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Holocene relative sea-level changes in western Brittany (France) between 7600 and 4000 cal. BP: Reconstitution from basal-peat deposits

Variations du niveau marin relatif holocène dans l'ouest de la Bretagne (France) : reconstitution à partir des tourbes de base entre 7600 et 4000 cal. BP

Jérôme Goslin*, Brigitte Van Vliet-Lanoë**, Pierre Stephan*, Christophe Delacourt**, Assia Fernane**, Emmanuel Gandouin***, Alain Hénaff*, Aurélie Penaud**, Serge Suanez*

Abstract

With respect to others European oceanic facades, the Holocene relative sea-level (RSL) changes along the French Atlantic coasts have received relatively little attention. Even if it received some attention for geophysical modelling (Van de Plassche, 1991; Lambeck, 1997; Leorri *et al.*, 2012), only two field-based studies really dealt with this subject in Western Brittany, agreeing on an oscillatory RSL pattern with a conspicuous pluri-metre negative variation occurring around 3000 BP (Morzadec-Kerfourn, 1974; Stephan, 2011). This paper is the first step on the way to update Western Brittany Holocene RSL data. It presents a new long-term Holocene RSL reconstruction based on basal peat deposits, compaction-free deposits that have been accumulated on top of the Pleistocene formations during the early-Holocene stages of the post-glacial transgression. Data used for the sea-level reconstruction are both new data and previously published datasets we have reassessed. New cores, extracted along the Finistère peninsula in the framework of a coastal risk assessment research program, allowed us to collect new stratigraphic data. Dates initially published on basal peat deposits in previous studies (Morzadec-Kerfourn, 1974) were re-assessed through the same process to allow their incorporation in a combined dataset. In the absence of microfossils in most of our deposits, an alternate approach was used to determine the salinity regime of the basal peat deposit environments through the use of stable carbon isotope ratios and the observation of macro-botanical remains: brackish peat deposits were used as sea-level index points, while freshwater ones provided only high-limiting constraints. Eight new radiocarbon datings were obtained. A total of six new sea-level index-points and six new limiting points allowed us to derivate the long-term (millennial) changes in RSL in Western Brittany. A comparison of these data with some foraminifera-based regional RSL data shows that both data sets closely match. Altogether, the combined data show the RSL bending *ca.* 7000 and 3000 cal. BP, indicating progressively decreasing rising rates. Further work is needed to fill the centennial to pluri-centennial gaps that remain to ascertain potential periods of stability or strong decrease in the rising rates of the RSL *ca.* 6200 ± 500 and 3000 ± 500 BP.

Key words: Holocene, RSL, basal peats, Brittany, stable C isotopes.

Résumé

En comparaison des autres façades océaniques européennes ayant déjà fait l'objet de nombreux travaux sur le niveau marin relatif holocène, les côtes atlantiques françaises demeurent quelques peu ignorées. Malgré quelques travaux de modélisation géophysique ayant intégré (entre autres) l'ouest de la Bretagne (Van de Plassche, 1991 ; Lambeck, 1997 ; Leorri et al., 2012), seules deux études, se basant sur des données de terrain, se sont véritablement intéressées au sujet (Morzadec-Kerfourn, 1974 ; Stephan, 2011). Celles-ci s'accordent sur un niveau marin relatif connaissant des oscillations au cours de l'Holocène, la plus importante devant se situer autour de 3000 BP. Cet article présente la première étape d'un travail de remise à jour des données disponibles sur le niveau marin relatif holocène dans l'ouest de la Bretagne. Les tourbes de base sont des dépôts considérés comme incompressibles (car formés soit au-dessus des formations limono-graveleuses pléistocènes ou directement sur le substrat géologique) qui représentent les premières phases de la transgression post-glaciaire. Leur utilisation nous a permis de reconstituer l'évolution à long-terme du niveau marin relatif dans la région. Les données

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mobilisées pour ce travail proviennent à la fois de nouvelles datations et de la recalibration de données précédemment publiées. Les nouvelles dates ont été obtenues à partir de carottages réalisés sur plusieurs sites autour de la pointe finistérienne, dans le cadre de l'ANR COCORISCO (Historique de la tempétoiosité holocène pour l'étude des risques côtiers). En l'absence d'indicateurs micro-faunistiques dans la plupart des dépôts prélevés, les conditions de salinité du milieu de sédimentation originel ont été déterminées par l'utilisation de mesures des isotopes stables du carbone (^{13}C) et par la détermination des macro-restes végétaux. Les tourbes de base, considérées comme s'étant formées en milieu saumâtre, ont été utilisées comme « points-index » du niveau marin tandis que celles relevant d'un milieu d'eau douce ont été utilisées comme points limitants. Huit nouvelles datations radiocarbone ont été obtenues. Un total de six nouveaux points-index et six points limitants a permis de reconstituer les évolutions à long-terme du niveau marin relatif dans l'ouest de la Bretagne. Les résultats ont été comparés avec une reconstitution des variations du niveau marin dans la région effectuée à partir de l'étude des foraminifères. L'ensemble montre une très bonne cohérence et indique que le niveau marin relatif a connu des ralentissements de son rythme de remontée autour de 7000 et 3000 cal. BP. Des travaux supplémentaires demeurent néanmoins nécessaires dans la mesure où des doutes persistent dans les périodes autour de 6200 ± 500 et 3000 ± 500 cal. BP.

Mots clés : Holocène, niveau marin relatif, tourbes de base, Bretagne, isotopes stables du carbone.

Version abrégée en français

Utilisés dans des domaines variés, les études portant sur la reconstitution du niveau marin relatif (NMR) holocène ont connu un regain d'intérêt au cours des dernières années (Leorri et al., 2012), que ce soit pour la prédiction des futurs changements du niveau marin dans une optique de maîtrise des risques côtiers qu'en tant que jalon pour la calibration des modèles géophysiques. Les variations du NMR résultent d'un processus complexe, déterminées par une combinaison de facteurs variables dans le temps et l'espace. Bien qu'en premier lieu déterminée par le niveau marin « eustatique », découlant de la fonte des inlandsis continentaux après le Dernier maximum glaciaire (DMG), l'histoire du niveau marin relatif d'une région est aussi le produit de facteurs plus locaux (Shennan et al., 2012) ayant dicté le comportement vertical de la zone d'étude durant l'Holocène (isostasie et tectonique). Les processus qui déterminent la qualité de l'enregistrement du NMR dans les séquences sédimentaires, tels que la compaction, les modifications éventuelles des régimes tidaux au cours de la période d'étude, les phénomènes d'érosion et/ou de troncature des dépôts, jouent aussi un rôle majeur dans ces reconstitutions. Considérés comme des facteurs clés nécessaires pour comprendre comment les systèmes sédimentaires côtiers ont autrefois réagi face aux changements de NMR, ces derniers ont fait l'objet de nombreux travaux récents (Shennan et Horton, 2002 ; Edwards, 2006 ; Long et al., 2006 ; Massey et al., 2006b ; Behre, 2007 ; Vink et al., 2007 ; Horton et Shennan, 2009 ; Bungenstock et Weerts, 2010 ; Baeteman et al., 2011 ; Brain et al., 2011). Si les côtes du nord-ouest de l'Europe ont fait l'objet de nombreuses études portant sur le NMR holocène, la façade atlantique française souffre quelque peu d'un manque d'attention. Dans le Finistère, seules deux études se sont réellement attardées sur le sujet (Morzadec-Kerfourn, 1974 ; Stephan, 2011). Celles-ci font état d'un NMR oscillant, notamment autour de 3000 BP où une baisse pluri-métrique du NMR est constatée par les auteurs. Cette période a été identifiée à l'échelle du nord-ouest de l'Europe comme une période de détérioration du climat (tempétoiosité accrue, hiatus importants au sein des séquences sédimentaires ; e.g., Lamb, 1977 ; Long et Hughes, 1995 ; Van Geel et al., 1996 ; Moura et al., 2007), posant ainsi la question de l'authenticité de l'épisode régressif observé.

Dans le cadre d'un programme de recherche portant sur les risques côtiers (ANR COCORISCO), un important travail de terrain a été mené au cours des trois dernières années autour de la péninsule finistérienne. Des dizaines de carottes ont été prélevées avec pour objectif principal l'étude des effets de la paléo-tempétoiosité holocène. Par ailleurs, ces données ont pu être utilisées à des fins de reconstitution du NMR, permettant ainsi de densifier de manière significative les données déjà disponibles sur la région. La Bretagne est un domaine géologique n'ayant pas été directement concerné par les glaciations du DMG. Néanmoins, plusieurs études mettent en lumière le fait que cette région a pu être concernée par le dégonflement du rebond isostatique post-glaciaire lié à la fonte des calottes britanniques et scandinaves (Lambeck, 1997 ; Massey et al., 2008 ; Bradley et al., 2011 ; Leorri et al., 2012 ; Shennan et al., 2012). L'importance de la tempétoiosité dans cette région ainsi que les marnages importants complexifient quelque peu la reconstitution des NMR passés. Les carottes ont été collectées en utilisant un carottier à percussion, une tarière à vis (instrumentation BRGM) ou une tarière manuelle. Leurs positions ont été relevées au GPS différentiel et raccordées au système NGF. Les dépôts ont été datés par le radiocarbone (AMS). La moitié des datations a été réalisée sur l'ensemble du sédiment. Pour l'autre moitié, l'échantillonnage s'est attaché à réduire au maximum les possibilités de pollution potentiellement induites par les apports de carbone allochtone, en sélectionnant des fragments végétaux à plus faible potentiel de resédimentation (Gehrels et al., 1996 ; Törnqvist et al., 1998 ; Gehrels, 1999). Les isotopes stables du carbone ont été mesurés en routine lors des mesures du ^{14}C . Toutes les dates sont présentées calibrées avec un intervalle de probabilité de 95 % (2σ).

Une approche reposant sur les tourbes de base a été utilisée au travers de cette étude, afin de reconstituer une enveloppe générale des variations du NMR (de l'ordre du millénaire ; Gehrels, 1999). Comme l'ont prouvé un grand nombre de travaux tant sur les côtes européennes (Jelgersma, 1961 ; Van de Plassche, 1982 ; Törnqvist, 1993 ; Denys et Baeteman, 1995 ; Van de Plassche, 1995 ; Beets et Van Der Spek, 2000 ; Shennan et Horton, 2002 ; Makaske et al., 2003 ; Berendsen et al., 2007) que sur d'autres façades océaniques (e.g., Redfield et Rubin, 1962 ; Pirazzoli et Pluet, 1991 ; Gehrels et Belknap, 1993 ; Gehrels et al., 1996 ; Long et al., 1998 ; Törn-

qvist et al., 2004, 2006), il est maintenant largement accepté que ce type de dépôt représente un témoin particulièrement adapté pour la reconstitution du NMR holocène sur les littoraux de submersion (zones subsidentes). Les tourbes de base ont donc été utilisées comme indicateurs du NMR passé de la manière suivante : lorsque des indices ont permis d'identifier une influence marine à saumâtre dans les dépôts, il a été alors possible de leur appliquer un « indicative meaning », c'est-à-dire une relation altitudinale reliant leur milieu de sédimentation au niveau de la mer au moment du dépôt (Shennan, 1986 ; Van de Plassche, 1986 ; Gehrels et al., 1996). Celui-ci a été fixé entre les plus hautes mers astronomiques et les pleines-mers de morte-eau, avec une erreur (nommée « indicative range » ; Gehrels et al., 1996) fixée à la moitié de ce rapport. Au contraire, lorsqu'aucun indice n'a permis de déceler une quelconque influence marine, il n'a pas été possible de déterminer l'altitude à laquelle s'est formé le dépôt par rapport au niveau marin. Dans ce cas, l'altitude du dépôt a servi à fixer une limite supérieure maximale (« high limiting deposits » ou HL) au niveau marin de l'époque.

