INVESTIGATE THE SHORE, SOUND OUT THE PAST:

METHODS AND PRACTICES OF MARITIME PREHISTORY

EXPLORER LA CÔTE, SONDER LE PASSÉ :

MÉTHODES ET PRATIQUES DE LA PRÉHISTOIRE MARITIME

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INVESTIGATE THE SHORE, SOUND OUT THE PAST: METHODS AND PRACTICES OF MARITIME PREHISTORY

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ACTES DE LA SÉANCE DE LA SOCIÉTÉ PRÉHISTORIQUE FRANÇAISE

BREST

2 ET 3 DÉCEMBRE 2020

Textes publiés sous la direction
de Grégor Marchand (†), Yvan Pailler et Pierre Stéphan

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Grégor Marchand (†) (1968-2023)

Nous apprenons le décès de Grégor alors que ce supplément de la SPF est en plein bouclage… Avec son départ, nous perdons un grand frère en archéologie, un collègue, un ami. Depuis les stages de prospection autour du Mésolithique menés en Finistère sous la houlette de Pierre Gouletquer dans les années 1990 jusqu'aux projets récents sur la Préhistoire atlantique que Grégor portait, la route a été longue et nombreux furent les projets, les publications, les terrains qui nous ont réunis. Grégor n'était jamais rassasié, toujours curieux, foisonnant d'idées, avec plusieurs publications sur le feu ou une fouille à mener, qu'elle se situe sur ses terres, dans sa « Cornouaille riante », comme il la nommait, en Oman ou à l'autre bout de l'Atlantique, au Labrador, à Terre-Neuve et dans l'archipel de Saint-Pierre-et-Miquelon qu'il affectionnait tant. Au-delà du chercheur brillant et de renommée internationale, spécialiste des chasseurs-pêcheurs-collecteurs, il y avait surtout l'homme, un personnage haut en couleur, parfois déjanté et sans filtre, qui aimait les bons mots et qui maniait la langue française avec maestria, quelque part entre la verve d'un San Antonio et la plume d'un Victor Hugo. Malgré notre grande tristesse, on ne peut s'empêcher d'esquisser un sourire en repensant à son humour décapant, tandis que son rire tonitruant résonne encore dans nos oreilles. Grégor forçait l'admiration par son enthousiasme à toute épreuve et l'esprit combatif dont il a fait preuve dans sa lutte acharnée pour repousser la venue de l'Ankou. RIP, camarade !

Yvan Pailler et Pierre Stéphan

Île d'Hoedic, juin 2021 © Martin Moucheron

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Introduction

Grégor Marchand (†), Pierre Stéphan, Yvan Pailler

ABOUT PREHISTORY ON THE COAST

When it carefully dips its toe into the sea, prehistoric archaeology is at risk of losing its bearings somewhat, and skill is needed to navigate the evidence available to us. There are several reasons for this. Firstly, human occupation at the interface between the maritime and continental domains is a complex topic of research, due to changes in the shoreline over time relating to sea level change, coastal erosion or sedimentation. Revealing the natural and humanly-altered characteristics of the foreshore at different times in the past requires the use of a wide range of techniques, many of which are undergoing a complete metamorphosis today: geophysical surveys, GIS-based approaches to spatio-temporal modelling, the acquisition and processing of topographic and bathymetric data, image processing, stratigraphic analyses, etc.

Secondly, shell middens, with their marine and mollusc shells, remains of crustaceans and echinoderms, bones of fish, sea mammals and birds (and occasionally people) and their macroplant remains including charcoal, contain a wide range of information about the human exploitation of the maritime environment, and require a multi-disciplinary approach to their study. There is much that we can learn from them about the behaviour of coastal populations, be they hunter-fisher-gatherer groups or agro-pastoralist societies, over the natural cycles of seasons and tides. The different disciplines that are brought to bear on the study of shell middens each have their specific methods and timescales for the acquisition of data and an interdisciplinary approach, if it is to succeed, has to accommodate this diversity.

Thirdly, the evidence for coastal occupation and exploitation should not be considered in isolation from the broader geographical picture, since coast dwellers and users will have participated in economic and social networks that extended far inland. It is over such networks that items such as whalebone projectile heads or shell ornaments could have travelled considerable distances from the coast. Here again, the use of advanced scientific methods can be required to track such movements.

Finally, we cannot ignore the regulatory aspects that apply to archaeological interventions in the coastal zone: there are many and diverse rules relating to the human and natural heritage of the coast, and many institutions can be involved. Dealing with these rules, regulations and stakeholders can significantly slow down progress, and this is particularly regrettable where the pace of marine erosion can demand a rapid response.

Held in early December 2020, after several postponements due to the Covid-19 pandemic, the international round-table *Investigate the Shore, Sound out the Past: Methods and Practices of Maritime Prehistory* was intended to offer a critical overview of the new methods at our disposal to explore prehistoric sites in the maritime domain, thereby opening up scientific perspectives. This initiative was funded as part of the European Research Network (IRN) project “Coast-inland dynamics in prehistoric hunter-gatherer societies” (PrehCOAST), supported by the CNRS, Institute of Ecology and Environment from January 2019, under the direction of G. Marchand. It also benefited from involvement by the ArMeRIE programme (“Maritime Archaeology and Interdisciplinary Environmental Research”), directed by Y. Pailler and co-funded by the University of Brest and the INRAP Institute, and from the interdisciplinary approaches that have been developed within the SeaLex research project (“The SEA as a Long-term socio-ecological EXperiment”), directed by P. Stéphan and funded by the university research school ISblue, and the French LTSER site “Zone Atelier Brest-Iroise”.

The meeting brought together 192 researchers from seven countries (Canada, Spain, France, Ireland, Norway, Latvia and the United Kingdom), with 27 papers being presented. English was used as the *lingua franca* of the event. This volume presents nine articles that attest to this highly stimulating encounter and which reflect the diversity of perspectives and approaches to coastal archaeology that are currently used around the world.

DETECTION: NEW TOOLS, NEW DATA

In their article, “Potential and Limitations of Geomagnetic Prospecting for the Imaging of Prehistoric Sites in Coastal Areas: A Case Study of the Port Neuf Site (Hoedic)”, F. Lévêque and his colleagues describe the conditions for undertaking geomagnetic prospecting in dune-covered coastal sites, with their irregular vegetation cover and variable topography. The use of other geophysical methods such as magnetometry allows for the refinement of the proposed interpretations, in particular in detecting the presence of fireplaces. These are not “turnkey” methods, but rather an initial approach that requires a constant dialogue between the archaeologist and the geophysicist.

G. Marchand et al.’s contribution, “Geoarcheology and Prehistory of the St. Pierre and Miquelon Archipelago: Theoretical Issues, Methods and Preliminary Results”, addresses a wide range of methods and techniques in an area that has hitherto received very little archaeological attention. The project, begun in 2018, originally focused on the emergency excavation of the coastal site of Anse à Henry, which had been occupied for approximately five thousand years from the Maritime Archaic to the Historic period. However, from the outset, the approach that was taken integrated multiple scales of analysis, with a geomorphological component (monitoring of erosion, changes in sea levels) and an archaeological component (inventory of remains, dating of the various episodes of occupation, investigating coastal-inland networks, geochemical analysis of rocks).

PROSPECTING AND EXCAVATING: FIELD PRACTICES IN A COASTAL CONTEXT

The article by E. Lopez Romero: “The Potential of Analysing Prehistoric Human Occupation in the Western Rias of Galicia, Northwest Iberia: Methods and Prospects”, reviews the methods developed in this region of Spain over the last ten years. Until now, the commonest type of archaeological investigation along the coast of Galicia has been small-scale survey or short-term rescue operation, undertaken within the context of developer-funded archaeology, without any real continuity of research. This work highlights the high diversity of prehistoric remains along the shoreline, a density that has been largely underestimated until now.

The article by S. Piper, “Empty Edges? Ten Years of Searching for Prehistory on the Atlantic Coasts of Scotland”, is based on very different data, in areas that are scarcely touched by developer-funded archaeology. In the Highlands and Western Isles of Scotland, archaeological research has been much more limited due to the lack of current major economic infrastructural development in these parts of Scotland. Here, the loss of archaeology through coastal erosion is a major concern. After ten years of field research, the author presents a highly original and ambitious review of the archaeology. The burial of sites under peat or sand dunes makes geophysical surveys or visual reconnaissance ineffective. The three projects presented in this paper illustrate the benefits to be gained from regular monitoring of coastal erosion, which reveals Mesolithic sites, particularly shell middens, as they are exposed and destroyed by coastal erosion. Studying the geomorphological parameters of such sites enables predictive modelling of the location of further sites.

CONTEXTUALISING SITES BASED ON BIOLOGICAL INDICATORS

C. Dupont et al. develop an approach for the Mesolithic period that straddles marine biology and archaeology in their paper, “A Question of Size! The Importance of Marine Crabs in Food Remains from Mesolithic Fisher-Hunter-Gatherers at Beg-er-Vil, Quiberon, Morbihan, France”. They are interested in the abundant (but often neglected) remains of crabs, which highlight the role of the foreshore in the daily search for food, and they present a novel perspective concerning the exploitation of the wrack zone. This approach has only been possible thanks to the development of a demanding and meticulous scientific method, from the excavation right through to the laboratory analysis, taking here as a model the excavation of the Late Mesolithic site of Beg-er-Vil.

MODELLING: LANDSCAPES, POPULATIONS, HUMAN MOBILITY AND ADAPTATION PROCESSES

The policy of preventative archaeology that has been applied in Norway over the last twenty years has led to the discovery and detailed study of a large number of Mesolithic sites (9300-3900 cal. BC), mainly in coastal areas. This abundance of well-excavated and well-dated sites allows for improved modelling, supported by completely re-thought theoretical frameworks and novel methodological tools. The article by A. Schülke and colleagues, “New Perspectives on Old Shores: Current Approaches on the Mesolithic in Southeastern Norway and their Potential”, takes us through their analysis of the archaeological sites in their landscape, exploring the question of paleo-shorelines raised by the Scandinavian isostatic rebound. The article then addresses themes such as population dynamics estimated by radiocarbon dates, settlement patterns and site location, and technical traditions. The new perspectives offer a better, holistic perspective on social life, rituals and even cosmogonies.

In their contribution, “Detecting the Displacement of the Baltic Basin’s Ancient Shorelines by Clustering of Terrain and Distance Data along the Glacioisostatic Uplift Axis", E. Breijers et al. also deal with modelling human settlement dynamics on the coastline, pointing out the difficulties in dating the early Holocene raised shorelines along the eastern coasts of the Baltic Sea in Latvia. A GIS-based modelling of the isostatic uplift was carried out using a very detailed digital terrain model. This work identified 25 successive paleo-shorelines during the Ancylus Lake and Littorina Sea stages. These data now provide a robust basis for the interpretation of the archaeological sites that were initially located on the coast but were subsequently raised by post-glacial isostatic rebound.

B. Gehres introduces an additional dimension to this modelling of coastal areas in his chapter, "Archaeology of Neolithic Island Networks: Diachronic and Paleo-Economic Approaches to Island Occupation through the Contribution of Ceramic Analysis", through the petrological and chemical study of ceramics. These methods shed light on socio-economic processes (uses and exchanges) and on the management of mineralogical resources. Focusing on the Neolithic occupation of the islands of Brittany, the study also addresses fundamental questions of interactions with the mainland by these early agro-pastoral societies and, more generally, the influence of the marine environment on settlement systems in areas that are not *a priori* favourable to the expansion of agropastoral practices.

I. M. Berg-Hansen et al. propose a theoretical framework for prehistoric coastal research, based on works carried out in Norway ("Coast-Concepts in Norwegian Stone Age Archaeology"). The very important glacio-isostatic rebound in this country has preserved the ancient shorelines of the Mesolithic period, thereby providing from the outset a rough dating of the coastal human occupation (Beach Model). The authors argue that the theoretical foundations of the approaches that have been developed over the last few decades are too simplistic. Insufficient attention has been paid to inland areas. It is now necessary to reintegrate inland and coastal archaeology within a broader perspective, characterised as the landscape of practice.

This article closes the proceedings of the round table in a beautiful way by placing the emphasis not on the methods and techniques of our investigations, but rather on their ideological and conceptual basis. It acts as a call to others to ensure that themes, concepts and methods all mesh together. Scientific approaches to prehistoric coastal occupation, here around the North Atlantic and the Baltic Sea, often demand a strong association between geomorphology and archaeology: how else can it be done in the context of severe coastal erosion? The methods used range from geophysics to the study of ceramic fabric, each providing clues about these vanished worlds. The pooling of these approaches is desirable in order to arrive at the clearest possible picture of the past, but many methodological obstacles must be overcome along the way. In the current context of global warming and predictable rise in the average level of the oceans, it is more important than ever that we speed up, and join up, our investigations of marine erosion and the human use of the coastal zone.

The organisers would like to express their gratitude to Alison Sheridan who agreed to proofread this introduction and polish it in academic English.

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Introduction

Grégor Marchand (†), Pierre Stéphan, Yvan Pailler

AUTOUR DE LA PRÉHISTOIRE SUR LE LITTORAL

Lorsqu'elle plonge avec précaution un orteil dans la mer, l'archéologie préhistorique oublie quelque peu ses repères. Les occupations humaines à l'interface entre les domaines maritimes et continentaux sont des objets de recherche complexes à appréhender, en premier lieu parce que la position de cette ligne de côte a fluctué au cours du temps, au gré des transgressions marines, de l'érosion, des apports sédimentaires ou des mouvements verticaux du sol (relèvement isostatique). Révéler ces habitats ou ces aménagements anthropiques sur les estrans impose un large éventail technique, en totale métamorphose aujourd'hui : prospections géophysiques, approches géomatiques de modélisation spatio-temporelle, acquisition et traitement de données topographiques et bathymétriques, traitements d'images, analyses stratigraphiques, etc.

En deuxième lieu, la multiplicité des domaines environnementaux exploités par les êtres humains, accumulés au sein de *shell middens*, engendre une très large gamme de vestiges archéologiques et bioarchéologiques. Les coquilles de mollusques, comme les restes de crustacés ou d'échinodermes, viennent s'ajouter aux ossements de mammifères, de poissons et d'oiseaux ou aux carporestes et aux charbons de bois. Leur étude démultiplie les savoirs et permet de mieux comprendre la gestion des cycles naturels – saisons ou marées – par les populations littorales, que l'on ait affaire à des sociétés de chasseurs-pêcheurs-collecteurs ou à des sociétés agropastorales. Il convient tout particulièrement de se pencher sur les interactions entre ces disciplines et sur leurs différentes temporalités dans l'acquisition des données, qui conditionnent souvent la réussite ou l'échec de ces entreprises scientifiques.

En troisième lieu, les occupations côtières de la Pré- ou de la Protohistoire ne se limitent pas à une installation de funambule sur le fil d'un écotone, mais elles sont le point de départ de réseaux économiques et sociaux qui s'enfoncent amplement dans les masses continentales : des pointes en os de baleine ou des parures en coquillages sont transférées loin dans les terres, prolongeant d'autant les réseaux littoraux. Là encore, l'étude de ces artefacts fait intervenir des méthodes scientifiques de pointe. Enfin, on ne peut pas faire l'impasse sur les aspects réglementaires qui pèsent sur ces interventions en milieu côtier : la diversité des réglementations sur le patrimoine humain ou naturel et la multiplicité des acteurs institutionnels engendrent des blocages importants, alors même que l'érosion marine ne connaît pas de répit.

Après avoir été plusieurs fois reportée en raison de la pandémie de Covid-19, la table ronde *Explorer la côte, sonder le passé : méthodes et pratiques de la préhistoire maritime*, qui s'est tenue au début du mois de décembre 2020, entendait donc proposer un très large bilan de ces nouvelles méthodes d'exploration des habitats préhistoriques en domaine maritime, en donnant la part belle aux perspectives scientifiques. Cette table ronde internationale était adossée au réseau européen de recherche (IRN) « Coast-inland dynamics in prehistoric hunter-gatherer societies (PrehCOAST)/Dynamiques des sociétés de chasseurs-cueilleurs littorales de la Préhistoire », soutenu par l'Institut écologie et environnement du CNRS depuis janvier 2019 et dirigé par G. Marchand. Elle a profité également de la dynamique scientifique du programme ArMeRIE (« Archéologie maritime et recherche interdisciplinaire environnementale »), dirigé par Y. Pailler et cofinancé par l'université de Brest et par l'Inrap, et des approches interdisciplinaires développées au sein du projet SeaLex (« The SEA as a Long-term socio-ecological EXperiment »), piloté par P. Stéphan et financé par l'école universitaire de recherche ISblue, et de la Zone Atelier « Brest-Iroise » (LTSER France).

La rencontre était centrée sur les aspects méthodologiques et techniques d'une préhistoire en plein renouvellement. Elle a réuni 192 chercheurs de sept pays (Canada, Espagne, France, Irlande, Norvège, Lettonie, Royaume-Uni), pour 27 communications. Les archéologues de la planète se sont emparés de cette question, avec des déclinaisons très diverses liées aux pratiques nationales et aux conditions géomorphologiques ; pour les faire se rencontrer, la langue d'expression choisie exclusivement ne pouvait donc qu'être l'anglais. Neuf articles ont été réunis dans ce volume pour témoigner de cette rencontre fort stimulante. Ils présentent une large gamme d'actions et de réflexions en cours sur les littoraux de la planète.

DÉTECTER : NOUVELLES DONNÉES, NOUVEAUX OUTILS

F. Lévêque et ses collègues exposent dans leur article (« Potentiels et limites de la prospection géomagnétique appliquée à l'imagerie de sites préhistoriques en zone côtière : le site de Port Neuf, Hoedic ») les conditions de mise en œuvre de la prospection géomagnétique dans les sites littoraux couverts de dune(s) – c'est-à-dire avec un couvert végétal et une topographie irrégulière. Le recours à d'autres méthodes géophysiques, comme les méthodes électromagnétiques, permet d'affiner les interprétations proposées, en particulier sur la présence de foyers. Il ne s'agit pas de méthodes « clés en main », mais plutôt d'une approche initiale qui impose un dialogue permanent entre l'archéologue et le géophysicien.

L'article proposé par G. Marchand et ses collègues (« Géoarchéologie et préhistoire de l'archipel de Saint-Pierre-et-Miquelon : problèmes théoriques, méthodes et résultats préliminaires ») permet d'aborder un large champ de méthodes et de techniques sur un territoire pour l'instant peu exploré dans sa dimension archéologique. Le projet, amorcé en 2018, était à l'origine centré sur la fouille en urgence du site côtier de l'Anse-à-Henry, occupé pendant environ cinq mille ans (de l'Archaïque maritime à la période historique). Mais la démarche empruntée a d'emblée intégré de nombreuses échelles d'analyse, avec un volet géomorphologique (suivi de l'érosion, changement des niveaux marins) et un volet archéologique (inventaire des vestiges, datation des différentes occupations, restitution des réseaux d'occupation, analyses géochimiques des roches).

PROSPECTER ET FOUILLER : LES PRATIQUES DE TERRAIN EN CONTEXTE CÔTIER

L'article d'E. Lopez Romero (« Le potentiel de l'analyse des occupations humaines préhistoriques dans les rias occidentales de la Galice : méthodes et perspectives ») dresse un bilan des méthodes développées dans cette région d'Espagne depuis une dizaine d'années. À l'heure actuelle, le type d'intervention le plus fréquent dans les zones côtières reste la prospection ou la fouille ponctuelle, sous la forme de sauvetage, sans réelle continuité des actions de recherche. Dans cette région au littoral très développé, et contrairement à d'autres régions atlantiques européennes, la présence de vestiges préhistoriques dans des zones côtières basses a été considérée comme rare, ce que les nouveaux travaux démentent.

L'article de S. Piper (« Une bordure vide ? Dix ans à la recherche de la Préhistoire sur les côtes atlantiques de l'Écosse ») s'appuie sur des données totalement différentes, loin de l'accumulation de sites qu'autorise le cadre préventif. Dans les Highlands et les îles occidentales de l'Écosse, les recherches archéologiques ont été bien plus limitées, faute d'aménagements de grandes infrastructures économiques. Les menaces érosives qui pèsent sur le patrimoine littoral sont une préoccupation majeure. Après dix années de recherche de terrain, l'auteure présente une archéologie fort originale et ambitieuse. L'enfouissement des sites sous les tourbes ou les dunes rend inefficace les prospections géophysiques ou les reconnaissances visuelles. Les trois projets présentés ici illustrent le parti à tirer d'un suivi régulier de l'érosion côtière qui révèle, en les détruisant, les sites du Mésolithique, notamment les amas coquilliers. La prise en compte des paramètres géomorphologiques permet une prédictibilité des découvertes.

CONTEXTUALISER LES SITES À PARTIR DES INDICATEURS BIOLOGIQUES

C. Dupont et ses collègues développent une approche à cheval entre biologie marine et archéologie, pour la période du Mésolithique (« Une question de taille ! L'importance des crabes marins dans les vestiges alimentaires des pêcheurs-chasseurs-cueilleurs de Beg-er-Vil, Quiberon, Morbihan, France »). Les auteurs s'intéressent à des vestiges délaissés et pourtant abondants : les restes de crabes. Ces derniers permettent d'aborder des comportements du quotidien sur l'estran, avec par exemple la mise en évidence d'une exploitation des laisses de haute mer. Cette approche n'est permise que par le développement d'une méthode scientifique exigeante et vétilleuse, depuis la fouille jusqu'à l'analyse en laboratoire, en prenant ici comme modèle la fouille du site du second Mésolithique de Beg-er-Vil.

MODÉLISER : PAYSAGES, POPULATIONS, MOBILITÉ HUMAINE ET PROCESSUS D'ADAPTATION

La politique de fouilles archéologiques préventives menée en Norvège depuis une vingtaine d'années a permis de constituer un corpus de sites mésolithiques (9300-3900 cal. av. J.-C.) de premier plan, principalement dans le domaine côtier où se concentrent les aménagements actuels. Cette abondance de sites bien fouillés et datés autorise des modélisations améliorées, soutenues par des cadres théoriques et des outils méthodologiques totalement renouvelés. L'article d'A. Schülke et ses collègues (« Nouvelles perspectives sur d'anciens rivages : les approches actuelles du Mésolithique du sud-est de la Norvège et leur potentiel ») développe une analyse des sites dans leur paysage, avec toujours en filigrane la question des anciennes lignes de rivage désormais exondées après le rebond isostatique qui a affecté la Scandinavie. L'article aborde des thématiques comme la dynamique des populations, estimée par les dates radiocarbone ; les modèles de peuplement et la localisation des sites ; ou encore les traditions techniques. Les perspectives nouvelles s'élargissent vers une perception améliorée de la vie sociale, mais aussi des rituels voire des cosmogonies, dans une perspective holistique.

E. Breijers et ses collègues questionnent également la modélisation des dynamiques des implantations humaines sur le littoral, en insistant sur la datation difficile des lignes de rivage du début de l'Holocène, aujourd'hui exondées, le long des côtes de l'actuelle Lettonie, sur la rive orientale de la mer Baltique (« Identifier le déplacement des anciennes lignes de rivage de la mer Baltique par le *clustering* des données de terrain et de distance le long de l'axe du soulèvement glacio-isostatique »). Un travail de modélisation géomatique du relèvement isostatique a été réalisé à partir d'un modèle numérique de terrain très détaillé. Cette modélisation a permis d'identifier 25 lignes de rivage successives durant les stades du lac Ancylus et de la mer à Littorines. Ces données constituent désormais une base solide pour l'interprétation des sites archéologiques qui, initialement côtiers, se sont retrouvés exondés sous l'effet du relèvement isostatique post-glaciaire.

B. Gehres introduit quant à lui une dimension supplémentaire dans cette modélisation des espaces littoraux (« L'archéologie des réseaux insulaires néolithiques : contribution de l'analyse de la céramique à une approche diachronique et paléo-économique des occupations insulaires »), avec l'étude pétro-archéologique et chimique des céramiques. Ces méthodes permettent d'éclairer des processus socio-économiques (transferts, usages, échanges) ou encore la gestion des ressources minéralogiques. Centrée sur les occupations néolithiques des îles bretonnes (France), l'étude permet en outre d'aborder des questions fondamentales concernant les interactions de ces premières sociétés agro-pastorales avec le continent et, plus généralement, concernant l'influence du milieu marin dans les systèmes de peuplement de milieux *a priori* peu favorables à l'expansion de ces pratiques.

I. M. Berg-Hansen et ses collègues (« Les modèles conceptuels du littoral dans l'archéologie paléolithique norvégienne ») proposent un cadre théorique à la recherche préhistorique sur le littoral, à partir des travaux menés en Norvège. Le rebond isostatique très important dans ce pays permet aujourd'hui de disposer des anciennes lignes de rivage du Mésolithique, livrant d'emblée une datation grossière des occupations humaines littorales (*beach model*). Les auteurs soutiennent que les fondements théoriques de ces approches développées depuis des décennies sont trop simplistes. Une moindre attention a en effet été accordée aux zones situées à l'intérieur des masses continentales. Il convient désormais de les réintégrer dans une réflexion plus large, identifiée comme « les pratiques du paysage (*landscape of practice*) », c'est-à-dire la manière dont on construit mentalement ces espaces en agissant en leur sein.

Cet article vient clore les actes de la table ronde de belle manière en mettant l'emphase non plus sur les méthodes et les techniques de nos explorations mais sur l'assise idéologique et conceptuelle de ces travaux. Il résonne comme un appel à d'autres manifestations scientifiques sur ces thèmes ; concepts et méthodes voguent de concert. Les approches scientifiques des occupations préhistoriques des littoraux – ici autour de l'Atlantique Nord et de la Baltique – font souvent appel à une association forte entre géomorphologie et archéologie : comment faire autrement dans un contexte de forte érosion littorale ? L'éventail des méthodes employées va de la géophysique à l'étude des pâtes de céramique, chacune livrant un reflet de ces mondes disparus. La mise en commun de ces approches est souhaitable pour les restituer au mieux ; mais bien des obstacles méthodologiques devront être surmontés. Dans le contexte actuel de réchauffement climatique global et de remontée prévisible du niveau moyen des océans, espérons être en mesure de gagner de vitesse sur l'érosion marine ou les aménagements humains souvent intempestifs.

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Potential and Limitations of Geomagnetic Prospecting for the Imaging of Prehistoric Sites in Coastal Areas: a Case Study of the Port Neuf Site (Hoedic)

Potentiels et limites de la prospection géomagnétique appliquée à l'imagerie de sites préhistoriques en zone côtière : le site de Port Neuf (Hoedic)

Francois Lévêque, Grégor Marchand (†), Martin Moucheron, Luis Teira, Pablo Arias

Abstract: Through a case study of the coastal Mesolithic site of Port Neuf (Hoedic), this article aims to introduce archaeologists to the use of geomagnetic prospection methods in the context of irregular vegetation cover and topography inherent to this type of coastal site. The constraints and limitations of the method are discussed, e.g. the negative influence of pollution by a large metal mass on the information obtained. The data processing carried out to attenuate the disturbance induced by this magnetic pollution does not allow relevant information to be extracted over the entire polluted area. It is also shown that in the context of the presence of dune cover, such as that covering the archaeological levels, it is necessary to study the variation in magnetic field intensity rather than its vertical gradient by gradiometry. The use of other complementary geophysical methods provides information to refine the proposed interpretations, particularly concerning the presence of hearths. For example, electromagnetic methods, such as the use of conductivity meters, provide information on the spatial variation of the substrate's capacity to conduct electricity or a magnetic field at the site scale, or the use of contact sensors, which at the scale of the excavation help to determine areas of potential hearths by detecting zones of magnetic enhancement. The need for archaeologists and geophysicists to work together and for excavators to adopt these tools is discussed.
Keywords: Geomagnetic prospection, coastal archaeology, hearth, Armorique, magnetic susceptibility, Hoedic.

Résumé : Les sites archéologiques littoraux constituent des objets pour lesquels le recours aux méthodes géophysiques est pertinent, que ce soit avant d'entreprendre des fouilles ou au cours de leur réalisation. L'utilisation du feu par les sociétés préhistoriques est la source de thermoaltérations des phases minéralogiques riches en fer, qui sont produites par l'élévation de température des matériaux, à partir de températures de l'ordre de 200 à 250 °C. Ces transformations produisent un enrichissement en minéraux magnétiques. De plus, l'élévation de température engendre une augmentation de l'ordre magnétique de ces minéraux qui vont avoir tendance à acquérir une aimantation dans la direction du champ magnétique ambiant lors de leur refroidissement. Les méthodes magnétiques sont, de ce fait, des outils privilégiés pour étudier les sites archéologiques préhistoriques. Ces enrichissements magnétiques et les aimantations thermorémanentes acquises lors du dernier refroidissement des matériaux sont la source d'anomalies locales du champ magnétique. La prospection géomagnétique a pour objet de cartographier ces anomalies. Grâce aux cadences de mesures élevées des magnétomètres, plus de dix mesures par seconde, la prospection géomagnétique est une méthode performante pour obtenir une information de résolution spatiale élevée en un temps d'acquisition limité. Les enrichissements magnétiques peuvent aussi être détectés par la réalisation de mesures de susceptibilité ou de viscosité magnétique avec des capteurs de contact, directement sur les matériaux exposés à l'affleurement. Cet article se focalise sur la prospection géomagnétique et présente les prospections géophysiques réalisées sur le site mésolithique de Port Neuf (Hoedic) au titre d'exemple d'étude de site des îles armoricaines.
En contexte littoral, le couvert végétal et la topographie constituent des contraintes importantes pour la mise en œuvre d'une prospection géomagnétique. Afin d'obtenir une densité spatiale de mesures, régulière, à plusieurs dizaines de mesures par mètre carré, néces-

saire pour disposer d'une information de qualité suffisante, des repères visuels sont implantés tous les mètres. Un dispositif permet à l'opérateur de porter les deux capteurs du magnétomètre (GSMP35-G, GEM system) à une vingtaine de centimètres au-dessus de la surface du sol et à 25 cm de part et d'autre de l'axe d'avancée, permettant ainsi d'acquérir des profils de mesures tous les 50 cm.
La présence des vestiges d'un relais télégraphique est la source d'une anomalie magnétique majeure qui masque le signal archéologique recherché. La modélisation de cette anomalie par une équation mathématique permet de minimiser cette perturbation. Une information archéologique peut alors être extraite de la partie périphérique de l'anomalie majeure indésirable. La présence d'une couverture dunaire recouvrant les niveaux archéologiques éloigne les sources magnétiques potentielles de la surface de mesure. La mesure du gradient du champ magnétique (gradient vertical du champ magnétique ou pseudogradient de l'intensité du champ magnétique), classiquement mise en œuvre pour s'affranchir facilement de la variation temporelle du champ magnétique, n'est pas pertinente dans ce cas de figure à cause de l'éloignement des sources dont l'intensité est vraisemblablement modeste. Il est alors nécessaire de déterminer les variations d'intensité du champ magnétique. Pour éviter l'utilisation d'un second magnétomètre pour enregistrer en position fixe la variation temporelle du champ magnétique qui sera retranchée de l'enregistrement dynamique, celle-ci est estimée à l'aide d'une fonction polynomiale établie à partir de valeurs de mesures médianes de chaque profil aller-retour. Cette démarche permet de mettre en évidence des anomalies étalées spatialement mais d'intensité modeste, non visibles en gradiométrie. Ces anomalies constituent potentiellement les traces magnétiques de foyers enfouis sous la couverture dunaire. Afin d'affiner les interprétations de cette prospection géomagnétique, des prospections ont été menées avec un conductivimètre dans le secteur situé autour de la fouille effectuée par les époux Péquart dans les années 1930 (Péquart et Péquart, 1954). Les informations de conductivité électrique et de susceptibilité magnétique apparente apportées par ces dernières prospections sont décorrélées de l'information géomagnétique, ce qui est en faveur d'une source magnétique associée à une aimantation thermorémanante, de fait détectable uniquement par l'anomalie magnétique qu'elle crée.
La présence de coupes naturelles en bord de falaise et au niveau des sondages archéologiques a permis d'effectuer des relevés à l'aide d'un susceptibilimètre et d'un viscosimètre magnétique. Ces mesures révèlent la séquence de trois corps dunaires successifs, au niveau du sondage étudié, surmontant le niveau d'occupation mésolithique qui présente un fort enrichissement magnétique. Ces mesures de caractérisation des propriétés magnétiques des unités stratigraphiques sont complémentaires des autres prospections géophysiques. Réalisées au cours d'une fouille – d'abord par le géophysicien pour cerner la signification des variations constatées (variations qui dépendent fortement de la dynamique du fer dans les processus de pédoaltération), puis par le fouilleur en présence d'indices de feu, ou de manière systématique –, ces mesures permettraient de visualiser des objets invisibles à l'œil, sortes de « fantômes magnétiques », telles des soles de foyers dont la présence n'est pas trahie par des rubéfactions. L'existence d'un enrichissement magnétique dépend de la nature des matériaux chauffés. Un matériau dépourvu de fer ne sera pas impacté thermiquement du point de vue magnétique. En revanche, un fort enrichissement ne traduit pas systématiquement la présence de traces d'un foyer. Seule la caractérisation de la présence d'une aimantation thermorémanente, ou du moins de l'anomalie magnétique associée, est un gage de la présence d'un foyer. Pour réaliser cela, une prospection 3D à résolution infradécimétrique, comme celles réalisées dans les grottes préhistoriques (Burens et al., 2014 ; Grussenmeyer et al., 2014 ; Lévêque et Mathé, 2015, Jaubert et al., 2016), est envisageable. Cependant, cette démarche n'est pas concevable de manière systématique. L'alternative à une prospection 3D serait que les fouilleurs utilisent un gradiomètre magnétique miniature en complément d'un susceptibilimètre et/ou d'un viscosimètre. Un tel instrument n'existe pas sur le marché mais sa réalisation est tout à fait possible.
Mots-clés : prospection géomagnétique, archéologie littorale, foyer, Armorique, susceptibilité magnétique, Hoedic.

INTRODUCTION

The use of geophysical methods for the study of coastal prehistoric sites is on the increase (Bates et al., 2019; Napora et al., 2019; Giovas et al., 2020; Wilken et al., 2022), but identifying the best geophysical investigation approach is still an elusive goal as each case study has its own specificities. Indeed, the soil of each site will have its own particular physical characteristics and the nature, geometry and the depth of burial of the archaeological objects sought will differ. This article focuses on the use of magnetic methods and more specifically on the implementation of geomagnetic surveys. It provides a progress report on the evolution of the methods used on the coasts of the Armorican Massif (France) for several years (Cousseau et al., 2019; Duval et al., 2021; Pailler et al., 2022), the protocols being adapted to each new site according to the presumed specificities, access constraints (which may limit the technical means that can be applied) and to the archaeological problematic.

Although we are dealing with geomagnetic prospecting here, it is important to remember that the comparison of results obtained by several different geophysical methods is generally more informative than basing one's approach on a single method. Indeed, each method exploits different physical properties of the environment: mainly a site's capacity to sustain magnetisation and the presence of thermoremanent magnetisations (TRM), but also the capacity of the environment to propagate an electric current or electromagnetic wave. The same physical quantity may also be measured by instruments operating on different principles. Depending on the properties of the environment, significant differences can be observed due to differences in instrumental limits. For example, the study of variations in the magnetic properties of the environment can be addressed using (1) the spatial variation of the magnetic field through geomagnetic prospecting, which detects both variations in the magnetising capacity of the environment and the presence of permanent, mainly thermoremanent, magnetisations; (2) in a complementary way by measurements of magnetic susceptibility, a quantity that expresses the capacity of a material to carry a magnetisation, which is done by contact measurement with a kappameter on volumes smaller than a cubic decimeter; or (3) with a conductivity meter, which will determine variations in the so-called apparent magnetic susceptibility of the environment on much larger volumes, generally in cubic metre, varying according to the dimensions of the conductivity meter used.

A comprehensive presentation of all the geomagnetic surveys carried out in the Armorican coastal area in recent years is not feasible in this article. For this reason, this article will focus on a single representative site, the Mesolithic site of Port Neuf on the island of Hoedic (south Brittany, France). Before presenting this case study, we will first discuss the constraints of geomagnetic prospecting in the coastal context.

1. APPLICATION OF GEOMAGNETIC PROSPECTING TO THE IMAGING OF PREHISTORIC SITES IN COASTAL AREAS

1.1. Data acquisition

In near-surface geophysical imaging, whatever method is used, the spatial density of the measurements determines the accuracy of the observations that can be made. As magnetic field measurements do not require contact with the ground, they can be collected continuously, while moving. This and the high measurement rates of magnetometers (10 measurements per second or more) make geomagnetic prospecting a powerful method for obtaining high spatial resolution data in a limited measurement time. The usual type of area where the method is used is open land with an even surface and sparse vegetation, or after harvesting of arable crops. This is because, on the one hand, the absence of obstacles allows for movement along regularly spaced profiles and, on the other hand, the topographical effects on the deformation of the magnetic field are limited to those of the microreliefs generated by tillage. It is thus easy to obtain information at a regular spatial density of several tens of measurements per square metre over the surface of the surveyed area.

Apart from this high spatial resolution, however, the ability to image an object depends on there being a sufficient magnetic contrast between the surrounding materials and the object of interest. On a prehistoric site, the soil environment can be complex, and its magnetic properties can vary greatly. A sequence of paleosols may exist, marking phases of slowing down or non-deposition that favour pedogenesis. The present soil can form on various substrates: on the alterite of an ancient paleosurface, for example, if it has not been stripped by Quaternary erosion, or on a young substrate formed during the Holocene, such as alluvial deposits, coastal dune sands or bedrock brought to the surface by Quaternary erosion. As a general rule, a soil is more magnetic than the substrate on which it forms (Le Borgne, 1955; Fassbinder, 2015; Lévêque, 2021). However, the magnetic signature of a soil depends on its nature, specifically on the dynamics of iron in relation to those of organic matter. Its magnetisation capacity, classically assessed by magnetic susceptibility measurements, is strongly dependent on the amount of the most magnetic natural iron oxides it contains, namely the nanometric mineralogical phase of magnetite (Fe_3O_4) or its oxidized form maghemite (γ-Fe_2O_3). These substances, which are black and brown pigments, respectively, are inherently undetectable to the eye. Without a visual indicator, given the complexity of the generation of a soil's magnetic signature, it is difficult to estimate the magnetisation capacity of a soil without measuring its magnetic susceptibility.

An archaeological soil is generally more magnetic than a natural soil (Tite and Mullins, 1971), which can be explained by the addition of organic matter, compaction, clearing by burning, emptying of hearths, etc. Among influencing factors, the use of fire is of major interest for magnetic methods. Indeed, fire produces a thermo-alteration of the minerals present in its substrate. Depending on the redox conditions of the fire, iron-containing minerals can be the source of new magnetic particles. Thus, if the thermal wave, after evaporation of water (Brodard et al., 2016), exceeds 200-250°C, then magnetic minerals (known as ferrimagnetic minerals) are neoformed by the thermal action of fire on minerals containing iron in a weakly magnetic or non-magnetic form (known as canted antiferromagnetic and paramagnetic, respectively).

Thus, iron oxyhydroxides FeOOH (goethite, lepidocrocite) are dehydrated to form, depending on the oxidizing or reducing conditions of the gas phase, hematite (α-Fe_2O_3), maghemite (γ-Fe_2O_3) or magnetite (Fe_3O_4; Cudennec and Lecerf, 2004; Brodard et al., 2014). In the presence of carbon monoxide (CO), produced by partial fat burning for example, hematite can also be reduced to magnetite (Colombo et al., 1967; Yu et al., 2017), probably at temperatures below 400°C.

Besides the phenomenon of magnetic enhancement produced by thermo-alteration associated with fires, the magnetisation of the heated materials are heightened by this enhancement and by the magnetic order produced. The magnetic minerals originally present or neoformed, can carry, depending on their size, a permanent magnetisation, which is called thermoremanent. It is produced by the rise in temperature of the substrate to several hundred degrees Celsius. In addition to the thermo-alteration generated, this temperature frees the magnetic order of the magnetic minerals. During the cooling process, this magnetic order of these minerals is locked once again. The ambient geomagnetic field favours the alignment of magnetisations according to its direction, increasing the magnetic order.

This permanent magnetisation, called thermoremanent, thus fossilizes the past magnetic field. It is associated with a magnetisation induced by the interaction of the magnetisations of the magnetic minerals with the present geomagnetic field. This induced magnetisation varies with the geomagnetic field. The intensity of this induced magnetisation is increased in the thermo-altered zones by the magnetic enhancement produced. As the present geomagnetic field has a direction close to the fossil geomagnetic field for archaeological sites, these permanent and induced magnetisations add up to form a local dipolar magnetic field anomaly, with a magnetic field that is weaker in the north and stronger in the south at the latitude of France. For this reason, hearths or ovens are objects for which geomagnetic prospecting is the preferred method of geophysical imaging.

In prehistoric contexts, there are generally no highly magnetic objects. The geomagnetic anomalies, which reflect the local deformation of the geomagnetic field by these sources, remain moderate in amplitude. In the case of prehistoric caves, surveys are carried out almost in contact with the paleo hearth (Burens et al., 2014; Lévêque and Mathé, 2015; Jaubert et al., 2016). The signal amplitude is then at its maximum. In a coastal situation, the archaeological horizon may be covered by a dune. The thickness of the sand, which increases the distance between the source and the measurement, causes an attenuation of the signal amplitude. This attenuation approximately follows a law inversely proportional to the distance cubed (actually closer to between squared and cubed). In practice, therefore, a moderate source is no longer detectable from a few tens of centimetres to a few metres of vertical distance, depending on its intensity. Source intensity is an unknown a priori. If it is of sufficient intensity to have a detectable signal under the thickness of a dune, then the anomaly will be moderate and spatially extensive. If the source is closer, the intensity of the anomaly will be stronger but have a lower spatial extent.

Apart from the effect of distance from the source, dunes can also produce a topographical effect on the geomagnetic signal. For a terrain with no variation in magnetic properties, the hilltops will be characterised by positive geomagnetic anomalies. Their intensity will be proportional to the magnetic susceptibility of the topsoil horizons because the contrast with the magnetic susceptibility of the air, which is zero, will be all the greater. As a result, the geomagnetic anomaly will be more marked when the relief is higher and the topsoil more magnetic and thicker. In contrast, this effect will be absent for non-magnetic soils, i.e. those with diamagnetic susceptibility for which the iron in the upper horizons is leached out, such as in a podzol.

The vegetation can also be locally thick with bushes. Clearing is sometimes necessary, but this is not always possible for the sake of preserving the biodiversity in protected areas. The distance between the ground surface and the measurement then becomes irregular. To take these effects into account in the analysis of a geomagnetic survey, it is necessary to have a detailed spatialisation of the geomagnetic measurements made and a digital model of the topography in order to determine the distance to the ground for each measurement. Ideally, a spatialisation of the measurements would be performed by laser tracking with a total station (Lévêque and Mathé, 2015). This approach requires the use of a large volume of equipment, which is not always logistically possible to transport, especially on uninhabited islands. In this case, spatialisation can be provided by a GNSS device, but the equipment coupled to the magnetometers have antennas of limited size to minimise magnetic disturbances. Absolute horizontal accuracy does not exceed 0.7 m at best and vertical information is generally not usable.

To cover the area to be surveyed in a homogeneous way, in a topographic context that is generally hilly, visual markers are placed every metre to create parallel lines (fig. 1). The operator walks carrying the measuring device with the help of a frame (fig. 1) allowing them to keep the sensors (at the front of the device) away from sources of magnetic pollution (the acquisition console is in the centre, with the operator, the batteries at the back and the GNSS antenna offset 1.5 m above the sensors). While walking and controlling the recording of measurements on the console, the operator must maintain their alignment with the visual guides.

Finally, the temporal variation of the geomagnetic field, whose amplitude is often similar to that of the signal studied, must be taken into account. The simplest approach, classically used, consists in using gradiometry, i.e. determining the difference in intensity of the total magnetic field (optically pumped magnetometer; fig. 2), called the pseudogradient, or the difference in intensity of the vertical component of the magnetic field (fluxgate gradiometer; fig. 3), called the vertical gradient. Unfortunately, this approach favours sources close to the surface, in the first few decimetres, and the implementation of vertical fluxgate gradiometers requires the sensors to be kept vertical, which is sometimes difficult when the topography is uneven. If the sources are assumed to be further away than the first metre, it is then necessary to work on the intensity of the total geomagnetic field. The temporal variation of the geomagnetic field can then, ideally, be corrected by the variation measured by a second stationary magnetometer located near the surveyed area. This requires having a second magnetometer with identical technology. The alternative is to use the temporal variation of the measurement acquisition, which presents pseudoperiodic variations over the time of a two-way survey trip due to the spatial variations of the magnetic field. The general trend of the temporal variation over the duration of the survey can then be estimated and subtracted from the measurements. This trend will subtract 1) the temporal variation of the geomagnetic field over the duration of a round trip, but also 2) a regional variation of the local magnetic field that is not the object of study. Only short duration variations, of the order of one minute, will not be corrected, but their intensities are generally negligible with respect to the signal studied (less than 1 nT in periods of low geomagnetic activity compared with a signal whose dynamics generally exceed 20 nT, for an average field of 45 000 to 49 000 nT for France).

Fig. 1 – Device of realization of the geomagnetic prospection on the Port Neuf site in Hoedic. The diagonal of coloured field markers planted in the ground corresponds to one of the parallel lines of visual markers placed every meter. The operator follows the alignment of the same coloured field markers, from one line of markers to the next, in order to cover the space evenly. The magnetometer's magnetic field intensity measurement sensors, shown here in the black of the GSMP-35G used, are placed at the front of the carrying structure. The GNSS antenna is offset above the sensors at the end of a pole so as not to pollute the magnetic field intensity measurements. The measurement acquisition console is carried against the operator's midriff. The electronic control units for the sensors and the battery are offset to the rear to limit the pollution from to their movement. This position also allows them to serve as a counterweight (photo P. Arias).

Fig. 1 *– Mise en œuvre de la prospection géomagnétique sur le site de Port Neuf, à Hoedic. La diagonale de fiches de couleur plantées dans le sol correspond aux repères placés tous les mètres, selon des lignes parallèles. L'opérateur suit l'alignement des fiches d'une même couleur, d'une ligne de repère à la suivante, afin de couvrir l'espace de manière homogène. Les capteurs de mesure d'intensité du champ magnétique du magnétomètre (GSMP-35G), ici de couleur noire, sont disposés à l'avant de la structure de portage. L'antenne GNSS est déportée au-dessus des capteurs, à l'extrémité d'une perche pour ne pas polluer les mesures d'intensité de champ magnétique. La console d'acquisition des mesures est plaquée sur le ventre de l'opérateur. Les boîtiers électroniques de contrôle des capteurs et la batterie sont déportés sur l'arrière pour limiter les pollutions liées à leur déplacement ; ils servent aussi de contrepoids (cliché P. Arias).*

1.2. Interpretation of the measurements

Having addressed the issue of measurement recording, we must move on to measurement interpretation. The presence of anomalies following curves or alignments is not necessarily a sure sign of archaeological information. Indeed, both the geological and pedo-geomorphological contexts must be considered. We will take the example of the coastline of the Armorican massif, which is primarily crystalline. Although less magnetic rocks (granites, gneiss and schists) dominate here, other much more magnetic rocks of basaltic composition are also present as veins, due to the Hercynian orogeny. These magnetic veins in much less magnetic rocks lead to linear magnetic anomalies.

The soils that develop on these crystalline massifs, which have high porosity, tend to leach the iron present on the surface causing it to migrate to the interface of the alterite, where it concentrates. This iron accumulation horizon has a high magnetic susceptibility. If erosion brings this deep horizon to the surface, then this outcrop margin will manifest itself as a positive anomaly that follows the topography of the alteration surface.

In order to identify these cases, it is necessary to combine geomagnetic surveys with those using a magnetic susceptibility meter, or kappameter, which is a contact measurement instrument (fig. 4) that determines the capacity of a material to acquire magnetisation when subjected to a magnetic field (weak in this case) in order to determine the variations in magnetic susceptibility of the profiles of the soils and materials present at the outcrop.

2. STUDY OF THE PORT NEUF SITE (HOEDIC ISLAND, MORBIHAN)

2.1. Presentation of the site

The Port Neuf site is a Mesolithic site where burials were made, associated with shell deposits, hearths, lithic material and food bone waste. This site was excavated between 1931 and 1934 by the Péquart couple (Péquart and Péquart, 1954). It is located on the edge of the coast in the north-western part of Hoedic island (fig. 5 and 6), in a dune sector covered by very sparse vegetation, apart from a few bushes (fig. 7).

During the Late Mesolithic, the age of occupation of the Port Neuf site, the Houat and Hoedic archipelago (fig. 5B) was isolated from the mainland by the sub-

Fig. 2 – Sensor arrangement of a G858 Geometrics optically pumped magnetometer in a gradiometer (photo L. Carozza).
***Fig 2** – Disposition des capteurs d’un magnétomètre à pompage optique G858 Geometrics en gradiomètre (cliché L. Carozza).*

Fig. 3 – Vertical fluxgate gradiometer FEREX (Foerster Holding GmbH) with four sensors mounted on a carrying frame. The operator follows a line marked by a cord (photo V. Mathé).

Fig. 3 *– Gradiomètre vertical fluxgate FEREX (Foerster Holding GmbH) avec quatre capteurs montés sur un châssis de portage. L'opérateur suit la ligne matérialisée par une cordelette (cliché V. Mathé).*

merged Vilaine valley to the north and the Artimon valley to the east (Menier et al., 2006). The break in continuity between these two islands occurred during the Mesolithic. The analysis of recent bathymetric data (fig. 5B), seems to indicate that this break could have occurred before the occupation of the Port Neuf site, contrary to what is generally accepted (Menier et al., 2009). This analysis, based solely on the current bathymetry, remains highly hypothetical as the extent of the erosion of the submerged land surfaces remains unknown. In any case, the site appears to overhang the bay located to the north of the island, a few hundred metres from the shore.

The excavations carried out by the Péquart couple at Hoedic (1931-1934; Péquart and Péquart, 1954), but also on the island of Téviec (1928-1930; Péquart and Péquart, 1929) some twenty kilometres north-east of Hoedic, provided one of the richest funerary assemblages of the last hunter-gatherers in Europe. The human remains and associated archaeological objects have been one of the main sources of information on the Late Mesolithic of western Europe. However, the success of reanalysis of this material with recent isotope or paleogenomic techniques has been limited despite the quality of the Péquart excavation and the good conservation of the collections. The chal-

Fig. 4 – Implementation of susceptibility meters by contact measurement. A: MS2K (Bartington) computer controlled with its MS3 electronics. The advantage of this probe is its small diameter, about 2.5 cm, but the downside is its shallow depth of investigation, of about 1 cm. B: KT9 (Exploranium). The advantage of this instrument is its speed of measurement. The probe diameter of about 6 cm provides a detection depth of 2 to 3 cm. A measurement in air is necessary before and after the measurement carried out in contact with the measured surface.

***Fig. 4** – Mise en œuvre de susceptibilimètres par mesure de contact. A : MS2K (Bartigton) piloté par ordinateur avec son électronique MS3. L'avantage de cette sonde est son faible diamètre, environ 2,5 cm ; le corollaire est sa faible profondeur d'investigation, de l'ordre de 1 cm. B : KT9 (Exploranium). L'avantage de cet instrument est sa rapidité de mesure. Le diamètre de la sonde, environ 6 cm, apporte une profondeur de détection de 2 à 3 cm. Une mesure dans l'air est nécessaire avant et après la mesure réalisée au contact de la surface mesurée.*

lenge is, therefore, to resume the excavation to clarify the chronologies and obtain fresh material. As the site is in a protected area, it is necessary to limit excavations. The use of geophysical imagery is, therefore, necessary both to find the extent of the 1930s excavation and to identify the location/s of potential remains.

2.2. Geophysical surveying problematic

Several geophysical surveys, conducted by several teams using different methods, were carried out on the site with the aim of resuming this excavation. In this article, only results associated with the total field geomagnetic survey and the complementary measurements of apparent magnetic susceptibility are presented. To supplement this mapping information, magnetic susceptibility and viscosity measurements were made using contact sensors on sections after the opening of an archaeological pit.

The presumed presence of hearths in the area not opened in the 1930s is a good reason for using geomagnetic prospecting. The sparse vegetation is favourable to both easy movement and keeping the sensors close to the ground, except for two bushes which would need to be removed for the area to be surveyed. The constraints of the environmental protection of this Natura 2000 site means that this is not possible, however. The presence of a dune complex, one or more metres thick, covering the site is a factor that causes signal attenuation and lateral spreading of the observable anomalies. Indeed, the sand layer separates potential magnetic sources, such as hearths, from the measurements made at the surface, thus reducing the signal. The topography is another tricky aspect that complicates both the implementation of the survey and the interpretation of the signal. Indeed, the surface is marked by decametric undulations, with a vertical amplitude in metres. The most marked slope corresponds to the edge of a mound. In the immediate vicinity of this mound are the remains of a telegraph relay (fig. 7) with a solid metal door, which is a major source of magnetic pollution in the area. In the 1970s this area was also used as a wilderness camping area before the municipal campground was created. The presence of metallic remains (nails, tent pegs, etc.) of this recent occupation on the surface is a concern, as it may be another source of potential magnetic pollution. As the measurements are made in the immediate vicinity of such potential sources, close to the surface, the anomalies they generate will be of high intensity and low spatial extent and, therefore, easily identifiable. In view of all these elements, the chances that a geomagnetic survey could successfully identify hearths appear to be mixed. However, as it is not possible to predict the intensity of the sources associated with the presumed hearths or their depth of burial, only by actually prospecting can we determine its relevance.

2.3. Investigation methods and measuring instruments

The geomagnetic survey presented here was carried out in 'total field', i.e. by measuring the intensity of the magnetic field. This method is preferable to vertical gradiometry when the sources are buried and of moderate intensity. Indeed, gradiometry is efficient in the case of high gradients, for example those associated with (1) highly magnetic sources and/or those located at the surface, such as abandoned explosive devices left over from

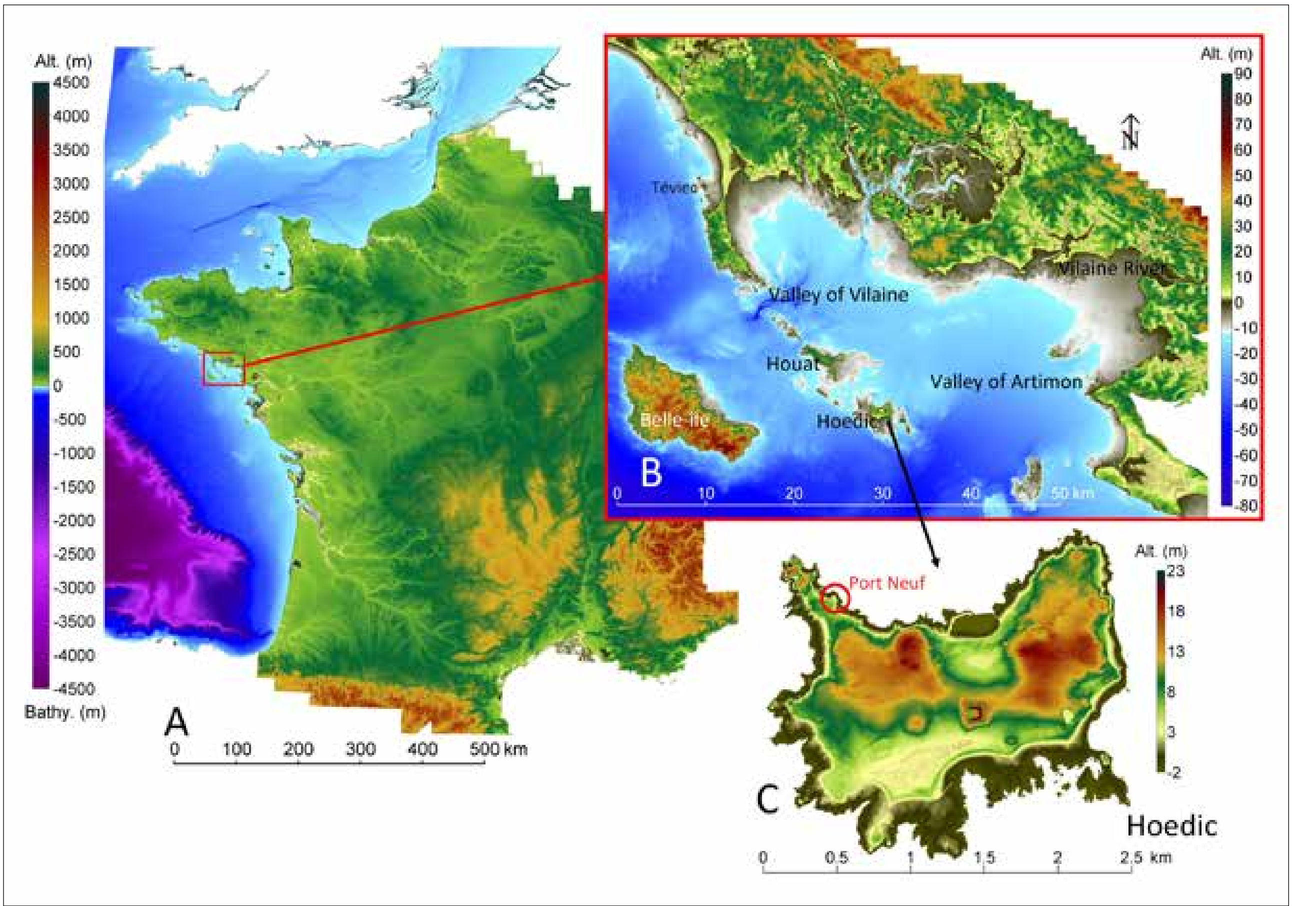

Fig. 5 – Paleogeographic context of the Port Neuf site. The maps were produced in RGF93 Lambert 93 projection. The bathymetric and altimetric levels -12, -11.5, 0 and 3 m are systematically represented in light blue, white, black and yellow, respectively. The levels -12 and -11.5 m, taken arbitrarily, can be considered as a low tide level during the spring tide at a period corresponding to the end of the Mesolithic period (considering a retreat of the order of 3 m at low tide and an isostatic rebound of the order of 1 m since this period, the sea level considered would be of the order of -8 m in relation to the mean reference level). A: Location map of the study area. The map was produced from DTMs from SHOM (2015a), for bathymetry, and from IGN (RGEALTI, 2018) for the altimetry of the map of France. The reference datum is the mean sea level. B: Map of the Morbihan area obtained from the SHOM coastal topo-bathymetric DTM (2015b). C: Topographic map of Hoedic Island obtained from the RGEALTI 1 m DTM (RGEALTI, 2021). The location of the Mesolithic site of Port Neuf is shown by a red circle.

***Fig. 5** – Contexte paléogéographique du site de Port Neuf. Les cartes sont réalisées en projection RGF93 Lambert 93. Les cotes bathymétriques et altimétriques -12 m, -11,5 m, 0 m et 3 m sont systématiquement représentées respectivement par les couleurs bleu clair, blanc, noir et jaune. Les cotes -12 m et -11,5 m, prises arbitrairement, peuvent être considérées comme un niveau de basse mer en vives eaux à une période correspondant à la fin du Mésolithique (en considérant un retrait de l'ordre de 3 m à basse mer et un rebond isostatique de l'ordre de 1 m depuis cette période, le niveau marin considéré serait de l'ordre de -8 m par rapport au niveau moyen de référence). A : carte de localisation de la zone d'étude. La carte est produite à partir des MNT du SHOM (2015a), pour la bathymétrie, et de l'IGN (RGEALTI, 2018), pour l'altimétrie de la carte de la France. Le zéro altimétrique de référence correspond au niveau marin moyen. B : carte du secteur du Morbihan obtenue à partir du MNT topo-bathymétrique côtier du SHOM (2015b). C : Carte topographique de l'île de Hoedic réalisée à partir du MNT RGEALTI 1m (RGEALTI, 2021). La localisation du site mésolithique de Port Neuf est figurée par un cercle rouge.*

the wars of the 20th century, or (2) material contrasts over large volumes, such as the edges of ditch fillings done with magnetic soils in a surrounding material that is not very magnetic.

The magnetometer used was an optically pumped magnetometer GSMP-35G (GEM System; fig. 1), which offers the advantage of being able to measure the intensity of the magnetic field at a rate of 20 measurements per second, with an instrumental sensitivity of 0.0015 nT at this frequency, i.e. well above one millionth of the earth's field. This sensitivity is much finer than the effective repeatability of the measurements, which can be estimated at a value between 0.1 and 0.5 nT according to the configuration of the device implementing the magnetometer. Indeed, the presence of the battery, which is discharging current, and the measuring console, whose position in relation to the sensors and the direction of the magnetic field is constantly changing, generate disturbances. To minimize this effect, a homemade carrying frame has been designed to move the sensors to the front and the batteries to the rear, thus acting as a counterweight. The console is attached to the operator to ensure that it wobbles as little as possible and allows them to follow the recording of the measurements (fig. 1). Ideally, this console could also be positioned as a counterweight to move it away from the sensors, but then the operator would no longer be able to verify the correct recording of the measurements so this set-up was not chosen for the present study.

The profiles, marked on the ground with visual markers spaced 1 m apart, are arranged perpendicularly to the direction of the magnetic field in order to minimize the artifacts generated by the console and batteries. Indeed, if the sensors were aligned in the direction of the mag-

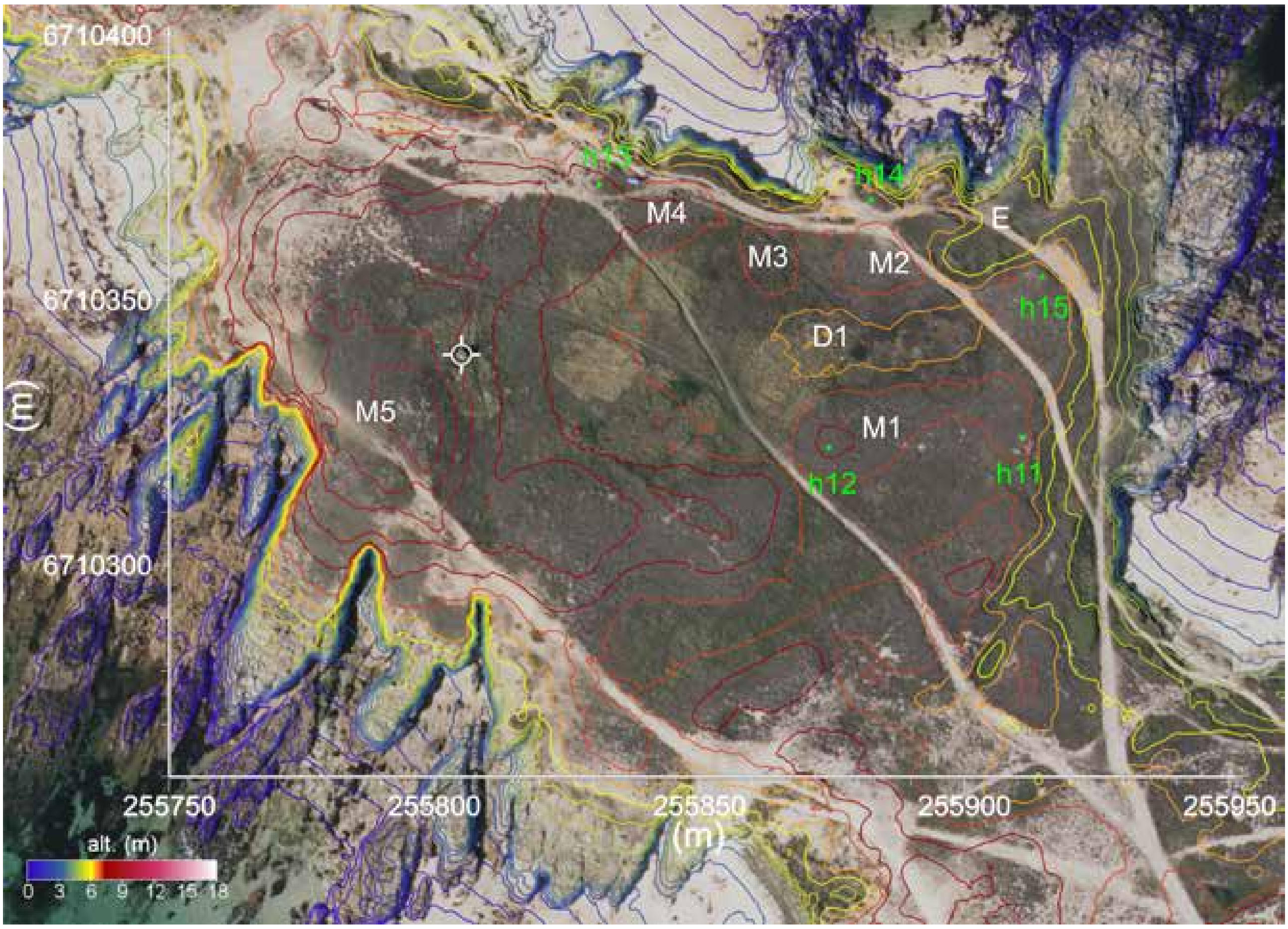

Fig. 6 – Location of the area covered by the geophysical survey on the NW tip of Hoedic island at Port Neuf. The reference used is Lambert93. The orthophotograph is an extract of ORTHOHR_1-0_JP2-E080_LAMB93_D56-2019 (IGN). The contour lines were established from the RGEALTI_FXX_0255_6711_MNT_LAMB93_IGN69 (IGN) and are spaced at 0.5-m intervals. E: area of the 1930s excavation (Péquart and Péquart, 1954). M1 to M5: topographical mounds; D1: topographical depression; h11 to h15: spatial reference marked by green dots corresponding to metal rods driven vertically into the ground. The remains of the telegraph relay station are indicated by the symbol ⌖.

Fig. 6 *– Localisation du secteur couvert par la prospection géophysique sur la pointe NW de l'île d'Hoedic à Port neuf. Le référentiel utilisé est Lambert93. L'orthophotographie correspond à un extrait de ORTHOHR_1-0_JP2-E080_LAMB93_D56-2019 (IGN). Les courbes de niveaux sont espacées de 0,5 m. Elles ont été établies à partir du RGEALTI_FXX_0255_6711_MNT_LAMB93_IGN69 (IGN). E : secteur de la fouille des années 1930 (Péquart et Péquart, 1954). M1 à M5 : buttes topographiques ; D1 : dépression topographique ; h11 à h15 : référence spatiale matérialisée par des points verts correspondant à des tiges métalliques enfoncées verticalement dans le sol. Les vestiges du poste de relais télégraphique sont marqués par le symbole ⌖.*

Fig. 7 – View of the vegetation cover of the Port Neuf site. A first line of field markers is visible in the foreground and a second one can be seen about 30 m away. The building visibly standing out on the skyline is the remains of the telegraph relay station.
Fig. 7 – *Vue du couvert végétal du site de Port Neuf. Une première ligne de repère est visible au premier plan ; une seconde se distingue à une trentaine de mètre. La construction visible se détachant sur la ligne d'horizon correspond aux vestiges du relais télégraphique.*

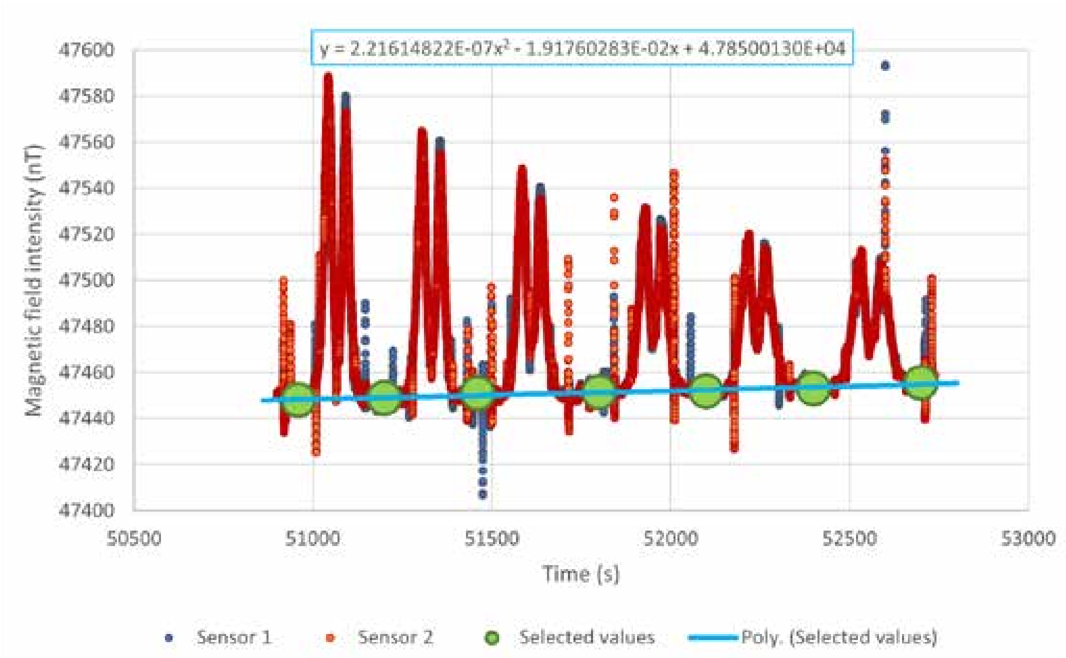

Fig. 8 – Correction of the variation of the magnetic field with time. A polynomial function, used as an estimator of the temporal variation of the magnetic field strength, is determined by fitting selected values considered as median with respect to the observed variation. The round trips generate a pseudoperiodic structure whose extreme values correspond to passage close to magnetic sources. These temporal variations linked to the displacement are not taken into account when bulding the polynomial function equation.
Fig. 8 – *Correction de la variation temporelle du champ magnétique. Une fonction polynomiale, utilisée en tant qu'estimateur de la variation temporelle de l'intensité du champ magnétique, est déterminée par ajustement de valeurs sélectionnées considérées comme médianes par rapport à la variation constatée. Les allers-retours génèrent une structure pseudopériodique dont les valeurs extrêmes correspondent au passage à proximité de sources magnétiques. Ces variations temporelles liées au déplacement ne sont pas prises en compte pour la recherche de l'équation de la fonction polynomiale.*

netic field with these sources of magnetic disturbance, then their influence would be at its maximum. The two sensors are spaced 0.5 m apart horizontally and held by the operator at about 0.2 m above the ground. At a speed of movement of the order of 1 m/s, each round trip makes it possible to acquire two lines of measurements with 20 measurements per metre for each trip, i.e. 40 measurements per metre. The homogeneity of the distribution of measurement points along the ground depends on the evenness of the operator's movement. The temporal variation of the magnetic field is corrected by the removal of a polynomial function passing through the median values of the measured temporal variation exploiting the pseudoperiodic variation of the round trips as mentioned at the end of section 2.1 (fig. 8).

This magnetometer has a GNSS satellite positioning system of the SBAS type with an absolute horizonal accuracy of 0.7 m. For successive measurements over a short time, the relative accuracy is better. The vertical position is recorded with an accuracy in metres. This accuracy is insufficient to obtain relevant height information in the dynamic topographic setting of the Port Neuf site. It would have been preferable to double the positioning of the measurements by laser tracking of a reflector fixed on the carrying structure, using a motorised total station (Lévêque and Mathé, 2015). This approach would allow a positioning accuracy of the order of a few centimetres in all directions in space (the main error comes from the reflector not remaining vertical with respect to the sensors on slopes). The choice was made not to use a total station here, mostly because of the need to reduce the volume of material to be transported, a choice that proved to be detrimental.

The apparent magnetic susceptibility measurements were carried out with a GEM 2 conductivity meter (Geophex, Ltd.; fig. 9). Just as in geomagnetic prospecting, measurement with a conductivity meter does not involve contact with the ground. However, this method, known as electromagnetic, is an active method, unlike geomagnetic prospecting, which is a passive method. A transmitter coil generates a magnetic wave that propagates in the ground. Depending on the electrical and magnetic properties of the surroundings, the magnetic field produced will generate induced electric currents and induced magnetisations, respectively. The latter will, in turn, generate a secondary magnetic field, the variations of which are measured by a

Fig. 9 – Implementation of the GEM 2 conductivity meter (Geophex, Ltd). The GNSS antenna is placed at the end of a mast to maintain a constant relative position between the measurement and the determination of its position. The carrying device, made of neutral materials (plastic and fibreglass tube), helps to keep the conductivity meter horizontal as the operator is walking (photo P. Arias).

***Fig. 9** – Mise en œuvre du conductivimètre GEM 2 (Geophex, Ltd). L'antenne GNSS est disposée à l'extrémité d'un mat permettant de conserver une position relative constante entre la mesure et la détermination de son positionnement. Le dispositif de portage, réalisé en matériaux neutres (plastique et tube en fibre de verre), favorise le maintien de l'horizontalité du conductivimètre tout en marchant (cliché P. Arias).*

receiver coil, distant from the first (transmitter) coil. The original signal will be distorted according to the capacity of the environment to conduct the magnetic field and the electric current. These two properties correspond to two physical quantities, the magnetic susceptibility (which is magnetic permeability expressed in another form) and the electrical conductivity.

The distance between the transmitting and receiving coils is approximately 1.6 m. The depth of investigation and the volume of the ground explored depend on the electrical properties of this environment and the height of the instrument above the ground. Surveying is carried out trying to keep the device horizontal at about 0.3 m above the surface (the minimum distance needed to minimise correction artefacts from the instrumental drift compensation coil, situated between the transmitting and receiving coils). Although it is difficult to estimate this depth of investigation, we can consider that it is of the order of the spacing between the coils, from must be subtracted the height of surveying, i.e. approximately 1.3 m (value of the probable response, knowing that part of the signal potentially reaches down to 10-20 m depth). The volume of investigation is then calculated in m^3.

Magnetic susceptibility measurements were carried out using contact sensors (fig. 4). The KT9 (Exploranium) is used for fast measurements on areas of about 6 cm in diameter. With this type of sensor, the signal produced by a magnetic source decreases with the distance between the sensor surface and the object of interest. For a homogeneous material, 95% of the signal comes from a detection volume of about 150 cm^3 for a penetration depth of 3 cm (Lecoanet et al., 1999). For higher spatial resolution profiles, the MS3 control unit (Bartington) and the probe MS2K, with a detection diameter of about 2.5 cm, were used. These measurements were complemented by magnetic viscosity measurements made with the similar 2.5 cm diameter MVM1 probe (Pulsepower Developments; fig. 10). The reduction in sensor diameter results in a reduction in detection volume and depth of investigation, which does not exceed 1 cm for the MS2K probe.

2.4. Geomagnetic mapping

The geomagnetic mapping of the Port Neuf area is shown in figure 11. The metal door of the telegraph relay generates a major dipole anomaly (negative pole in blue to the north, positive pole in red to the south), impacting the western half of the covered area. Smaller dipoles appear in a line northward of the telegraph relay (only the positive parts stand out). One remedy for these strong spatial variations is to observe only the variations on a sub-metric scale. To do this, it is sufficient to calculate the local horizontal gradient by the difference between the two sensors (fig. 12). This approach also has the advantage of eliminating temporal variation while attenuating major large-scale anomalies. Sub-metric anomalies, from point sources close to the surface, are thus well isolated. This information is similar to what would be produced by a vertical gradient survey. However, anomalies greater than a metre in size and from a much deeper source disappear because the signal they produce at the surface is very similar viewed from the positions of each of the two sensors.

To try to distinguish the minor anomalies present in the western area under the influence of the telegraph relay anomaly, another solution consists in subtracting the general trend from the main dipole structure. The magnetic anomaly generated by the main source is simulated by a simple mathematical model approximating the structure of a real magnetic anomaly:

$$\left(\frac{Y}{\sqrt{Y^2}}\right)\cdot\left(\frac{(\alpha.X)^2}{((\alpha.X)^2+(\beta.Y)^2)^3}\right)^{\gamma}$$

α, β and γ are fit variables of the model and X and Y are the horizontal coordinates. A translation and rotation of X and Y is performed to centre and orient the mathematical model generated. The version presented in figure 13 has been empirically optimised. Although a model closer to the main variation can certainly be obtained, it is not necessary to improve the fit. Indeed, once subtracted from the data, it appears (fig. 14) that the edges of the anomaly in the sloping areas near the telegraph relay show shifts between two successive profiles. This shift is due to differences in the altitude of the sensors between the profiles made during ascent and descent because the distance to the source is different. Furthermore, there is also a shift in horizontal positioning caused by the failure to maintain verticality between the GPS antenna and the sensors. It should, therefore, be possible to correct the effects of this horizontal shift and, above all, to take into account the differences in altitude in the model so as to significantly improve it. Unfortunately, there is too little precision in the determination of the altitude to obtain a reasonable correction of these effects with the set-up used here.

