

## PhD Proposal

# Chronology of Holocene Coastal Sand Drift Events along the Atlantic coasts of Europe: role of climate and implication on coastal landscapes and societies (ChronoDune)

**Keywords:** coastal dune, chronology, OSL dating, geomorphology, archaeology

## Useful information

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## Abstract

The ChronoDune thesis aims to reconstruct the chronology of dune activity phases during the Holocene period along the European coast. What were the constraints imposed by sand-drift events on both landscape changes and human populations living along the coasts? What was the role of climate changes in the dynamics of dune environments during the Holocene? Three spatial scales will be considered in this work. At the scale of the European coast, the thesis will seek to develop a robust chronological model, based on a probabilistic approach (Bayesian statistics) integrating numerical chronology data such as radiocarbon and optically stimulated luminescence (OSL) dating, but also historical data available in scientific papers. Along the western coasts of France, the chronology of the coastal dunes of Brittany will be reconstructed from geomorphological and stratigraphical analyses on a set of dune fields. A fieldwork will be carried out using sediment cores. Extensive work on sample preparation and analysis in the laboratory will also be carried out in order to acquire several dozen OSL dates. On a local scale, the thesis will carry out more targeted work on several archaeological sites currently being excavated on islands of B niguet and Hoedic.

## Context

The thesis project entitled "Chronology of Holocene Coastal Sand Drift Events along the Atlantic coasts of Europe" is part of the flagship research project entitled "SEALEX: *The Sea as a long-term socio-ecological experiment*" funded by the ISblue University Research School (EUR) over the period 2020-2024. Using an interdisciplinary approach, the SEALEX research project focuses on the response of past coastal societies to environmental transformations induced by natural forcing such as climatic, hydrological and geomorphological changes. The SEALEX project brings together a dozen research laboratories in the Human and Social Sciences, Natural Sciences and Engineering Sciences. This thesis project will also be part of the GEOPRAS project "*GEOarchaeology and PRehistory of Atlantic Societies*" financed by the French national research agency (ANR) over the period 2022-2026. The GEOPRAS project analyses the coastal societies of recent Prehistory (Mesolithic and Neolithic) on the shores of the North Atlantic, in order to understand their role in historical dynamics. Our purpose is to lay down the conceptual, methodological and technical foundations of a maritime prehistory. The identification and measurement of environmental fluctuations are central to this interdisciplinary investigation, both to assess the functioning of these human communities in rapidly changing spaces and to ensure the reception of an archaeological signal that is subject to very severe erosion and/or sedimentation processes. One of the central questions of the project is: What was the impact of the sometimes radical transformations of maritime landscapes on human settlements, access to resources and human networks? The Chronodune thesis project will seek to answer this question by focusing on the impact of coastal dune mobility on past coastal populations.

## Assumptions, questions asked, identification of bottlenecks

During the Holocene period, coastal environments experienced deep landscape transformations due to natural and anthropogenic forcing such as (i) relative sea level changes, (ii) climate fluctuations known as "RCCs" (Mayewski *et al.*, 2004)<sup>1</sup> or "Bond events" (Bond *et al.*, 2001)<sup>2</sup>, (iii) variations of sediment budget, (iv) vegetation cover dynamics, (v) human induced imprint on natural environments. Along the English Channel and Atlantic coasts of France, coastal landscapes were gradually flooded by the sea and/or invaded by significant volumes of aeolian sands. Locally, coastal dune complexes were formed that modified the physiography of large coastal areas. Episodic sand drift events have represented a natural constraint to the human settlement along the coast. The proposed thesis aims to reconstruct the chronology of the phases of aeolian activity along the Atlantic coast of Europe. The Holocene morphodynamic of coastal dunes will be crossed with archaeological and historical data in order to estimate the implication of these changes on both past coastal landscapes and societies.

Along the Atlantic coast of Europe, a large number of studies in geology, geomorphology, archaeology and history have focused on the Holocene coastal dune morphodynamic with the objective of reconstructing the periods of dune installation and aeolian remobilisation, both in time and space. Chronologies were established at local and regional scales and have highlighted a connection between periods of dune mobility and climatic conditions (intensity of atmospheric flows). Recently, Jackson *et al.* (2019)<sup>3</sup> focused on the Little Ice Age period (ca.1300-1850 cal.AD) and showed that cooling climatic conditions led to widespread mobility of coastal dunes in Western Europe. During this period, many

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<sup>1</sup> Mayewski P.A., Rohling E.E., Curt Stager J., Karlén W., Maasch K.A., Meeker L.D., *et al.* (2004) – Holocene climate variability » *Quaternary Research*. 62(3), 243–55.

<sup>2</sup> Bond G. (2001) – Persistent Solar Influence on North Atlantic Climate during the Holocene. *Science*, 294, 2130–2136.