Du fait de la très faible présence, voire la totale absence de proxys micro-faunistiques dans les dépôts, la détermination du régime de salinité de l'environnement originel de formation des niveaux datés s'est effectuée via l'utilisation conjointe de plusieurs indicateurs. Ceux-ci ont livré notamment des informations sur les formations végétales établies au moment de la mise en place du dépôt. Les isotopes stables du carbone ($^{13}\text{C}/^{12}\text{C}$) ont été utilisés sous la forme d'un indicateur nommé « $\delta^{13}\text{C}$ ». Celui-ci permet de distinguer entre différentes catégories de plantes suivant le type de photosynthèse (C_3 ou C_4) qu'elles effectuent. Par exemple, les valeurs du $\delta^{13}\text{C}$ dans un environnement de slikke sont bien plus élevées que celles obtenues au sein d'une roselière à phragmites. Si cela permet parfois de distinguer clairement des dépôts saumâtres, le plus souvent, le recouvrement des valeurs du $\delta^{13}\text{C}$ fait que cet indicateur doit être utilisé en association avec d'autres. Quelques fois, l'identification des macrorestes végétaux a pu fournir des informations utiles. Les données de M.-T. Morzadec-Kerfourn (1974) ont été actualisées et utilisées de la même façon que nos propres données. Seules les tourbes identifiées comme basales ont été conservées. La détermination de l'environnement original de dépôt des tourbes de base décrites par cet auteur s'est fait sur la base des informations palynologiques telles que présentées dans le manuscrit original. Des marges d'erreurs ont été ajoutées aux données originales (± 50 cm pour le positionnement vertical du dépôt, recalibration des dates selon le standard utilisé pour nos propres datations).

Six points index et six points limitants ont permis d'obtenir les tendances à long-terme (millénaire) d'évolution du NMR dans le Finistère entre ~ 7500 et 4000 cal. BP. Une remontée globale du NMR de $9,5 \pm 0,5$ m est observée depuis 7500 cal. BP. La vitesse de relèvement semble s'infléchir aux environs de 7000 cal. BP, suivant un rythme d'environ 1,3 mm/a jusqu'à ~ 4500 cal. BP. La période entre 6500 et 5000 cal. BP demeure mal définie, aucune tourbe de base n'ayant été obtenue pour cette période. De la même façon, aucun point n'a pu être obtenu après 4500 cal. BP avec cette méthode. Nos données

montrent une très bonne cohérence avec les données obtenues par P. Stephan (2011) en rade de Brest à partir de l'étude des foraminifères, à l'exception d'un point bas identifié par cet auteur autour de 2800 BP. Ce point fut obtenu à partir d'un dépôt potentiellement issu d'un épisode morphogène ayant pu artificiellement abaisser le niveau de sédimentation (e.g., reprise de sédimentation après un épisode érosif). Nous avons donc considéré que ce point n'était pas représentatif du NMR de l'époque. L'ensemble des données disponibles, toutes marges d'erreur prises en compte, permet de dresser des tendances claires d'évolution du NMR pour les périodes entre 7500-7000 cal. BP et 7000-3000 cal. BP, avec des taux de remontée respectivement autour de 8 mm/a et 1,4 mm/a. Après 3400 cal. BP, les données de P. Stephan (2011) permettent d'évaluer le taux moyen de remontée à $\sim 0,3$ mm/a. Ces valeurs ne doivent être prises qu'à titre indicatif, des doutes demeurant autour de 6000 et 3000 cal. BP. En effet, à l'heure actuelle, il n'est pas possible d'affirmer que le NMR n'a pas connu des périodes de remontée très lente, voire de stabilisation entre les phases de transgression bien marquées. Ces périodes de fléchissement du rythme de remontée du NMR ont probablement eu des effets importants sur le fonctionnement des systèmes lagunaires et des marais d'arrière-cordon à partir desquels nos données ont été obtenues. Ainsi, nous suspectons que des problèmes de datation, liés par exemple à des remaniements, ont pu venir complexifier la reconstitution du NMR à ces périodes avec ce type de données. Les travaux sont en cours afin d'apporter des données supplémentaires qui permettront sans doute d'arriver à une reconstitution fiable du NMR holocène pour l'ouest de la Bretagne.

Introduction

Recent years have seen a revival of interest in the use of relative sea-level (RSL) curves for a wide range of applications (Leorri et al., 2012) from the prediction of future sea-level changes in coastal risk assessment issues to the fine-tuning of geophysical Earth rheology models. The behaviour of coastal systems in reaction to Holocene sea-level rise is a complex process. To derive RSL (taken here as the relative altitude of past sea-level relative to a present reference level) changes from observations is hence a complex challenge. Though primarily determined by eustasy, RSL changes result from the combination of many interdependent processes. As clearly stated by I. Shennan et al. (2012), sea-level changes for a precise geographical location and epoch result from the sum of the following factors: (A) Eustatic sea-level, which varies in time following the melting history of ice-caps ("ice-equivalent" eustasy), changes in the ocean-basin volume ("tectono-eustasy"), and changes in the ocean mass-water distribution. (B) Isostatic processes affecting the vertical behaviour of the lithosphere during the post-glacial period of study, dependent on the geographical position relative to the past extension of ice-caps (glacio-isostasy) and of the loading by the water-charge (hydro-isostasy) during transgression. The sum of (A) and (B) produces the global trend in the RSL rise. Along with those major factors must be added: (C) Tectonic activity expressed

by vertical displacements that could have occurred during the considered period. These latter displacements can explain rapid jumps in the RSL signal and must be looked for in regions known as tectonically active during the Holocene (Fouache, 2006; Morhange *et al.*, 2006; Gandouin *et al.*, 2007). In addition to these factors are superimposed more local effects, which bear direct consequences on the way the sedimentary sequences record the RSL changes: (D) Local effects are likely to control the sedimentary record and, as a consequence, the preservation and the present-day restitution of Holocene RSL. In fact, locally, sedimentary sequences undergo syn- and/or post-deposit processes: major local effects are traditionally considered as being the compaction of the deposits (effect of post-depositional consolidation), lowering the original altitude of a considered unit, and thus the RSL corresponding points), and the changes in tidal regime (leading to an alteration of the sea-level indicative meaning, which is derived from the present day tidal regimes). (E) Finally, I. Shennan *et al.* (2012) consider an additional factor regrouping other unspecified, random and hard-to-quantify factors influencing the RSL reconstruction at a given site. We propose here that erosion truncations of sedimentary sequences must be considered as one of the major components of this additional factor of the RSL equation, considering the importance of its probable impacts on both the indicative meaning of the studied sedimentary sequences and on the compaction processes. Several recent works have attempted to sort out the relative importance and the timing of local parameters (D) and (E), considering them as keys to a better understanding of the response of coastal systems to past sea-level rises (Shennan and Horton, 2002; Edwards, 2006; Long *et al.*, 2006; Massey *et al.*, 2006b; Behre, 2007; Vink *et al.*, 2007; Horton and Shennan, 2009; Bungenstock and Weerts, 2010; Baeteman *et al.*, 2011; Brain *et al.*, 2011).

Northwestern European coasts have been the subject of several works dealing with Holocene RSL variations (*e.g.*, among many others: Fairbridge, 1961; Ters, 1973; Morzadec-Kerfourn, 1974; Ters, 1986; Van de Plassche, 1991; Denys and Baeteman, 1995; Long *et al.*, 1996; Lambeck, 1997; Shennan and Horton, 2002; Massey *et al.*, 2006a; Edwards and Horton, 2007; Massey *et al.*, 2008; Bungenstock and Schäfer, 2009; Stephan, 2011; Leorri *et al.*, 2012). In comparison with British coasts, French Western Atlantic and Channel coasts have been the subjects of fewer studies (Delibrias and Guillier, 1971; Ters, 1973; Morzadec-Kerfourn, 1974; Van de Plassche, 1991; Morzadec-Kerfourn, 1995; Lambeck, 1997; Clavé *et al.*, 2001; Stephan, 2011; Leorri *et al.*, 2012). In the Finistère region, only two authors really focused on this subject (Morzadec-Kerfourn, 1974, 1995; Stephan, 2011). Both authors proposed that plurimetric oscillations in RSL curves could have taken place *ca.* 3000 cal. BP. However, these works were conducted in two areas of relatively limited extension and produced curves based on a limited number of sea-level index points (a total of around fifteen dates for each of the two studies). Such limitations make inter-comparisons between sites difficult and hence can impair the deciphering of local processes in the RSL signal. Finally, the period *ca.* 3000 cal. BP was generally identified

around northwestern European coasts as a period of increased storminess, which has caused strong perturbations and large hiatuses in the sedimentary sequences (Lamb, 1977; Long and Hughes, 1995; Van Geel *et al.*, 1996; Moura *et al.*, 2007). Hence, we consider that obtaining a reliable and high-frequency sea-level curve for Western-Brittany is of prime interest, as it will contribute both to the understanding of the coastal processes, which may be the consequences of the sea-level variations and, at a broader scale, the comprehension of post-glacial isostatic history of North-Western Europe.

Within the framework of a coastal risk assessment research program (ANR COCORISCO, French National Research Agency), an extensive fieldwork has been conducted during the last three years all around the Finistère peninsula (Western part of Brittany, France). Tens of cores and drillings have been carried out in sites of various sedimentary environments and expositions. Whilst the principal objective of this fieldwork was to obtain data that would allow the study of the palaeostorminess during the Holocene, the sampled sedimentary sequences could also be fruitfully interpreted to derive RSL data. This allowed us to densify significantly the Holocene RSL data available for this region and also to reassess and update the results of M.-T. Morzadec-Kerfourn (1974) and P. Stephan (2011). This paper is the first step of an effort in updating Western Brittany RSL data. The first part will briefly outline the geological context of the study area, considering possible internal geodynamic controls on vertical crustal movements that could have occurred during the period of investigation. The methodology we used to reconstruct RSL changes will be described in a second part, with particular attention paid to possible errors that may occur at various stages of the reconstruction process. In order to allow comparisons between previously published interpretations and our own results, derived from an extended new data set, the same methodology has been applied to both to new and previously published data. Finally, the ongoing need for a better deciphering of both local and regional effects for the fine-tuning of the Holocene RSL history is exemplified and the possible behaviour of coastal systems in reaction to the proposed Holocene RSL rise is briefly evaluated.

The study area

This paper presents new stratigraphic data and RSL data collected along the coast of the Finistère peninsula (Western Brittany, France). As stated above, the rationale for the choice of site locations primarily resulted from the objectives of the COCORISCO program, which privileged sites showing very different exposures to major forcing agents (large tidal ranges, storms swells), resulting in diverse sedimentation conditions (in terms of sediment supply, accumulation and preservation). This largely explains why the selected sites are not always the most favourable to derive a long and continuous RSL signal. Nevertheless, we believe that these widespread and diverse site locations and types can be profitable to improve the regional representation of reconstructed RSL. Moreover, such

Fig. 1 – Location maps of the study area. Numbers refer to sites presented in the text. 1: Kerlouan-Guissény; 2: Landeda-Tariec; 3: Porsmilin; 4: Treffiatgat; 5: Kermor-Tudy; 6: Guidel. Letters A to D refer to sites from which sedimentary sequences were re-assessed from M.-T. Morzadec-Kerfourn (1974). A: Plouescat-Porsguen. B: Ploudalmezeau-Treompan. C: Argenton. D: Trézien. Letters H to J refer to sites studied by P. Stephan (2011) in the Bay of Brest. H: Porzguen marsh. I: Troaon marsh. J: Arun marsh.