The analysis of the anomalies extracted after correction of the major anomaly (fig. 14) shows two linear structures starting almost at right angles to the telegraph relay. These anomalies correspond to the cables linking with the mainland to the NNE and the centre of the island to the ESE, which are visible on the ground locally. In addition, several dipolar anomalies stand out to the north of the relay. Considering the intensities, these correspond to metallic masses, either related to the telegraph relay or to a historical use of the sector as a rubbish dump (P. Buttin, Pers. Comm.).

A series of isolated anomalies, ranging in size from metric to sub-metric, are clearly identified (red ellipses; fig. 14). These anomalies were already identifiable on the horizontal gradient representation (fig. 12), but less marked than those observable with the corrected total field (fig. 14). They are sometimes aligned in a circle or an arc and seem to be associated with the presence of stone blocks on the surface. A systematic survey would be necessary to clarify this. Indeed, it is unlikely that a stone block of the substrate could produce such geomagnetic anomalies as the material is naturally not very magnetic. Some of these blocks show

Fig. 10 – Recording of magnetic viscosity measurements with an MVM1 (Pulsepower Developments). The measurements are complementary to those made with the KT9 (Exploranium). Magnetic viscosity is an estimator of the concentration of nanometric magnetic phases (ferromagnetic in the broad sense, mainly ferrimagnetic), and is therefore independent of the low or non-magnetic matrix (paramagnetic or diamagnetic), unlike the measurement of magnetic susceptibility. The latter will be sensitive to the enhancement of the magnetic phase, mainly ferrimagnetic. These measurements were successively carried out on the same area (photo P. Arias).

***Fig. 10** – Mise en œuvre de mesures de viscosité magnétique avec un MVM1 (Pulsepower Developments). Les mesures sont complémentaires de celles réalisées avec le KT9 (Exploranium). La viscosité magnétique est un estimateur de la concentration en phases magnétiques (ferromagnétique au sens large, principalement ferrimagnétique) nanométrique, elle est donc indépendante de la matrice peu ou non magnétique (paramagnétique ou diamagnétique), contrairement à la mesure de la susceptibilité magnétique. Cette dernière sera sensible à l'enrichissement en phase magnétique, principalement ferrimagnétique. Ces mesures sont réalisées successivement sur une même surface (cliché P. Arias).*

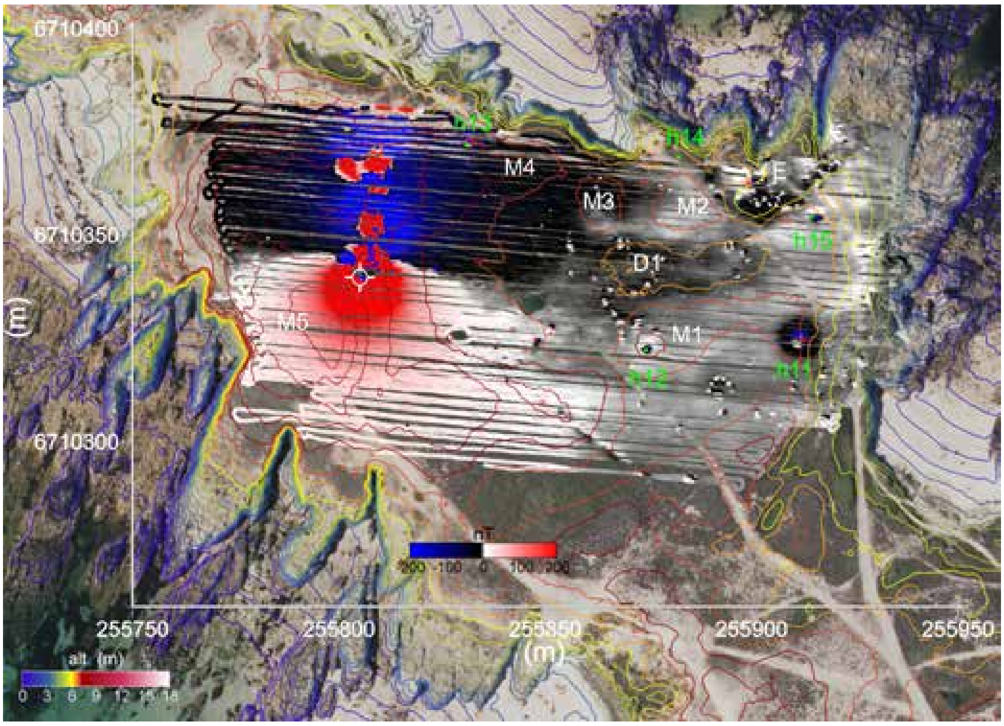

Fig. 11 – Geomagnetic survey of the Port Neuf sector (see legend fig. 1). Each magnetic field intensity measurement is represented by a point whose succession forms the lines along the profiles. The spatial marker h11 is at the centre of the strong anomaly produced by the metal rod. The other four markers are associated with smaller anomalies or are at the edge of the covered area, to the North. (For additional information see the legend fig. 6.)

***Fig. 11** – Prospection géomagnétique du secteur de Port Neuf (voir légende de la figure 1). Chaque mesure d'intensité du champ magnétique est représentée par un point dont la succession forme les lignes selon les profils. Le repère spatial h11 est au centre de la forte anomalie produite par la tige métallique. Les quatre autres repères sont associés à des anomalies plus modestes ou sont en bord de zone couverte, au nord. (Informations complémentaires dans la légende de la figure 6.)*

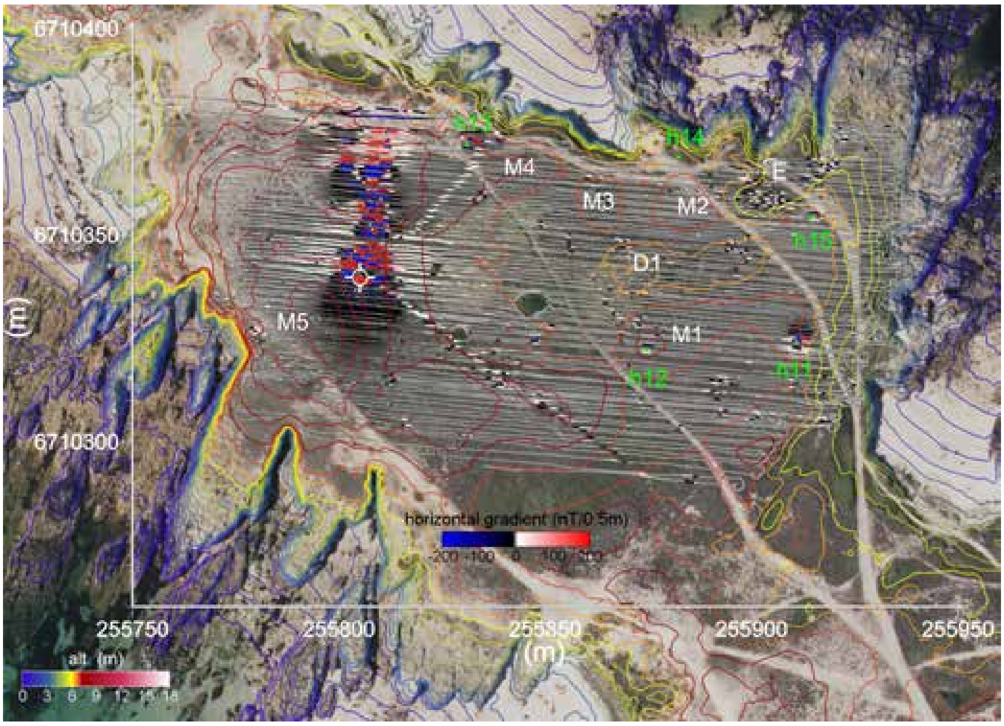

Fig. 12 – Horizontal gradient of the Port Neuf area (see legend fig. 1).
The colour scale is the same, to allow easy comparison. The unit is nT/0.5m rather than nT/m.

***Fig. 12** – Gradient horizontal du secteur de Port Neuf (voir légende figure 1).*
L'échelle de couleur est inchangée pour permettre une comparaison immédiate. Pour cela l'unité est en nT/0,5 m au lieu de nT/m.

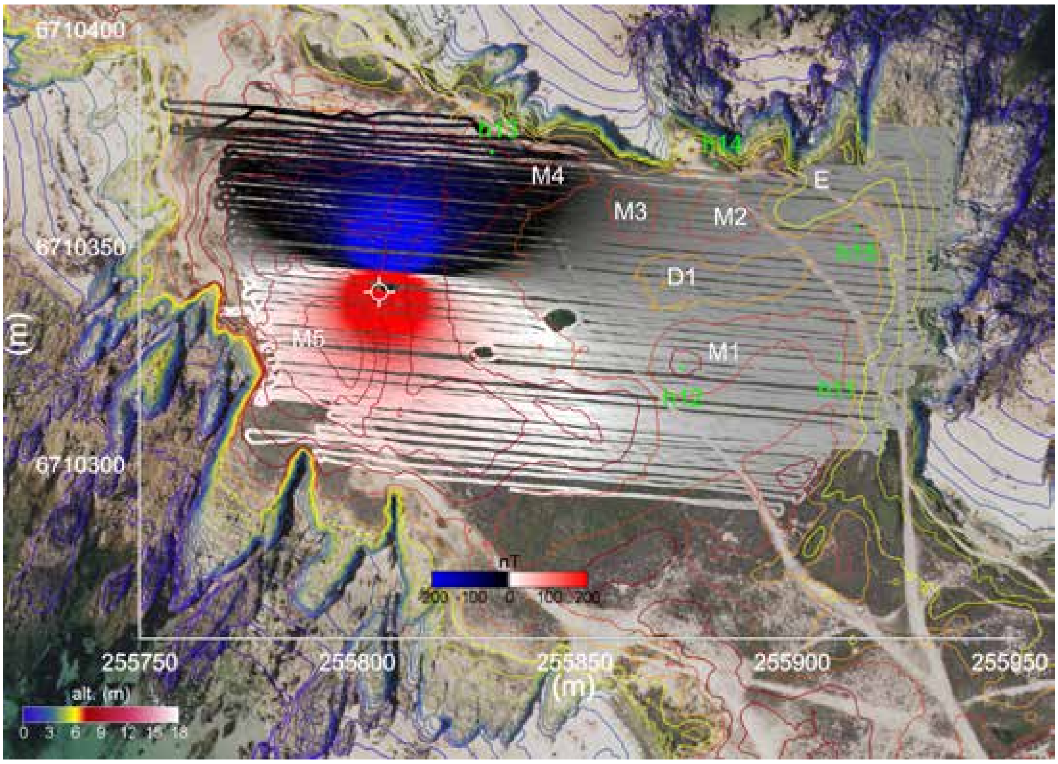

Fig. 13 – Model of the dipole anomaly produced by the remains of the telegraph relay (see legend fig. 6).
Fig. 13 *– Modèle de l'anomalie dipolaire produite par les vestiges du relais télégraphique (voir légende figure 6).*

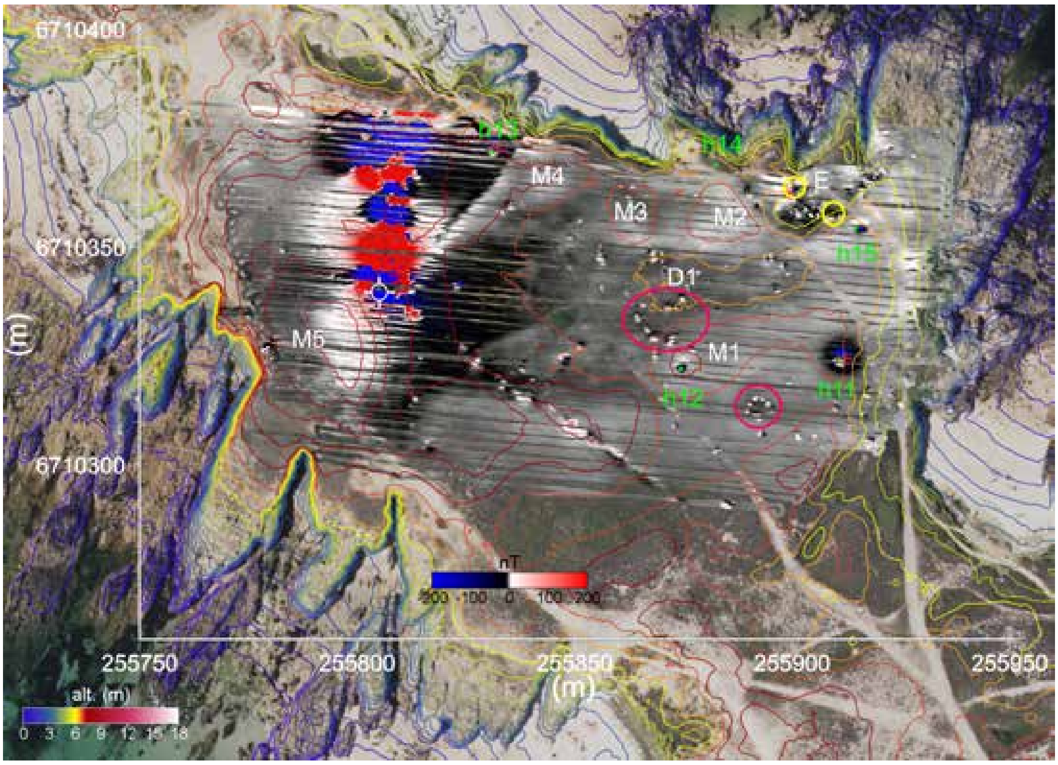

Fig. 14 – Model-corrected total field strength of the major anomaly produced by the telegraph relay door (see legend fig. 6). The red ellipses mark groups of anomalies. The yellow circles in the area of the excavations (E) mark dipolar magnetic sources; the one closest to the h15 mark could be a hearth and the second one a metallic mass due to the E–W orientation of the dipole.
Fig. 14 *– Champ total corrigé du modèle de l'anomalie majeure produite par la porte du relais télégraphique (voir légende figure 6). Les ellipses rouges marquent des groupes d'anomalies. Les cercles jaunes dans la zone des fouilles (E) marquent des sources magnétiques dipolaires qui pourraient correspondre à un foyer, pour la plus proche du repère h15, ou une masse métallique du fait de l'orientation E-W du dipôle, pour la seconde.*

rubefaction of their surfaces. The spatial resolution of the geomagnetic survey, with profiles about 0.5 m apart, does not allow us to say whether these anomalies are dipolar. However, the action of fire on the stone blocks seems likely to have produced the thermo-alterations, as indicated by the rubefaction, but also to have led to the acquisition of strong thermoremanent magnetisations.

The analysis of the data in terms of magnetic field intensity (fig. 14) integrates the correction of the relay effect and thus allows the exploitable area to be extended compared with the gradiometry (fig. 12). Its major interest is to reveal anomalies of weaker intensity and decametric dimensions not visible by gradiometry, such as those to the south of mounds M2, M3 and M4 (fig. 14). The relationship of these decametric anomalies with topographic variations appears complex. The topography here is potentially influenced by the presence of excavated material from the old 1930s excavation (probably the case for the slight relief present to the west of marker E, figure 14, associated with a positive anomaly in its eastern part). Material from deep archaeological horizons, potentially more magnetic, may have been brought to the surface. In this case, the spoil creates a local positive anomaly. In contrast, a similar anomaly may be produced by a deeper, more magnetic source, such as a hearth. The anomalies associated with mounds M2 and M3 and possibly M4 (fig. 14), north of the main depression (D1), could indicate the presence of such objects. To attempt to clarify this interpretation, we conducted an electromagnetic survey.

2.5. Electromagnetic survey

The area covered by the electromagnetic survey was limited to the eastern part of the site (fig. 15 and 16) close to the area of the 1930s excavation with potentially interesting geomagnetic anomalies. The measurements were carried out using a prototype carried device currently under development (a more advanced version of which is illustrated figure 9). Measurements were acquired every 0.12 s with three excitation frequencies, 475, 1575 and 45075 Hz. The swaying of the device relative to the control tablet caused disturbances in the form of high frequency fluctuations in the signal. To mitigate this noise, sliding window smoothing was applied with the median calculated over a 0.84 s window. Only the most representative data with the least noise are presented.

Electric conductivity

The electrical conductivity, proxied by the quadrature signal at 45075 Hz, is shown in figure 15. Its values, marked in blue on the figure, are low, consistent with the southern mound M1 (fig. 15). This mound corresponds to a dry, slightly clayey material. Given the context, this feature must correspond to a dune structure. A similar zone of low conductivity, shown by the yellow and orange contour line, to the north-east, corresponds to the area excavated in the 1930s (E, fig. 15) and extends eastwards. This area appears to be dominated by a very close or outcropping bedrock signal or by the presence of the heap of excavated material to the east. The north-eastern end shows a highly conductive zone which, given its proximity to the sea, must correspond to a zone salted by evaporation of sea spray. A zone of high conductivity lies between the two zones of low conductivity, located between the main depression D1 and the mound M2 (fig. 15). This zone seems to be too far from the area exposed to sea spray that the high conductivity could be explained by a salty environment. Therefore, these high values most certainly indicate a more clayey material. Such clayey layers can be observed on the top of the beach cliff located to the east. They correspond to a layer of alterite, autochthonous or reworked with aeolian deposits, covering the bedrock. This alterite seems to have been preserved from erosion in the depressions of the bedrock. The erosion must have been pre-Mesolithic. Indeed, according to the illustrations of Péquart's observations, the Mesolithic occupations seem to be on this clay layer (Péquart and Péquart, 1954).

The two small elevations, mounds M2 and M3 (fig. 15), to the north of depression D1, have different electrical conductivity. The westernmost of these, M3, has an average conductivity, while the second, M2, shows an offset from the contour lines. We need to ask if this is the result of the accumulation of excavated material from the 1930s, consisting of dune material (low electrical conductivity) to the east and deeper material to the west (higher electrical conductivity due to increased clay content). An analysis of the sediments in the column would be needed to answer this question. To the east of the survey area, the concordance of the two high conductivity anomalies with the position of the paths casts doubt on the origin of the signal. It could be explained by the filling of the roads with materials more clayey than the dune materials. An extension of the survey to the east would be necessary to propose a reliable interpretation.

Apparent magnetic susceptibility

The apparent magnetic susceptibility, proxied by the signal in phase at 1575 Hz (fig. 16), has a very different spatial signature from that of the electrical conductivity. The lowest values recorded in the south-east and at the north-east show very strongly negative values with low consistency indicating that the phase signal values cannot be converted into a true magnetic susceptibility value. Only the relative variations are to be taken into consideration. The high values define a structure located halfway up the slope between the main depression (D1, fig. 16) and the mounds to the north (M2 and M3, fig. 16). The position of this structure, which has a high magnetisation capacity, is south of the positive geomagnetic anomalies associated with the mounds (M2 and M3). There is, therefore, no direct relationship between these geomagnetic anomalies and increases in the magnetising capacity of the materials. There are two possible explanations for this: either the sources of the geomagnetic anomalies are too small with respect to the volume explored for apparent magnetic susceptibility, or their source corresponds

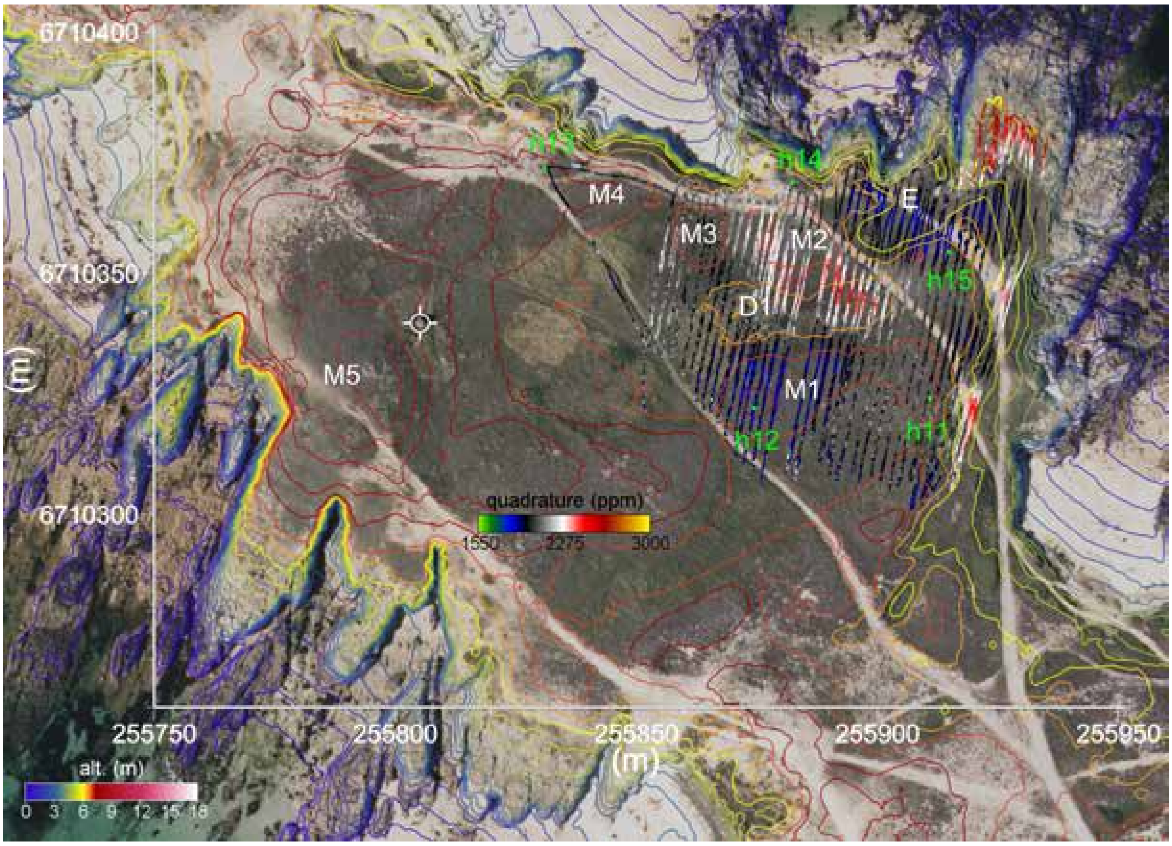

Fig. 15 – Electrical conductivity estimated by the quadrature signal (see legend fig. 6).
Fig. 15 *– Conductivité électrique estimée par le signal en quadrature (voir légende figure 6).*

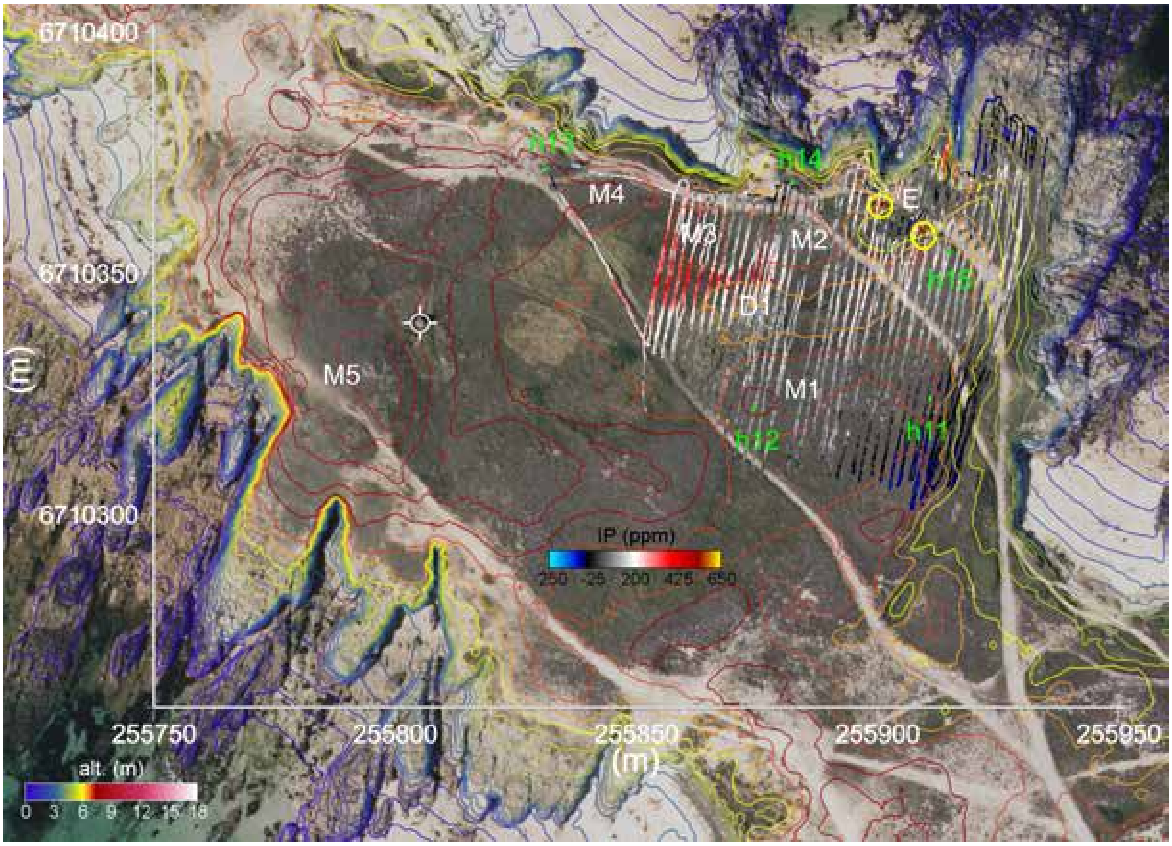

Fig. 16 – Apparent magnetic susceptibility estimated by the phase signal (see legend fig. 6).
Fig. 16 *– Susceptibilité magnétique apparente estimée par le signal en phase (voir légende figure 6).*

mainly to remanent magnetisations such as thermoremanent magnetisations produced by fire. Such magnetisations are not picked up by instruments taking magnetic susceptibility measurements (conductivity meter, susceptibility meter). Only the thermo-alteration effect would be detectable in this case, but the volume involved would be too negligible to generate a significant signal. However, this structure of high apparent magnetic susceptibility reflects the presence of more magnetic materials than the poorly magnetic dune environment. The layer of alterite already mentioned may be locally close to the surface. It certainly has a higher magnetic susceptibility than the levels of the dune. Its magnetic susceptibility may also have been locally increased by the action of pedogenesis or by human occupation, which would have produced magnetic enhancement.

The excavation area (E, fig. 16) is complex. In the north, the high values are related to the remains of a motor embedded in a fault between the rocks. Overall, the excavated area has low values, which reflect the outcropping of the bedrock. This is because the bedrock has a low magnetic susceptibility. At the southern edge of this depression, positive values define an anomaly of more than 2 m at the limit of the yellow contour line (yellow ellipse, fig. 16). This apparent positive magnetic susceptibility anomaly is at the limit of the slope break and the survey profiles are sub-perpendicular to it. This ‘step’ is the source of an artefact caused by the failure to maintain the conductivity meter horizontal and at a constant distance from the ground. However, the consistency of the two successive profiles, first in one direction and then the return, supports the presence of a magnetic source. The electrical conductivity shows no variation in this sector, indicating no metallic mass, but does not indicate any anomaly around the motor remains either. However, a geomagnetic dipole anomaly coincides with these high apparent magnetic susceptibility values. This geomagnetic anomaly could, therefore, indicate the presence of a hearth. However, a slight spatial offset cannot be ruled out, but remains within the relative inaccuracy of the satellite positioning of the two instruments. These findings, therefore, support the probable presence of a hearth at the edge of the area stripped in the 1930s.

A second individual analogous positive anomaly is located about 10 m to the NW (yellow circle, fig. 16). However, in this case, it is associated with a very strong geomagnetic dipole anomaly whose dipole axis is very far from magnetic north, suggesting the presence of a ferrous metal artefact, such as that which was identified in the 2021 test pit.

3. SUMMARY AND SYNTHESIS

When there is dune surface cover, as in the case of the Port Neuf site, an archaeological hearth seems to produce a moderate geomagnetic anomaly. The attenuation of this anomaly is, therefore, rapid with distance. Its identification is only robust in places where the covering of the hearths is thin, such as in the area excavated in the 1930s (yellow circle close to h15, fig. 14). The anomalies associated with mounds M2 and M3 (fig. 14) are still potential hearth targets but are much more uncertain. Indeed, these anomalies are well associated with variations in apparent magnetic susceptibility, but their positions are shifted. The origin of the geomagnetic anomalies in mounds M2 and M3 could also be the result of a topographic effect associated with a more magnetic fill. To propose a reliable interpretation of the observations, it would be necessary to carry out core sampling or sondage to study the variations in the magnetic properties of the sedimentary column in this area.

Apart from the anomalies associated with the telegraph relay, the isolated anomalies associated with the boulders could be related to recent activity. However, the position of the excavation area observed on the aerial photograph from 1932 does not seem to correspond (red ellipse between E and M2, fig. 17). The Péquart camp is located at the western end of the central depression D1 (red ellipse, fig. 17), while the nearest anomalies are spread along the northern and southern edges of this depression. This aerial view allows us to propose a reconstruction of the position of the past excavation of the four successive years according to the superposition of the diagram published in 1954 (Péquart and Péquart, 1954). The geomagnetic anomalies associated with the SW and SE sides of the excavated area could be associated with the edges of the dig. In this case, an offset of 1.5 m to the east and south would be required to match these edges with the anomalies.

In the vicinity of this excavation area, measurements were made using contact sensors to observe the variations in magnetic susceptibility in situ. The variations observed on three vertical profiles of the same trench, about 0.5 m apart, show strong similarities overall (fig. 18). The two extreme profiles allow the identification of variations associated with the melanisation of certain horizons. These organic levels are associated with low magnetic susceptibility values, as is the surface horizon. These black horizons, therefore, appear to be palaeosols, the horizon of organic accumulation that led to the leaching of iron. Their formation would correspond to three periods without aeolian inputs –including the present one – or at least to a marked slowing down of these inputs. If we can draw a parallel with the loess of China (Maher, 2011), these periods of increased pedogenesis would potentially correspond to warmer and wetter periods. It should be noted, however, that the loess cycles in China are on a different time scale. They are produced by the forcing of the Earth’s orbital cycles, specifically the cycles of precession of the equinoxes, with a period of around 20 ky. Similarly, the pedogenesis of loess, which is more clayey than dune materials, generates a magnetic enhancement of the soil, whereas layers of soil on dune sands cause a depletion of the magnetic phase through iron leaching.

The alternative would be to consider the forcing of dune soil cycles by fluctuations in the extreme wind regime that produces the dunes. At the base of the sedimentary sequence, the Mesolithic deposits are associated with more clayey layers with values two to three times higher than the overlying dune deposits. These layers correspond to the Mesolithic occupation surface on the aforementioned alterite layers, potentially associated or mixed with poorly developed loess. Here, blocks of rubified rock show magnetic susceptibility values up to 2.3 10^{-3} SI, i.e. almost double the values of the surface soil of the Mesolithic occupation, which is a marker of thermal alteration. In contrast, the bedrock reached in the test pits has values more than 10 times lower than the dune levels (<0.2 10^{-3} SI).

The three cycles of aeolian deposition and pedogenesis are clearly identifiable on the two extreme profiles. The dune part of the central profile appears to have much smoother and weaker values, as though there had been a mixture between the surface horizon, which is the least magnetic, and the underlying dune horizons. In the field, as we approach this central profile, the black horizons show a deepening and thinning, as though they correspond to the subsidence of the edges of a trench (fig. 18). The central magnetic susceptibility profile, therefore, seems to correspond to the filling of this trench.

Locally, very high magnetic susceptibility values (> 2 10-3 SI) were measured on the Mesolithic layers uncovered in one of the test pits. From an archaeological point of view, no hearth structures were observable. In view of the values seen on this level, in the vicinity or in the other test pit, such values can only be explained by thermo-alterations producing magnetic enhancement. The measurement of the magnetic susceptibility does not allow us to determine whether the thermo-altered material is still in its place in the hearth floor or whether it has since been displaced. To determine this, it would have been necessary to map the spatial variation of the magnetic field with the devices used in prehistoric caves (Burens et al., 2014; Grussenmeyer et al., 2014; Lévêque et Mathé, 2015). Such a mapping would have allowed either to identify a strong dipolar anomaly of the magnetic field, revealing the presence of a hearth, or the absence of such an anomaly, demonstrating that the high magnetic susceptibility recorded corresponds to hearth discharges. The absence of an archaeological structure identifiable as a hearth is not an argument for rejecting the hearth hypothesis. Such 'magnetic ghosts' are described in the literature (Linford, 2004; Schleifer, 2004; Simon et al., 2012).

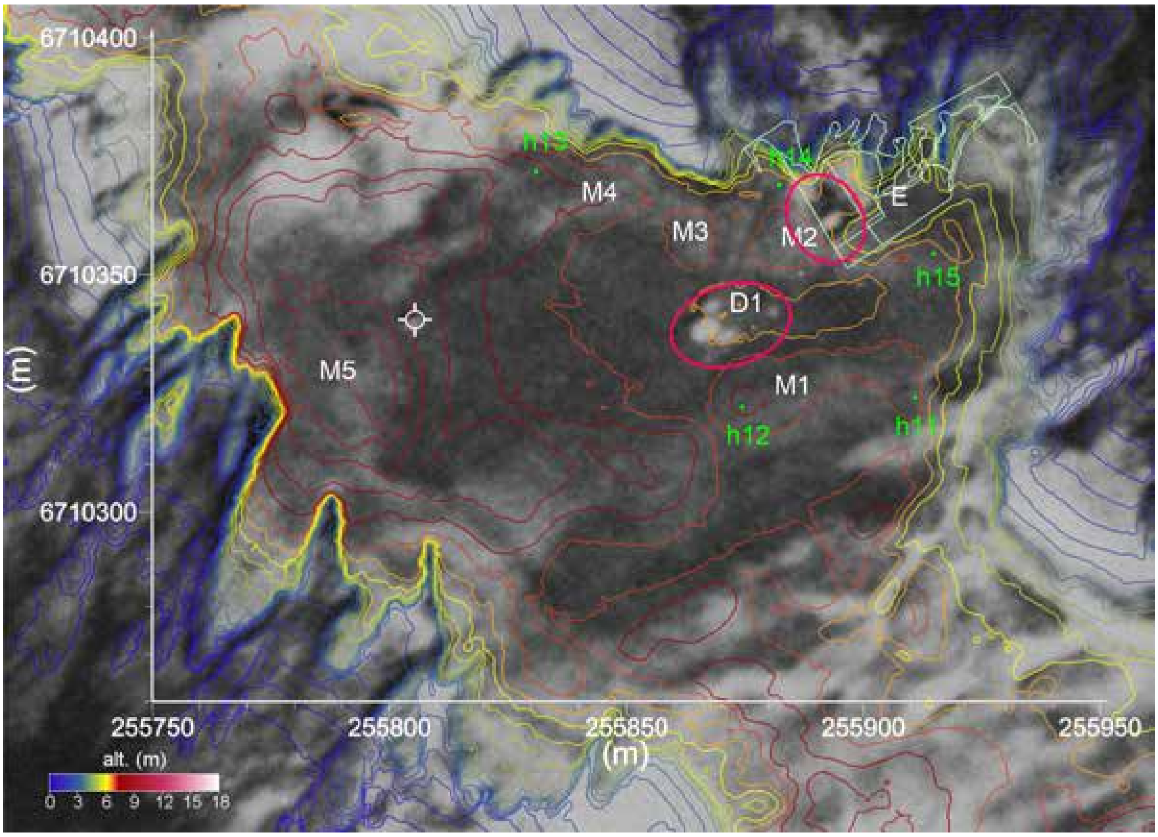

Fig. 17 – Position of the excavations carried out between 1931 and 1932 from an aerial view taken in August 1932. The 1932 image corresponds to the digitisation of a 1932 photograph negative (original IGN archive, Pierre Buttin's collection). The image is projected on a slightly slanted axis to reduce the distortion with respect to the 2019 orthophotograph. The presumed borders of the excavation are shown in green and the rock edges in light green (legend fig. 1).

***Fig. 17** – Localisation des fouilles réalisées entre 1931 et 1932 sur une vue aérienne prise en août 1932. L'image de 1932 correspond à la numérisation d'un contretype argentique d'une photographie de 1932 (original archive IGN, collection P. Buttin). L'image est projetée selon un axe légèrement incliné pour atténuer la distorsion par rapport à l'orthophotographie de 2019. Les limites présumées de la fouille sont figurées en vert et les limites des rochers, en vert clair (voir légende de la figure 1).*

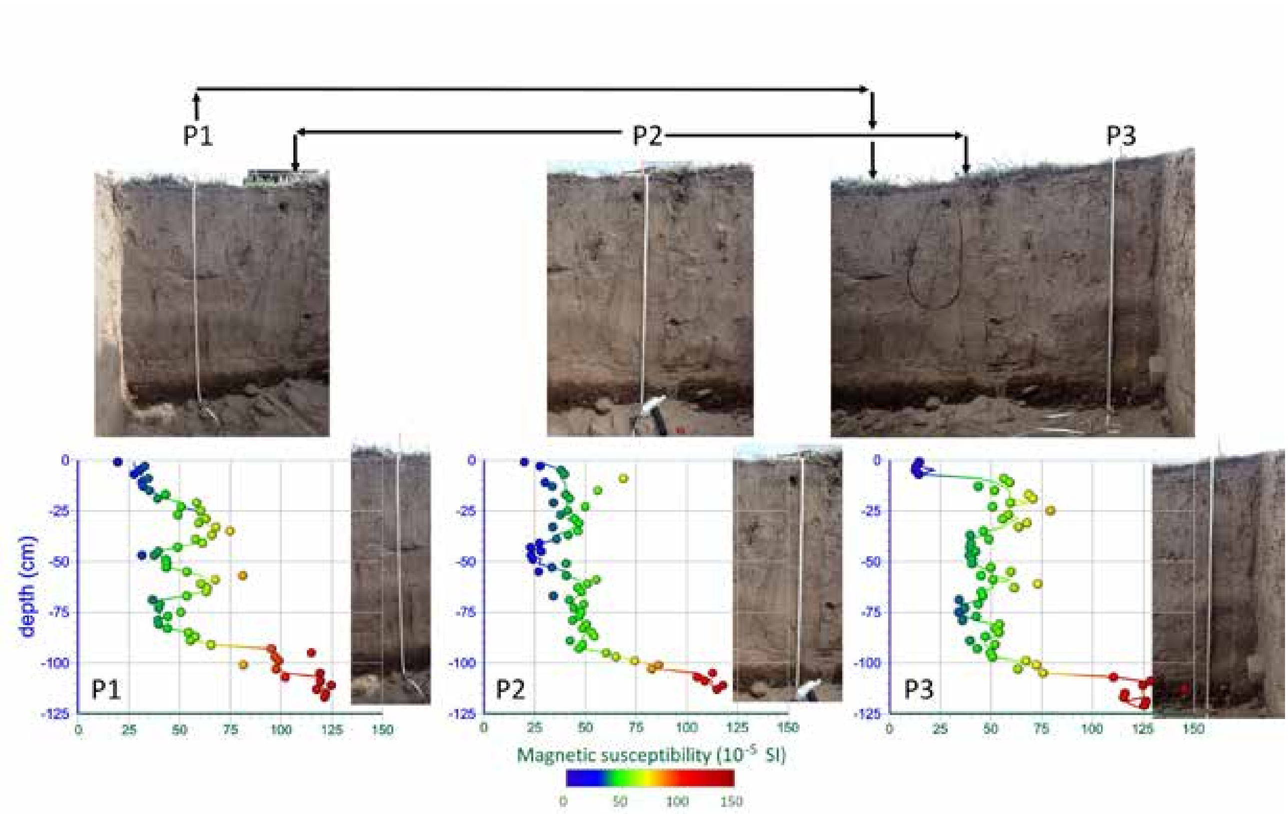

Fig. 18 – Magnetic susceptibility profiles in an archaeological test pit. Three magnetic susceptibility profiles taken less than a metre apart in the same pit. The information provided by the magnetic viscosity is similar and not shown. Profiles P1 and P3 show a similar signal. Profile P2 shows lower values in its upper part, indicating a mixture of materials from the less magnetic upper horizons. Thus, three levels of dune are identified, two capped by a paleosol and the last by a soil, showing a leaching of iron in the A horizon that implies low magnetic susceptibility values. Profile P2 seems to be located on a recent pit whose contours are difficult to identify.
Fig. 18 *– Profils de susceptibilité magnétique dans une fosse de sondage archéologique : trois profils réalisés à moins de 1 m d'intervalle dans une même fosse. L'information apportée par la viscosité magnétique est similaire et non présentée. Les profils P1 et P3 montrent un signal similaire. Le profil P2 présente des valeurs inférieures dans sa partie supérieure, attestant d'un mélange de matériaux issus des horizons supérieurs moins magnétiques. Ainsi trois niveaux de dune sont identifiés, chacun coiffé par un paléosol, ou sol pour le dernier, montrant un lessivage du fer dans l'horizon A, impliquant des valeurs de susceptibilité magnétique faibles. Le profil P2 paraît être situé sur une fosse récente dont les contours sont difficilement identifiables.*

This observation at the scale of a sondage shows the importance of observations made along vertical profiles, but also on the excavation surface. The data collected in this way completes the information obtained by the surface surveys. They allow a more in-depth interpretation of the data obtained on the surface, but also provide information that cannot be observed visually.

4. RECOMMENDATIONS FOR FUTURE STUDIES OF COASTAL SITES BY GEOMAGNETIC PROSPECTING

The purpose of this article is not to produce a plan for the use of geophysical or magnetic methods for geophysicists. It is rather to present them to archaeologists wishing to use them on their sites, to show how to proceed to obtain the best results possible. A part of this concerns what we could improve, or the instruments that could be developed to adapt our approaches to the problematic of the geophysical study of coastal archaeological sites, particularly to the detection of hearths.

4.1. Geopositioning

Given the unknowns about the intensity of the magnetic sources, their contrast with the surrounding materials and the depth of their burial, it is necessary to carry out a 'total field' survey (for geomagnetic field intensity), to be certain of being able to detect all potential sources. In addition, it is preferable to ensure the geopositioning of the measurements using a total station for laser-tracking. Indeed, the determination of the position of the spatial reference (antenna/reflector) can be increased from 1 per second using common GNSS up to 20 per second with the most powerful total stations. Accuracy also increases from a range of a few decimetres to centimetres using GNSS devices coupled to magnetometers to a range of centimetres or millimetres with a total station. The use of a miniature GNSS system with correction would allow centimetric geopositioning in planar space at rates that could reasonably reach five measurements per second. The vertical accuracy would remain lower than with a total station.

This 3D centimetric geopositioning will be all the more important as high spatial resolution 3D surveys will be implemented during excavation. Indeed, the integration of all the magnetic field intensity measurements into a common point cloud will require the precision of a total station.

To ensure repeatability of georeferencing, it is preferable to establish local reference points prior to any survey. If these points are to be within the survey area, non-magnetic materials such as brass, marine stainless steel (reference A4), wood or plastic should be used to mark them, so as not to disturb the magnetic signal.

4.2. Topography

It is preferable to plan the setting up of a survey to optimise the direction of the axis of the profiles to be covered so as to minimise variations in elevation (close to an East–West direction to minimise operator artefacts in geomagnetic prospecting). It is also preferable to foresee the placement positions of the total station to cover the entire target area, without masked areas. To prepare for these aspects, a digital terrain model (DTM) is required. In France, in the areas currently covered by Litto3D® coastal LiDAR surveys, a metric resolution DTM is available up to at least an altitude of 10 m and a distance of 2 km inland from the coast[1]. For areas not covered, the RGE ALTI® 1m[2] provides similar information, but the altitude is only known to the decimetre whereas Litto3D® gives a centimetric accuracy. Artefacts do, however, appear in RGE ALTI®, in the connection zones between the different data sources used to build this model.

To obtain a more accurate elevation model, photographic coverage of the site can be made by drone, for example during the geophysical surveys. Photogrammetric processing of this coverage can then be used to obtain a digital elevation model (DEM) with sub-decimetric to centimetric spatial resolution depending on the flight parameters. Although a model with such a resolution is not necessary to define the implementation of geomagnetic prospection, in the future, the deliverables of a geomagnetic survey should correspond to a map of the sources and not of the anomalies they produce. For this, precise information on the microtopography must be integrated, requiring a DTM with centimetric resolution. Indeed, to obtain a geomagnetic signal with strong dynamics, it is necessary to be as close as possible to the source, i.e. to the ground surface. The microtopography generates a signal related to the contrast between the magnetic properties of the air and those of the ground. It is, therefore, necessary to take microtopography into account in future data processing algorithms for locating sources.

4.3. Apparatus

Similarly, the verticality error between the reflector and the sensors, linked to the failure to maintain the horizontality of the carried device during ascents or descents, generates spatialisation errors. These errors must be corrected to improve data quality. The change in incline can be determined from the change in altitude. However, this determination is not without uncertainty. Correcting this artefact at its source avoids the need to apply such an imperfect correction. To this end, a prototype carried device is being developed that will maintain the verticality between the reflector, the target of the laser tracking, and the magnetic field intensity measurement sensors. This new device will considerably reduce positioning errors linked to the problems of parallax deficiencies between the operator's perception of the relative position of the reflector in relation to the sensors and the horizontality of the device, which it is not always possible to maintain.

4.4. Complementary data

Improving the quality of the information provided should not only mean improving the geomagnetic survey protocols used or the processing of the data collected. It is also important to produce complementary data. Two types of complementary data can be distinguished. The first concerns the use of complementary geophysical imaging methods, which explore the environment based on properties of the ground other than magnetic properties. The second type of data results from a change of scale in the observation of magnetic properties, in contact with the archaeological layers after they have been exposed by excavation. Prior to the examination of these stratigraphic units, the collection of magnetic susceptibility measurements or high spatial resolution geomagnetic prospecting can provide information that is not visually observable, as a complement to the measurements carried out before stripping.

In the first of these types of data, the use of a conductivity meter shows the interest of observing the properties of the propagation of electrical currents. Depending on the nature of the remains, this property makes it possible to distinguish between clay enrichment (increase in electrical conductivity) or, on the contrary, stoniness (decrease in electrical conductivity). To increase the spatial resolution, but also to specify the depth of the variations observed, the electrical resistivity must be measured. This method is more complicated as it requires electrodes to be inserted into the ground. The distance between the electrodes determines the depth of investigation. Implemented along lines of electrodes or with fixed-distance electrodes mounted on a frame, this method allows either vertical profiles or maps to be made. If the electrical and magnetic property contrasts of the materials present are not correlated, then the information obtained will be complementary. Because of the relative speed of coverage of a surface with geomagnetic prospecting or with a conductivity meter, electrical methods are generally implemented on relevant sectors identified based on the information provided by the former. If the ground surface is sufficiently regular, then a ground-penetrating radar survey can be carried out. This will determine the presence of areas of abrupt material change, which are reflectors of the high frequency (hundreds of MHz) electromagnetic wave emitted.

Measuring apparent susceptibility with a conductivity meter provides a measurement of magnetic properties on a geomagnetic prospecting scale. By comparison with the geomagnetic information, its variation should, therefore, make it possible to determine the geomagnetic anomalies associated with sources carrying a strong remanent magnetisation, which is usually thermoremanent in archaeological contexts. Indeed, geomagnetic anomalies not associated with strong positive magnetic susceptibility anomalies are probably areas of strong thermoremanent magnetisation and, therefore, of a hearth still in place.

4.5 Nesting the scales of analysis

Moving from the scale of the site to that of the soil profile provides important information for understanding. Indeed, each soil has specific magnetic properties according to the dominant soil processes. The broad outlines of the dominant processes were described by the pioneer of the subject, E. Le Borgne (1955 and 1965). Since then, thanks to paleoclimatic studies of Quaternary loess, the role of rainfall has been identified. However, neither this last parameter nor those identified by E. Le Borgne can explain all the variability of the magnetic properties of the soils observed. In an area such as France, differences in rainfall are too small to be an explanatory factor. Therefore, our understanding is limited and, consequently, only observations using contact sensors can determine whether the soil is magnetically enhanced at the surface or, conversely, it is magnetically depleted in the organic horizon, as in the case of the dune soils presented. The two types of instruments to be preferred are susceptibility meters and magnetic viscometers. The former quantify an overall response of all soil constituents. Magnetic minerals, which have a very high susceptibility, are generally present in trace amounts. As a result, this quantity is strongly influenced by the relative content of the so-called non-magnetic minerals (diamagnetic: quartz, calcite, = slightly negative value; paramagnetic: ferromagnesian minerals, clays, = positive value). Magnetic viscosity has the advantage of being independent of these non-magnetic minerals since it only looks at the unstable part of the remanent magnetisation borne by ferromagnetic minerals, in the broad sense, of nanometric size, called superparamagnetic. This nanometric phase is classically produced by pedogenesis or by thermo-alteration. By comparing different soil profiles, the joint observation of the variations of these two quantities makes it possible to determine the materials showing a magnetic enhancement that may be associated with thermo-alteration processes from those more likely to be of pedological origin, based on the differences in signatures observed.

These soil profiles can be accessed either by coring or archaeological test pits. Coastal erosion has also provided access to profiles in the vicinity of the target site, allowing easy examination of the spatial variability of the magnetic signature of the surface cover. Such measurements can also be made during an excavation. The presence of a geophysicist during a whole excavation does not appear to be the best solution. Similarly, the production of a susceptibility or magnetic viscosity variation map is laborious. Consequently, it is necessary for the excavator to become familiar with the use of these instruments. A phase of analysis to understand the sources of variability of magnetic susceptibility and viscosity must be conducted by a geophysicist. Then, once the geophysicist has defined the protocol, it will be up to the excavator to make the measurements. However, this approach does not allow the detection of magnetic ghosts, i.e. hearth floors leaving no significant visible trace.

One solution is to carry out geomagnetic surveys with sub-decimetric spatial resolution, similar to what is done in prehistoric caves (Burens et al., 2014; Grussenmeyer et al., 2014; Lévêque et Mathé, 2015; Jaubert et al., 2016). Necessarily, due to the attenuation of the signal with distance, these surveys must be done in contact with the archaeological layer. This implies that the targeted archaeological surface must be cleared over a significant area in order to obtain an image of exploitable space. The use of iron pegs for the archaeological grid is, therefore, not recommended. Instead of the commonly used metal nails, plastic or wooden equipment should be used. It is also necessary to allow for the time needed to carry out the prospection in the absence of any moving metal object or other source of magnetic disturbance meaning that a halt in excavation activities would be necessary. Finally, once the image of the magnetic field variation has been obtained, it is necessary to go back over the site to identify the origin of the anomalies observed by means of magnetic susceptibility measurements.

Because of the need for a spatialised measurement to obtain an image, this approach, although very informative, requires complex instrumentation. An alternative to this approach would be to proceed as for the detection of networks in public works, through the identification of anomalies by the detection of extreme values. This would require an instrument that is quick to use on the excavation site without requiring interruption of the excavation. An instrument is, therefore, needed that determines strong spatial variations in the magnetic field over short distances so that variations induced by disturbances produced a few metres away by other excavators are not detectable. Such a signal can be obtained with a device that determines the differences in magnetic field strength over a short distance. For the signal to remain detectable, a distance of a few decimetres is required. Such a gradiometer does not yet exist but seems easy to design.

In the presence of burnt or rubified materials, the excavator could search for the presence of a hearth by looking for zones of magnetic enhancement with the susceptibility meter or viscometer. If they identify such a zone, then they can then locate the hearth by looking for magnetic field gradient peaks. At our latitude, the hearth should be approximately halfway between the positive and negative peaks. If no significant magnetic field anomaly is detected at the level of the magnetic enhancement zone, then this means that a hearth emptying zone is present.

This shows that geophysical investigations can also be carried out during an excavation. The archaeological observations made during the excavation must also be cross-referenced with the geophysical information (this work remains to be done in the case of the test pits at Port Neuf). The interest is to compare the geophysical interpretations with the reality of the field. In case of discrepancy, the new data will allow us to identify the interpretation error and explain its origin. The geophysicist, therefore, acquires new experience that will allow them to adapt their investigation protocol for the study of another similar site. The interpretation of their data will be improved and thus better guide archaeological excavations on new sites. Open areas can be limited and areas not yet in danger of erosion will be preserved.

The geophysicist's interpretation is based on the spatial coherence of the nature of the physical contrasts observed. However, the study of a site cannot be limited to a geophysical study as this cannot provide chronological data. Archaeological excavation provides stratigraphic information that is otherwise inaccessible. Geophysics makes it possible to widen the area of investigation and to place an excavation in its context. For this reason, it is important that the geophysicist carries out their surveys before any test pit is made. Indeed, a test pit brings about modifications of the spatial variation of the physical properties of the environment. It is, therefore, important that archaeologists and geophysicists work together.

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The digitization of the countertype of the aerial photograph of 1932 (31e RAO Esc. 15 19-8-32 Rec no. 3, cl no. 10, collection Pierre Butin) was carried out by Philippe Lévêque on a scanner V850 (Epson) of the photography section of the lycée professionnel Victor-Laloux, 6 avenue Monge, 37200 Tours, France.

NOTES

(1) https://services.data.shom.fr/static/specifications/DC_Litto3D.pdf
(2) https://geoservices.ign.fr/rgealti

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Coast Concepts in Norwegian Stone Age Archaeology

Les modèles conceptuels du littoral dans l'archéologie paléolithique norvégienne

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Abstract: The sea and coast have always been central to Norwegian Stone Age research, and most of the archaeological sites we know from the period are located along the coast. Natural conditions associated with the land uplift after the last Ice Age have provided unique opportunities for exploring the coastal settlement of the Stone Age. The general sentiment in the literature is that the Stone Age hunter-gatherers on the Scandinavian Peninsula mainly hunted, moved and settled along the coastline. Less attention has been paid to the areas behind the coast – the coastal hinterland –, although a number of sites are also known further inland and in mountain areas. Central to this perception is the 'shoreline model', which has developed gradually over a century of research. While this model has resulted in the identification of thousands of sites, it does have a simplistic eco-functional foundation. Is it possible that such a conceptual starting point in some ways limits our opportunities to explore the coastal landscape from other perspectives, or even prevents us from discovering archaeological material in other landscape settings?

To explore this possibility, we ask whether there are conditions in our research, or circumstances in its underlying framework that have contributed to the strong coastal focus. How did today's concepts and knowledge of the Stone Age coastal settlement come about, and what roles have been played by the natural environment and topographical character of the landscape? How has this influenced our perception of Stone Age settlement, and what other factors have been important?

We identify five main factors that each work toward strengthening the coastal focus in different ways. Furthermore, we examine strengths and challenges of the coastal concepts employed in present research and suggest possible future exploration of Stone Age coasts within a broader perspective of a 'landscape of practice'. Although the coast was central to the people of the Stone Age, this article argues that a one-sided focus on the coast and coastline may hinder a broader knowledge of Stone Age society and human life.

Keywords: Stone Age, Mesolithic, shoreline displacement, coastal adaption, archipelago landscape, hinterland, site location, archaeological survey methods, site concepts, Norway.

Résumé : La mer et la côte ont toujours été au centre des recherches sur la Préhistoire récente en Norvège, et la plupart des sites archéologiques de cette période que nous connaissons sont situés le long de la côte. Les conditions naturelles associées au soulèvement des terres après la dernière période glaciaire ont fourni des occasions uniques pour explorer les habitats côtiers mésolithiques. La vision générale que l'on peut se faire à travers la littérature est que les chasseurs-cueilleurs du Mésolithique de la péninsule scandinave chassaient, se déplaçaient et s'installaient principalement sur le littoral, et qu'une moindre attention a été accordée aux zones situées dans l'arrière-pays côtier, bien qu'un certain nombre de sites soient également connus plus à l'intérieur des terres et dans les zones montagneuses. Au cœur de cette perception se trouve « le modèle de la ligne de rivage », qui s'est développé progressivement pendant un siècle de recherche. Bien que ce modèle ait permis d'identifier des milliers de sites, il repose sur un fondement éco-fonctionnel simpliste. Est-il possible qu'un tel modèle conceptuel limite d'une certaine manière nos possibilités d'explorer le paysage côtier à partir d'autres perspectives, ou même nous empêche de découvrir du matériel archéologique dans d'autres paysages ?

Pour explorer cette question, nous nous demandons s'il existe des conditions dans notre recherche, ou des circonstances dans le cadre de la recherche, qui ont contribué à la forte concentration de sites sur le littoral. Comment sont nés les concepts et les connaissances actuelles sur les établissements côtiers de la Préhistoire récente, et quel rôle a joué l'environnement naturel dans cette région, le caractère topographique du paysage ? Comment ce dernier a-t-il influencé notre perception du peuplement ancien, et quels autres facteurs ont été importants ?

Nous identifions cinq facteurs principaux, chacun contribuant à renforcer de différentes manières l'accent mis sur la côte. En outre, nous examinons les forces et les défis des concepts côtiers utilisés dans la recherche actuelle, et nous suggérons une exploration future possible des côtes passées dans une perspective plus large de « paysage de la pratique ». Bien que la côte ait été centrale pour les peuples mésolithiques et néolithiques, cet article soutient qu'une focalisation unilatérale sur la côte et le littoral peut entraver une connaissance plus large de la société et de la vie humaine à cette période.

Mots-clés : Préhistoire récente, Mésolithique, déplacement du littoral, adaptation côtière, paysage d'archipel, arrière-pays, localisation du site : méthodes d'enquête archéologique, concepts de site, Norvège.

INTRODUCTION

The coast plays a major role in Norwegian Stone Age archaeology. Thousands of sites dated to the Mesolithic and Early/Middle Neolithic (9300-2350 cal. BC) are situated close to or directly at the shoreline (fig. 1), testifying to the economic, social and ritual significance of the coastal zone during these periods (Schülke et al., in this volume). However, this 'normality' of the coastal site seems to have prevented further reflections around concepts used in studies of settlement patterns in these regions. This is prominent when Norwegian coastal Stone Age sites are brought into discussions of marine adaptations or settlement in coastal areas in a wider European context. It becomes clear that the prevailing concept of the coastal settlement is often vaguely defined, and that the focus on settlements along the shoreline has drawn attention away from the past complexity and variation in human–landscape relations. The concept also poses a problem related to finding Stone Age sites in other locations and, while this is specific to each geographical region and often reflects an opposite situation – with the focus on inland sites –, we believe the challenges faced are not unique to Norwegian archaeology.

This article identifies the dominant coastal concept in Norwegian Mesolithic archaeology and its historical and epistemological background, providing perspectives on how researchers have perceived patterns of coastal sites. This extends from early geoarchaeological studies focusing on the Holocene land uplift and the 'shoreline model', to more processually oriented divisions of landscapes and their environmental characteristics. We also discuss the main factors working to strengthen the dominant coast and shoreline concept at the expense of other approaches and identify future perspectives involving a coastal 'landscape of practice'.

1. COAST CONCEPTS – THE NATURAL GEOGRAPHICAL BACKGROUND

The western and northern coasts of the Scandinavian Peninsula are characterized by a diversified archipelago landscape with an exposed outer coastal zone, an inner coast protected by islands, and deep fjords offering easy access to inland areas with forests and mountain terrain. This coastal zone forms a nearly continuous 5-50 km broad strip that stretches from Gothenburg, Sweden, in the south, all the way to the North Cape: a journey of about 2500-3000 km by boat (fig. 1). While the distances between islands in the archipelago are often small, there are areas with long stretches of open sea (>20 km) between islands or the mainland and islands. The coastal mainland of south-eastern Norway is relatively flat, with mountain areas up to an altitude of around 2000 m a.s.l. further inland (Puschmann, 2005). Flat areas also exist along the coast of western and northern Norway, although often only comprising a narrow strip, with fjords and high coastal mountains more dominant in these regions. In total, these landscapes have offered countless places with good natural harbours and suitable places for settlements, well protected from wind and waves (fig. 2). The Norwegian coastal zone is, and has been since the Ice Age, rich in marine and terrestrial resources, such as fish, shellfish, birds, marine and land mammals, as well as a diverse flora with edible nuts and berries (Hufthammer, 2006; Jonsson, 2018). There is no doubt that boat transport was a necessity for movement between sites, resource exploitation, transport of goods and social integration (Bjerck, 2009; Berg-Hansen 2018, p. 82-86; Gjerde, 2021).

In this paper, we focus particularly on the coast of south-eastern Norway, which is centrally located in this archipelago landscape, but the discussion is relevant to Norway as a whole. In the coastal areas of southern Norway, large nemoral and coniferous forest areas replaced a tundra vegetation during the Early Mesolithic (Sørensen et al., 2014b), while a maritime forest of birch expanded in the north (Sjögren and Damm, 2019). Around c. 4000 cal. BC, a process of gradual degeneration of the forests towards more open birch woodland started along parts of the Atlantic facade, which eventually led to an open coastal heathland (Hjelle et al., 2018; Sjögren and Damm, 2019). In recent times, farming and fishing have been closely integrated along the coast, and fisher-farmers settled close to the shores (Gjerdåker, 2002, p. 120-123). When the idea of Stone Age settlement patterns was formed in the early 20th century, the importance of marine resources was clearly visible to the researchers in the regions they studied, and the shorelines themselves stood out as the optimal location for exploiting the resources offered by the sea.

Another factor in the understanding of Stone Age settlement patterns is the tidal range. In south-eastern Norway this range has always been small, less than 0.5 m at spring tide since c. 8000 cal. BC (Uehara et al., 2006), but varying more along the Norwegian Atlantic west

Fig. 1 – A nearly continuous archipelago landscape stretching from Gothenburg to the North Cape, approximately 2500-3000 km by boat along the west coast of the Scandinavian Peninsula. The main map shows only the southern parts of this area (map by A. Mjærum, Museum of Cultural History [MCH], University of Oslo [UiO]; distribution of sites from Askeladden, 2022; imagery reproduced from© Service Copyright EEA Copenhagen/the GEBCO_2020 Grid, GEBCO Compilation Group [2020] GEBCO, 2020 Grid [doi:10.5285/a29c5465-b138-234d-e053-6c86abc040b9]).

***Fig. 1** – Un paysage d'archipel presque continu s'étend de Göteborg au Cap Nord, soit une distance d'environ 2 500 à 3 000 km en bateau le long de la côte ouest de la péninsule scandinave. La carte principale ne montre que les parties sud de cette zone (carte A. Mjærum, musée d'Histoire culturelle d'Oslo [MCH], université d'Oslo [UiO]; ; distribution des sites d'après Askeladden, 2022 ; images reproduites à partir de© Service Copyright EEA Copenhagen/the GEBCO_2020 Grid, GEBCO Compilation Group [2020] GEBCO 2020 Grid [doi:10.5285/a29c5465-b138-234d-e053-6c86abc040b9]).*

Fig. 2 – Many coastal shores in Norway are easily accessible by boat and well protected from waves and wind (photo T. Ingebrigtsen).
***Fig. 2** – De nombreux rivages norvégiens sont facilement accessibles par bateau, bien protégés des vagues et du vent (cliché T. Ingebrigtsen).*

coast. However, combined with relatively steep shores, the tidal zones are generally small, which provided great possibilities for settling close to the low water mark. Furthermore, activities such as fishing are possible at various depths, either from dry land, by standing on rocky outcrops along the shore, or from boats close to the shore as well as further from land.

Apart from general topographical characteristics, isostatic uplift has continuously formed and reshaped the archipelago landscape during the Holocene. This process of land uplift has played a crucial role in the formation of the idea of the importance of former coastlines for Stone Age settlement patterns.

2. THE FORMATION OF THE 'SHORELINE MODEL' IN NORWEGIAN STONE AGE RESEARCH

In Norwegian Stone Age studies, researchers' perception of the coast and its characteristics has been essential for establishing a basic location model that connects settlement sites to the seashore. This so-called 'shoreline model' is based on the notion that settlement sites in general were situated very close to or at the shoreline (here: fig. 3; Berg-Hansen, 2009). This model has played a major role since the early 20th century, especially in the survey of Stone Age sites. It has also been important in the interpretation of the sites and for indirect dating of the settlements. While research the last decades has concentrated on developing the model by specifying topographical attributes, it has seldom been subject to critical discussion (see however Bjørgo, 1988; Bjerck, 1990; Bergsvik, 1991; Bjørgo et al., 1992; Barlindhaug, 1996; Berg-Hansen, 2009; Mjærum 2019; Schülke 2020a and 2020b).

In early 20th century research, an important task was to identify Stone Age sites in the landscape and obtain relative dates of when they were in use. Along the coast, the sites were mainly found in forested areas, located way above the present-day shorelines (fig. 4). By assuming that Stone Age sites were located on the shores when they were in use, a link between geological and archaeological studies of past coastlines was established by using the site locations to date Stone Age sea levels (A.W. Brøgger, 1905; W.C. Brøgger, 1905; Berg-Hansen, 2009, p. 37-42). At the same time, these levels were applied as guides to identify suitable site locations, hence inevitably confirming the model in a circular argument. The significance of the practical application of this framework in the efforts to locate Stone Age sites was emphasised through the systematic surveys carried out in the first half of the 20th century. These surveys succeeded in identifying several hundred Stone Age sites in different parts of Norway, all situated along raised shorelines. Additionally, the knowledge of Holocene shoreline displacements was used for an approximate dating of sites (Nummedal, 1924 and 1933; Petersen, 1944). Many researchers contributed to the consolidation of the shoreline model during this time, and by the 1950s the model had obtained an axiomatic status (Berg-Hansen, 2009, p. 35-51 and p. 73-82).

During the second half of the 20th century, the consolidation and development of the shoreline model continued through extensive archaeological rescue projects in coastal areas on the Norwegian west coast, where site features and environmental factors that would possibly have affected the choice of site location in the Stone Age were also debated (e.g. Bruen Olsen, 1992; Simpson, 1992; Nærøy, 2000; Bergsvik, 2002). Rescue projects were also undertaken in the inland and mountain areas of southern Norway, where similar perspectives on shoreline-based location were transferred to lakes and riverbanks (e.g. Hagen, 1959; Martens and Hagen, 1961; Johansen, 1979; Indrelid, 1994; Boaz, 1998; here: fig. 3). During this time, the model was rationalised through a series of economic and functional arguments, connecting site location to economically favourable spots where certain resources could be easily exploited, or to topographically suitable places that would provide good natural harbours for small kayaks or canoes (e.g. Martens and Hagen, 1961; Bjerck, 1990; Bergsvik, 1991). On the coast, the sites were associated with the importance of marine resources and boat transport, while in the mountains large game drift hunt and fishing were viewed as essential locating factors (Berg-Hansen, 2009, p. 42-65).

Over the last two decades, the model has remained highly relevant, and is to a large degree supported by

Fig. 3 – The 'shoreline model' is based on the notion that settlement sites in general were situated very close to or at the shoreline, both at the coast and by watercourses inland. The photo, showing the excavated area of a small inland lake Stone Age site, Søndre Oddenvika in Stange, Hedmark County, illustrates how these sites were situated relative to the shoreline (photo MCH, UiO).

***Fig. 3** – Le* shoreline model *s'appuie sur l'idée selon laquelle les sites de peuplement étaient généralement situés très près du littoral ou sur le littoral, à la fois sur la côte et le long des cours d'eau à l'intérieur des terres. La photo, qui montre la zone fouillée d'un petit lac de l'intérieur du pays, Søndre Oddenvika, à Stange, dans le comté de Hedmark, illustre la façon dont ces sites étaient situés par rapport au rivage (cliché MCH, UiO).*

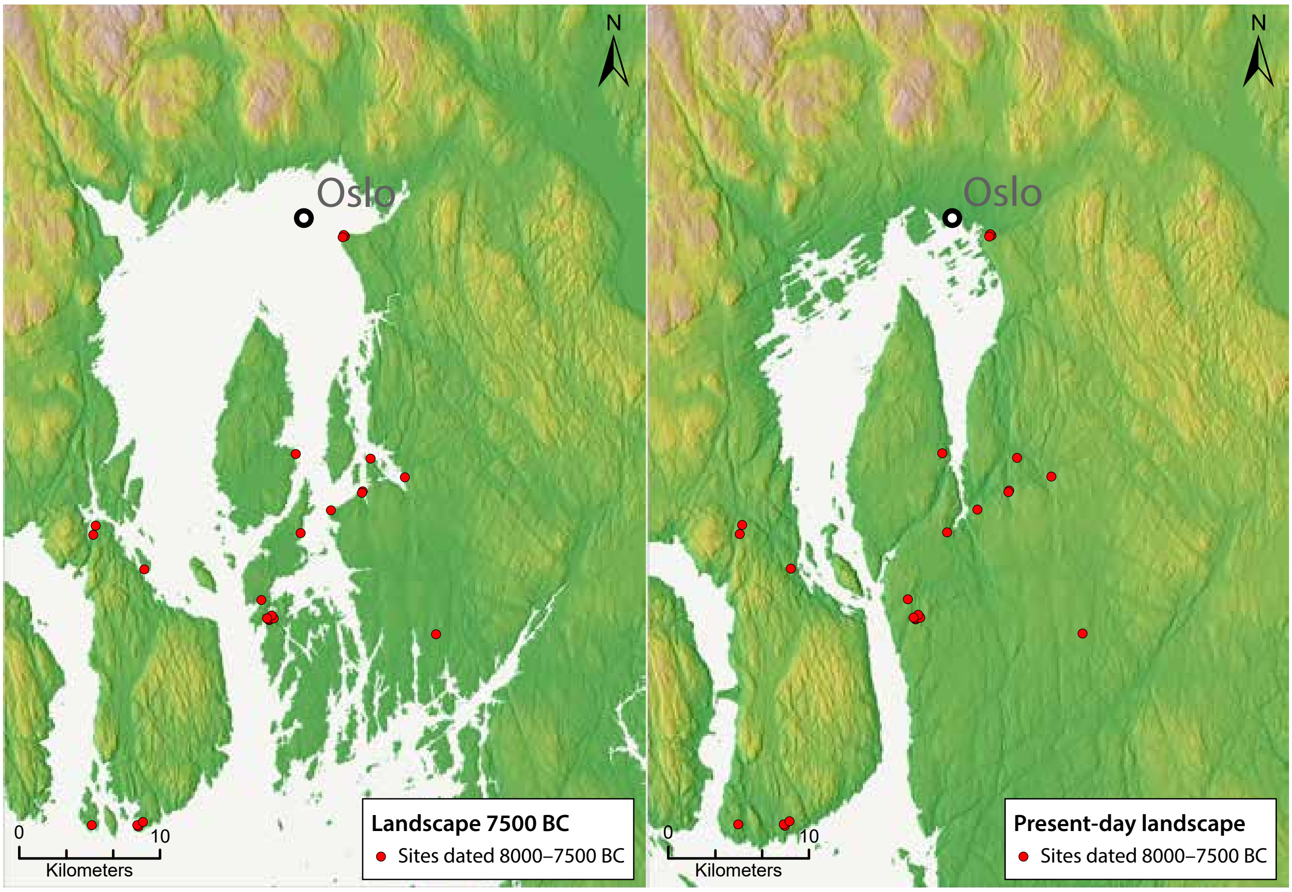

Fig. 4 – Due to the Holocene land uplift, the coast of the inner part of the Oslo fjord changed significantly during the Mesolithic. Therefore, we find Mesolithic coastal sites, which originally were situated by the shore, far from today's coast. Red dots indicate sites that are interpreted as shore-bound around 8000-7500 cal. BC. The black circle indicates the position of the present-day city centre of Oslo (map by I. Roalkvam, DACH, and A. Mjærum, MCH, UiO).

***Fig. 4** – La côte de la partie intérieure du fjord d'Oslo a considérablement changé au cours du Mésolithique en raison du soulèvement des terres à l'Holocène. Les points rouges marquent les sites qui sont interprétés comme étant liés à la côte, vers 8500 cal. BC, 7500 cal. BC et 4000 cal. BC. Le cercle noir indique la position de l'actuel centre-ville d'Oslo (carte I. Roalkvam, DACH, et A. Mjærum, MCH, UiO).*

close correspondence between the results of independent dating methods such as radiocarbon dating and typological indicators, and the dates indicated by reference to relative sea-level change (Bjerck, 2008a; Bjerck et al., 2008; Simpson, 2009; Breivik et al. 2018; Solheim and Persson, 2018; Fossum, 2020; Jørgensen et al., 2020; Solheim, 2020; Tallavaara and Pesonen, 2020; Damlien et al., 2021; Mjærum, 2022; Roalkvam, 2022). At the same time, increased attention has been paid to other approaches than site location, focusing on holistic and long-term perspectives on landscape use and revisiting of sites (e.g. Bjerck 1990; Koxvold, 2013; Mansrud and Eymundsson, 2016; Dugstad 2020; Schülke, 2020b; Berg-Hansen et al. 2022). Large development projects along the coast do however continue to produce overwhelming evidence for the significance of the coast for Stone Age settlement, economic activities and transport (e.g. Bergsvik, 2002; Glørstad, 2004; Bjerck, 2008b; Hesjedal et al., 2009; Skandfer et al., 2010; Solheim and Damlien, 2013; Jaksland and Persson, 2014; Nergaard et al., 2016; Solheim, 2017; Reitan and Sundström, 2018; Bondevik et al., 2019; Bergsvik et al., 2020; Damlien et al., 2021). Although no remnants of boats have been found (however, see Gjerde, 2021), the central role that watercraft must have had for communication and for traversing the archipelago has been stressed. It has also been suggested that the boat was an important structural element for the social organisation of coastal hunter-gatherers, which must have brought with it a specific mentality and way of living (Bjerck, 2008c and 2009; Glørstad, 2013). The significance for people's worldview and relations with their environment has also been emphasized (Svendsen, 2018; Schülke, 2020b). The use of boats is further considered to have been decisive during the first colonisation of the Scandinavian Peninsula (Bang-Andersen, 2003; Bjerck, 2009; Fuglestvedt, 2009; Nyland, 2012; Breivik, 2014; Berg-Hansen, 2017 and 2018).

The evidence for the significance of the coast for Stone Age settlement in Norway is not in dispute. We will argue, however, that the strong focus on the coastline, and the almost automatic linking of sites to this line and exploitation of aquatic resources, has prevented the exploration of alternative site locations in coastal areas, the significance of other aspects of the sites, and the broader use of coastal landscapes.

3. CAUSE AND EFFECT OF THE SHORELINE MODEL

Over time, we have seen development in the coast concepts and shoreline model, resulting in the identification of a very high number of Stone Age sites (c. 10 400 in south-eastern Norway by 2022, Askeladden database, 2022; here: fig. 1), although these concepts have only been subject to a limited degree of systematic scrutiny or critical discussion. The shoreline model is still prevalent as the main concept for the Stone Age coastal settlement and strongly influences our perception of the period. It also functions as a main guide in the search for new sites, and no comprehensive alternative models for locating sites have been developed. This poses a challenge to, and most likely biases, our understanding of Stone Age landscape use as it leads to difficulties in finding sites in other locations and, possibly, with other functions. The reasons underlying the persistence of the concept are diverse and are linked to theoretical and methodological challenges, natural conditions, and the administrative frames of archaeology. In the following, we identify five main factors that have influenced the Norwegian Stone Age coast concepts and shoreline model, factors that at the same time have prevented the exploration of alternative models for site location and landscape use:

- production of archaeological data – theoretical considerations,
- shoreline displacement,
- Stone Age surveys – methodological premises,
- the site concept,
- modern development activity.

3.1 Archaeological data production

An important factor that has enabled the success of the shoreline model is the general lack of critical theoretical approaches to archaeological data production, particularly field methods and practices. Naive positivist approaches have mainly focused on how to scientifically control the processing of already excavated and collected material (e.g. cataloguing, measuring, sampling and scientific analysis), failing to consider the highly subjective and experience-based observations and selection processes involved in archaeological data production (Wylie, 1992; Solli, 1996; Hodder, 1999; Berg-Hansen, 2009). This lack of critical awareness of the researcher's creative influence on the archaeological record or the historicity of scientific knowledge (Gadamer, 1997[1960]; Olsen, 1997, p. 112), has contributed significantly to the confirmation and reproduction of our knowledge about the Norwegian coastal Stone Age. It has also promoted the creation of an axiomatic model that has served as the basis for both data production and interpretation for more than a century. Its combination with simplistic eco-functional explanations has operated as a natural extension of the model, linking the placement of sites directly to the exploitation of marine resources. To avoid this situation in future research, an enhanced focus on, and critical awareness of, the role of preconceptions in data production and interpretations would be advantageous and help to open up the field to alternative approaches.

3.2 The Holocene shoreline displacement

Across large areas of Europe, Stone Age coastlines are submerged and mostly inaccessible to archaeological investigation, strongly affecting our understanding of the exploitation of the Stone Age coast (Gaffney et al., 2007; Astrup, 2018; Schülke, 2020a and refs therein). Although the Holocene shoreline displacement along the coast of Norway represents the opposite situation, it has similarly had a great impact on our perception of coastal settlement, serving as an important element in the success of the shoreline model.