<sup>3</sup> Jackson D.W.T., Costas S., Guisado-Pintadoa E. (2019) – Large-scale transgressive coastal dune behaviour in Europe during the Little Ice Age. *Global and Planetary Change*, 175, 82–91.

coastal villages were buried by the aeolian sand that induced large population movements. We hypothesise here that such events occurred several times during the Holocene. Although many papers establish synchronicities from one region to another, comparisons remain very descriptive, draw too vague chronological frameworks, and rely on non-harmonised data and deterministic chronological approaches. Therefore, the first objective of the thesis will be to take up this work by developing a more robust chronological model, based on a probabilistic approach (Bayesian statistics) integrating digital chronology data such as radiocarbon and optically stimulated luminescence (OSL) dating, but also archaeological and historical data available in the European scientific literature.

In France, coastal dunes chrono-stratigraphic data are spatially limited to the dune complexes of the Aquitaine region (*e.g.* Bertran *et al.*, 2021)<sup>4</sup> where interbedded palaeosol series within the aeolian sandy deposits were dated from numerous radiocarbon dates. More recently, this work was completed by new OSL dating (Kreutzer *et al.*, 2018; Bosq *et al.*, 2019)<sup>5</sup>. On the coastal dunes of Brittany (west of France), only fine humic horizons are preserved within the dune sedimentary sequences. The absence of well-developed palaeosols or organic horizons strongly limits the establishment of chronologies based on radiocarbon dating. The use of alternative approaches is therefore essential. Currently, Aneta Gorczyńska's thesis work aims to re-evaluate the existing archaeological documentation on the coastal dunes of Brittany. A total of 236 archaeological sites distributed along the coast were selected to provide precise information in terms of coastal dune stratigraphy and chronology. This approach considers the archaeological sites as indicative of periods of stability of the dune environments. The synthesis of these data highlights three main phases of aeolian activity on the scale of Brittany: from 1600 to 500 cal.BC (phase 1), from 800 to 1400 cal.AD (phase 2), from 1650 to 1850 cal.AD (phase 3). A synchronicity is found between the North, West and South coasts of the Brittany peninsula and suggests that periods of sand dune invasion were triggered by a regional forcing, involving a decreasing relative sea-level rise, significant changes in the coastal sediment budget and changes in accommodation space. Now, this chronology needs to be reinforced by approaches using digital dating methods such as OSL. Indeed, OSL will be used to estimate periods of dune mobility by dating the last exposure of quartz grains to daylight. Holocene coastal dunes deposits are particularly suitable sedimentary archives for OSL dating: firstly, because they contain a lot of quartz grains in the 100-250 µm size fraction; secondly, because exposure to light prior to burial was sufficient to reset the OSL signal; and thirdly, because the dose response of OSL for this time range is particularly rapid to measure and easy to exploit. The Chronodune thesis project aims to acquire a significant number of OSL dates on dune sedimentary sequences, in order to constrain chronologically the phases of dune mobility. These data will be compared to chronologies established in Aquitaine region and in other coastal areas in west of Europe.

On a local scale, several archaeological operations are currently underway on various dune sites in Brittany. The excavation of the "Porz Ar Punz" archaeological site on the island of Béniguet (Molène archipelago, western Brittany) began in August 2021 under the direction of Y. Pailler and C. Nicolas. The archaeological excavation revealed three anthropogenic levels (shell middens and stone structures) attributed to the Bell Beaker, Early Bronze and Middle Ages periods, respectively. These

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<sup>4</sup> Bertran P., Andrieux E., Bateman M.D., Fuchs M., Klinge M., Marembert F. (2021) – Mapping and chronology of coversands and dunes from the Aquitaine basin, southwest France. *Aeolian Research*, 47, 100628.

<sup>5</sup> Kreutzer, S., Duval, M., Bartz, M., Bertran, P., Bosq, M., Eynaud, F., & Mercier, N. (2018) – Deciphering long-term coastal dynamics using IR-RF and ESR dating: a case study from Médoc, south-west France. *Quaternary Geochronology*, 48, 108-120.

Bosq, M., Bertran, P., Beauval, C., Kreutzer, S., Duval, M., Bartz, M., & Stéphan, P. (2019) – Stratigraphy and chronology of Pleistocene coastal deposits in northern Aquitaine, France: a reinvestigation. *Quaternaire. Revue de l'Association française pour l'étude du Quaternaire*, 30(1), 275-303.

levels are interbedded in aeolian sand deposits. One of the scientific challenges of this archaeological excavation is to reconstruct the general stratigraphy of the deposits and the chronology of the periods of dune mobility in order to assess the impact of these changes on human settlements. A second archaeological site currently excavated under the direction of G. Marchand is located on the island of Hoedic (south of Brittany). Here, human occupations dated from the Mesolithic period were buried under a thick layer of aeolian sand deposits which has favoured the exceptional conservation of these remains. On the same island, the Neolithic sites of “Groah-Denn” and “Douet” excavated by J.-M. Large (Large & Mens, 2008)<sup>6</sup> will be the subject of more in-depth chrono-stratigraphic analyses in order to date the period of burial of the remains by aeolian sand deposits. Finally, the island of Tévéc could also be investigated by vibracores during next years. Once again, it appears necessary to reconstruct the chronology of the sand-drift events and to reconstruct the environment surrounding the archaeological discoveries. The third objective of the thesis will therefore be to participate in the archaeological operations and to reconstruct the lithostratigraphy and chronostratigraphy of the sites from (i) a series of cores and sections taken in the field and (ii) absolute or relative dating acquired during the thesis.