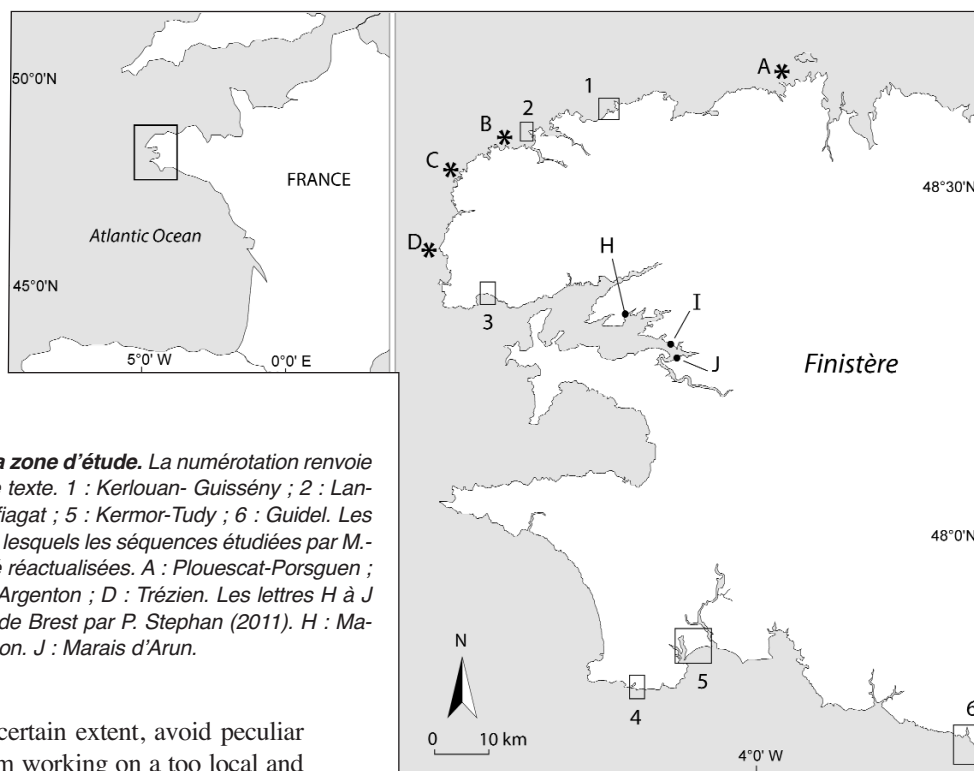


Fig. 1 – Cartes de localisation de la zone d'étude. La numérotation renvoie aux sites tels que présentés dans le texte. 1 : Kerlouan- Guissény ; 2 : Landeda-Tariec ; 3 : Porsmilin ; 4 : Treffiatgat ; 5 : Kermor-Tudy ; 6 : Guidel. Les lettres A à D désignent les sites pour lesquels les séquences étudiées par M.-T. Morzadec-Kerfourn (1974) ont été réactualisées. A : Plouescat-Porsguen ; B : Ploudalmezeau-Treompan ; C : Argenton ; D : Trézien. Les lettres H à J désignent les sites étudiés en rade de Brest par P. Stephan (2011). H : Marais de Porsguen. I : Marais de Troaon. J : Marais d'Arun.

a choice of the sites may, to a certain extent, avoid peculiar RSL biases that could result from working on a too local and geographically restricted dataset. New stratigraphic data were collected on eight sites distributed all along the Finistère peninsula: Kerlouan-Guissény and Landeda in the North Finistère, Porsmilin in the central part of the peninsula, and Treffiatgat, Kermor-Tudy and Guidel in the southern part (fig. 1).

Geological and geodynamic setting

Geological and geodynamic factors, which control the possible vertical movements of any particular crustal area, are of prime importance in RSL reconstitutions and can be considered as the primary producers of RSL histories. They can be divided as follows: (i) Long-term geological evolutions, typically spanning over tens of thousands to millions years, (ii) Holocene glacio- and hydro-isostatic processes (from a few hundreds to a few thousands of years), and (iii) short-term tectonic events (a few days). As geological processes are concerned, the following will be considered as the basis of this study and be used for the comparison of our data with southern-UK works. On a long timescale, Brittany is considered to subside step-wise since the opening of the Bay of Biscay during Early Cretaceous (Evans, 1990), as a passive margin and as a flank of the Western Channel graben. Globally, long-term subsidence has been evaluated between 0.02 mm/a and 0.04 mm/a since the Eocene for the northern coasts and western/southern coasts of Brittany, respectively (Bonnet *et al.*, 2000). The regional subsidence can be considered as negligible at the timescale of the Holocene (~ 40 mm for the last 10,000 years), with respect to the amplitude of the RSL changes we consider.

As underlined in the introduction, estimations of the amplitude of potential isostatic adjustments undergone by Western Brittany, as a consequence of the melting of the North-western Europe and North hemisphere ice caps still lack precision,

awaiting specific numerical studies and geophysical models, well-constrained by local high-quality and dense RSL information. During the Last Glacial Maximum, Brittany occupied a peripheral position with respect to the British Ice Sheet (BIS). The maximum extent of the BIS reached the Scillies (Scourse *et al.*, 1990; Scourse 1991) and had already retracted before 17 ka as evidenced from the dating of loess along the coasts of Wales (Wintle, 1981). Recent studies, conducted in South-Western UK (Massey *et al.*, 2008; Bradley *et al.*, 2011; Shennan *et al.*, 2012), consider that this latter region must have been under the joint influence of both the BIS forebulge and long wavelength isostatic responses related to Fennoscandia ice-sheet. E. Leorri *et al.* (2012) performed modelling work from RSL datasets around the Bay of Biscay and conclude that a north-south increasing RSL gradient exists between Brittany and Portugal. As primarily proposed by K. Lambeck (1997), this would confirm that vertical land-motions induced by the subsidence of a peripheral bulge, associated to the melting of Eurasian Ice-Sheets, have had (and maybe still have) noticeable effects at least as far south as the southern Bay of Biscay. While both (i) the position, size and migration timing of the forebulge apex remain uncertain and (ii) the role of the deep faults bordering the Channel and Western Approaches domains during the Holocene is still questionable, it appears that Brittany could have also been concerned by such glacio-isostatic vertical movements. Nonetheless, modelling work performed by E. Leorri *et al.* (2012) has to be taken with caution as Brittany RSL reconstruction on which are based these modelling are rather old and did not received proper error re-assessment. Furthermore, this study got RSL data from different regions confusedly mixed up from their original locations. In fact, a careful inspection of the datasets reveals that a site named

no.	Location	Latitude	Longitude	Tidal range (in m)	HAT (in m NGF)	MHWST (in m NGF)	MHWNT (in m NGF)	MTL (in m NGF)	MLWST (in m NGF)
A	Plouescat	48°39' N	4°12' W	7.43	5.10	4.26	2.49	0.67	-3.17
1	Guisseny	48°38'14 N	4°23'56 W	7.52	4.74	4.06	2.36	0.62	-3.46
2	Landeda-Tariec	48°36'10 N	4°36'30 W	6.75	4.57	3.78	2.13	0.46	-2.97
B	Ploudal.-Treompan	48°34' N	4°40' W	6.6	4.54	3.69	2.11	0.46	-2.91
C	Argenton	48°31' N	4°45' W	6.47	4.48	3.68	2.08	0.47	-2.79
D	Trezien	48°25' N	4°47' W	6.08	4.32	3.51	1.96	0.48	-2.57
3	Porsmilin	48°21'19 N	4°40'49 W	5.55	3.99	3.17	1.67	0.39	-2.38
4	Treffiatgat	47°47'29 N	4°15'54 W	4.20	3.16	2.66	1.56	0.50	-1.54
5	Kermor-Tudy	47°51'54 N	4°07'37 W	4.20	3.09	2.45	1.35	0.41	-1.75
6	Guidel	47°45'44 N	3°30'10 W	4.15	2.78	2.23	1.18	0.17	-1.92

Tab. 1 – **Present-day tidal ranges on studied sites.** HAT (Highest Astronomical Tide), MHWST (Mean High Water Spring Tides), MHWNT (Mean High Water Neap Tides), MTL (Mean Tide Level), MLWST (Mean Low Water Spring Tides). Letters and Numbers in the first column refer to fig. 1.

Tab. 1 – **Marnages actuels sur les sites d'étude.** HAT (plus hautes mers astronomiques), MHWST (pleines mers de vive-eau moyenne), MHWNT (pleines mers de morte-eau moyenne), MTL (marée moyenne), MLWST (basses mers de vive-eau). Les lettres et numéros figurant dans la première colonne renvoient aux sites tels que présentés dans la fig. 1.

“Saint-Marc” is taken by the authors to be in south-Brittany, while original data from M. Ters (1973) mention “Côtes-du-Nord” which is situated in north-Brittany. Hence, in absence of more precise work regarding this problem, the question of the Holocene vertical behaviour of the Brittany region towards the glacio-isostatic effects remains suspended.

The hydro-isostatic vertical movement induced by the loading of the Atlantic continental shelf and the Channel platform during the Holocene transgression can be considered as of comparable amplitude between South-Western UK and Brittany, considering the similar ages and, therefore, the comparable rigidities of the crust of the two regions. Finally, neotectonics is generally considered to have been inactive in Brittany over the study period.

Morphodynamic setting

Due to the direct opening of the region towards the Atlantic Ocean, the Finistère peninsula is the part of Brittany most exposed to dominant storm winds and swells. These exposure conditions result in (i) a majority of sand-dominated sedimentary environments and (ii) a rather limited number of protected low-energy environments susceptible to have recorded continuously the RSL history. As revealed by the several erosion surfaces observed within our sequences, impacts of storminess during the Holocene have heavily disturbed and discontinued mid- to late-Holocene sedimentary sequences along the Finistère coasts. As this study principally focuses on basal deposits, this will not bear consequences on the results presented in this paper. The possible role played by storminess and sedimentary hiatuses will be discussed when comparing our results to other studies, which use non-basal deposits to derive RSLs.

Tidal setting

Tidal settings are of major importance in RSL studies. In fact, most RSL reconstructions are based on the study of the altitudinal zonation of intertidal indicators (whether biological or sedimentological) with respect to a reference tidal level (such as the Mean High Water Spring Tide, MHWST, or the Mean Sea Level, MSL). Hence, by determining the vertical range in which an indicator could have been emplaced (the “indicative range”), the tidal range of a studied site will partially determinate the accuracy of past RSLs. While micro-tidal regions, such as the Mediterranean Sea, allow well-constrained and precise indicative ranges (pluri-centimetres to decimetre scale), macro-tidal conditions, such as the ones encountered along the coast of Brittany, can introduce larger errors in RSL reconstitutions (pluri-decimetres to metre-scale error terms). Moreover, potential changes in the tidal ranges during the Holocene could have resulted in supplementary errors in past RSL reconstitutions, by over- or under- estimating the indicative meaning. Indeed, as stated by W.R. Gehrels *et al.* (1995), many RSL studies are based on high-tide indicators. Thus, changes in tidal ranges through time may cause the reconstructed RSL curve to differ from the “true” MSL curve (as termed in Gehrels, 1999). The Finistère peninsula is concerned by macro- to meso-tidal conditions, with tidal ranges globally decreasing from north to south (tab. 1). Variability in the tidal ranges between the different study sites will be taken into account in the determination of the indicative ranges error terms (see methodology). Evaluation of possible changes in the tidal ranges and regimes during the study period is beyond the scope of this paper. Possible implications of these changes will be discussed in the quantification of the RSL reconstruction error-terms.