Due to the land uplift after the Ice Age, the relative sea level has changed significantly in most areas. On the Norwegian Atlantic coast, developments are varied with periods of both regressions and transgressions, while in south-eastern Norway the shoreline has continuously regressed since the start of the Holocene. This has left the coastal Stone Age sites situated at different heights above current sea level. Today these sites are situated up to almost 200 m a.s.l., and are commonly located in landscapes far away from the present coastlines (fig. 4). Over past decades, large resources has been invested in developing precise shoreline displacement curves for several regions of Norway (e.g. Møller, 1989; Prøsch-Danielsen, 2006; Romundset et al. 2010, 2011 and 2018; Sørensen et al., 2014a; Romundset, 2021; here: fig. 5). By determining what elevation the sea level would have had at any given time, the displacement curves provide valuable guides for coastal surveys to identify potential areas of Stone Age sites in relation to prehistoric shores (Bjerck, 1990; Bergsvik, 1991; Berg-Hansen, 2009; Simpson 2009; Solheim and Persson 2018).

Within the same frame of thinking, the detailed knowledge of shoreline displacement offered by these curves is used as a strong argument in the dating of sites, independent of C14-dating of organic material or technological/typological dating of artefacts. The combination of the shoreline model – the assumption that the sites were shore-bound – and the displacement curves is thereby used as a method for indirectly dating the activities on the sites. This works especially well in south-eastern Norway, where there has been a continuous drop in sea level since the Ice Age (fig. 4 and 5). Based on the point in time when the sea retracted from the position of an archaeological site, we can determine the earliest possible date (terminus post quem) of that site (Solheim and Persson, 2018; Damlien et al., 2021).

3.3 Survey methods

Although several survey methods are used, test-pitting by shovel in combination with landscape reading is by far the most common and has, since the 1960s, been the

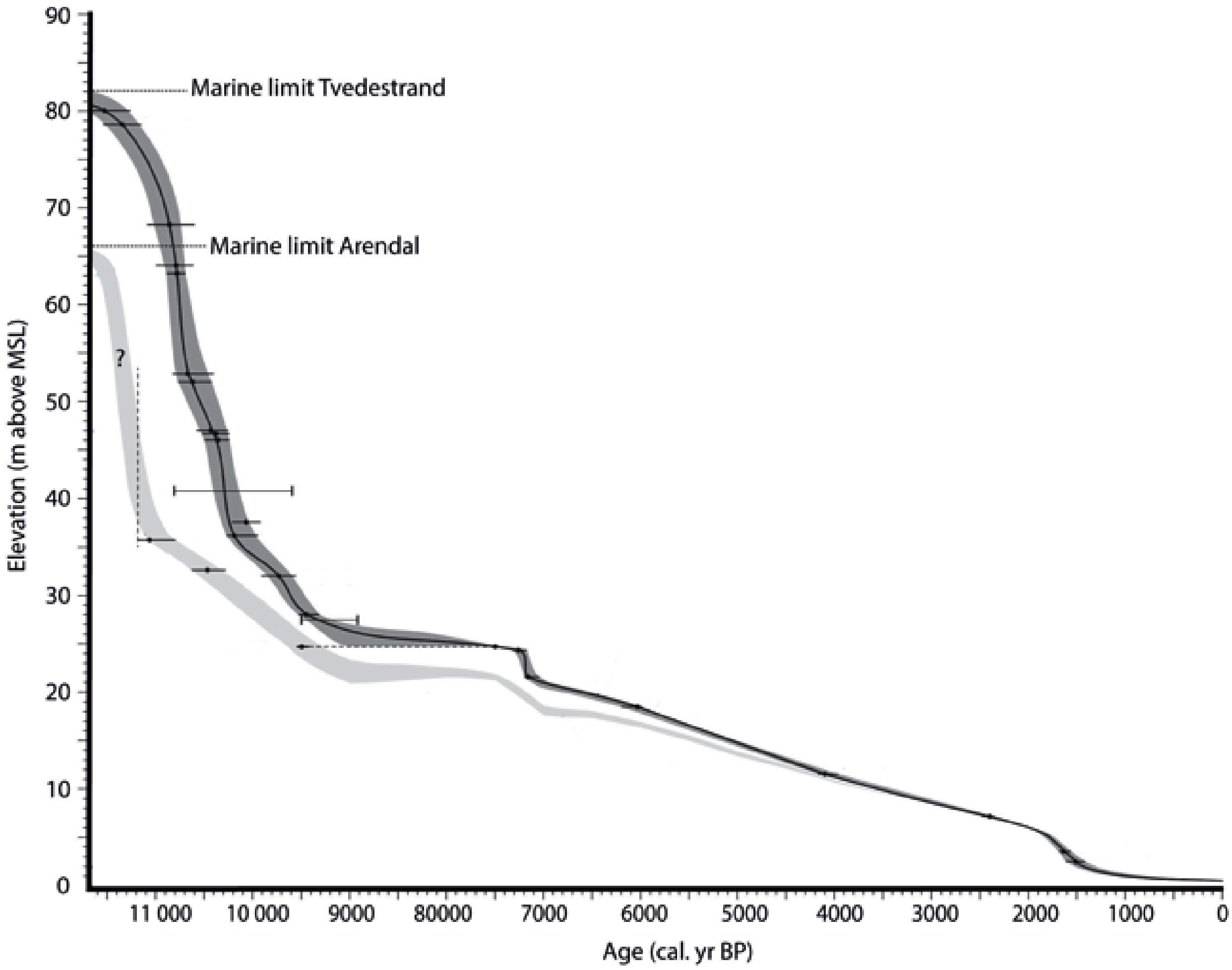

Fig. 5 – Curves displaying relative sea-level change during the Holocene are crucial in studies of Stone Age settlements along the Norwegian coast. Tvedestrand (light grey) and Arendal (dark grey) municipalities along the southernmost coast are among the best mapped stretches along the coast (see map figure 1), due to Quaternary geological studies performed as part of large-scale cultural heritage management excavations in the area (Reitan and Sundström, 2018; curves by A. Romundset [Romundset, 2018], simplified by A. Mjærum, MCH, UiO; CC BY-NC 4.0.).

Fig. 5 *– Les courbes montrant le changement relatif du niveau de la mer pendant l'Holocène sont cruciales dans les études sur les établissements de la Préhistoire récente le long de la côte norvégienne. Tvedestrand (gris clair) et Arendal (gris foncé) font partie des étendues les mieux cartographiées le long de la côte (voir carte figure 1), en raison des études géologiques du Quaternaire réalisées dans le cadre de fouilles de gestion du patrimoine culturel à grande échelle dans la région (Reitan et Sundström, 2018 ; courbes réalisées par A. Romundset [Romundset, 2018], simplifiées par A. Mjærum, MCH, UIO ; CC BY-NC 4.0.).*

standard method for mapping Stone Age activity in Norway (Bjerck, 1990; Bergsvik, 1991; Åstveit, 2005; Berg-Hansen, 2009; Damlien et al., 2021, p. 165-67). Most lowland areas are covered with forest and a thin turf layer, which makes other survey methods less applicable. Due to acidic soils, the preservation of organic material is limited, leaving lithic artefacts as the main trace of activity.

Landscape reading, which is an integral part of this method, builds on a mixture of general knowledge, preconceptions and the personal experience of the surveyor concerning where Stone Age sites are typically situated in different environments, i.e. what topographic features generally characterise a suitable site location, with reference to a reconstruction of the prehistoric shoreline. These features include, for example, easy access to the sea and marine resources, good harbours, an overview of the surroundings, wind shelter, flatness and dryness of the site, and so on, hence binding the site location to the coast based on functional and economic criteria (Berg-Hansen, 2009; Breivik, 2014; Bjerck et al., 2016; Ritchie et al., 2016; Roalkvam, 2020). Although these features might be relevant to Stone Age settlement, they also describe a modern western perception of what characterises a good camp site. Today, this perspective still largely dominates the field practice of Stone Age surveys, while excavations and current research generally have a broader approach including topics such as movement in the coastal zone, enculturation of landscapes, and interaction with surroundings, taskscapes and nature, as well as dynamic perspectives on the coast-hinterland relation (see below).

This difference in approaches springs from the plurality of theoretical frameworks and questions that have developed in Stone Age research (see Schülke et al., this volume) rather than from methodological advances in field archaeology. The established survey method still constitutes a possible source of bias, and methodological developments are needed. One possible way forward could be the application of probability sampling to achieve a statistically representative sample of the distribution of sites and artefacts, a methodological survey framework that has so far received limited attention in Norwegian archaeology (but see Bjerck, 1989; Bergsvik, 1991 for modified approaches). With probability sampling, the aim is that only chance and the nature of the archaeological distributions dictate the results of the survey (e.g. Binford, 1964; Shennan, 1997, p. 361-398). Such a framework would offer a clear way to test previously proposed settlement models, while also providing an estimate of the confidence we should have in any observed pattern. The nature of the archaeological record, topographical character of the environments, and practical realities of archaeological fieldwork all pose challenges to obtaining such a sample. It should be possible to overcome these hurdles, however, through methodological developments involving rigorous planning and the adoption of comparable frameworks from other settings (e.g. Orton, 2000, p. 67-111). One proposition is to have parts of a future survey project conducted in a probabilistic manner to evaluate its merits and to obtain a better grasp of the challenges associated with such approaches in a Norwegian setting.

3.4 Site concept

Our site concept is essential for how we perceive the traces of the Stone Age. The site constitutes the basic unit and the analytical starting point for most studies (e.g. Dunnell, 1992; Fretheim, 2017; Nærøy, 2018; Schülke et al., this volume). The concept of what a site is, and how it can be recognized, influences our survey and excavation strategies. Sites are generally perceived as strictly delimited areas, or as points or nodes in the landscape, between which Stone Age people moved. Combined with the rugged topography of the Norwegian coast, with rocky outcrops and pockets of soils in between that have escaped most forms of agricultural activity and modern development, this site concept enables the discernment of places in the landscape suitable for test-pitting. However, while partly related to what we are able to recognize as physical traces of prehistoric activity (i.e. artefacts and structures) and partly to the need for operational units in practical and legal administration, this concept fails to consider the area surrounding the sites, demonstrating the need for theoretical and methodological developments (Dugstad, 2020; Schülke, 2020b; Berg-Hansen et al., 2022). By neglecting the activities that were performed outside the immediate limits of the settlements, whose traces are possibly less visible today, and prehistoric people's relations with their wider surroundings, including the hinterlands (Foley, 1981; Schülke, 2020a and 2020b), the prevailing site concept has added to the apparent success of the shoreline model.

3.5 Modern development

Finally, modern development areas, which are concentrated mainly in the lowlands along the coast, or along waterways inland, present a decisive factor. Building activity has caused an immense production of archaeological data during the last 20 years, resulting in unprecedented research opportunities. Even so, this represents a problem that is often overlooked. In Norway, virtually all excavations are carried out as rescue excavations, i.e. as part of the governmental heritage management through legislation. Hence, the areas where archaeological investigations take place and the geographical limits for the excavations are being dictated by what areas that are desirable for modern land development. Although we have seen an increased awareness of this problem in the last two decades, it has resulted in a bias concerning the type of landscapes in which the surveys and excavations have been conducted, and while coastal areas are over-represented, large parts of the hinterlands remain underexplored.

To conclude, most known sites in Norway are situated along or near prehistoric shorelines. However, as we have pointed out, there is a bias in the data that has influenced our understanding and led to an insufficient concept of Stone Age coastal societies. Culture heritage management as well as research have mainly focused on sites connected to shorelines and inland watercourses, while limited knowledge has been developed concerning the activities in the areas between large waterbodies (Mjærum, 2019; Damlien et al., 2021). Site location along shorelines is easy to explain within eco-functionalistic frames of thought, especially linking the choice of location to the exploitation of food resources. We argue that this way of connecting coastal settlements with a marine economy has resulted in less interest in exploitation and management of terrestrial resources. Furthermore, the dominant site concept has for more than a century influenced our perception of settlements as delimited areas or points in the landscape that were interconnected by the means of boats travelling along the coastline. However, in recent years several studies have presented new perspectives on landscape use, site location and distribution, challenging the established concepts of the coastal Mesolithic (e.g. Berg-Hansen 2009; Fuglestvedt, 2017; Svendsen, 2018; Mjærum, 2019; Nyland, 2020; Roalkvam, 2020; Schülke, 2020b). The historical development and maintenance of the shoreline model, as well as recent results questioning the established views, call for a review of existing coast concepts.

4. COASTAL SITE CONCEPTS REVISITED – FROM COASTLINE TO LANDSCAPES OF PRACTICE

An increasing number of Stone Age excavations and surveys in Norway over the last couple of decades (Indrelid 2009; Bergsvik et al., 2020; Henriksen et al., 2020; Skogstrand 2020; Damlien et al. 2021), combined with improvement of excavation methods, has expanded our possibilities for conducting empirically based studies of site location and settlement patterns. Simultaneously, the capability to date sites has been significantly improved by an increased availability of precise C14 data, more detailed shore-level displacement curves (see above), and as a result of refinement of chronological schemes. These developments, along with the application of statistical methods, a gradually increased plurality of theoretical approaches and a growth in research resources, have to some extent improved our ability to test, nuance and challenge the shoreline model.

In many studies, shoreline displacement curves have been compared with radiocarbon dates from Stone Age sites. Such tests have generally proved a strong vertical affinity between known Mesolithic sites and former coastlines (e.g. Breivik et al., 2018; Solheim and Persson, 2018; Fossum, 2020; Solheim, 2020; Bergsvik et al., 2021; Mjærum, 2022; Roalkvam, 2023), while less is known about the horizontal distance from the settlements to the littoral zone. These studies thereby strengthen a key premise in the shoreline model: that the main parts of settlements were located only a few meters above the mean sea level in the former archipelago landscape. At the same time, the increased amount of data and research have made the outliers in the coastal model more numerous and easier to detect. Today, we know that house structures and hearths were established and lithic scatters and cremated bones left behind in the coastal hinterland at varying distances (some hundred meters to several kilometres) from the Mesolithic seashores (e.g. Eigeland et al., 2016; Mjærum, 2019; Schülke, 2020b).

We also see that some of these sites were re-visited over a long period, starting when they were closely related to the seashore. During their time of use, they underwent a transformation due to the land uplift and ended up as completely disconnected from the shore in their last stage of usage (e.g. Mjærum and Mansrud, 2020, p. 286-288). A conceptual challenge is whether these sites mirror regular inland activity, or if they would mainly have been associated with coastal activity. While our perception of such sites will be closely related to interpretations of the specific site's function in settlement systems and their organisation, there will always be an ambiguity in the definition of where the coast ends and the inland area starts. Still, the finds indicate that the coastal hinterland played a more important role for the groups frequenting the coastal areas of Norway than hitherto assumed. These finds have opened up a new empirically based debate about the nuances in the shoreline model and calls for a review of our concepts of Stone Age settlement, movement and landscape use (Mjærum, 2019; Schülke, 2020b, p. 387). The evidence of hinterland visits has been interpreted as places where the coastal population could find supplementary inland resources (Bergsvik, 2009; Blankholm, 2011; Nyland 2016; Mjærum, 2019), such as observation posts on high terrain (Schülke, 2020b) and transit sites used by people traveling between watercourses or to places further inland (Gundersen, 2013). However, research has also emphasized that inland activities fulfil more than material needs. By revisiting places that were once located on shores, they also went back to their ancestors' sites and their former world (Glørstad, 2010; Mansrud and Eymundsson, 2016; Schülke, 2020b).

Outward perspectives are needed to supplement this inward view, however. Recent publications have addressed this critique by widening the perspectives from the littoral zone itself to broader economic, social and cultural taskscapes, including inland waterways and forested hinterland areas. The shoreline sites were also a vantage point for marine activities related to the outer coast, such as deep-water fishing and sea mammal hunting (Bjerck, 2009 and 2021; Skar et al., 2016; Bergsvik, 2017, p. 84; Mjærum and Mansrud, 2020; Mansrud and Berg-Hansen, 2021). Areas along the coast and watercourses represent specific ecotones or the border or transition between two ecotones, comprising certain biological recourses. Such zones often represent fertile areas containing a variety of species, and hinterland watercourses provide easy access to fresh water.

Waterbodies, both coastal and inland, also represented important transport opportunities, either by boat or on ice in the winter, enabling the maintenance of social networks and indispensable knowledge exchange (Solheim 2012; Damlien, 2016; Berg-Hansen, 2017). Our conclusion is, therefore, that Stone Age sites situated in the littoral zone should not be viewed as a string of pearls along a narrow coastline. Rather, we advocate a more holistic perspective on spatial movement, where the coast should be viewed as a wider 'landscape space of practice' where land and sea met, with special meanings and ways of living (Schülke et al., this volume). The coast was a good place for people; however, their world was surely extended not only by voyages on the water but also through an active use of the hinterland.

5. FINAL REMARKS

The questions we ask and the methods we employ are governed by our analytical terms and concepts. Hence, our general perceptions of the significance of the coast to Stone Age societies, which in principle have prevailed for a century, affect how and where we look for sites and how we interpret our findings. While this emphasises the need for self-critical awareness in our scientific practice, our concepts nevertheless make us able to recognise the traces from these societies along the Stone Age coasts. The shoreline model has resulted in the discovery of a high number of relatively undisturbed sites, which together stand out in an international setting and offer excellent opportunities for further research. However, our discussion has pointed out some of the challenges in the existing concepts and approaches. We can, therefore, say that our concept of the site and the coast, with the strong emphasis on the proximity of the Stone Age sites to the shore, both helps and limits our understanding of Stone Age coastal societies. The question remains, however, of what part of prehistoric reality we are able to capture within this frame of thinking, and how we can move beyond this.

While the geographical limits for archaeological investigations are generally set by administrative factors outside the control of the research community, the survey methods, location models and site concept are ours to define. In searching for a broader, more holistic perspective on Stone Age life and societies, we would benefit from addressing these concepts critically, acknowledging the variety of individual and societal practices in coastal landscapes.

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Geoarcheology and Prehistory of the St. Pierre and Miquelon Archipelago: Theoretical Issues, Methods and Preliminary Results

Géoarchéologie et préhistoire de l'archipel de Saint-Pierre-et-Miquelon : problèmes théoriques, méthodes et résultats préliminaires

Grégor Marchand, Réginald Auger, Cédric Borthaire, Mikaël Guiavarc'h, Maureen Le Doaré, Lolita Rousseau, Pierre Stéphan

Abstract: The French overseas territory of St. Pierre and Miquelon comprises three main islands and is located approximately 20 km south of the island of Newfoundland (Canada). As part of a Unesco project to classify maritime heritage, a Franco-Canadian team has begun excavating the coastal site of Anse-à-Henry, which was occupied from the Maritime Archaic time to the historical period. Integrating multiple scales of analysis, the scientific approach adopted is more global than just a simple excavation. It includes a geomorphological component (monitoring erosion, changes in sea levels) and an archaeological component (inventory of the heritage, dating of the various occupations, reconstruction of occupation networks). The project began in 2018 with a systematic survey of archaeological anomalies using LiDAR data, which led to the identification of 43 areas with high potential for habitat remains. Analyses of the shoreline morphologies of Anse-à-Henry reveal that different sectors of coastline have been affected either by marine erosion processes (wave action) or by subaerial processes such as runoff, colluviation, etc. The 2019 and 2021 excavations uncovered extremely well-preserved Groswater occupations in the low-lying area of the site and demonstrated the extent of the site area; a substantial addition to what was excavated in the early 2000s. The Middle Dorset and First Nations occupations (Recent Tradition) have also left abundant remains, but more scattered over the 3.6 ha site. Surveys throughout the archipelago led to the discovery of five quarries, including the Bois Brûlé quarry in St. Pierre exploited for its rhyolite deposits. Results of the geochemical analyses conducted on the Bois Brûlé samples link some of these quarries to objects collected at Anse-à-Henry.
Keywords: Dorset, Groswater, rhyolite, St Pierre and Miquelon, Recent Period.

Résumé : Territoire français d'outre-mer, l'archipel de Saint-Pierre-et-Miquelon comprend trois îles principales, situées à une vingtaine de kilomètres au sud de l'île de Terre-Neuve (Canada). Dans le cadre d'un projet de classement de patrimoine maritime par l'Unesco, une équipe franco-canadienne a entamé la fouille du site côtier de l'Anse-à-Henry, occupé de la période Archaïque maritime à la période historique. La démarche scientifique empruntée est plus globale qu'une simple fouille, avec l'intégration de multiples échelles d'analyse. Elle comprend un volet géomorphologique (suivi de l'érosion, changement des niveaux marins) et un volet archéologique (inventaire du patrimoine, datation des différentes occupations, restitution des réseaux d'occupation). Le programme a débuté en 2018 par le relevé systématique des anomalies archéologiques à l'aide de données LiDAR, ce qui a mené à l'identification de 43 zones à fort potentiel de vestiges d'habitat. L'analyse des morphologies rencontrées à l'Anse-à-Henry, le long du rivage, a permis de distinguer différentes portions de côte affectées soit par les processus d'érosion marine (action des vagues) soit par les processus subaériens (ruissellement, colluvionnement, etc.). Les nouvelles fouilles ont permis de détecter des occupations Groswater très bien préservées dans la zone basse du site, tout en montrant l'ampleur des remaniements post-dépositionnels dans la zone principale, fouillée dans les années 2000. Les occupations du Dorset moyen et des Premières Nations (période qualifiée aussi de « Tradition récente ») ont également laissé des vestiges abondants, mais davantage dispersés sur les 3,6 ha du site. Les prospections pédestres menées dans tout l'archipel ont conduit à la découverte de cinq carrières, dont celle de Bois brûlé, à Saint-Pierre, destinée à l'exploitation de la rhyolite. Des analyses géochimiques ont été menées sur ces roches ; elles permettent d'ores et déjà de lier certaines des carrières à des objets lithiques recueillis à l'Anse-à-Henry.

Mots-clés : Dorset, Groswater, Paléo-Inuit, rhyolite, Saint-Pierre-et-Miquelon, Tradition récente.

1. QUESTIONS POSED ON THE ARCHAEOLOGICAL HERITAGE OF ST PIERRE AND MIQUELON

1.1. Cultural context: First Nations in Newfoundland

A brief cultural context is necessary to better understand the issues developed in the St. Pierre and Miquelon archipelago (fig. 1). The first occupations around the St. Lawrence River estuary are attributed to the Early Maritime Archaic, initially defined by J. A. Tuck (1971), around 7500 BCE (Betts and Hrynick, 2021). Their extension onto the island of Newfoundland is only identified during a recent phase (Late Maritime Archaic), in a cultural movement described as "Southern Branch" common to southern Labrador and northern Newfoundland (around the Strait of Belle Isle). There would be a gap of one millennium with the Labrador occupations, i.e. around 2600 BC (Renouf, 1999; Betts and Hrynick, 2021). Despite a scarcity of reliable archaeological data, the strong maritime tropism of these populations is underlined, as well as the existence of long-distance material acquisition networks (e.g. the Ramah chert, whose sources are more than 1,000 km from Newfoundland and notably the major archaeological sites of Port-aux-Choix).

The irruption of totally different populations from the Arctic Circle, previously described as "Paleo-Eskimo" and now as "Paleo-Inuit" or "Pre-Inuit", occurred during a marked cooling episode around 2100 BC. The first of these to reach the island of Newfoundland was the Groswater, initially defined by W. Fitzhugh (1972) on the basis of an eponymous site in Labrador. This phase is thought to date from 800 to 100 BC, at a time of marked climatic improvement. Bifacial points with lateral notches and a square base (box-base), burin-like tools, bipointed armatures, small wide-fronted scrapers and microblades are attributed to this group (Auger, 1984; Betts and Hrynick, 2021; Lavers and Renouf, 2012). The emergence of the Groswater represents a period of dramatic population growth and maximum expansion of this region. Sites from this phase are found throughout the region, from the northern part of Labrador to St. Pierre island (LeBlanc, 2008).

It was succeeded by the Dorset culture around 500 BCE in northern Labrador and a few centuries later in Newfoundland. This again appears to be a southward movement of populations and not an in situ evolution of the Pre-Dorset (Tuck and Fitzhugh, 1986; Renouf, 1993 and 1999). It is during the middle phase of its development, between 0 and 500 AD, that Dorset clearly asserts its presence (Renouf, 2003, 2005 and 2006). The endblades with a groove and concave base are particularly characteristic of the Middle Dorset (LeBlanc et al., 2001). In a comparative study of eight Middle Dorset sites (including Anse-à-Henry), S. LeBlanc (2008) proposed the hypothesis of a regionalism of Dorset culture in Newfoundland. This idea was first expressed in the work of U. Linnamae (1975) under the name of Typical Newfoundland Dorset. It would be expressed by triangular distal armatures with concave bifacial bases. While Groswater groups had a diet based on land and sea resources and moved strategically with the seasons to take advantage of the availability of small marine mammals, caribou and other small land mammals (LeBlanc, 2000), the Dorset groups appear to have been better adapted to the exploitation of marine resources (Renouf, 1999). The disappearance of this culture remains an enigma of archaeological research in the Atlantic Northeast (Betts and Hrynick, 2021), as well as at Port-aux-Choix in Newfoundland around 800 CE, four centuries before their decline in Labrador.

This was followed by a cultural group described as "Maritime Woodland" in the continental provinces around the St. Lawrence and "Boreal Woodland" in Newfoundland and Labrador (Betts and Hrynick, 2021). Once again, there is a sharp break with the technical traditions and lifestyles of the Paleo-Inuit groups. In Newfoundland, this culture would only appear around 200 BC (Late Boreal Woodland), which implies a coexistence of almost a millennium with the Dorset populations. Formerly called "Recent Indian" (LeBlanc et al., 2001; LeBlanc and Rabottin, 2000, 2003 and 2005; Betts and Hrynick, 2021), these cultures are now integrated into a "Recent Tradition" of the Early First Nations of Newfoundland. There are three successive phases on this large island: Cow Head, Beaches and Little Passage. The latter is directly linked to the Beothuk who were contemporary with the European arrival from the 16th century. The arrow fittings with stems are characteristic of these groups; this technical change is probably linked to modifications in terms of subsistence economy resulting in a decrease of the marine mammals hunting in favour of land mammals.

The prehistory of Newfoundland thus shows series of population breaks (Archaic/Groswater; Groswater/Dorset; Dorset/Recent Tradition). J. A. Tuck and R. T. Pastore (1985) linked them to the resources available, marked by successive extinctions of caribous and harp seals followed by repopulations from Labrador, a hypothesis challenged by M. A. P. Renouf (1999) who emphasised periods of cohabitation. Located at the southern tip of the island of

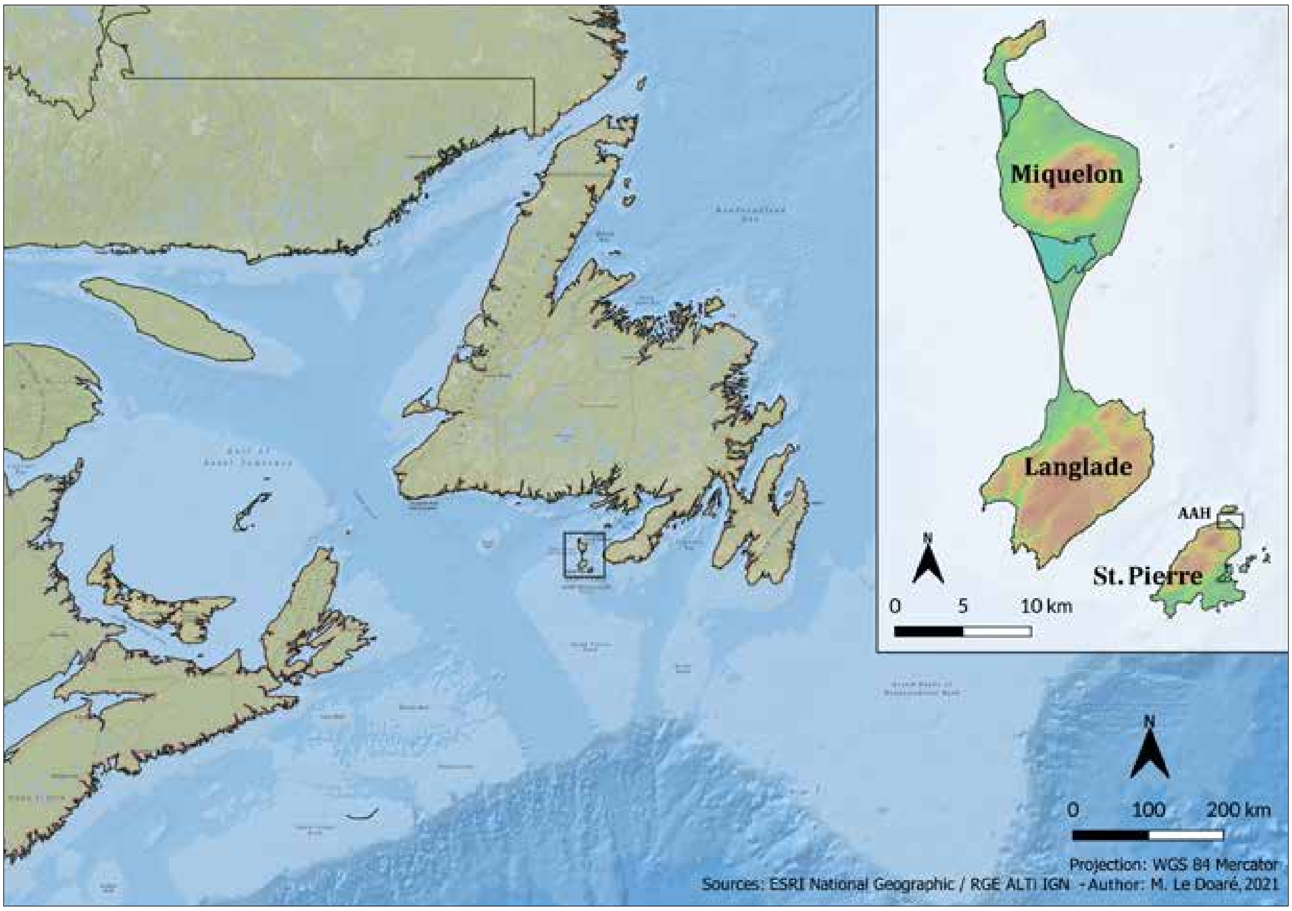


Fig. 1 – Location of the St. Pierre and Miquelon archipelago to the south of Newfoundland, Canada (map M. Le Doaré).
***Fig. 1** – Localisation de l'archipel de Saint-Pierre-et-Miquelon, au sud de Terre-Neuve, Canada (carte M. Le Doaré).*

Newfoundland, the St. Pierre and Miquelon archipelago has been part of this history, as evidenced by the remains collected from the 1980s until the recent operations discussed in this article.

1.2. Initial project scope

The French overseas territory of St. Pierre and Miquelon comprises three main islands and is located 20 km south of the island of Newfoundland (Canada; fig. 1). The recent archaeological work reported in this article is being carried out as part of a proposal to classify the St. Pierre and Miquelon archipelago as a Unesco World Heritage Site, with fishing activities as its corner stone. The first step in this long-term process, which combines heritage considerations and political orientations supporting economic development, was jointly initiated in 2017 by a local heritage group, the prefecture of St. Pierre and Miquelon and France's department of Culture. The temporal depth of the fisheries was an essential consideration when developing the classification proposal. This necessarily involved a new examination of the Anse-à-Henry site, located on the north tip of St. Pierre which already provided clues to the entire archaeological chronology of the region, from the Maritime Archaic to the ancestors of the Beothuk. Anse-à-Henry is also the southernmost Paleo-Inuit presence, first with the Groswater phase, which is identified in Newfoundland during the last millennium BCE, and then with the Dorset (Middle Dorset) that succeeded it until about 800 CE (Renouf, 1999; Betts and Hrynick, 2021). Understanding the cultural and technical organisation of these ancient cultures' exploitations of the halieutic resources is a challenge. There is also evidence of a European occupation in the upper part of the site, which remains to be characterised.

The Anse-à-Henry site was first identified by J. Chapelot during his fieldwork in the archipelago between 1979 and 1983 (Schmidt, 1983). While limited test pit excavations were conducted in the mid-1990s by J. A. Tuck, professor at Memorial University of Newfoundland at the time, a number of systematic studies were carried out in the early 2000s by S. LeBlanc in collaboration with J.-L. Rabottin, a geomorphologist from St. Pierre and Miquelon (LeBlanc and Rabottin, 2000, 2003 and 2005). That work provided an overview of the existing knowledge of this extensive site, whose surface area was estimated at approximately four hectares. The dwellings and activity areas that have been uncovered show evidence of frequent occupations, probably dating back as far as 3000 BCE. In addition, the Dorset component was the subject of a doctoral dissertation submitted to the University of Alberta by S. LeBlanc (2008). Because this unique site was being irremediably impacted by coastal erosion, R. Auger and G. Marchand were called upon in 2018 to rescue the site in order to finish documenting both the seasonal hunter-gatherer populations and the fishers of European origin, whose dwellings, workshops, fish processing structures (also called *grave* in French, not to be confused with the word "cemetery" in English!) and ceramics testify to their presence in the modern period (Marchand et al., 2020).

How can the diversity of the economic strategies of these Amerindian and Paleo-Inuit societies be fully evaluated? The exploitation of different parts of the maritime ecosystems was based on collective mobility practices, whether within the archipelago or around Newfoundland. The origin of the lithic materials is the readily available interpretative keys we have to establish an initial map of the exchange networks. The uniqueness of the Anse-à-Henry site in such a large archipelago was paradoxical; it points out to an important gap in our understanding. Limited prospections carried out in 2019 and 2020 have demonstrated the extant of the task of achieving an exhaustive knowledge of the territorial occupation networks prior to the European occupation. The development of an archaeological map under the aegis of France's ministry of Culture and the prefecture of St. Pierre and Miquelon should enable us to better manage the archipelago buried heritage.

For reasons of principle, it is no longer possible to ignore the erosive factors, which have an effect on the nature of the "archaeological record". In this period of accelerated global warming, erosion is particularly active both from the onslaught of waves that erode the shorelines, which freeze for ever shorter durations each winter, and from the intense movement of the colluvium that migrates down slopes. An understanding of the landscapes of the past and of the resources available at these different times is not possible without a thorough investigation of the geographical conditions, specifically, changes to sea levels. The St. Pierre and Miquelon archaeological project has therefore from the outset combined an examination both of the human remains and the conditions of geological deposits. The project has also provided an opportunity to incorporate various methodological approaches and schools of thought bringing together, for example, a dialogue with the First Nations, a concern in Canadian archaeology and the geoarchaeological approaches developed in French prehistory over the past half-century.

1.3. Integration of the scales of analysis

In order to work on and integrate the various geographical scales, our strategy comprises a number of objectives:

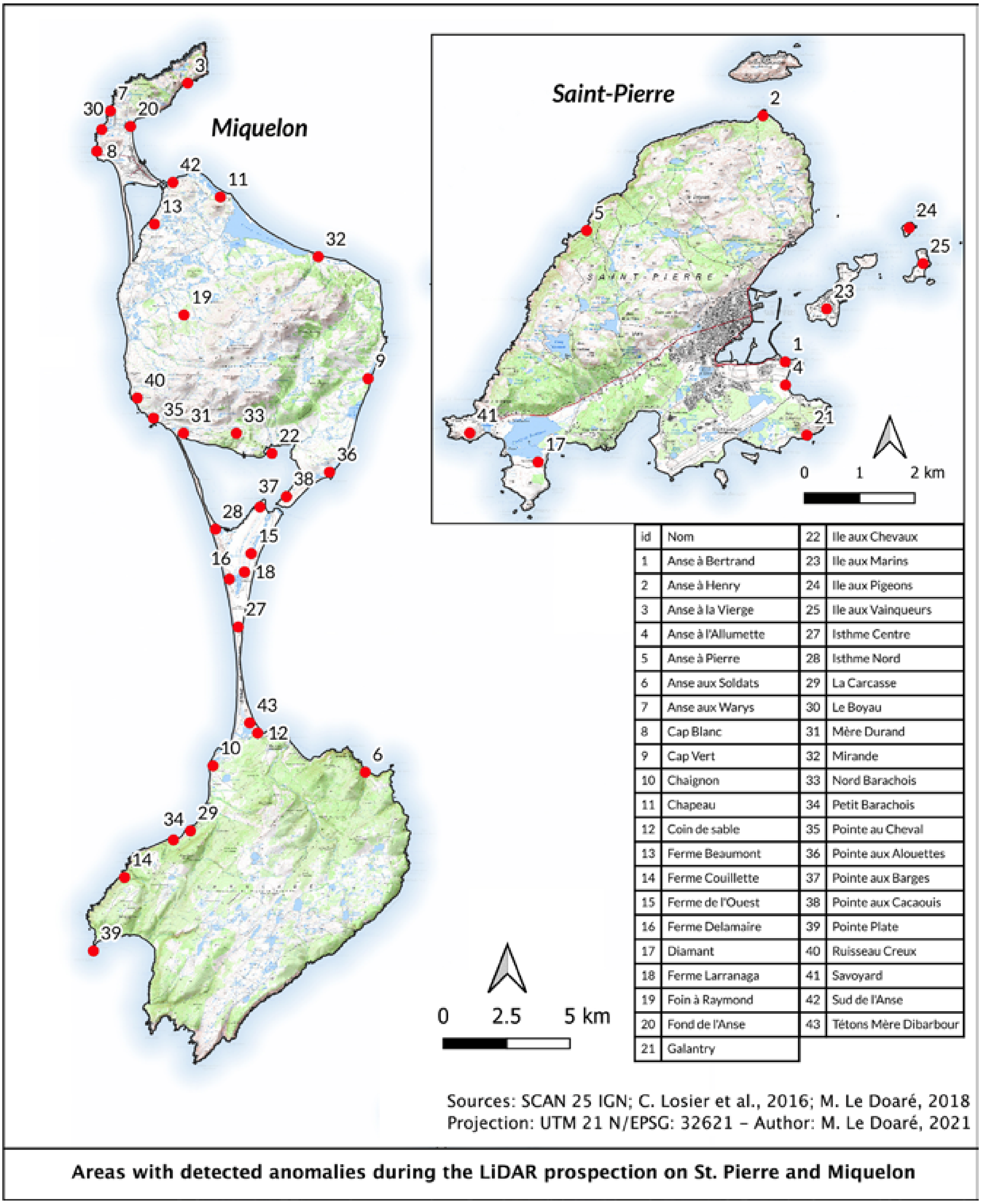
1. Systematic survey of archaeological anomalies using LiDAR data and analysis in connection with historical knowledge (leader: M. Le Doaré).
2. Integration of the archaeological programme into various institutions and communities in St. Pierre and Miquelon and Newfoundland (prefecture of St. Pierre and Miquelon; Service Régional de l'Archéologie de Bretagne; l'Arche Musée et Archives; Lycée Émile-Letournel; Mi'kmaw Community of Miawpukek in Newfoundland).
3. Establishment of a protocol for the monitoring of coastal erosion at Anse-à-Henry over three years (leader: P. Stéphan, with the active support of the direction des Territoires, de l'Alimentation et de la Mer).
4. Archaeological excavation and mapping of the Amerindian, Paleo-Inuit and European occupations at Anse-à-Henry (directors: R. Auger and G. Marchand, 2019-2023).
5. Extensive prospections in the archipelago (historical and prehistoric archaeology as well as petroarchaeology), begun in September 2019 and extended in August 2020.
6. Archival research to better understand the nature of the European and indigenous occupations of the territory.

2. A PRELIMINARY ANALYSIS OF THE LiDAR DATA ON THE ARCHIPELAGO

In 2018, a member of our team (M. L. D.) carried out a remote sensing study on the archipelago using LiDAR. Remote sensing makes it possible to study vast areas in a short time span. It allows to collect initial spatial information on the archipelago, whose surface area totals 242 km². The LiDAR survey results were compared to historical maps, texts and aerial photographs (current and old) to support our interpretations of the anomalies identified. The promising features, in addition to those found at Anse-à-Henry, were investigated during the 2019 season.

This first stage suggested the presence of 43 potential sites across the archipelago: 32 are on Miquelon, 10 on St. Pierre and its islands and one on l'Île Verte (Green Island; fig. 2). However, low and dense vegetation in many areas proved a major obstacle to the analysis and rendered the information collected worthless. The study focused on the coastline as this had been the most utilised space on the islands (for accessibility and resources reasons). Inland areas were explored less thoroughly due to a lack of time. Most of the sites that were identified dated from the historic period while prehistoric sites are difficult to identify in this environment using LiDAR since they present few or no surface features that can be detected. The small number of structures visible through LiDAR at the Anse-à-Henry site dated from the historic period (fig. 3). Finally, the reading was also disrupted by periglacial geometric elements, therefore, field verification of the anomalies detected during this first stage was necessary.

The archipelago has a troubled and violent history dating from its discovery by Europeans in 1520 to the signing of the Treaty of Paris in 1814, which declared that the archipelago belonged to France. Its shores were pillaged alternately by the French and the English numerous times over the intervening three centuries (Ribault, 1962; Lebailly, 2015). As a result, many of the former settlements were either destroyed or forgotten by the popula-



id	Nom	id	Nom
1	Anse à Bertrand	22	Ile aux Chevaux
2	Anse à Henry	23	Ile aux Marins
3	Anse à la Vierge	24	Ile aux Pigeons
4	Anse à l'Allumette	25	Ile aux Vainqueurs
5	Anse à Pierre	27	Isthme Centre
6	Anse aux Soldats	28	Isthme Nord
7	Anse aux Warys	29	La Carcasse
8	Cap Blanc	30	Le Boyau
9	Cap Vert	31	Mère Durand
10	Chaignon	32	Mirande
11	Chapeau	33	Nord Barachois
12	Coin de sable	34	Petit Barachois
13	Ferme Beaumont	35	Pointe au Cheval
14	Ferme Couillette	36	Pointe aux Alouettes
15	Ferme de l'Ouest	37	Pointe aux Barges
16	Ferme Delamaire	38	Pointe aux Cacaouis
17	Diamant	39	Pointe Plate
18	Ferme Larranaga	40	Ruisseau Creux
19	Foin à Raymond	41	Savoyard
20	Fond de l'Anse	42	Sud de l'Anse
21	Galantry	43	Tétons Mère Dibarbour

Fig. 2 – Sites with anomalies in the St. Pierre and Miquelon archipelago detected using LiDAR (analyses and maps M. Le Doaré).
Fig. 2 *– Sites de l'archipel de Saint-Pierre-et-Miquelon présentant des anomalies détectées à l'aide du LiDAR (analyses et cartes M. Le Doaré).*

tions, who were deported on several occasions. The historical occupation of the archipelago is therefore largely unknown, except through few maps and archives. The numerous presumed historical structures that have been uncovered during the present investigation will therefore contribute to expand our knowledge of the troubled history of the archipelago.

Pointe aux Cacaouis site illustrates such potential for remembering the past. Numerous topographical anomalies have been identified on the LiDAR and verified

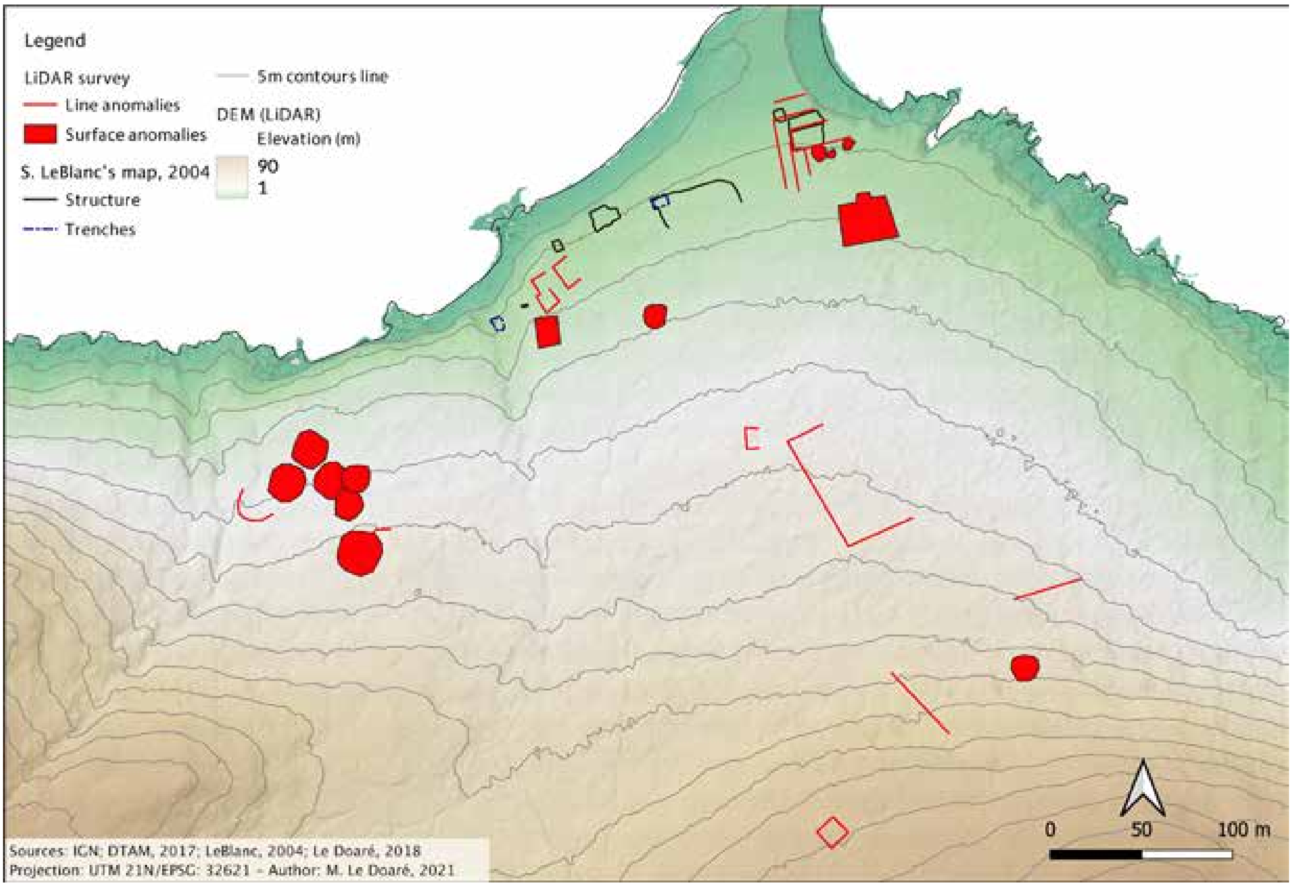


Fig. 3 – Anomalies detected at the Anse-à-Henry site using LiDAR in 2018 (map and analysis: M. Le Doaré).
***Fig. 3** – Anomalies détectées à l'aide du LiDAR sur le site de l'Anse-à-Henry en 2018 (carte et analyses M. Le Doaré).*

in situ, however, there are very few historical sources indicating human occupations in this area (fig. 4). This headland is located to the south of the island of Miquelon and it juts out to create the narrow mouth of the Grand Barachois lagoon. The vegetation is low and composed mainly of Gramineae, which allows for a good penetration of the LiDAR signal. J. Billy's (2014) findings that the headland was formed late compared to the rest of the isthmus, around the 16th century, when the first Europeans arrived on the island, make it possible to establish a dating terminus for the anomalies encountered on the headland. Based on the sources, we can put forward

Fig. 4 – Pointe aux Cacaouis (photo R. Auger).
***Fig. 4** – Pointe aux Cacaouis (cliché R. Auger).*

several hypotheses on the origin of these structures and their occupation. Aubert de La Rüe (1937) and Sasco (1931) mention traces of enclosures and encampments north of the Grand Barachois, though they remain vague about their locations. É. Aubert de La Rüe (1944) also refers to the presence of Mi'kmaq from Conne river, who came to the area in 1865 to hunt seals. D. Gauvain (1916) writes that fishers had settled on this headland. Finally, J. de La Roche-Poncié's 1841 map indicates a building, possibly a farm or a dwelling, as well as a name ("M. Le Fèvre"?). During field prospections, some Miquelon inhabitants have also mentioned the presence of an old farm in this area. Most of the structures have been identified during our surveys along with stoneware potsherds seemingly dating to the 19th century (Auger et al. 2019. The favourable position of this headland due to its sheltered location (from the prevailing winds and sea swell), its proximity to numerous resources (scallops, seals, fish) and its accessibility (from both the lagoon and the sea) makes it a strategic zone that is likely to reveal several occupations. Further research will help to refine its understanding. Its occupation should be linked to the shell mounds located to the north of the Grand Barachois and to other possible structures around the lagoon.

The sites identified on the archipelago using these LiDAR data thus have considerable potential, particularly for the modern period. It has enabled us to map the areas of potential archaeological interest, to orient future prospections and to highlight potential archaeological and historical clusters, particularly around the Grand Barachois.

3. CRUCIAL MONITORING OF THE EROSIVE DYNAMICS AT THE ANSE-À-HENRY SITE

3.1. A site subject to major erosive phenomena

The Anse-à-Henry site is located at the northern end of the island of St. Pierre (fig. 5). It occupies an area of morainic deposits approximately 300 m long west to east and 150 m wide north to south. Forming an isthmus, the area slopes gently towards the sea to the north and ends in a low-lying topographical bench connected to a small rocky outcrop called the Rocher de La Vierge (fig. 6). There is a perennial stream situated to the west around which, according to the results of the excavations carried out in 2000 and our own recent prospections, the prehistoric occupations were concentrated.

The soft cliffs at Anse-à-Henry are very exposed to the weather and are regularly undermined by the sea during winter storms (fig. 7). On both sides of the site, the coastline is affected by a rapid retreat at an average rate of 0.5 m/year (LeBlanc and Rabottin, 2005; Le Doaré, 2018). The cross-sections extracted in these heterometric, loosely compacted moraines reveal a large number of lithic remains at a submittal archaeological level just below the topsoil. Anse-à-Henry also lies below a rocky slope and is an outlet zone for several ponds, peat bogs and streams that have their sources in the island's hills. Because the island's bedrock is impermeable, all precipitation flows on the surface and impact the sedimentation processes around the site. Rainfall on the archipelago is high, averaging 1.326 mm/year (Météo France, 2020). The spring snowmelt combined with rainfall increases the volume of surface runoff. In winter time, the cold oceanic climate is marked by alternate freezing and thawing. These alternations can lead to frost shattering, which can cause instabilities on the rocky coasts and the occasional landslides. This erosion process is clearly visible on the southeaster flank of Pointe à Henry, where plurimetric basalt boulders are scattered about the upper beach having come away from the outcrop.

3.2. Methodology for the topo-morphological monitoring of Anse-à-Henry

In 2019, we began the topo-morphological monitoring to determine the erosion processes along the Anse-à-Henry coastline. A set of topographic markers was installed and connected to the IGN (Institut National de l'Information Géographique et Forestière) geodetic marker located on Mont Trépied, the highest point on St. Pierre. Topography was reconstructed using the "structure from motion" method based on aerial images taken on a Phantom IV Pro drone at an average altitude of 50 m. That information was processed using Agisoft Metashape software to produce an orthophotograph and a Digital Elevation Model with a resolution of 2 x 2 cm on the ground. A set of targets installed on the ground and surveyed with DGPS allowed the georeferencing of these data with an estimated reliability of ± 3 cm in *X* and *Y*, and ± 2 cm in *Z*. The acquisitions are ongoing and will be compared on a yearly basis to measure the erosion phenomena and determine the respective part of subaerial and marine processes.

Our initial results have already revealed the sectors most affected by erosion processes. Sector 5 in figure 8 is the most impacted by marine and subaerial erosion. The top of the cliff shows large scars indicating extensive slides of deposits towards the base of the cliff, probably during spring snowmelt and following episodes of heavy rainfall. Runoff and surface water saturation cause the moraine deposits to migrate downslope. Surface water runoff leads to gullying of the slopes in the newly exposed deposits (fig. 9). The base of the slides locally covers the upper beach and seems to be rapidly removed by wave actions. This part of the coast is directly exposed to west-northwest swells. The base of the slopes is therefore frequently eroded, maintaining a sufficiently steep slope to trigger further landslides. This combination and sequence of processes over time is accountable for the rapid retreat of the coastline.

Fig. 5 – View from the southwest of the Anse-à-Henry headland located in the north of the island of St. Pierre. On the left, the island of Grand Colombier (photo G. Marchand).
***Fig. 5** – Vue depuis le sud-ouest de la pointe de l'Anse-à-Henry, située dans le nord de l'île de Saint-Pierre. À gauche, l'île du Grand Colombier (cliché G. Marchand).*

Fig. 6 – View of the site from the north, with Rocher de La Vierge in the foreground and the low-lying area behind (photo P. Stéphan).
***Fig. 6** – Vue du site depuis le nord, avec le rocher de La Vierge au premier plan et la zone basse derrière (cliché P. Stéphan).*

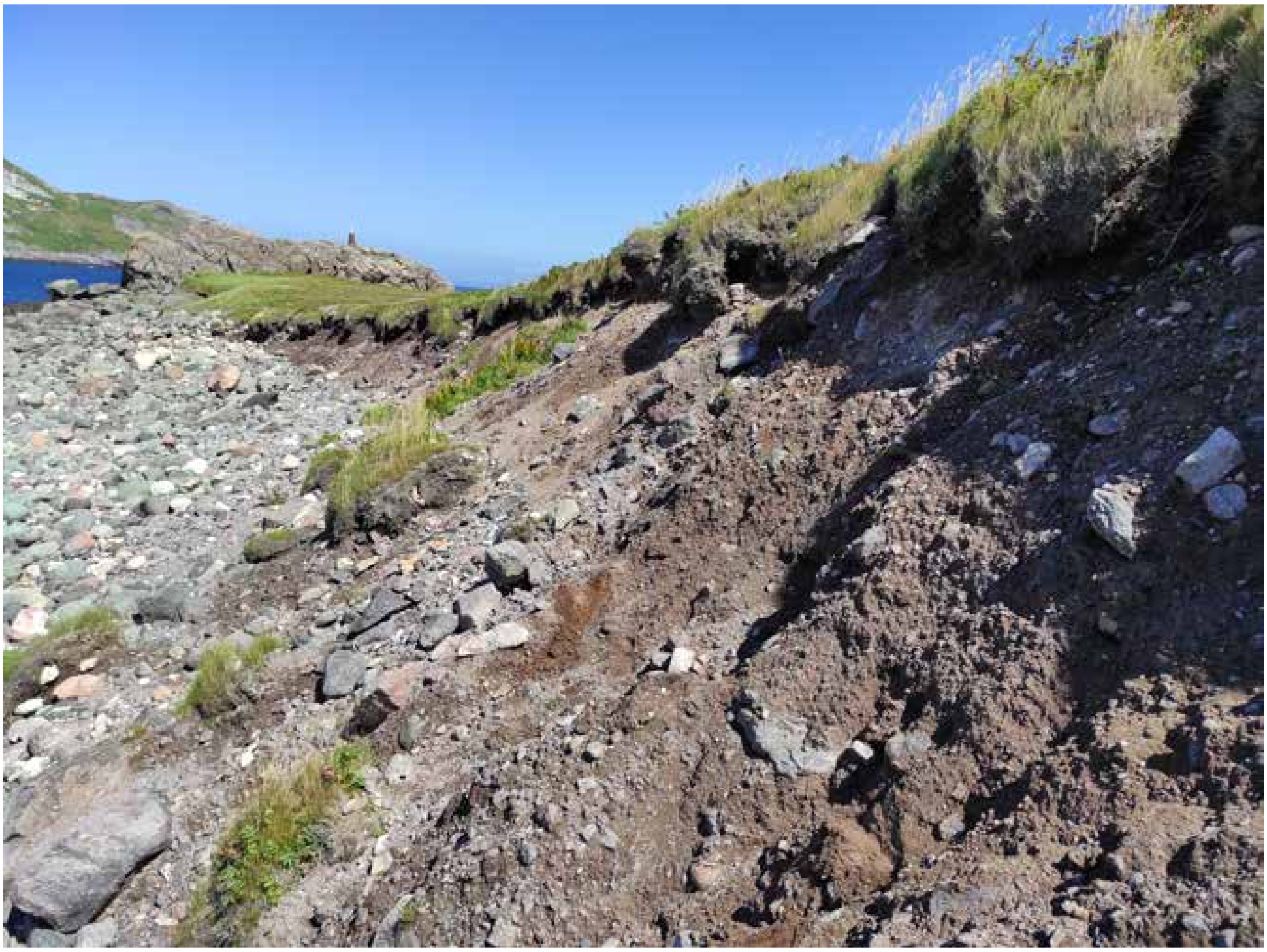


Fig. 7 – Erosion of the cliff in the western cove of Anse-à-Henry in August 2020 (photo G. Marchand).
***Fig. 7** – Érosion de la falaise dans l'anse ouest de l'Anse-à-Henry en août 2020 (cliché G. Marchand).*

3.3. Shoreline survey

The pluri-decadal shoreline changes were reconstructed from a digital processing of the aerial photographs taken by the IGN between 1952 and 2017. Using ArcMap software, the historic images were geometrically rectified and georeferenced from a set of fixed control points common with the IGN orthophotography dating from 2017. For the year 2019, the coastline was surveyed in the field with DGPS. The supratidal vegetation limit, which is easily identifiable in the aerial images, was taken as the reference baseline corresponding to the coastline. On the soft cliff sectors, the top of the slopes was also used as a reference baseline for digitising the coastline. The shoreline advance and retreat values were measured along transects perpendicular to the shoreline and spaced approximately 10 m apart using the Digital Shoreline Analysis System add-in within the ArcMap software. Uncertainty in the positioning of the coastlines was estimated at ± 1 m.

3.4. Assessment of the initial geomorphological observations

The initial topo-morphological data acquired in September 2019, as well as the data we collected during our geomorphological field observations, have provided preliminary elements that improve our understanding of the erosive dynamics along the coastline as well as the action of certain processes in the area around the Anse-à-Henry site. Our analysis of the morphologies found along the shoreline recognised different sectors of the coastline, which were affected by either marine erosion processes (wave action) or subaerial processes (runoff, colluviation, etc.).

To the southeast of the site, the cove formed by morainic deposits corresponds to a small pocket beach flanked by two rocky headlands (fig. 8, sector 1). Subvertical cliffs around one meter height extend over a linear distance of approximately 100 m. This morphology reflects the regular mechanical action of the waves on the coastal slope. This sector is exposed to swells from the east. At the foot of these soft cliffs, the upper beach is mainly composed of pebbles and shows a berm several metres wide. The beach thus seems to benefit from abundant sedimentary input resulting from the erosion of the morainic deposits, which the coastal currents cannot carry to the open sea or to adjacent areas. Combined with a spring tide, the storm waves here have an abrasive load capable of undermining the base of the cliff and maintaining a steep slope. Erosion here takes place through a direct retreat of the coastline

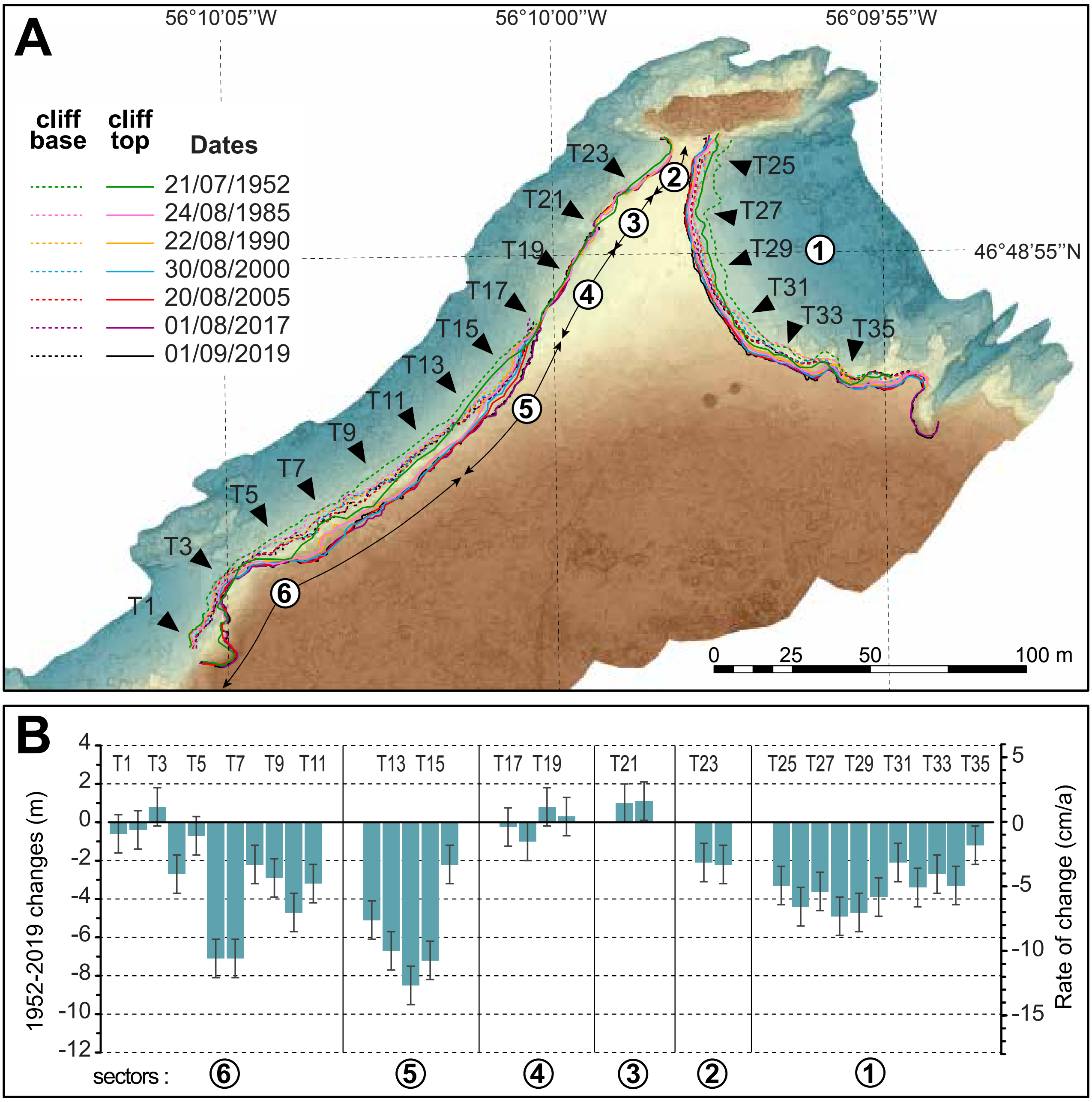


Fig. 8 – A: Location of Anse-à-Henry; B: Digital Elevation Model distinguishing six affected littoral sectors impacted, to varying degrees, by marine and subaerial erosion processes (map P. Stéphan).

***Fig. 8** – A : Localisation de l'Anse-à-Henry ; B : modèle numérique d'élévation distinguant six secteurs littoraux touchés, à des degrés divers, par les processus d'érosion marine et subaérienne (carte P. Stéphan).*

parallel to itself. The coastline retreat is estimated to be an average of 3.7 m for the period 1952 to 2019, which represents an erosion rate of 5.5 cm/year.

The southwestern part of the site presents more complex slope dynamics (fig. 8, sectors 2-6). The morainic deposits are thicker here with cliff heights of between 1 m and 4 m. The slopes appear to be subjected to a combination of marine and subaerial erosion processes. By following the coastline from north to south, the kinematics of the coastline coupled with a detailed analysis of the landforms allow us to subdivide this section into five distinct sectors:

1. Immediately to the south, the coastline is formed into micro-cliffs stretching over approximately 20 m (fig. 8, sector 2). The deposits are thus eroded over a few decimetres in height. A wide band of vegetation covers a mass of angular boulders at the foot of the slope, which themselves rest on a basalt outcrop with an irregular topography. The coastline retreat here is estimated at 2.2 m for the period 1952 to 2019.

2. Further to the south, in sector 3, the basalt micro-cliff stretches along approximately 20 m (fig. 8, sector 3) and shows no significant change from 1952 to 2019. Behind that stable section, we notice an anthropic

structure (stone slabs) in a stable state of preservation beneath a few centimetres of topsoil. The presence of such structures in this sector, which is protected from the waves by an outcrop does not appear to be affected by erosion.

3. To the south of this rocky section, the coastline corresponds to a boulder barrier approximately thirty metres in length, the top of which is partly covered by vegetation (fig. 8, sector 4). Measurements taken between transects T17 and T20 show no significant shoreline change over the last seven decades. The boulder accumulation results from a northward drift along the shore. Farther south, the crest elevation is lower and it facilitates the projection of boulders by storm breaking waves several metres as indicated by numerous scattered boulders distributed over the ground.

4. Sector 5 corresponds to soft cliffs formed in the glacigenic deposits which extend approximately 60 m farther south (fig. 8 and fig. 9). The height of the cliffs increases from 1.5 m to over 3 m from north to south. The slope gradient ranges from 70% to 100%. This sector is affected by strong marine and subaerial erosion processes. As recorded along the transect T14, rates of shoreline retreat are up to 10 cm/year and 13 cm/year at base and the top of the cliff, respectively. The mean values of shoreline retreat range from 4.1 m to 5.9 m from 1952 to 2019. Large scars on the top of the cliffs indicate mass sliding, probably during spring thaws and following episodes of heavy rainfall (runoff and surface water saturation of the moraine deposits). Surface water runoff also carves out numerous gullies in the newly exposed deposits. The base of the slides locally covers the upper beach and seems to be rapidly removed by the erosive action of the waves. This sector of coastline is directly exposed to west-northwest swells. The sea thus regularly clears the base of the slopes and maintains a sufficiently steep slope to ensure continuous landslides. This combination and sequence of processes over time explains the rapid retreat of the coastline in that sector.

5. Finally, sector 6 is an approximately 120 m stretch of soft cliffs leading to the outlet of an intermittent stream that is impacted by localised rotational slides identifiable as large scars at the top of the slope and in the tumbling down of large slabs of vegetation (fig. 8). The height of the cliff ranges from 5 m to 8 m and the removal of the eroded deposits at the base of the slope, because of erosion from the waves is slower, since that sector is less exposed to westerly swells. Nonetheless, the retreat of the cliff base reached 3 m between 1952 and 2019. At the top of the cliffs, fluvial gravel deposits have been identified and it seems to favour the infiltration of water into the substratum hence triggering of landslides (see infra). In its upper area, the cliff has retreated by 2.8 m over the period 1952-2019.

Fig. 9 – Anse-à-Henry, western cove. Sector 5 is marked in red, sector 6 in yellow (photo and CAD M. Le Doaré).
Fig. 9 *– Anse-à-Henry, anse ouest. Le secteur 5 est marqué en rouge ; le secteur 6, en jaune (cliché et DAO M. Le Doaré).*

4. ARCHAEOLOGY OF ANSE-À-HENRY SITE

4.1. Why are there so many human occupations in this area?

Research initiated at Anse-à-Henry since the 1980s has led to the identification of Paleo-Inuit, Amerindian and European human settlements. Those discoveries testify to the strong appeal of the northern point of the island of St. Pierre. Oriented towards the north and exposed to westerly and easterly winds, the site is difficult to gain access by sea except for the mouth of a small brook (Ruisseau de l'Ouest) which offers limited protection. Therefore, the continuous interest for such a location during the last four millennia raises the question of why there has been a recurrent interest for human settlements at that location. A clue may lay in the site location. Anse-à-Henry faces the island of Grand Colombier, a bird sanctuary situated on the opposite side of a 500 m-wide strait (fig. 5). That treeless island is a 1,200 m long and reaches an altitude of 149 m. Its rocky slopes covered with grass and fern offer the ideal conditions for nesting migratory seabirds. Thus, on a yearly basis, the occupants could count on aviary resources such as Atlantic puffins (*Fratercula arctica*) nesting in June, and also the only French breeding site for Leach's storm petrel (*Oceanodroma leucorhoa*). Common murre (*Uria aalge*) thrive in the colony where it stays during the winter. Razorbill (*Alca Torda*) are also plentiful on Grand Colombier where they lay their eggs in crevices on cliffs or among boulders (Bird Life International, 2021). Another important source of food that we still see going through the channel between the rocky point of Anse-à-Henry and Grand Colombier are humpback whales (*Megaptera novaeangliae*) and the finback whales (*Balaenoptera physalus*), dolphins (*Delphinus delphis*) and seals (*Phoca vitulina*). If the current ecological situation reflects those of the past, then the above parameters could explain the enduring value of this habitat. However, since the acidic soils preclude the preservation of osseous remains, the sources that can shed light on the nature of the human activities here are limited to the particularly plentiful lithic artefacts, the dwelling structures and the anthracological remains. Three main physiographic contexts can be defined here, namely the slope, the low-lying area and the terraces near the stream, whose morpho-sedimentary nature conditions the reconstruction of archaeological information.

4.2. Occupations on the slope

The excavation campaigns carried out by S. LeBlanc and J.-L. Rabottin focused on the slope to the west of the site. A total of 71 test pits measuring 0.50 m x 0.50 m were positioned with a grid at intervals of 5 m to 10 m (fig. 10). During the summers of 2003 and 2004, S. LeBlanc and J.-L. Rabottin concentrated on an area to the east of the stream, which they described as "central" in terms of the site occupation. Moreover, they conducted open area excavations over a surface area of 63 m² (36 m² in 2003; 27 m² in 2004). Immediately below the 20 cm thick plant litter, they discovered an abundance of lithic remains in association with combustion structures and activity areas such as flintknapping. Radiocarbon dating and tool typology showed a predominance of what was interpreted as being the ancestors of the Beothuk, preceded by the Middle Dorset occupants, whose way was paved by the early Paleo-Inuit Groswater phase.

In 2019, three new test operations were carried out on this slope, close to the edge of the eroding bank in order to identify future interventions and to hone our own methodology to dig in a disturbed sedimentary context (test pits G, H and I). Those 4 m² to 6 m² test pits allowed a different assessment of the sedimentary nature of this slope affected by various natural and cultural disturbances. The circulation of water under the recent stone beds (fig. 11, fluvial gravel deposits), within the soils themselves, severely constrained the excavation in sediments which appeared to have been reshuffled through time. Specifically, water ran under the fluvial gravel deposits bringing with it abundant lithic material. In addition, numerous boulders dotted about the surface, sometimes measuring over a metre in size. Upslope behind them, we systematically noted a depression often filled with stagnant water; in front a bulge of sediments pushed downslope. The whole process boulder migration resulted into the creation of a furrow which could measure up to 10 m in length and a slightly larger than the boulder. This is a well-documented colluvial phenomenon in the periglacial and montane contexts where huge boulders slide in response to freeze and thaw (Ballantyne, 2001), slowly migrating downslope and pushing a bulge of sediments in front of them. The vegetation covering the bulge and often hiding the presence of a furrow demonstrates the extreme slowness of the process (fig. 12). The "ploughing boulder" phenomenon is non-incremental and directly affects the stratigraphy of an archaeological site especially, when it is buried beneath a few decimetres of a peaty soil. Thus, our recognition of that geomorphological process has brought us to question the authenticity of many of the hearth features interpreted during the excavations carried out in the 2000s, since many of them were located against large boulders. Of course, there are combustion areas in association with fire cracked rocks, however, the challenge of the excavations in such context is to define the conditions of preservation of what appears to be a patchwork of some well-preserved and other less-preserved areas.

4.3. Western stream

To the west of the site, the low terraces of a small stream shows a different type of sedimentary context, less disturbed than the section described above. In 2002, S. LeBlanc and J.-L. Rabottin set up a 35 m² excavation area on a bench on the right bank (LeBlanc and Rabottin, 2003). A thin archaeological level was present under

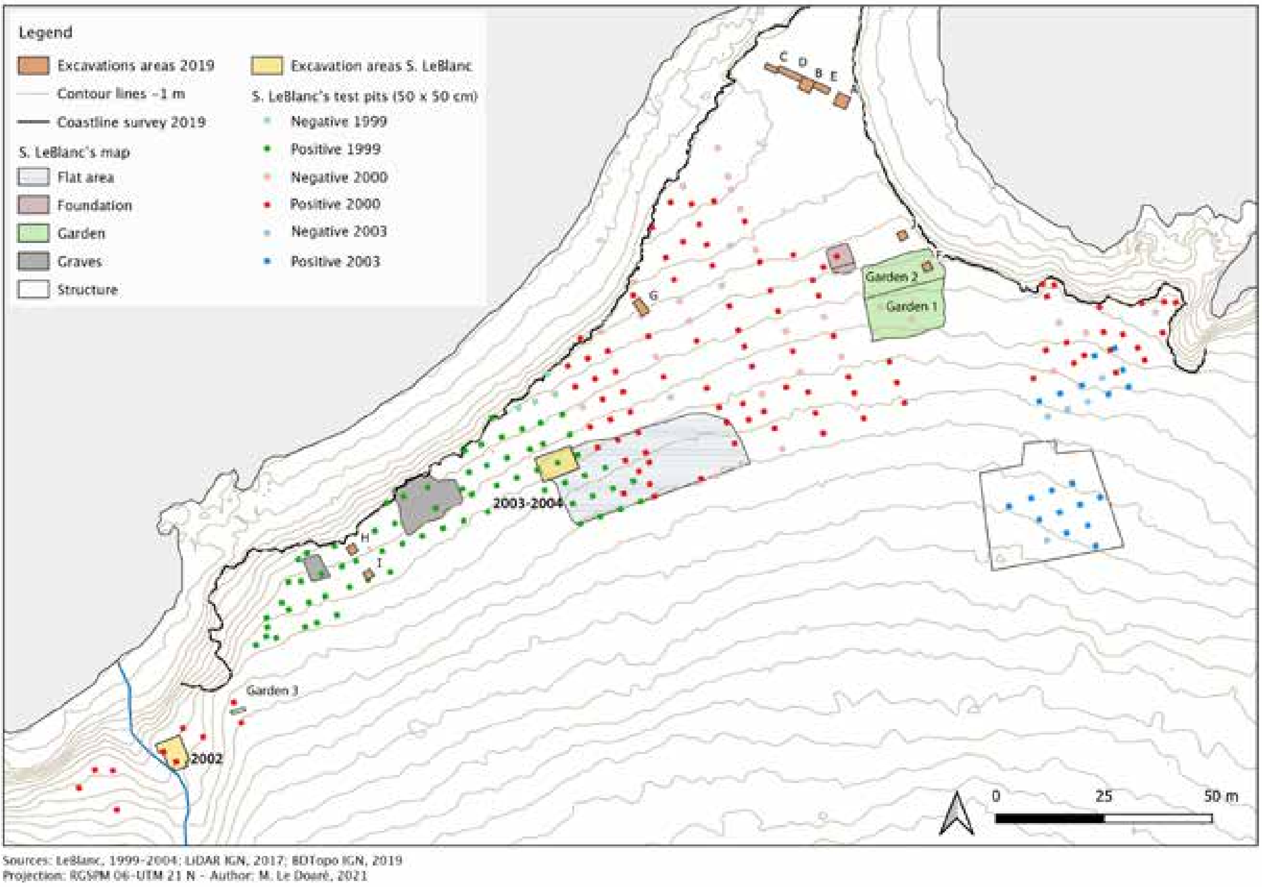


Fig. 10 – Plan of the various archaeological interventions carried out between 2000 and 2019 at Anse-à-Henry (LeBlanc and Rabottin, 2003, 2005; LiDAR, IGN, 2007; BDTopo IGN, 2019; CAD: M. Le Doaré).

***Fig. 10** – Plan des différentes interventions archéologiques réalisées entre 2000 et 2019 à l'Anse-à-Henry (LeBlanc et Rabottin, 2003, 2005 ; LiDAR, IGN, 2007 ; BDTopo IGN, 2019 DAO : M. Le Doaré).*

20 cm of sediment between the large natural boulders. Seven structures were identified: bowl-shaped firepits (structures 1, 4 and 6), a ring of stones interpreted as a feature to protect against the wetness of the ground (structures 3, 5 and 7) and a firepit dump (structure 2). The C^{14} dates from charcoal recovered from the firepits range from 660 CE to 1118 CE, with a concentration between 660 CE and 780 CE. These dates are consistent with the artefacts found at the site, including the lithic end-blades corresponding to the Beaches phase (McLean, 1994), an intermediate phase dating to between 1 CE and 1500 CE. Middle Dorset artefacts (end-blades and schist plates) were also found in that part of the site, and the dates are coherent with what we know of this well-documented phase in Newfoundland.

4.4. Occupations in the low-lying area

Even though the first mention of the site was based on the discovery of artefacts discovered in the eroding bank of the low-lying area near the point of land, no excavation was carried out in that sector prior to our 2019 intervention. Our pits were set up on an axis orthogonal to the headland between the two coves, over a length of 16 m with pits ranging from 1.5 m or 3 m in width. A total surface area of 42 m² was excavated (fig. 10, test pits A, B, C, D and E). Apart from erosion, no post-depositional disturbance had affected the prehistoric occupations in a stratigraphy that was less than half a metre in thickness (fig. 13). At some point, a cobble layer (US 2) was spread immediately underneath the actual vegetation. That cobble layer is interpreted as an overwash deposit coming from the eastern beach during a sudden submersion by one or more waves coming from either a storm or the 1927 tsunami which hit St. Pierre. The underlying level (US 3) is a peat layer devoid of any remains. The archaeological level underlying the peat (US 4) was remarkably well preserved (fig. 14) and yielded four areas of combustion measuring a few decimetres in diameter each (structures 4, 7, 8 and 9), a small quantity of pink rhyolite debitage (structure 3), a concentration of grey chert debitage (structure 6) and a small amount of crystal quartz debitage (structure 10). That archaeological level rested on a sterile till found throughout the entire site.