### Methodological and technical approaches

Three spatial scales of analysis will be considered in this doctoral research:

(i) On the scale of the Atlantic coasts of Europe, the major phases of aeolian activity will be reconstructed from a re-analysis of the scientific literature. A database of absolute dates (14C, OSL, IRSL) and available archaeological and historical information will be constructed and analysed using statistical methods. The use of probabilistic (Bayesian) approaches is envisaged using ChronoModel software. The chronological information available in the ChronoModel software will be integrated to produce one (or more) model(s) that will allow the establishment (or constraint) of chronologies of dune mobility and stability (Lanos & Philippe, 2017)<sup>7</sup>. These data will be crossed with paleoclimatic signals in order to estimate the role of climatic forcing in the morphosedimentary dynamics of coastal dunes.

(ii) On the scale of the Armorican peninsula (western France), a series of field missions will be carried out on the most interesting dune complexes, selected on the basis of their mobility potential and the complexity of the stratigraphy encountered. A series of vibracores will be carried out in order to reconstruct the stratigraphy of the deposits. This approach will be complemented locally by the use of geophysical tools (GPR). Along the coastline, the eroding sequences will also be studied. The sandy sediments will be sampled using an adapted procedure with a view to their dating by OSL. A granulometric study of the sediments will also be undertaken. In order to obtain the best possible chronological resolution, models combining radiocarbon, OSL and archaeological or historical information will be constructed using the BayLum modelling tool. Indeed, thanks to the consideration of stratigraphic constraints and measurement uncertainties specific to OSL, this tool can significantly improve the accuracy and precision of OSL dating (Christophe *et al.*, 2020; Combès *et al.*, 2017; Philippe *et al.*, 2019; Heydari *et al.*, 2018, 2020, 2021; Guérin *et al.*, 2021)<sup>8</sup>.

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<sup>6</sup> Large J.-M. & Mens E. (2008) - L'alignement du Douet à Hoedic (Morbihan, France). *L'anthropologie*, 112, 544–571.

<sup>7</sup> Lanos P., Philippe A. (2017) – Hierarchical Bayesian modeling for combining dates in archeological context. *Journal de la Société Française de Statistique*, 158 (2), 72-88.

<sup>8</sup> Christophe, C., Philippe A., Kreutzer S., et G. Guerin. «BayLum: Chronological Bayesian Models Integrating Optically Stimulated Luminescence and Radiocarbon Age Dating. R package version 0.2.0.» 2020. <https://CRAN.R-project.org/package=BayLum>.

(iii) On the scale of the Porz ar Punz (Béniguet Island) and Beg ar Vil (Saint-Pierre-Quiberon) archaeological sites, a geoarchaeological approach will be carried out using vibro-coring and analysis of sedimentary sections excavated during the excavations. Based on sedimentological analyses and OSL and radiocarbon dating obtained from sedimentary and/or anthropogenic deposits, a chronology of the silting phases will be reconstructed. These data will be cross-referenced with archaeological information to study the impact of these environmental changes on human occupations.

### Profile of the PhD candidate

The candidate should have acquired knowledge in coastal geomorphology, sedimentology and palaeoenvironments throughout his/her training, particularly at Master level. He/she should master the fundamental principles of absolute dating (<sup>14</sup>C, OSL) and the associated processing tools (OxCal, Calib, ChronoModel), sedimentological measurement tools and have field experience, particularly in sedimentary coring, topo-morphological measurements with DGPS and/or archaeological excavations. He/she should be proficient in GIS mapping software (ArcGis or QGis). Experience in the use of GPR (Ground Penetrating Radar) type geophysical tools is also desirable. Experience as a volunteer on an archaeological excavation site or an interest in archaeology in general is also desirable.

### Hosting conditions

The candidate will be registered at the University of Western Brittany, in the Ecole Doctorale des Sciences de la Mer, under the supervision of Serge Suanez, professor of geography and under the co-supervision of Guillaume Guérin (researcher at the CNRS). His office will be located within the UMR 6554 LETG at the Institut Universitaire Européen de la Mer (Plouzané).

### Required qualities

- Good interpersonal and teamwork skills
- Ability to listen and reformulate
- Ability to analyse, summarise and write
- Rigour and organisation
- Autonomy and creativity

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