RSL reconstruction from Holocene basal deposits: Methodological background

Sea-level index points

RSL reconstitutions generally rely on the acquisition of Sea-Level Index Points (SLIPs), or Sea-level Indexes (SLIs), which characterise the altitudinal position of a chosen tide level (*e.g.*, the Mean High Water Spring Tide, which will be the reference throughout this work) relative to its modern altitude, considered as the zero reference level. As stated by W.R. Gehrels (1999), the vertical determination of a SLIP at time (t) can be expressed as:

$$\text{SLIP}(t) = H - D - I(t) + T(t) - L + A(t) \quad (1)$$

where H is the height of the coring station from which the indicator sample is taken relative to the modern tidal altitudinal reference, D is the depth of the sample in the core, $I(t)$ is the “indicative meaning”, *i.e.* the relation between the altitude of the original deposition environment of a given sample and the palaeo-tidal reference level (*e.g.*, MHWST) at the time of deposition (Shennan, 1986; Van de Plassche, 1986; Gehrels *et al.*, 1996), $T(t)$ represents the potential changes in tidal amplitude between time (t) and present, L stands for the compaction induced by the coring-process as evaluated in the field and $A(t)$ is the auto-compaction undergone by the sample after deposition. If an “indicative meaning” cannot be properly assessed for a deposit, then a status of “limiting point” is generally attributed to the sample. Limiting points can help to constraint former RSL positions, and are defined as follow: “High-Limiting” (HL) or “Low-Limiting” (LL) whether the deposit is identified to have formed at an unquantified altitude above or below the reference tidal level, respectively. To reach some reliability and precision, RSL reconstructions must rely on a combination of methods, as no single method is considered to be unequivocal. The methods used in this study, or in re-assessed previous works, are detailed below in some details. For a general view on RSL reconstruction methods, readers can refer to I. Shennan (2007), R.J. Edwards (2007), and to the publications of the UNESCO-IGCP projects (*e.g.*, projects no. 61, 274, 588).

Holocene basal peats

Basal peats have been extensively used in Holocene sea-level studies, especially in northwestern Europe (*e.g.*, Jelgersma, 1961; Van de Plassche, 1982; Törnqvist, 1993; Denys and Baeteman, 1995; Van de Plassche, 1995; Beets and Van Der Spek, 2000; Shennan *et al.*, 2000; Shennan and Horton, 2002; Makaske *et al.*, 2003; Berendsen *et al.*, 2007), and also along other oceanic facades (*e.g.*, Redfield and Rubin, 1962; Pirazzoli and Pluett, 1991; Gehrels and Belknap, 1993; Gehrels *et al.*, 1996; Long *et al.*, 1998; Törnqvist *et al.*, 2004, 2006). As underlined by T.E. Törnqvist *et al.* (2004), this approach is particularly suitable for reconstructing RSL history along submerging coastlines and has widely proven its accuracy to provide consistent RSL records. Indeed, the submergence of the Pleistocene glacial plains by the coastal

Ground Water Level (GWL) wedge during post LGM sea-level rise provoked a decrease of the drainage and subsequently the formation of freshwater to brackish marsh environments belts environments, in which peat accumulated (Baeteman *et al.*, 1999; Vink *et al.*, 2007). A landward and upward progression of the peat layers marks the emplacement of the rising water level. Moreover, basal peats directly overlay the geological substrate or, more often, Pleistocene silty-loess of fluvial deposits, traditionally considered as having experienced negligible compaction during the Holocene. The altitude of the basal peats hence can be used as a reliable marker of RSL rise.

Nonetheless, the representativeness of basal peats as RSL indicators has been regularly discussed. Several limitation problems have been identified in their use as sea-level indicators. The unclear relations between the GWL and sea level may cause errors in RSL reconstructions. As identified by O. Van de Plassche (1982, 1995), distortions of the tidal wave in large deltaic plain environments (“flood-basin effect”) or in estuarine settings (Fairbridge, 1961; Vink *et al.*, 2007), can lead to under- or over-estimation of the RSL. The importance of local continental hydrological and drainage conditions can also be invoked. In order to avoid these errors, some authors recommended that only basal peats should be used as an upper RSL limit (Edwards, 2007; Vink *et al.*, 2007). Others (Gehrels *et al.*, 1996; Gehrels, 1999; Törnqvist *et al.*, 2004) advocated that basal peats remain usable as SLIPs if a clear relationship between their original deposit environment and sea level can be established (*i.e.*, from the presence of indicators undoubtedly attesting that peat formed in an environment submitted to brackish to saline conditions). Only in this case, basal peats can be considered to have formed between MSL and HWST and can be used as SLIPs (Van de Plassche, 1982; Törnqvist *et al.*, 2004).

The salinity regime of the original deposit environments can be assessed by several methods. Microfossils, such as diatoms or foraminifera, are considered to be the most reliable method available to achieve such an aim. When present, microfossils attest at least a minimal influence of marine conditions (Gehrels, 1999). The importance of this influence can be deduced by the determination of species assemblages. Unfortunately, foraminifera were absent or very scarce in the samples we studied, probably due to their limited potential of conservation or to unfavourable living conditions (sand dominated deposits). Micro- and macro-faunal indicators can also provide useful information. Plant communities obey a vertical zonation with respect to ecological factors (among which the frequency of inundation is dominant) and thus can be used as indicators to determine the salinity regimes. Pollen assemblages have been widely used in Holocene palaeo-environmental studies, as a proxy for reconstructing past landscapes and anthropogenic activity. It also revealed capacities to decipher between different sedimentary environments, especially in intertidal mud-dominated environments (such as mudflats and salt-marshes), where strong environmental gradients exist. Transitions between marine and freshwater dominated environments can be identified following the succession of dominating plant species.

Stable carbon isotope ratios ($^{13}\text{C}/^{12}\text{C}$) have been less often used to recognise salt-marsh environments within organic sedimentary sequences (Chmura and Aharon, 1995; Gehrels *et al.*, 1996; Törnqvist *et al.*, 2004; Wilson *et al.*, 2005; Lamb *et al.*, 2006, 2007; Kemp *et al.*, 2010). The stable carbon isotope ratio $^{13}\text{C}/^{12}\text{C}$ is noted $\delta^{13}\text{C}$, and expressed in parts per thousand PDB (‰ PDB) relative to the reference ^{13}C value (standard determined from a Cretaceous marine fossil named Pee Dee Belemnite, “PDB”). Mudflat/low-marsh and high-marsh/supratidal specific plant species were found to follow different photosynthetic pathways (termed “C₃” and “C₄”), inducing very different $\delta^{13}\text{C}$ imprints in the surface sediment on which those latter grow. Unfortunately, values in $\delta^{13}\text{C}$ sometimes largely overlap and therefore preclude using $\delta^{13}\text{C}$ directly as a ‘true’ RSL proxy (Wilson *et al.*, 2005). This ratio has nevertheless proved its ability to clearly decipher between low-marsh and high-marsh environments. Thus, the $\delta^{13}\text{C}$ stable carbon isotope ratio can help to provide qualitative data about the depositional environment of radiocarbon-dated samples (Wilson *et al.*, 2005; Lamb *et al.*, 2006, 2007; Kemp *et al.*, 2010), especially if associated with other indicators (foraminifera, diatoms, C/N ratio). T.E. Törnqvist *et al.* (2004) used $\delta^{13}\text{C}$, together with the study of plant remains, to determine the salinity regime of basal peats found in the Mississippi delta, and consequently to determine if these basal peats could be used as reliable markers of past RSL values. The same approach has been followed in this study.

Methods

Corings and drillings

Field data were collected by three techniques: corings (using an Eijkelkamp 60 mm Ø, hand-held and motor-driven percussion corer), screw drillings (using BRGM vehicle, French Research Agency for Geology and Mines) and hand-auguring (3-cm diameter/1-m long Eijkelkamp gouge). Cores positions were surveyed using a Trimble Differential Global Positioning System (DGPS). All locations were tied to geo-referenced IGN (French National Geographic Institute) benchmarks and levelled with respect to the NGF datum (French levelling datum, tied to the present MSL in Marseille, France). Possible deformations of the sequences during the coring stage (*e.g.*, compaction induced by percussion corings) were measured in the field and taken into account in the vertical positioning of the samples. Percussion cores (recovered in 1-m long plastic tubes) were cut in half cylinders and sealed by plastic film. Screw-drillings and auguring samples were kept in sealed plastic bags. All were stored at +4 °C to slow down desiccation and oxidation of the deposits.

Deposits were rapidly described by a litho-microstratigraphic study, in terms of grain size, colour (Munsell color chart), organic content, and characterisation of macrofossils. Particular attention was paid to identify possible reworked levels or erosion surfaces, as these define morphogenic active periods and can give hints on subsequent potential problems in sample dating. Sampling was performed with a 5-cm mean spacing and adapted to the complexity of the sequences. Grain size was measured after destruction of organic material with a solution of hydrogen peroxide in each sample for the <1-mm fraction with the help of a Malvern Mastersizer 2000 laser analyser. The size of the grains coarser than 1 mm was analysed by sieving.

AMS radiocarbon dates were performed at the “*Laboratoire de Mesure du Carbone 14*” (Gif-sur-Yvette) and at the Poznan Radiocarbon Laboratory (Poland). Half of the new dates presented here were dated from bulk deposits (Guisseny cores). Other dated material was sampled with care in order to minimise sources of carbon pollution: *in situ* material was always preferred to potentially reworked material, such as charcoals or drifted wood. When present, plant remains were preferred as their fragility reduces the potential of re-deposition (Gehrels *et al.*, 1996; Törnqvist *et al.*, 1998; Gehrels, 1999). Stable carbon isotope ($\delta^{13}\text{C}$) was routinely measured for all the samples dated at the *Gif-sur-Yvette* laboratory. Calibration was performed with the Calib 6.0 software, using IntCal09 calibration curve (Reimer *et al.*, 2009). All dates in this study are presented in calibrated age BP, with a 2- σ (95%) probability confidence interval (tab. 3 and tab. 4).

Stratigraphy

Sampled basal peats, lying at the basis of the Holocene sedimentary sequences we sampled, were generally found lying on a thin Pleistocene silt layer resting either directly on the weathered basement or, more often, on a mixed silt and gravel formation. This layer could either consist of a periglacial loess formation (Monnier, 1973; Hallégouët and Van Vliet, 1986) or of an inter-bedded lacustrine mud layer formed by the hampered drainage during the RSL rise. Those units generally progressively evolve towards an organic rich silt layer, which is interpreted as the response to the pro-

	This study	Re-assessment of M.-T. Morzadec-Kerfourn (1974)
Percussion coring	Ø	Ø
Screw-drilling	± 20 cm	Ø
Hand-auguring	-2 cm/m depth	Ø
Levelling	±2 cm	±50 cm
Present tidal frames	±5 cm when estimated from distant tidal references	
Indicative ranges	(HAT-MHWNT)/2	(HAT-MHWNT)/2

Tab. 2 – Errors terms used in RSL reconstruction.

Tab. 2 – Marges d’erreurs utilisées dans la reconstitution du niveau marin relatif.