The 2,181 lithic artefacts found in the low-lying area came mainly from US 4. It comprises an asymmetrical bifacial artefact with a convex edge (fig. 15, no 6); asymmetric points with lateral notches (box based; fig. 15,

Fig. 11 – Test pit I in September 2019, bottom of the slope, top of the fluvial gravel deposit (photo G. Marchand).
Fig. 11 *– Sondage I en septembre 2019, bas du talus, haut du dépôt de gravier fluvial (cliché G. Marchand).*

Fig. 12 – A ploughing boulder, with a bulge on the left and its upstream furrow on the right, at the bottom of the Anse-à-Henry slope (photo G. Marchand).
Fig. 12 *– Un bloc de labour, avec un bourrelet à gauche et son sillon amont à droite, en bas du versant de l'Anse-à-Henry (cliché G. Marchand).*

Fig. 13 – Northern cross-section of test pit E. The black-coloured archaeological level (US 4) is at the base, on the huge boulders level. The pebbles bed covering the isthmus is at the top of the stratigraphy under the vegetation level (photo A. Naud).
Fig. 13 *– Coupe transversale nord du sondage E. Le niveau archéologique de couleur noire (US 4) se trouve à la base, sur le niveau des énormes blocs rocheux. Le lit de galets recouvrant l'isthme est au sommet de la stratigraphie, sous le niveau de végétation (cliché A. Naud).*

Fig. 14 – Flat firepit (structure 8) on the left and a pile of grey chert debitage (structure 6) on the right, in US 4 of test pit D (low-lying area; photo L. Rousseau).
Fig. 14 *– Foyer plat (structure 8) à gauche et tas de débitage en chert gris (structure 6) à droite, dans l'US 4 du sondage D (zone basse ; cliché L. Rousseau).*

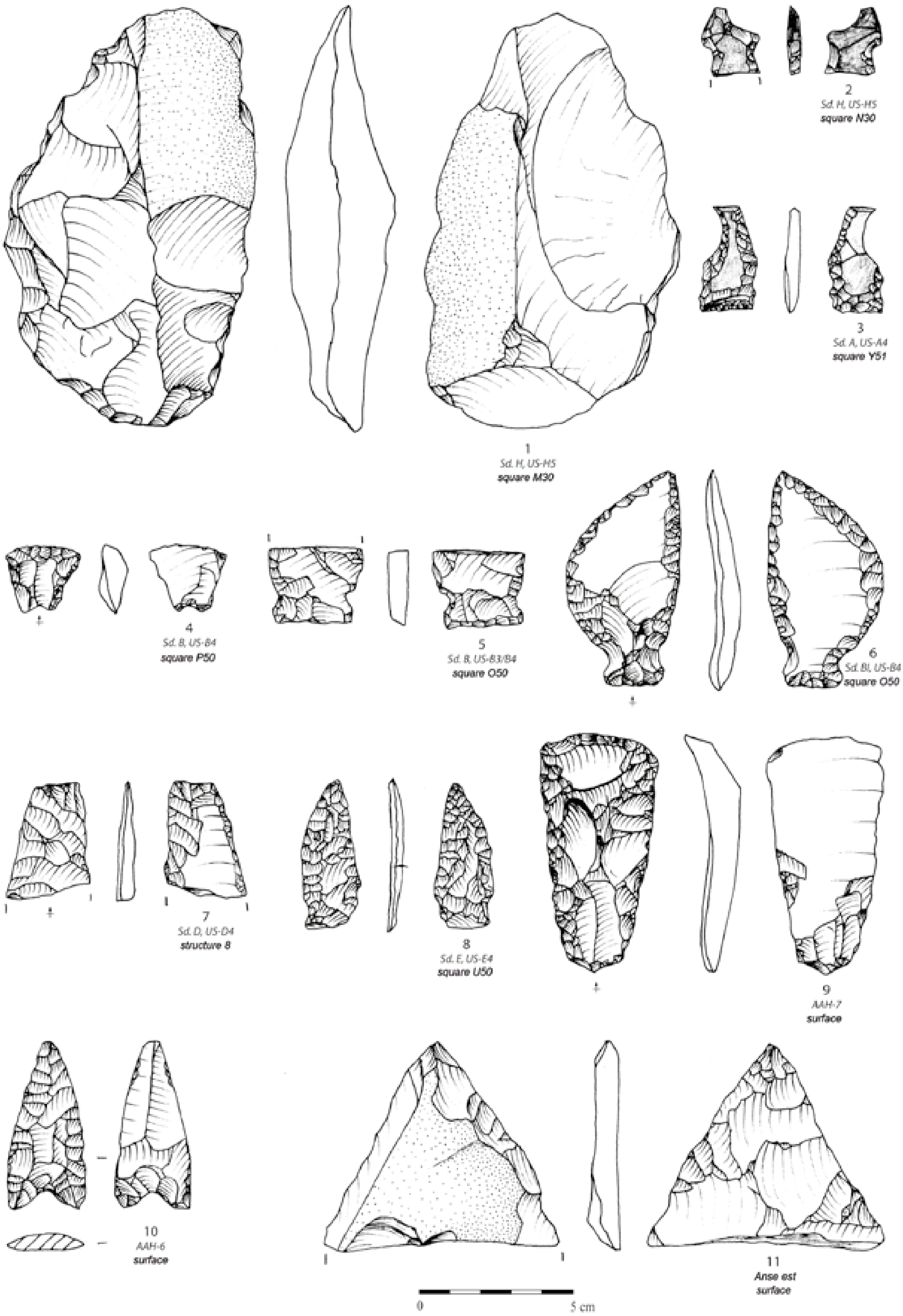


Fig. 15 – Some projectile points and tools (1: Drawing L. Bélanger; 2-3, 6, 9: Drawing L. Rousseau; 4, 11: Drawing F. Bisson; 5, 10: Drawing G. Marchand; 7-8: Drawing M. Pallares; 1-11: inking, shading and CAD L. Rousseau).

***Fig. 15** – Quelques pointes de projectiles et outils (1 : dessin L. Bélanger ; 2-3, 6, 9 : dessin L. Rousseau ; 4, 11 : dessin F. Bisson ; 5, 10 : dessin G. Marchand ; 7-8 : dessin M. Pallares ; 1-11 : encrage, ombrage et DAO L. Rousseau).*

no 5); a small bipoint; an end-blade with a straight base; a small, broad-faced trapezoidal flake scraper and a burin-like tool (fig. 15, no 3). All these are characteristic of the Groswater phase as we know it from Newfoundland and Labrador (Auger, 1984; Erwin, 2003; Renouf, 2003). The C^{14} dates on charcoal from structures 6 and 9, (found near one another), range from 500-400 BCE. Structure 7, to the east, gave a more recent date (360-200 BCE). This suggests two temporally distinct Groswater occupations within a single well-structured level.

4.5. Notes on the cultural components detected

The various archaeological operations conducted at Anse-à-Henry have revealed a number of human occupations over a long period of time which are yet to be better differentiated spatially. As for the Amerindian components, they include the Maritime Archaic and a late tradition that we assume to be ancestral to the Beothuk. The Maritime Archaic complex, first defined by J. A. Tuck (1971), originated from the Atlantic provinces approximately 9000 BP; they roamed the Southern Labrador coast from 7500 to 3500 years ago and were in Port-aux-Choix, Newfoundland at least 4300 BP (Hood, 1993, p. 164). We attribute to those hunter-gatherer populations the earliest harpoon heads to (LeBlanc et al., 2001). The late tradition concept brings together several cultural groups that succeeded one another from the beginning of the Common Era to the European arrival, in particular complexes such as the Cow Head, the Beaches and the Little Passage. Their stemmed arrow fittings stems or side-notched points are characteristic of some of these groups. That technical evolution is likely to be linked to changes in the subsistence economy with a shift from hunting marine mammals to land mammals (ibid.).

The Paleo-Inuit tradition is represented here by the Groswater and Middle Dorset phases. The Groswater, which takes its name from the eponymous site in Labrador (Fitzhugh, 1972), is a cultural group dated, for the regions that concern us, to between 800 BCE and 100 BCE (Renouf, 1999; Betts and Hrynick, 2021). Bifacial points with lateral notches and a box base, burin-like tools, double points, small broad-faced scrapers and microblades are attributed to this cultural group (Lavers and Renouf, 2012). The Dorset phase, originally identified at Cape Dorset (Kinngait), an Inuit village situated on Dorset Island near the Foxe Peninsula in Nunavut, appeared nearly 2,500 years ago in the Eastern Arctic. A characteristic phase developed in Newfoundland (the Newfoundland Dorset) between 100 and 900 CE and extended to St. Pierre and Miquelon. Polished or finely worked stone endblades with straight or sometimes concave bases were hafted to harpoon heads. These distinctive endblades are present in large numbers both at Anse-à-Henry (fig. 15, no 10; fig. 16, no 2) and in Newfoundland (Renouff, 1999; Betts and Hrynick, 2021). This phase, which is typical in Newfoundland, is known as the Middle Dorset in Labrador, Nunavik and Nunavut and covers a comparable time span.

4.6. Radiocarbon dating: are there chronological gaps?

The excavations conducted by S. LeBlanc and J.-L. Rabottin between 2002 and 2004 were accompanied by 19 radiocarbon dates, seven obtained from the 2002 excavation area and 12 from the 2003-2004 area (table 1). The radiocarbon dating was carried out at the Brock University laboratory in St. Catharines, Ontario, Canada, using charcoal samples and allowing for correction of the carbon-13 isotope. This corpus was supplemented in 2019 by three new dates from the Laval University Radiocarbon Laboratory. While this may appear to be a significant number of radiocarbon dates, they do not cover the whole history of occupations at Anse-à-Henry (fig. 17). In particular, occurrences of Maritime Archaic are absent, while there appear to be gaps between the attested cultural phases. The archaeological assessment carried out in 2019 proposes a new reading of the sedimentary context, which seems to be marked by substantial post-depositional upheavals on the slope, resulting in a displacement of the fine elements. This is nevertheless offset by the fact that the sunken structures do not seem to have been affected to any great degree by the taphonomic phenomena of the site; thus, the dates obtained within the structures in the early 2000s show a coherence, however, the same cannot be said for those collected from outside the structures in 2003-2004, the latter are rather useless. In summary, if we discard the 12 dates coming from the 2003-2004 excavations and retain only the dates obtained on the charcoal from the firepits, that is the seven dates obtained in 2002 and the three dates we obtained in 2019, then we can confidently identify three cultural phases, each with a specific occupation period:

- phase 1: 500-200 BCE, Groswater (low-lying area or north zone);
- phase 2: 660-940 CE, Middle Dorset or Recent Period (slope);
- phase 3: 1320-1625 CE, Recent Period (slope).

Repositioned spatially, phase 1 was found in the low-lying area of the site near Rocher de La Vierge (also called “the north zone”), phase 2 was found on the slope in the two areas excavated in the 2000s, and phase 3 was recorded exclusively in the middle of the slope in the open area excavated in 2003 and 2004. Two phase 1 dates from an extremely erratic sedimentary context, suggest early occupations in the middle of the slope, but these are chronologically inconsistent with the low-lying area dates, one of which is older (BGS-2492) and one more recent (BGS-2614). By adopting this sampling strategy centred exclusively on the structures, the initial notion of continuous occupations from the Maritime Archaic to the recent period becomes irrelevant. There are substantial chronological gaps between 200 BCE and 600 CE and between 940 CE and 1320 CE.

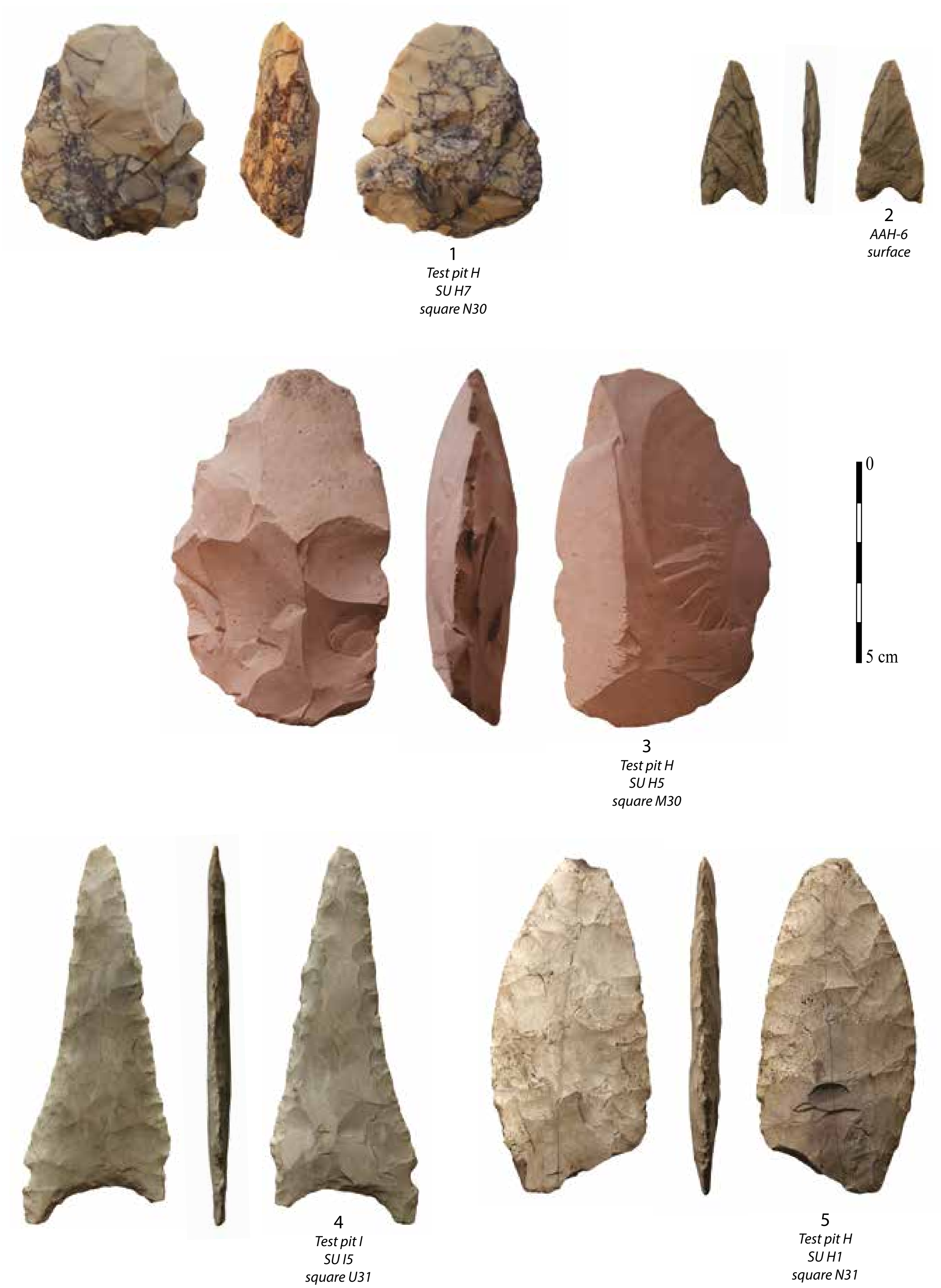


Fig. 16 – Examples of the most common rocks used in Anse-à-Henry toolmaking (excavation 2019). 1 and 2: Jasper from Grand Colombier (facies D); 3: Pink rhyolite (facies A); 4 and 5: Patinated rhyolite (facies C; photos and CAD L. Rousseau).

Fig. 2 *– Exemples des roches les plus courantes utilisées dans l'outillage de l'Anse-à-Henry (fouille 2019). 1 et 2 : Jaspe du Grand Colombier (faciès D) ; 3 : rhyolite rose (faciès A) ; 4 et 5 : rhyolite patinée (faciès C ; clichés et DAO L. Rousseau).*

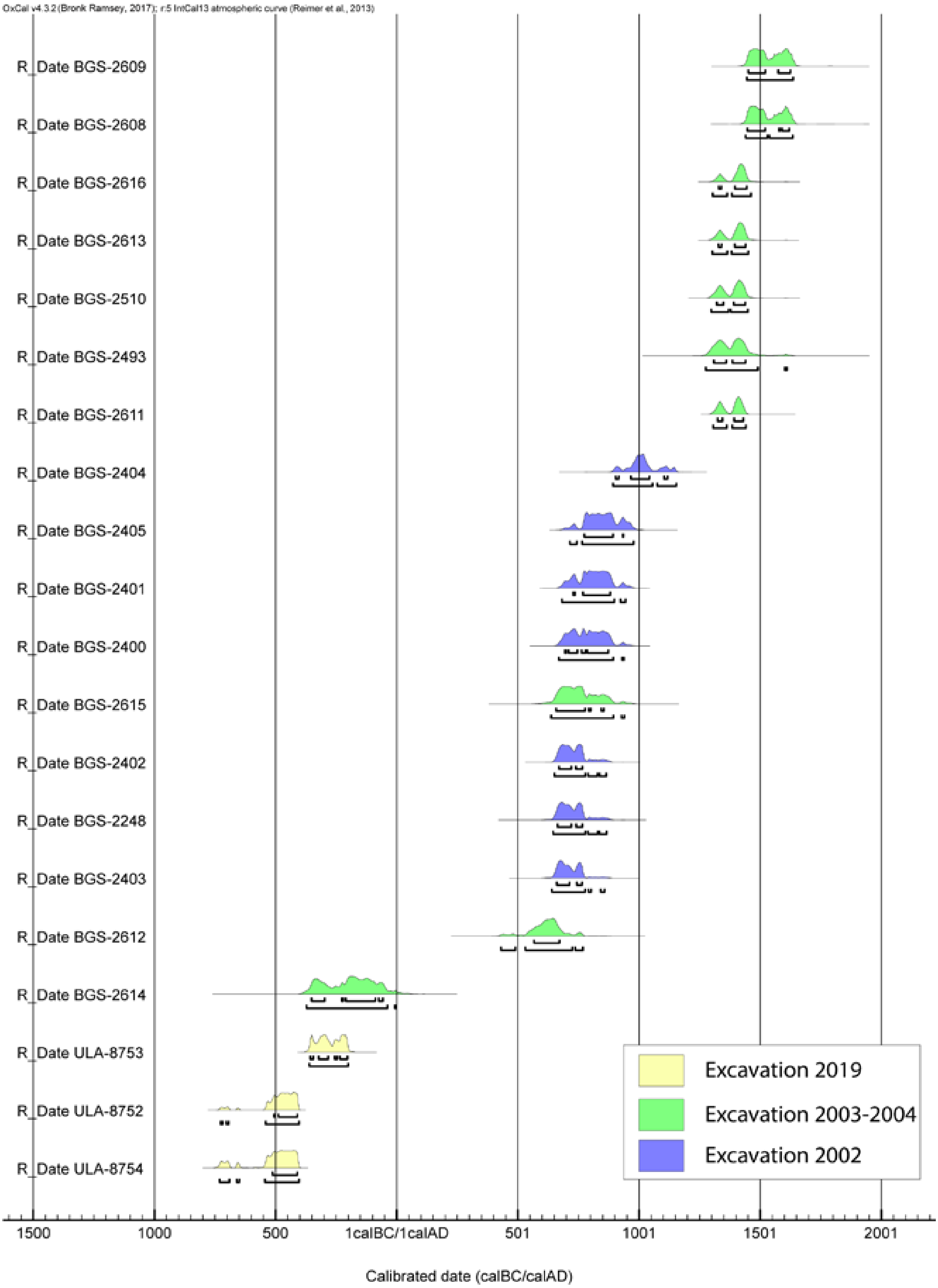


Fig. 17 – Distribution of radiocarbon dates (95.4% calibration with Oxcal 4.3) organised from oldest to most recent, with excavation areas indicated by colours (CAD G. Marchand, based on Oxcal 4.3; Reimer et al., 2020).

***Fig. 17** – Distribution des dates radiocarbone (calibration à 95,4 % avec Oxcal 4.3), de la plus ancienne à la plus récente ; les zones de fouilles sont indiquées par des couleurs (CAD G. Marchand, d'après Oxcal 4.3 ; Reimer et al., 2020).*

Code	Zone	Location	14C age (BP)	±	Calibration (cal. BC) – 95.4%	
ULA-8752	Excavation 2019 Test pit D	Test pit D US D4 N50/STR 6	2410	20	- 727	- 404
ULA-8753	Excavation 2019 Test pit D	Test pit B US B4 Q50/STR 7	2205	20	- 361	- 202
ULA-8754	Excavation 2019 Test pit D	Test pit D US D4 M51/STR 9	2415	25	- 731	- 404
BGS-2610	Excavation 2003-2004	Structure 1- Firepit	370	40	1446	1635
BGS-2609	Excavation 2003-2004	Structure 4 - Firepit	370	45	1445	1637
BGS-2608	Excavation 2003-2004	Structure 1 - Firepit	380	45	1441	1635
BGS-2616	Excavation 2003-2004	Structure 4 - Firepit	510	50	1305	1463
BGS-2613	Excavation 2003-2004	Structure 4 - Firepit	520	50	1304	1453
BGS-2510	Excavation 2003-2004	Structure 1 - Firepit	530	55	1299	1450
BGS-2493	Excavation 2003-2004	Structure 1 - Firepit	540	80	1277	1611
BGS-2611	Excavation 2003-2004	Structure 4 - Firepit	540	40	1307	1442
BGS-2615	Excavation 2003-2004	None	1280	70	638	940
BGS-2612	Excavation 2003-2004	Structure 3	1410	70	432	769
BGS-2614	Excavation 2003-2004	None	2140	65	- 373	- 4
BGS-2492	Excavation 2003-2004	Schist plate	2575	45	- 826	- 543
BGS-2404	Excavation 2002	Firepit 1	1025	50	893	1154
BGS-2405	Excavation 2002	Firepit 1	1175	45	716	979
BGS-2401	Excavation 2002	Firepit 1	1210	45	682	945
BGS-2400	Excavation 2002	Firepit 4	1230	50	669	938
BGS-2402	Excavation 2002	Firepit 6	1290	45	652	865
BGS-2248	Excavation 2000	Firepit 1	1300	50	646	867
BGS-2403	Excavation 2002	Firepit 6	1310	45	641	859

Table 1 – List of radiocarbon dates obtained on charcoal at Anse-à-Henry for all operations combined, ranked from most recent to oldest (LeBlanc and Rabottin, 2002 and 2005; and unpublished dates for the 2019 campaign). Calibration with OxCal 4.3 software (Reimer et al., 2020).

***Tabl. 1** – Liste des dates radiocarbone obtenues sur charbon de bois à l'Anse-à-Henry toutes opérations confondues, classées de la plus récente à la plus ancienne (LeBlanc et Rabottin, 2002 et 2005 ; et dates non publiées pour la campagne 2019). Calibration avec le logiciel OxCal 4.3 (Reimer et al., 2020).*

5. WAS THE ARCHIPELAGO PART OF A NETWORK IN THE DISTRIBUTION OF RAW MATERIAL? VOLCANIC ROCK QUARRIES AND RAW-MATERIAL TRANSFERS

5.1. Identification of worked ryolite at Anse-à-Henry

The use of local rocks can be easily detected at the Anse-à-Henry site from the abundance of flakes and biface preforms broken during preparation. A local origin is likely for these rocks, since nomadic groups would not have bothered to transport potentially flawed uncut boulders. The first phase of our research on the supply of workable rocks consisted in identifying the rocks used to make the tools (fig. 16). In the context of S. LeBlanc and J.-L. Rabottin's archaeological excavations (1997 to 2004), J.-L. Rabottin carried out an initial classification into 20 types, which are numbered 1 to 20 and displayed individually at Museum of L'Arche on St. Pierre. An examination of the lithic assemblage collected in 2019 and the discovery of certain deposits (Auger et al., 2019) have made it possible to group some of these types together to consider the extensive variability of volcanic rocks (table 2).

The dominant rock in our surveys was a glossy grey silicate (facies E), whose use is 98% attributable to the occupants of the low-lying area of Anse-à-Henry, in other words to the Groswater facies Paleo-Inuit. The facies D jasper was the second most common rock detected, but this was found almost exclusively on the slope, with tools attributable mainly to the Dorset period. The use of crystal quartz was also attributed to this period (LeBlanc and Rabottin, 2000, p. 15), but we found a considerable cluster in the low-lying area in the Groswater zone which may suggest that the space used during the Groswater phase may have been attractive to the Dorset as well. The pink rhyolites were the next most common (facies A and facies B), followed by facies C (patinated rhyolites). These were found in all areas of the site. Could the apparent diversity in the use of raw materials on this habitat over time correspond to a broad choice of geological deposits, or could it reflect local variations among the facies? The answer to this question inevitably lies in future studies of the extraction zones themselves.

5.2. Locating the rhyolite and ash tuff extraction zones

The second phase of our research consisted in ground surveys using geological maps and S. LeBlanc and J.-L. Rabottin's notes to identify certain extraction zones. This excluded, from the outset, the sedimentary silicates (facies E), which probably came from Cow Head in Newfoundland (Auger, 1984; Lavers and Renouf, 2012). The geological substratum of St. Pierre is mainly marked by intense explosive volcanic activity, dated between 585 and 575 million years ago, which left behind ash tuffs, lapilli tuffs and pyroclastic breccias (Blein et al., 2015). The resulting rocks suitable for tool production are fiamme ignimbritic rhyolites and silicified, very fine-grained ash tuffs**.** As we were able to observe, most of the rhyolites split naturally into plates measuring 10 cm to 20 cm long and 2 cm to 5 cm thick, which naturally configures them for bifacial productions with minor adaptations needed.

This identification of the lithology of the rocks used and/or present on the site must be considered in combination with their assumed geological location. How many geological deposits were actually exploited by the prehistoric occupants of the archipelago? What distances did they travel to obtain them? Was the supply local, or should we consider contributions from further afield? The accessibility of workable rocks as well as the knapper's

Name	Rabottin type	AAH-2019 Facies	Proportions in 2019 (%)
Homogeneous pink rhyolite	1, 2, 3, 5, 6, 13, 16, 17	A	9.4
Burgundy veined rhyolite	4, 9, 10	B	8.1
Patinated rhyolite	8, 18, 19, 20	C	3.8
Beige veined silicified tuffs	7a, 7 b, 12	D	31.9
Homogeneous glossy grey silicate	11	E	41.8
Blue-grey siliceous rock	14	F	Negligible
Reddish siliceous rock	15	G	0.5
Hyaline quartz	Crystal quartz	H	0.6
Brown quartzite sandstone		I	0.4
Other			3.5

Table 2 – Equivalence between the Rabottin types and the lithological facies established from worked lithic pieces found during the 2019 Anse-à-Henry excavation (AAH-2019).

***Tabl. 2** – Équivalence entre les types de J.-L. Rabottin et les faciès lithologiques établis à partir des pièces lithiques travaillées trouvées lors de la fouille de l'Anse-à-Henry 2019 (AAH-2019).*

selection principles and the values of certain rocks must all be considered in the study of human occupations and landscape perception. In the absence of ploughed fields on these islands, visual access to the substratum was gained through sea cliff cross-sections, the numerous windfalls in the low-lying forests, the periphery of huge boulders, which often leave large furrows devoid of vegetation, the edges of ponds, stream beds and even areas where the vegetation has been damaged by snow accumulations. Cliff bases were also explored, despite the difficulty to access them over scree slopes. Those provided opportune access to a series of geological strata in the slope deposits. In terms of cumulative surface areas, the observation windows were quite large and offered a good readability. We also noted that all the topographic contexts were accessible, whether located at the top of hills or the bottom of valleys. After identifying the areas of interest on the geological map, a random but sustained reconnaissance was carried out, with multiple visits over the course of the year.

Three provenance areas were reported by S. LeBlanc and J.-L. Rabottin for St. Pierre: the eastern part of the island of Grand Colombier, the Cailloux Rouges headland in the west of St. Pierre and the Cap Rouge headland in the northeast (fig. 18). Grand Colombier supplied a creamy yellow siliceous rock marbled with blue or violet veins and is rather unique in appearance (fig. 17, no 1 and no 2; fig. 19, photos GC-1 to GC-4). Those rocks are thought to be silicified tuffs due to the circulation of hydrothermal fluids (Olivier Blein: *in litteris*). On the site itself, at the eastern end of the island, we found no obvious traces of exploitation, but visibility was poor due to a thick vegetation cover of grass, fern and crowberries, which had no doubt been boosted by the concentration of guano on the ground. We collected raw material samples from four zones on Grand Colombier (GC-1, GC-2, GC-3 and GC-4).

Although the Cailloux Rouges headland does not provide any workable rock, we discovered a remarkable rhyolite quarry one kilometre to the south, which we propose to name Bois Brûlé (Marchand and Borthaire, 2020). This source of raw material extends over more than 20,000 m^2 and comprises at least seven pink, purple or black rhyolite outcrops (named SP-7, SP-8, SP-9, SP-10, SP-11, SP-12 and SP-13; Marchand and Borthaire, 2020). Thousands of flakes and unfinished bifacial artefacts strewn across these outcrops indicate intensive exploitations that are yet to be dated. To the northeast of the island, in the upper part of the volcanic formations, only the Étang de l'Île outcrop (SP-4) shows traces of spatially confined exploitations. We also sampled two comparatively small but good quality materials in the cliffs nearby (SP-5 and SP-14). Finally, three other rhyolite quarries, each a few metres in diameter, were discovered by Borthaire more than 30 km away from Anse-à-Henry in the south of Miquelon Island (MIQ-6, MIQ-7 and MIQ-8). Therefore, the question should be raised whether these recently discovered deposits were all exploited by the archipelago's occupants.

5.3. First results from the geochemical analyses of the worked siliceous rocks and quarries identified

To answer the above questions, geochemical analyses were conducted on rock samples from the quarry sites and on abandoned worked rock from the Anse-à-Henry archaeological site. One or two samples were analysed from each quarry. The analyses consisted firstly in specifying the nature of the volcanic rocks collected from the deposits. We then determined the most discriminating chemical elements in order to characterise the St. Pierre and Miquelon quarries. The objective was to compare the compositions of the worked rocks from the Anse-à-Henry habitat with those from the St. Pierre and Miquelon quarries. An origin can be proposed when there is a correlation between geochemical composition of the objects and what was recovered at the quarry.

The instrument used for our chemical analyses was a Thermo Scientific Niton XL3t Goldd+ portable X-ray Fluorescence (XRF) spectrometer. This instrument was used in the "TestAll Geol" pre-programmed mode. At least three analyses were performed on each sample and, where possible, on three different zones. This revealed the heterogeneity of the samples. We prioritised flat surfaces and avoided corrupted or patinated areas. The elements we detected using this method ranged from magnesium to uranium. The elemental chemical compositions were adjusted using international standards (UB-N, MAN, Mica-Fe, NIST610, NIST612 and NIST614) analysed under the same conditions.

Table 3 presents the mean spectrometer results identifying 22 chemical elements for each sample. The analyses confirmed that all the rocks were siliceous and that the SiO2 contents exceeded 69%. We compared the SiO2 contents for each analysis with the Zr/TiO2 ratio, which, expressed in the Winchester and Floyd diagram, made it possible to specify the volcanic nature of these rocks (fig. 20). We expected most of the rocks from the deposits to have a chemical composition like that of a rhyolite, but this was not the case. On the contrary, there was a considerable dispersion of values, which was not reported in a previous geochemical study of the acidic volcanic rocks in St. Pierre and Miquelon (Rabu et al., 1996).

This discrepancy in results may be related to the silicification phenomena that had locally affected the rocks during ignimbritic effusions. It is also possible that there were subsequent alteration processes that had affected the chemical composition of the rocks. Looking at the results, it is easy to distinguish between two sets of formations. The first concerns the rocks from the Grand Colombier deposit, whose SiO_2 concentration exceeds 85%, associated with a low Al_2O_3 concentration (less than 2%). This is an ancient, highly silicified rhyolitic tuff. The second set comprises the rest of the rocks in the study. This set has an Al_2O_3 content of more than 4% and a SiO_2 content that ranges from 69% to 85%, sometimes even within a deposit.

To distinguish the formations of this second set, we applied an additive log-ratio transformation of the data

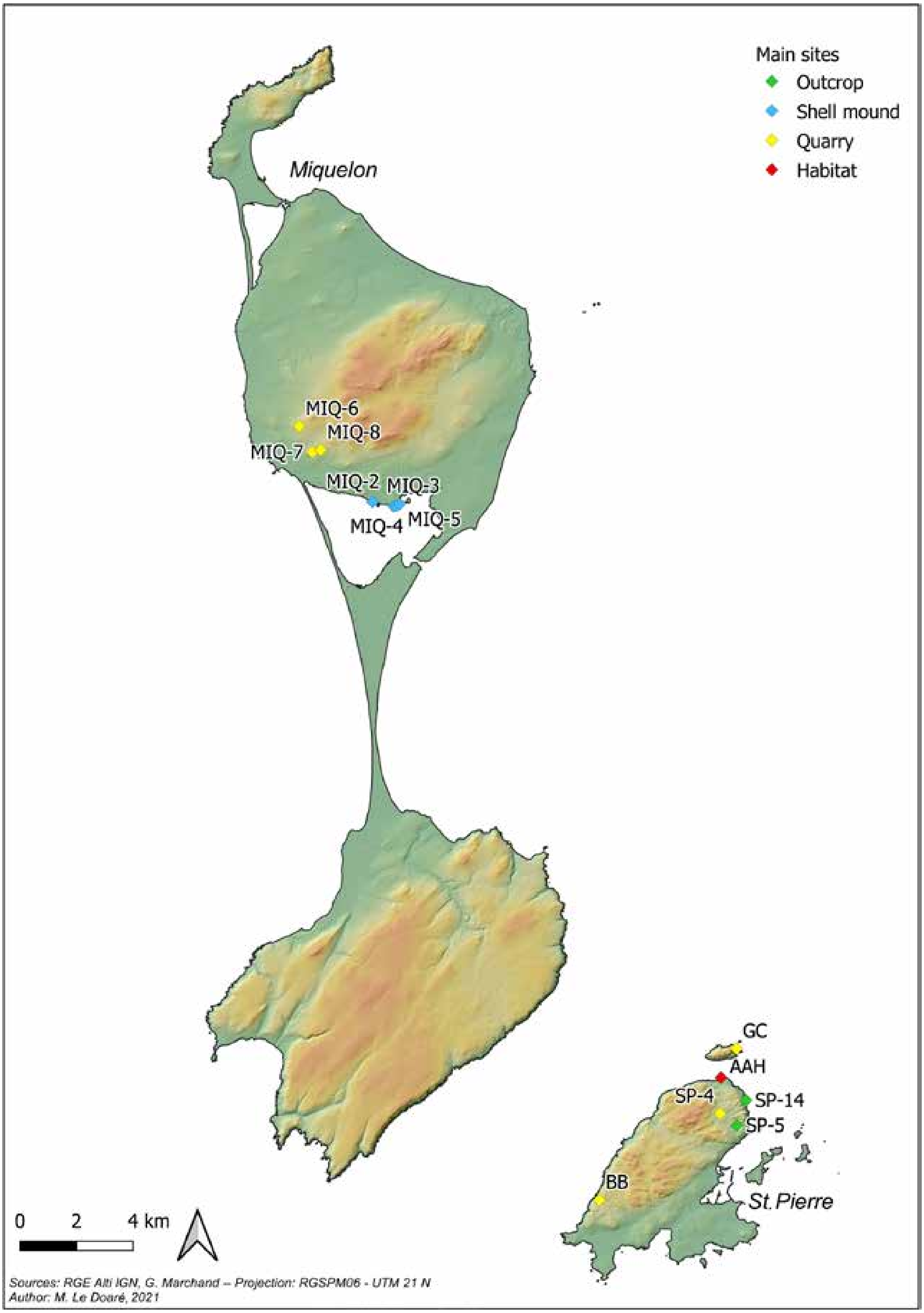


Fig. 18 – Main archaeological sites discovered by our team in 2019 and 2020. The Bois Brûlé quarry includes zones SP-7, SP-8, SP-9 and SP-10, which have been the subject of geochemical analyses (CAD M. Le Doaré, based on IGN map).

Fig. 18 *– Principaux sites archéologiques découverts par notre équipe en 2019 et 2020. La carrière du Bois brûlé comprend les zones SP-7, SP-8, SP-9 et SP-10, qui ont fait l'objet d'analyses géochimiques (CAO M. Le Doaré, d'après la carte IGN).*

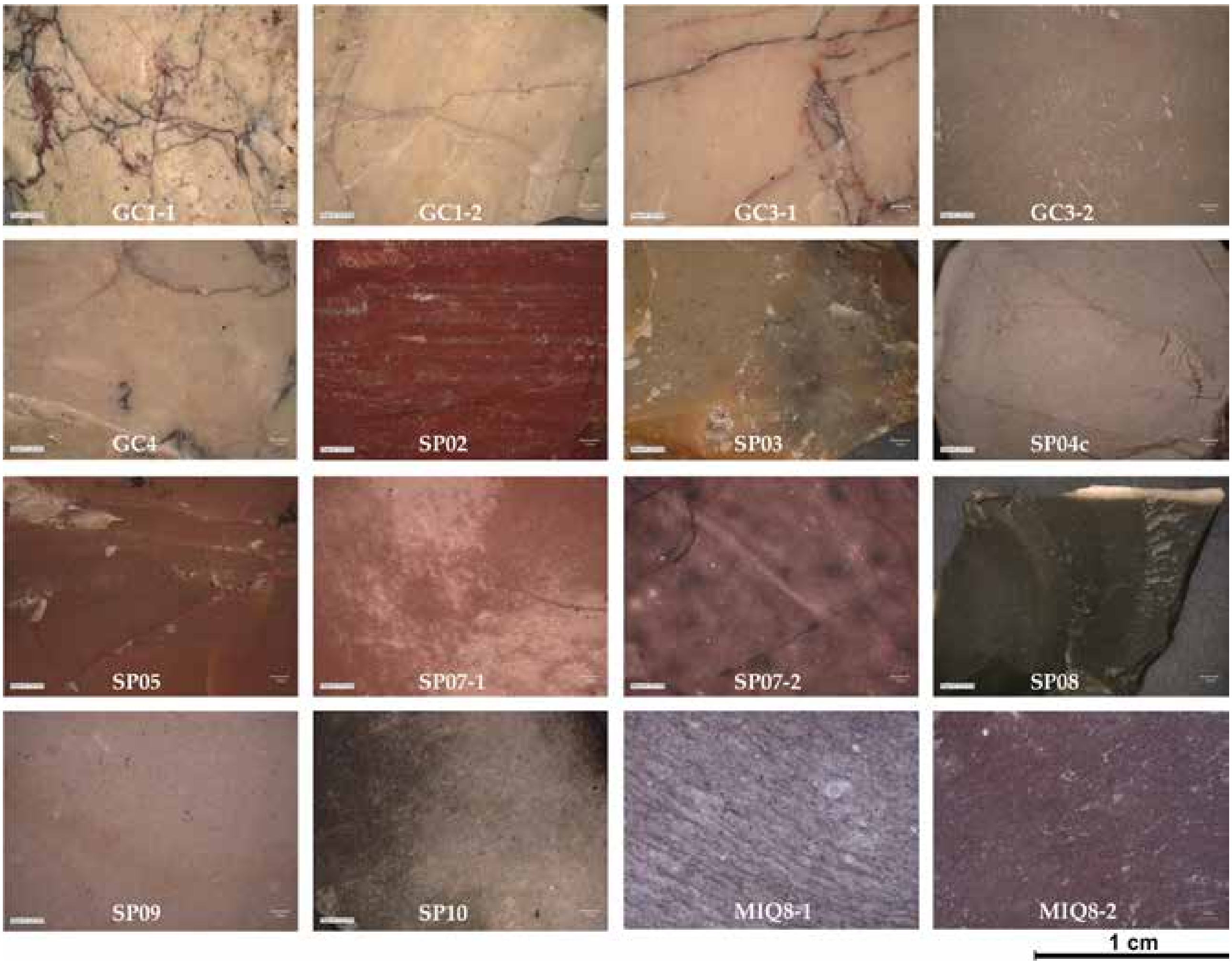


Fig. 19 – Macrophotographs of various rocks from the rock deposits discovered on the archipelago.
Photo dimensions W: 15 mm x H: 10 mm (photos M. Guiavarc'h).
Fig. 19 *– Macrophotographies de différentes roches issues des gisements rocheux découverts sur l'archipel.*
Dimensions des photos L : 15 mm x H : 10 mm (clichés M. Guiavarc'h).

following J. Aitchison and M. Greenacre's (2002) recommendations, a method previously developed on and for the study of Corsican rhyolites (Leck et al., 2018). This data processing was necessary because the results provided by X-ray fluorescence spectrometry are compositional data expressed as proportions (in ppm in our case). This transformation broke down the data interdependence and reduced the dispersion of the results linked to the heterogeneity of the rhyolites, which varied in degree, as we can see with the silicification phenomena. The element Si was therefore chosen as the log-ratio denominator. After transformation, the contents of the elements K, Ti, Zr, Mn, Rb, Fe, Ba, Nb and Sr, as expressed in different bivariate diagrams, allowed us to visualise the characteristic compositional zones of the rocks from the deposits. With this set of elements, the composition of the rock from the Cap Rouge deposit (SP-5) is particularly differentiated from the other compositions. In general, the chemical compositions of the rocks from the different Bois Brûlé deposits are similar. The two SP-7 facies can nevertheless be differentiated from the other Bois Brûlé deposits. A graph comparing the Ba and Nb contents shows the distinction between the rocks from Miquelon and those from Bois Brûlé in St. Pierre, those corresponding to sample SP7-2 (fig. 21).

The analyses conducted on the archaeological objects from the Anse-à-Henry site, which were selected according to their macroscopic type, were then compared with the data from the deposits. We noted that the occupants of the Anse-à-Henry site mainly obtained their raw materials from the Bois Brûlé deposit in St. Pierre and the Grand Colombier deposit. Types 7a and 7b from the site correspond to rocks from the Grand Colombier quarries GC-1, GC-3 and GC-4. The SP-7 quarry was used at Bois Brûlé; chemical data from sample SP-7-2 are like types 4, 9, 10 and 9-10 (fig. 21). The other quarries at Bois Brûlé are more difficult to distinguish from one another. Despite their different macroscopic aspects, their chemical compositions are similar. In addition, it seems the Miquelon deposit provided material for type 16, but this important connection is yet to be confirmed, because it is based on a single element: barium. The association of the archaeological objects with the SP-3, SP-4 and SP-5 quarries is not an obvious one. We nevertheless noted that type 16

Deposit		Al2O3	SiO2	P2O5	K2O	CaO	TiO2	MnO	Fe203	Total	Ba	Ni	Cu	Zn	Ga	Rb	Sr	Zr	Nb	Sn	Sb	Pb	Th	U
GC1-3-4	mean	0,466	92,769	0,37	-	0,025	0,429	0,013	0,085	**94,158**	65	75	8	-	-	-	14	172	7	-	-	13	3	-
	standard deviation	0,083	3,168	0,199	-	0,026	0,179	0,002	0,127	**3,011**	41	17	2	-	-	-	25	63	3	-	-	7	1	-
MQ8	mean	7,463	74,656	0,364	0,695	0,156	0,41	0,03	1,008	**84,781**	147	95	8	14	8	16	25	269	15	-	-	11	5	6
	standard deviation	1,043	9,401	0,16	0,116	0,071	0,349	0,003	0,283	**9,603**	74	14	1	4	1	1	2	30	1	-	-	1	1	1
SP2	mean	8,334	69,441	0,283	2,499	0,281	0,19	0,049	1,423	**82,5**	816	126	10	25	9	67	80	180	9	47	133	15	5	8
	standard deviation	1,277	2,593	0,027	0,438	0,078	0,072	0,015	0,755	**2,937**	182	13	1	8	2	6	18	41	4	24	68	2	1	1
SP3	mean	6,258	82,469	0,281	2,631	0,144	0,111	0,024	0,338	**92,255**	464	101	-	14	-	109	28	99	6	50	128	17	5	8
	standard deviation	0,568	7,905	0,048	0,46	0,075	0,024	0,003	0,034	**7,25**	128	21	-	8	-	7	1	4	2	9	24	5	1	2
SP4	mean	4,702	89,55	0,277	2,479	0,055	0,046	0,024	0,326	**97,46**	305	161	3	10	0	123	17	55	7	49	125	3	5	5
	standard deviation	0,605	0,915	0,016	0,187	0,009	0,004	0,003	0,003	**1,343**	14	126	5	2	0	4	3	4	1	8	16	5	0	5
SP5	mean	2,762	79,491	0,322	0,339	0,094	-	0,016	0,07	**83,1**	204	65	-	-	-	12	10	4	-	43	146	-	-	-
	standard deviation	2,285	10,553	0,06	0,17	0,052	-	0,004	0,012	**12,092**	14	6	-	-	-	2	5	1	-	3	12	-	-	-
SP7	mean	6,754	79,139	1,111	1,413	0,479	0,141	0,036	1,961	**91,034**	275	113	12	21	13	33	255	884	57	47	95	30	8	12
	standard deviation	1,498	5,4	0,573	1,168	0,884	0,099	0,023	1,068	**3,609**	95	24	2	10	4	26	290	158	8	10	22	18	2	4
SP8	mean	12,604	70,412	0,242	1,812	0,549	0,215	0,077	0,899	**86,81**	353	56	-	36	8	56	195	226	15	32	72	9	7	9
	standard deviation	0,103	0,511	0,039	0,021	0,006	0,008	0,002	0,009	**0,571**	15	17	-	2	1	1	3	2	1	2	10	0	1	1
SP9	mean	10,408	78,381	0,253	1,991	0,123	0,051	0,022	0,583	**91,812**	646	115	-	9	10	68	78	233	10	49	134	7	4	5
	standard deviation	0,3	1,755	0,036	0,073	0,007	0,007	0,003	0,016	**1,665**	21	12	-	4	3	2	2	2	1	7	11	1	0	4
SP10	mean	10,449	72,371	0,3	1,725	0,72	0,235	0,059	0,862	**86,721**	566	110	10	30	9	37	101	351	16	39	98	14	7	8
	standard deviation	1,433	2,872	0,026	0,079	0,435	0,062	0,026	0,333	**4,228**	131	26	2	14	2	1	36	25	2	27	63	5	2	2
SP11	mean	9,616	69,718	0,426	1,797	0,221	0,17	0,041	0,71	**82,699**	333	130	8	16	10	35	43	311	16	-	-	10	6	6
	standard deviation	0,399	1,297	0,054	0,053	0,007	0,001	0,005	0,036	**1,776**	9	20	1	1	3	1	8	11	1	-	-	2	1	1

Table 3 – Data from the X-ray fluorescence spectrometry analyses averaged for each deposit discovered at St. Pierre (SP), Grand Colombier (GC) and Miquelon (MQ). The weights of oxide concentrations are given in % and the elemental concentrations in ppm; SD = standard deviation.

Tabl. 3 *– Données des analyses par spectrométrie de fluorescence X moyennées pour chaque gisement découvert à Saint-Pierre (SP), au Grand Colombier (GC) et à Miquelon (MQ). Les poids des concentrations en oxydes sont donnés en % et les concentrations en éléments en ppm ; SD = écart-type.*

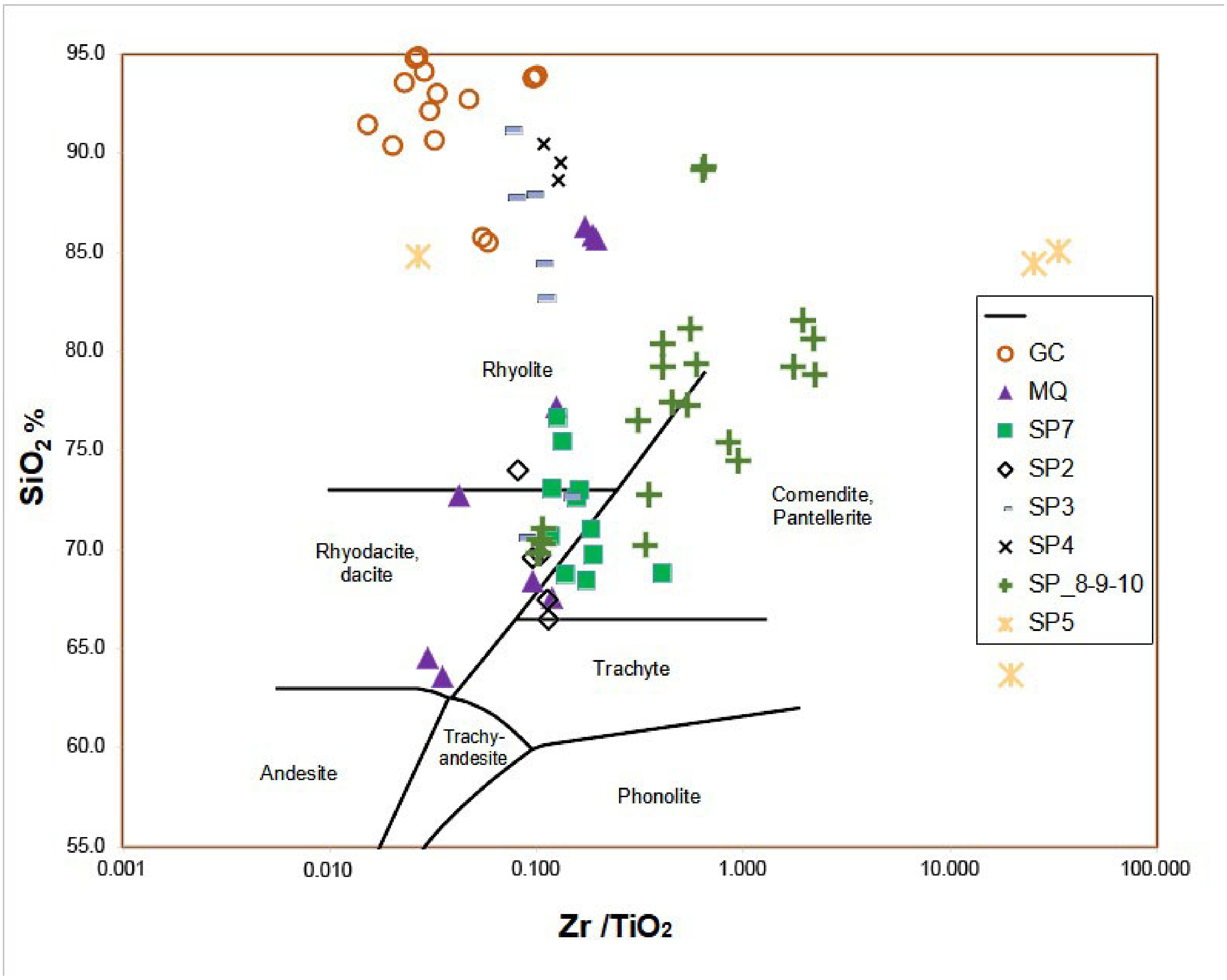


Fig. 20 – SiO2 diagram as a function of the Zr/TiO2 ratio (according to Winchester and Floyd, 1977; M. Guiavarc'h).
***Fig. 20** – Diagramme de SiO2 en fonction du rapport Zr/TiO2 (selon Winchester et Floyd, 1977 ; M. Guiavarc'h).*

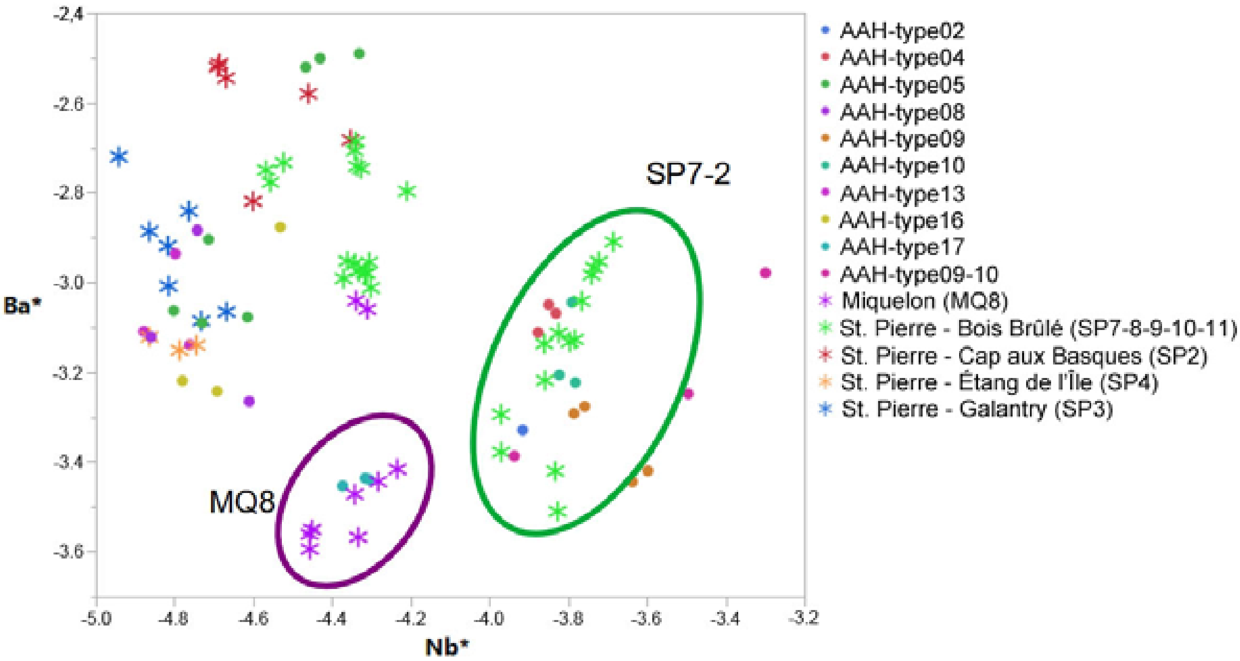


Fig. 21 – Bivariate graph comparing the Ba and Nb contents of rocks from the deposits and worked rocks from the Anse-à-Henry site. The stars correspond to the geological samples of the deposits, while the dots indicate the analysed artefacts.
***Fig. 21** – Graphique bivarié comparant les teneurs en Ba et Nb des roches des gisements et des roches exploitées du site de l'Anse-à-Henry. Les étoiles correspondent aux échantillons géologiques des gisements, tandis que les points signalent les artefacts analysés.*

rock has the same composition as the material from SP-4. The chemical analyses did not link type 15 to any quarry in St. Pierre and Miquelon. This rock type is probably not a rhyolite. The analyses also showed that the SP-5 quarry at Cap Rouge was not present in the Anse-à-Henry collection.

The research to determine the origin of the rocks used at the Anse-à-Henry site and the diffusion of the rocks from the St. Pierre and Miquelon quarries is in its very early stages. Petrographic characterisation of all these facies is imperative to guide our geochemical analyses. To refine the models for determining the origins of the rocks, it is also essential for statistical purposes to increase the number of reference samples. At least 30 samples should be analysed for each facies from a deposit. This will improve the assessment of the chemical variability of the rocks and refine the provenance models. Another important methodological consideration is the impact on chemical composition of rock alteration states and patinas on archaeological and geological objects. Finally, the use of more precise additional analytical techniques such as LA-ICP-MS will provide a more accurate evaluation of the geochemical methods.

5.4. How are raw materials circulating?

Identifying deposits and determining rocks is not sufficient to fully characterise the transfer networks of lithic materials. It is also essential to analyse the forms in which the materials were introduced into the sites (as raw or hewn boulders, raw materials or finished products). This information will provide an understanding of the ways in which resources were acquired and managed while considering the impact of the geological and geomorphological environment on the human groups' technical and economic choices. The stratigraphic complexity evident at the end of our first campaign is likely to complicate this project, because we will be looking at an average overall picture agglomerating at least 2,500 years of diverse practices. However, there is a clear diversity of supplies at the spatial level at the Anse-à-Henry site. Homogeneous glossy grey chert accounts for 41.8% of the pieces in the assemblages collected in September 2019. In the absence of sedimentary silicates on the St. Pierre and Miquelon archipelago, our predecessors have proposed comparisons with deposits found in Newfoundland, notably those on the west coast at Cow Head, situated approximately 350 km away as the crow flies (LeBlanc and Rabottin, 2005, p. 46). The debitage from the Factory Cove site, which was exploited for raw materials by the Groswater phase Paleo-Inuit hunters, includes unfinished objects and preforms (36% of the total collection) as well as 87,006 flakes recovered from a surface area of 160 m^2 (Auger, 1984, p. 62).

We are now able to affirm that some of the objects found at Anse-à-Henry were made on-site, as evidenced by the number of flakes and shaping splinters uncovered in test pit D (structure 6). The rhyolite from Grand Colombier represents the second largest volume of pieces in the 2019 corpus, accounting for 31.9%, but it was almost exclusively identified at test pit H, situated on the slope, and was almost totally absent from the test pits located in the low-lying area (north zone). As for the ignimbritic rhyolites, the *chaînes opératoires* (reduction sequences) identified at this site were almost exclusively oriented towards the production of bifacial pieces. Cutting activities are indeed only just visible in the very rare lithic core fragments and the flakes from striking platforms. The production process was sometimes initiated by direct percussion on the hard stone or during the cutting process to correct errors. The shaping was then done by direct gentle percussion, with a preparation of the striking platforms (removal of the overhang or even extensive grinding and sometimes faceting of the heel).

CONCLUSION

In the context of a strongly expressed social and political will (for the archaeological documentation of the maritime activities of an archipelago over a long period of time), the archaeological project described in this article has presented a variety of analyses and results. The processing of the LiDAR images immediately revealed the density of the historic settlements but provides no data as to the more discrete prehistoric habitats. These renewed excavations at Anse-à-Henry focused on the link between geomorphology and archaeology to consider the multitude of erosive processes that affect the archaeological signal had previously been overlooked. This ongoing interdisciplinary dialogue forms the basis for recommendations concerning the preservation of the archaeological heritage.

At the level of the Anse-à-Henry site, this approach has already led to an adjustment of some of the findings from the research carried out on the slope in the 2000s. On the other hand, the low-lying area of the site, near Rocher de La Vierge, has yielded a remarkably structured archaeological level attributable to the Groswater phase. The size of this site and the quantity of lithic remains it contains indicate that it was a node in what were probably very diverse economic and social networks, which must be characterised. The approach used here combines geoarchaeology and petroarchaeology and is based on intensive field prospections throughout the archipelago. This makes it possible to connect points in space, habitats and quarries. These will eventually need to be supplemented with evidence of tool use or the nature of habitat structures. By determining activity facies, we will then be able to provide a clearer picture of maritime mobility practices and thus better understand the connectivity of these networks.

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The Potential of Analysing Prehistoric Human Occupation in the Western Rias of Galicia (Northwest Iberia): Methods and Prospects

Le potentiel de l'analyse des occupations humaines préhistoriques dans les rias occidentales de la Galice : méthodes et perspectives

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Abstract: Located in the north-west of the Iberian Peninsula, Galicia is the region with the longest coastline in Spain. This coast is characterized by the presence of several estuaries (rias), the largest of which are located in the west. A number of islands and islets can be found within or at the mouth of such rias, as is the case in Ría de Vigo, Ría de Pontevedra and Ría de Arousa. Unlike other European Atlantic regions, the occurrence of prehistoric remains in topographically low coastal locations has traditionally been considered rare in the area. However, prehistoric human subsistence strategies in the region largely benefited from the extremely rich coastal and maritime resources, and there is increasing material evidence of sites dating from these periods, as well as of long-distance exchange of materials and ideas between these and other European Atlantic communities. In this paper we will focus on the different survey, fieldwork and dating methods and approaches recently used in these Western rias and will discuss the future prospects for prehistoric coastal research and heritage in the area.
Keywords: Prehistory, coastal archaeology, coastal erosion, Galicia, Iberian Peninsula.

Résumé : Située au nord-ouest de la péninsule Ibérique, la Galice est la région qui, en Espagne, possède le plus long littoral. Cette côte est caractérisée par la présence de plusieurs estuaires (*rías*), dont les plus grands sont situés à l'ouest. Un certain nombre d'îles et d'îlots se trouvent à l'intérieur ou à l'embouchure de ces rias, c'est le cas de la Ría de Vigo, de la Ría de Pontevedra et de la Ría de Arousa. En Galice, contrairement à d'autres régions atlantiques européennes, la présence de vestiges préhistoriques dans des zones côtières topographiquement basses a traditionnellement été considérée comme rare. Cependant, les stratégies de subsistance développées au cours de la Préhistoire ont largement tiré parti des ressources côtières et maritimes, et il existe de plus en plus d'indices de sites de ces périodes ainsi que d'échanges d'idées et d'objets entre ces communautés et d'autres communautés atlantiques européennes. Dans cet article, nous parlerons des différentes méthodes et approches relatives à la prospection, à l'enregistrement, à la fouille et à la datation des sites de la Préhistoire dans ces rias occidentales et nous discuterons à la fois des perspectives de la recherche et du patrimoine côtier préhistorique dans la région.
Mots-clés : Préhistoire, archéologie littorale, érosion côtière, Galice, péninsule Ibérique.

INTRODUCTION

The archaeological study of prehistory in coastal areas and their associated ecosystems (e.g. estuaries, marshes) has undergone fundamental changes at the international level in recent decades. Driven in part by Anglo-Saxon and Scandinavian research in the 1990s and 2000s, regional programs of an interdisciplinary nature have multiplied (e.g. Ashmore, 1994; Bell and Neumann, 1997; Bailey et al., 2020) and journals specialising in this type of environment have emerged. (e.g. *Journal of Island and Coastal Archaeology*, *Journal of Maritime Archaeology*, *Journal of Wetland Archaeology*). Advances in the field include, on the one hand, aspects of epistemological, theoretical and methodological positioning and, on the other, legal and administrative issues, which have had a notable impact on the data corpus at both qualitative and quantitative levels.

Unlike other Western European regions, specific research on and management of coastal archaeological heritage has not been fully addressed in the Iberian Peninsula until recent years. This is despite the known potential of the coastal areas for providing fresh quantitative and qualitative data on prehistoric societies and despite the fact that, like in neighbouring regions, there are severe threats to coastal cultural heritage from both natural and human factors. In Spain, specialists working in virtually all coastal regions have warned of the effects that climate change and coastal erosion are having on their cultural heritage. The situation is similar in Portugal, but with less regional variability as all the coastal regions face the Atlantic, none being open to the Mediterranean. It is noteworthy, however, that while Portugal is rich in prehistoric coastal sites (e.g. Sousa et al., 2016), only a few of them correspond to submerged or intertidal sites (Bicho et al., 2020).

Located in the north-west of the Iberian Peninsula, Galicia is the region with the longest coastline in Spain. This coast is characterized by the presence of several estuaries (*rías*), the biggest of which are located in the west. A number of islands and islets are found within or at the mouths of such rias (Rías Baixas; fig. 1). Despite growing interest in the archaeology of coastal areas in the region, the development of research programs and dedicated lines of research is relatively scarce. The 1980s and 1990s saw an increase in research and publications on coastal prehistory, with, for instance, the discussion of Mesolithic macrolithic industries, Neolithic and Bronze Age remains, rock art, the analysis of Iron Age shell middens and the reconstruction of sea-level fluctuations. (e.g. Aira Rodríguez et al., 1992; Martínez Cortizas and Costa Casáis, 1997). Despite these advances, researchers in the early 2000s drew attention to the fact that the development of studies on the use of the sea in the prehistory and antiquity of Galicia were not fully developed (Vázquez Varela and Rodríguez López, 1999-2000). Today, we know that prehistoric human subsistence strategies in Galicia largely benefited from the rich coastal and maritime resources, and there is increasing material evidence of coastal and island occupations from these periods, as well as of long-distance exchanges of materials and ideas between these and other European Atlantic communities.

In this paper, mainly focusing on our own work, we will discuss some of the methods and practices being implemented in current prehistoric coastal research in the western rias and the future prospects this research and management may address in the region.

1. THE PREHISTORIC ARCHAEOLOGICAL CONTEXT OF THE WESTERN RIAS OF GALICIA

Of all Galician coastal areas, the western rias are probably those that have attracted the most attention. A distinctive aspect of these rias is that they have a number of islands and islets located within them or at their mouths.

These rias are fluvial valleys partially flooded by the sea during the Quaternary interglacials, on a coastline undergoing lithospheric uplift (Viveen et al., 2013). Such river valleys were emerged during the last glacial period, being a coastal forest-like continental environment (Vidal-Romaní and Grandal-d'Anglade, 2018) with high archaeological potential, as expected for the Portuguese coast (Bicho et al., 2020). After this cold stage ended 20 ky ago (Vidal-Romaní et al., 2015), the post-glacial marine transgression started. As the sedimentary record shows, the sea level was then at -100 m below present sea level (bpsl) (Arce-Chamorro et al., 2021), reaching -73 m bpsl around 9 ky ago (Nombela et al., 2005). During this transgression, dune sands were transported from the emerged continental shelf to the present-day coastline (Arce-Chamorro et al., 2021). This is demonstrated by sand layers overlying wood remains from 4.5 ky (cal. BP) in the present intertidal area along the coast of Galicia (Nombela et al., 2005; Vidal-Romaní and Grandal-d'Anglade, 2018). Evidence of this can be observed in Galician sites such as Guidoiro Areoso (see below), where dune sand covered several archaeological sites *c.* 2.5 ky ago. Organic levels 4.5 ky (cal. BP) old were found below the dunes (Blanco-Chao et al., 2017) and in the intertidal area, most likely corresponding to buried wood remains. According to the aeolian accretion model (Arce-Chamorro et al., 2021), the age of the dune overlying the archaeological structures suggests a sea level well below the present one. This would indicate that the sea level raised to present-day levels after 2.5 ky ago[1], and progressively flooded the fluvial valley to form the present ria.

The chronocultural framework of Galician Prehistory has been the object of a wide debate, no less because the bad preservation of organic remains due to the predominance of acidic soils usually hinders the use of radiocarbon dating (see below, 3.2. Numerical dating of sites and sediments). The main available evidence comes from the Neolithic (*c.* 5000 to *c.* 2500 BC), the Bronze Age (*c.* 2500 to *c.* 800 BC) and the Iron Age (*c.* 800 BC to *c.* 1st century AD). The evidence from earlier periods is scarcer, and the identification of several lithic assemblages and remains dating from the Palaeolithic and – especially – the Mesolithic have proved to be controversial (see e.g. Vázquez Varela, 1984). This has resulted in the development of complementary approaches for understanding the human occupation of the region, such as the paleoenvironmental and chemical analysis of soils (Kaal et al., 2011) or the technological and archaeometric analysis of pottery (Prieto Martínez and Lantes Suárez, 2017).

The immediate area of the western rias shows an early Neolithic occupation, as the evidence from A Cunchosa suggests (Suárez Otero, 1997; here: fig. 1, nº5). From the middle of the 5th millennium cal. BC, and up to the beginning of the 2nd millennium, the landscape is dominated by the presence of megalithic monuments, some of which are organised in clusters in the higher areas of the sierras overlooking the sea (Criado Boado and Villoch Vázquez, 1998). Settlements are also abundant, especially compared with what is known for the rest of Galicia, although not many of them have been excavated in detail. Some of them, such as Monte dos Remedios (Fábregas Valcarce et al. 2007; here: fig. 1, nº6), seem to have been occupied intermittently throughout the aforementioned period, while others had more limited occupation (e.g. O Regueiriño and Montenegro: fig. 1, nº8 and nº7; Criado Boado and Cabrejas Domínguez, 2005). All of these settlements were open-air sites with huts made of perishable materials, without clear delimitation of the inhabited space or, at most, with possible palisades.

As the Bell-beaker pottery horizon disappeared, well into the Bronze Age (2nd millennium BC), the number of known settlements decreased. Settlements with elongated huts (e.g. Setepías; Acuña Piñeiro et al., 2011) and large storage pits (e.g. Monte Buxel; Lima Oliveira and Pri-

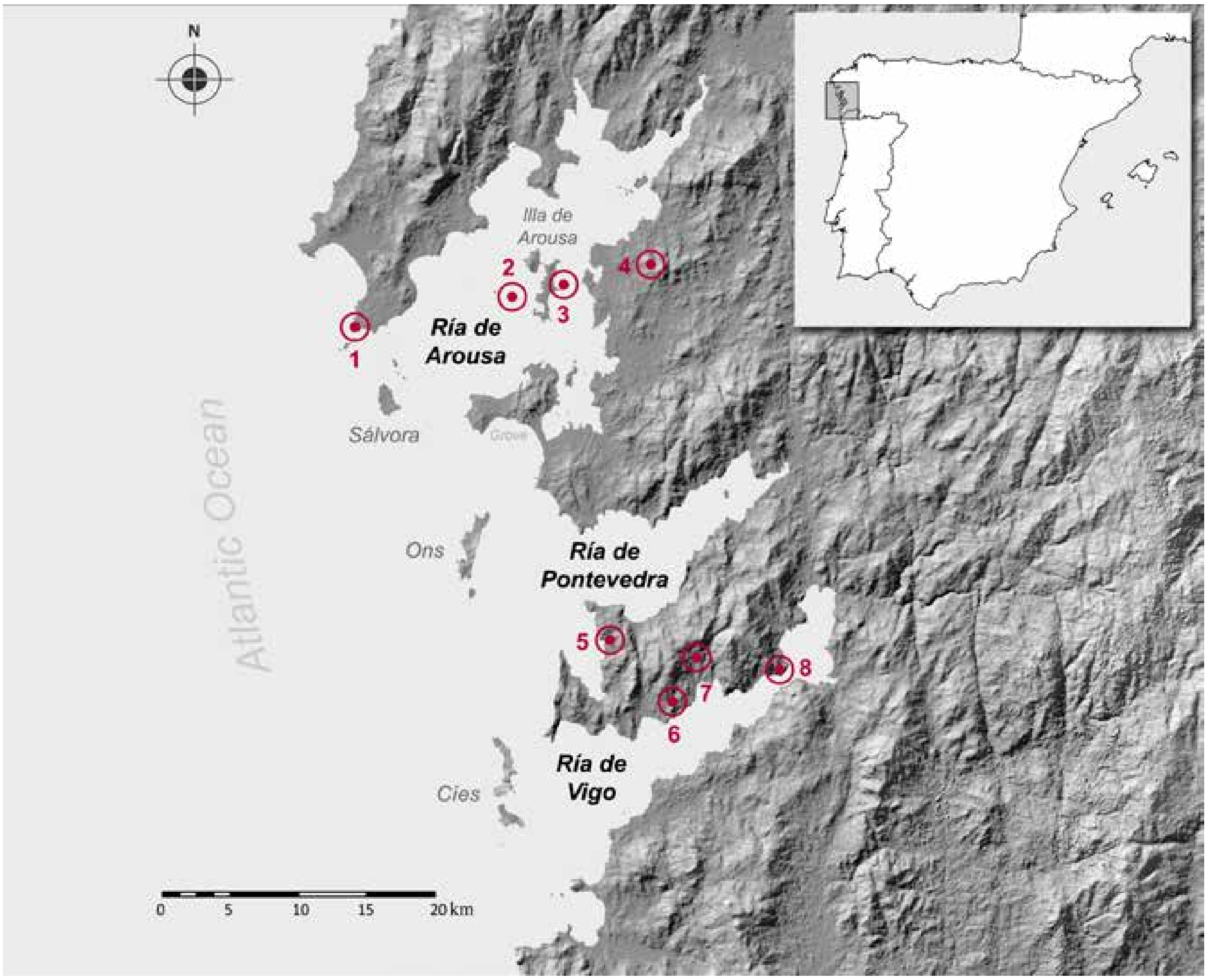

Fig. 1 – Map of the western rias of Galicia (Rías Baixas) indicating the main sites cited in the text: 1. Os Pericos; 2. Guidoiro Areoso; 3. Punta de Riasón; 4. Monte Lobeira; 5. A Cunchosa; 6. Monte dos Remedios; 7. Montenegro; 8. O Regueiriño.

Fig. 1 *– Carte de localisation des rias occidentales de Galice (Rías Baixas), avec les principaux sites mentionnés dans le texte : 1. Os Pericos ; 2. Guidoiro Areoso ; 3. Punta de Riasón ; 4. Monte Lobeira ; 5. A Cunchosa ; 6. Monte dos Remedios ; 7. Montenegro ; 8. O Regueiriño.*

eto Martínez, 2002) have nonetheless been found for the final phases of the period. At the same time, as megalithic monuments became less and less frequent, new forms of burial appeared, among which cist cemeteries stand out (Peña Santos, 1985). However, the main novelty of the Bronze Age is doubtless the open-air art of the so-called Galician group. These are carvings made on rocky outcrops, with geometric motifs (mainly circular combinations, spirals and labyrinths), quadrupeds – especially deer –, weapons and, to a lesser extent, human figures (Fábregas Valcarce and Rodríguez Rellán, 2015). It is precisely in the surroundings of the Western rias and the valleys that converge towards them that there is a greater concentration and variety of this type of manifestation. Their chronology is still debated. Although for some motifs and panels a late chronology has recently been suggested (Late Bronze Age or even the Iron Age; Santos Estévez, 2008), there seems to be a certain consensus that some of them belong to the transition between the 3rd and 2nd millennium BC. Finally, at the beginning of the 1st millennium BC, the archaeological record is reduced to the presence of fortified settlements (*castros*), since we still do not know where the dead were buried during the local Iron Age (Vilaseco Vázquez, 2000).

All things considered, the presence of sites from recent prehistory at low altitudes in the western rias is scarce, probably as a consequence of the palaeogeographic history mentioned above. (i.e. sea-level rise). In connexion with this, buried fossil forests with chronologies dating back to recent prehistoric times have been found at some locations along the coast. The most spectacular and recent example is the one at Rosalía de Castro Street in Vigo, where tree trunks dating back 8,000 years were found at a depth of 13 m below the current street level(2). Others are known to be located directly in intertidal areas, such as at Patos Beach (Nigrán) or Ladeira do Chazo (Boiro), dating from the Neolithic and the transition between the 3rd and 2nd millennium BC, respectively (Fábregas Valcarce and Rodríguez Rellán, 2012).

2. ANALYSING PREHISTORIC HUMAN OCCUPATION: METHODS AND APPROACHES

Since the beginning of the 21st century, we have witnessed the consolidation of a coastal and island archaeology (see Introduction). The reasons for this are multiple. Firstly, the generalization of archaeometry and of interdisciplinary approaches to archaeology has made the coast a privileged field of study for the analysis of human societies and their interaction with the environment. The often exceptional preservation of organic remains and the access to certain sedimentary archives (dunes, paleosoils) are key to understanding the interest in these areas (e.g. Verdin et al. 2019; López-Romero et al., 2023). Secondly, the reorientation of international research in the study of mobility, exchange, evolution and collapse of human societies (Kintigh et al., 2014) has enabled the coastline and wetlands to occupy a renewed place in the agendas of various projects. Finally, the vulnerability of these areas to the effects of climate change has recently placed them at the forefront of the discussion about the causes, consequences and solutions to this global issue. (i.e. numerous articles on this subject in the international archaeological journals).

Based on our own experiences and activities, we will discuss three essential aspects that relate to the recent methods and practices of prehistoric coastal archaeology in the western rias of Galicia: the survey of and excavation in coastal areas, the numerical dating of prehistoric sites and sediments, and the heritage dimension of prehistoric coastal sites.

2.1. Archaeological survey and excavation

Archaeological survey of coastal areas requires an understanding of natural and maritime cycles that makes it different from fully continental survey on dry land. Firstly, like in most European Atlantic regions, tidal regimes (two high and two low tides per tidal day) dictate the times and seasons that are more suitable for archaeological surveys. Secondly, differential erosion affects the visibility of the archaeological record; in this sense, several decades can elapse before a site that originally stood just a few meters apart from another is revealed (e.g. Guidoiro Areoso 'Monument 3'; Rey García and Vilaseco Vázquez, 2012). Thirdly, the rich biodiversity of most coastal areas in Galicia implies that specific planning is necessary, the presence of natural reserves and protected species necessitating additional permits.

Taking into account these factors, pedestrian surveys focus on dune horizons, the intertidal zone and the high water mark. While the survey of locations on continental dry land is obviously also necessary, the former contexts are those with the highest potential, having paradoxically received less attention. In the western rias, a dedicated survey of such targeted areas proved to be essential for the understanding of human occupation of small islands and islets (Ballesteros Arias et al., 2013).

