh, without any human disturbance during the early Neolithic. During the mid-Neolithic, between 6500 and 5500 cal years BP, the first episode of probable human settlement is recorded, as suggested by the increase of anthropogenic plants. This early record of human impact is consistent with archeological studies that find a high concentration of funeral monuments around Guidel during this cultural period. This complex first phase is interrupted by the disappearance of anthropogenic influence coinciding with a cold/humid climate period in the region characterized by recurrent major storms. Then, at the transition between the middle to late Neolithic, at 5500 cal years BP, a second phase of human retreat is signaled by both vegetation dynamics and archeological records; this interval also coincides with a climatic deterioration marked by cold/humid conditions recorded in the region (Sorrel et al., 2012). The results of the present study imply that human settlement/departure over the Neolithic was probably influenced by climatic variations. During the Bronze Age, Iron Age, and Middle Ages, a progressive decline of the arboreal forest, synchronous with an increase of anthropogenic plants, confirms the high and persistent human activity around the site. Furthermore, our results at Guidel suggest a different anthropogenic trend recorded between north and south Brittany. The human impact is well recorded during the Neolithic at Guidel, while in northern Brittany human settlement is not recorded before the Bronze Age, consistent with existing archeological data.

1. Introduction

High-resolution paleoclimate and paleoenvironmental studies over the Holocene are crucial in order to understand past forcing mechanisms and future climate trends superimposed on increasing human impacts. Millennial-scale climate oscillations are now well recognized throughout the Holocene (O'Brien et al., 1995; Bond et al., 2001; Mayewski et al., 2004; Wanner et al., 2011) and there is a rise in paleoclimate studies worldwide so as to better understand the nature, timing, and causes of these oscillations, e.g. solar activity and/or internal forcing mechanisms relative to the climate system, and the changing atmospheric and oceanic re-organizations through time (Bond et al., 2001; Mayewski et al., 2004; Wanner et al., 2008, 2011; Fletcher et al., 2013). Holocene mechanisms and global-scale representations of climate are still far from being well-understood and regional studies are required to understand the spatiotemporal complexity of our interglacial period.

This is especially true at a local scale when considering coastal zones that evolve fast, specifically to global changes including sea level, air temperature, continental precipitation changes, and human disturbances. Bio-indicator analyses are therefore crucial for detecting ecosystem changes in response to climatic and anthropogenic controls. Maritime marshes are remarkable coastal ecosystems in temperate regions, with dynamic ecological systems responding to changing environmental conditions such as sea level or river discharge variations. Hence, they are influenced by both continental and marine factors. The Grand Loc'h (GL) of Guidel, located south of Brittany (NW France, Fig. 1), consists of an ancient ria progressively transformed into a coastal salt marsh during the Holocene transgression. It is protected from direct

* Corresponding author at: UMR 6538 Domaines Océaniques, IUEM-UBO, Brest University, UEB, rue Dumont d'Urville, 29280 Plouzané, France. Tel.: +33 6 34 06 86 61.
E-mail addresses: assia.fernane@gmail.com (A. Fernane), aurelie.penaud@univ-brest.fr (A. Penaud).

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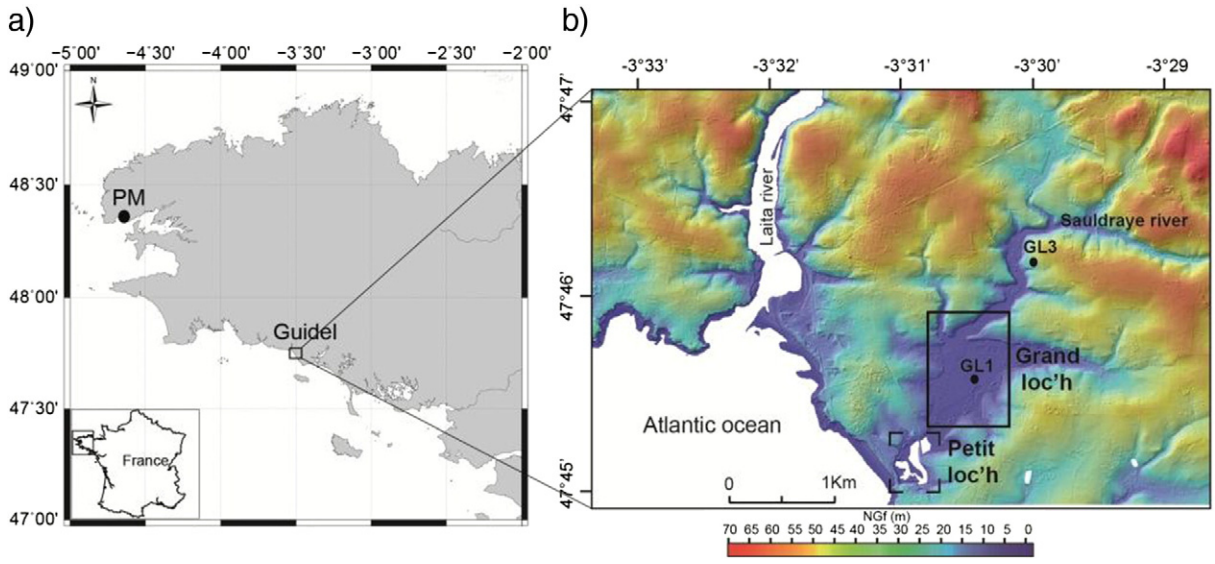