Index no.	Location	Core/ Drilling	Lab code	Dated material	Conv. Age BP	Cal. Age BP	Elevation in m NGF	Elevation Relative to present HWST	$\delta^{13}C$ value in ‰ PDB	TYPE	Indicative meaning	Indicative range	RSL
1	Guisseny	GUIS-S1	UBA-15461	Sediment (sample type) Reed peat (bulk)	4309±38	Min. (Mean) 4968 (4900) Max. 4832	-1.15	-5.21	-28.1	SLIP	-0.52	1.19	-4.69 ±1.31
2	Guisseny	GUIS-C2	UBA-15686	Silty-Peat (bulk)	5563±31	6403 (6351) 6299	-1.52	-5.58	-28.8	SLIP	-0.52	1.19	-5.06±1.26
3	Guisseny	GUIS-S2	UBA-15460	Brackish peat (bulk)	6033±29	6952 (6872) 6792	-3.52	-7.58	-23.4	SLIP	-0.52	1.19	-7.06±1.27
4	Landeda	TAR-S2	UBA-15458	Reed peat (bulk)	6001±28	6914 (6845) 6776	-3.6	-7.38	-26.9	SLIP	-0.43	1.22	-6.95±1.27
5	Porsmilin	PORS-C5	SacA 26811	Peat (plant remains)	6015±50	6990 (6863) 6737	-2.45	-5.62	-21.1	HL	-	-	<-5.62±0.02
6	Trefflagat	TREF-2	Poz-45390	Silty-mud (roots remains)	4340±40	4978 (4909) 4840	-0.95	-3.61	-	HL	-	-	<-3.61±0.07
7	Kernor	K-X	Poz-42854	Black peat (plant remains)	4800±40	5606 (5536) 5466	-2.49	-4.94	-	HL	-	-	<-4.94±0.22
8	Guidel	GLG-1	Poz-47039	Clay (organic content)	6650±40	7572 (7587) 7502	-7.87	-10.1	-	HL	-	-	<-10.1±0.22

Tab. 3 – New radiocarbon dates and Sea-Level Index Points (SLIPs) and limiting dates. “HL” notation states for “High-Limiting”.

Tab. 3 – Nouvelles datations radiocarbones, Sea-Level Index Points (SLIPs) et dates limitantes. HL correspond à « High-limiting ».

gressive flooding of coastal lowlands by the water table, as a primary response to sea-level rise. It generally ends up in a pluri-decamic to 1-m thick brown to black peat bed, often cut at its top by an erosional surface (fig. 2).

Sedimentary palaeoenvironments determination

The determination of the salinity regime in which basal peats formed is of prime importance. This determination states whether a peat level can be used as a SLIP (this is the case if the peat level formed under saline or brackish influences) or must be only considered as a high-limiting point (if the peat formed in freshwater environments, without any saline influences). In the absence of micro-faunal indicators in our basal deposits, the determination of the salinity regime was achieved using both stable carbon isotope ratios and the observation of macro-plants remains. As local $\delta^{13}C$ study is still in progress on present-day salt-marsh environments of our study zone, $\delta^{13}C$ ratios obtained by T.E. Törnqvist *et al.* (2004), G.P. Wilson *et al.* (2005), H.H. Lamb *et al.* (2007), A.C. Kemp *et al.* (2010) and S. Engelhart *et al.* (2013) were used as references for discriminating between mud-flats, low-saltmarshes and high-marshes environments. The results of G.P. Wilson *et al.* (2005) and S. Engelhart *et al.* (2013) proved especially useful, as the environments they describe are quite similar to those we observed. This led us to consider average $\delta^{13}C$ values over -16‰, between -17‰ and -27‰ and under -28‰ as limits for saline, brackish to intermediate and strictly freshwater environments, respectively. Nonetheless, the correlation between $\delta^{13}C$ values and foraminifera assemblages obtained by P. Stephan (2011), led us to slightly reconsider the -28‰ $\delta^{13}C$ value, fixed by these studies as the boundary between brackish and freshwater environments. In fact, $\delta^{13}C$ values as small as -28.8‰ were obtained by P. Stephan (2011) from deposits identified as high saltmarsh by foraminifera analyses (dominated by *Jadammina macrescens* and *Trochamina inflata* species). Nevertheless, taking into account the difficulties to unambiguously discriminate between high-marsh/supratidal environments solely on the basis of $\delta^{13}C$ values alone (a clearer distinction would require C/N measurements as noted by G.P. Wilson *et al.*, 2005 and H.H. Lamb *et al.*, 2007), this indicator will be only used only to confirm brackish conditions and not a RSL proxy. Additional information was retrieved from examination of macro-plant remains if those were easily identifiable. Palynological data were also used when available on the studied deposits.

Palaeo-RSL elevation reconstruction

Accordingly to O. Van de Plassche (1982), when salt-water-influenced basal peats can be clearly identified, they can be

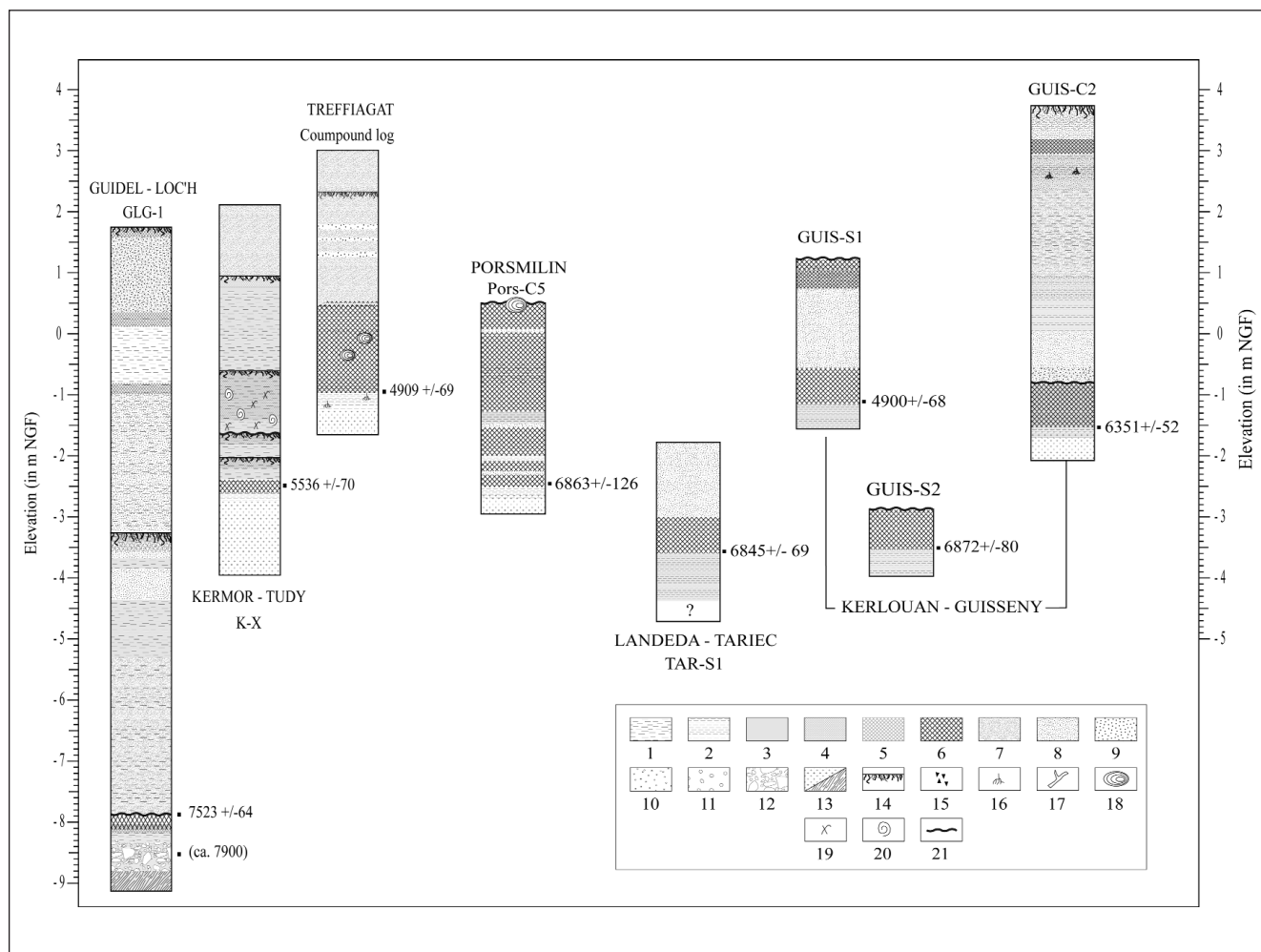


Fig. 2 – Stratigraphic logs of studied cores and drillings. 1: clay; 2: silt; 3: mud; 4: high organic content; 5: humifying level; 6: peat; 7: fine-grained sand; 8: medium-grained sand; 9: coarse-grained sand; 10: gravels; 11: pebbles; 12: fluvial gravels and pebbles; 13: geological substrate/weathered basement (granite/shale); 14: soil; 15: charcoals; 16: roots in living position; 17: wood fragment; 18: wood in living position/tree stem remains; 19: shell fragments; 20: shell in living position; 21: erosion surface.

Fig. 2 – Logs stratigraphiques des carottes et forages étudiés. 1 : argiles ; 2 : limons ; 3 : vase ; 4 : importante fraction organique ; 5 : niveau humifère ; 6 : tourbe ; 7 : sables fins ; 8 : sables moyens ; 9 : sables grossiers ; 10 : graviers ; 11 : galets ; 12 : graviers et galets fluviaux ; 13 : substrat géologique/régolithe (granite/schiste) ; 14 : sol ; 15 : charbons ; 16 : racines en position de vie ; 17 : fragment de bois ; 18 : bois en position de vie/restes de tronc ; 19 : fragments coquilliers ; 20 : coquille en position de vie ; 21 : surface d'érosion.

considered as having formed at an altitude between MSL and MHWST. We consider that this indicative range must be adapted on the basis of the $\delta^{13}\text{C}$ data available for our study zone. Indeed, a MSL deposition environment would have led to a very brackish environment characterised by very halophilous plant species, and hence to heavy $\delta^{13}\text{C}$ values. Stable carbon isotope measurements we obtained show that basal peat would rather have formed around the high-marsh / freshwater supratidal limit. Hence, we chose to change the indicative meaning associated to brackish peats and set it between high astronomical tides (HAT) and mean high-water neap tides (MHWNT). Freshwater deposits are considered as high-limiting deposits and form a very maximum for former MHWST levels. Tidal levels were obtained for each site from the data of the nearest tidal-gauge (or tidal reference) station.

Error terms

The evaluation of the error terms is of particular importance in RSL reconstructions. These error terms must be assessed before any RSL changes can be reliably proposed, and before any comparison between different studies can be attempted (Heyworth and Kidson, 1982; Shennan, 1982, 1986). Possible error sources are the following: (i) inaccurate altitude level of the borehole, (ii) imprecise position of the sampled horizon within the core, (iii) indicative meaning of the sample, (iv) contemporaneous differences of tidal ranges between surveyed site and reference tide-gauge, (v) potential tidal changes over the studied period, (vi) post-depositional compaction, (vii) effects induced by exceptional tides and storm surges, (viii) interferences induced by sedimentary processes (*e.g.*, accumulation rates, peat growth independent from water level,

Tab. 4 – Data re-assessed from M.-T. Morzadec-Kerfourn (1974). “HL” notation states for “High-Limiting”.

Tab. 4 – *Données réévaluées depuis M.-T. Morzadec-Kerfourn (1974)*. La notation HL correspond à « High-limiting ».

hiatuses), and (ix) age errors inherent to the radiocarbon dating process and potentially induced by the presence of allochthonous carbon in the sampled deposit. All these errors terms, considered for both our own and re-assessed dates, are detailed below and listed in table 2.

Both altitudinal and age error terms were quantified in this study. Altitudinal errors consist in the combination of errors associated to the fieldwork (coring, sampling, surveying) and of errors linked to the determination of the indicative meanings and indicative ranges (Shennan, 1986; Van de Plassche, 1986; Gehrels *et al.*, 1996; Brook and Edwards, 2006). Hand-augurings are known to be prone to a potential underestimation of the altitude of sampled layers due to the flexion of the rods. Hence, an error of -2 cm/m depth was applied to samples obtained by hand-augurings (Törnqvist *et al.*, 2004). As it was consistently checked in the field, verticality of the percussion and screw-drillings was not taken into account as a possible source of altitudinal error. An error of ± 20 cm was nonetheless assumed for the “twirl” effect potentially induced by the screw-drilling method. A total altitudinal error of ± 2 cm was applied for the GPS-surveys (Suanez *et al.*, 2008). In order to straddle the whole vertical range in which brackish basal peat may have formed, an error term (indicative range) was added to their altitude. Considering the indicative meaning we chose to apply to brackish-influenced basal deposits, this error was fixed to (HAT-MHWNT)/2 and at each site determined from the contemporaneous local tidal range. When tidal levels were obtained by interpolation between tide-gauges stations, an additional error of ± 5 cm was assumed to account for a possible interpolation inaccuracy. We assume the error associated with potential changes in the tidal ranges during the study period to be negligible over the last 7000 years cal. BP, even if no evidence unambiguously supports such an assumption. Modelling work by K. Uheara *et al.* (2006), though conducted at the scale of northeast Atlantic and thus ignoring a possible influence of changes in local sedimentary environments, predicted that such changes must have been smaller than 0.5 m over the study period. Age errors were directly obtained from the radiocarbon dating and calibration processes (2- σ confidence interval).