Due to edaphological conditions – shallow granitic soils – and rapid erosion, deposits containing substantial archaeological sequences are rare. This situation implies that repeated surveys of a same area are necessary through the year, something that is not always possible in the absence of long-term funded programmes. Added to this, seasonal deposition of sediments and organic remains such as algae limit both pedestrian and geophysical surveys (fig. 2). On the basis of these facts – erosion, research limitations and visibility of the archaeological record –, make the original density and spatial distribution of prehistoric remains difficult to judge.

In the western rias, gradiometer surveys were performed on the islet of Guidoiro Areoso (fig. 1, nº2) and on Monte Lobeira, (fig. 1, nº4), a hill near the coast. These surveys (fig. 3) show that, despite the shallow granitic

Fig. 2 – Algal deposition in the intertidal zone of Guidoiro Areoso (22/09/2014).
***Fig. 2** – Concentration d'algues sur l'estran de Guidoiro Areoso (22/09/2014).*

soils, relevant information can still be obtained through this technique (e.g. site extension). 3D recording of the visible structures also proved to be a cost-effective solution for the survey of areas that are difficult to access with heavy equipment (López-Romero and Mañana-Borrazás, 2013; López-Romero et al., 2015).

In recent years, interventions on coastal sites in the rias included the realization of test pits and open area excavations. For all of these, the collaboration with geomorphologists and geologists, from the Universities of Santiago de Compostela and A Coruña, was essential.

Test-pit excavation at Os Pericos (Ribeira, A Coruña; Vilaseco Vázquez, 2012; here: fig. 1, nº1), together with the geomorphological study of the surroundings (Costa-Casais et al., 2012), made it possible to document that the promontory had a long occupation history. In addition to a Bell-beaker phase, apparently restricted to the lowest sector of the peninsula, a small, fortified settlement from the Late Bronze Age (13th-10th centuries BC) was found in the northern sector and another, from the Second Iron Age, in the eastern sector. The latter was probably a hillfort settled on a dune formed at the beginning of the 1st millennium BC. Today coastal erosion has demolished most of this settlement and the dune where it stood.

Intense coastal erosion also led to the excavation of the Bronze Age cemetery of Punta de Riasón (Illa de Arousa, Pontevedra; Bóveda Fernández, 2017; here: fig. 1, nº3, and fig. 4). Here, three cists were located in the intertidal zone and test pits were opened in the surroundings to study the geomorphological stratigraphy of the area. The cists, rectangular in shape, were in varying degrees of preservation depending on their position in relation to the tides. In the case of one of them, only a slab was preserved in situ. The structure of the second was almost intact, lacking its cover, but having been subjected to the prolonged action of the tide it was empty. The third, also without a cover, was partially buried; the lower archaeological levels of this tomb were apparently intact and two small silver spirals were documented, allowing us to date it to the Bronze Age.

The coastal site that has received the greatest attention is Guidorio Areoso, (fig. 1, nº2), a small islet (*c.* 8 ha) in the centre of the Arousa estuary. An important occupation has been documented here from the Neolithic to the Iron Age. To date, five megalithic monuments are known on the islet, including one that was destroyed by coastal erosion in 2013, and abundant archaeological material is found on its beaches and in the intertidal zone (López-Romero et al., 2015). Excavations on the beach and on 'Monument 4', one of the megalithic monuments, took place between 2015 and 2017. Collaboration with geomorphologists was essential to understand and date the stratigraphic sequence, strongly conditioned by the formation of a dune system that ultimately covered the site. The analysis of a Bronze Age shell midden associated with the mound was performed by malacologists

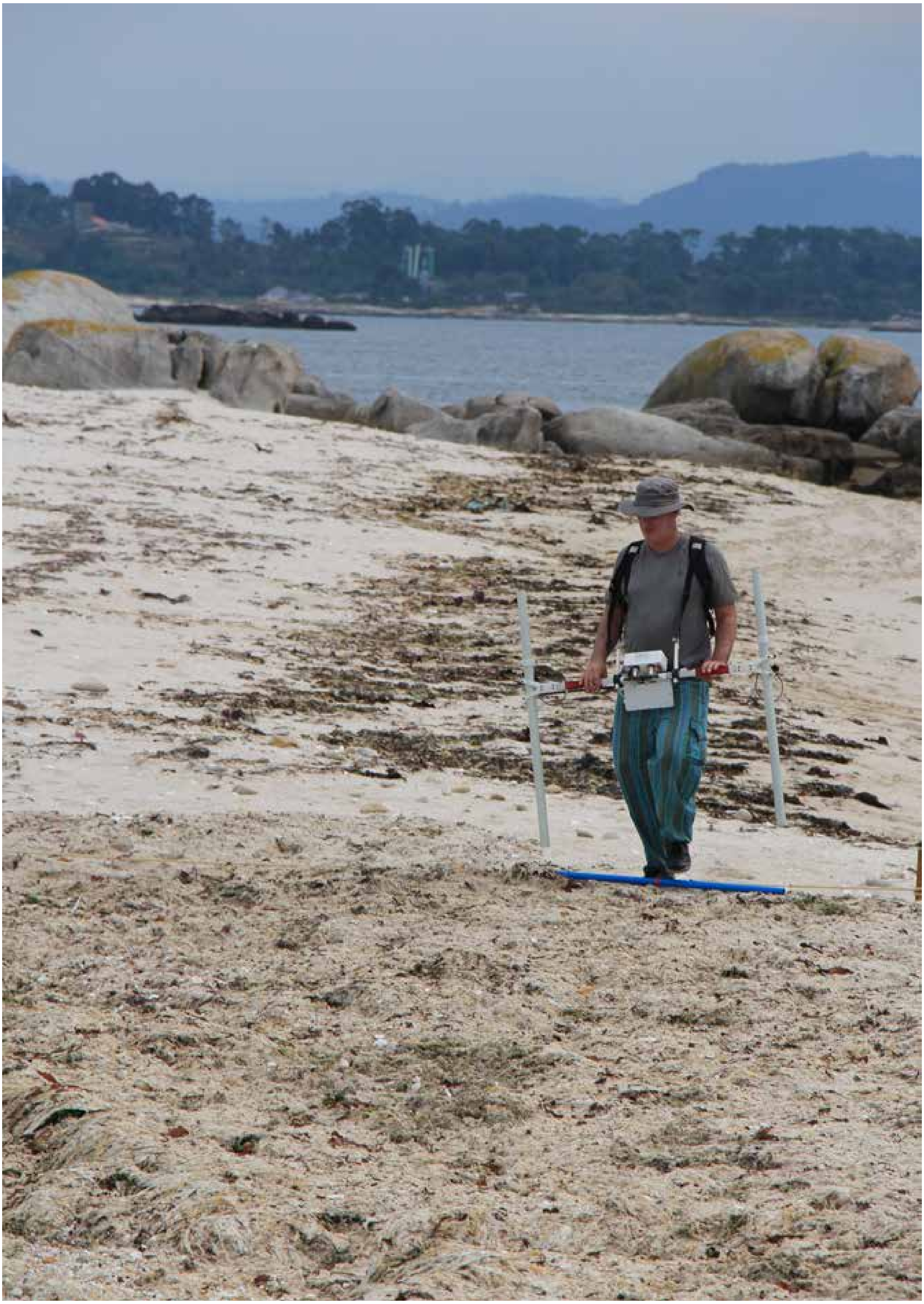

Fig. 3 – Gradiometer survey of the dune and intertidal zone in Guidoiro Areoso (22/09/2014).
***Fig. 3** – Prospection géophysique de la dune et de l'estran de Guidoiro Areoso par gradiométrie (22/09/2014).*

Fig. 4 – Punta de Riasón: Bronze Age cists (Illa de Arousa; 12/10/2017).
***Fig. 4** – Punta Riasón : cistes de l'âge du Bronze (île d'Arousa ; 12/10/2017).*

from the University of León, being the second of this age found on the islet (Rey García and Vilaseco Vázquez, 2012). This discovery is extremely important, as shell middens pre-dating the Iron Age are very rare in Galicia. 3D scanning and photogrammetry were also essential for the excavation processes, 'Monument 4' being a prime example of the integrated use of these techniques (Mañana-Borrazás et al., 2020).

2.2. Numerical dating of sites and sediments

Due to the acidic nature of most soils, ^{14}C dating of prehistoric sites in Galicia is most often dependent on the presence of charred remains and on the organic fraction contained in bulk sediments. Fieldwork in the western rias has shown that significant amounts of organic materials, including bone, were preserved here owing to the nature of sediments (calcareous, waterlogged). A human jaw discovered during the 2016 surveys in Guidoiro Areoso was ^{14}C dated to the Second Iron Age (Olalla Costas, USC, pers. comm.), becoming the first date on human bone for this period in Galicia. A ^{14}C date on oyster shell had previously been obtained from this same islet (GrN-16108, 4020 ± 40 BP; Rey García and Vilaseco Vázquez, 2012). Other recent ^{14}C dates on animal bone (Guidoiro Areoso, Beta-495147, 2820 ± 30 BP), plant remains (Punta Riasón, Beta-483265, 180 ± 30 BP showing a post-depositional alteration of the cists; Bóveda Fernández, 2017) and charred wood (Os Pericos, Ua-32504, 2895 ± 45 BP; Vilaseco Vázquez, 2012) confirm the potential of this area to contribute to the chronology of regional prehistory (table 1).

The use of other numerical dating techniques for archaeological purposes is virtually nil. Optically Luminescence Dating (OSL) of sediments has proven useful in coastal contexts, and its potential for the study of prehistoric monuments has been reviewed elsewhere (López-Romero, 2011). In this context, an eroding profile at 'Monument 4' in Guidoiro Areoso gave us the opportunity, for the first time, to use OSL to date the building sequence of a Neolithic monument in Galicia. Five OSL samples were taken (fig. 5). The two uppermost of these corresponded to dune sand overlying the excavated structure, while the three lowermost corresponded to organic sediments. The cores were dated at the Luminescence Laboratory of the University of A Coruña. Quartz grains were used for dating using procedures described in W. Viveen and colleagues (2013) and the blue-OSL (BL-OSL) single-aliquot regenerative dose (SAR) protocol (Murray and Wintle, 2000). Radiocarbon dating

Site	Sample	Context	Material	14C Age (BP)	d13C (‰)	(2s) cal. BC/AD	Reference
Guidoiro Areoso	GrN-16108	Shell midden	Shell (Ostrea edulis)	4020 ± 40	-	2225-1950 cal. BC (ΔR cal. as cited in the reference)	Rey García and Vilaseco Vázquez, 2012
Guidoiro Areoso Mound 4	Beta-495147	Upper level of the midden that covers the mound	Bone (Bos)	2820 ± 30	-20.9‰	1106-1098 (0.5%) OR 1079-1069 (0.7%) OR 1056-898 (94.2%) cal. BC	This paper (after excavations in 2017 funded by Xunta de Galicia; see Mañana-Borrazás et al., 2020)
Punta de Riasón	Beta-483265	Base of one of the cists' slabs (corresponding to a post-depositional alteration)	Plant remains (unidentified species)	180 ± 30	-10.9‰	1655-1698 (19.3%) OR 1722-1814 (50.1%) OR 1836-1883 (7.5%) OR 1910- (18.6%) cal. AD	Bóveda Fernández, 2017
Os Pericos (N terrace)	Ua-32504	Oldest archaeological level	Charcoal (deciduous Quercus)	2895 ± 45	-28.5‰	1219-969 (91.8%) OR 959-932 (3.7%) cal. BC	Vilaseco Vázquez, 2012

Table 1 – Radiocarbon ages on organic remains (excluding organic matter in bulk sediments) from sites in the western rias cited in the text. With the exception of GrN-16108, calibration data are from OxCal v.4.4.4 and the IntCal20 Northern Hemisphere radiocarbon age calibration curve from P. Reimer and colleagues (2020).

***Tabl. 1** – Dates radiocarbone effectuées à partir de restes organiques (à l'exception de la matière organique issue de sédiments) de sites des rias occidentales mentionnés dans le texte.*

was performed on organic matter obtained from samples MG-1, MG-2 and MG-3, by accelerator mass spectrometry (AMS) Beta Analytic laboratory in Florida. The ages were calibrated using the Oxcal 4.1 software package (Bronk Ramsey and Lee, 2013) based on the calibration curve of Reimer et al. (2020).

Gamma spectrometry provided a similar dose rate for all samples (table 2), as observed in coastal dunes of the area (Trindade et al., 2013). The Central Age Model (Galbraith et al., 1999) was used to estimate the ages. The resulting ages (table 2) are stratigraphically consistent and range from 4528 ± 284 to 421 ± 133 BC from the lowermost to the uppermost sample, respectively. Radiocarbon analyses of samples MG-1, MG-2 and MG-3 show ages younger than the OSL ages (table 3). Such ^{14}C ages are not stratigraphically consistent. The organic matter dated probably corresponds to vegetal remains or litter, as the d13C (‰) indicates. Thus, the discrepancy can be explained as a result of plants growing in the soil surrounding the mound. Interestingly, a ^{14}C age of organic sediment at the base of the head slab of this monument provided an age of 3777-3654 BC (Beta-495146; Mañana-Borrazás et al., 2020), making it slightly younger than the MG-1 OSL age. Organic sediments of two sedimentary studies of the surroundings (Blanco-Chao et al., 2017; Cajade-Pascual et al., 2019) provided a range of ^{14}C ages from 4449-4336 BC for the oldest to 328-204 BC for the newest. Other ^{14}C ages of organic matter provided in such studies fit our ^{14}C ages for MG-2 and MG-3. This means that the surroundings of the mound corresponded to a continental area with vegetation, and the sediments worked as soils, at least from the moment of construction of the mound until the point when the sand of the dune presently overlying it was deposited. This is shown by OSL ages of samples MG-4 and MG-5 (see fig. 5).

Such age results fit the model of coastal evolution in Galicia over the last 15 ky (Arce-Chamorro et al., 2021), from a lower sea level. Around 6 ky ago, the Ría de Arousa was a fluvial valley above the sea level (between -70 m and -50 m bpsl) that was located more than 3 km further to the west. In such valleys, forests spread over the land (Vidal-Romaní and Grandal-d'Anglade, 2018), surrounding the river channels and providing a suitable location for human settling. With the later sea level rise, aeolian sands were transported from coastal areas upstream in the fluvial valleys, causing dramatic changes in the forest ecosystems. Dunes moved through the inner part of the present rias, as evidenced by the dated dune that overlies the tomb and the surrounding continental soils. Local sedimentary records reveal that the sea level reached a height of -20 m bpsl around ≈2,000 BP(1). At this time, the shore was located in front of this promontory covered in sand (i.e. the present-day islet), the surroundings becoming flooded shortly after that period.

2.3. Coastal archaeology and heritage

As has been stated elsewhere (López-Romero et al., 2017), the heritage dimension of Galician prehistoric coastal sites has received little attention. Early research often failed to address questions that are essential to our understanding of past and present uses of the coastal zone

Sample	Depth (m)	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	D_r (mGy a-1)	N	D_e (Gy)	Age (a)	Age BC
GUIDM4_MG-1	2.55	94.3±3.8	85±3.6	857±38	5.37±0.11	30	35.17±1.36	6545±284	4528±284
GUIDM4_MG-2	1.10	65.8±4.1	52.8±3.0	1173±52	5.17±0.26	31	16.92±0.91	3273±240	1256±240
GUIDM4_MG-3	1.95	88.1±3.6	73.9±4.5	1018±45	6.10±0.12	28	27.56±0.80	4520±157	2503±157
GUIDM4_MG-4	0.85	52.9±2.2	47.0±3.1	1022±45	5.03±0.10	32	12.51±0.39	2489±92	472±92
GUIDM4_MG-5	1.55	31.4±1.3	26.6±2.3	946±41	3.61±0.11	32	8.77±0.48	2438±133	421±133

Table 2 – OSL age results. Activity concentration of radioisotopes, Dr, De and resulting ages.
Tabl. 2 *– Résultats des datations OSL. Concentration d'activité des radio-isotopes Dr, De et âges obtenus.*

Sample	Uncal ^{14}C Age (y)	Code	δ^{13}C (‰)	(2σ) cal. yr BP	(2σ) cal. yr BC
GUIDM4_MG-1	4260+±30	BETA - 588314	-25.7	4870-4655	2921-2706
GUIDM4_MG-2	2300+±30	BETA - 588315	-25.3	2357-2160	408-211
GUIDM4_MG-3	2900+±30	BETA - 588316	-25.9	3159-2953	1210-1004

Table 3 – Radiocarbon ages from sediments of the OSL samples.
Tabl. 3 *– Dates radiocarbone des échantillons OSL.*

and the sea, such as the way past societies adapted to changes in a highly dynamic environment or what effects these coastal dynamics and the global warming are having on heritage preservation today.

As is the case in neighbouring European regions, there is no specific regulation for coastal or intertidal heritage at risk in Galicia (for a review of the current Heritage Bill regulations see Barreiro and Varela-Pousa, 2017). In spite of this, the management of coastal heritage has benefited from increased collaboration between the regional authority responsible for their safeguard (Dirección Xeral de Patrimonio Cultural), researchers, governmental bodies (e.g. Dirección Xeral de Patrimonio Natural, Parque Nacional Marítimo-Terrestre de las Islas Atlánticas de Galicia) and the wider public. Significantly, citizens and associations have warned of the threats prehistoric coastal sites are being subject to, something that has enabled different actions on specific areas within the rias (Chao Álvarez, 2015; López-Romero et al., 2015; Mañana-Borrazás et al., 2020).

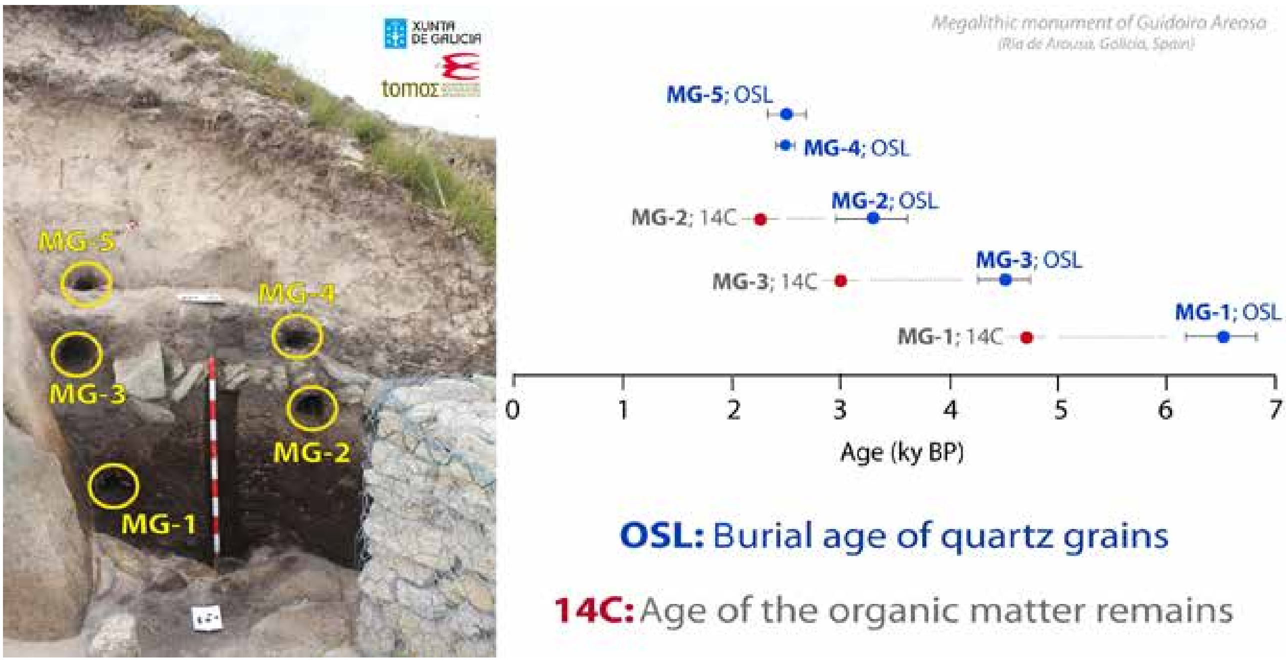

Fig. 5 – Megalithic monument of Guidoiro Areoso (Monument M4). Left: Sample location for OSL dating (image Tomos S.L.; 18/07/2017). Right: Comparison of OSL and 14C – bulk organic sediment fraction – dates from these samples (CAD C. Arce).
Fig. 5 *– Monument mégalithique de Guidoiro Areoso (monument M4). À gauche : localisation des échantillons pour la datation OSL (image Tomos S.L. ; 18/07/2017). À droite : comparaison des dates OSL et C14 – fraction organique des sédiments – de ces échantillons (DAO C. Arce).*

Rapid intervention is promoted by the regional authorities when works are planned in coastal areas within the rias (Vázquez Collazo, 2005) or when coastal erosion is threatening the destruction of relevant archaeological sites (fig. 6).

A wider perspective involved the application of the ALeRT methodology from western France (Daire et al., 2012) to the coastal archaeological record of the rias. This consisted in the analysis of sites at risk through a dedicated Vulnerability Evaluation Form and a public-science dimension, along with photogrammetry and 3D laser scanning monitoring of some of the most vulnerable sites (López-Romero et al., 2015). While many of the sites analysed through these actions were prehistoric, other archaeological and ethnographic heritage was also considered. Recently, a proposal for the prioritisation of action on a specific type of site – shell middens – has been published (González-Gómez de Agüero et al., 2019), but as far as we know it has not been implemented. We believe, however, that it is on the holistic approach to coastal heritage that research efforts need to be focused.

A no less important aspect of this heritage dimension is the fact that many sites at risk are located in areas protected from an environmental point of view, making it necessary to combine archaeological interventions with preservation of natural spaces. A large portion of the western rias coastline is protected either as part of the Islas Atlánticas de Galicia National Park or within the Natura 2000 Network. As mentioned earlier, one of the consequences of this is that fieldwork is sometimes dependent on wildlife cycles. A paramount example occurred at Guidoiro Areoso 'Monument 4', where the archaeological intervention required the dismantling of a dune more than 3 m high that buried the monument. The work was delayed and authorised only under special conditions, including the delay of the fieldwork due to the nesting of the Eurasian oystercatcher (*Haematopus ostralegus*), a species classified as vulnerable in Galicia.

3. DISCUSSION AND FUTURE PROSPECTS

Dedicated approaches to coastal prehistory in Galicia have emerged in recent decades. Understanding the nature, constraints and opportunities of coastal areas is not always straightforward. Adaptation of the planning and methods to marine ecosystems, to geomorphological conditionings and to natural cycles are a fundamental part of the research process.

The integration of Galician coastal prehistory into the current international debates on coastal societies, social complexity and exchange networks, as well as on coastal erosion and heritage management (Kintigh et al., 2014), is becoming increasingly evident. However, a coastal prehistory research agenda should integrate a number of

Fig. 6 – Dry-wall protection for monument M4 in Guidoiro Areoso (built in 2011; 17/06/2014).
***Fig. 6** – Muret en pierre sèche construit pour protéger le monument M4 de Guidoiro Areoso (bâti en 2011 ; cliché du 17/06/2014).*

aspects that still require implementation or further development. While it is not our intention to formalise such an agenda here, we would nonetheless like to highlight some future prospects that could contribute to the qualitative and quantitative improvement of our knowledge on coastal prehistory in the region. These future prospects can be seen as challenges that regional research has to address.

Firstly, administrative and financial issues should be addressed. Today, the most common types of intervention in the coastal areas of Galicia are punctual surveys or excavations, almost always in the form of rescue actions, without real continuity. There is a need to consolidate medium- to long-term actions and projects, which is something that partly relies on the regional and national R&D strategies. This does not only relate to funding but, more critically, to the need to consolidate research teams in the region. The 2008 economic crisis strongly impacted the commercial archaeology and research sectors in Spain (Parga Dans, 2010), resulting in a reduction in the number of companies, the reconversion of some archaeologists to other professional activities or their migration to other countries. Added to this, the recent impact of the global pandemic (and, ultimately, of the economic impact in Europe of the conflict in Ukraine) still needs to be evaluated.

Secondly, theoretical and methodological discussion should widen the approaches and techniques available for coastal and intertidal research. Acknowledging the importance of the preservation of organic materials and sedimentary archives in these settings is crucial for filling the gaps remaining in regional research. As we have shown, questions of chronology that cannot be addressed in other areas of Galicia can be approached here. The combined use of ^{14}C and OSL may help unravel some of the traditional issues of regional prehistory, such as the problems posed by bulk sediment dating (e.g. uncertainty about the origin of the organic matter, taphonomic processes resulting in stratigraphic chronological inversion), or the discussion of architectural sequences. Added to this, the preservation of organic remains can foster the analysis of the rich resources available in these coastal areas, as has recently been the case with the excavation of the Bronze Age shell midden associated with the excavation of 'Monument 4' in Guidoiro Areoso (Fernández-Rodríguez et al., 2017; Mañana-Borrazás et al, 2017). This will improve our knowledge on their availability to and exploitation by prehistoric societies, contributing to understanding questions of seasonality, biodiversity and ecosystems in the past, as has been the case in recent years in other European Atlantic regions like Brittany (Dupont and Marchand, 2021). Similarly, specific surveys of coastal areas still need to be further developed in Galicia, something to which intensive pedestrian survey, geophysics and airborne sensors (e.g. LiDAR) may largely contribute in the near future.

Thirdly, the heritage dimension of prehistoric coastal sites should be an immediate priority. While coastal erosion and heritage loss are particularly acknowledged at the local and regional scales, we must not forget that this is a global issue (i.e. effects of climate change and of human pressure on coastal areas) and that it therefore requires a global response. It is urgent to combine local and regional actions with wider national and international perspectives. For this, the integration of all layers of society in the diagnosis, research, decision-making and restitution processes should be a priority. Another important aspect concerns the relationship between cultural and natural heritage. While, as we have seen, nature conservation issues may condition archaeological research, the joint consideration of the cultural and natural heritage in coastal areas can result in a win-win situation. Many of the threats are similar to both types of heritage and adapted responses to their vulnerable situation can hence be jointly considered. This is the case for the integration of the public in the survey and monitoring phases, the sustainable exploitation of cultural and natural resources in natural parks, or the study of heritagisation processes (Barbeito, 2013; Sánchez Carretero, 2013).

Finally, all these challenges and gaps should not only be seen as negative. They can also be considered as opportunities to boost the visibility and the future of coastal research and management in the area. There is a real opportunity to situate the region in the international debate of the prehistoric uses of wetlands, estuarine and coastal environments. This can be achieved not only by addressing the aforementioned challenges, but also by proactively integrating the discussion of Galician case studies in European programmes and international working groups. Owing to their characteristics, the western rias and other Galician coasts are also well placed to become a reference for the discussion of the aforementioned natural-cultural heritage dimension. To succeed with this, it is again the multi-scalar perspective from the very local to the global that needs to be emphasised.

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NOTES

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A Question of Size!
The Importance of Marine Crabs in Food Remains from Mesolithic Fisher-Hunter-Gatherers at Beg-er-Vil (Quiberon, Morbihan, France)

Une question de taille !
L'importance des crabes marins dans les vestiges alimentaires des pêcheurs-chasseurs-cueilleurs de Beg-er-Vil (Quiberon, Morbihan, France)

Catherine Dupont, Yves Gruet, Mathis Arthur, Oriane Digard

Abstract: Mesolithic shell middens were excavated along European Atlantic coasts as early as the first half of the 19th century. At the end of the same century, researchers still showed little interest in the composition of these archaeological sites. While bones from mammals have been identified for this type of site, marine invertebrates have often been overlooked. A few short lines were dedicated to them in papers describing shell middens. The development of new disciplines in archaeology soon showed the limitations of past excavations. In fact, only the elements considered to be useful to the person in charge of the excavation have been preserved, such as flint, large mammal bones and ornaments, with an emphasis on burial components. Despite the sieving of sediments, past excavations yielded a very partial version of the food remains of these populations, where marine invertebrates are often the poor relations of the archaeozoological remains. In the 2000s, developments in sieving techniques combined with laboratory sorting made it possible to expand our vision of the diversity of marine and terrestrial resources exploited by these coastal populations. The visible minority, represented by crabs and other invertebrates, is now more commonly described in shell middens. On account of the high meat yield of crustaceans, they may even have been key components in the diet of coastal populations. Moreover, sieving and sorting of remains show that these shell middens are not homogeneous layers of shell. The example of the Beg-er-Vil shell midden shows that our vision of the way of life of fisher-hunter-gatherers along the European Atlantic coast depends on excavation techniques. The methods of excavation applied in the field have a direct impact on our description of the activities of these coastal populations. They were not solely focused on hunting large mammals.
Keywords: Fisher-hunter-gatherers, crab, crustacean, Mesolithic, seafood, diet, methodology, taphonomy, sieving.

Résumé : Des fouilles ont été menées dans les amas coquilliers dès la première moitié du xxe siècle le long de la côte atlantique européenne. Plus de 330 d'entre eux sont actuellement recensés pour le Mésolithique. Ils doivent leur conservation partielle à un ralentissement de l'augmentation du niveau de la mer. Pour le littoral atlantique français, les plus anciens datent d'il y a 8000 ans. L'intérêt pour la composition en coquillages de ces accumulations était encore peu développé à la fin du xxe siècle ; si une liste d'animaux était parfois publiée, les invertébrés marins y étaient souvent oubliés ou ne représentaient que quelques lignes dans les articles. Force est de constater qu'ils sont souvent associés à du sédiment au pH basique qui a permis la conservation des ossements. Par le passé, seuls les éléments jugés utiles à la fouille étaient conservés, comme les silex, les ossements de grands mammifères. L'hégémonie de la chasse aux grands gibiers et les valeurs qu'elle véhicule n'y sont sans doute pas étrangères. De même, les parures et éléments associés aux sépultures étaient privilégiés à la fouille. Ainsi, malgré le tamisage des sédiments, ces fouilles passées nous ont donné

une image très partielle des restes alimentaires de ces populations, où les invertébrés marins sont souvent les parents pauvres des vestiges archéozoologiques.
Le développement de nouvelles disciplines en archéologie a rapidement montré les limites de ces fouilles anciennes et les hiatus liés au choix des archéologues. Le retour sur le terrain dans les années 2000 a permis, grâce au tamisage combiné au tri en laboratoire, d'accroître notre vision de la diversité des ressources marines et terrestres exploitées par les populations côtières mésolithiques. Désormais, mollusques et crustacés accompagnent poissons, oiseaux et mammifères marins au côté des mammifères et oiseaux terrestres.
Une minorité visible a été conservée jusqu'à nous sous la forme de fragments de crabe mesurant moins de 1 cm. Souvent, un crabe consommé par ces populations mésolithiques se traduira, pour l'archéologue, par la découverte de minuscules fragments d'extrémités de doigts de pince. Le rendement élevé de ces crustacés – si le poids de leur squelette est considéré par rapport à celui de la chair qu'il fournit – pourrait pourtant en faire un des éléments clés de l'alimentation de ces peuples du bord de mer.
La question posée par cet article est de savoir si la méthode de prélèvement influe sur notre vision du mode de vie des populations mésolithiques. Pour y répondre, le site de Beg-er-Vil, localisé au nord-ouest de la France, sur la côte sud de la Bretagne, a été choisi. Dans les années 1980, O. Kayser avait fouillé cet amas. Il avait alors réalisé un tamisage à sec des sédiments de l'amas à 4 mm et avait stocké les refus de tamis dans des sacs en papier kraft. Lors de la reprise de l'étude de l'amas, dans les années 2000, ces refus ont été tamisés en laboratoire, à l'eau douce, sur des mailles de 5 mm et de 2 mm. Dans les années 2010, le site a été fouillé à nouveau, sous la responsabilité de G. Marchand et de C. Dupont. Avec leur équipe, ces derniers ont tamisé tout le sédiment à l'eau de mer, puis ils l'ont rincé à l'eau douce avec des tamis de 4 et de 2 mm. Le matériel de 1980 a subi un tamisage en laboratoire lors de la reprise de l'étude des composants de l'amas dans les années 2000. Il a été réalisé à l'eau douce sur des mailles de 5 et de 2 mm. Les crabes de ces différentes campagnes de fouille ont en partie été étudiés : ceux retenus sur la maille de 5 mm pour les fouilles des années 1980, avec un contrôle visuel de ce qui a été retenu sur la plus petite maille ; et l'intégralité des restes retenus sur les refus de tamis de 4 mm et de 2 mm pour les fouilles des années 2010. Les restes de crabe ont été décomptés suivant les méthodes classiques de l'archéozoologie : nombre de restes, nombre minimum d'individus et poids. Des reconstitutions de la largeur des carapaces ont aussi été réalisées. Cette étude met en évidence des interprétations différentes de l'exploitation du crabe par les derniers chasseurs-cueilleurs de la côte atlantique française en fonction de la maille de tamisage utilisée. La maille la plus fine permet de déterminer plus d'espèces. Les petites espèces ont clairement été évincées lors de l'analyse sur la maille de 5 mm. Au total sept espèces ont pu être déterminées : le dormeur ou tourteau *Cancer pagurus* Linnaeus, 1758, le crabe verruqueux *Eriphia verrucosa* (Forskål, 1775), le crabe vert *Carcinus maenas* (Linnaeus, 1758), l'étrille *Necora puber* (Linnaeus, 1767), le crabe enragé *Xantho* sp. (Leach, 1814), le crabe marbré *Pachygrapsus marmoratus* (J.C. Fabricius, 1787) et l'araignée de mer *Maja squinado* (Herbst, 1788). Cette diversité observée aussi sur les gabarits des crabes montre une exploitation de tous les individus accessibles sur l'estran, qu'ils soient grands ou petits. Le cas de l'araignée de mer mérite d'être souligné. En effet, de nos jours, cette espèce est généralement subtidale. Elle se rapproche des côtes lorsque l'eau de mer se réchauffe, actuellement à la fin du printemps. Elle a pu être pêchée à ce moment-là par les populations mésolithiques.
Les fragments de crabe prélevés en 2013 sur les tamis de 4 mm et de 2 mm ont été observés en fonction de la stratigraphie : ils montrent une conservation plus importante au cœur de l'amas. Les parties sommitales et basales de ce dernier semblent encore subir l'acidité du milieu. Ce résultat est intéressant et pourrait expliquer le fait que, dans les années 1980, certains doigts de crabe ont été isolés à vue à la fouille, à la différence des années 2010 où ces vestiges étaient tellement petits qu'ils n'ont pas été repérés lors la phase de terrain. Ils montrent que le système représenté par l'amas n'est sans doute pas stabilisé.
Quoi qu'il en soit, cette étude indique que les crabes doivent, comme tout artefact, être pris en compte. Ils permettent de décrire des activités liées à la mer, comme la pêche à pied sur estran et peut-être même l'exploitation des laisses de haute mer. Ils ont participé à la diversité des aliments consommés par ces populations et, par leur rendement, peuvent constituer des sources non négligeables de nourriture. Ainsi, malgré leur faible lisibilité et la petitesse des fragments conservés, les crabes méritent d'être considérés comme un autre indice du mode de vie des populations de pêcheurs-chasseurs-cueilleurs de nos côtes.
Mots-clés : pêcheurs chasseurs-cueilleurs, crabe, crustacé, Mésolithique, fruits de mer, alimentation, méthodologie, taphonomie, tamisage.

INTRODUCTION

Every year, new Mesolithic shell middens are discovered, excavated or re-studied (for example Gutiérrez-Zugasti et al., 2016; Finlay et al., 2019; Moe Astrup et al., 2021). To date, more than 330 of these Prehistoric shell middens have been recorded from northern Norway to southern Portugal (Dupont, 2016). New studies of material from older excavations are regularly undertaken (for example Moreno Nuño, 2017; Jackes et al., 2019). These are linked to variations in researchers' interests and to recent developments in archaeological disciplines (Dupont and Marchand, 2021). Thus, in the first half of the 20th century, most archaeologists tended to only consider lithics, human skeletons and ornaments. The other components of shell middens were considered as sediment or remains bereft of archaeological interest. It was not until the end of the century that publications began to take stock of the scientific interest of these archaeological sites and their components such as fish, mammals, birds, molluscs, crustaceans, charcoal and seeds (Dupont and Marchand, 2021). The example of north-western France and the shell middens of Téviec and Hoëdic excavated between 1928 and 1934 is telling in this regard. The first study of shell ornaments was not carried out there until 1971 (Taborin, 1971). Isotopic analyses of the human skeletons from these two necropolises (Schulting, 1996) and the study of the lithic industry (Marchand, 1999) cast new light on these shell accumulations, which are places of life and death of the last populations of fisher-hunter-gatherers along the French Atlantic coast. However, these two sites are no exception to the rule, as the first artefacts to be studied were ornaments, human skeletons, and lithics. The mammals, birds, crustaceans and molluscs collected by the Péquart couple in the middle of the 20th century had to wait until the beginning of the 21st century to be analysed and published. This newfound scientific impetus can now be observed along the European Atlantic coast (Gutiérrez-Zugasti et al., 2011). It is reflected in the adaptation of excavation techniques to the search for minute remains, less than a centimetre long (for example Dupont, 2006; Gutiérrez Zugasti, 2010 and 2011).

Among these remains, crabs are still given little consideration in archaeology despite the fact that they have been detected in at least 59 of the Mesolithic shell middens on the European Atlantic coast (fig. 1). This count is possible thanks to a database that lists all the published archaeological components of Mesolithic shell middens (for a succinct description of the database see Dupont, 2016). These listed crustaceans would therefore be present in 18% of known shell middens and a relationship can be established between their discovery and the application of sieving during excavation (Dupont and Gruet, 2022). However, this proportion should be treated with caution as it only takes into account published data. Only 47% of sites where crabs were identified give the name of one or more species (Dupont and Gruet, 2022). Only 20% of crab quantifications are published (Clark, 1971; Zilhão, 2000; Dupont and Gruet, 2005; Gutiérrez Zugasti, 2010; Pickard and Bonsall, 2009; Dupont et al., 2010; Dupont, 2011; Gutiérrez-Zugasti et al. 2016). The low proportion of crab presence in Mesolithic shell middens can be explained by several factors. Some fisher-hunter-gatherer populations may not have consumed these crustaceans, either because they were not accessible near the sites, or because populations chose not to consume these crabs despite their existence. It is also possible that the skeletal parts of consumed crabs were dissolved by taphonomic factors. Such factors may have led to the fragmentation of the entire crab exoskeleton. Like all archaeological remains, the study of crabs is dependent on the sampling techniques used during excavation. As with molluscs (Dupont and Marchand, 2021), the absence of sieving may have led to the erasure of exoskeletal remains of crabs from the archaeologist's regard.

These questions of the visibility of crabs in Mesolithic contexts is addressed using the example of the Beg-er-Vil site (Quiberon, France). Excavations were carried out in the 1980s under the direction of O. Kayser (1987) and then in the 2010s by G. Marchand and C. Dupont (Marchand et al., 2018). The fact that these two excavation phases were thirty years apart enables us to compare the effects of sieve meshes on the interpretations of crustacean selection on the seashore by the last fisher-hunter-gatherers of north-western France. The present article also gives us the opportunity to describe the complete methodology of the study of the Beg-er-Vil crabs, from their identification and quantification to the reconstitution of crab sizes fished by the Mesolithic populations.

1- MATERIALS AND METHODS USED ON THE BEG-ER-VIL CRABS

1.1- In the field

The Beg-er-Vil shell midden was identified in the 1970s in an eroded part of a cliff section (Kayser, 1987). This archaeological site was already eroding at that time, as it still is today (fig. 1). The midden's minimum surface area has been estimated at 130 m², but its original extent is not known (Dupont and Marchand, 2021). Its current thickness is 50 to 40 cm. This shell level is protected by a dune with a height of 0.5 to 2 m (Dupont and Marchand, 2021). The shell midden takes the form of a black organic layer comprised of concentrated waste from the daily life of the Mesolithic people who occupied the site (Dupont et al., 2009). The observed structures include pits, hearths and post holes delimiting one or even two presumed huts (Marchand et al. 2019). Most dates obtained for this level are from twigs or burnt fruit and fall within the same 7300-7200 BP range (uncalibrated; Marchand and Schulting, 2019).

Between 1985 and 1988, O. Kayser excavated 22 m² of the Beg-er-Vil shell midden (Kayser and Bernier, 1988; for a plan see Marchand et al., 2019). The excavation was carried out in arbitrary levels in the shell midden and pit infills were separated from the rest of the material. All the sediment was dry sieved with a 4-mm mesh. At the excavation, only the most significant artefacts were separated from the sieves (large faunal remains, burnt fruit, perforated shells and lithics). The rest of the sediment was stored in kraft paper bags.

A new excavation over an area of 350 m² was undertaken in the Beg-er-Vil site between 2012 and 2018 (Marchand et al., 2018). The aim was to excavate in detail not only the shell midden but also its periphery. As in the 1980s, the layer of shells was excavated in arbitrary horizontal levels and material from the structures was identified. All the sediment was sieved with seawater and then rinsed with fresh water on 4- and 2-mm square meshes. Systematic sampling of the sediment was also carried out to measure the acidity of the soil. Some elements were removed on sight during the excavation, such as armatures, macro tools and large faunal remains. Some of the sieved sediments were directly sorted dry during the excavation in a makeshift laboratory. All of the crab fragments were isolated from the small and large meshed sieves. They were then placed in bags for analysis.

1.2- In the laboratory

The material from O. Kayser's excavations in the 1980s was studied in the early 2000s. This material was sieved with fresh water on 5- and 1-mm meshes and sorted by C. Dupont (2006). Initially, only crabs from the 5-mm mesh were selected and analysed by Y. Gruet (2002). A quick visual check of the 1-mm sieved sediments was carried out. During this study in the early 2000s, the crab remains were not deemed to be very informative in relation to what was studied from the larger meshed sieve. Therefore, they were not sorted or analysed. The studied crabs from the 5-mm mesh correspond to about 8 m² of the shell midden for this phase of the excavation. They consist of some rare fragments of crabs collected on sight during the excavation, material from four quarters of a square metre (sub-squares: AE20B, AE23B, AF21B, AG23B) and from the infill of structures considered to be

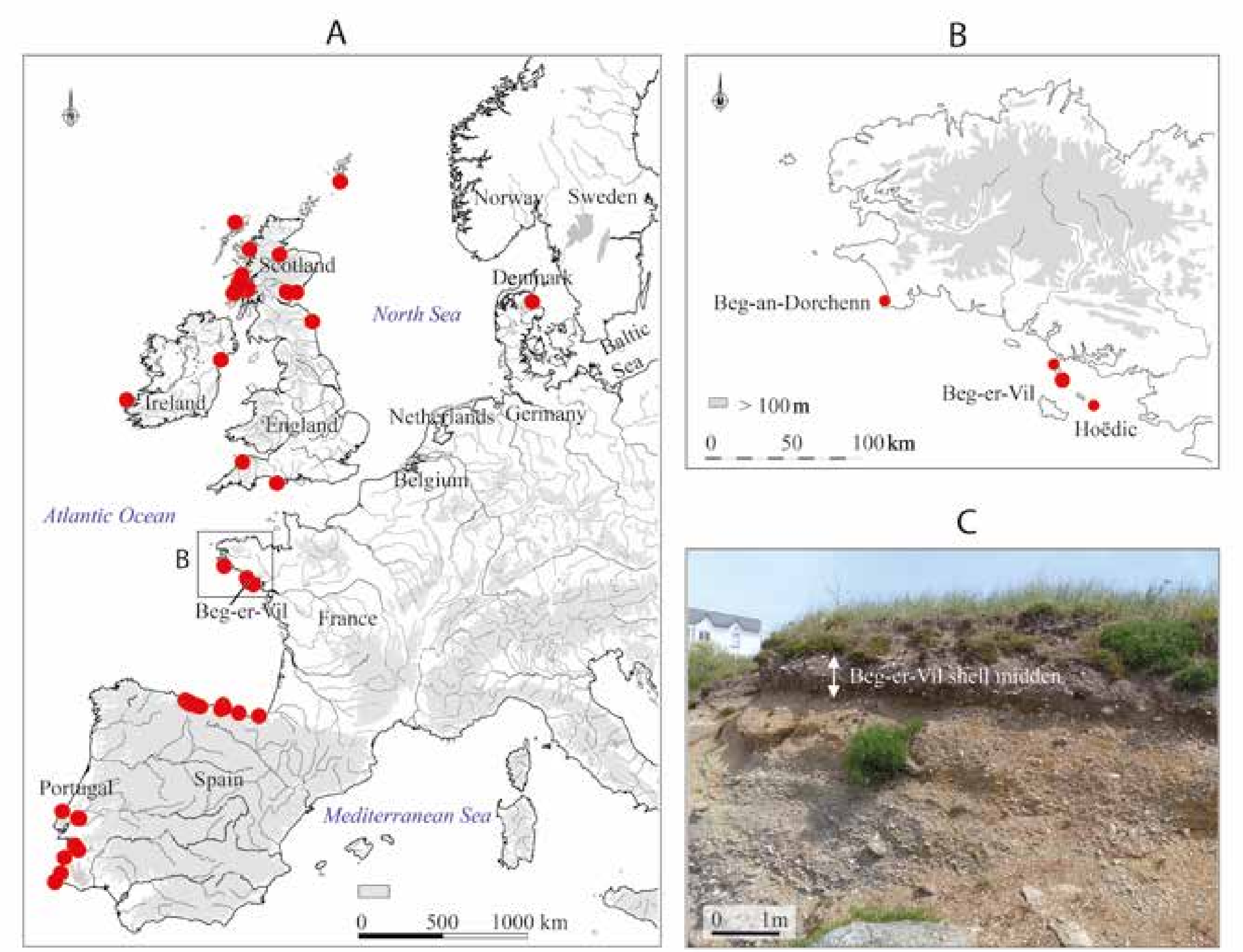

Fig. 1 – A. Distribution of Mesolithic shell-middens for which reports of crabs have been published and the quoted site locations (Grieve, 1874; Ribeiro, 1884; Anderson, 1898; Bishop, 1914; Péquart and Péquart, 1934; Stevenson, 1946; Péquart and Péquart, 1954; Roche, 1960 and 1965; Clark, 1971; Coles, 1971; Mellars, 1978; Woodman, 1978; González Morales, 1982; Lentacker, 1986; Ortea, 1986; Bell, 1987; Arnaud, 1989; Arias Cabal, 1991; Myers and Gourlay, 1991; Connock et al., 1993; Pollard et al., 1996; Tavares da Silva and Soares, 1997; Araújo, 1998; Woodman et al., 1999; Arnaud, 2000; Zilhão, 2000; Mannino et al., 2003; Melton and Nicholson, 2004; Dupont and Gruet, 2005; Bailey and Milner, 2007; Lubell et al., 2007; Zapata et al., 2007; Gutiérrez Zugasti, 2010; Valente, 2008; Milner, 2009; Pickard and Bonsall, 2009; Dupont et al., 2010; Iriate et al., 2010; Álvarez-Fernández, 2011; Dupont, 2011; Gutiérrez-Zugasti et al., 2016; Moreno Nuño, 2017; Evans, 2021; Araújo: unpublished for Vale Frade Portugal; CAD L. Quesnel and C. Dupont); B. Location of Beg-er-Vil (CAD G. Marchand, after Dupont et al., 2009); C. Eroded cliff showing Beg-er-Vil midden (Photo C. Dupont).

***Fig. 1** – A. Distribution des amas coquilliers du Mésolithique pour lesquels les crabes ont été publiés (Grieve, 1874 ; Ribeiro, 1884 ; Anderson, 1898 ; Bishop, 1914 ; Péquart et Péquart, 1934 ; Stevenson, 1946 ; Péquart et Péquart, 1954 ; Roche, 1960 et 1965 ; Clark, 1971 ; Coles, 1971 ; Mellars, 1978 ; Woodman, 1978 ; González Morales, 1982 ; Lentacker, 1986 ; Ortea, 1986 ; Bell, 1987 ; Arnaud, 1989 ; Arias Cabal, 1991 ; Myers and Gourlay, 1991 ; Connock et al., 1993 ; Pollard et al., 1996 ; Tavares da Silva and Soares, 1997 ; Araújo, 1998 ; Woodman et al., 1999 ; Arnaud, 2000 ; Zilhão, 2000 ; Mannino et al., 2003 ; Melton et Nicholson, 2004 ; Dupont et Gruet, 2005 ; Bailey et Milner, 2007 ; Lubell et al., 2007 ; Zapata et al., 2007 ; Gutiérrez Zugasti, 2010 ; Valente, 2008 ; Milner, 2009 ; Pickard et Bonsall, 2009 ; Dupont et al., 2010 ; Iriate et al., 2010 ; Álvarez-Fernández, 2011 ; Dupont, 2011 ; Gutiérrez-Zugasti et al., 2016 ; Moreno Nuño, 2017 ; Evans, 2021 ; pour Vale Frade, Portugal : Araújo, inédit ; DAO L. Quesnel et C. Dupont) ; B. Localisation de Beg-er-Vil (DAO G. Marchand, d'après Dupont et al., 2009) ; C. Falaise en phase d'érosion montrant Beg-er-Vil (cliché C. Dupont).*

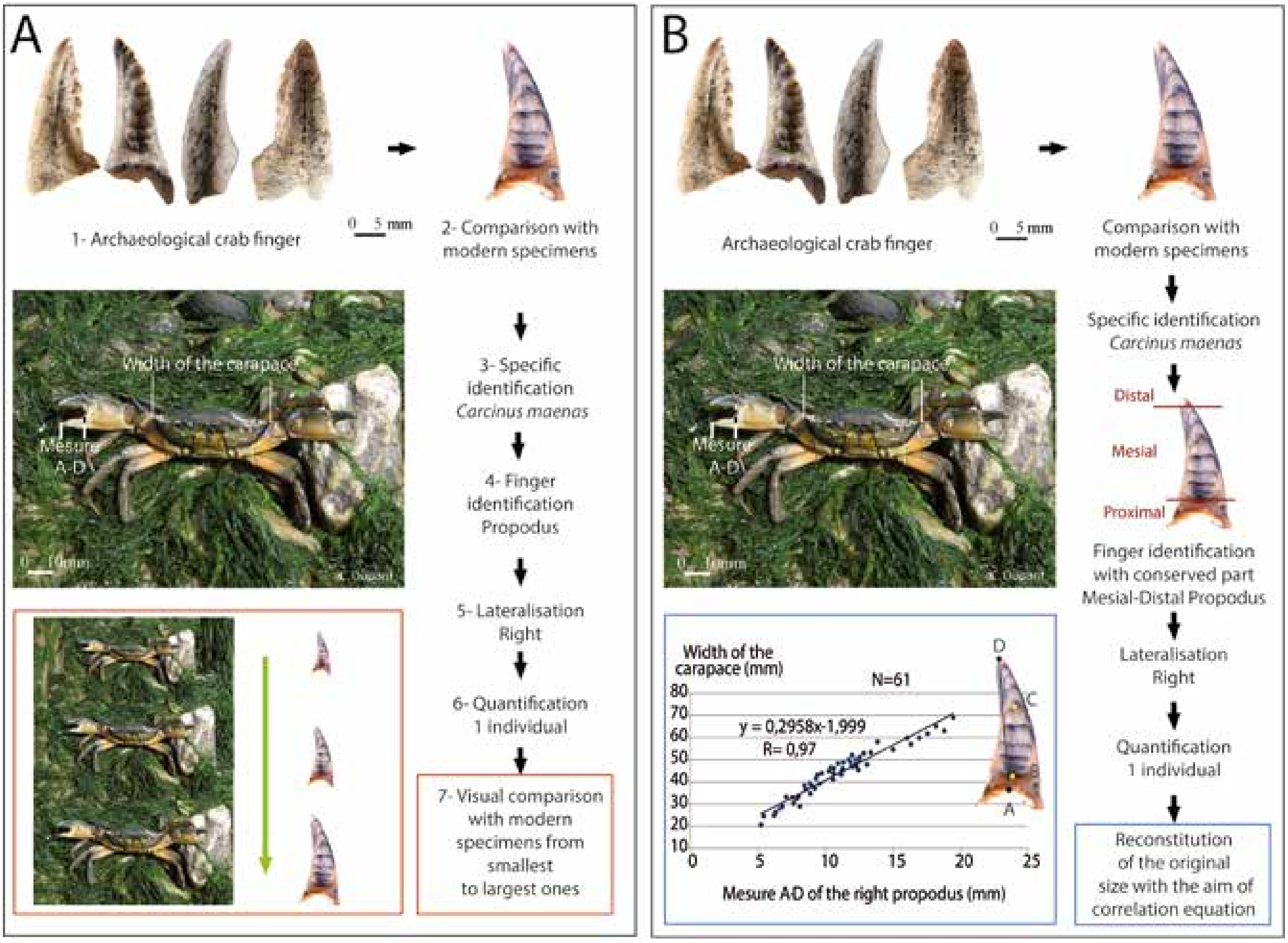

Fig. 2 – Method applied to archaeological remains of crabs on Beg-er-Vil, 1985-1988 (A); Beg-er-Vil, 2013 (B; photos and CAD: C. Dupont).

***Fig. 2** – Méthodologie appliquée aux restes archéologiques de Beg-er-Vil 1985-1988 (A) ; Beg-er-Vil 2013 (B ; clichés et DAO C. Dupont).*

anthropogenic (sub-squares: AE20-21, AE22-23/St87-5, AF20/St87-6, AG20- AG21/St87-7).

The material from the excavations of G. Marchand and C. Dupont in the 2010s was sorted in the field and during post-excavation sorting sessions. All the crustacean fragments retained on the 4- and 2-mm meshes were selected. For this study, only part of the crab remains from the 2012 excavation were taken into account. These were analysed by O. Digard and C. Dupont in 2019 and correspond to 2 m² of the midden (squares BB33 and BB35). All of the remains from 2013 were analysed by M. Arthur and C. Dupont in 2018. These correspond to an opened area of 44 m² (Marchand and Dupont, 2014).

1.2.1- Identification

All the crab fragments were counted from the 5-mm mesh for the 1980s material and on 2- and 4-mm meshes for the 2010s material. We summarise the various stages of our analyses once the crab appendages were extracted from sieved sediments in figure 2. These fingers were then compared with a comparative collection of modern crabs[(1)] for the purposes of determination (fig. 3). These determinations were based on the general shape of the appendages, the texture of their surface (smooth, granular, porosity, presence of grooves), and the shape and size of the different teeth that adorn the inside of the claw (fig. 3, Right). The scientific names used were taken from the DORIS database[(2)].

1.2.2- Quantification

Once determined, the appendages were identified as either dactyls or propodi (fig. 2). All the elements mentioned above were used for determining species. The orientation of fragments was proposed for the 2012 and 2013 material based on the natural position of the finger on an individual (fig. 2B). The proximal part of a dactyl or a propodus is the area closest to the body, their distal part is the furthest away and the mesial part is intermediate. The dactyls and propodi were then lateralised. The MNI (Minimal Number of Individuals) was obtained from the number of right and left dactyls and propodi.

All the crab exoskeleton fragments were also weighed as is common practice in archaeology. Weight is a value that can be compared to other artefacts and that can be used to judge the degree of preservation of faunal remains.

1.2.3- Size reconstruction

After quantifying the crabs, we sought to estimate the original size of the carapaces. This reconstruction was carried out using two methods. On the material from the 1980s, we made a visual comparison of the sizes of finger fragments from Beg-er-Vil with fingers from the modern comparative collection. Modern appendages were classified from the smallest to the largest to facilitate this stage of the study. This visual comparison was conducted on *Cancer pagurus, Eriphia verrucosa, Necora puber* and *Carcinus maenas*. On the 2012 material, comparative equations were used to reconstruct the dimensions of the *Cancer pagurus* crabs (fig. 4). These equations were calculated from the comparative collection (fig. 4). They show significant correlations of more than 90% between finger measurements (fig. 4 A-2 and B-2) and the width of the crab. The time available for this study did not allow us to reconstruct templates for the other species in the 2010 material.

2- BEG-ER-VIL CRABS

2.1- Stratigraphy and fragmentation

The archaeological material from 2013 corresponds to the analysis of two square metres (BB33 and BB35) located in the heart of the midden (Marchand et al., 2019). These are both adjacent to O. Kayser's survey, which may have accelerated the deterioration of archaeological remains, as observed at Beg-an-Dorchenn (Dupont et al., 2010). Crab fragments between 2 and 4 mm are

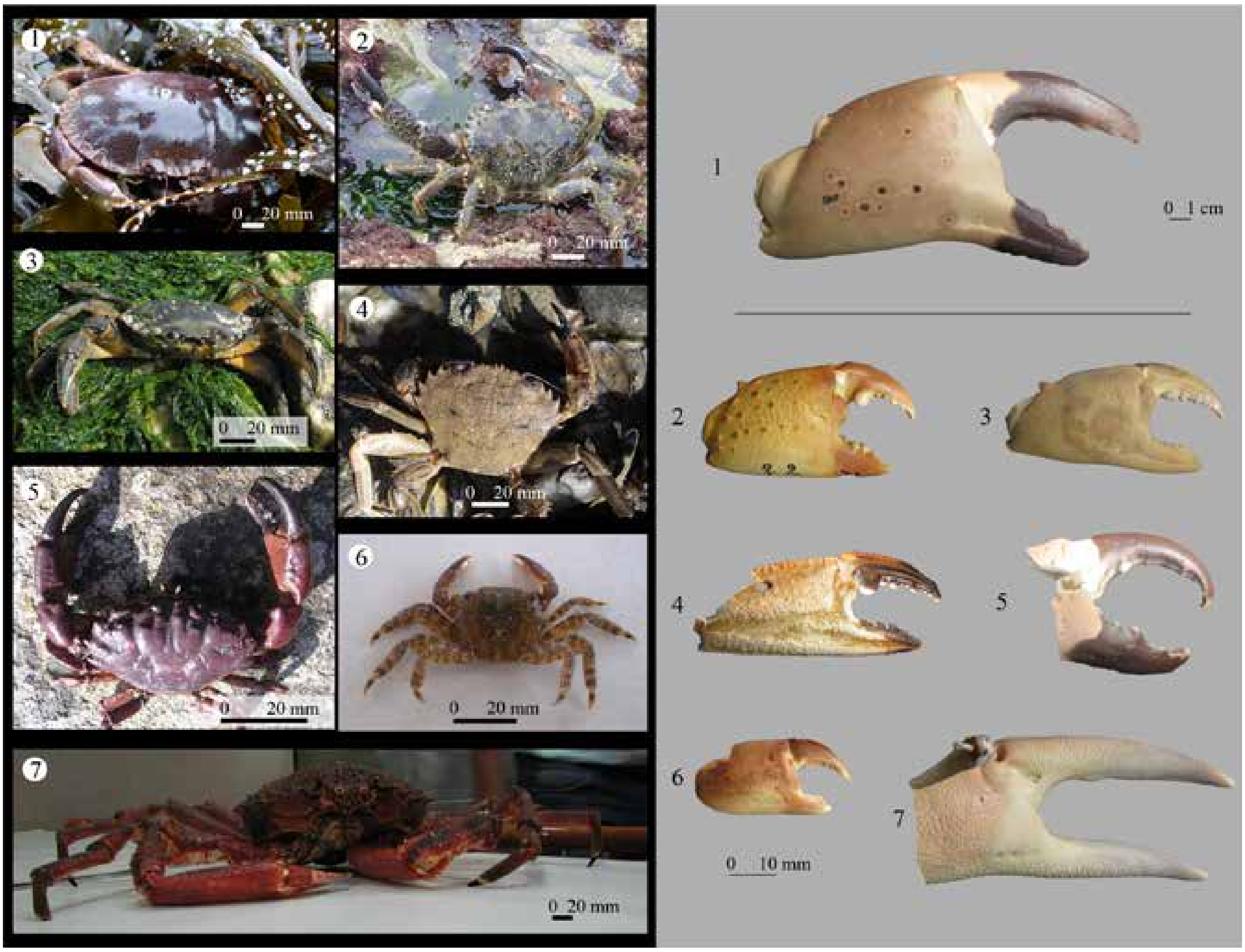

Fig. 3 – Modern crabs from the reference collection: Left, complete specimens; Right, right pincers: Edible crab *Cancer pagurus* (1); Warty crab *Eriphia verrucosa* (2); Green crab *Carcinus maenas* (3); Velvet swimming crab *Necora puber* (4); Furrowed crab *Xantho* sp. (5); Marbled rock crab *Pachygrapsus marmoratus* (6); Spider crab *Maja squinado* (7; right: Photos 1, 2, 3 and 7 C. Dupont; photos 4 to 6 Y. Gruet; left: Photos M. Arthur; CAD C. Dupont).

***Fig. 3** – Les crabes modernes de la collection de comparaison : à gauche, spécimens complets ; à droite, pince droite : Crabe dormeur* Cancer pagurus *(1) ; Crabe verruqueux* Eriphia verrucosa *(2) ; Crabe vert* Carcinus maenas *(3) ; Étrille* Necora puber *(4) ; Xanthe* Xantho *sp. (5) ; Crabe marbré* Pachygrapsus marmoratus *(6) ; Araignée de mer* Maja squinado *(7 ; à droite : clichés 1, 2, 3 et 7 C. Dupont, clichés 4 à 6 Y. Gruet ; à gauche : clichés M. Arthur ; DAO C. Dupont).*

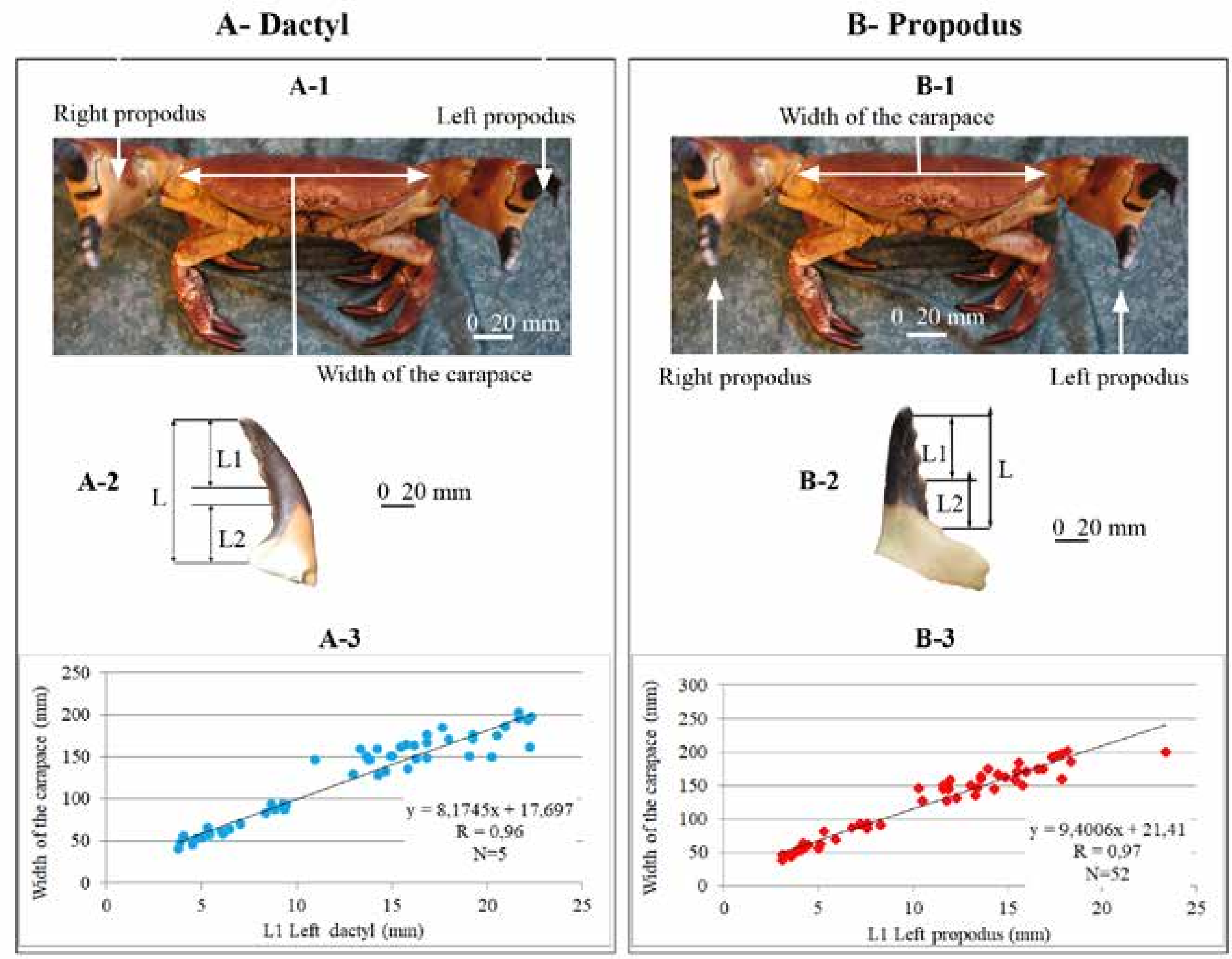

Fig. 4 – Example of correlations between a fragment of crab finger and the width of the carapace based on modern samples: Measure of the carapace and location of the fingers according to their lateralization (A); Different measures on a finger (B); Example correlation equation (C; Photos: pincers M. Arthur; complete crab C. Dupont; CAD C. Dupont).

***Fig. 4** – Exemple de corrélations entre un fragment de doigt de crabe actuel et la largeur de sa carapace ; mesure de la carapace et localisation des doigts en fonction de leur latéralisation (A) ; différentes mesures sur un doigt (B) ; exemple d'équation de corrélation (C ; photos pinces M. Arthur, crabe complet C. Dupont ; DAO C. Dupont).*

more frequent than fragments over 4 mm (fig. 5). The average weight of a crab fragment from the 2010 excavations was 0.15 g. The size of these fragments seems to vary depending on their position in the shell midden (fig. 5). The density of shells observed at the excavation seems to be in keeping with the numbers of crab remains, when these are cumulated. Level 4 is a transitional layer between the midden and the current ground surface with few shells. Level 5 is the heart of shell midden where shells are more concentrated. The shells are more dispersed in levels 6 and 7 which are located below the midden in contact with the substrate. The fact that the 4-mm fragments are predominantly present in the core of the midden may correspond to a lower acidity of the sediment in that area. The most basic pH value measured reaches 9.1 in layer 5.3 of BB35, and the least basic pH is 8 in layer 4.1 of BB33 (Querré and Le Bannier, 2013). This shows that the 'self-digestion' of the shell midden is probably still in progress, leading to an increase in the fragmentation of crab remains as time goes by.

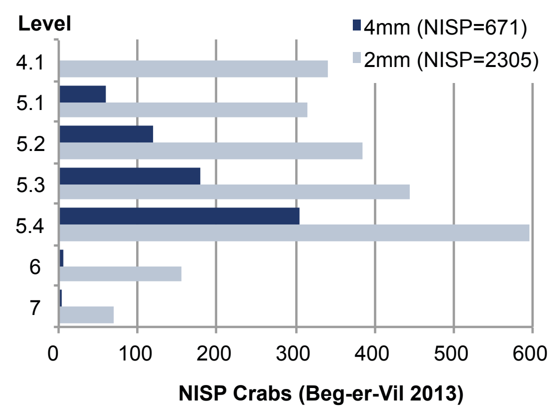

Fig. 5 – Number of Identified Specimens (NISP) of crabs counted at Beg-er-Vil 2013 according to sieve mesh size and archaeological level.

***Fig. 5** – Nombre de restes de crabe décomptés à Beg-er-Vil 2013, en fonction de la taille des mailles des tamis et du niveau archéologique.*

2.2- Represented species and sieve size

The most abundant crab fragments are the fingertips (fig. 6), as in most archaeological sites (Dupont and Gruet, 2022). This observation is correlated with a higher mineral density of the crab exoskeleton (Bosselmann et al., 2007, p. 67). The cumulative analysis led to the identification of seven species (table 1): the edible crab *Cancer pagurus* (Linnaeus, 1758), the warty xanthid crab *Eriphia verrucosa* (Forskål, 1775), the green crab *Carcinus maenas* (Linnaeus, 1758), the velvet swimming crab *Necora puber* (Linnaeus, 1767), the furrowed crab *Xantho* sp. (Leach, 1814), the marbled rock crab *Pachygrapsus marmoratus* (J.C. Fabricius, 1787), and the spider crab *Maja squinado* (Herbst, 1788). The latter three quoted species (*Xantho* sp. *Pachygrapsus marmoratus, Maja squinado*) were not observed in the material from the 1980s excavation (fig. 7 and table 1). They were identified in smaller quantities in the material from the 2010s. Their low proportions may account for their rarity in the material from the 1980s. Another factor may explain this absence: the natural small size of the furrowed crab and of the marbled rock crab *Pachygrapsus marmoratus* and their claws (fig. 8). The width of the carapace of these two species is at least twice as small as that of the velvet swimming crab. The fingertips of these two species may not have been retained in the 5-mm mesh. The size criterion may also have affected spider crab identification. The fingers of this species are relatively straight and thin and it is likely that sieving the sediments on a 5-mm mesh in the 1980s removed the smallest crabs and spider crab fragments.

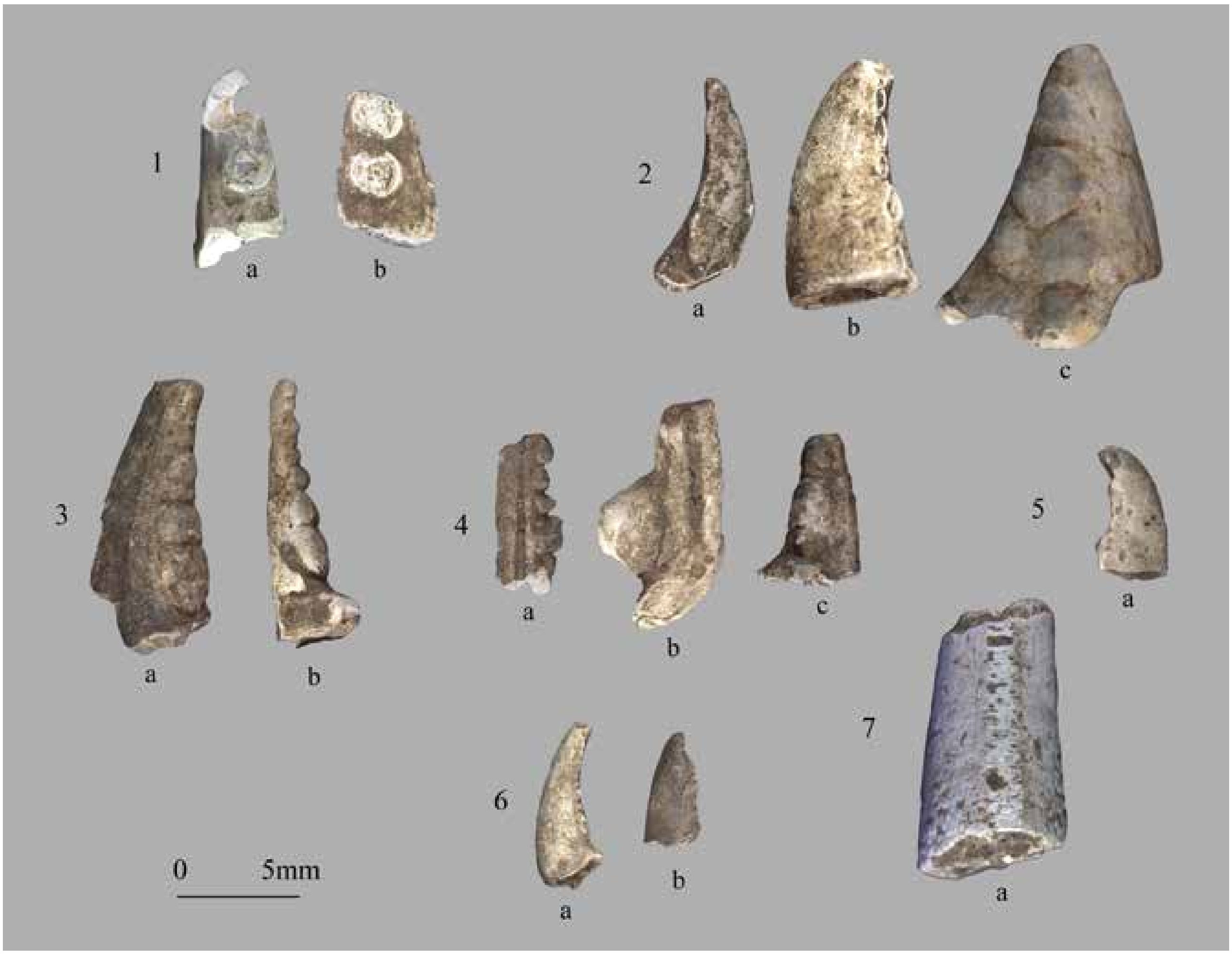

Fig. 6 – Best preserved crab fragments from Beg-er-Vil: Edible crab *Cancer pagurus* (1a left dactyl, 1b left propodus); Warty crab *Eriphia verrucosa* (2a right dactyl, 2b left dactyl, 2c right propodus); Green crab *Carcinus maenas* (3a and 3b right dactyl); Velvet swimming crab *Necora puber* (4a left dactyl, 4b right dactyl, 4c right propodus); Furrowed crab *Xantho* sp. (5a left dactyl); Marbled rock crab *Pachygrapsus marmoratus* (6a and 6b right dactyl); Spider crab *Maja squinado* (7; Photos M. Arthur except no. 1 O. Digard; CAD C. Dupont).

***Fig. 6** – Fragments les mieux conservés de Beg-er-Vil : Dormeur* Cancer pagurus *(1a dactylopode gauche, 1b propode gauche) ; Crabe verruqueux* Eriphia verrucosa *(2a dactylopode droit, 2b dactylopode gauche, 2c propode droit) ; Crabe vert* Carcinus maenas *(3a et 3b dactylopode droit) ; Étrille* Necora puber *(4a dactylopode gauche, 4b dactylopode droit, 4c propode droit) ; Xanthe* Xantho *sp. (5a dactylopode gauche) ; Crabe marbré* Pachygrapsus marmoratus *(6a et 6b dactylopode droit) ; Araignée de mer* Maja squinado *(7 ; clichés M. Arthur excepté le n° 1 O. Digard, DAO C. Dupont).*

Beg-er-Vil	1985-1988			2012			2013		
Opened area	8 m²			2 m²			44 m² (partial)		
Mesh	5 mm			2 and 4 mm			2 and 4 mm		
Crabs	NISP	MNI	Weight (g)	NISP	MNI	Weight (g)	NISP	MNI	Weight (g)
Cancer pagurus	64	39	136	136	35	10.18	2253	318	130.76
Eriphia verrucosa	21	19	2.4	27	10	2	351	104	3.28
Carcinus maenas	5	6	0.2	4	3	0.07	178	70	1.27
Necora puber	11	7	1.3	2	2	0.03	129	37	1.04
Xantho sp.	0	0	0	3	2	0.13	95	24	0.8
Pachygrapsus marmoratus	0	0	0	1	1	0.03	27	10	0.24
Maja squinado	0	0	0	1	1	0.3	16	8	0.19
Indetermined	294	-	51.81	39	-	1.29	696	-	-
Total	395	71	69.31	213	54	14.03	3049	571	137.58

Table 1 – Quantities of crabs according to excavation year and sieve mesh size (NISP: Number of Identified Specimens; MNI: Minimum Number of Individuals).

Tabl. 1 *– Données quantitatives pour les crabes en fonction des années de fouille et de la taille de la maille des tamis (NISP: nombre de restes identifiés; MNI: Nombre Minimum d'Individus).*

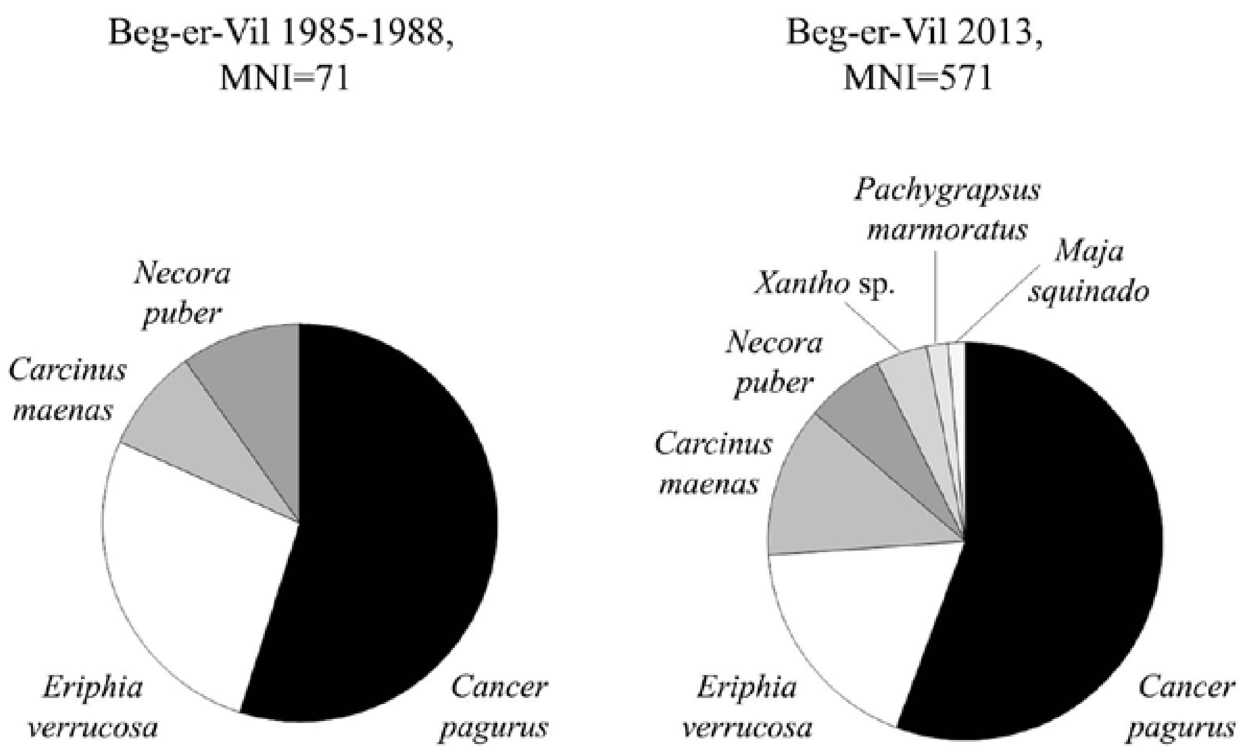

Fig. 7 – Crab spectra in Beg-er-Vil 1985-1988 and Beg-er-Vil 2013 (CAD C. Dupont).