Fig. 1. a) Location map of the Guidel study area, b) sediment precise core locations: GL3 (47°46′13.90″N, 3°30′2.60″O; 6 m long, pollen analysis: this study), and GL1 (47°45′43.70″N, 3°30′10.75″O; 11 m long, foraminiferal analysis: Fernane, 2014).

marine intrusion by a late Holocene sandy dune barrier. The GL marsh is therefore a perfect area to perform paleoenvironmental studies of the Holocene period using comprehensive sediment records. Additionally, several studies conducted around Brittany previously confirmed that coastal environments represent pertinent and key study areas to decipher Holocene climatic and/or anthropogenic changes (Sorrel et al., 2009, 2012; Baltzer et al., 2014; Fernane et al., 2014; Van Vliet-Lanoë et al., 2014).

Based on pollen analysis conducted on a sediment core retrieved from southern Brittany, we discuss the paleoenvironmental history of the region over the last 7000 cal years BP. Pollen analyses will allow us to discuss, in parallel, both climate fluctuations and agro-pastoral activities over the surrounding GL watersheds. Hence, the present paleoenvironmental study should enable us to: 1) detect past environment changes, 2) try to relate these changes to the climate pattern, and 3) supply information about the impact of human expansion on ecosystems through time.

2. Environmental context

2.1. Geomorphological context

The study area, Guidel ("Grand Loc'h", GL, Fig. 1), is a maritime coastal marsh located in southern Brittany (NW France). The site is fully incised in weathered Paleozoic bedrock; the gneiss is saprolite, mostly impervious, and induces rapid and superficial drainage over the watershed as well as toward the ocean. Despite its present low altitude, less than +2 m NGF ("*Nivellement Général de la France*", French reference system for sea level elevation), and the prevailing macro-tidal regime, the marsh is protected from marine intrusion by a coastal dune ridge. Since 1989, these coastal dunes support a road that isolates GL from a sandy beach about 500 m long (Fig. 1).

The present-day GL marsh surface, stretching from north to south, covers 70 ha, and its surrounding catchment covers about 2600 ha. GL marsh consists of two asymmetrical parts: the northern part or "Grand Loc'h" (GL) and the southern part or "Petit Loc'h" (PL), this latter being partly embanked during the 1960s (Fig. 1). The two parts are separated by a small dam constructed during the 19th century in order to stop marine intrusion toward GL and to allow agriculture activities. Furthermore, between 1942 and 1945, the Germans created an airport, the superficial ground scraping then perturbed the top of the stratigraphical sequence. According to these anthropogenic morphological configurations, hydrological differences can be observed between the GL and PL Loc'hs. Brackish hydrological conditions dominate in PL due to its connection to the sea via a tide gate (1884 AD). During the summer period, PL is dry with few permanent brackish ponds, while the rest of the year PL marsh is subject to marine submersion. In contrast, the GL surface waters today are fully protected from the influence of seawater, and GL shows more complex environmental processes over the year. Hence, the GL marsh is subject to fluctuating fresh (river discharges) and marine water conditions (via PL) from winter to late spring while, during late summer, the marine water prism may reach the surface, resulting in brackish to salty vegetation establishment. In the upstream part of GL, a persistence of high groundwater levels leads to a continuous freshwater peat development, within a depression separated from the Sauldraye river by a fluvial sandy bank (Fig. 1a). The spatial heterogeneity of the Guidel marsh, consisting in a total of 5 km of channeled rivers, as well as in permanent/temporary small ponds, offers diversified and numerous habitats for floral and faunal species.

2.2. Present-day climate and associated vegetation

The climate in Brittany is characterized by temperate oceanic conditions (due to the North Atlantic Ocean influence) with generally cool, rainy winters and fresh summers. Mean annual temperature ranges between 10.9 and 12.6 °C with weak thermic seasonal amplitudes. Mean annual precipitation rate ranges from 800 to 850 mm. The climate of Brittany is strongly influenced by the North Atlantic Oscillation (NAO) pattern that governs the strength and persistence of the westerly winds (Hurrell, 1995). This natural pattern of atmospheric variability directly influences temperatures and hydrological conditions (precipitation, river discharges, and water table levels), which in turn influence vegetation cover.

Regarding current vegetation, the Guidel marsh was extensively cultivated until the last decade of the 20th century. Nowadays, only pastoral activities continue. In this area, vegetation is constituted by several kinds of meadows characterized by associations of different species. Among these, notable and rare species are observed, such as *Salicornia ramosissima*, *Puccinellia distans*, *Agrostis stolonifera*, *Potamogeton crispus*, *Eleocharis palustris*, *Trifolium fragiferum*, *Trifolium resupinatum*, *Prunus* sp., and *Potentilla neumanianna*. Some other species such as *Carex punctata*, and *Orchis laxiflora* are classified as endangered species. The landscape throughout the Guidel marsh is mainly open and the sparse