New data

As only basal deposits are addressed in this study, only simplified stratigraphic sequences will be presented (fig. 2). Work on producing fully detailed sequences is still underway and will be presented in a forthcoming paper. Study sites are presented from the north to the south of the study area (fig. 1). The coring sites coordinates are listed in table 1 as well as the tidal setting for each site.

no.	Location	Type of deposit	Lab code	Conv. Age BP in years BP	Cal. Age BP min (mean) max	Indicators of salinity regime of deposit environment	Elevation in m NGF	Elevation in m relative to present local HWST level	Indicative meaning in m	Indicative range in m	TYPE	RSL in m relative to present local HWST level
9	Trezien	30 cm thick arenaous peat layer with plant remains and wood-fragment	GIF-714	3660 \pm 115	4299 (3994) 3689	from M.-TH. Morzadec-Kerfourn (1974) Total absence of salt-water influence indicators	1.5 \pm 0.5	-2	-	-	HL	$< 2 \pm 0.55$
10	Argenton-Gwentrez	20 cm peat layer on grey silt	GIF-816	3970 \pm 35	4525 (4453) 4382	Domination of Chenopodiaceae and gramineae in the pollen assemblage. Presence of cruciferous (Cakile maritima) plant species. Dyncocysts and hystrichospherids are present.	-0.5 \pm 0.5	-4.01	-0.4	1.2	SLIP	-3.61 \pm 1.75
11	Plouescat-Porsguen	10 cm thick peat layer on loess deposit	GIF-711	4120 \pm 140	4976 (4605) 4234	Absence of Halophilous pollen species within the peat layer	2.4 \pm 0.5	-1.86	-	-	HL	$< -1.86 \pm 0.55$
12	Ploudal-Treompan	5 cm thick peat layer on gery silt deposit	GIF-766	5770 \pm 150	6933 (6610) 6288	Halophilous plant species (Chenopodiaceae, plantago maritima, armeria). Presence of hystrichospherids.	-4.4 \pm 0.5	-8.1	-0.37	1.22	SLIP	-7.73 \pm 1.77

Kerlouan – Guissény (1. North-Finistère)

The bay of Tressény is the northernmost site studied in this work. It is a N 315°-oriented narrow bay, terminated at its southernmost part by a relatively sheltered salt-marsh cove, forming the mouth of the small “Quillimadec” River. The study of Kerlouan-Tressény site was conducted within the framework – and funded by – the Molène Archipelago archaeological research program of the Brittany Region Archaeology Service (Pailler *et al.*, 2011). The present local tidal levels (table 1) were estimated from the two nearest tidal-references stations (Aber-Wrac’h and Brignogan, ~10 km west and east of the site, HAT=4.74 m NGF, MHWST=4.06 m NGF, MHWNT=2.36 m NGF).

Core Guis-C2

The base of the sedimentary record consists in 0.4 m of Pleistocene gravel rich clay of probable fluvial origin, progressively topped with ~0.6 m of a highly-organic stratified peaty-mud, containing very scarce foraminifera and reed fragments. This basal-deposit then evolves into a 0.15 m layer of black-peat ending in an abrupt erosive contact (-0.8 m NGF). Above this contact rests a 0.6 m thick sand layer, turning progressively finer from coarse to medium sand. Above, sedimentation alternates between more or less organic silty deposits. Some sand-enriched levels are observed that could be interpreted as either storm deposits for the shell-rich ones or as emplaced by the shifting of river channels. Above 2.95 m NGF, the sequence becomes highly organic again to the top of the core, the topmost part being composed of the contemporaneous salt-marsh soil (at 3.75 m NGF). The very base of the basal peat-mud layer (-1.52 m NGF) was dated 6351 ± 52 cal. BP. Used alone, the -28.8‰ ¹³C value does not allow to clearly discriminate between brackish or freshwater supratidal environment but the presence of reeds leaves remains and foraminifera attests for brackish influences. Former MHWST on the site ca. 6351±52 cal. BP can hence be positioned at -5.06±1.26 m below contemporaneous MHWST level (Index no. 2).

Cores Guis-S1 and S2

Two hand-augurings were made at the bottom of the Vougot beach situated at the mouth of Tressény cove. The first core (Guis-S1) recovered 0.6 m of a brown reed peat resting on the Pleistocene loess layer. Overlying this peat deposit is ~1.6 m of white sand, progressively gaining in organic content towards its top, till it becomes a true sandy-peat layer at ~1.05 m NGF. The topmost 10 cm of the core correspond to the dark-massive brown peat layer today outcropping at the bottom of the beach. Base of the base peat layer (-1.15 m NGF) was dated to 4900±68 cal. B.P (UBA 15461). Reed fragments reveal a brackish deposit environment, confirmed by the ¹³C value yielding -28‰. This deposit was considered to have formed between HAT and MHWNT and permitted to reconstruct a RSL position of -4.69±1.31 m below contemporaneous ones for the 4900±68 cal. BP period (Index no. 1). The

second core (Guis-S2) permitted to retrieve 0.65 m of brown peat before reaching the underlying loess formation. Base of the peat was dated to 6872±80 cal. BP (UBA 15460) at -3.52 m NGF. Its brackish character is attested by a heavy ^δ¹³C value of -23.4‰. Hence, the palaeo-RSL at 6872±80 cal. BP can be positioned at -7.06±1.27 m under the present MHWST level (Index no. 3).

Landéda – Tariec (2. North-West Finistère)

An auguring was drilled on the foreshore of the Sainte Marguerite dunes, a N 315°-exposed site, located between the mouths of two large rivers (Aber-Benoît and Aber-Wrac’h). Local present tidal levels (table 1) were directly obtained from the Aber-Benoît tidal-reference situated ~3 km from the site (HAT=6.75 m NGF, MHWST=4.57 m NGF, MHWNT=2.13 m NGF). An approximately 0.6-m thick peat deposit was reached at -3 m NGF, under ~1 m of sand. This basal peat lies over a Pleistocene loessy silt level of unknown thickness. It consists of a highly fibrous peat, principally composed of embedded reed-leaves fragments, suggesting a brackish swamp sedimentation environment. Base of the peat layer yielded an age of 6845±69 cal. BP at -3.6 m NGF. This date is thus contemporaneous with that of the peat layer of the Curnic beach. As already revealed by the reeds remains embedded in the peat, the brackish conditions and a probable high-marsh environment of deposition are confirmed by a ^δ¹³C value of -26.9‰. Palaeo-RSL position on the site ~6845 cal. BP was -6.95±1.27 m under present MHWST (Index no. 4).

Porsmilin (3. Western end of the Finistère peninsula)

Porsmilin is a cove situated in the Bertheaume Bay. The site comprises a small sandy beach limited landward by a small dune barrier which somewhat isolates a presently filled marsh. On the foreshore of the beach a large step of peat crops out, covered with fallen tree stems. The exceptionally good state of conservation of the deposit in such a situation (S to SW-oriented beach, highly exposed to storm swells), was an incentive to retain Porsmilin as a study site in the framework of the COCORISCO project. Five piston-cores were carried out from the foreshore to the bottom of the back-barrier but only the lowermost core (Pors-C5) reached Holocene basal deposits. Local present tidal levels (table 1) were determined according to the Trez-Hir tidal reference situated at ~2 km west of the site (HAT=3.99 m NGF, MHWST=3.17 m NGF, MHWNT=1.67 m NGF). Core PorsC5 was made from a peat-step surface cropping out at the bottom of the beach. The weathered basement was reached at an approximate depth of 3.25 m below the surface. On top lies 25 cm of Pleistocene sandy silt, which becomes progressively organic in its upper part before turning in a 0.15 m thick black peat deposit at around -3.5 m NGF. A complex high frequency layering of organic-mud and peat patterns makes up the rest of the sequence. The base of the basal peat deposit was dated on organic content to 6863±127

cal. BP at -2.45 m NGF. The high $\delta^{13}\text{C}$ value (-21‰) seems to clearly attest for a brackish-influenced intertidal environment (e.g., lagoonal marsh). *Poacea* and *Cyperacea* pollen spores were found to dominate the plant palynological assemblages (A. Fernane, pers. comm.). Whilst species were not differentiated, this could correspond to brackish adapted plant species such as *Spartina alterniflora*, *Phragmites australis* and *Juncus roemarianus*, respectively. If it appears that this deposit may have formed in brackish conditions, we consider that we lack sufficiently reliable indicators to use it as a SLIP. It was therefore taken as a high-limiting deposit, constraining the former MHWST level to lay at a maximum of 5.62 m below present one around 6863±127 cal. BP.

Treffiatgat (4. South Finistère)

Treffiatgat is a flat south-oriented site situated in the south of our study zone. A large dune-barrier isolates a back-barrier swamp today still awash with water. On the foreshore just in front of the dune an important peat body is cropping out, eroded seaward by a micro-cliff. Two piston-cores were taken near the swamp in the back-barrier zone, respectively at 2.2 m NGF and 1.75 m NGF. Local present tidal levels (table 1) were determined according to the tidal reference of Le Guilvinec harbour, situated directly to the west of the site (HAT = 4.20 m NGF, MHWST = 3.16 m NGF, MHWNT = 1.56 m NGF). The observed sequence begins at -1.25 m NGF with ~0.3 m of a probably Pleistocene silty-mud complex overlaying the weathered basement. This deposit contains many traces of oxidation and undated roots remains, attesting of its surface exposure. Above, lies a 30-cm thick organic silty-peat layer, progressively turning into a wooden black peat above ca. -0.7 m NGF. This peat layer is capped by ~1.80 m of sand-barrier medium to coarse sand. A date was obtained on organic contents at the transition between the Pleistocene silty-mud and the silty-peat (-0.95 m NGF), giving an age of 4909±69 cal. BP. No arguments exist to date in favour of a brackish or freshwater deposit environment. This deposit was hence considered as high-limiting, and led to assess that former mean MHWST level was at least -3.61 m below contemporaneous MHWST ca. 4900 cal. BP (Index no. 6).

Kermor – Tudy (5. South Finistère)

The site of Kermor/Tudy is situated in the Bénodet cove. The site is composed of a large dune barrier oriented N 135° that isolates a back-barrier lagoon nowadays polderized. Several drillings were taken in the polder in the back-barrier zone. Only one drilling taken at the eastern end of the site, near to the barrier root, permitted to reach basal peat deposits. Local contemporaneous tidal levels (table 1) were determined accordingly to the tidal reference for the harbour of Loctudy situated directly northwest of the site (HAT=3.09 m NGF, MHWST=2.45 m NGF, MHWNT=1.35 m NGF). Core K-X reached the weathered geological substrate at a depth of 4 m, the top of the core being situated at 1.3 m NGF. The base of the sequence is composed by a 0.1-m thick sandy silt layer, progressively evolving into a black peat until ca. -2.6 m NGF.