Fig. 7 *– Spectre des crabes de Beg-er-Vil 1985-1988 et de Beg-er-Vil 2013 (DAO C. Dupont).*

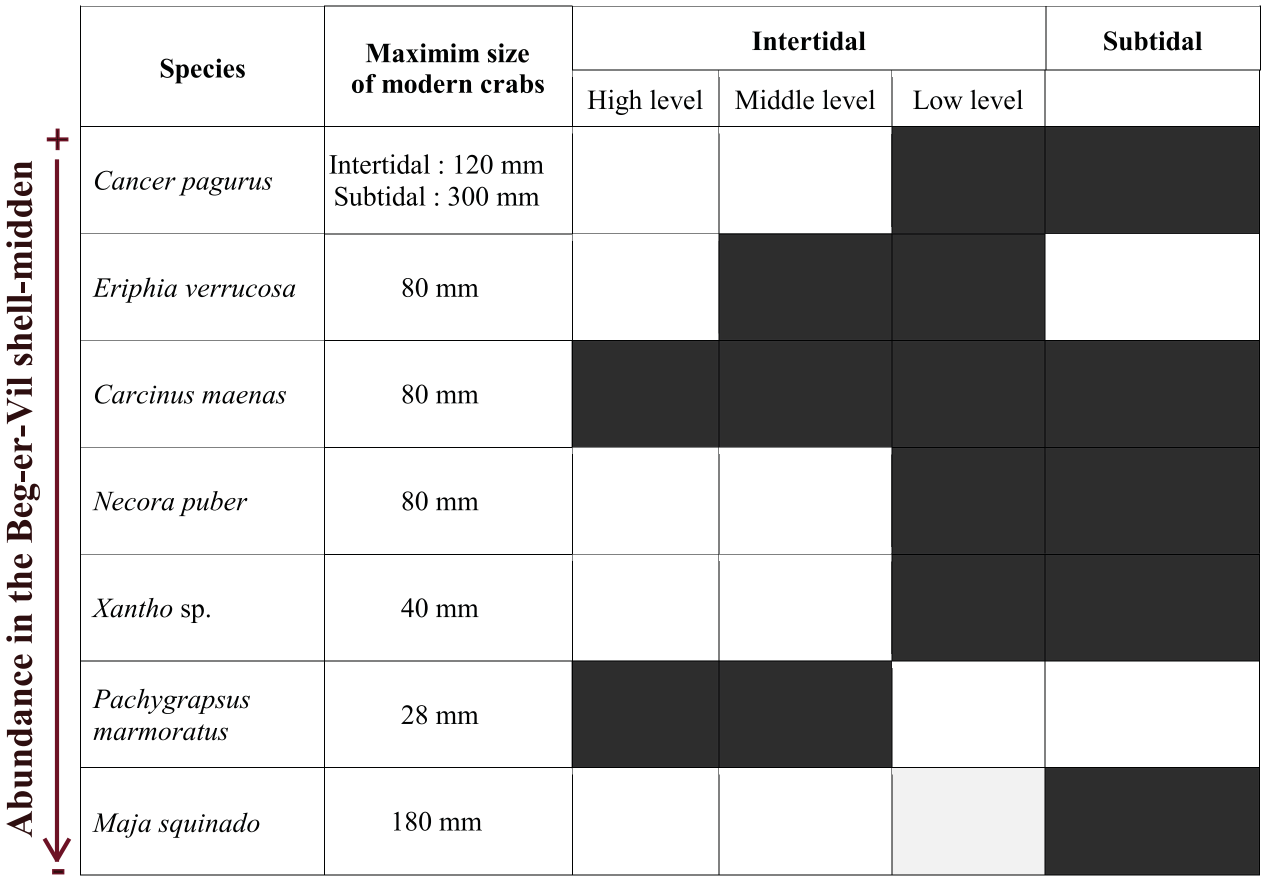

Fig. 8 – Altitude on the shore and maximum carapace size of the species determined at Beg-er-Vil based on data from present-day specimens (Photos C. Dupont and Y. Gruet; CAD C. Dupont).

***Fig. 8** – Altitude sur le littoral et largeur maximale de la carapace des espèces déterminées à Beg-er-Vil, à partir d'observations sur les spécimens actuels (clichés C. Dupont et Y. Gruet ; DAO C. Dupont).*

2.3- Spectra from archaeological crab remains

All the species determined at Beg-er-Vil are accessible on the foreshore, with the exception of the spider crab. Currently, this species moves closer to the coast when the sea water warms up in the late spring and may even be found washed up on the beaches. The low proportion in both the assemblages from the 2010s, representing less than 2%, can thus be explained by its lack of accessibility. The other species present percentages in accordance with the size of adult individuals: the bigger they are, the more abundant they are in the archaeological record. The most abundant are the largest, with proportions close to 56 to 65% for *Cancer pagurus*, 18 to 19% for *Eriphia verrucosa*, 6 to 12% for *Carcinus maenas*, 4 to 6% for *Necora puber*, 4% for *Xantho* sp. and 2% of the MNI for *Pachygrapsus marmoratus*, for the material from 2012 and 2013. These proportions do not seem to be strictly dependent on the foreshore level where crabs are accessible. The edible crab, velvet swimming crab and furrowed crab are indeed accessible from the lowest foreshore level. It is likely that the prehistoric populations turned to the larger and therefore more fleshy species. Another compelling question is: What about the sizes exploited within each species?

2.4- Impact of sieve mesh on crab size

The reconstruction of the carapace width of edible crabs caught by Mesolithic populations was performed for the material from the 1980s (N = 39) and the 2013 excavation (N = 18) at Beg-er-Vil (table 2). The reconstructed crab quantities are not proportional to the volume of sorted sediment. This observation may be linked to the different methods used for these size reconstructions (fig. 2 and fig. 4). The method based on correlation equations requires the preservation of the tubercles adorning the finger, while the other method is based on a visual comparison of the overall shape of the preserved finger part or its tubercles. The visual comparison method seems to be applicable to a greater quantity of fragments. Reconstructions show the presence of edible crabs between 40 and 170 mm. This result is interesting as it shows that these Mesolithic populations fished larger crabs than those currently available in the intertidal zone. The currently observed maximum carapace width of this animal on the foreshore is 120 mm (DORIS, 2020). It is possible that fishing gear, such as crab pots and dilly nets or traps, provided access to crabs in the subtidal zone. A second hypothesis that should also be considered is the current overexploitation of crabs on the foreshore.

This potential overexploitation is difficult to demonstrate because of the lack of current data on fished crabs or on the ethology of each species of crab (Hunter et al., 2013; Tully et al., 2016). For example, the maximum size that you can fish at low tide seems to be smaller than in the past, at the scale of a human lifetime. On the other hand, the observations on marine molluscs do not show any signs of capture from the subtidal zone. Reconstructions of the 2010s material show a shift towards smaller values compared with the 1980s and vice versa. This shift may be partly explained by the size of the sieve mesh used (5 mm for 1980 and 2 mm for 2010). The excavations by O. Kayser may have overlooked the smaller individuals because their smaller remains were not retained by the 5-mm sieve.

CONCLUSIONS

Several factors can affect the visibility of crabs to archaeologists. Not all parts of their exoskeleton are preserved in the same way. Most of the time, as at Beg-er-Vil, only the ends of crab claws are preserved and recorded by archaeologists for the Mesolithic sites of the Atlantic coast of Europe, whether in Ireland (Woodman et al, 1999, p. 96), England (Bailey and Milner, 2007; Milner, 2009), Scotland (Grieve, 1874, p. 46; Anderson, 1898; Coles, 1971; Myers and Gourlay, 1991, p. 21; Finlay et al., 2019), Spain (Fano Martínez, 1998) or Portugal (Lentacker, 1986; Pinto, 1986; Arnaud,1989; Valente, 2008). The study of crab fragments according to the stratigraphy of the Beg-er-Vil shell midden also shows that sediment acidity affects their degree of fragmentation. It is possible that the effects of soil acidity increased between 1980 and 2010.

This study of the crabs from a Mesolithic shell midden also shows the importance of sampling methods on the results obtained. The material found during O. Kayser's excavations in the 1980s was sieved with a 5-mm mesh and indicated that Mesolithic crab fishing targeted the largest species and individuals. The use of finer sieve meshes shows that some of the animals caught by the inhabitants of Beg-er-Vil had been invisible until now. New studies show a greater diversity of crab species, all of which are accessible on the foreshore. As with marine molluscs, everything that was edible and accessible at low tide was consumed (Dupont, 2021; Dupont and Marchand, 2021). The presence of the spider crab could also be a temporal indicator of site occupation as this species currently approaches the coast in late spring during the warming period. The spider crab is only accessible on the foreshore at that time. Size reconstruction of the identified species show that a wide range of crab sizes were consumed. Analysis of the 2010 material is underway, and the question remains open as to the cumulative presence of crabs that were consumed and other crabs transported with other marine resources (rock and/or seaweed, for example). The concomitant analysis of marine molluscs should make it possible to highlight such contributions. Due to their low food value in terms of quantity of flesh, the use of small crabs as bait is also sometimes

Cancer pagurus **Reconstitution of the width of the carapace (mm)**	**Beg-er-Vil 1985-1988 MNI (Gruet, 2002)**	**Beg-er-Vil 2013 MNI (Unpublished)**
20	0	0
30	0	0
40	0	1
50	0	7
60	0	6
70	3	1
80	8	1
90	9	0
100	3	0
110	3	1
120	0	0
130	7	0
140	2	1
150	3	0
160	0	0
170	1	0
Total fragments	**N = 39**	**N = 18**

Maximum size of modern intertidal *Cancer pagurus*

Table 2 – Estimation of the size of the *Cancer pagurus* based on the archaeological fragments from Beg-er-Vil.
***Tabl. 2** – Estimation de la taille des tourteaux à partir des fragments archéologiques de Beg-er-Vil.*

mentioned (Lentacker, 1986, p. 18). However, even very small crabs can be used as food in the form of preparations such as soups, for example. Few reconstructions of crab sizes from Mesolithic shell middens have yet been attempted (for more details see Dupont and Gruet, 2022). Estimates from the Scottish site of Ulva Cave are similar to those described at Beg-er-Vil (Pickard and Bonsall, 2009). The four represented species all comprise juveniles and adults.

Many of the crab remains from Beg-er-Vil are charred, representing 45% of the 3049 fragments analysed in the 2013 survey. Such burn marks, when they are located at the tips of the fingers, have been associated with Mesolithic roasting of crabs (Milner, 2009). Unfortunately, it is difficult to identify the position of the burn marks at Beg-er-Vil. These burns may well have occurred during cooking, but also through exposure to fire after the crabs were eaten. Fires or the cleaning of waste by lighting fires are all possible explanations for these burn traces (Mougne, 2015).

The size of crab fragments largely explains the lack of interest in these animals by archaeologists in the past. Other factors may have influenced the fact that crab fishing was generally overlooked. The same scenario is observed for shellfish (Dupont and Marchand, 2021, p. 66) and shell middens. In the past, shell middens were only described in terms of lithic industry and large mammal remains (Dupont and Marchand, 2021, p. 60). The shellfish and crab catching activities by the fisher-hunter-gatherer populations were underestimated or even devalued by archaeologists in favour of the hunting of big game. This devaluation is even apparent in the hunter-gatherer appellation. It may also be due to 'an androcentric bias' (Milner, 2009).

Despite all these obstacles, the crab deserves to be considered in the archaeological record because upon closer inspection, it is undeniably present. Its meat yield is high, since more than a third of its fresh weight is meat and it contributes to food diversity. The food source represented by this meat was easily accessible and Mesolithic populations probably consumed a great deal of it. Furthermore, we now know that crabs are a good source of omega-3 fatty acids (Anacleto et al., 2016) and "essential elements such as K, Ca, Cu, Zn, Se and n - 3 PUFA, namely, EPA and DHA" (Maulvault et al., 2012, p. 6). These nutritional elements may have enabled coastal populations to overcome certain dietary deficiencies and may also have contributed to their prolonged presence in this part of the territory throughout the annual cycle.

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NOTES

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(2) Données d'observations pour la reconnaissance et l'identification de la faune et la flore subaquatiques (Doris, 2021) : *https://doris.ffessm.fr/*

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New Perspectives on Old Shores: Current Approaches to the Mesolithic in South-Eastern Norway and their Potential

Nouvelles perspectives sur d'anciens rivages : les approches actuelles du Mésolithique du sud-est de la Norvège et leur potentiel

Almut Schülke, Inger Marie Berg-Hansen, Axel Mjærum, Isak Roalkvam, Steinar Solheim

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Abstract: Research on coastal societies in Mesolithic south-eastern Norway (9300-3900 cal. BC) has increased significantly in recent years, against the backdrop of a much larger, more substantial and constantly growing source material over the last two decades, but also through the adoption of different theoretical frameworks and methodological tools. Thus, various new insights into Mesolithic coastal living have been gathered. However, the diversity in theoretical and methodological approaches has received rather little theoretical reflection concerning the aims and potential of these various ways of dealing with the archaeological material. This article presents and discusses a number of current approaches on human relations with the shore in the Mesolithic in south-eastern Norway. It reflects on differences and similarities with respect to underlying concepts, theory, and methodology within these approaches. We ask which aspects of our topic do the different approaches actually shed light on, and whether the approaches are compatible. By comparing these approaches this article aims at clarifying the investigatory breadth present, but also at highlighting challenges and limitations pertaining to individual analytical perspectives. This can contribute a better understanding of hunter-gatherer lifeways on the Mesolithic coast, potentially through a combination of approaches that have so far been applied separately. We will focus on five thematic areas and on the potential for combining them: population dynamics and radiocarbon dates, settlement patterns and site location, adaptation and choice of place, moving and dwelling, and technology as tradition.
Keywords: Coastal society, Mesolithic, hunter-gatherers, south-east Norway, theoretical framework, methodology, population dynamics, site location, choice of place, movement, technology.

Résumé : La recherche sur les sociétés côtières mésolithiques (9300-3900 av. J.-C.) du sud-est de la Norvège s'est considérablement développée ces dernières années, grâce à un matériel archéologique toujours plus important, plus substantiel et en constante augmentation au cours des deux dernières décennies. L'adoption de différents cadres théoriques et outils méthodologiques a éclairé sous différents angles la vie côtière mésolithique. Cependant, ces diverses approches théoriques et méthodologiques n'ont pas été accompagnées d'une réflexion sur les objectifs et sur le potentiel de ces différentes manières de traiter l'information archéologique et de l'interpréter. Cet article présente et discute un certain nombre d'approches actuelles portant sur les relations qu'ont entretenues les sociétés humaines avec le littoral durant le Mésolithique dans le sud-est de la Norvège. Il réfléchit aux différences et aux similitudes en ce qui concerne les concepts sous-jacents, la théorie et la méthodologie des recherches récentes dans ce domaine. Quels sont les différents aspects mis en lumière ? Comment les différentes manières d'aborder ces relations peuvent-elles s'enrichir mutuellement ? En comparant ces approches, le présent article souligne l'ampleur des investigations archéologiques menées actuellement, en insistant également sur les défis et les limites des perspectives analytiques individuelles. Ce travail souhaite contribuer à une meilleure compréhension des modes de vie des chasseurs-cueilleurs mésolithiques sur la côte, en recommandant une combinaison d'approches qui, jusqu'à présent, ont été mises en œuvre séparément. Nous nous concentrerons sur cinq domaines thématiques et sur le potentiel de leur combinaison : la dynamique de la population et les dates radiocarbone, les modèles de peuplement et la localisation des sites, l'adaptation et le choix du lieu, le déplacement et l'habitation, et enfin la technologie comme tradition.

Mots-clés : société côtière, Mésolithique, chasseurs-cueilleurs, sud-est de la Norvège, cadre théorique, méthodologie, dynamique de population, emplacement du site, choix du lieu, mouvement, technologie.

INTRODUCTION AND AIM

Research on Mesolithic coastal societies in south-eastern Norway has increased significantly in recent years, activating the constantly growing amount of archaeological material brought forth by extensive development-led excavation. Hence, our knowledge of the Mesolithic period (9300-3900 cal. BC) in this area has increased dramatically. We have to deal not only with a much larger, more substantial, and constantly growing amount of source material compared with only two decades ago but, through the adoption of different theoretical frameworks and an increasing range of applied methods, a variety of different perspectives now being leveraged in the study of this material. This variety of approaches being published side by side surely mirrors the diversity that is characteristic of present-day archaeological practice, with a post-positivistic understanding that many perspectives can contribute in a valuable way to the understanding of the whole. It is striking, though, that this recent period of gathering new insights, especially related to the application of a number of theoretical and methodological approaches, has received rather little attention in terms of theoretical reflection on the aims and the potential of these various different ways of dealing with what is often the same archaeological material.

To gain a better awareness of the variety of existing approaches, we[1] will present and analyse a number of studies on human relations with the shore in the Mesolithic of south-eastern Norway, including coastal settlement, the wider use of coastal landscapes and social organisation and networks in coastal areas. We will reflect on differences and similarities with respect to underlying concepts, theory and methodology within these approaches. We will examine which aspects of our topic the different approaches actually shed light on. We will also ask to what degree these approaches might be compatible. A comparative dissection of these approaches can help to clarify the investigatory breadth present in the literature, while also highlighting challenges and limitations pertaining to individual analytical perspectives. This will in turn facilitate ways of better understanding hunter-gatherer lifeways on the Mesolithic coast, potentially through a combination of approaches that have so far been applied separately.

We chose five thematic areas that each of the present authors have worked on in recent years: population dynamics and radiocarbon dates, settlement patterns and site location, adaptation and choice of place, moving and dwelling, and technology as tradition. These do not necessarily cover the full spectrum of concepts applied on our topic. To compensate for this bias, we will frame each approach by providing a short overview of the current discussion, allowing the reader to assess the broader context of the research.

Due to the nature of the archaeological material, mainly lithic artefacts, and the way it is discovered through survey and excavation, all of the approaches presented here study the coastal zone in the Mesolithic period on the basis of the analytical unit of 'the site'. We will, therefore, especially ask how, through which theories, terms, concepts and methods, we have investigated sites to study living in coastal areas in the Mesolithic. We will also explore on which scales we have approached the Mesolithic people behind this work, in terms of e.g. society, groups, communities, populations or individuals, and how the various perspectives in the different studies can contribute to the discussion of hunter-fisher-gatherer social life in a more holistic way.

1. BACKGROUND: COASTAL TOPOGRAPHY AND ARCHAEOLOGICAL EVIDENCE

South-eastern Norway has a coastline thousands of kilometres in length, from the Skagerrak coast in the south-west to the Oslo fjord in the north. The modern topographic appearance of the coastal areas is a result of complicated geological processes. Since the last Ice Age, processes of land-uplift connected to isostatic rebound have led to a growth of landmasses throughout the region, especially along the Oslo fjord. Consequently, large parts of the Stone Age shorelines and coastal sites are today found in the wooded hinterland (for details see Berg-Hansen et al., this volume[2]).

Around 10 400 Stone Age sites are known and documented in the national database of archaeological sites and monuments. Over the last 15 years, the Museum of Cultural History (MCH) has excavated c. 450 of these sites (Damlien et al., 2021).

A large number of excavations have been conducted in former coastal areas, which is where most modern development is taking place (fig. 1); in historic times and up to today these are also the most densely popu-

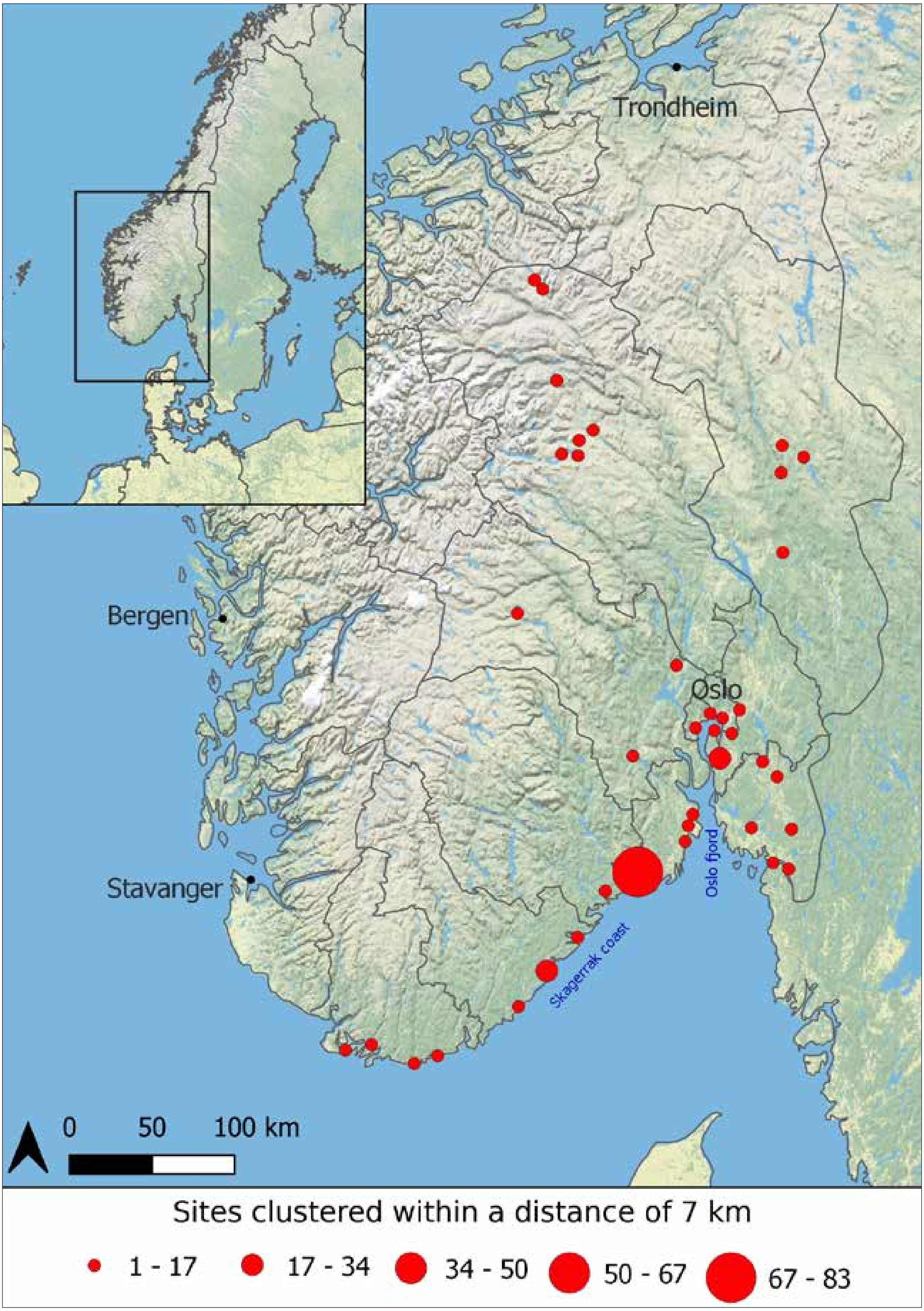

Fig. 1 – South-eastern Norway. The locations of the c. 450 Mesolithic sites excavated in the period 2000–2017 are marked with red dots (archaeological data in Damlien et al., 2021; map I. Roalkvam).

Fig. 1 *– Sud-est de la Norvège. Les emplacements des quelque 450 sites mésolithiques fouillés au cours de la période 2000-2017 sont marqués de points rouges (données archéologiques dans Damlien* et al.*, 2021 ; carte : I. Roalkvam).*

lated areas in the region. Most of the excavated Mesolithic sites are interpreted as shore-bound or situated close to the contemporary shoreline during their time of use in the Mesolithic. Combined with the specific geological processes in the Oslo fjord region, this archaeological evidence provides unique opportunities to study long-term development in Mesolithic coastal settlement.

Four concepts closely connected to the specific geological development with constant land uplift have heavily influenced the archaeological picture and thus archaeological studies of Stone Age coastal societies in south-eastern Norway (for more details see Berg-Hansen et al., this volume):

a) a specific perception of 'the coast' which is very much focused on the shoreline;
b) a specific understanding of a 'site' representing a delimited and mainly shore-based settlement;
c) the so-called shoreline model for dating;
d) surveying practices with focus on identifying Stone Age coastal sites, as a result of a), b) and c).

Thus, the archaeological picture of Mesolithic sites clustering along the contemporaneous shoreline is reinforced through modern development in these former coastal areas. While it is evident that the coast was the main living arena of hunter-gatherers in the region, the use of the land beyond the coast was presumed in earlier works with ecological perspectives (Mikkelsen, 1977 and 1989; Lindblom, 1984). Also, the mountain areas and the large waterways leading into the mountains were recognised as part of hunter-gatherers' territories (e.g. Boaz, 1998; Damlien and Solheim, 2018; Mjærum and Mansrud, 2020).

A recent review of the known the Stone Age sites in the region (Damlien et al., 2021) shows that most of the sites consist of lithic scatters, sometimes with structures (mostly hearths), and, more seldomly, sunken floors of huts or remnants of possible tent rings; so far, we know of only one burial. Some deposits (caches) are known. Rock art and stone quarries occur and mark fixed rock outcrops in the landscape. Unlike many other northern European coastal areas, larger human-made shell middens, which usually have good preservation conditions for organic material, are uncommon. Generally, due to the acid soils in the coniferous wood landscapes, relatively little organic material is preserved. This hampers broader studies of human-environment interaction. The limited bone material that has been unearthed in the region is mostly burnt, often coming from sites with sandy/gravelly soils.

Research has activated the archaeological material from the region in novel ways in recent years. Amongst these are the marine orientation of Stone Age settlement and society, with the use of the sea and the coast as a varied biotope, adaptation to climate, diachronic population dynamics, lithic technology, social organisation and perception of surroundings.

2. APPROACHES TO MESOLITHIC HUNTER-GATHERER LIVING IN THE OSLO FJORD REGION, SOUTH-EASTERN NORWAY

2.1. Preliminary remarks: From sites to social life

The five approaches to be discussed, and which we authors have worked on respectively (see sections 2.2. to 2.4.), explore Mesolithic hunter-gatherer living in the coastal areas of the Oslo Fjord. The theories or models of Mesolithic worlds behind these approaches are different, depending on the particular research problems. Thus, they activate the archaeological sources – often even the same ones – from different theoretical and methodological angles, applying different analytic scales and, thus, extracting different data, from large- to small-scale analysis and from long- to short-term perspectives.

As mentioned above, the analytical entry point to the archaeological material is usually via 'the site'. The site is first of all a modern archaeological unit that denotes a place at which archaeological material (artefacts, structures, ecofacts, etc.) has been found and which is registered with a name and/or number and delimited within a defined area (see Berg-Hansen et al., this volume). In Stone Age studies such sites are often equated with e.g. Mesolithic 'settlements'. However, a site can be composed of diverse traces of human activity, which do not necessarily have to be related to settlement in the literal sense of the word. Through the long-term/repeated use of the same places, for example, material remains of quite different activities might have accumulated over hundreds of years at a site (Solheim, 2013; Schülke, 2020).

Our different approaches study these sites or aspects of them by comparing the presence and/or absence of specific material traits, interconnecting them in time and space and thus detecting continuities and changes. This is done either – from a more distant perspective – in terms of material structures and their function, or – from a more experiential perspective – regarding the lived life embedded in them.

In some of our approaches (see below), the mass material of sites and their finds, such as lithic artefacts or radiocarbon dates, is used to conduct statistical analysis. Quantification is used to standardise variables, which can facilitate synthesisation and allows comparisons across a large number of cases, by maintaining analytical structure. In other approaches, the encounter between humans and their surroundings is the focus, exploring topics such as social exchange, experience and perception of the animate and inanimate world.

Furthermore, the contexts or environments of these sites are integrated differently in the studies, with, for example, emphasis on the contemporary shoreline (Roalkvam, 2020; Solheim, 2020), on adaption strategies in a regressing shoreline (Mjærum, 2022), or on approaches to social space including hinterland surroundings (Schülke, 2020). Comparative approaches to cultural transmission of technological tradition, e.g. regarding stone technology, can form the basis for theories on (coastal) mobility and social density (i.e. social closeness or distance; Berg-Hansen, 2017 and 2018).

Finally, the approaches use different terms to denominate the humans whose traces we study through the sites, such as population, group, community or society, and thus – consciously or unconsciously impart different concepts and perceptions of Mesolithic social life.

2.2. Studying population dynamics based on radiocarbon dates

In Norway, as elsewhere, radiocarbon dates are increasingly used as an exploratory tool to investigate change over time among foraging and farming societies (Kelly et al., 2013; Jørgensen, 2018; Arroyo-Kalin and Riris, 2021; Nielsen, 2021; Timpson et al., 2021). The method provides good opportunities to address questions of temporal change in human activity, but the use of radiocarbon dates is not without its drawbacks and there are several challenges to the "dates as data" approach (e.g. Rick, 1987; Williams, 2012; Carleton and Groucutt, 2020). The different methodological pitfalls have been addressed and the method is constantly being developed and improved (e.g. Crema and Shoda, 2021; Timpson et al., 2021; Crema, 2022). Important methodological concerns such as sample size, taphonomic loss, and the combination of sampling error and systematic measurement errors due to calibration or eyeballing of data are discussed elsewhere (e.g. Timpson et al., 2014; Carleton and Groucutt, 2020; Crema, 2022) and will not be addressed here.

An aspect that needs consideration is the premise of using dates as data to infer population dynamics. Originally, J. W. Rick (1987) proposed that the amount of waste that people left behind in a certain area at a certain time corresponds to the number of people. As pointed out by J. Freeman and colleagues (2018), we cannot assume that this is a direct and straightforward relationship. These authors instead propose that radiocarbon dates and the amount of available dateable material reflect variations in energy consumption in a given society at a given time. Importantly, and as discussed by M. Tallavaara and E. K. Jørgensen (2021), the summed radiocarbon probability distributions (SPDs) reflect long-term mean population dynamics and cannot account for short-time fluctuations in population size.

Parallel to the increase in number of excavated sites in south-eastern Norway, the amount of available radiocarbon dates has grown considerably since the early 2000s. Radiocarbon dates are now increasingly used to study long-term processes, e.g. population variation and cultural historical development, rather than just dating events (Jørgensen, 2018; Nielsen et al., 2019; Bergsvik et al., 2021). To date, only a few studies have used SPDs to investigate long-term population variation among Mesolithic marine foragers of south-eastern Norway (Solheim and Persson, 2018; Solheim, 2020; Nielsen, 2021). While S. V. Nielsen's paper aims to address migration of foragers into south-eastern Norway in the Late Mesolithic by studying population growth rates, S. Solheim and P. Persson's studies (2018) set out to investigate variations in population dynamics in the Oslo Fjord region by comparing the radiocarbon data with other proxies, such as site counts (Solheim and Persson 2018; Solheim, 2020).

An adjusted SPD based on S. Solheim's (2020) study of Mesolithic sites from the coastal region, is shown in figure 2. The SPD consists of 589 dates grouped in 150-year bins at site level fitted to a null model of exponential growth. The SPD demonstrates a long-term growth throughout the Mesolithic disrupted by shorter periods of growth and decline (fig. 2). No severe population crashes are identified. This leads to the conclusion that the population was relatively stable in the Mesolithic on the longer time scale. A possible explanation for this relative stability in population dynamics is an adaptation to the coastal region and continual access to abundant and varied resources (Fossum, 2020; Mjærum and Mansrud, 2020).

2.3. Settlement, choice of place and mobility in coastal areas

Three of the approaches deal in rather different ways with topics regarding human settlement in and inhabitation of coastal environments and hunter-gatherer mobility.

2.3.1. Settlement patterns and site location

M. Lake and P. E. Woodman (2003) proposed a tripartite division for the classification of visibility studies in archaeology, categorising them as either informal, statistical or humanistic. This framework offers a useful point of departure for the characterisation of inferential frameworks adopted by studies of settlement patterns and site location in Mesolithic Norway.

Informal inferences pertain to approaches that are not nested in an explicit and comprehensive theoretical or methodological framework. This type of approach has certainly dominated the study of settlement patterns in Norwegian Mesolithic archaeology. These studies have focused on the location of sites relative to geographic factors such as distance to fresh-water, natural harbours or resource patches, the degree of drainage or slope on the site locations, how sheltered these locations are with respect to wind and waves, to what degree they offer commanding views over the surrounding landscape, and whether they are oriented to receive sunlight throughout the day (e.g. Bjerck, 1989; Mikkelsen, 1989; Indrelid, 1994). However, little consideration is typically given to what variables are considered, discarded, found not to be relevant, or precisely where the suggested behavioural relevance of these variables stems from. Instead, their importance appears to be based on an underlying notion of universal relevance to hunter-gatherers and their economic basis (see Berg-Hansen, 2009, p. 37-66). While recent investigations often involve more sophis-

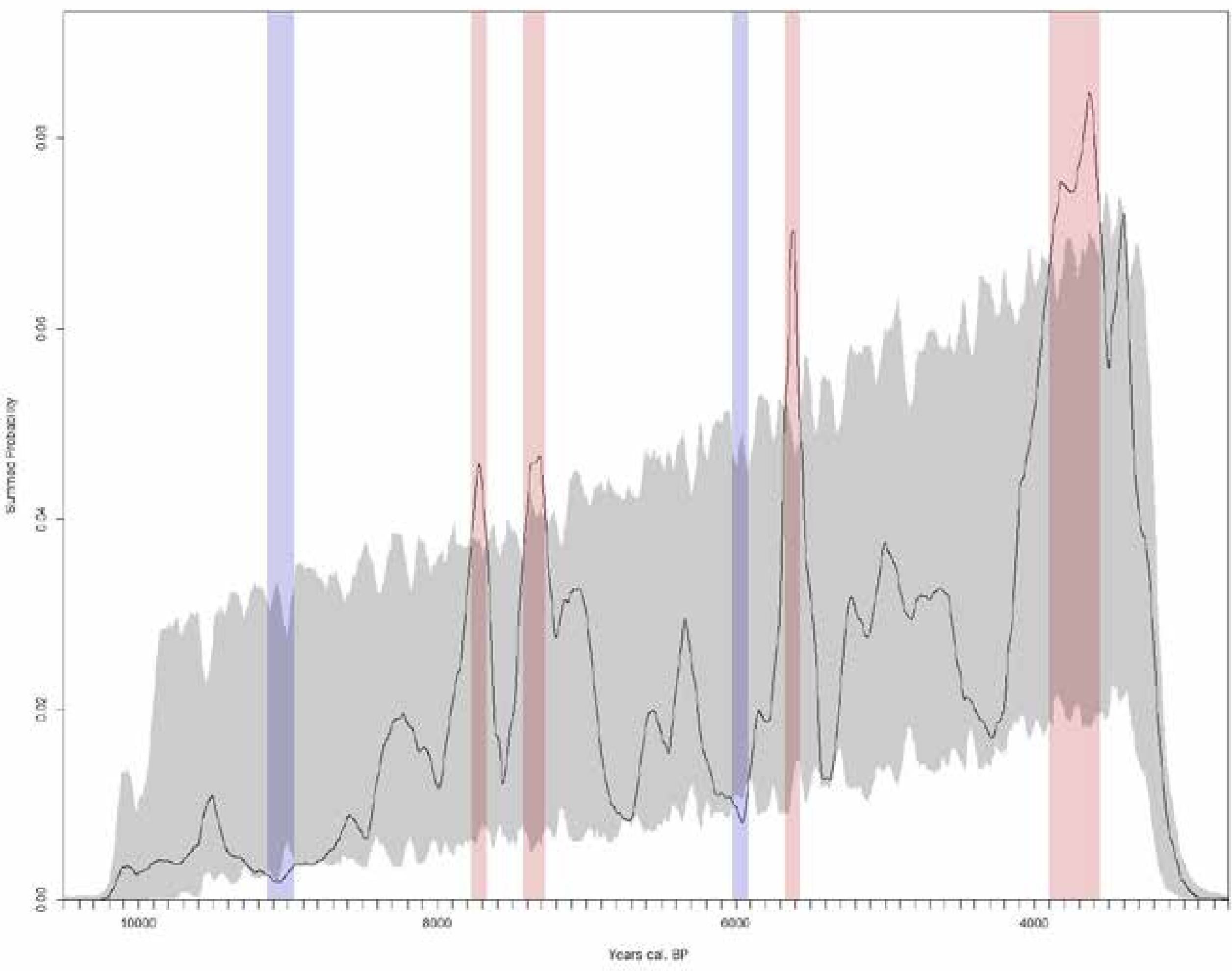

Fig. 2 – Summed probability distribution (SPD) of 589 dates from 167 Mesolithic sites in the coastal region of south-eastern Norway (dates = 589, sites = 167, bins = 172, simulations = 1000, p-value = 0.02398). Model produced using Rcarbon in Rstudio (Crema and Bevan, 2020). The blue bars demonstrate the negative deviations of the empirical SPD from the growth model, while the red bars show the positive deviations of the empirical SPD from the growth model. These indicate population decline or growth, respectively, within the marked time periods (years cal. BC; graph S. Solheim).

***Fig. 2** – Distribution la somme des probabilités (SPD) de 589 dates provenant de 167 sites mésolithiques de la région côtière du sud-est de la Norvège (dates = 589, sites = 167, bins = 172, simulations = 1000, valeur p = 0.02398). Modèle produit à l'aide de Rcarbon dans Rstudio (Crema et Bevan, 2020). Les barres bleues montrent les écarts négatifs du SPD empirique par rapport au modèle de croissance, tandis que les barres rouges montrent les écarts positifs du SPD empirique par rapport au modèle de croissance. Cela indique un déclin ou une croissance de la population au cours des périodes marquées (années cal. BC ; graphique S. Solheim).*

ticated treatment of the locational factors of interest (e.g. Nyland, 2012a; Breivik, 2014; Darmark et al., 2018; Fossum, 2020, p. 192), their underlying inferential frameworks tend to follow the same logic. In consequence, the issue one might take with these studies is that they offer no comprehensive theoretical justification for what variables were chosen – and by extension not chosen – nor a statistical evaluation of the significance of any detected patterns. Even if most sites in an area are located on islands, are southward facing, or are sheltered from winds, contending that this was of importance to past inhabitants arguably requires an additional step. This can be a statistical assessment to evaluate whether the observed patterns are likely the result of inhabitants actively choosing site locations relative to these variables, as opposed to simply a passive reflection of the landscape. Alternatively, and depending in part on one's disciplinary convictions, this can be achieved by means of a theoretical justification as to why these factors might have been of importance, even irrespective of any statistical tendencies. The relevance of the considered variables might be immediately and logically appealing, but without further justification is ultimately commonsensical and informal.

Statistical inference frameworks have seen some use in the study of Mesolithic settlement patterns in Norway (e.g. Bergsvik, 1995; Blankholm, 2018; Roalkvam, 2020). They can be considered with reference to the above cases by asking what the probability would be of finding the same settlement characteristics if the analysed sites were randomly distributed in the same landscape instead. Answering this question would allow for a statistical evaluation of the likelihood that the considered variables shaped the location of the sites under study.

In the study conducted by I. Roalkvam (2020) concerning coastal settlement patterns in south-eastern Norway, this involved drawing a random sample of control points representing assumed non-sites in the landscape surrounding the 462 sites that were analysed (fig. 3).

These random control points were constrained to avoid extremely steep areas where one can reasonably assume that occupation was not desirable, and areas that would not have been located on the coast at the same time as the archaeological sites. The following variables were subsequently measured for both the sites and non-sites: visibility, wind fetch, degree of southward orientation, variability in the surrounding shoreline displacement, whether they were situated on islands, the size of the islands, and finally the infiltration capacity of the sediments on which they were situated. The data were then statistically compared in an attempt to tell whether the site data could be separated from the random samples based on these variables. The findings indicate that an overview over immediate surroundings and shelter from larger expanses of open sea were the most important factors for choice of site location within the study area throughout the Mesolithic.

What sets studies such as this apart from those termed informal is that they employ a statistical framework to assess the relevance of any observed patterns by evaluat-

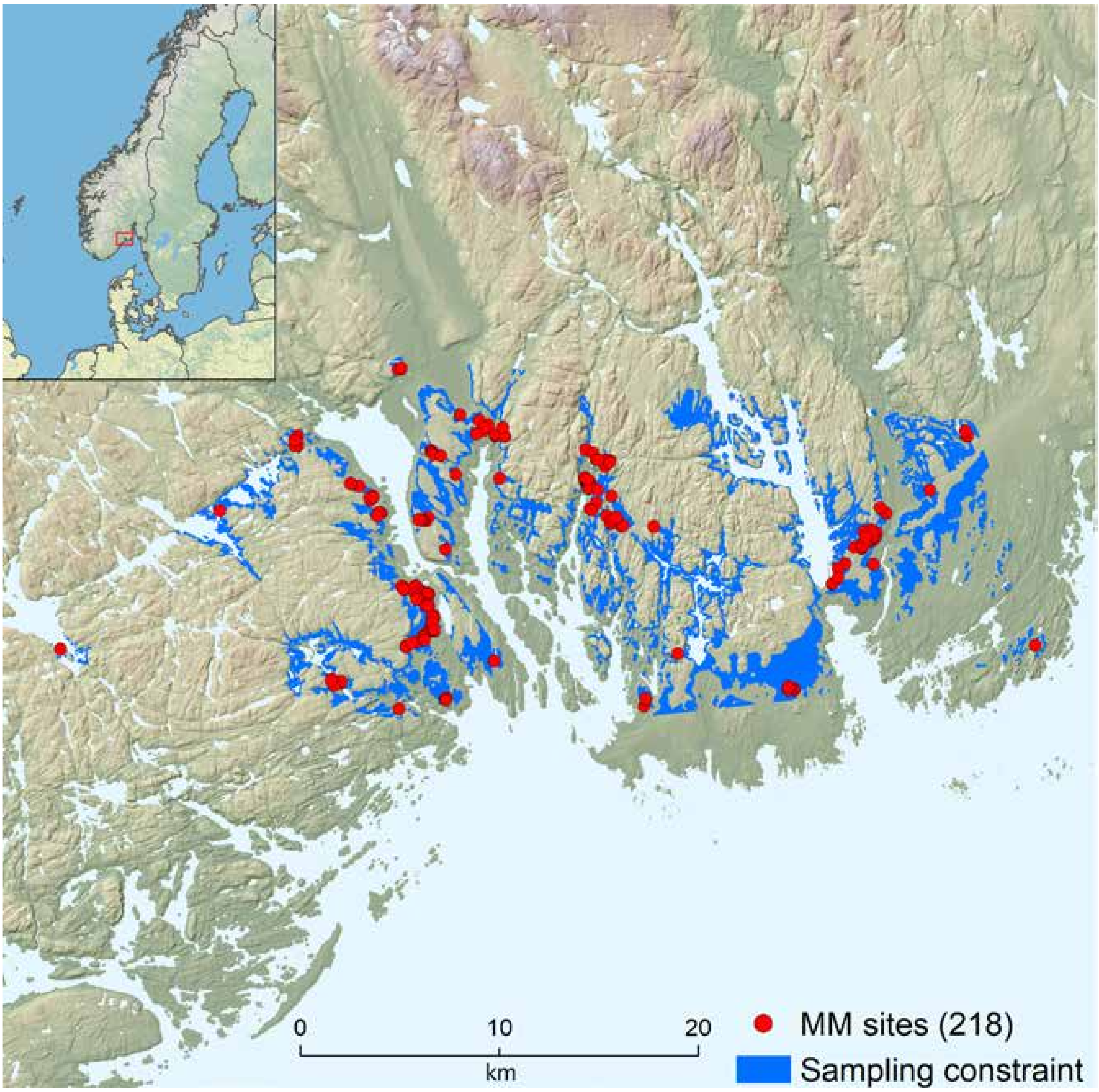

Fig. 3 – Illustration of one of the sampling constraints from which 1000 random points were generated and compared with the location of a subset of 218 sites that were given a shoreline date falling within the Middle Mesolithic (map I. Roalkvam).

Fig. 3 *– Illustration de l'un des cadres d'échantillonnage à partir duquel 1 000 points aléatoires ont été générés et comparés à l'emplacement de 218 sites. La datation des sites a été estimée par le modèle de rivage au Mésolithique moyen (carte I. Roalkvam).*

ing the degree to which these could be expected to have occurred by chance, given the characteristics of the surrounding landscape. This is especially pertinent for the study of coastal settlement patterns in Norway, where dramatic changes in the landscape due to sea-level change mean that not accounting for variation in the surrounding landscape makes it impossible to separate changes in settlement patterns due to natural processes from change due to active choices made by past inhabitants. However, the variables chosen for analysis in the statistical studies referenced here are arguably not given any comprehensive theoretical justification. One possible consequence of this could, therefore, be that the identified relevance of any given variable might in reality be caused by another, confounding, variable unless these are otherwise taken into account (e.g. Kohler and Parker, 1986, p. 415). One could for example envisage that an identified relevance of altitude for locational patterns might actually reflect a desire to situate sites relative to tree cover. In the study of I. Roalkvam (2020), for example, the apparent relevance of visibility for locational patterns might, in reality, be a reflection of a tendency to situate sites relative to natural harbours. Other limitations (see, for example, Kohler and Parker, 1986; Verhagen and Whitley, 2012) can arise from the dependency on quantification, which can lead to an over-representation of easily quantifiable environmental variables, as well as a dependency on adequate sample sizes to draw statistical inferences, which can result in an artificial aggregation of site data. While statistical approaches like this are not, therefore, without problems of their own, the framework does offer a clearer inferential framework that dictates when a result should be considered meaningful or not.

Humanistic analyses of settlement and habitation, which is to say studies that explicitly leverage a humanistically informed inferential strategy, are set apart from the studies mentioned so far in that the justification for how the material is approached is instead nested in an understanding of how humans interact with, respond to and/or perceive and assign meaning to the environments/surroundings that they inhabit, and how this in turn influences and is influenced by their interaction with and movement in these landscapes. The following two approaches can be assigned to this category.

2.3.2. Adaptation and choice of place in changing environments

Present-day global warming has enormous consequences both for individuals and on a larger scale. However, environmental changes also affected people's everyday lives in the past. In a new study, contemporary adaptation strategies to shore level changes were applied to gain a better understanding of Mesolithic coastal adaption, both on a site level and on a regional scale (Mjærum, 2022). The author of this study discusses four main adaption strategies to such changes; to accommodate, relocate, protect or not respond to the changing environment (Diaz, 2016; Oppenheimer et al., 2019; here: fig. 4a).

Over a period of 2500 years (c. 7500-5000 cal. BC), a bountiful system of straits existed in the inner Oslo Fjord area. The large and intensively used settlement area of Havsjødalen was centrally positioned in this fjord system. Extensive excavations in 2015 offered an opportunity to gain detailed information on the correlation between radiocarbon dated and typologically dated sites, shore level displacements and local landscape changes (Mjærum, 2022). Supported by studies in other parts of the region (e.g. Breivik et al., 2018; Fossum, 2020; Solheim, 2020), it is argued that some settlements were systematically adapted by moving the activity to lower terrain, in line with the regressing shores. In most other cases, activity was relocated when the distance to the shores increased. This result confirms the widespread assumption that a large part of the settlements were in fact closely linked to former seashores and that, consequently, many of them can be precisely dated based on shore level displacement curves and their height above present sea level (see however Berg-Hansen et al., this volume, for a discussion of the approach).

The latter study also discusses adaption strategies on a regional scale, related to environmental changes in the course of the closing of a sound due to land-upheaval processes. Based on the conclusion that shore level datings are relatively precise in most cases, 529 sites positioned between 195 and 18 m above present sea level were included in a study of regional developments before, during and after the 'sound phase' in the inner Oslo Fjord (fig. 4b). These site counts point towards a significant increase in the number of sites in the 'sound phase', and consequently a larger population (Manninen et al., 2018; Solheim and Persson, 2018; Fossum, 2020; Jørgensen et al., 2020). However, when sea level changes closed the fjord system around 5000 cal. BC, an ecological crisis occurred. The society does not seem to have responded adequately. Instead of decreasing activity in the area, site counts strongly indicate that a main part of the population chose to stay. The subsequent sharp drop in the number of sites is interpreted as a direct consequence of hundreds of years of maladaptation, which resulted in a regional population collapse (fig. 4b).

The region's population dynamics reveal some of the larger-scale problems that can occur when societies face environmental crises that demand great societal changes. In such a way, the situation is similar to what humanity faces today: humans adapt well on a small scale but struggle to take action when they meet environmental crises of large proportions.

2.3.3. Moving and dwelling in landscapes

How Mesolithic people who lived in the coastal zone might have dwelled in, moved in and perceived their surroundings is the subject of a number of recent studies on the region. These explore human encounters and experience, including the physical, social and mental. They understand prehistoric humans as embedded in a world with a social and cosmological dimension, including

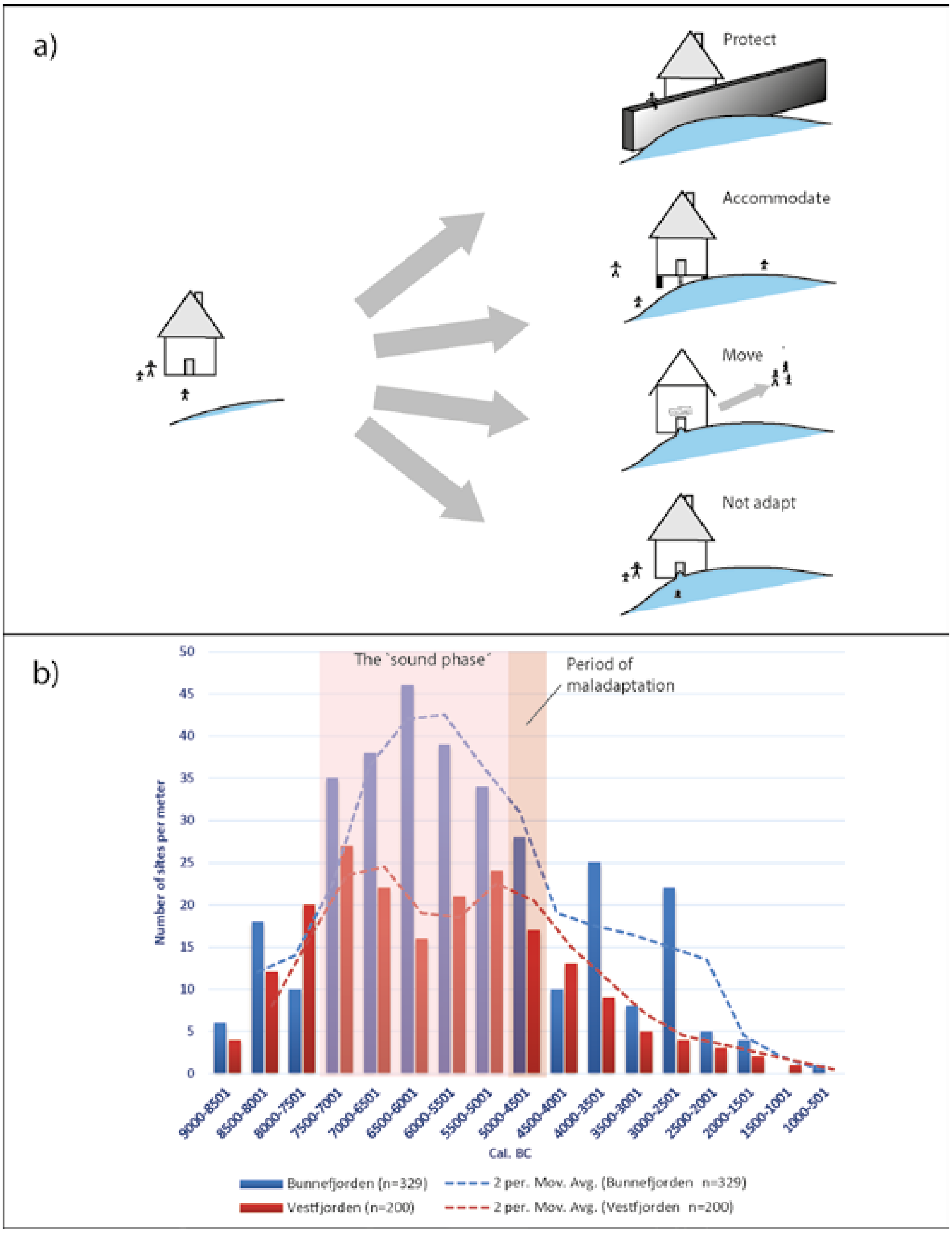

Fig. 4 – a) In general, people choose one or more of four strategies when they adapt to changing sea levels: they protect, they accommodate, they leave the area, or they continue their activities without any form of adaptation. b) The bar chart displays the number of sites in Bunnefjorden and the nearby Vestfjorden (both parts of the inner Oslo fjord) before, during and after the 'sound phase', distributed in 500-year intervals. Site counts show a significant increase in population during the time when the sound still was open (the 'sound phase'), followed by a period of maladaptation and population collapse after the sound was closed due to land upheaval. Vestfjorden went through less dramatic landscape changes during the Mesolithic, which probably explain the more stable population in this region. The dashed lines represent the changes in form of two period moving averages (2 per. Mov. Avg. ; illustration and graph A. Mjærum).

***Fig. 4** – a) En général lorsqu'ils s'adaptent à la modification du niveau de la mer, les individus choisissent une ou plusieurs des quatre stratégies suivantes : ils se protègent, ils s'adaptent, ils quittent la région ou ils poursuivent leurs activités sans aucune forme d'adaptation. b) Le diagramme à barres montre le nombre de sites dans le Bunnefjorden et dans le Vestfjorden voisin (deux parties du fjord intérieur d'Oslo) avant, pendant et après la « phase du détroit », distribué en intervalles de 500 ans. Le décompte des sites montre une augmentation significative de la population pendant la période où le détroit était encore ouvert (« phase du détroit »), suivie d'une période d'inadaptation, puis d'un effondrement de la population après la fermeture du détroit, en raison d'un rebond isostatique. Vestfjorden a connu des changements de paysage moins drastiques pendant le Mésolithique, ce qui explique probablement la population plus stable dans cette région. Les lignes pointillées présentent les évolutions sous forme de moyennes mobiles sur deux périodes (2 per. Mov. Avg.; illustration et graphique A. Mjærum).*

both the animate and inanimate, which is to say human beings, animals, plants, water, land formations and so on. Using specific material phenomena as a starting point for analysis, these studies aim to lift the material into a human dimension by applying, for example, theories of phenomenology (e.g. M. Merleau-Ponty), the concept of the taskscape (Ingold, 1993) or by using ethno-archaeological examples. Topics that have been discussed from such perspectives include: the encounter of the first Early Mesolithic pioneers, who arrived by boat, with the unknown environment (Fuglestvedt, 2009); the recurrent quarrying of lithic raw materials at rock formations both at the coast and in the mountains, which can be seen as persistent places (Nyland, 2016 and 2020); the handling and perception of abandoned places of settlement (Mansrud and Eymundsson, 2016); or the discussion of cosmological dimensions of the coastal zone (Bergsvik, 2009; Mansrud, 2017a and 2017b). Such studies operate within specific theoretical frames, often on the basis of fewer finds/find contexts within larger chronological and spatial frames, which are not statistically relevant but which are noticeable from a comparative perspective. They can contribute to changing the traditional perception of e.g. a mainly economic explanation of human use of the coastal zone in the Mesolithic.

A. Schülke (2020) combines the aspect of human movement and experience with an empiric approach, which as a starting point analyses site location and its possible meaning. The aim is to better understand hunter-gatherer social space by integrating the land in between sites into the analysis, including the topography and communication potential of the respective landscape space. Her study puts the use of the coastal hinterland through Mesolithic people more explicitly on the agenda. The above-mentioned focus on Mesolithic coastal sites in our region has, to a certain extent, biased our idea of hunter-gatherer communities' use of the environment beyond simply the coastal strip, which might have masked the relevance of the hinterland for Mesolithic coastal communities. While the hunter-gatherer use of the mountain areas and the waterways leading into the mountains is well known, the areas in-between the coast, the mountains and the large waterways, namely the woods in the coastal hinterland, have received very little attention (but see the recent Wiekowska-Lüth et al., 2018; Mjærum, 2019).

A. Schülke's (2020) study (further developed in Schülke, forthcoming) argues that hitherto disregarded 14C dates found in certain contexts in hearths on typologically/technologically dated Early and Middle Mesolithic coastal settlement sites, which date from later in the Mesolithic than the artefact material indicate a use of these earlier coastal site locations after they had become hinterland ones in later Mesolithic times. GIS reconstruction of the topography of these sites at the time of the later Mesolithic radiocarbon dates, using the shoreline model, revealed that most of these sites exhibit a similar topographic placement: in elevated positions in the coastal hinterland, at or very close to an excellent viewpoint overlooking a valley, a conjunction of valleys or a watercourse. The combination of later, but still Mesolithic, dates from a secure context and the similar topographic positioning of the locations of the hearths greatly strengthens the hypothesis that the locations of the earlier coastal sites were reused in later times. By this time, they were located strategically well at observation spots overlooking valleys and watercourses in the hinterland (figure 5 shows one example; for a list of other relevant sites, their placement and datings see Schülke, 2020 and Schülke, forthcoming). The identification of the lighting of fire in hearths at such strategic locations with good overviews stresses the importance of the hinterland for coastal hunter-gatherer communities. They used these areas for resource acquisition, movement and as a social arena, not least to observe the surroundings including humans and animals. Such evidence also raises the question of whether these places were known or recognised as specific ancient (= former coastal) places, e.g. because lithic scatters or even existing fireplaces were identified as former human occupation. They might have had important significance as ancient places or anchor points in the world of these hunter-gatherers.

A. Schülke's (2020) approach is based on sites that exhibit similar features (late 14C dates, type of structures, topography). That the locations had good views when they were used in later times, was determined through visual map analysis and experience in the field. The study's potential to help us understand hinterland use could be further enhanced by integrating this approach into a broader topographic analysis by using a GIS-based analysis of not only the views from the sites in question but from the region as a whole to perform viewshed analysis. This would compare, for example, places with good views but no signs of human activity with those where evidence of such activity has been found.

2.4. Social networks and communication: technology as tradition

The social structure and organisation of Mesolithic coastal societies has been a central issue in Norwegian archaeology, mainly concentrating on settlement site variation and dwelling structures, and economic adaption and organisation, while purely typological studies are also common (e.g. Nærøy, 2000; Bjerck, 2008 and 2009; Fuglestvedt, 2009; Glørstad, 2010; Bergsvik et al., 2016; Fretheim, 2017; Darmark et al., 2018; Viken, 2018). Recently, focus has been directed towards the roles of tradition, social networks and communication in such societies, where the coast plays a decisive role. In particular, *chaîne opératoire*-based approaches to technological studies have provided new perspectives on this topic, offering a potential for deeper insights into prehistoric social processes compared with typologically based studies (e.g. Apel, 2001; Sørensen, 2006; Dugstad, 2010; Eigeland, 2015; Damlien, 2016; Berg-Hansen, 2017 and 2018; Mansrud, 2017b). Building on theory from sociology and pedagogy, topics such as mobility and social

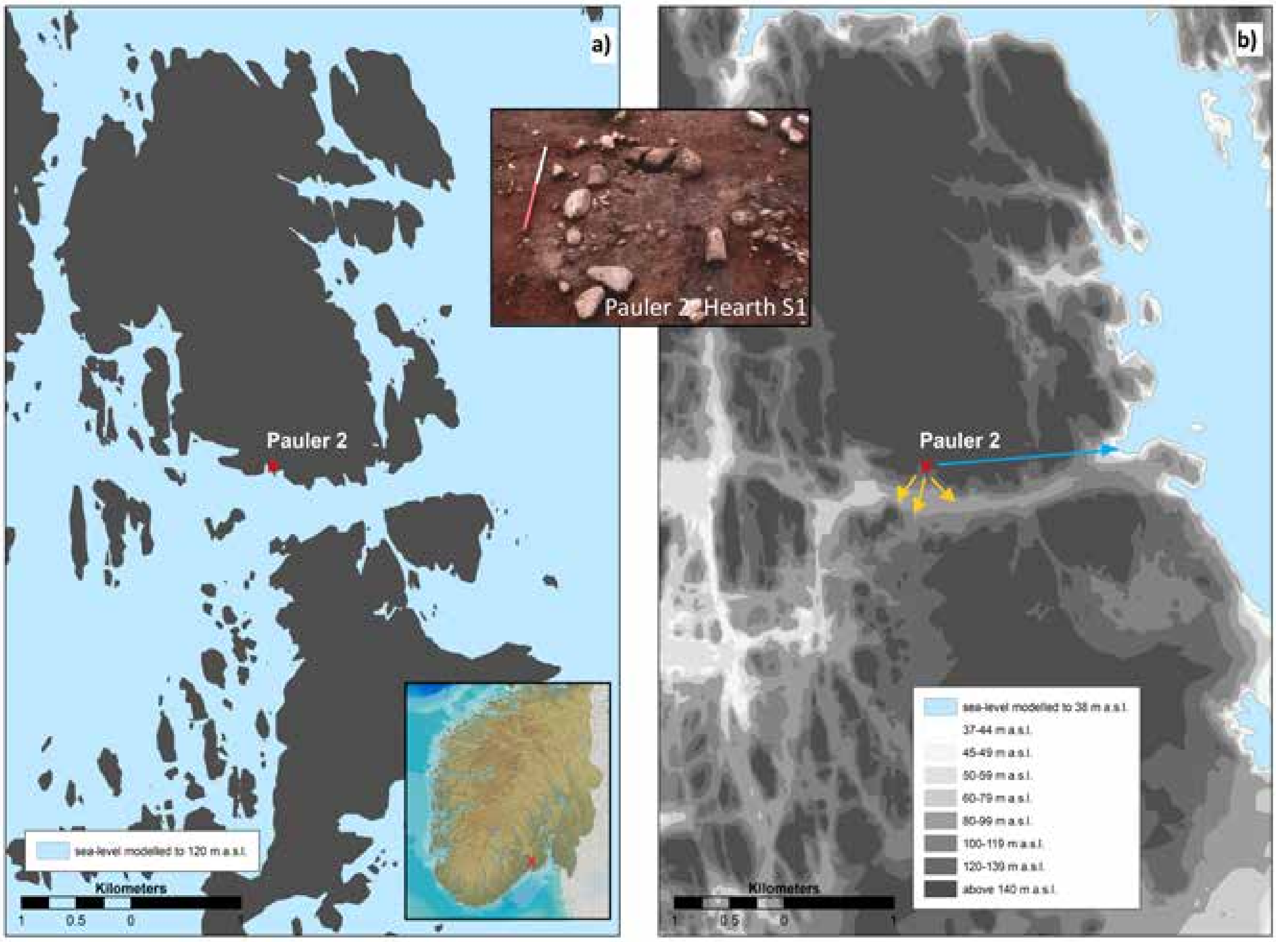

Fig. 5 – Example of the location of an Early Mesolithic coastal site (a) that was most likely reused in the Late Mesolithic after it had become a hinterland site overlooking a valley (b). The site of Pauler 2 was frequented in the Early Mesolithic period (9150-8850 cal. BC) according to the typology/technology of 3 708 lithic artefacts (Nyland, 2012b), at a time when the site was placed in a sheltered bay at the southern coast of an island (see a, to the left). Two 14C dates (on charred hazelnut: Beta-234403 6910 ± 40 BP, 5880-5720 cal. BC and on charcoal: Beta-234404 6990 ± 40, 5980-5720 cal. BC) from hearth S1 located on the site suggest that the site was reused in the Late Mesolithic, at a time when the former coastal site was located around 2 km from the coast and overlooking a valley (see b, to the right; Schülke, 2020; illustration A. Schülke based on a landscape model by G. Steinskog, MCH, UiO and on the photograph of hearth S1 by A. Nyland for MCH, UiO; Nyland, 2012b).

***Fig. 5** – Exemple d'un site côtier du Mésolithique ancien (a), qui a très probablement été réutilisé au Mésolithique récent après s'être transformé en site d'arrière-pays surplombant une vallée (b). Le site de Pauler 2 a été fréquenté au Mésolithique ancien (9150-8850 cal. BC), selon la typo-technologie des 3 708 artefacts lithiques (Nyland, 2012b), à une époque où il était situé dans une baie abritée, sur la côte sud d'une île (voir a, à gauche). Deux dates 14C (sur noisette carbonisée : Beta-234403 6910 ± 40 BP, 5880-5720 cal. BC, et sur charbon de bois : Beta-234404 6990 ± 40, 5980-5720 cal. BC) provenant du foyer S1 suggèrent que le site a été réutilisé au Mésolithique final, à une époque où le rivage était à environ 2 km et surplombait une vallée (voir b, à droite ; Schülke, 2020 ; illustration A. Schülke, d'après un modèle de paysage de G. Steinskog, MCH, UiO, et d'après la photo du foyer S1 par A. Nyland, MCH, UiO ; Nyland 2012b).*

organisation have been discussed within this approach. In particular, combinations of detailed dynamic-technological studies and attribute analyses offer great potential to clarify these issues through the mapping of behavioural patterns and handicraft traditions on various levels. From such empirical investigations, it is possible to study the actions and choices of Mesolithic people. In combining the identification of technological traditions with theories of social knowledge transmission and societal density (Mauss, 1973 [1935]; Boyd and Richerson, 1985; Cavalli-Sforza, 1986; Guglielmino et al., 1995; Durkheim, 1989 [1893]), we are not only able to discuss individual actions, but also the structure and social organisation within a society as well as the level of communication within and between societies. We can thereby connect the level of agency and small-scale short-term events with the societal level and large-scale long-term sociocultural processes, enabling the understanding of local and regional developments in a larger social frame (Berg-Hansen 2017 and 2018; Damlien et al., 2018; Berg-Hansen et al., 2019a and 2019 b). This provides the opportunity to study the way of life in specific geographic and historical landscapes from an overall social perspective.

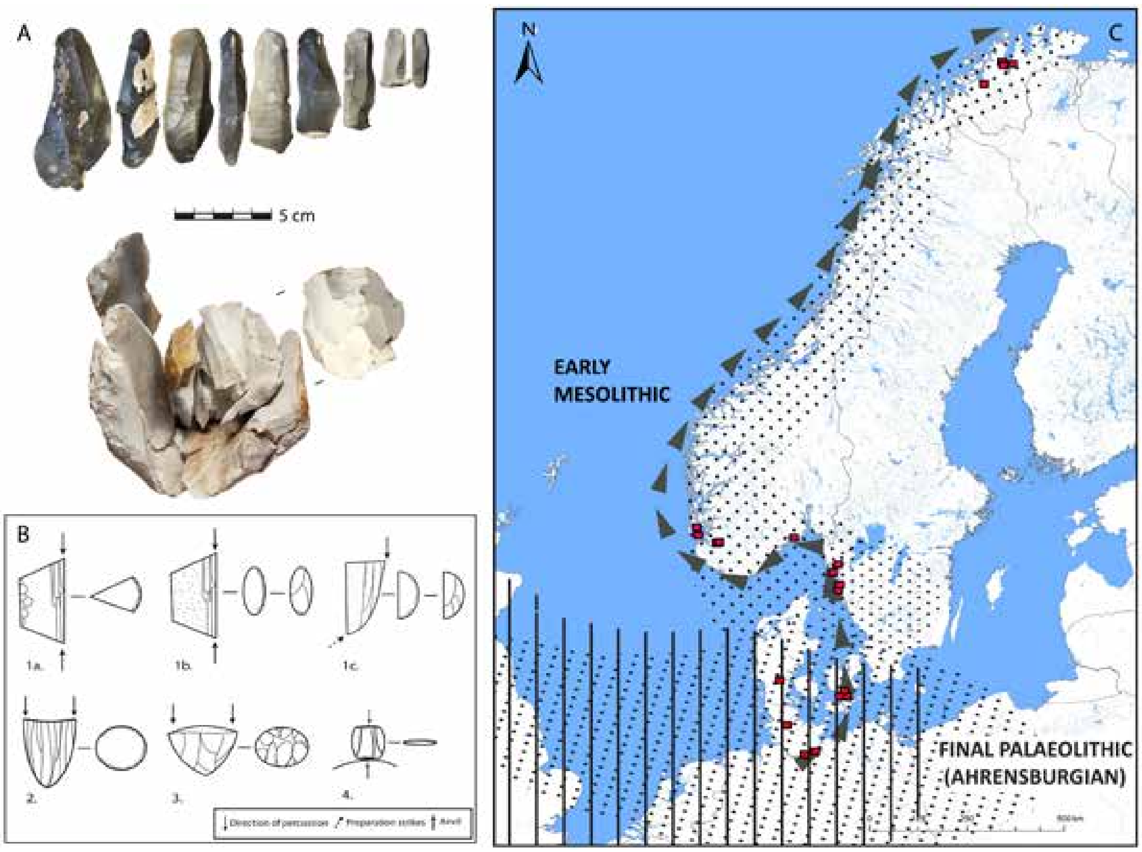

Fig. 6 – A detailed study of blade technology from the period 10900-8300 cal. BC in north-western Europe shows that the same methods and techniques were used for production of blade blanks and tools (A and B). This demonstrates that a common tradition of blank and tool production was maintained throughout the area for more than two and a half thousand years, during which there were large environmental changes and the first immigration to the Scandinavian Peninsula from the south took place, following the coast. It also implicates a continuity of the population from the Final Palaeolithic to the Early Mesolithic. The study reveals a society with conservative knowledge transmission mechanisms and technological tradition, but also regular contact within the area and well organised communication in which boats must have played a decisive role (Berg-Hansen, 2017 and 2018). A shows an example from the Early Mesolithic south-Norwegian site Pauler 2 of typical blades made by direct percussion, and a refitting of a sequence of core preparation and blade production from a one-sided single-platform core. B presents the common production methods illustrated by schematic drawings of the four different core types that occur (1a-c: variations of one-sided dual- and single-platform cores; 2: sub-circular production on conical core with smooth, concave platform; 3: sub-circular production on sub-conical core with prepared, convex platform; 4: bipolar production on anvil). Method 1a-c and 2 dominate the Final Palaeolithic Ahrensburgian technology in the south, continuing throughout the Early Mesolithic and spreading with the pioneer settlement of the Scandinavian Peninsula. Method 3 occurs in the Early Mesolithic in the whole area, while method 4 is found in assemblages from the Scandinavian Peninsula. C illustrates the distribution of the Final Palaeolithic (hatched) and Early Mesolithic (dotted) settlement, respectively. Red squares mark the location of the 20 excavated open-air settlement sites included in the study. The arrowed line indicates the direction of the spread of the settlement in the Early Mesolithic (illustration I. M. Berg-Hansen).

***Fig. 6** – Une étude technologique détaillée des lames durant la période 10900-8300 cal. BC en Europe du Nord-Ouest montre que les mêmes méthodes et techniques étaient utilisées pour la production d'ébauches de lames et d'outils (A et B). Cela indique qu'une tradition commune de production d'ébauches et d'outils s'est maintenue dans toute la région pendant plus de deux mille cinq cents ans, alors que d'importants changements environnementaux se sont produits et que la première immigration vers la péninsule scandinave en provenance du sud a eu lieu, en suivant la côte (C). Cela implique également une continuité de la population du Paléolithique final au Mésolithique ancien. L'étude révèle une société avec des mécanismes de transmission des connaissances et une tradition technologique conservatrice, mais aussi des contacts réguliers dans la région et une communication bien organisée dans laquelle le bateau a dû jouer un rôle décisif (Berg-Hansen, 2017 et 2018). A) Mésolithique ancien du sud de la Norvège, Pauler 2 : exemples de lames typiques fabriquées par percussion directe, ainsi qu'un réaménagement d'une séquence de préparation d'un nucleus unipolaire à table unique destiné à une production laminaire. B) Illustration schématique des méthodes de production des quatre types de nucleus les plus courants (1a-c : exemple de nucleus à double et à simple plan de frappe ; 2 : production sub-circulaire sur nucleus conique, avec plan de frappe lisse et concave ; 3 : production sub-circulaire sur nucleus sub-conique, avec plan de frappe aménagé convexe ; 4 : production bipolaire sur enclume). Les méthodes 1a-c et 2 sont dominantes dans la technologie ahrensbourgienne du Paléolithique final dans le sud et se poursuivent tout au long du Mésolithique ancien en se propageant avec le peuplement pionnier de la péninsule scandinave. La méthode 3 est présente au Mésolithique ancien dans l'ensemble de la région, tandis que la méthode 4 se retrouve dans les assemblages de la péninsule scandinave. C) Distribution des peuplements du Paléolithique final (hachuré) et du Mésolithique ancien (en pointillés). Les carrés rouges marquent l'emplacement des 20 sites de plein air fouillés inclus dans l'étude, et la ligne fléchée indique la direction de la propagation du peuplement au Mésolithique ancien (illustration I. M. Berg-Hansen).*

In general, lithic technology assemblages are better suited than others for comparative studies on both regional and cross-regional scales, due to poor preservation of organic materials. The potential drawback of only focusing on one technology, however, is the lack of opportunities to compare different technologies, possibly creating biased data. Nevertheless, as with all other technologies, lithic technology is a part of the cultural systems of any Stone Age society, being expressed through and carried by traditional technological actions and techniques.

Our example of such an approach focuses on the pioneer settlement on the Scandinavian Peninsula, including south-east Norway, after the Ice Age (Berg-Hansen, 2017 and 2018). In the Early Mesolithic (9300-8300 cal. BC) after the retreat of the Fennoscandian Ice Sheet, the coast of the Scandinavian Peninsula was rapidly settled from the south (Bjerck, 2009; Bang-Andersen, 2012; Berg-Hansen, 2017). A comparative analysis of 20 lithic assemblages from excavated sites in north-west Europe, dated to the Final Palaeolithic and Early Mesolithic (10900-8300 cal. BC), sheds light on the social background and advancement of this settlement (fig. 6). The similarities in lithic craft traditions demonstrate the level of social density, i.e. the frequency and quality of communication and the degree of interconnection in social networks. The results show that coastal mobility and social connectivity played a central role in the societal development of the pioneer settlement of the Scandinavian Peninsula.

The study documents striking similarities in the methods and techniques for lithic blade blank production across both a very long time span and a huge geographical area. These similarities demonstrate a conservative tradition of lithic tool production that would require a well-connected society to support it. Assuming the population of hunter-gatherers was small implies there were specific organisational traits, such as small social groups managing the main traditional knowledge as well as regular contact and communication between these groups for the vital exchange and maintenance of the technological traditions and knowledge (Berg-Hansen, 2017 and 2018).

This result supports previous arguments for the significance of mobility and efficient travelling. On the Scandinavian Peninsula, the Early Mesolithic sites are mainly found along the coast, and many are located on islands in an almost continuous archipelago (Nyland, 2012a; Svendsen, 2018). Although walking on ice in the wintertime, or possibly travelling by sledge, would have made it possible to hunt on the ice and reach islands close to the mainland (Bjerck, 2021), mastering advanced boat technology would have been necessary to reach islands far out at sea and to live along this coast in the summer months (Berg-Hansen, 2017; Gjerde, 2021). Boats must have been part of daily life, making transportation of people, equipment and raw materials much easier than moving on dry land. The significance of boat travel and transportation has previously been emphasised, and it is pointed out that boats not only played an important role in the exploitation of marine resources, but also influenced people's perception of their world and worked as a structuring element for the social organisation (Bjerck, 2008 and 2009; Svendsen, 2018; Gjerde, 2021). Additionally, efficient travel along the coast was also a necessity for maintaining common knowledge and tradition through cultural transmission during social interaction in both individual meetings and larger gatherings, thus sustaining the community itself.