Superimposed on this peat level is 0.8 m of very organic stratified silt horizons. On top of a sharp sedimentary hiatus appears a *Hydrobia ulvae*-dominated marine mud layer. This layer becomes more and more organic to the top (grey to brown mud, with less shell fragments, implying a probable salt-marsh facies) until ca. -1 m NGF. The uppermost part of the core is composed of 1.3 m of brown to green clay, on which rests a dune sand level. The basal peat was dated on organic content to 5536±70 cal. BP. at -2.49±0.22 m NGF, ~10 cm above the contact between the sandy silt and the peat. No clear argument could help us to determine the original deposit environment. Hence, this sample was considered as a high-limiting point. It constrains the former MHWST level to a lay at a maximum of -4.94±0.22 m under present one (Index no. 7). Due to the elevation uncertainties induced by the sampling method, it cannot be fully attested that this deposit is a “pure” compaction-free basal peat. It must so be kept in mind that it could have undergone an unknown compaction-induced lowering.

Guidel (6. South Finistère)

Guidel-Loc'h is the southernmost site of this study. It consists in a south 225°-oriented ria, polderized since the 19th c. Two screw drillings were completed along a SW/NE transect across the Guidel-Loc'h pond: GLG-1 was drilled in the middle of the pond, while GLG-2 was drilled about 500 m seaward. Only GLG-1 reached a basal peat deposit. Local contemporaneous tidal levels were determined according to the tidal reference of Le Pouldu situated at ~2 km north of the site (HAT=2.78 m NGF, MHWST=2.23 m NGF, MHWNT=1.18 m NGF). GLG-1 is an 11-m deep drilling, reaching the micaschist, weathered basement at -8.3 m NGF. The base of the sequence consists of ca. 0.2 meter of lacustrine clay encroaching the weathered, micaschist basement. It may represent a lacustrine environment that was emplaced as a result of the hampered drainage in the RSL rise context or a Pleistocene floodplain deposit. The centre of this layer was dated to ca. 7900 cal. BP in GLG-2 drilling, but we also consider probable that this datation could have been rejuvenated by roots penetration. The clay evolves upwards into a 20 cm silty peat layer, overlaid in unconformity by 2.5 m of silty sand. The sequence continues with a succession of 7 m of a sand and muddy-silty layers interrupted by several organic-rich salt-marsh soils. The roof of the sequence is composed of 1 m of sandy marine deposits. The basal-peat and the underlying silt deposit was dated to 7523±64 cal. BP on organic fragments embedded in the peat matrix at -7.87±0.22 m NGF. In the absence of microbiological or geochemical indicators, this layer could only be considered as a high-limiting deposit. It led to assess a former maximum MHWST level of -10.1±0.22 m below the present one (Index no. 8). As it cannot be ruled out that the underlying clay deposit is totally compaction-free and because the peat layer was not sampled at its very base, a potential shortcoming exists in the representativeness of this deposit as a basal-deposit. Thus, again, it cannot be considered as a fully reliable upper-constraint of the RSL and must be only considered as indicative.

Previous studies re-assessment

In order to allow comparisons between our results and previously published ones, former RSL results had to be re-assessed. Such a re-assessment requested older data to be re-processed through the same method we used.

Original methodology

M.-T. Morzadec-Kerfourn (1974) constructed a Holocene RSL curve for northwestern Brittany based on 15 radiocarbon dates. Results were presented in an age/altitude diagram. Though the question of the importance of altitude and age error terms was originally addressed in the text, these error terms were taken into account neither in the data analysis nor in the curve construction. An estimation of possible errors must therefore be re-addressed. The deposits were observed and sampled either on outcrops or by the use of a hand-drilling instrument. Altitudes were presented in m NGF, even if no details were given on the levelling method used. The deposit environments of the layers were originally determined by M.T. Morzadec-Kerfourn using palynological assemblages and absence/presence of dinocysts. The deposits were hence described as either fresh or brackish and related to a relative a sea-level position. Past RSL positions were determined and

linked to actual HWST level on the study sites. Error terms on the indicative ranges of brackish peat deposits are lacking. In addition, archaeological megaliths were used in order to refine past HWST maxima. Radiocarbon datings were performed on wood fragments and bulk deposits and presented as conventional carbon ages.

Re-assessments

In the absence of information concerning the levelling methods used by M.-T. Morzadec-Kerfourn (1974) and the potential uncertainty of those used in the 1970s, a conservative ± 0.5 m vertical error term was tied to the elevation of sampled deposits. Indicative meanings of M.-T. Morzadec-Kerfourn were re-assessed following the approach used in the present study. As error terms on the indicative ranges of brackish peat deposits were found lacking in the original paper, those were fixed, as above, as equal to $(HAT-HWNT)/2$, as can be measured on present-day tidal ranges on the sites. Above cited error terms are listed in table 2. All dates were recalibrated with respect to modern standards. After re-calibration, the dates close to the boundaries of the study period show a spectacular mean shift of 300 years, even reaching 840 years for GIF-766 (index-point number 12, 6610 ± 323 cal. BP). All the dates retained from the work of M.-T.

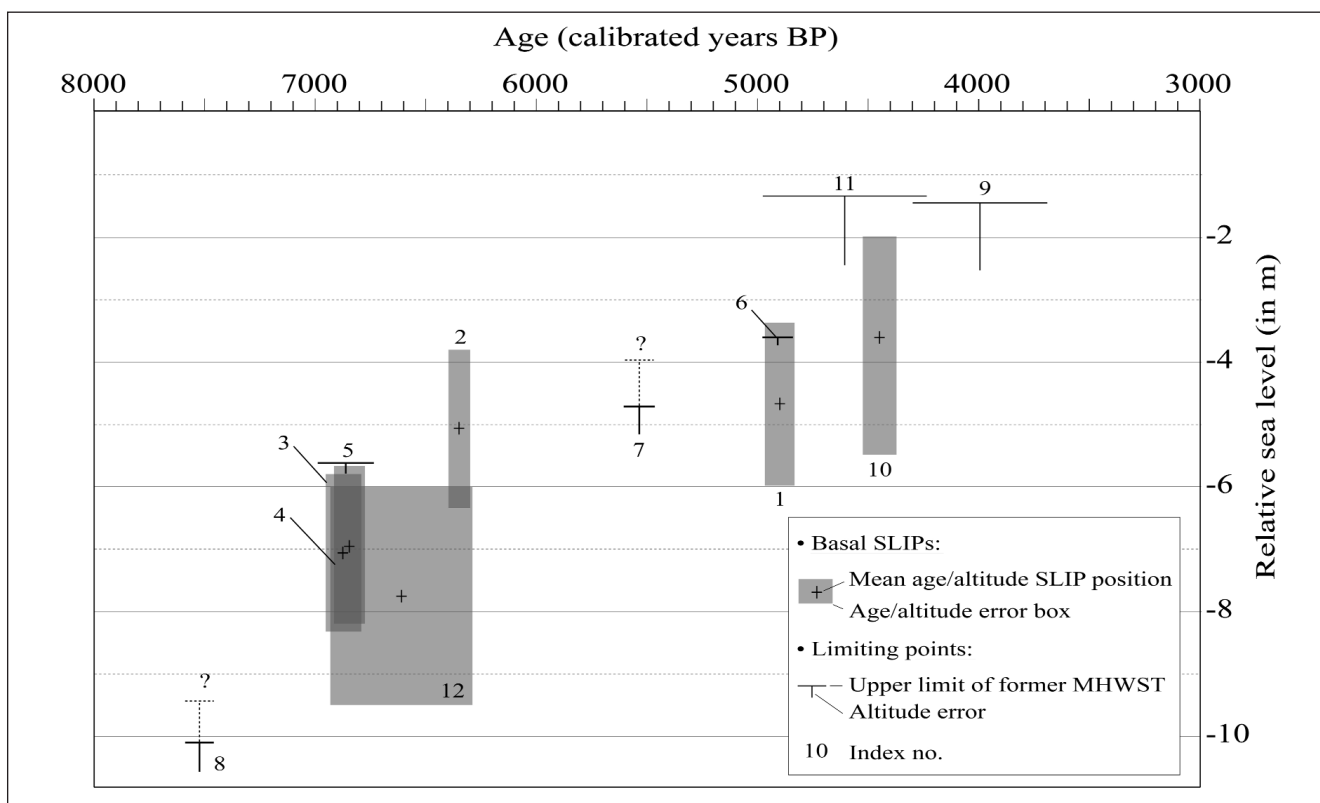


Fig. 3 – Former Holocene RSL positions derived from basal peat deposits dated ca. 7600-4000 cal. BP in the Finistère region. A detailed legend is included in the figure. Numbers correspond to table 3 and table 4. Dotted lines indicates points for which potential compaction cannot be ruled out.

Fig. 3 – Positions passées du niveau marin relatif holocène dans le Finistère obtenues à partir des tourbes de base pour la période entre environ 7600 et 4000 cal. BP. Légende incluse dans la figure. La numérotation correspond au tableau 3 et au tableau 4. Les pointillées indiquent les points pour lesquels une potentielle compaction ne peut être exclue.

Morzadec-Kerfourn (1974) are presented in table 4, accompanied by their original summarised stratigraphic, palynological and micro-faunal data.

Results and discussion

Basal peat based long-term RSL reconstruction

Four new basal SLIPs, together with two others re-assessed from previously published work (Morzadec-Kerfourn, 1974) and six limiting dates are used to reconstruct long-term (millennial) trends of western Brittany RSL history from ca. 7600 and ca. 4000 cal. BP. Total RSL rise reaches ca. 10±0.2 m since ca. 7500 cal. BP (fig. 3). The RSL rise seems to slow down ca. 7000 cal. BP, to an average value of ca. 0.92 mm/a until ca. 4500 cal. BP. A gap in the data exists between ca. 6300 and 5000 cal. BP, period from which only one basal peat could be retrieved within the sequences we worked on: Limiting date no. 7 constrains the rising tendency and indicates a RSL being -4.7 m below present-day HWST around 5500 cal. BP but it cannot be fully attested that this point has not undergone some lowering due to compaction. No SLIPs were obtained from basal-peat data after ca. 4500 BP (fig. 3).

Comparison with RSL data based on the study of foraminifera

P. Stephan (2011) published a Holocene RSL curve for the Bay of Brest, based on 15 SLIPs retrieved from three cores obtained in saltmarshes. Indicative meanings were originally determined by a transfer function, constructed from two present-day salt-mashes of the Bay of Brest. Log and reconstructed palaeo RSL are presented in fig. 4. Dates were recalibrated with respect to our standard to allow comparisons. As underlined by P. Stephan (2011), all dates he used were obtained on bulk deposits and hence may have suffered dating problems.