3. DISCUSSION – LANDSCAPES OF PRACTICE

The five approaches presented above explore different aspects of living in coastal areas in the Oslo Fjord region in the Mesolithic, operating against the backdrop of diverse research traditions and methods. In the following discussion, we would like to reflect on the ways they could complement each other and how a more active interconnection among them could be useful for developing more holistic and reflective research on coastal hunter-fisher-gatherers. This can activate the potential of each specific approach in new ways and might also help to alleviate the limitations inherent to each of them. We would like to highlight the following topics, which are important for understanding Mesolithic life, and which all of these approaches directly or indirectly touch upon 1. Time and temporality, 2. Site and settlement, 3. Social life and networks, 4. Mobility.

These four thematic areas are closely intertwined, exploring how Mesolithic people lived in their respective social and environmental surroundings through studies on different scales (small scale – large scale, e.g. from site to region) and within different time spans (looking at a certain time/moment/event, or over a certain period).

3.1. Time and temporality

Time and chronology is one of the structuring principles in archaeology. The Mesolithic period in south-eastern Norway (c. 9300-3900 cal. BC) encompasses more than 4000 years. Even though the number of archaeologically investigated sites is relatively high (with around 250 in the last two decades), this is still too few to gain fuller descriptions of Mesolithic living and social organisation. In our interpretations, we are dependent on binding together archaeologically traceable prehistoric activity and events, which are spread in time and space. The identification of cultural/technological and temporal sub-phases (e.g. the Early, Middle and Late Mesolithic) can help to bind observations together with a narrative, but we are still faced with serious challenges regarding time and temporality. Amongst these are insights, such as that a substantial agglomeration of artefacts might represent a knapping sequence that took surprisingly little time to produce. However, the question remains of how to understand the individual and their lifetime without having substantial traces of actual Mesolithic humans and how to grasp the archaeological void between sites and the events/activities that they represent. Combining approaches that work on different scales can help us to reflect on these challenges, and thus to integrate them into research. While large-scale analysis in time and/or space on e.g. energy/population development (S. Solheim), the development of the placement of settlements within a region (A. Mjærum), or on lithic technology (I. M. Berg-Hansen) show general trends, smaller-scale investigations give more detailed insights into single events such as lithic artefact production (I. M. Berg-Hansen) or the reuse of ancient places by lighting a fire (A. Schülke). The analysis of places and their continuous or repeated use can further reveal deep-time use of sites or areas (A. Schülke, A. Mjærum). Taking our approaches together we can better discuss diverse levels of temporality: cultural time, human lifetime, time of an event, etc.

3.2. Site and settlement

The site is the starting point for most archaeological interpretation (see also Berg-Hansen et al., this volume). From such a spot, which is marked 'positively' through archaeological finds, the different interpretations unfold, encompassing many different levels. Sites are interpreted as important places in Mesolithic landscapes and thus people's lives, can be interpreted and explained in manifold ways. Integrating diverse perspectives can lead to more holistic and reflective insights on the Mesolithic meaning and function of these materially marked places in their wider landscape context. These perspectives include – from statistical and thus more general points of view – the choice of topographic/geographic qualities (I. Roalkvam), or sites as containers of 'energy' in the form of radiocarbon samples and dates or as relative numbers (site counts; S. Solheim). Furthermore, looking at the qualities of the sites (materially marked places of stay) can indicate the importance of the concrete environmental conditions in the form of biomass/ecology in the decision of people to stay at a place (A. Mjærum). Sites' (shifting) topographic conditions can help us to understand the human use of places in different situations, in different social and economic contexts, indicating the overlap of tasks and meanings of a specific location (A. Schülke). The location of a site can be an arena for both agency and cultural transmission of tradition (I. M. Berg-Hansen), through which intra-site analysis, events, practices, and areas of (different) social activity can be explored.

We observe that the notions of site and settlement are often used as a kind of substitute for human groups rather than as material evidence of diverse human activities, which occupy places along the coast in a more general mode of 'settling'. However, the understanding of what settling, or dwelling is, should be explored more critically comparing and combining our approaches. What does it mean to 'settle' in a social sense, and from diverse hunter-fisher-gatherer perspectives? In future, we need to further stress the differences in types of material expressions on the sites to understand the practices, life ways and events that have happened, and also to ask to what extent the notion of 'settling' is actually appropriate, which leads us to the next point.

3.3. Social life and networks

How do we actually understand and envision hunter-fisher-gatherer social life? Comparing our approaches we find an array of perceptions: resource and food management are seen as a central driving force, and a very good knowledge and reading of environments is seen as crucial. Social life is thus highly connected to adaption to the environment and to the ability to cope or not to cope with crisis (A. Mjærum). Social life is on a more general level and rather indirectly represented in population growth or decline, which is archaeologically approached through energy expressed in radiocarbon dates (S. Solheim). Studies of settlement patterns address social life indirectly and not explicitly, as represented in the placement of site locations along the coast (I. Roalkvam). For example, the topic of view(shed) analysis has a huge potential to further explore social communication and visual contact. When understanding sites in their wider social and environmental context and from an experiential perspective, the exploration of the social is closer to the (possible) perception of the individual, which of course is always daring from a modern archaeologist's perspective. It can, however, bring in aspects of social life as contextual, with diverse temporalities, and always taking place within and in contrast with the social and environmental surroundings, the animate and the inanimate (A. Schülke). Putting the communicating, moving, cautious and curious individual or group on the agenda is necessary so as to include the human perspective in studies of Mesolithic social life, but needs to be constantly challenged. Another way of bringing in individuals, groups and, not least, societies is to study social life through technology, which can enable us to grasp aspects such as learning, copying, communicating, socially organising, networking and bridging or creating distances (I. M. Berg-Hansen).

What we are presently lacking, and what we could integrate more purposefully into our interpretations, are studies of how hunter-gatherer groups actually live, work, move and are social together in their respective surroundings, including the cosmological perspective. In our region there is no evidence of and thus no records from recent hunter-fisher-gatherers. Even though ethnographic studies have been a part of Norwegian Stone Age Archaeology for a long time (e.g. Gjessing, 1944 and 1977 with further refs.), an enhanced focus on ethnographic and ethnoarchaeological work is much needed in our region. Since the 1980s, ethnological records (Binford, 1980; Grøn et al., 2008; Kelly, 2013) have been applied to discuss site formation processes (e.g. Boaz, 1998) and settlement systems for the Middle and Late Mesolithic (e.g. Mjærum, 2019). In more recent years, ethnographical perspectives have been most commonly applied in studies of the region's Early Mesolithic pioneers. Analogies from both the Arctic and the southernmost part of America (Tierra del Fuego) have been used in studies of the process of colonisation, social organisation, economy, and technology (Bjerck, 2009; Glørstad, 2013; Fretheim et al., 2016). They have also been more generally applied in studies on human-animal relations, especially as related to hunting practices (e.g. Fuglestvedt, 2009 and 2018). However, there is a need for in-depth analyses that target a more holistic and deeper understanding of the more complex societies in the later part of the Mesolithic in this region. These should include not only isolated aspects of hunter-gatherer studies such as settlement or hunting, but also the complexity and various aspects of the living worlds and networks of these communities with each other and with and as part of environments, which have important cosmological dimensions.

3.4. Mobility

A central question in hunter-gatherer studies is the extent and characteristics of their mobility patterns. Through our approaches, we touch on a number of relevant aspects. These include small-scale mobility through time with a relocation of settlements following the shoreline, making a novel focus on the people who relocate the sites (A. Mjærum) rather than on the more frequently used abstract notions of sites that 'followed' the shoreline. This latter approach presupposes that the people who used the sites were familiar with, and very bound to, specific regions. Furthermore, settlement patterns that study regional developments might indicate long-term stability (I. Roalkvam), as do to some extent the continuities in population development according to radiocarbon dates (S. Solheim). However, other studies pinpoint long-distance mobility, including pioneering along the coast (I. M. Berg-Hansen) and daily/regular mobility or observation/scouting into the woods beyond the coast, binding coast and hinterland together (A. Schülke).

Thus, there is the view of population and settlement as representing a kind of continuous organism, but at the same time, there are observations that lead to the suggestion of different types of human mobility on different scales, both linear in time and more circular/recurring, intertwined and adjusted to the animate and inanimate surroundings. Narratives of more experiential aspects, such as crossing the woods and visiting hinterland sites, would gain from e.g. corrections from statistical analysis of geographic factors. Furthermore, the more generalising terms under which the latter work would gain from including variables encompass more experiential aspects of movement and change – in a contemporary or a diachronic perspective – most importantly including more targeted in-depth ethnographic studies of mobility in hunter-fisher-gatherer communities.

CONCLUSION

In the light of the above, possible future avenues for exploring hunter-gatherer living, settling, mobility and economy in the coastal areas of the study region should include the following.

- To activate the volume (the mere number) of the archaeological sites and material, together with the diversity of long-term development of varied and compartmentalised coastal areas, against the backdrop of geological data, in order to perform large- and small-scale analyses.
- To challenge the rather static beach model by developing more nuanced interpretative frameworks to include a wider spatial/landscape perspective.
- To understand the diversity of social activity that is embedded in the ambiguous site material and to include it in an analysis of practices along and beyond the coast.
- To broaden perspectives on humans in their environment (from sites to social life), as the lack of organic material hampers studies of human-environment relations and ritual (related to e.g. mortuary practice, economy, etc.), by including more purposeful ethnographic and ethnoarchaeological frameworks.
- To reflect on the respective frames of interpretation applied in a study, in terms of theory and methodology, and their limitations and possibilities. We need to reflect on how the terminology that we use actually shapes the narrative that we develop, e.g. in terms of how we address Mesolithic people and their social organisation.
- To use more targeted and in-depth ethnographical studies to better understand the archaeological record.

This will lead to a more holistic understanding of hunter-fisher-gatherer living in terms of e.g. social organisation, mobility, enculturation, communication, settling, economy and cosmology in the relatively stable coastal environments of south-eastern Norway.

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(2) Berg-Hansen I., Mjærum A., Roalkvam I., Solheim S., Schülke A. (this volume) – Coast-concepts in Norwegian Stone Age Archaeology.

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Archaeology of Neolithic Island Networks: Diachronic and Paleo-Economic Approaches to Island Occupations through the Contribution of Ceramic Analysis

L'archéologie des réseaux insulaires néolithiques : contribution de l'analyse de la céramique à une approche diachronique et paléo-économique des occupations insulaires

Benjamin Gehres

Abstract: The study of economic systems is a central theme of anthropological and archaeological research. At the intersection of questions on human behaviour and issues related to material culture, this discipline opens up theoretical perspectives for reflection that can link artefacts, individuals and processes, such as changes in livelihoods or the intensification or impoverishment of relationships. This communication focuses on the development and adaptation of existing economic models to the diachronic and territorial issues of our research, focused on the islands of Brittany (western France), through the petrographic and chemical analysis of the raw materials of pottery. It is a question of observing the evolution of the island's economic and production system over a long period of time during the Neolithic period. These environments are in fact strongly influenced by the ocean, the exploitation of the marine environment, both for food and for the production of goods, and also by displacement by cabotage or open sea shipping. These populations were therefore able to develop economic, production and distribution systems that were different from those of their fully continental neighbours. The question is whether existing economic models are suitable for these populations and whether new models adapted to more accurate data, and directly attributable to these groups, are likely to emerge.
Keywords: Neolithic, Brittany, islands, ceramic analysis, socio-economic models.

Résumé : L'étude des systèmes économiques est un thème central de la recherche anthropologique et archéologique. À l'intersection des questions sur les comportements humains et des problématiques liées à la culture matérielle, cette discipline ouvre des perspectives de réflexion théoriques permettant de relier les artefacts, les individus et les processus tels que les changements de moyens de subsistance, l'intensification des relations ou leur appauvrissement. Cet article porte sur le développement et l'adaptation des modèles économiques existants aux enjeux diachroniques et territoriaux de notre recherche, centrée sur les îles de Bretagne (ouest de la France), à travers l'analyse pétrographique et chimique des matières premières de la poterie. Il s'agira d'observer sur une longue période de temps l'évolution du système économique et productif insulaire au Néolithique. Ce milieu est en effet fortement influencé par l'océan et l'exploitation du milieu marin, tant pour l'alimentation que pour la production de biens, mais aussi par le déplacement par cabotage ou par la navigation en haute mer. Ces populations ont donc pu développer des systèmes économiques de production et de distribution différents de leurs voisins entièrement continentaux. La question est de savoir si les modèles économiques existants sont recevables pour ces populations et si de nouveaux modèles adaptés à des données plus précises, et directement attribuables à ces groupes, sont susceptibles d'émerger.
Mots-clés : Néolithique, Bretagne, îles, analyse céramique, modèle socio-économique.

INTRODUCTION

The study of the socio-economic organisation of human groups is a central theme in anthropological and archaeological research. At the intersection of questions about human behaviour and issues of material culture, this discipline opens up theoretical perspectives for thinking about linking artefacts, individuals and processes such as changes in livelihoods, intensification of relationships or their impoverishment. For example, anthropological studies suggest that the unpredictability of food supply is correlated with extensive reciprocal exchange systems. Reciprocity is more common among hunters, fishers and farmers than among gatherers and pastoralists who exploit relatively predictable resources (Pryor, 1977). Where then does this leave island populations who are heavily dependent on fisheries resources? Their environments strongly influence their lifestyles, through their subsistence strategies, but also through their movements, which are necessarily carried out by boat (coastal or high seas).

To examine this, we will focus on the island populations of the Atlantic coast and their socio-economic organisations during the Neolithic. What were the relationships and structures of island societies? What types of economic systems existed between the islands and with the mainland? Can we observe differences with continental groups? The islands of Brittany are very good laboratories for exploring these issues (fig. 1). Indeed, they are characterised by a diversity of forms and settlements, from large, isolated islands such as Groix, to archipelagos such as the Molène or Glénan. They thus allow us to put into perspective the socio-economic relations of the populations with the morphology and the surface of the islands.

The approach we will use here is based on ceramics, from the origin of their raw materials to the technical traditions of preparation and treatment of the clay used in their production process. These everyday objects allow us to carry out analyses at the micro-territorial and macro-regional levels, in order to examine the functioning of domestic units and their exchanges. The use of ceramics in everyday life, in all communities and over time, makes it an excellent diachronic thread for looking at many aspects of the domestic and economic life of populations. Ceramics can be examined from different angles, such as the characterisation of anthropic actions on the raw materials, the organisation of production, and its distribution. Like all craft products, ceramics are not only material objects made of a raw material and shaped according to a technique. Ceramics also represent cognitive knowledge and motor habits that follow the potters throughout their lives (Arnold, 1985; Bril, 2002; Roux, 2010). The mechanisms of transmission of the technical traditions used by a potter are the result of a learning process ‘of actions observed within a social group’ (Roux, 2010, p. 6), which limit the possibilities of potters modifying by themselves the concepts and actions of the *chaîne opératoire* they will have learned (Bril 2002; Roux 2010). It is then possible to establish links between the actions of the *chaîne opératoire* and ‘communities of practice’ (Stark, 1998; Roux, 2010, p. 6), bringing to light the limits of extension of different technical traditions (Gosselain, 2008; Roux, 2010). The identification of these ‘ways of doing’ and the processes of transmission is therefore a gateway to social groups, their extensions, their interactions and their evolution over time.

1. METHODOLOGY

The approach developed in this research consisted in determining the origin of the raw materials of the ceramics discovered on island sites: local or exogenous. It is then possible to identify the degrees of openness and withdrawal of the occupations, and the links that may have existed between islands and with continental communities. These approaches are based on multiscalar analyses. Firstly, following the typo-technological studies, a macroscopic sorting of the pastes is made in order to carry out petrographic studies on the ceramics. These analyses are conducted by observing thin sections of the pottery under a polarising microscope and involve identifying not only the nature of the non-plastic inclusions within the clay matrix, but also the modifications made by the potters (addition of degreaser, purification of the paste, grinding of the clay, etc.). Greater detail on these approaches can be found in reference works dealing with this subject (Echallier, 1984; Rice, 1987; Convertini and Querré, 1998; Quinn, 2009 and 2013).

In order to accurately determine the origin of the granitic inclusion clays, chemical point analyses were performed by plasma mass spectrometry coupled with a laser ablation sampling system (LA-ICP-MS; Gehres and Querré, 2018). A plasma source quadrupole mass spectrometer (Agilent Technologies, 7700 Series), coupled to a 213 nm Nd:YAG laser ablation system (Cetac Technologies, LSX-213, G2) was used. The instrument was calibrated using international geological standards: DR-N, DT-N, UB-N (Govindaraju and Roelandts, 1989) and MICA-Fe (Govindaraju and Roelandts, 1988). In total, 46 elements were determined: Na, Mg, Al, Si, K, Ca, Ti, Mn, Fe, Li, Sc, V, Cr, Co, Ni, Cu, Zn, As, Rb, Sr, Y, Zr, Nb, Cd, Sb, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Tl, Pb, Th and U. The aim of using this approach was to compare the chemical signature of one or more mineral species contained in the ceramic pastes and within the regional granites. We were able to demonstrate that biotite tablets allow the precise determination of the origin of clays with granitic inclusions (Gehres and Querré, 2018). Based on these approaches, it was possible not only to identify the geological and geographical origin of the raw clays, but also to characterise the technical traditions used by the potters during ceramic production.

2. RESULTS

The analyses were carried out on 191 ceramics, from origins spread over eight sites located on 12 islands, from Morbihan to the Channel Islands (table 1; fig. 1.).

2.1. Early and Middle Neolithic periods

The Early (4900-4700 B.C.) and Middle Neolithic I (4600-4300 B.C.) are poorly represented in the Brittany islands and thus difficult to understand. They are documented in the Channel Islands (fig. 1) at the Fouaillages site (Guernsey). However, these areas were still connected to the mainland during these periods. Production tends to be local with a low rate of imports, probably from the Paris Basin (Patton, 2001).

These data were obtained from petrographic and chemical analyses of ceramics discovered on four Middle Neolithic I and II (4200-3800 B.C.) sites (table 1; fig. 1) located on the island of Hoedic (Morbihan), Île aux Moutons (Finistère) and Herm (Channel Islands).

The pottery items are mainly made from granitic clay, resulting from the disintegration of the basement of the islands. These materials are characterised by mineralogical assemblages comprising mainly grains of quartz, potassium feldspar, plagioclase feldspar (acid) and mica tablets (muscovite and biotite). The treatment of the pastes was observed very little, and could only be observed for some pottery items from the sites of Le Douet and Groah Denn at Hoedic in the Middle Neolithic I. These were vessels made from a purified clay and tempered with sand grains (Gehres, 2018a). During this period, the addition of temper was more frequent on the mainland. This mainly involved the addition of grog to the paste (Hamon, 2003), a phenomenon found to be almost absent from island sites of this period (Gehres, 2018a).

The Middle Neolithic II is characterised by an increase in the practice of adding temper to mainland pastes, while this remains absent on the islands. These additions are mainly crushed bone fragments (Morzadec, 1995; Colas, 1996; Hamon, 2003), or the addition of sandy temper observed at the Er Grah site (Morbihan; Le Roux, 2006).

These observations correspond to a domestic production of ceramics. The rather occasional 'household' type of production is characterised by the use of a simple technology (Balfet, 1965). This was geared towards self-sufficiency, and the pottery produced is used within the household, and is hardly ever exchanged. The shape of the ceramics was not standardised, and the raw material was modified little or not at all (Rice, 1987). The communities were virtually autonomous and produced what they consumed.

There were a few diffusions between islands and with the mainland. These were mainly ceramics made from granitic clay. Their origins were determined from the comparison of the chemical signatures of the biotite tablets included in the pastes of the ceramics and those of the granitic rocks of the region, obtained by LA-ICP-MS (Gehres and Querré, 2018). These pottery items do not present any technical or decorative specificity in their assembly or in the preparation of the clay. They therefore seem to have been spread as containers during trade.

During the Middle Neolithic I on the island of Hoedic, the origins of these pottery items were located on Belle-Île-en-Mer (Morbihan) and on the mainland. During the Middle Neolithic II, on Île aux Moutons, some pottery came from the continent. Finally, on the island of Herm in the Channel Islands, we note that the Middle Neolithic is characterised by mainly local ceramics production, although we note the existence of transfers from the neighbouring island of Guernsey (fig. 1 and 2a). We can therefore observe that these exchanges are over short distances, of less than fifteen kilometres. These exchanges

Departement	Island	Site	Chronology	Amount of ceramic studied
Morbihan	Hoedic	Groah Denn	Middle Neolithic I - Late Neolithic	Mid. Neo. 13 - Late Neo. 13
Morbihan	Hoedic	Le Douet	Middle Neolithic I - Late Neolithic	Mid. Neo. 15 - Late Neo. 20
Morbihan	Houat	Er Yoh	Late Neolithic	54
Morbihan	Belle-Île-en-Mer	Le Lanno	Late Neolithic	12
Morbihan	Belle-Île-en-Mer	Castel Pouldon	Late Neolithic	1
Morbihan	Belle-Île-en-Mer	Ty-Seveno	Late Neolithic	1
Morbihan	Belle-Île-en-Mer	Les Quatre-Chemins	Late Neolithic	1
Morbihan	Belle-Île-en-Mer	Kerbellec	Late Neolithic	1
Finistère	île aux Moutons	Île aux Moutons	Middle Neolithic II	19
Finistère	Glénan archipelago	Saint-Nicolas	Late Neolithic	22
Finistère	Molène archipelago	Quéménès	Late Neolithic	6
Channel Island	Herm	Herm	Middle Neolithic	13

Table 1 – Summary table of the different sites studied and presented in this article.
Tabl. 1 *–Tableau synthétique des différents sites présentés et étudiés dans cet article.*

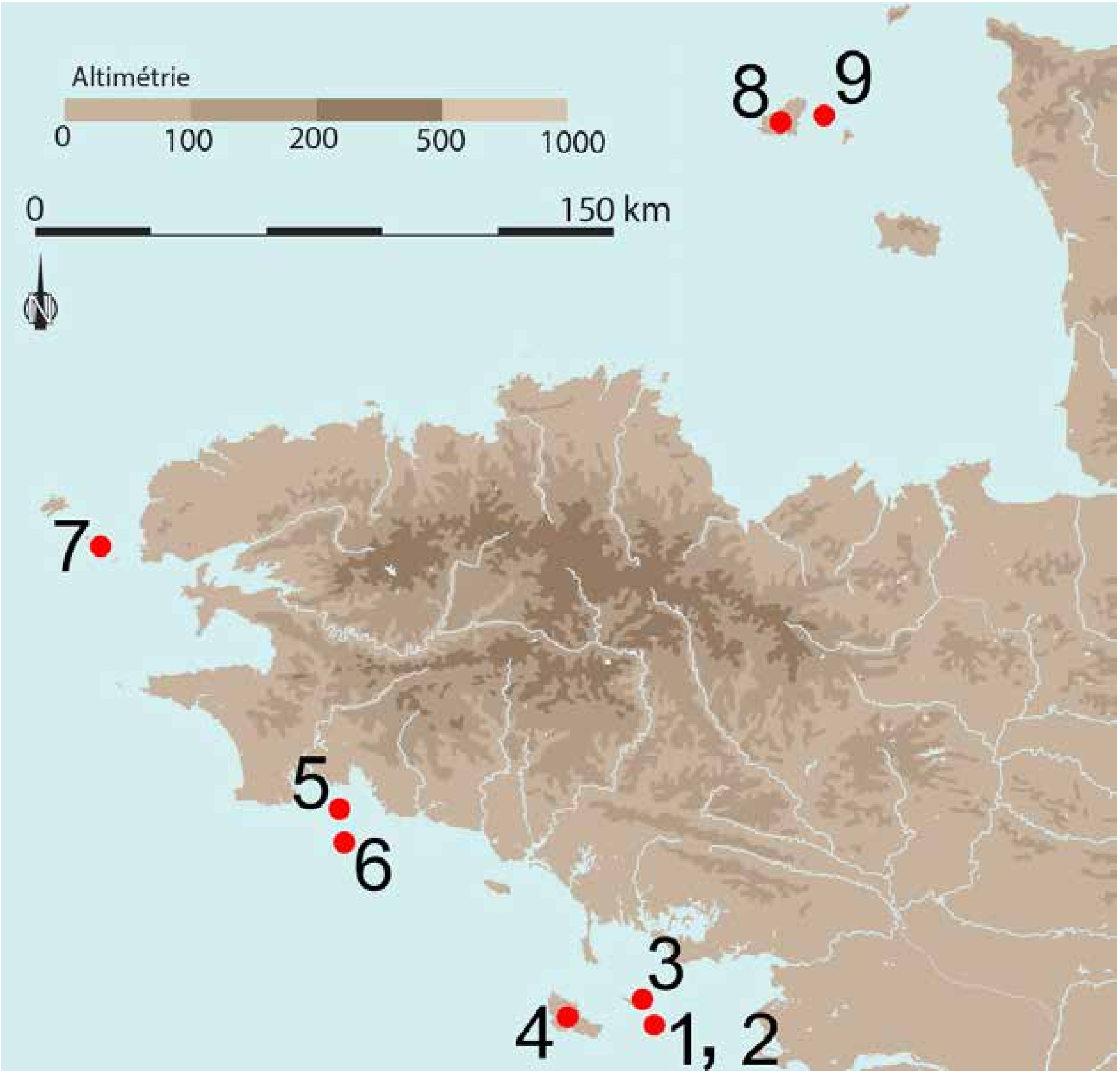


Fig. 1 – Locations of sites mentioned in the text. 1. Groah Denn (island of Hoedic, Hoedic); 2. Le Douet (island of Hoedic, Hoedic); 3. Er-Yoh (island of Er-Yoh, Houat); 4. Belle-Île-en-Mer (Castel Pouldon, Locmaria; Ty-Seveno, Locmaria; Les 4 chemins, Bangor; Kerbellec, Le Palais; Le Lanno, Sauzon); 5. Île aux Moutons (île aux Moutons, Fouesnant); 6. Saint-Nicolas (island of Saint-Nicolas, Fouesnant, Glénan Archipelago); 7. Quéménès (island of Quéménès, Le Conquet, Molène Archipelago); 8. Les Fouiallages (Bailiwick of Guernesey, Clos du Valle, Channel Islands); 9. Herm (Bailiwick of Herm, Channel Islands).

Fig. 1 *– Localisation des sites mentionnés dans le texte. 1. Groah Denn (île d'Hoedic, Hoedic) ; 2. le Douet (île d'Hoedic, Hoedic) ; 3. Er-Yoh (îlot d'Er-Yoh, Houat) ; 4. Belle-Île-en-Mer (Castel Pouldon, Locmaria ; Ty-Seveno, Locmaria ; les 4 chemins, Bangor ; Kerbellec, le Palais ; le Lanno, Sauzon) ; 5. île aux Moutons (île aux Moutons, Fouesnant) ; 6. Saint-Nicolas (île de Saint-Nicolas, Fouesnant, archipel des Glénan) ; 7. Quéménès (île de Quéménès, le Conquet, archipel de Molène) ; 8. les Fouiallages (Bailiwick de Guernesey, clos du Valle, îles Anglo-Normandes) ; 9. l'aéroport (Bailiwick d'Herm, îles Anglo-Normandes).*

were probably made directly between communities and based on reciprocity. These transfers can therefore be interpreted as exchanges allowing the creation and consolidation of social links between communities that were physically and socially close.

2.2. Recent and Late Neolithic (3600/3500-2800 BC)

Several island sites from the Late Neolithic were studied (table 1; fig. 1). During this period, we notice a different management of the production and distribution of ceramics compared with the Middle Neolithic. Indeed, an increase in transfers can be noted, both between the islands and with the mainland. This increase in transfers is particularly visible in the Glénan archipelago at the Saint-Nicolas site, and at Belle-Île-en-Mer (table 1; fig. 1). At Quéménèz (fig. 3a; Gehres, 2018a) and Beg Ar Loued (Convertini, 2019) sites in the Molène archipelago (Finistère), but also on Saint-Nicolas in the Glénan archipelago (fig. 3b; Finistère), the Douet and Groah Denn sites on the island of Hoedic, and Er-Yoh on the island

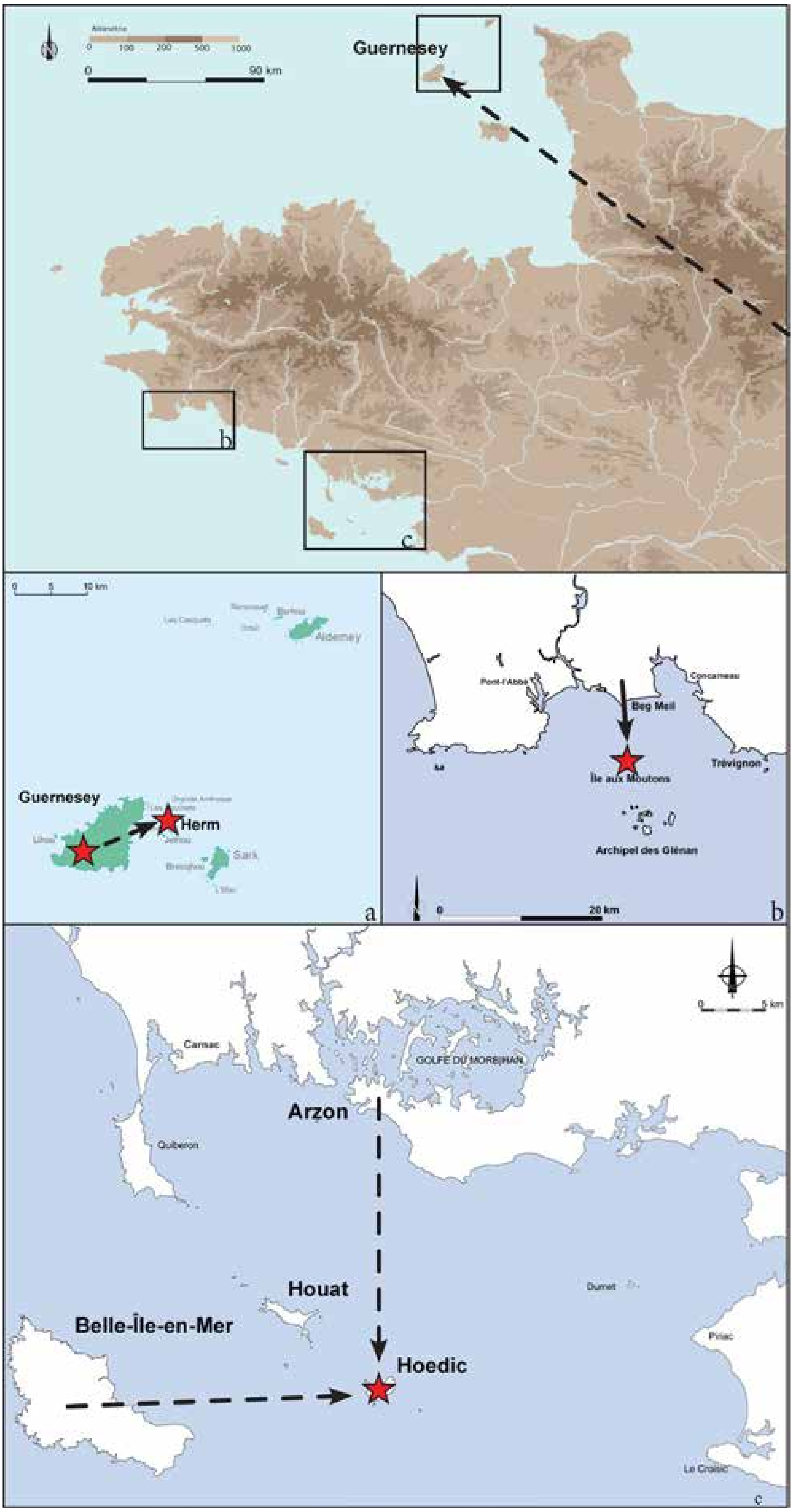


Fig. 2 – Origins of the different Early and Middle Neolithic ceramics studied (★ origin of the pottery raw material).

***Fig. 2** – Origines des différentes céramiques du Néolithique ancien et moyen étudiées (★ origine de la matière première des poteries).*

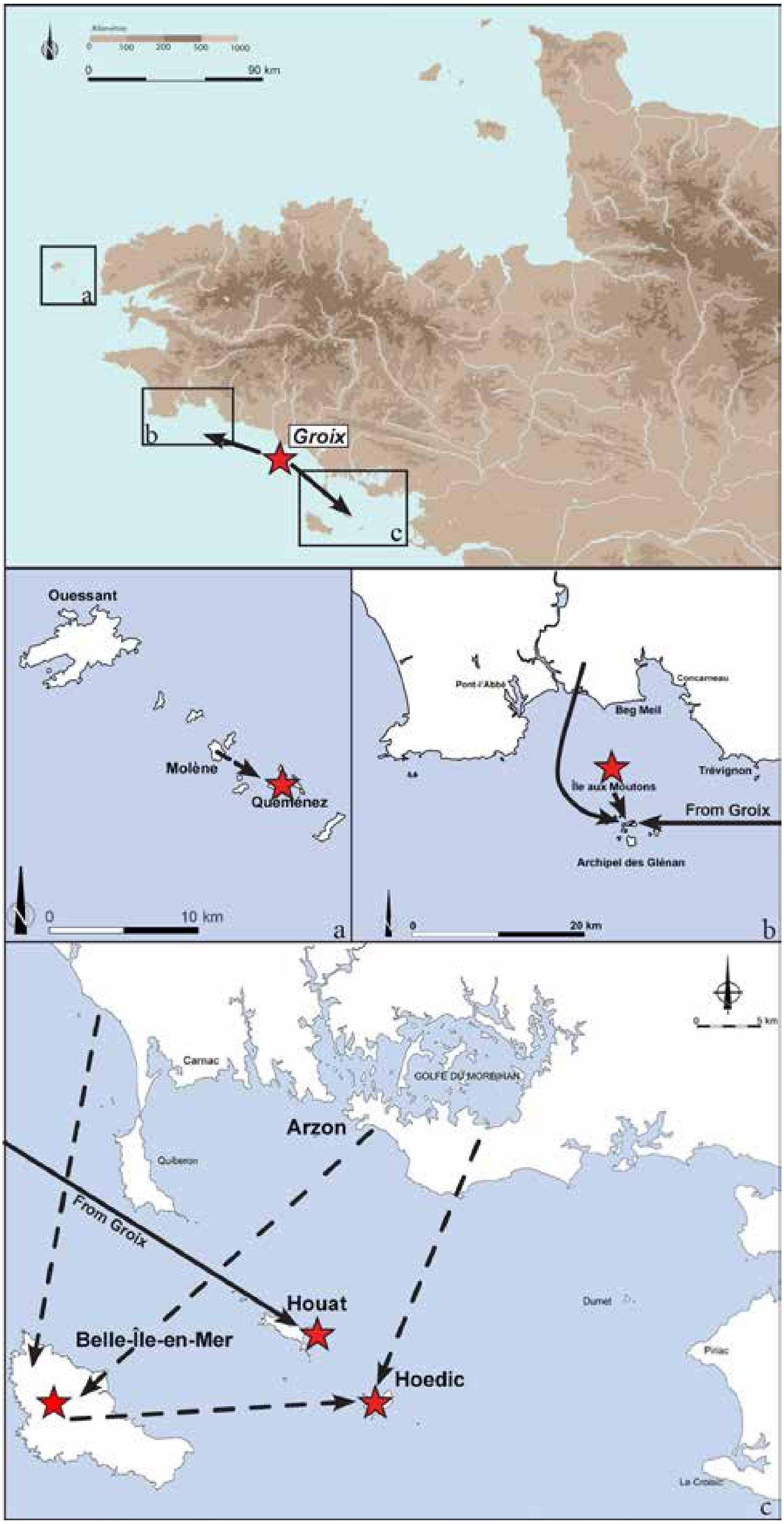


Fig. 3 – Origins of the different Late Neolithic ceramics studied (★ origin of the pottery raw material).

***Fig. 3** – Origines des différentes céramiques du Néolithique récent étudiées (★ origine de la matière première des poteries).*

of Houat (fig. 3c; Gehres, 2018a), the pottery items are mainly made with local clay, and no continental imports were observed despite a large corpus being analysed. Thus, the study of different island complexes has made it possible to highlight a mosaic of island socio-economic organisations.

2.2.1. Are majority mainland transfers an indication of a centralised island economy? The case of Belle-Île-en-Mer

The case of Belle-Île-en-Mer is special on several levels. On the one hand, the ceramics analysed all come from prospecting collections on the sites of Lanno (12 ceramics), Castel Pouldon (2 ceramics), Les Quatre Chemins (1 ceramic) and Ty-Seveno (1 ceramic; Locmaria), due to the lack of recent excavations on this island. However, their forms and decorations have allowed us to set a reliable chronological reference point for them. On the other hand, petrographic and chemical analyses, carried out within the framework of the PCR (Projet Collectif de Recherche) "Belle-Île-en-Mer : Espaces et territorialité d'une île atlantique" (Audouard and Gehres dir.), have identified a very high percentage of continental imports from different sources.

Of the 16 ceramics studied, one has mineralogical characteristics that can be linked to the particular geology of the island (fig. 4e and 4f). Indeed, this pottery is distinguished by grains of quartz and potassium feldspar (highly altered). These minerals are associated with grains of plagioclase feldspar and clay pellet in accessory quantities. The inclusions are sparse and mostly fine. Their shapes vary from subrounded to subangular, indicating the use of a mature clay. These observations may therefore correspond to the feldspathic sandstone from Belle-Île present in the southern part of the island.

One ceramic has gabbro-granitic inclusions, a rock not present on Belle-Île-en-Mer. This ceramic is characterised by a mineralogical assemblage mixing the main inclusions of granitic rocks such as quartz, potassium feldspar and micas (biotite and muscovite). To this are added elements of gabbroic rock such as grains of colourless and green amphibole and basic plagioclase feldspar. The origin of this ceramic is probably continental and seems to come from the Arzon region where a gabbroic massif is known to exist alongside granitic outcrops.

The remainder of the corpus, i.e. 14 pieces of ceramics, were all made from granitic clays (fig. 4a to 4d). Belle-Île-en-Mer has no granite outcrops, so these ceramics were made from materials exogenous to the island. LA-ICP-MS analyses were carried out in order to determine the chemical signatures of the biotite tablets in the ceramic pastes. These were compared with a reference framework made up of the chemical compositions of biotite tablets from the granite forming the Houat/Hoedic/Quiberon oceanic ridge, and of several Late Neolithic ceramics from the Douet excavation (Hoedic) and a pottery item from the Er-Yoh site (Houat). Thus, according to the model we developed (Gehres and Querré, 2018), the concentrations of lithium (Li) and vanadium (V) allowed us to distinguish the sources of materials. The results show a multiplicity of raw material origins: four sources of clay with granitic inclusions among the ceramics analysed (fig. 5).

- The first source corresponds to the granite taken from the island of Hoedic (Group 1 - Houat/Hoedic/Quiberon granite). According to BRGM geologists, the islands of Hoedic, Houat and as well as the Quiberon peninsula were formed by a single granite upwelling, and thus theoretically have common geochemical characteristics. This group is therefore linked to the granitic ensemble forming Houat/Hoedic/Quiberon. Within this group there are two ceramics from the Douet site (Hoedic) and as well as two ceramics (BI-PCR 27-1; BI-PCR 27-4) from collections at the Lanno site (Sauzon).
- A set of biotite minerals (Group 2 - Unknown Granite 1), including 2 ceramics (BI-PCR 17-3; BI-PCR 27-2) from the Lanno site (Sauzon), and a pottery item found during the survey at Castel Pouldon (Locmaria). The geographical origin of this group is probably continental but remains unknown at the current point in our research.
- A group of crystals brings together the materials used to make three ceramics (Group 3 - Unknown Granite 2), one from Lanno (Sauzon), one from the Quatre Chemins site (Bangor) and one from the site of Er-Yoh site (Houat island).
- The last group (Group 4 - Unknown Granite 3) corresponds to two pottery items from the Ty-Seveno (Locmaria) and Lanno (Sauzon) sites (BI-PCR 17-1). It is interesting to note that the biotites of the Lanno pottery (BI-PCR 17-1) present two chemical signatures. Indeed, several biotites belong to the latter group (Group 3 - Unknown Granite 2). This distribution between the two groups (Groups 3 and 4) of a Lanno ceramic, as well as the techno-petrographic observations, allow us to assume a mixing of the alterations of unknown granites 2 and 3, which is probably natural. Thus, we can think that these two granites are geographically close, and that the raw material was collected in a zone of convergence of the alterations of the two rocks.

Belle-Île-en-Mer is thus strongly distinguished from its neighbours by its very high rate of transfer of ceramics from many continental areas. The Neolithic populations of the island therefore seem to have had a more important and diversified contact with continental groups, and to have turned more rarely to the occupations of Hoedic and Houat. This observation is accentuated when we see that the majority of the ceramics from these islands are made from local clay. Mainland or Belle-Île productions are almost absent.

Belle-Île-en-Mer therefore appears to be distinct in terms of the origins of its ceramics. These ceramics, which do not have any specificities in their technical or, decorative characteristics or in the materials used to shape them, tend to demonstrate their transfer as con-

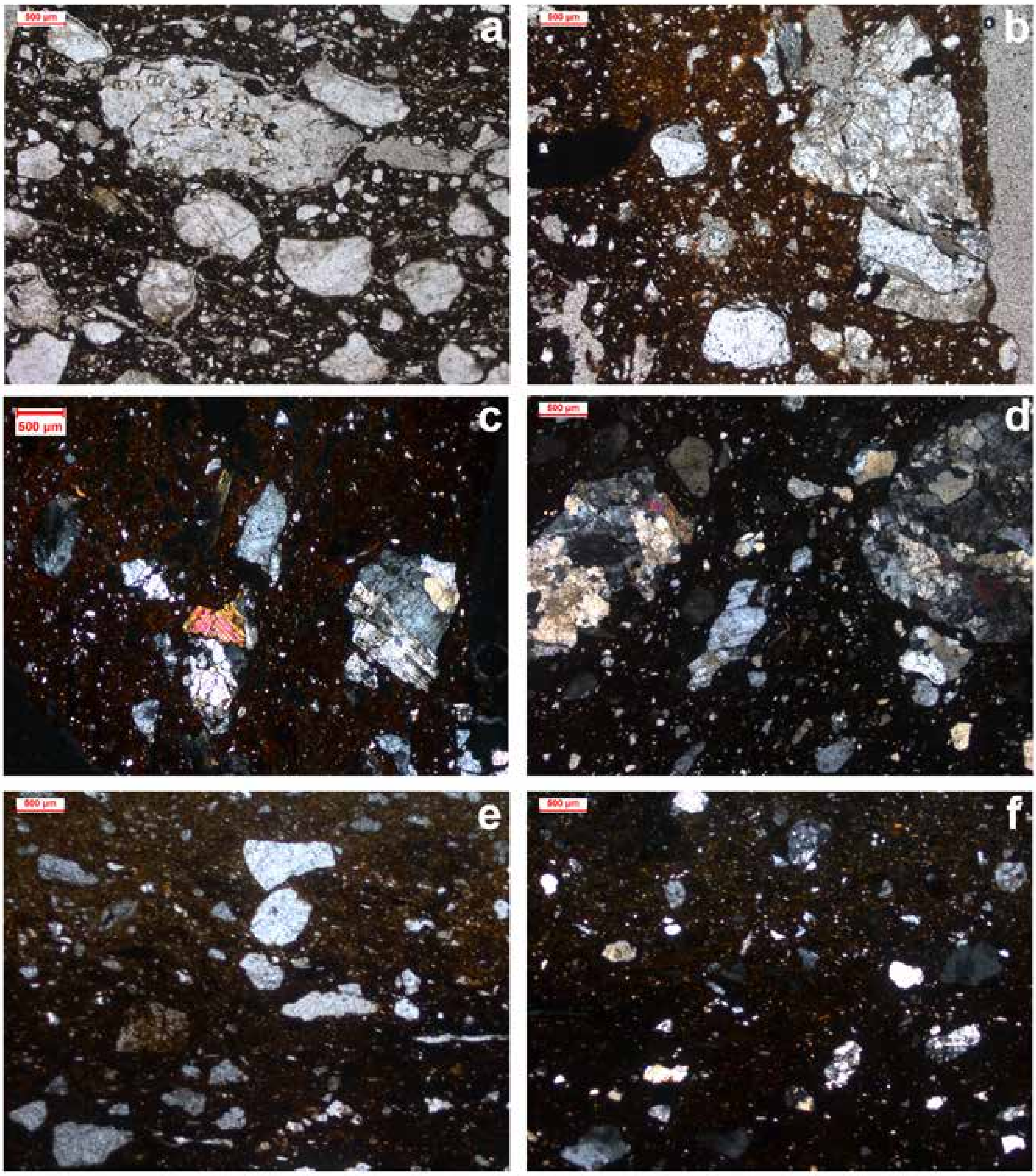
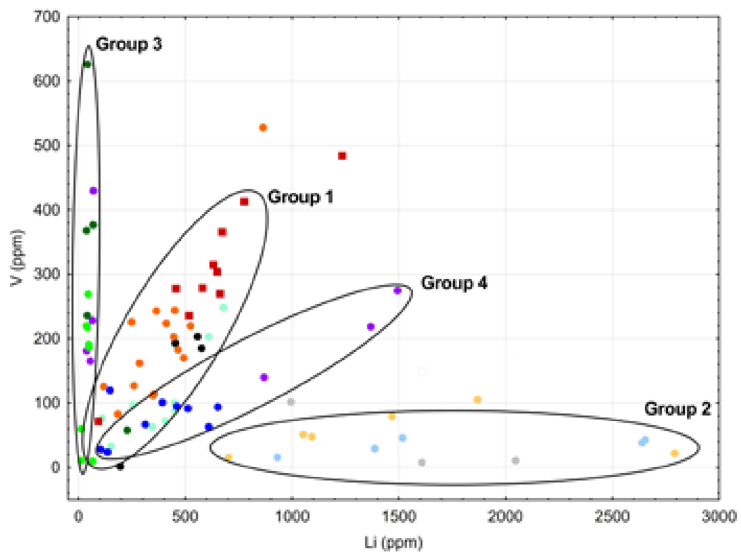


Fig. 4 – Micrographic sheet of thin sections of the different petrographic fabrics from the Late Neolithic sites of Belle-Île-en-Mer: a to d) granitic inclusion fabric; e and f) feldspathic inclusion fabric).

***Fig. 4** – Planche de micrographies des différents faciès pétrographiques observés en lame mince sur les sites du Néolithique récent à Belle-Île-en-Mer : a à d) pâte à inclusions granitiques ; e et f) pâte à inclusions feldspathiques.*

tainers. It Belle-Île-en-Mer thus seems to be a point of convergence of goods between island and continental populations. This hypothesis is particularly reinforced by the presence of 21 fragments of flint from the Grand Pressigny (Audouard, 2014 and 2016), the largest known concentration in the islands of Brittany. This attraction had already been highlighted by E. Ihuel concerning the Gulf of Morbihan (Ihuel, 2004). Thus, the geographical position, but also the morphology of the island and its numerous natural harbours, make Belle-Île-en-Mer an excellent central place within the exchange networks. Considering these aspects, the hypothesis of the existence of a centre for the accumulation of goods from the exploitation of the sea, but also from maritime traffic, with a redistribution towards the continent seems to emerge. This type of economy implies the existence of redistributing authori-



■ Biotites from the granite sample taken on the island of Hoedic.
● Biotites from ceramics of le Douet occupation (Hoedic island).
● Biotites from a ceramic of Er-Yoh occupation (Houat island).
● Biotites from a ceramic of the 4 chemins site (Bangor, Belle-Île-en-Mer).
● Biotites from ceramics of the Ty-Seveno occupation (Locmaria, Belle-Île-en-Mer);
● Biotites from a ceramic of the Lanno occupation (BI-PCR 17-1; Sauzon, Belle-Île-en-Mer).
● Biotites from a ceramic of the Lanno occupation (BI-PCR 27-1; Sauzon, Belle-Île-en-Mer).
● Biotites from a ceramic of the Lanno occupation (BI-PCR 17-4; Sauzon, Belle-Île-en-Mer).
● Biotites from a ceramic of the Castel Pouldon occupation (Locmaria, Belle-Île-en-Mer).
● Biotites from a ceramic of the Lanno occupation (BI-PCR 17-3; Sauzon, Belle-Île-en-Mer).
● Biotites from a ceramic of the Lanno occupation (BI-PCR 27-2; Sauzon, Belle-Île-en-Mer).

■ Biotites présentes dans le prélèvement de granite réalisé sur l'île d'Hoedic.
● Biotites de céramiques du site du Douet (Hoedic).
● Biotites d'une céramique du site d'Er-Yoh (Houat).
● Biotites d'une céramique du site des 4 Chemins (Bangor ; Belle-Île-en-Mer).
● Biotites de céramiques du site du Ty-Seveno (Locmaria ; Belle-Île-en-Mer).
● Biotites d'une céramique du site du Lanno (BI-PCR 17-1 ; Sauzon ; Belle-Île-en-Mer).
● Biotites d'une céramique du site du Lanno (BI-PCR 27-1 ; Sauzon ; Belle-Île-en-Mer).
● Biotites d'une céramique du site du Lanno (BI-PCR 17-4 ; Sauzon ; Belle-Île-en-Mer).
● Biotites d'une céramique du site de Castel Pouldon (Locmaria ; Belle-Île-en-Mer).
● Biotites d'une céramique du site du Lanno (BI-PCR 17-3 ; Sauzon ; Belle-Île-en-Mer).
● Biotites d'une céramique du site du Lanno (BI-PCR 27-2 ; Sauzon ; Belle-Île-en-Mer).

Fig. 5 – Diagram showing the lithium (Li) and vanadium (V) concentrations of the analysed biotite crystals. Each point corresponds to an analysis of a biotite crystal by LA-ICP-MS. Each colour corresponds to a ceramic. Several crystals are therefore analysed within each ceramic.

***Fig. 5** – Diagramme représentant les concentrations en lithium (Li) et vanadium (V) des cristaux de biotite analysés. Chaque point correspond à une analyse d'un cristal de biotite par LA-ICP-MS. Chaque couleur correspond à une céramique. Plusieurs cristaux sont donc analysés au sein d'une céramique.*

ties, whose role was to reallocate goods to other satellite occupations. This implies the formation of elite groups that would take control of production and regulate its distribution within a stratified society. However, given the current state of research, and the absence of any planned excavations on the island, it remains difficult to bring any elements of reflection to this proposal.

2.2.2. The Saint-Nicolas site: a seasonal occupation of the Glénan archipelago?

The ceramics studied come from a survey carried out in 2006 on the island of Saint-Nicolas (table 1; fig. 1) in the Glénan archipelago (Finistère) by G. Hamon (Hamon et al., 2006). The results of the excavation highlighted the existence of a Late Neolithic habitat (Hamon et al., 2006), as well as a strong presence of fusiform drills, fragmented or with a blunt edge suggesting the drilling of a hard material (Hamon et al., 2006). These tools are typologically comparable to those discovered at the Final Neolithic sites of Ponthezières and Beg ar Loued, where they were used to pierce shells for the manufacture of ornaments (Laporte, 2009; Dupont, 2019).

The petrographic study was carried out on a corpus of 22 pottery items (Gehres, 2018a). Two types of pastes could be distinguished by the analyses. The first set, consisting of 15 ceramics, is characterised by granitic inclusions (fig. 6), i.e. grains of quartz, potassium feldspar and acid plagioclase (albite and oligoclase) as well as mica tablets (biotite and muscovite).

Because the Glénan archipelago and the island of Saint-Nicolas are constituted of a granitic base, a local origin of the raw material appears likely (Béchennec et al., 1999). However, chemical analyses of the biotite tablets by LA-ICP-MS (Gehres and Querré, 2018), which allowed us to specify the origin of the clay, demonstrated that the majority of the ceramics with granitic inclusions were made from raw materials that could be linked to the granitic basement of the Île aux Moutons, 7 km to the north, and a minority from mainland clay. Thus, no ceramics were produced during the Late Neolithic from materials collected in the Glénan archipelago.

It is therefore necessary to question this absence of production and to identify its reasons. The study of the second petrographic group of paste and the origin of the materials used to make these ceramics can then shed light on these questions. Indeed, the second group is composed of seven pottery items, corresponding to a very unusual paste (fig. 7a and 7b). They are characterised by a large quantity of talc and clusters of colourless amphiboles constituting the main inclusions. This set of minerals is completed by more accessory quantities of quartz and

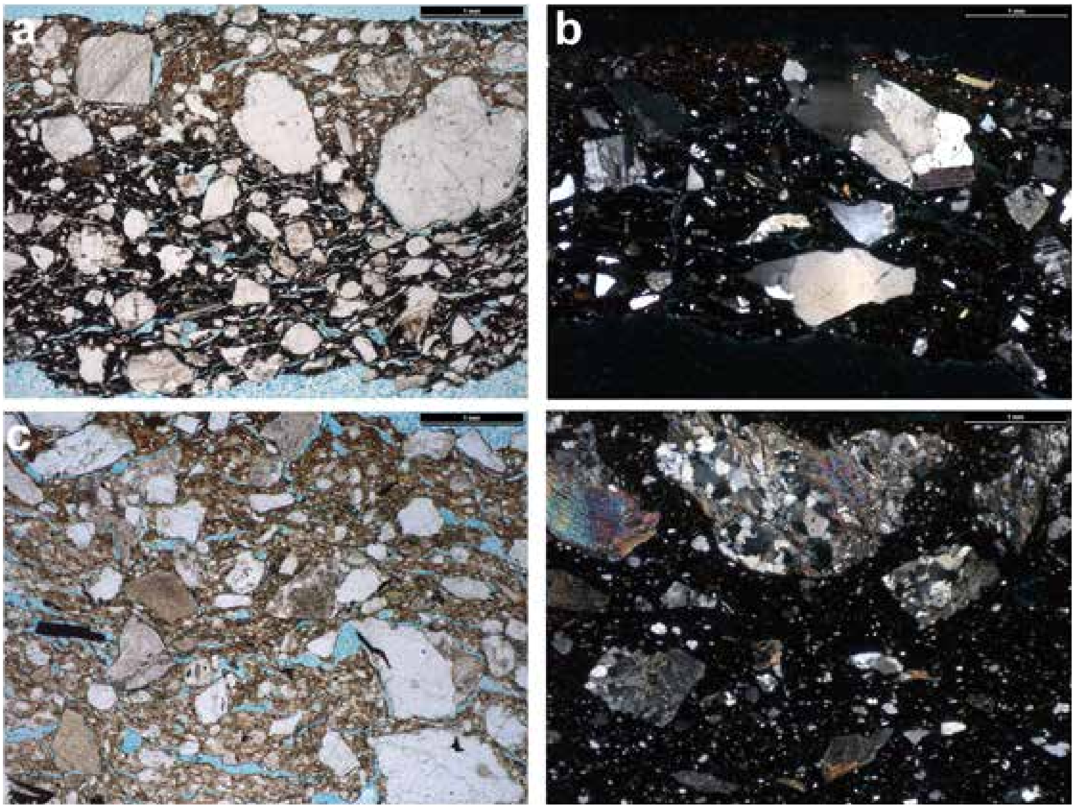


Fig. 6 – Micrographic sheet of thin sections of granitic facies from the Late Neolithic site of Saint-Nicolas in the Glénan Archipelago.
Fig. 6 – *Planche de micrographies des faciès granitiques observés en lame mince sur le site du Néolithique récent de Saint-Nicolas, dans l'archipel des Glénan.*

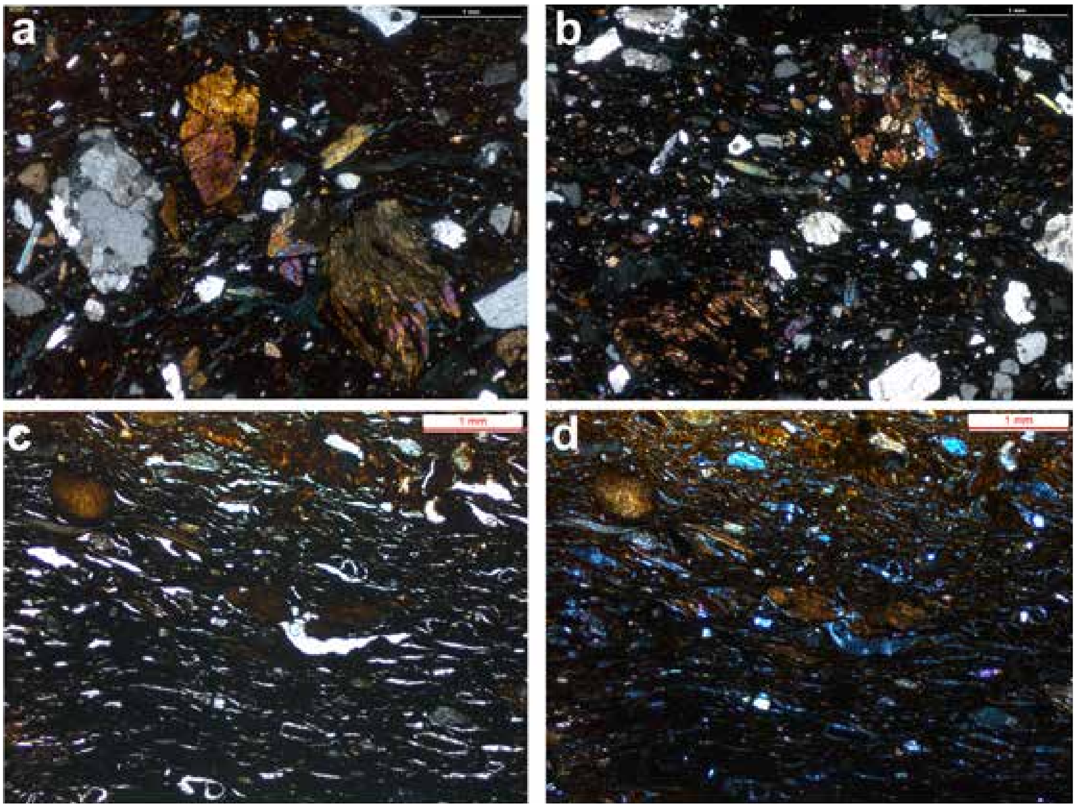


Fig. 7 – Micrographic sheet of thin sections of talcous facies from the Late Neolithic sites: a and b) Saint Nicolas (Glénan Archipelago); c and d) Er-Yoh (Houat island).
Fig. 7 – *Planche de micrographies des faciès talqueux observés en lame mince sur les sites du Néolithique récent : a et b) Saint Nicolas (archipel des Glénan) ; c et d) Er-Yoh (île de Houat).*

potassium feldspar grains, and glaucophane inclusions. The latter are fresh, poorly rolled and subautomorphic, which indicates that they have travelled little and have been trapped in clays not far from their place of formation. Their presence clearly indicates an origin on the island of Groix. Indeed, this mineral is only present in its natural state in France in Groix rocks or in certain rocks outcropping in the Alpine massif. The source of these clays is a magnesian schist (also called talcschist), located on the north-east coast of the island of Groix, on the points of Pen Men, Er-Fons, Bileric, at Sémaphore and Beg-Melen (Audren et al., 1993). This rock has the particularity of being composed essentially of ribbons of talc and clusters of colourless amphiboles. This mineralogical assemblage is identical to that found in the ceramics from the Saint-Nicolas site. Contacts must therefore have taken place between the island of Saint-Nicolas-des-Glénan and the island of Groix, more than 50 km to the east. This type of pottery was also observed at the Late Neolithic site of Er-Yoh (Houat Island, Morbihan; fig. 1) presented in the following section (fig. 7c and 7d). The existence of a value-added good status for these ceramics was due to the use of a material with physical and mechanical characteristics superior to common clays. Indeed, talc and amphiboles give these ceramics better impermeability and resistance to thermal shocks (Gehres, 2018b). A specific type of ceramic was therefore produced on the island of Groix and exported to other islands several dozen kilometres away. Analyses of the Glénan and Houat Island corpus has not identified other groups of wares from Groix. It is therefore a question of a preferential diffusion of these ceramics. The hypothesis of an exchange of talc-containing ceramics for other value-added goods to these workshop sites is therefore questionable.

The analysis of ceramic materials has shown that the pottery discovered in the Glénan archipelago were not the object of any particular technological investment. They do not have any specific characteristics and may have been made as part of domestic production. However, the fact that all the pottery studied was imported is an argument in favour of a possible seasonal occupation of the Glénan. The islanders were able to move from one island to another, depending on the accessibility and availability of resources and the seasons. These mobile groups were thus able to operate in a large maritime territory encompassing the Glénan archipelago and the Île aux Moutons. Their position allowed them to exchange sea products and their crafts over distances of several dozen kilometres with other island communities and continental groups.

2.2.3. Could a unique technical tradition at the Er-Yoh site (Houat island) be a sign of an insular retreat?

Analysis of the Er-Yoh ceramics has identified a very significant use of purified and tempered clay using dune sand and beach sand (fig. 8). This phenomenon is unique in the Brittany islands, and the addition of temper was rarely practised in the region on the mainland during the Late Neolithic.

This site, discovered at the end of the 19th century by Abbé Lavenot (Lavenot, 1886), was subsequently excavated by Z. Le Rouzic and M. and S.-J. Péquart from 1923 to 1924. Their investigations led to the discovery of post-holes and "a fairly regular pavement that seemed to have been made to level the top of the platform and on which the dwellings were established, around which the remains of the kitchen were thrown" (Le Rouzic, 1930). From the point of view of lithic and ceramic material, the Er-Yoh site is considered homogeneous (Guyodo, 1997 and 2007). The predominance of tools such as drills and scrapers on the Er-Yoh site has been interpreted as being the remains of specialised activities (Guyodo, 2007). Finally, we note the presence of eight fragments of daggers and a flint scraper from Grand Pressigny (Guyodo, 2007).

The petrographic analyses carried out on 54 pottery items (Gehres, 2018a) allowed the identification of three main types of paste. The first set corresponds to four pottery items, made from the clay resulting from the alteration of a granite, where large aggregates of clay of multi-millimetre size are detectable. Their origin seems to be due to the use of poor-quality clay, rather than to a voluntary act. The mineralogical assemblage accompanying these clays is mostly composed of inclusions of granitic origin, which could correspond to a local raw material.

The second group consists of 47 ceramics. It is characterised by the presence of well-sorted rounded grains of quartz and feldspar (fig. 8), corresponding to inclusions of beach and dune sand (Gehres, 2018a). As these clays are derived, in the Armorican massif, from the weathering of basement rocks, the absence of lithoclasts or unsorted elements usually present in this type of clay is an indication that the raw material was purified by the potters. The material once separated from these natural inclusions was subsequently tempered with sand.

This type of paste represents more than 95% of the corpus studied. This practice is known on the continent from the Middle Neolithic II on the continent, at the Er Grah site in particular (Le Roux, 2006), but has no known parallel in the Late Neolithic in the West.

The use of sand as temper can be considered a technically poor choice due to the higher expansion coefficient of quartz compared with clays (Rye, 1976; Woods, 1986; Gibson and Woods, 1990). The pottery loses strength and toughness with each firing. However, as shown in the recent work of N. Müller: "Quartz, which at 573 °C undergoes a reversible phase transition accompanied by a 7 vol % change, is frequently cited in discussions of strength reduction. However, the volume fractions of the quartz component in both temper types, as determined by XRD methods, are quite similar, reasonably low (0.26 for granite and 0.19 for phyllite), and cannot account on their own for the observed differences" (Müller et al., 2010, p. 2460). It is therefore difficult to determine whether the use of this sandy temper in Er-Yoh ceramics originates from a technical choice or a tradition. It is interest-

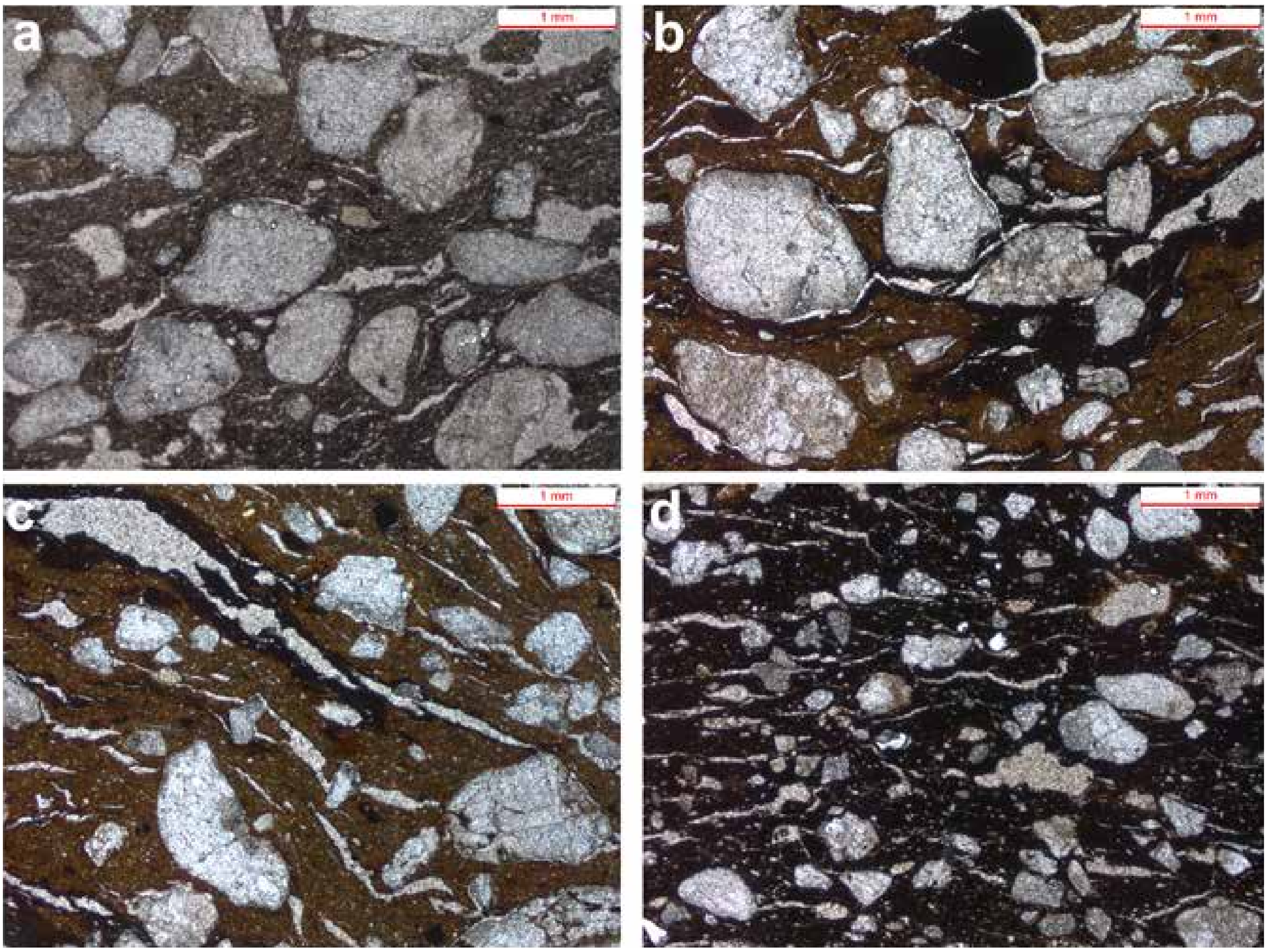


Fig. 8 – Micrographic sheet of thin sections of facies with sandy temper from the Late Neolithic site of Er-Yoh on the island of Houat.
Fig. 8 *– Planche de micrographies des faciès à dégraissant sableux observés en lame mince sur le site du Néolithique récent d'Er-Yoh, sur l'île de Houat.*

ing to note that no technical or ceramic transfer could be observed on the neighbouring and or contemporary sites.

Finally, the last set of three vases corresponds to the type of paste previously observed on the Saint-Nicolas site in the Glénan archipelago (fig. 7c and 7d). These pottery items present the same petrographic characteristics, i.e. a high rate of talc ribbons, but also numerous clusters of colourless amphibole. Finally, the presence of angular grains of glaucophane confirms Groix as the origin of these vases.

Er-Yoh seems less connected within the Houat/Hoedic/Belle-Île-en-Mer group, with the absence of transfer of ceramics produced in the region, but also by the use of a very specific pottery production process that is limited to this site. The lack of diffusion of this technique to other islands or continental sites raises the question of the mobility of populations between occupations, but also of the pressures that may have existed within the Er-Yoh group for the adoption of the community's technical traditions. This type of phenomenon has been described by ethnoarchaeology. O. P. Gosselain points out that when a Cameroonian potter uses recipes for preparation that differ from those of the group, the group could be openly denigrating toward them: "Social integration would require a certain conformism, while individual 'deviations' would be sanctioned by one or other form of segregation" (Gosselain, 2002, p 76). Such pressure could explain the homogeneity of practices on the Er-Yoh site.

This lesser connection is, however, relative, as shown by the discovery of fragments of dagger and a flint scraper from Grand Pressigny (Guyodo, 2007), but also by the presence of talcous ceramics from Groix. Like the occupants of the island of Saint-Nicolas, the inhabitants of Er-Yoh seem to have been well integrated into the communication and exchange networks of the Late Neolithic. This group seems to have developed craft skills that enabled them to access value-added goods and to acquire a certain independence from their neighbours.

2.2.4. Long-distance transfers

The transfer of ceramics over more than 50 km from the island of Groix raises questions about the status of these goods. Thus, we have proposed that these pottery items, whose raw material has superior qualities, should be considered as value-added goods (Gehres, 2018b). This has repercussions on for issues related to the management of the raw materials and the production of these ceramics. Indeed, the use of a rare, value-added raw materials tends to demonstrate the existence of a 'household industry' type of production (Balfet, 1965; Rice, 1987; Perlès, 2012). In this type of organisation, the technology used is simple, as shown by the absence of specific preparation of the paste (no addition of temper or grinding of the material). Ethnographic observations suggest that this type of system was practiced on a part-time basis, and that production was most often directed towards a consumer market wider than the community (Arnold III, 1991), which could be the case for the production of talcous pottery from Groix. Access to these quality deposits may therefore have been unequal due to control by hierarchical groups. Within this type of production system, ceramics no longer only have a use value, but also acquire an exchange value (Rice, 1987). The pottery is therefore the result of an intentional surplus of production, the aim of which is to feed an economy partially oriented towards the exchange of goods. It is then necessary that the production system be more organised at the level of the communities exploiting these deposits, notably by a management and control of the resource within a socially stratified society.

CONCLUSION

Based on the analysis of ceramic materials, it is possible to point out changes between the island groups of the Middle Neolithic and the Late Neolithic (fig. 2 and 3). The potters used more diverse materials for their ceramic production, which they modified less. On the one hand, the territories of the technical traditions in the stages of clay preparation of the clay are restricted and do not seem to have spread any further. On the other hand, the economic territories were expanding and exchanges between islands and with the mainland were increasing strongly, as were the distances over which these transfers took place. Some island occupations show high rates of importation, such as Saint-Nicolas in the Glénan archipelago, or several sites located on Belle-Île-en-Mer (fig. 3b and 3c). The ceramics were therefore transferred for their contents, but also for themselves as objects with added value linked to the quality of the raw materials used to shape them (Gehres, 2018b). The organisation of production, as well as that of the groups in which these value-added ceramics were produced, then subsequently tended to become more complex. There is currently no evidence for the existence of such a status in the Middle Neolithic.

Thus, we observe a change in ceramic production behaviour, but also in economic organisation. From the point of view of ceramic production and circulation, the Late Neolithic appears to have been a turning point between two socio-economic states in these islands. First, a heterarchical[(1)] status during the Middle Neolithic may have been in place in the island populations. The island groups would have been socially organised in a horizontal way, but with well-defined roles within society. Ceramics would have been produced within domestic units, without great technical investment, and would have been oriented towards use within the occupation. Their role was thus limited to being containers. Exchanges between the groups would seem to have been based mainly on family ties and relationships of trust. They would therefore have been restricted in space and have taken place among nearby islands.

The Late Neolithic appears to be different from the Middle Neolithic, as the mosaic of social organisations and ceramic production seems to have become more complex. Indeed, ceramic analyses have shown an increase in the volume of transfers between the islands and with the mainland, over distances of up to several dozen kilometres. This is particularly the case for the Late Neolithic sites of Belle-Île-en-Mer, where almost all the ceramics were produced on the mainland, or in the nearby islands (fig. 3c). This raises the question of whether Belle-Île-en-Mer had a role as a central and redistributive place within the exchange networks. Similarly, at the Saint-Nicolas site in the Glénan archipelago, all the vessels were imported (fig. 3b). The connections between the islands and with the mainland seem to have multiplied and the exchange networks strengthened.

The ceramics were produced in different contexts, mostly domestic but also as a household industry in the case of the value-added pottery from the island of Groix. The technology used was simple and practiced on a part-time basis with the production most often directed towards a wider consumer market (Arnold III, 1991). Ceramics no longer only had a use value but also acquired an exchange value (Rice, 1987). The ceramics were then the result of an intentional surplus of production, the aim of which was to feed an economy partially oriented towards the exchange of goods. The production system would have been more organised at the level of the communities exploiting these deposits, notably through the management and control of the resource. Such a system generally leads to a socially stratified society in a heterarchical or hierarchical way (Crumley, 1995).

These contacts allow us to propose a first scenario, concerning the coexistence of several socio-economic organisations within the island populations. The large islands such as Belle-Île-en-Mer and Groix could have had stratified organisations, with hierarchical groups. The smaller islands such as Houat, Hoedic, Ile aux Moutons or those of the Glénan archipelago could be a continuation of the less complex socio-economic organisations of the Middle Neolithic (fig. 2 and 3). Indeed, the extension of the surface area of the islands may have played an important role in the socio-economic organisation of the island populations. The groups present on the larger islands had access to more resources and developed a more extensive agro-pastoral economy.

Because of their size, these large islands were able to play the role of centres of gravity, attracting not only sailors but also goods. Belle-Île-en-Mer thus seems to have been at the centre of exchanges, as shown by the large number of imported ceramics, but also by the numerous fragments of flint blades from Grand Pressigny (Audouard, 2014 and 2016), the largest known concentration in Brittany's islands. These particularities are exacerbated when compared with the very local productions of the neighbouring sites on Hoedic and Houat. Thus, the hierarchical organisation of Belle-Île could be contrasted with more heterarchical groups within the neighbouring islands, which may have been satellite occupations and interdependent with those of Belle-Île-en-Mer.

These questions allow us to introduce an important notion into our considerations of island occupations and their functional spaces. Indeed, for the Saint-Nicolas site in the Glénan archipelago, we saw that all the ceramics from the site were imported (fig. 3b). The vast majority of them came from the Ile aux Moutons, about 7 km to the north. This is the maximum distance, as defined by the work of D. Arnold, at which most of the materials necessary for the production of ceramics are collected (Arnold, 1985). Beyond this, the cost of supply is considered to be higher than the 'benefits'. This is referred to as a 'preferential exploitation territory' (Arnold, 1985). However, it should be noted that the notion of 'cost' is not necessarily comparable between companies. For example, the distance travelled at sea by island populations does not have the same 'cost' as that travelled on a mainland plain. It is therefore necessary to propose new models, adapted to the territories we are studying and to the impact of their geographies, but also to the means of travel. Indeed, as the distances between the islands are often greater than 7 km, the data resulting from the exploitation of the clayey raw materials of the islands do not always correspond to the distance models of resource exploitation proposed by D. Arnold (Arnold, 1985). These models are therefore not adapted to these territories, particularly those with multiple islands. The hypothesis of expeditions and movements from one island to another, or from the mainland, depending on the season and the raw materials sought, could correspond to the observations made. The territory of exploitation is then not limited to the island, but to a group of islands and the coast, as suggested by L. Marrou (Marrou, 2005), who proposed to use the term 'merritoire', the oceanic equivalent of the term for continental territory.

It is possible to propose the concept of a 'preferential exploitation area' adapted to the problems of material acquisition. This concept would be able to evolve with the improvement of navigation technologies and the socio-economic systems in place. It may function differently according to the layout of the islands, their size, and the distances that may separate them, or their distance from the coast. It is therefore essential to consider these marine populations as highly mobile groups, taking advantage of the biological and mineral resources of the different environments at their disposal. Ceramic transfers can therefore reflect contacts between different populations, but also the temporary movements and settlements of groups.

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NOTES

(1) "Heterarchy may be defined as the relation of elements to one another when they are unranked or when they possess the potential for being ranked in a number of different ways" (Crumley, 1995, p. 3).