Stephan's SLIPs plot in relatively good accordance with our basal SLIPs (fig. 5). Vertical discrepancy between our data and P. Stephan's one can be explained by the fact that 13 of the 15 dates published by this author were obtained from intercalated deposits particularly prone to compaction, while it could not have been the case for the basal peats we worked on. On the meantime, two of the 15 SLIPs published by P. Stephan (2011) are also basal deposits and it can be observed that these also plot quite low regarding our data. The ca. 2800 BP point was obtained from the base of a basal mud deposit full of fragmented shells. We believe that this point may have been reworked and deposited in a highly-

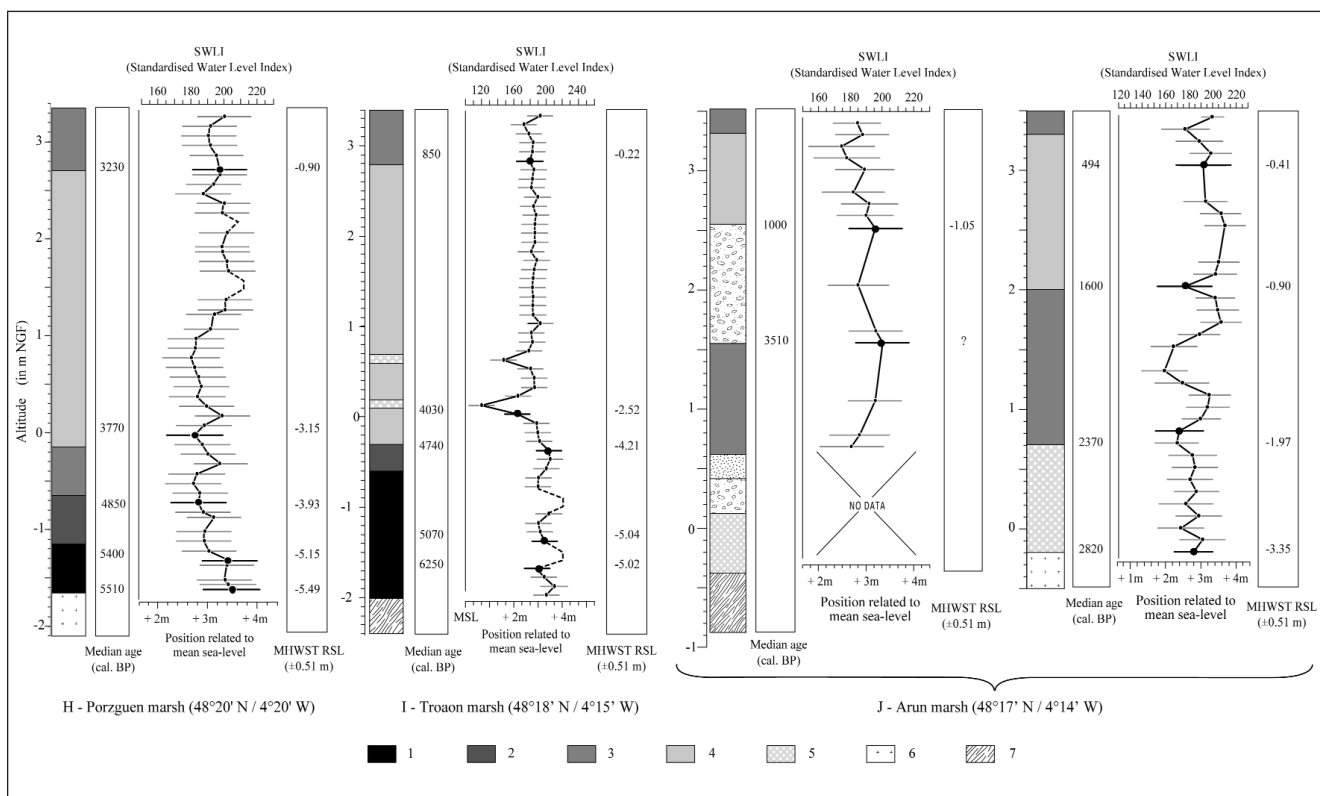


Fig. 4 – Sedimentary sequences studied in the Bay of Brest by P. Stephan (2011) and associated RSL positions. Modified from P. Stephan (2011). Data as originally published. 1: peat; 2: silty-peat 3: organic mud; 4: marine mud; 5: shelly mud; 6: bed-rock (granite); 7: bed-rock (shale)

Fig. 4 – Séquences sédimentaires étudiées par P. Stephan (2011) en Rade de Brest et positions associées du niveau marin relatifs. Modifié de P. Stephan (2011). Données telles qu'originellement publiées. 1: tourbe ; 2: tourbe argileuse ; 3: vase organique ; 4: vase marine ; 5: vase coquillière ; 6: substrat granitique ; 7: substrat schisteux.

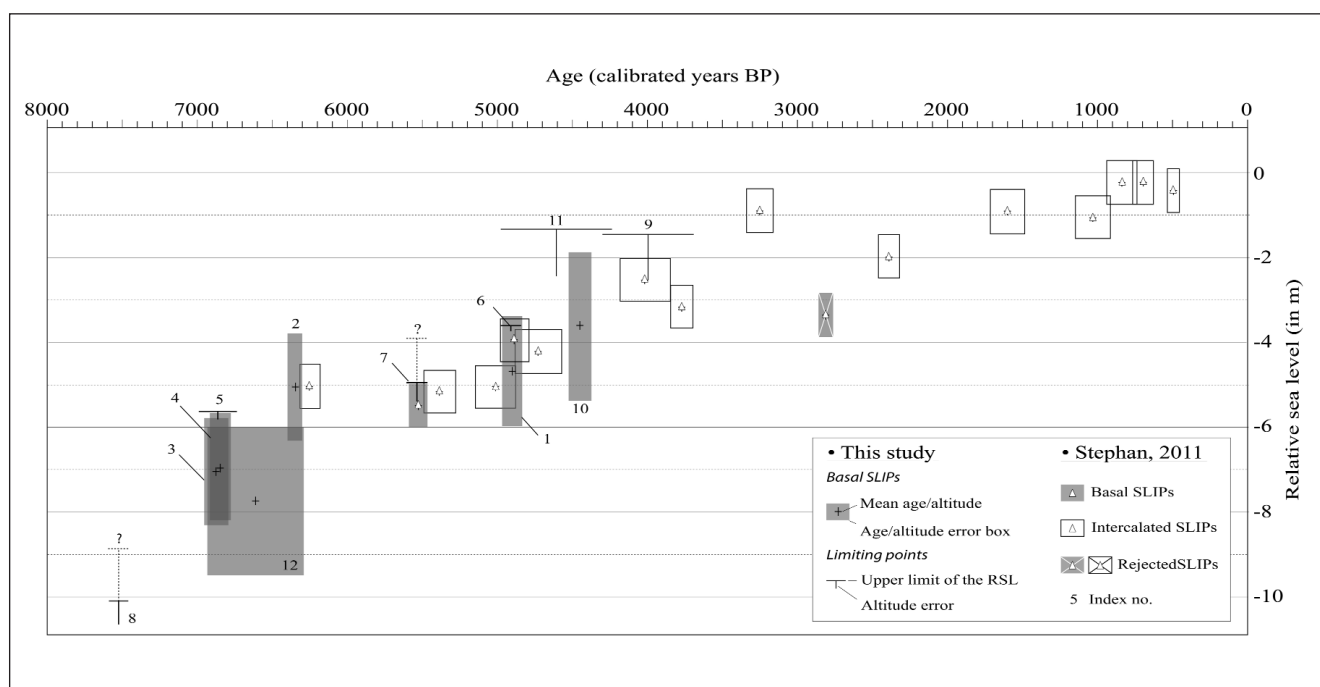


Fig. 5 – Comparison of long-term RSL reconstruction based on basal peats (this study) and data obtained by P. Stephan (2011) from foraminifera analyses. Numbers correspond to table 3 and table 4. Dotted lines indicated that some potential compaction cannot be ruled out.

Fig. 5 – Comparaison entre les données de niveau marin relatif obtenues dans cette étude à partir des tourbes de base et celles obtenues par P. Stephan (2011) à partir de l'étude des foraminifères. La numérotation correspond au tableau 3 et au tableau 4. Les pointillées indiquent les points pour lesquels une potentielle compaction ne peut être exclue.

morphogenic period, probably after an erosional event that artificially created an accommodation space and induced a lowering of the subsequent sedimentary infill. If this is the case, it casts doubts on its usefulness for RSL reconstruction purpose. We therefore considered this point as unreliable and chose to reject it for RSL reconstruction purpose. Indeed, *ca.* 3000 BP period is widely recognised in northwestern Europe (Lamb, 1977; Long and Hughes, 1995; Moura *et al.*, 2007) as a period of highly increased storminess during which large perturbations on the sedimentary sequences may have occurred. The 5500 cal. BP point is more doubtful. As noted by P. Stephan (2011), the foraminifera assemblage obtained for this point had no modern analogues and thus reliability of the RSL position produce by the foraminifera transfer function may have been biased. Moreover, it was dated on bulk peat material, it cannot be ruled out this date was not rejuvenated by roots penetration.

Large uncertainties remain on RSL changes during the *ca.* 6300-5000 cal. BP period. Indeed, considering the doubtful basal SLIP presented above, RSL evolution during the former period is only constrained by three SLIPs and one limiting date, which contribute to give to the RSL envelope a somewhat stabilising to character that cannot be at all ascertained, due to the lowering effect compaction surely had on these points. Further work is clearly needed in order to precise the RSL behaviour within this time-period.

In spite of the above mentioned uncertainties and when the maximal extents of the SLIPs error boxes and limiting

dates are taken into account, simplified RSL sub-trends can reliably be drawn between *ca.* 7500 and 7000 cal. BP and between *ca.* 7000 and 3000 cal. BP, corresponding to mean RSL rise rates of *ca.* 8 mm/a and 1.4 mm/a, respectively (fig. 5). After *ca.* 3400 cal. BP, P. Stephan data give an average rising rate of *ca.* 0.31 mm/a. We stress the fact that these average “sub-rates” must only be considered as indicative values, as they do not take quantitatively into account the errors tied to both the basal SLIPs and the high-limiting points and because of the uncertainties around the periods of RSL rise rates changes. RSL data still lack definition *ca.* 6000 cal. BP and *ca.* 3000 cal. BP to undoubtedly state on the RSL behaviour around these periods. Indeed, it cannot be ruled out that “stair-steps” of either stabilising or very-slowly rising RSL did not take place in between the more clearly defined transgressive periods. We speculate that barrier (and hence back-barrier) environments may have been particularly impacted during those decreasing RSL rising rates periods, surely bearing consequences on the RSL signal recorded as it was noted by A.C. Massey *et al.* (2008). Particularly, we speculate that compaction processes surely had major impacts on back-barriers lagoonal deposits during barriers landward shifts.

Conclusions

New data were obtained on Holocene RSL for the western Brittany region and allowed RSL history to be recon-

structured on a longer period than was previously possible in the region. These new data are in good agreement with the data published in previous studies, after the latter have been re-assessed. Our work gives a new and more precise overall vision on RSL changes in western-Brittany during the Holocene.

Basal peat deposits obtained from several sites around the Finistère peninsula show long-term millennial trends of RSL during the study period. RSL was situated around -10 m under present-day level *ca.* 7500 cal. BP, between -7 and -5 m *ca.* 7000 cal. BP, and around -1 m *ca.* 3200 cal. BP. The study of basal peat only allowed a long-term RSL reconstruction, but this reconstruction nevertheless reliably shows that the rate of the sea-level underwent a dramatic decrease *ca.* 7000 cal. BP and a further, if more minor, surely somewhere between 4000 and 3000 cal. BP. The comparison with foraminifera-based RSL data obtained in the region shows the good accordance between the datasets. Elevation discrepancies between both datasets can surely be partly attributed to compaction having lowered the elevation of non-basal Holocene deposits. Hence, it allows to gain in point density and to reach a better resolution for RSL reconstruction, as foraminifera-based RSL data available for the region obviously lacked basal compaction free-deposits while our data take advantage of the better-constrained elevation of the foraminifera-based SLIPs. It tends to confirm that RSL rise occurred at progressively decreasing rates before *ca.* 7000 cal. BP, between *ca.* 7000 and *ca.* 3000 cal. BP, and after *ca.* 4000-3000 BP. Doubts remain on the turning points of RSL rise changes because of pluri-centennial gaps existing between the dates around these periods. Dating-related problems are also suspected for some of the index-points defining those changes. It can be suspected that periods of diminishing rate in RSL rise each time provoked deep modifications in the functioning of the back-barrier sedimentary systems from where most of the data were retrieved.

Further work is in progress to incorporate additional data obtained in several sites along the Brittany. When completed, this work will allow to better constrain the RSL history of western Brittany and will be of great importance to better understand the morphosedimentary dynamics that took place during the Holocene in reaction to the different changes in the RSL rise rates.

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