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Detecting the Displacement of the Baltic Basin's Ancient Shorelines by Clustering of Terrain and Distance Data along the Glacio-Isostatic Uplift Axis

Identifier le déplacement des anciennes lignes de rivage du bassin de la mer Baltique par le clustering *des données de terrain et de distance le long de l'axe du soulèvement glacio-isostatique*

Edijs Breijers, Edyta Kalińska, Māris Krievāns

Abstract: The successive development phases of the Baltic Sea basin have affected areas that are nowadays exposed, giving rise to numerous ancient shoreline landforms. In present-day Latvia, on the eastern shore of the Baltic Sea, however, these are only vaguely traceable. In order to grasp the dynamic relationship between ancient human activities and the ever-changing shorelines, a case study was carried out on the ancient Ventspils lagoon, north-western Latvia, where several Mesolithic and Neolithic settlements have been investigated. Using an automated LiDAR data-processing method, a highly detailed digital terrain model was created. It has served as the main data source for detecting the ancient shorelines; firstly, for deciphering the most pronounced ridges, and, secondly, as the input data for cluster analysis as elevation data, adjusted according to glacio-isostatic uplift direction and rates. The adjusted ridges were clustered (k-means clustering), and after manual filtering, 25 ancient water levels corresponding to 10 shores in four time periods during the Ancylus Lake and Littorina Sea stages were modelled as trend surfaces. These trend surfaces were then compared with the modern-day terrain to delineate the ancient shores. While the results correspond well with previous findings of shoreline remnants and could be detected in the field, the models show a disconnection from consensual studies in the area when it comes to the positioning of the stages' maximum water levels due to glacio-isostatic uplift. Also, the 25 new ancient water levels reveal a discrepancy with previous studies, where only one or two levels per stage were considered. The methodology developed and the results have various applications in the field of archaeology at sites impacted by glacio-isostatic uplift and with a highly variable water level.
Keywords: Highly detailed digital terrain model, Ancylus Lake, Littorina Sea, Mesolithic, Neolithic.

Résumé : Les phases successives de développement du bassin de la mer Baltique ont affecté des zones qui sont aujourd'hui exondées, donnant naissance à une multitude d'anciennes lignes de rivage. Le long des côtes de l'actuelle Lettonie, sur la rive orientale de la mer Baltique, ces rivages anciens ne sont que vaguement traçables. Afin de saisir la relation dynamique entre les anciennes activités humaines et l'évolution des littoraux, une étude de cas a été réalisée sur l'ancienne lagune de Ventspils, au nord-ouest de la Lettonie, là où plusieurs établissements mésolithiques et néolithiques ont été étudiés. En utilisant une méthode automatisée de traitement des données LiDAR, un modèle numérique de terrain très détaillé a été créé ; il a servi de source principale de données pour détecter d'anciennes lignes de rivage. Les crêtes littorales les plus prononcées ont tout d'abord été identifiées, puis leur altitude a été ajustée en tenant compte de la direction et des taux du soulèvement glacio-isostatique. Les crêtes ajustées ont ensuite été regroupées (*clustering k-means*), et, après un filtrage manuel, 25 anciens niveaux d'eau ont été modélisés au cours des stades du lac Ancylus et de la mer à Littorines. Si les résultats correspondent bien aux découvertes antérieures de vestiges de rivages et ont pu être identifiés sur le terrain, les modèles montrent une déconnexion avec les travaux faisant consensus sur le territoire lorsqu'il s'agit de positionner les niveaux

d’eau maximum des stades, et cela en raison du soulèvement glacio-isostatique. De même, les 25 nouveaux niveaux de paléo-rivages montrent un décalage avec les études précédentes, où seuls un ou deux niveaux par étage étaient identifiés. La méthodologie développée et les résultats obtenus ont différentes applications dans le domaine de l’archéologie, particulièrement sur des sites affectés par le soulèvement glacio-isostatique et de fortes variations du niveau d’eau.
Mots-clés : modèle numérique de terrain à haute résolution, lac Ancylus, mer à Littorines, Mésolithique, Néolithique.

INTRODUCTION

Postglacial isostatic rebound started in the Baltic Sea basin right after the Last Glacial Maximum (LGM), around 20 ka BP, and continues to the present day, with a maximum rate in the Gulf of Bothnia of ca. 1 cm a^{-1} (Ojala et al., 2013). Nevertheless, the uplift rate has been irregular both spatially and temporally. The major components driving this specific spatiotemporal aspect of the development of the Baltic Sea basin are the changes in the global mean sea level and, regionally, the changes triggered by glacio-isostatic adjustment (Björck, 1995).

Once the Fennoscandian ice sheet retreated, the inflow of viscous mantle started raising the terrain back to its original state, thus resulting in a complex pattern of shoreline development. The development of the coasts and shoreline displacement has been extensively studied for years along the Baltic Sea, in its eastern (Tikkanen and Oksanen, 2002; Miettinen, 2004; Ojala et al., 2013; Rosentau et al., 2013), western (Lambeck, 1999; Berglund et al., 2005; Hansson et al., 2019; Kalińska-Nartiša et al., 2017) southern (Schumacher and Bayerl, 1999; Schwarzer et al., 2003; Uścinowicz, 2006; Lampe and Lampe, 2020) and central parts (Svensson, 1991; Wastegård et al., 1995). The first glacio-isostatic rebound rate map for the whole Baltic Sea region, based on the analysis of gravity measurements, levelling data and tide gauge records, was created by M. Ekman (1996). Its general validity has been demonstrated by the correlation with several subsequently created models, such as the latest NKG2016LU model (Vestøl et al., 2019), with some changes in radiality and uplift rates.

While a part of the Baltic coast has been thoroughly studied with respect to tracing ancient shorelines, until now, the Latvian coast of the Baltic Proper is under-studied except for some older studies followed by the later works of G. Eberhards (2003) and G. Eberhards and V. Brenners (2010). The ancient Ventspils lagoon, near the present-day port town of Ventspils, constituting the central-northern part of Latvia’s west coast, provides valuable information on the geomorphological and geological development of this area and its surroundings, which can be related to ancient human activity. There have been several previous studies, with E. Grīnbergs developing the initial ideas (Grīnbergs, 1957) and I. Veinbergs continuing the work (Veinbergs, 1979 and 1996) on the geomorphological aspects, while V. Podgurskis and his team carried out geological mapping of the area (Podgurskis et al., 1987). Despite these studies, the developmental stages and corresponding shorelines have not been well identified in the Ventspils lagoon. This is because the relatively calmer conditions in the lagoon compared with the open sea were not favourable for the formation of distinct shorelines, and also because of the present-day conditions in the area of the ancient lagoon, where several types of erosion have affected the site during the time since the active lagoon stage. Consequently, ancient shorelines were poorly developed and are thus difficult to trace in this area.

This study aims to provide the first high-detail digital terrain model of the ancient Ventspils lagoon in order to detect the past shorelines along the coast of western Latvia. The work proceeded in two steps: (1) deciphering the most pronounced ridges, followed by (2) cluster analysis of adjusted elevation data.

1. REGIONAL GEOLOGICAL BACKGROUND AND THE STUDY AREA

The Ventspils lagoon was located on the eastern coast of the present Baltic Sea, in north-western Latvia (fig. 1). The emergence of this ancient waterbody was related to the retreat of the Fennoscandian ice sheet after the Late Glacial Maximum (LGM) and at the end of the Weichselian glaciation. The development of the present Baltic Sea started with the formation of the Baltic Ice Lake through the merging of several proglacial lakes in the region at around 16 ka BP (Houmark-Nielsen and Kjær, 2003). However, a fully-developed water body, which also encompassed the lowest-lying parts of the present-day dry-land area of Latvia, formed at around 14 ka BP (Vassiljev and Saarse, 2013). Since the coasts of the Baltic Ice Lake stages are 40-60 m above the present sea level in the vicinity of the study area, whereas stretches of the shorelines of the lagoon have been detected at much lower heights (Grīnbergs, 1957), it is safe to assume that the actual formation of the Ventspils lagoon took place after the rapid drainage of the Baltic Ice Lake near Mt. Billingen (Björck 1995) and even after the Yoldia Sea stage, which took place approximately between 11.7 ka BP and 10.7 ka BP, when the coastline formed 5-15 m below the present sea level near the location of the lagoon (Veinbergs, 1979). A freshwater Ancylus Lake started to develop right after the damming of Närke strait, south-eastern Sweden, which was induced by glacio-isostatic rebound (Jensen et al., 1999; Björck, 2008). The rising water level of the Ancylus Lake and continuing longshore sediment drift gave rise to the first coastal formations of the Ventspils lagoon, still detectable in the modern terrain and sediment (Grīnbergs, 1957; Veinbergs 1996). After the initial transgression, which put the Ancylus Lake approximately 10 m above the global mean sea level for 500 years, a rapid regression ensued, signifying the end of the Ancylus Lake stage and the start of the Littorina Sea stage in the Baltic basin (Andrén et al., 2011). The onset of the Littorina Sea stage occurred gradually due to the shallow connections with the North Sea. This stage is often characterized as being marked by several distinct transgressions, with the maximum at about 7.6 ka BP (Björck et al., 2008; Bendixen et al., 2017). Previous studies indicated two traceable Littorina Sea stage transgression coasts in the modern terrain of the ancient Ventspils lagoon (Grīnbergs, 1957; Veinbergs, 1996), while other studies in areas close to the lagoon, for example on the Ruhnu Island (Muru et al., 2018) and in Pärnu Bay (Rosentau et al., 2011; Rosentau et al., 2020), have detected only one major transgressive episode. As the Ventspils lagoon diminished, with a gradual lowering of the water level to its present level, the Littorina Sea stage ended and the present-day Baltic Sea stage commenced.

The Ventspils lagoon spanned ca. 45 km in length and ca. 20 km in width. The present-day Venta river, with several terraces and numerous oxbow lakes, meanders through the ancient lagoon from south-east to north-west and enters the sea in Ventspils harbour. The lowermost parts of the Ventspils lagoon lie between ca. 2.5 and 4.6 m a.s.l. and are occupied by bogs and the coastal lake of Būšnieki. The higher ground, 9.5-19.2 m a.s.l., constituted a set of ancient islands and peninsulas with some pronounced margins, which in many cases provided suitable locations for an ancient human settlement.

According to archaeologists, the unique circumstances that dictated the region's geomorphological and geological development partly explain the somewhat unusual pattern of human settlement during the Stone Age. Since the lagoon served as a very important resource area for fishing, the first human inhabitants created their settlements near the shores of the lagoon, and since the water level in the lagoon fluctuated, there was a need for the inhabitants to shift their settlement locations. Several artefacts that indicate recurring occupation of the same sites have been identified and dated, for example, the Sise site in the southern part of the lagoon (fig. 2) has yielded artefacts correlating temporally with both the Ancylus Lake and the Littorina Sea maximums (Bērziņš et al., 2016). Reuse of some settlements has also been noted at other sites around the ancient lagoon (fig. 2) and, likewise, in the Pärnu Bay area (Rosentau et al., 2011; Rosentau et al., 2020), showing a unique pattern of shifting settlement and suggesting that further investigation of the palaeogeographical setting could lead to the discovery of more similar archaeological sites.

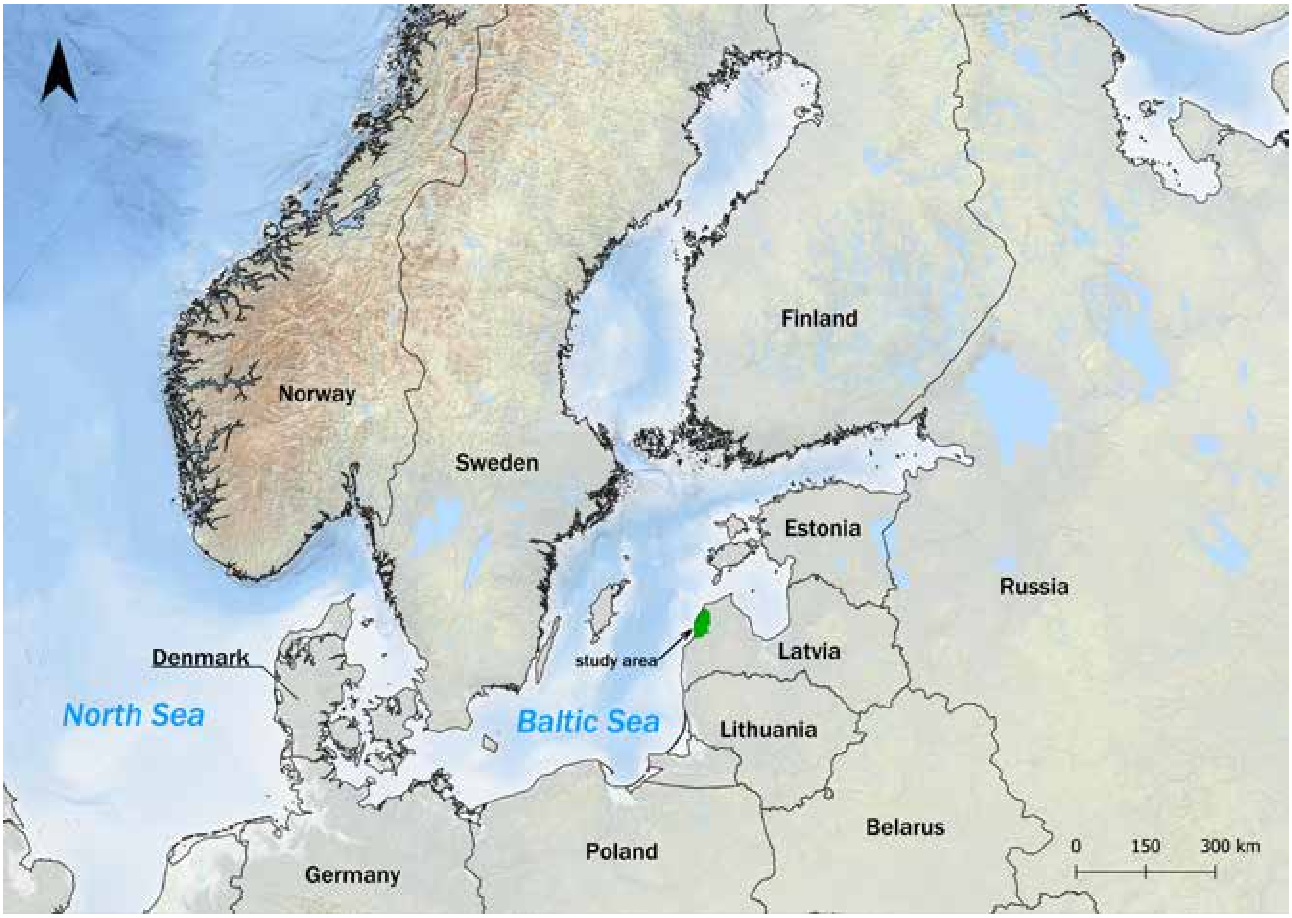

Fig. 1 – The location of the ancient Ventspils lagoon, marked in green (map EMODnet Bathymetry Consortium, 2020).
Fig. 1 – *En vert: emplacement de l'ancienne lagune de Ventspils (carte EMODnet Bathymetry Consortium, 2020).*

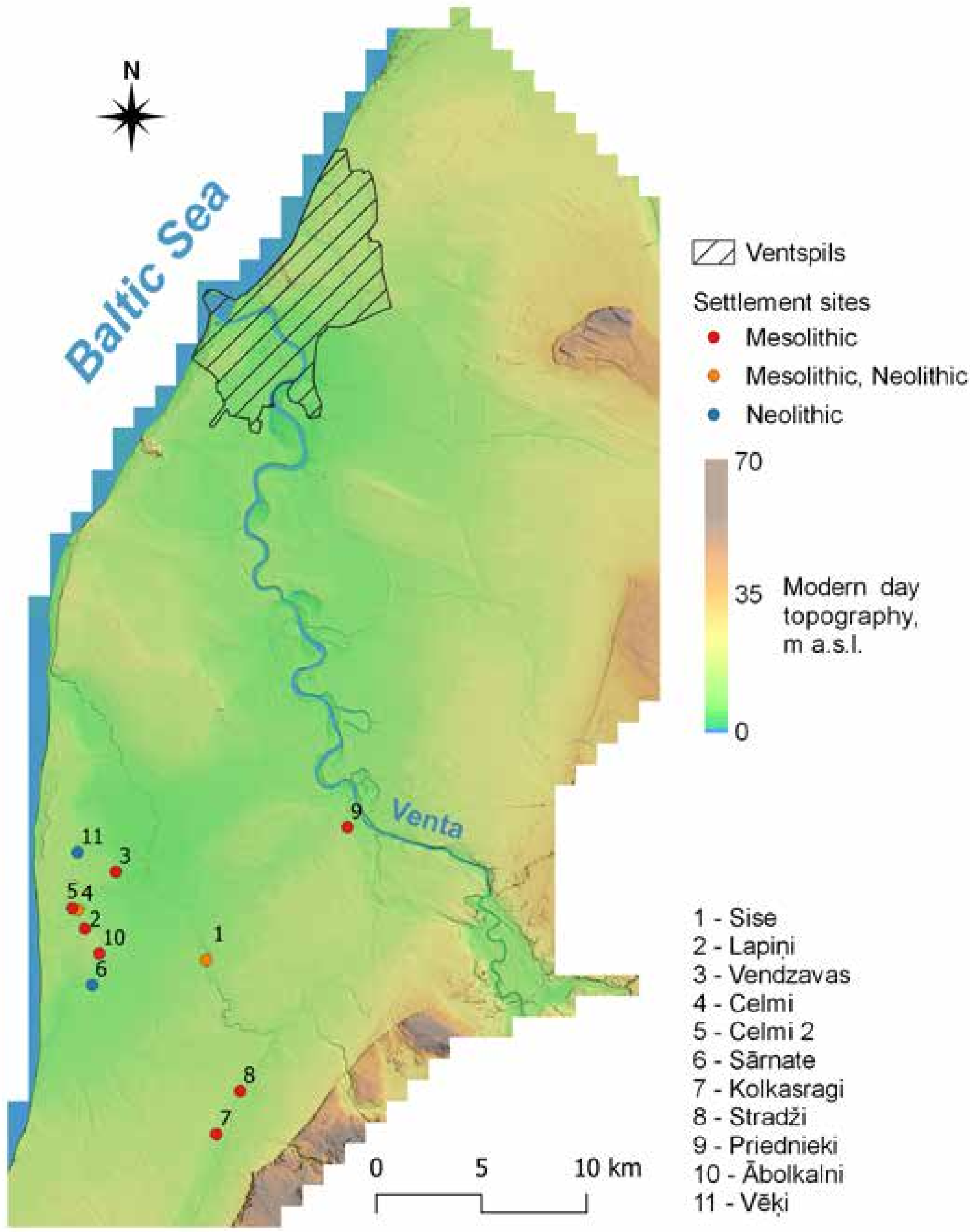

Fig. 2 – Stone Age settlements in the vicinity of the ancient Ventspils lagoon.
***Fig. 2** – Sites préhistoriques situés à proximité de l'ancienne lagune de Ventspils.*

2. MATERIALS AND METHODS

After examining the various studies on the development of the Baltic basin and the impact of glacio-isostatic adjustment in the region, and studies on the ancient Ventspils lagoon itself, a set of materials and methods was compiled to detect the ancient shorelines. Our approach involved, (1) determining the research area and creating a Digital Elevation Model (DEM) and (2) generating the palaeogeographical models to detect the suspected remnants of ancient shorelines in the field. Since this approach is considered valid for application to other similar sites, automatization tools for data acquisition, processing and analysing were built with highly customisable open source tools for work with open data.

2.1. DEM creation and cleaning

With LiDAR remote sensing technology becoming more readily available, the Latvian Geospatial Information Agency has published its survey results as open data in LAS format (LGIA, 2016). In order to acquire the data needed to build the DEM, a simple data download script was created in *Python 3* with *urllib* and *tqdm* libraries, for making URL requests and monitoring progress, respectively. Since the data is stored in 1 km^2 map tiles according to TKS-93, a topographic map system under the coordinate system for Latvia (LKS-92), which is not easily accessible for large regions, the input for the script is a simple list of the specific map tiles, which are selected based on water levels of previous studies in the region and the underlying geology of the lagoon. The tiles list is then iteratively processed, compiling web request links according to the storage template and subsequently downloading and storing each LAS data tile needed for further processing.

After acquiring LiDAR data for the whole study area, each LAS file is classified and filtered in order to obtain the ground points with the Simple Morphological Filter (SMRF) implementation in the Point Data Abstraction Library (PDAL; Pingel et al., 2013; PDAL Contributors, 2018). The ground points are then converted to a point cloud format used by the System for Automated Geoscientific Analyses (SAGA) GIS software and subsequently gridded into a raster format at 5 m resolution, using the Natural Neighbour method. Each resultant raster data file is converted from a SAGA GIS proprietary raster format to *GeoTiff* format using the Geospatial Data Abstraction Library (GDAL) translate function. The creation of the DEM for the study area is automated in *Python 3* using the *subprocess* library to sequence the above-mentioned processing tools, which are packaged in the open source *OSGeo4W* distributions. The terrain models for each of the LiDAR data tiles are obtained and combined (fig. 2) using the GDAL virtual raster format driver (GDAL/OGR contributors, 2019).

2.2. Palaeogeographical modelling

While similar studies (Leverington et al., 2002; Ojala et al., 2013) rely on manually digitizing and grouping ancient shoreline ridges and combining them with various chronological data to obtain ancient water level trend surfaces, this study focuses on terrain changes resulting from glacio-isostatic adjustment. This is done because the ancient shoreline ridges of the lagoon themselves are not prominent enough to be definitive. According to the most successful principles developed in the palaeogeographical reconstructions in the region (Rosentau et al., 2011; Habicht et al., 2017; Rosentau et al., 2020), the water level trends modelled in this study were also compared to the actual terrain.

For a precise analysis and interpretation based on the palaeogeographical models, any major changes to the terrain subsequent to the existence of lagoon conditions in this area, such as dune formation, bog development and various anthropogenic modifications, needed to be excluded. This was done by digitizing the most prominent of these forms from the geological maps (Podgurskis et al., 1987) and the terrain, then rasterizing the polygons and removing them from the DEM with a raster calculator. Holes in the resultant DEM were then closed with the SAGA GIS *Close Gaps* tool.

An ancient shoreline can be detected in various ways, e.g. by carrying out a survey in the field or by marking specific ridge points in the DEM, but the size of the study area, the characteristics of the formation of lagoonal coastal ridges, and even the specific pattern of development of the study area along with the development of the Baltic basin are all limiting factors for implementing the previously established approaches. To detect the potential shoreline ridges in the present-day DEM, downslope index analysis with a drop factor of 1.5 m was carried out using the *WhiteboxTools 1.1.0.* plugin in *QGIS 3.17.0.* The index is output as metres, so the lower the index, the nearer it is to the set 1.5 m drop (fig. 3).

The downslope index, originally created for quantifying topographic impact on local drainage basins, has several other applications in the fields of hydrology, biochemistry and geomorphology (Hjerdt et al., 2004). In this study, this index was used to limit the terrain model to ridges by constraining the index output to 300 m, thus returning only those DEM raster cells that show a relative downward change in elevation by 1.5 m within the nearest 300 m (fig. 4), analogous to current beach ridges in Latvia at sites with similar lowland morphology, and to account for erosion. The set values were empirically acquired to optimally highlight the potential ancient shorelines in the terrain model.

Since the azimuth of glacio-isostatic uplift in the study area is at about 335° (Rečs, Krievāns, 2013), a raster map (d), representing relative distance in the direction of the uplift, was created for the study area. The elevations of the detected ridges (k) were adjusted with the raster calculator according to the uplift rates (g) in the Pärnu Bay area (Saarse et al., 2003; Rosentau et al., 2011). This results in input data needed for further analysis for each stage of interest (P_x, 1.):

$$P_x = \frac{k-(d_{max}-d)*g}{1000}; \quad (1.)$$

since the lagoon existed during the Ancylus Lake and Littorina Sea stages, uplift rates of 0.272 m/km (initial Ancylus Lake stage, approx. 10.5 ka BP), 0.256 m/km (Ancylus Lake maximum, approx. 10.2 ka BP), 0.129 m/km (Littorina Sea maximum, approx. 7.3 ka BP) and 0.106 m/km (post-maximum Littorina Sea, approx. 6.0 ka BP) were used (Saarse et al., 2003; Rosentau et al., 2011). For each of the uplift rates, the adjusted ridge height raster, depicting the palaeoelevations of the ridges, was clustered with the *K-Means Clustering for Grids* tool from SAGA GIS. After several tests with various cluster numbers, division into 30 clusters was chosen. This made it possible to remove invalid clusters depicting, for example, portions of the Baltic Ice Lake stages that might have appeared in the terrain model or riverbanks (fig. 4), while keeping the number of clusters to a manageable level. Each cluster represents the raster cells closest to the respective palaeoelevation centroid, which is determined iteratively by the k-means algorithm, in accordance with the initial cluster number. The hill-climbing method, originally developed to tackle biological taxonomy problems (Rubin, 1967), was used for clustering, rather than the iterative hierarchical minimal distance method (Forgy, 1965), since it yielded more precise results than the full

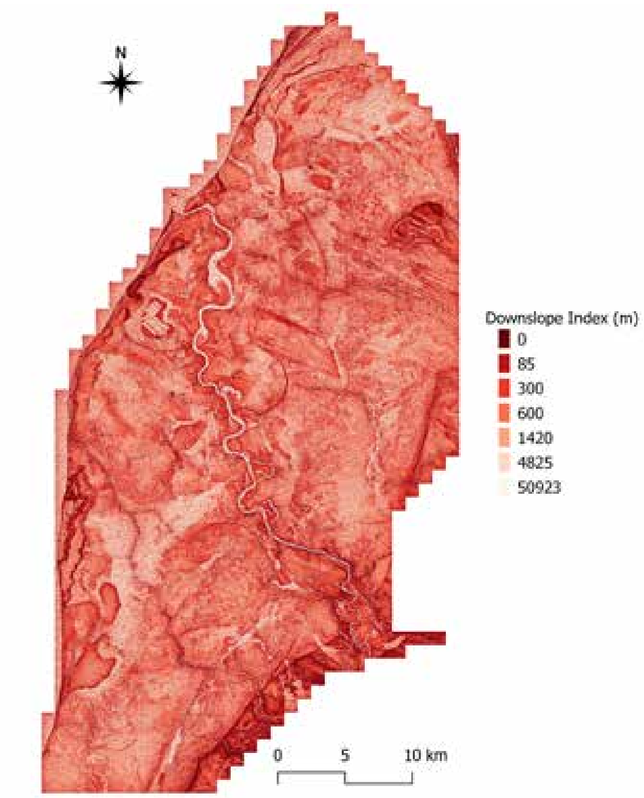

Fig. 3 – Downslope index output for the study area.
Fig. 3 *– Indice de pente descendante pour la zone d'étude.*

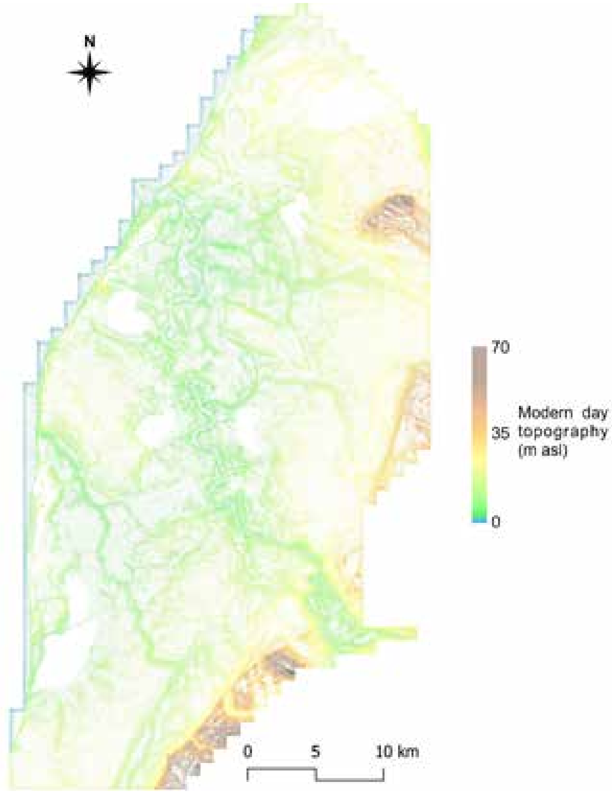

Fig. 4 – Initial terrain raster cells acquired by filtering downslope index values.
Fig. 4 *– Cellules raster de terrain acquises par filtrage des valeurs de l'indice de pente descendante.*

terrain model. Both of these methods are available in the SAGA GIS tool.

After clustering each of the adjusted ridge height rasters, the results were used in an automation script for shoreline detection. The *Python 3* script was written to operate with *QGIS 3.17.0* environment variables by initializing *QGIS* resources, e.g. *qgis.core* and *qgis.analysis* modules alongside the *processing* framework (Graser and Olaya, 2015). By building a standalone script and initializing the *QGIS* resources separately, modularity could be maintained, permitting the addition of external operators to the workflow, like the *WhiteboxTools Python* library (Lindsay, 2014). Once the environment was set and all the required tools imported, the overall script variables were set, such as the number of clusters to be created (or specific clusters to be created for testing purposes) and paths to the cluster raster file, the terrain data file and the output folder. The cluster raster files for each uplift rate were then iteratively processed cluster by cluster, defining paths for temporary data layers and for the resulting data in raster and vector formats. Present-day terrain values were assigned to the cluster's raster cells with GDAL's raster calculator from the *QGIS processing* framework by obtaining the clustered cells and multiplying them by the DEM. A linear trend surface for each surface was computed with the *TrendSurface* tool from the *WhiteboxTools* library. A first order polynomial linear trend was chosen, because of the relatively small size of the study area in terms of glacio-isostatic adjustment, where the models show linearity in the current adjustment rate at the ancient Ventspils lagoon (Ekman, 1996; Vestøl et al., 2019). The initial trend surface was compared with the input data in the raster calculator to narrow it down to ± 0.4 m before the final trend surface analysis using the *TrendSurface* tool. By comparing the final trend surface of each cluster with the terrain model in the raster calculator, the extent of the lagoon at the given cluster and, therefore, the respective shoreline, can be derived. Since the expression is set up to return a value of '1' for the raster cells 'submerged' at the time of the cluster, and a value of '0' for terrestrial cells, the result can be extracted as both vector and raster data, which are useful for faster verification workflows and storage saving, and for quality visualisation rendering, respectively. The script allows the shorelines to be described as polygons, using the GDAL *Polygonize* tool coupled with several simplification tools, such as *Keep N biggest parts*, *Simplify geometries* and *Delete holes*. Respective water levels and adjusted terrain raster data are generated by carrying out operations in the raster calculator, e.g. by subtracting the trend surface from the present-day DEM to get the terrain situation at the time of the specific water level. After processing a cluster, temporary data layers are deleted to clean up the workspace. The full palaeogeographical modelling workflow is shown in figure 5.

To validate a cluster, its trend surface data of glacio-isostatic rebound rate and the direction of the surface uplift, calculated trigonometrically from the trend surface regression coefficient values reported by the *TrendSur-*

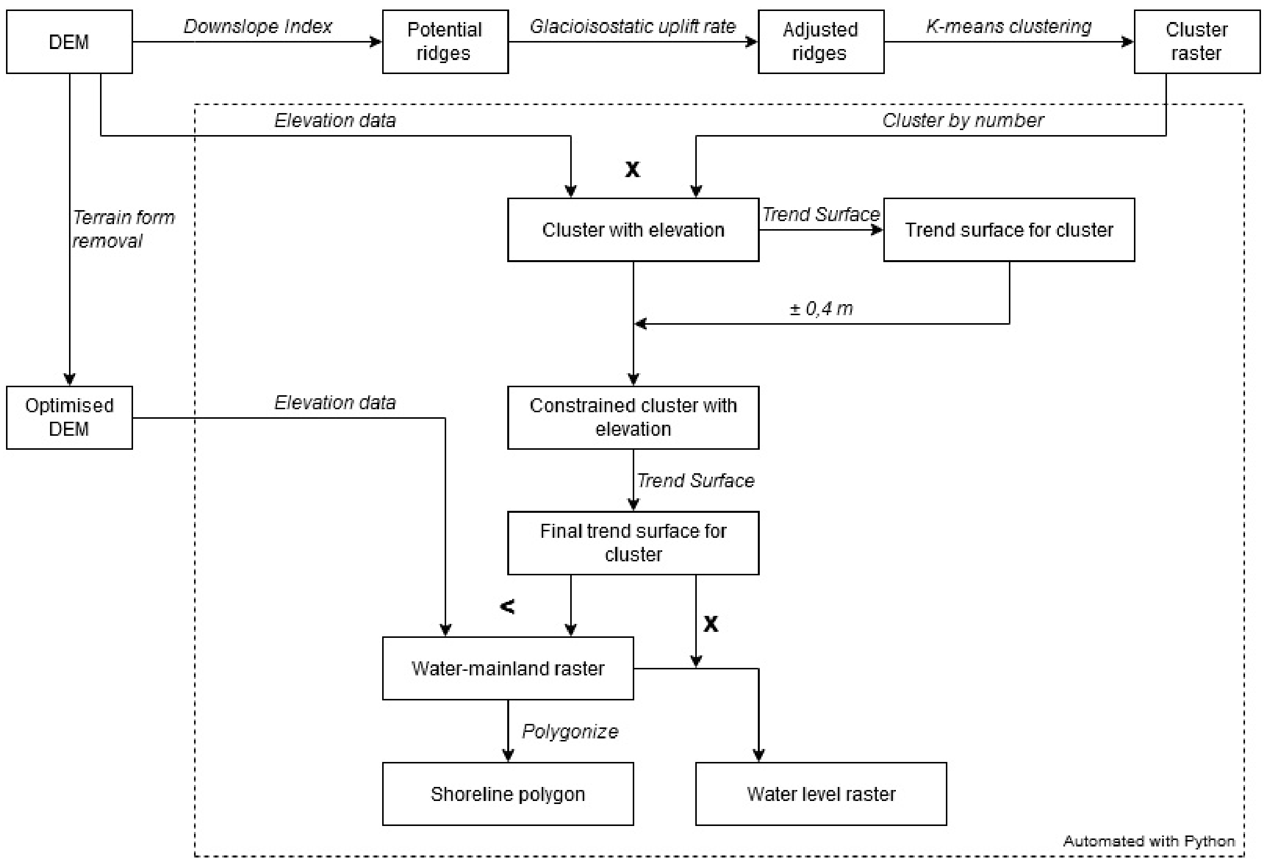

Fig. 5 – Palaeogeographical modelling workflow developed by the authors in the course of the study.
***Fig. 5** – Workflow de modélisation paléogéographique développé par les auteurs au cours de l'étude.*

face tool, are compared to the original input rebound rates and direction data. Additionally, manual verification using the *Profile Tool* plugin in *QGIS* was carried out to determine the conformity of clusters and the DEM. In the example shown in figure 6, the terrain profile is shown in black and the coloured line represents the clusters, which show a good fit for the fourteenth and twenty-first clusters, as they depict a zone in the terrain that resembles a water level right by the shoreline ridge.

3. RESULTS AND DISCUSSION

Several elements were comprehensively developed over the course of this study: (1) the DEM for the study area as a base for this and further studies, (2) a workflow for the detection of ancient shorelines applicable in situations with known glacio-isostatic uplift rates and directions, along with (3) various workflow automation scripts. These three elements have contributed to the building of palaeogeographical models for different time/stage slices, which not only serve to validate the workflow but are also of use with archaeological data, since correlations could be drawn between the obtained models and the previously known settlement sites located on the same shore and relating to the same time (fig. 6).

3.1. Terrain creation and optimisation

Data acquisition was automated, which saved an estimated 9 hours of manual work for the 1257 km^2 of the study area and ensured that no human error could occur during the download of the required data, which can otherwise lead to downloading superfluous data or incomplete download of the required data. The workflow regarding DEM creation is constituted by several steps utilising several open source tools, which all have to be engaged for each of the LiDAR data tiles. Since this workflow was automated in our study, it omitted steps that would normally require thousands of manual actions. The removal of relief forms post-dating the lagoon stage of the area from the DEM (fig. 7) essentially provided not only the basis for palaeogeographical reconstructions, but also data for further archaeological investigations in the area.

3.2. Palaeogeographical modelling

With a view to possible application to other sites, the highly customisable automation script, which chains together 13 different open source tools, creates a palaeogeographical model with all of the requested data, e.g. a terrain raster for the specific period or the shoreline polygon, in approximately 4 minutes. Four specific time slices are considered in the Baltic Sea basin: initial Ancy-

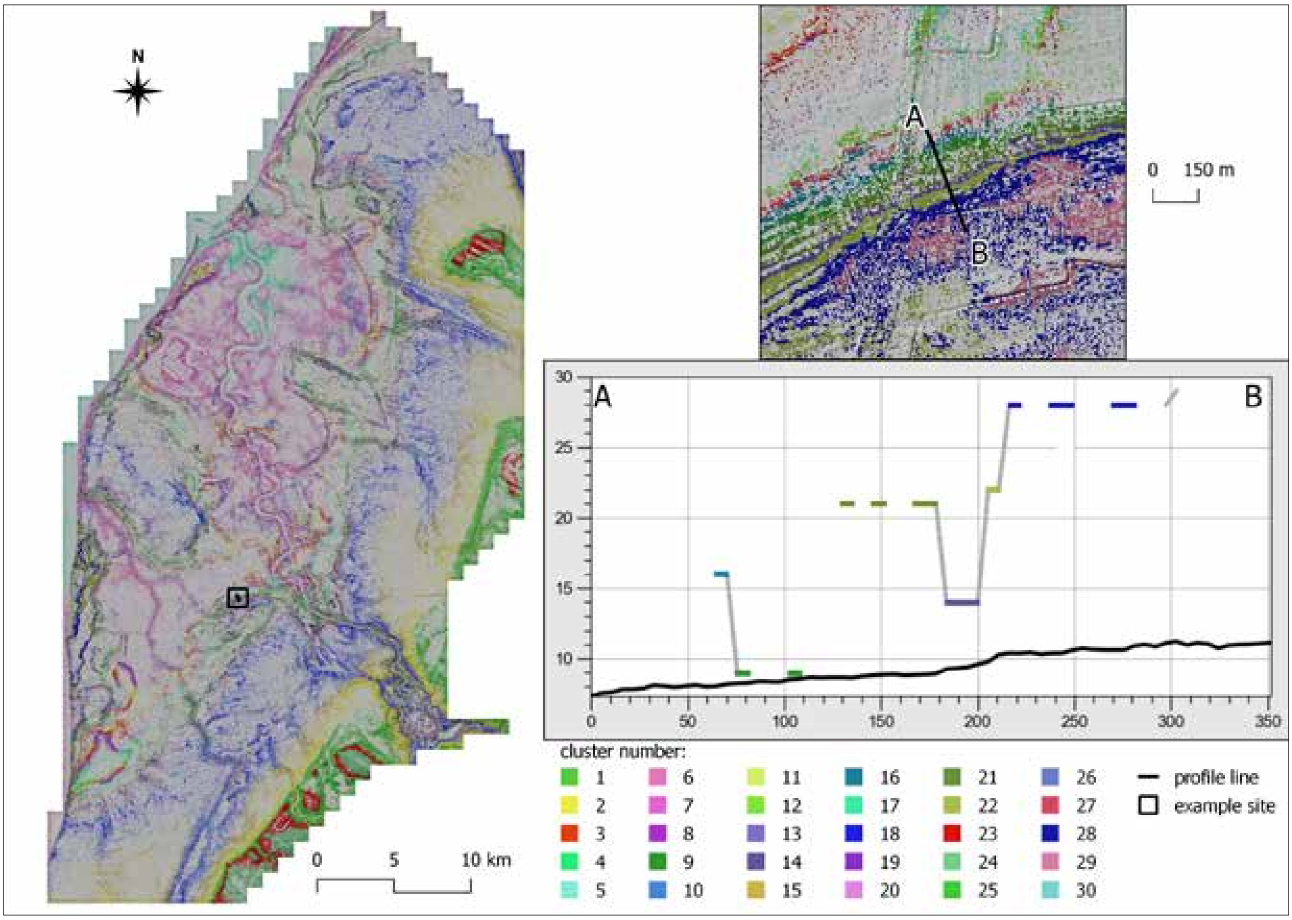

Fig. 6 – An example of manual verification process using the profile tool (green, blue, red, deep pink areas show resultant clusters).
***Fig. 6** – Exemple du processus de vérification manuelle à l'aide de l'outil de profil (les zones vertes, bleues, rouges et rose foncé montrent les clusters résultants).*

lus Lake (approx. 10.5 ka BP), Ancylus Lake maximum (approx. 10.2 ka BP), Littorina Sea maximum (approx. 7.3 ka BP) and post-maximum Littorina Sea (approx. 6.0 ka BP; Saarse et al., 2003; Rosentau et al., 2011), and these were selected for reconstruction in this study. Each time frame was clustered into 30 clusters, and the automatic process of creating these 120 (4 x 30) initial variants took ca. 8 hours.

After comparing the trend data with the input data and manual verification, 25 out of 120 models were determined to be valid for use in this study. For the initial Ancylus Lake stage, there are four shorelines, belonging to a single stable period, most likely depicting a part of the transgressive phase of the Ancylus Lake stage because this occurred before and is located below the maximum stage. A large proportion, namely eleven out of the 25 valid models align with the Ancylus Lake maximum, grouping into five distinct shoreline groups. Six of the models are grouped into three stable groups belonging to the Littorina Sea maximum, and finally the four remaining models belong to one stable shore during the post-maximum Littorina Sea stage. The results of our modelling work disagree to some extent with previous studies, which considered only one or two shorelines per stage (Grīnbergs, 1957; Veinbergs 1996).

Although deciphering from the relative displacements of the shorelines in this way does present some difficulties due to readability issues, when viewed together, the overall relations of the modelled time period shorelines can be interpreted (fig. 8). For example, a closer look at the northernmost part of the Ventspils lagoon reveals the highest modelled shorelines for each modelled period (fig. 8).

With the start of the Ancylus Lake stage, when a separate water body developed, several islets were formed (fig. 8), and a rapid water level rise took place over the course of a few hundred years in the Ventspils lagoon. A similar rise is also known in the literature in connection with the development of the Baltic Sea basin (Björck, 1995; Andrén et al., 2011) and from the investigation of the archaeological record of the Ventspils lagoon itself (Bērziņš et al., 2016). The existence of a separate water body can also explain the relatively large difference in the elevations of modelled shorelines corresponding to the Ancylus Lake stage. After the retreat of the Ancylus Lake, when the water level in the region fell below the present sea level (Rosentau et al., 2020), the Littorina Sea stage commenced, with a number of islands emerging in the Ventspils lagoon (fig. 8). After reaching its maximum, the water level fell gradually, since the height difference

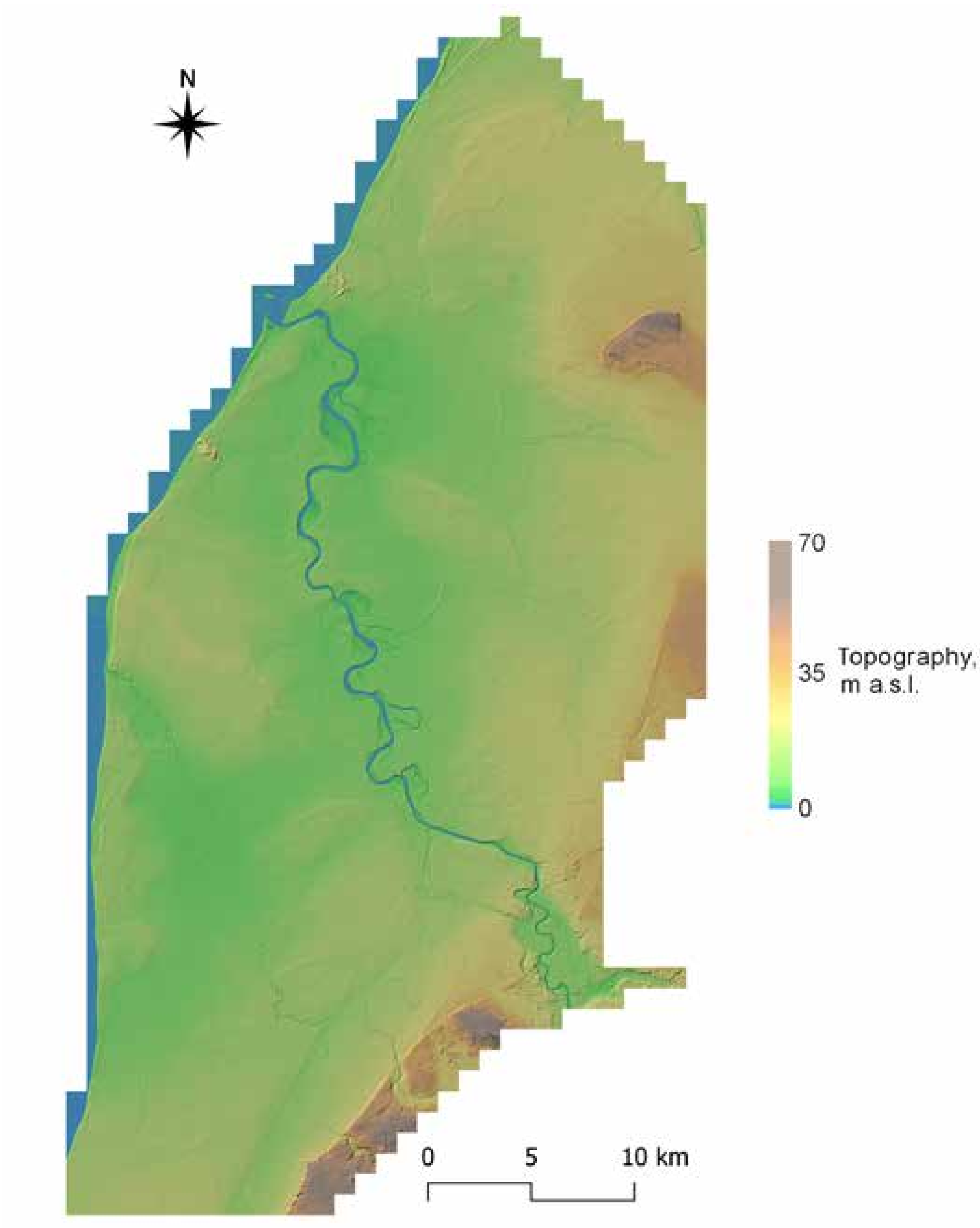

Fig. 7 – Optimised terrain model for palaeogeographical modelling, where relief forms post-dating the lagoon (major dune formations, raised bog, etc.) have been removed.

Fig. 7 *– Modèle de terrain optimisé pour la modélisation paléogéographique ; les formes de relief postérieures à la lagune (formations dunaires majeures, tourbières hautes, etc.) ont été supprimées.*

between the Littorina Sea maximum and the post-maximum Littorina Sea periods, corresponding to approximately 1.3 ka, is relatively small (fig. 8).

Even though the ancient shoreline fragments, detected at several sites across the area of the Ventspils lagoon (Grīnbergs, 1957; Veinbergs 1996), fit very well with the models height-wise, the apparent consensus view, according to which the Ancylus Lake stage is generally positioned above the Littorina Sea stage, cannot be confirmed. This is because several Littorina Sea stage maximum models are above some of the Ancylus Lake maximum models in the southern part of the lagoon, while the same models show an inverted hypsometric relationship in the northern part of the area, with some fragments overlapping. Looking at the highest modelled shorelines that mark maximum stages reveals the differences in shoreline displacement and an apparent impact of glacio-isostatic uplift. In the southern part of the lagoon, the shorelines are virtually the same, whereas on the northern side, the Ancylus Lake maximum is substantially higher than the Littorina Sea maximum compared with modern-day topography. Situations like these cause difficulties for the task of precisely placing the modelled shorelines in time by dating techniques. While the ridges in the southern part of the ancient lagoon can be visually detected in the field, there is no guarantee that a particular

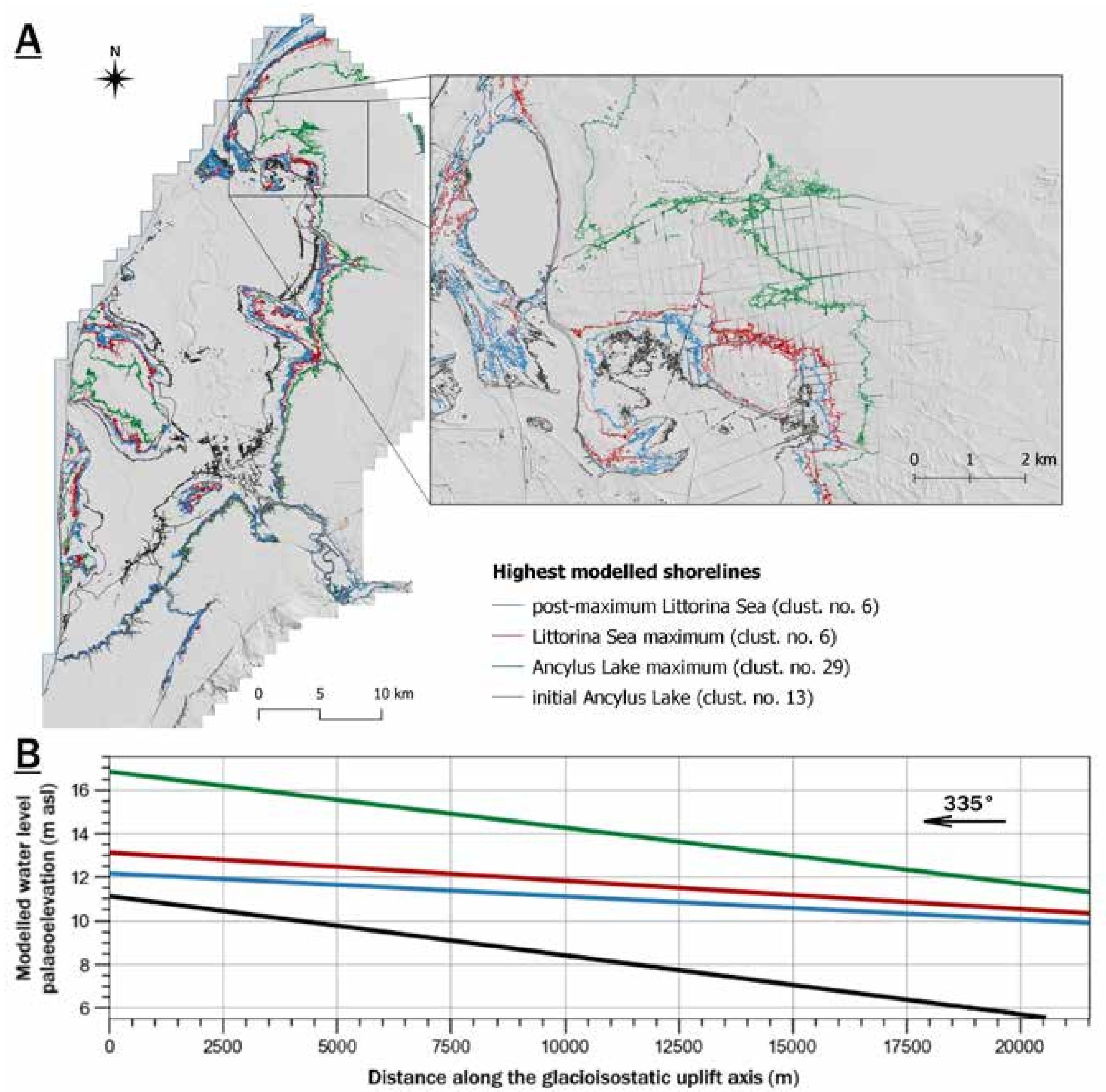

Fig. 8 – Highest shorelines for each modelled time period (A) and their respective water level trends along the glacioisostatic uplift axis (B).

***Fig. 8** – Lignes de rivage les plus élevées pour chaque période modélisée (A) et leurs tendances respectives du niveau d'eau le long de l'axe du soulèvement glacioisostatique (B).*

ridge corresponds to the maximum of the Ancylus Lake stage or the maximum of the Littorina Sea stage, since the models overlap (fig. 9).

3.3. Archaeological context

The model could have a wide range of applications in archaeology: it will permit a more comprehensive understanding of Stone Age settlement dynamics and living conditions, in particular with respect to fishing and other subsistence activities, which are influenced by the terrain and water depths; it extends the possibilities of targeting specific locations over the course of future archaeological prospection aimed at discovering Stone Age sites; and it enables the correlation of dated sites with sites that have not been dated, by comparing their geographical association with particular shorelines. For example, at the Lapiņi site (Bērziņš and Doniņa, 2014) and Sise site (Bērziņš et al., 2016), artefacts have been recovered that correspond to the onset of the Ancylus Lake stage, which occurred ca. 10.5-10.2 ka BP (Rosentau et al., 2011). The Priednieki site has not been dated yet, but it is thought to be Middle Mesolithic, i.e., 10.3-8 ka BP (Damlien et al., 2018). If we assume that this site was located by one of the Ancylus Lake maximum shorelines (fig. 10), then the model helps to narrow down the age of this site.

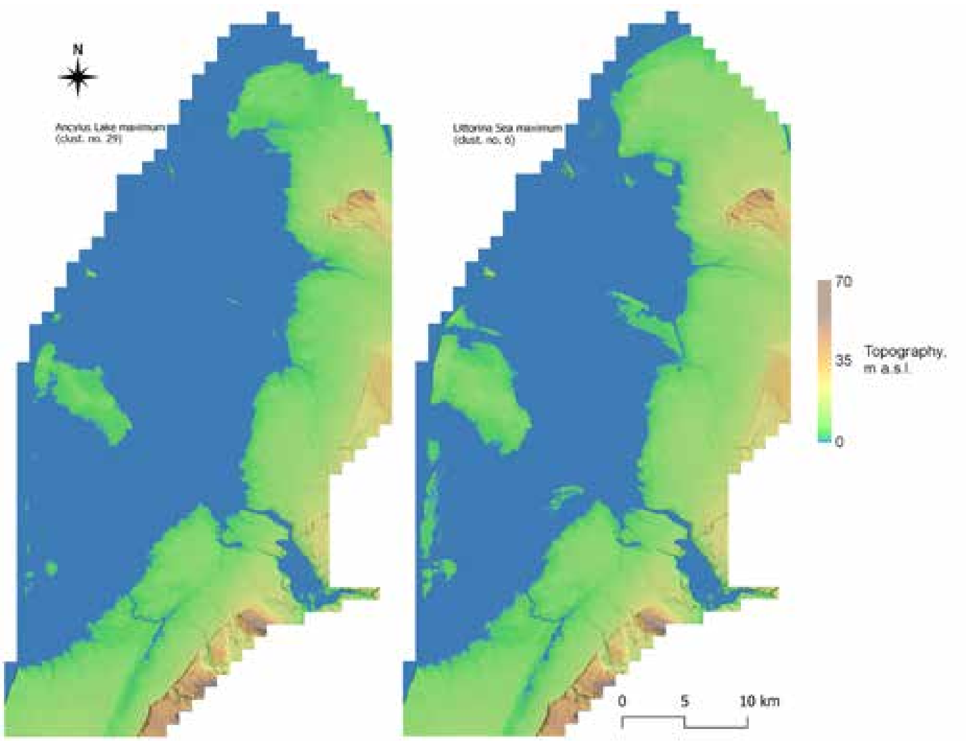

Fig. 9 – Comparison of the highest modelled shoreline palaeogeographical models for the Ancylus Lake maximum (cluster no. 29) and the Littorina Sea maximum (cluster no. 6) periods.

***Fig. 9** – Comparaison des modèles paléogéographiques des plus hauts rivages modélisés pour les périodes du maximum du lac Ancylus (cluster n° 29) et du maximum de la mer à Littorines (cluster n° 6).*

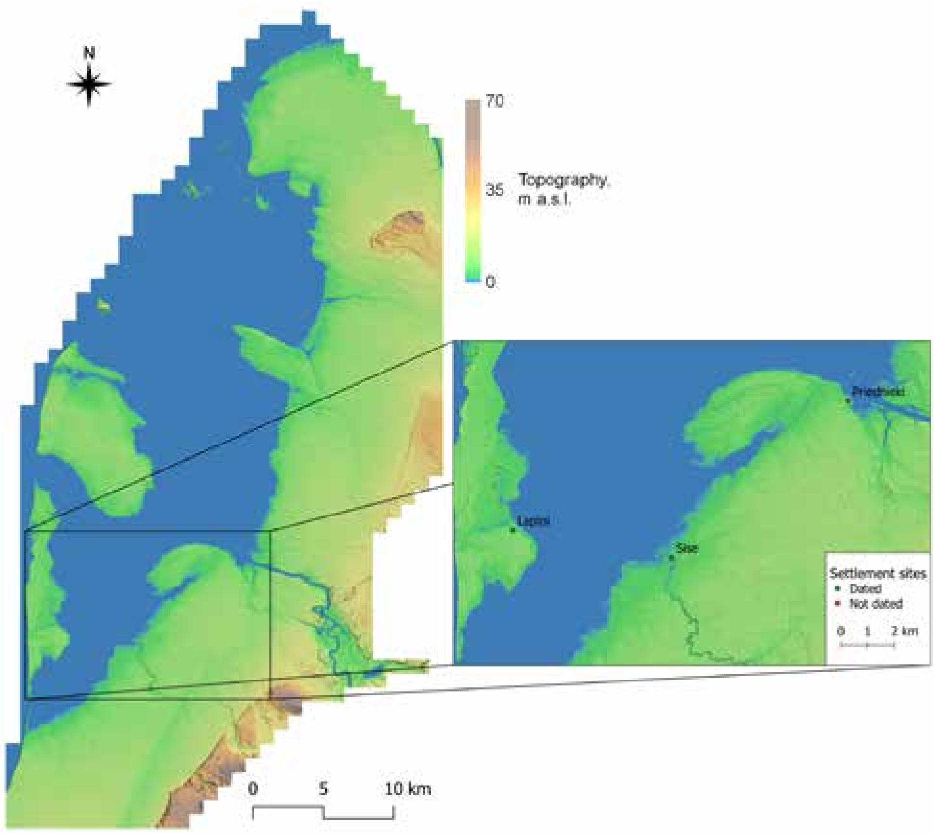

Fig. 10. The position of the Lapiņi, Sise and Priednieki sites in relation to the Ancylus Lake maximum (cluster no. 27) palaeogeographical model.

***Fig. 10.** Position des sites de Lapiņi, de Sise et de Priednieki par rapport au modèle paléogéographique du maximum du lac Ancylus (cluster n° 27).*

CONCLUSIONS

The development of automation scripts enables the workload to be reduced. For example, approximately 9 hours of manual work was eliminated during the data acquisition phase alone. Furthermore, the automation of processes gives a degree of leeway when experimenting with various values during the methodology -building phase. Making the scripts modular allows the user to acquire the resultant data in the formats as desired for overview, analysis, or visualisation purposes.

In the vicinity of the ancient Ventspils lagoon, 25 shorelines, which are divided into 10 relatively stable shore phases, corresponding to four selected periods of time during the Ancylus Lake and Littorina Sea stages, have been identified in this study. This contrasts with previous studies, where only one or two shorelines per development stage were considered and further correlated with the maximum phases of the Ancylus Lake and Littorina Sea. Our study reveals that these stages are not so homogeneous, and that parts of the Littorina Sea stage models could be detected relatively higher than parts of the Ancylus Lake stage models, due to the impact of glacio-isostatic adjustments. Nevertheless, the models correlate well with the previously described heights of ancient shoreline remnants.

Our results have a wide application and can be used for archaeological interpretations and studies in nearby regions. The results could also be used for narrowing down the age of ancient settlements, although further investigations are needed in this regard to warrant the spatiotemporal connection of settlements located beside the same modelled shorelines.

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Empty Edges? Ten Years of Searching for Prehistory on the Atlantic Coasts of Scotland

Une bordure vide ? Dix ans à la recherche de la Préhistoire sur les côtes atlantiques de l'Écosse

Stephanie F. Piper

Abstract: The Highlands and western islands of Scotland demonstrate great potential to further understanding of prehistoric occupation at the most north-western edges of Atlantic Europe, where intensive research strategies are employed. However, several factors limit archaeological investigation, resulting in large gaps in the record from both a geographic and chronological perspective. This paper presents the different survey and excavation techniques that have been employed in three areas, and the contribution the results have made towards a better understanding of prehistory along the "empty" coastal edges of this remote and under-investigated region. These projects have yielded evidence from late Mesolithic shell middens, buried land surfaces and lithic scatters, to a burnt mound of probable Bronze Age date. Issues of the effects of coastal erosion and heritage protection of prehistoric archaeological sites with no upstanding remains unite these projects and are discussed in relation to national and regional archaeological frameworks.
Keywords: Scotland, Mesolithic, Early Neolithic, Bronze Age, burnt mound, lithic scatter, coastal erosion, walk over survey, survey methodology, research framework.

Résumé : Les Highlands et les îles occidentales de l'Écosse présentent un fort potentiel pour améliorer notre compréhension de l'occupation préhistorique des régions les plus septentrionales de l'Europe atlantique. Cependant, un certain nombre de facteurs ont limité les recherches archéologiques et de nombreuses lacunes subsistent, aussi bien géographiques que chronologiques, subsistent. Cet article présente les progrès réalisés et les défis relevés grâce à différentes méthodes de recherche et techniques de fouille appliquées dans trois zones au cours de dix années de travail de terrain. Les résultats qui en découlent nous offrent une meilleure compréhension de la Préhistoire des côtes de cette région septentrionale, éloignée et peu étudiée.
Dans le nord-ouest de l'Écosse, les indices d'une occupation préhistorique précoce sont très rares et souvent profondément enfouis sous la tourbe ou des dunes de sable (machair). Par conséquent, les techniques traditionnelles de prospection archéologique non invasive, telles que l'étude géophysique et la prospection de terrain, sont inefficaces. De plus, il existe peu de grands projets d'infrastructure susceptibles de faciliter l'identification de nouveaux sites dans le cadre de fouilles préventives financées par des promoteurs.
Dans cet environnement exposé à l'Atlantique, les menaces qui pèsent sur le patrimoine côtier, en raison des changements climatiques et des aléas naturels, constituent une préoccupation majeure pour la gestion future des ressources archéologiques. Les risques les plus importants pour la zone des Highlands sont la variabilité extrême des précipitations, qui provoque des inondations, et l'instabilité du sol, car le ralentissement du soulèvement isostatique ne compense plus l'élévation croissante du niveau de la mer.
Des études antérieures ont intégré l'érosion dans leurs méthodologies pour détecter de nouveaux sites préhistoriques. Les trois projets présentés ici appliquent ces méthodes et les modèles prédictifs existants pour détecter des occupations préhistoriques dans des environnements côtiers où leurs traces sont rares.
Le premier projet a été mené dans les Hébrides extérieures. Des amas de coquillages de la fin du Mésolithique et des surfaces d'occupation contenant des éclats lithiques, des foyers et des restes fauniques ont été découverts sur plusieurs années en raison de l'érosion côtière. Ces sites sont disposés selon le *Danish fishing site model* et fournissent des preuves rares de la préservation des matières organiques.
Le deuxième projet, sur l'île de Muck, dans les îles Small, a permis d'identifier des assemblages lithiques et des poteries dans des puits

de sondage, à proximité de baies abritées. Ces assemblages indiquent une occupation datant du Mésolithique et du Néolithique-âge du Bronze, venant compléter les précédentes découvertes : des restes lithiques hors stratigraphie et une épée datant de l'âge du Bronze. Les faibles concentrations au sein d'un horizon stratigraphique homogène semblent toutefois représenter un « bruit de fond » plutôt que de véritables zones d'activité. Il semble que l'absence de couverture protectrice de la tourbe ou du machair ainsi que la longue histoire de cultures des sols aient considérablement perturbé les sites préhistoriques.

Dans le troisième projet, une prospection de terrain a été menée sur une section de la côte de Wester Ross, en Écosse continentale. Un monticule brûlé, datant probablement de l'âge du Bronze, a été identifié par la découverte de fragments lithiques et de pierres brûlées, dans une section érodée par le passage du bétail et le glissement du sol. Au cours des fouilles, dans les surfaces d'occupation identifiées sous le monticule, du charbon de bois a été récupéré et daté. Les datations radiocarbone du site ne sont postérieures que d'environ 200 ans aux premières dates néolithiques de la région des Highlands, en Écosse. Ces résultats sont particulièrement importants, étant donné que les vestiges néolithiques solidement datés dans la région sont presque absents. Le travail de post-fouille, en cours, permettra d'approfondir la compréhension de ces monuments, particulièrement rares dans l'ouest de l'Écosse.

L'impact de l'érosion côtière et la protection du patrimoine des sites archéologiques côtiers préhistoriques sont au cœur de ces projets. L'érosion est indéniablement dommageable pour l'environnement naturel, mais l'exposition causée par ces processus peut être utilisée pour faciliter la recherche de sites et de paysages archéologiques souvent profondément enfouis et difficilement détectables en surface. Il est reconnu que si les stratégies de prospection employées sont systématiques, la nature de l'érosion ne l'est pas. Ainsi, les mêmes régions doivent être fréquemment réexaminées à mesure que l'érosion se poursuit. La compréhension de la géomorphologie locale, combinée à la connaissance des zones à haut risque d'érosion, peut alors être utilisée pour développer des méthodologies prédictives qui facilitent une approche d'investigation plus ciblée et une surveillance active.

Mots-clés : Écosse, Mésolithique, Néolithique ancien, âge du Bronze, monticule brûlé, érosion côtière, prospection pédestre, méthodologie de prospection, cadre de recherche.

INTRODUCTION

The coasts and islands of western Scotland present highly enigmatic archaeological evidence regarding early prehistoric occupation at the edges of the European continent. Until recently, in situ evidence for an Upper Palaeolithic presence was unknown (Mithen et al., 2015; Hardy et al., 2020); Mesolithic occupation of the Western Isles remained speculative (Edwards and Mithen, 1995; Gregory et al., 2005); and chronologies for the Atlantic spread of Neolithic lifeways to the area still lack resolution (Whittle et al., 2011; Garrow et al., 2017). It is a region that has remained comparatively empty in our understanding, but the extent to which this reflects true absence of prehistoric populations or, more likely, bias in research activity remains unresolved.

In this exposed Atlantic environment, threats to Scotland's coastal heritage from the effects of changing climate and natural hazards are a significant priority in the future management of the archaeological resource (Harkin et al., 2018). Coastal Zone Assessment Surveys (CZAS) conducted between 1996-2010 recorded threat levels to archaeological sites, yet only cover 30% of the Scottish coastline (Dawson, 2010). The Historic Environment Scotland Climate Change Risk Assessment indicates that in the coastal Highland region, the greatest risks are twofold: more extreme variation in precipitation has implications for flooding and instability of sloping ground; and slowing isostatic uplift no longer offsets increasing rates of sea level rise (Rennie and Hansom, 2011; Harkin et al., 2018, p. 37-39). This assessment only accounts for properties in its care however, of which there are few in the Highlands and Hebridean islands (Harkin et al., 2018, p. 8). These reports nevertheless provide a baseline for the impact of erosion in the coastal zone and highlight areas where such information is lacking.

In north-west Scotland, the evidence for early prehistoric occupation is highly ephemeral and often deeply buried. The Highlands are dominated by mountains, heathland, and peat formations up to 7 m deep; substantial tracts of managed forestry cover 13% of the region (The Scottish Government, 2011, Annex C; The Highland Council, 2018). This severely limits the use of traditionally non-invasive survey methods to identify new archaeological sites without upstanding remains (Edwards and Mithen, 1995, p. 349). Furthermore, developer-funded rescue excavations favour the urbanised central belt and east coast (Phillips and Bradley, 2004, p. 20).

Whilst much of south-western Scotland is undergoing isostatic uplift, other areas are experiencing marine transgression. The zero isobase for the Main Postglacial Shoreline cuts a north-easterly trend through the centre of Skye and the north-western coastline of Wester Ross (fig. 1; Smith et al., 2000, p. 499). In the Western Isles, the Mesolithic shoreline c 6200 cal. BC may have been c -2.17 m to -5 m OD than at present (Jordan et al., 2010, p. 131). Here, the inland incursion of machair (calcareous shell sand) dunes have buried some coastal regions in the same way peat formations have inland, paradoxically providing ideal preservation conditions for organic remains, where the acidic peats do not (Edwards and Mithen, 1995).

This combination of factors means the early prehistoric archaeological record of western Scotland often goes undetected or unrecognised and is therefore extremely vulnerable to loss. Despite these challenges, erosive processes have also played an important role in exposing invisible sites, often with excellent levels of preservation, especially after periods of extreme weather (Dawson, 2010; Atkinson and Hale, 2012, p. 48; Hambly, 2017).

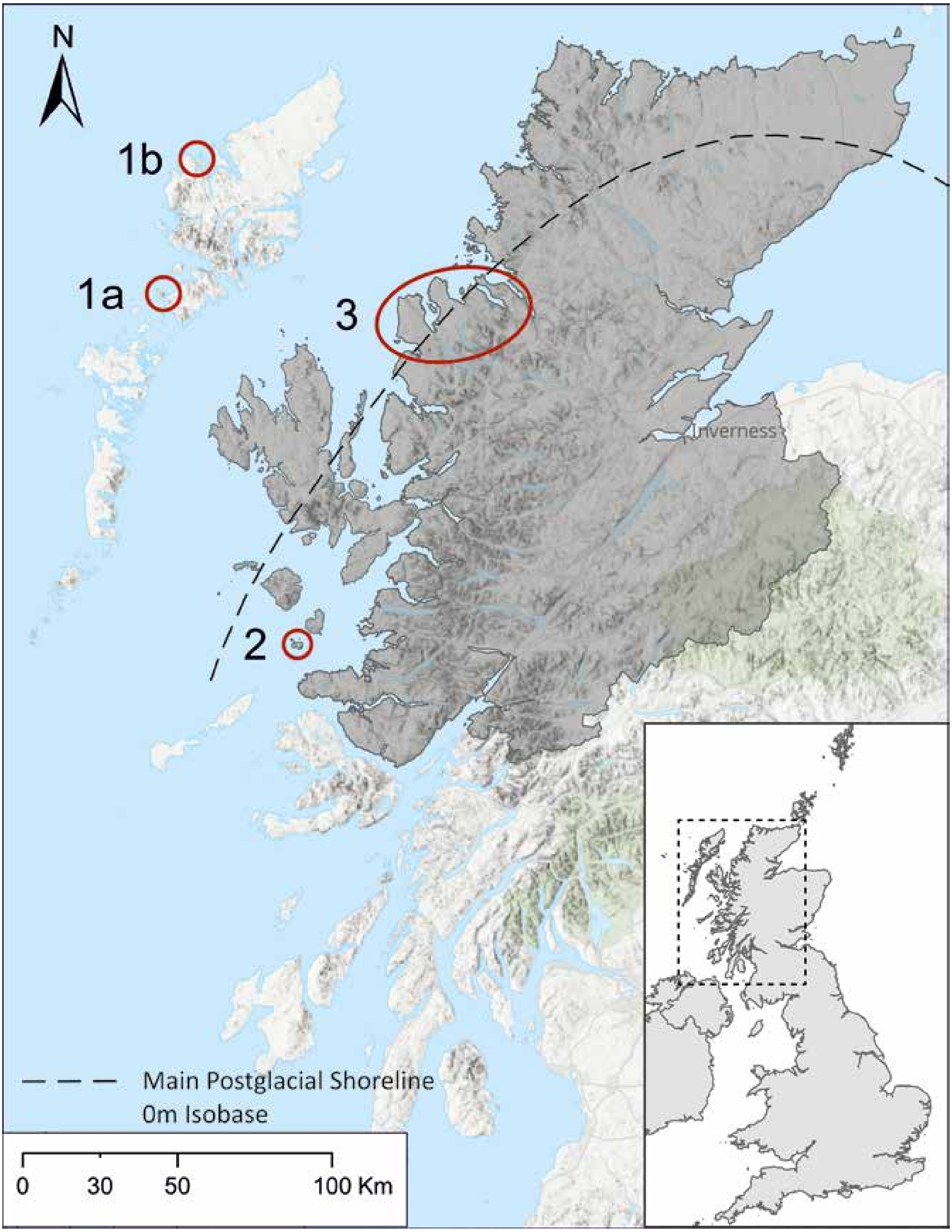

Fig. 1 – Project locations. Western Isles Mesolithic Project: Harris (1a); Lewis (1b). Early Prehistoric Maritime Communities of Western Scotland, Muck (2); CAERoS (3). The Highland Council area is shaded dark grey (© Crown copyright and database right 2021 Ordnance Survey).

Fig. 1 *– Sites présentés dans le projet. Projet mésolithique sur les Hébrides extérieures : Harris (1a) ; Lewis (1b). Premières communautés maritimes préhistoriques de l'ouest de l'Écosse : Muck (2), îles Small ; CAERoS (3). La zone du Highland est colorée en gris foncé.*

1. EROSION AS A RESEARCH METHOD IN WESTERN SCOTLAND

Discoveries of buried early prehistoric sites in western Scotland have primarily arisen from intensive research strategies of survey and test-pitting in exposed coastal locations of the mainland and islands. Over the last twenty-five years concentrated investigations, with a particular focus on the Mesolithic period, have resulted in a corpus of new archaeological data that has substantially broadened our understanding of hunter-gatherer occupation in this corner of Europe. Such examples include the Scotland's First Settlers (SFS) project which targeted the coasts of Skye and the Inner Sound, identifying 129 new archaeological sites, of which 48 were prehistoric (Hardy and Wickham Jones, 2009), and the Inner and Southern Hebrides Mesolithic projects (Mithen, 2000; Mithen et al., n.d.).

These projects have collectively implemented inspection of all forms of erosion as part of their research strategies, successfully yielding new evidence for prehistoric activity both inland and on the coast. Erosion events may be natural, for instance along rivers where sections cut by fluvial processes expose buried ground surfaces and wash out material (e.g. Edwards et al., 1983; Piper et al., 2018), or movement of sand dunes (Dawson, 2010); human, including footpaths, tracks, peat and drainage cuttings (e.g. Hardy and Wickham-Jones, 2009, p. 49; Mithen, 2000, p. 57-60); or animal induced. On Skye, a Mesolithic lithic scatter was exposed in a "scrape", a deliberate hollow made by sheep for shelter (Kozikowski et al., 1999).

2. INVESTIGATING THE "EMPTY EDGES"

Despite the achievements of heritage assessments and research projects in raising awareness of Scotland's fragile coastal archaeology, there are still large gaps that remain both chronologically and geographically. Over the last ten years, three new projects have sought to find evidence with which to populate these "empty edges" with their earliest prehistoric inhabitants. Individually, their primary aim was to identify Mesolithic activity, yet each has also shed new light on other periods of prehistory that are equally underrepresented in the western Highland region, specifically the Western Isles, the Small Isles, and Wester Ross (fig. 1). Their results reinforce existing predictive models, whilst informing development of regionally specific field survey methods.

2.1. The Western Isles Mesolithic project

Until 2001, no definitive archaeological evidence existed for Mesolithic occupation in the Western Isles, despite hints at a possible Mesolithic lithic scatter at Traigh na Beirigh, Lewis (Lacaille, 1937). Only palaeoenvironmental indicators of vegetation disturbance suggested any human activity on these islands (Edwards and Mithen, 1995, p. 349-350). This was in stark contrast to the numerous sites known from the Inner Hebrides and south-western mainland.

The first confirmed site at Northton, Harris was identified below a later prehistoric Scheduled Ancient Monument in 2001. It comprised a buried ground surface containing an assemblage of lithics, burnt faunal material and hazelnuts dating to 7060-6100 cal. BC (Gregory et al., 2005; Simpson et al., 2006). Further fieldwork from 2010-2012, led by Prof M. Church, established that serious erosion had almost destroyed the later prehistoric settlement and encroached on the Mesolithic deposits (fig. 2-A). Ensuing excavation consolidated evidence for Mesolithic activity, including lithic working, fish processing, hunting, and gathering activities at the site. Sampling along the eroding coastal edge and a borehole survey indicated the buried ground surface extends across an area at least 50 m along the coast and 40 m into the interior (Gregory et al., 2005; Bishop et al., 2010a and 2011; Ascough et al., 2017).

Between 2011-2012, another exposure of a relic land surface was observed less than 500 m to the north-east of Northton, at Tràigh an Teampuill. The eroding deposits spanned c 5 m in width and were buried beneath substantial machair accumulation (fig. 2-B). These yielded a similar suite of Mesolithic occupation debris to Northton, albeit a millennium later in date (Church et al., 2012a).

On Lewis, prior survey of the Bhaltos peninsula had recorded a shell midden of undetermined date on a rocky promontory at the western edge of Tràigh na Beirigh beach (Armit et al., 1995, p. 90). The CZAS highlighted the site's significant risk of destruction (Burgess and Church, 1997, p. 117; Church and Burgess, 2003, p. 61). In 2011, a coastal erosion assessment determined that almost the entirety of the midden (TnB1) had eroded due to its exposed location; it was excavated in full the following year and produced a late Mesolithic date of 4330-4240 cal. BC (Church et al., 2012b; Ascough et al., 2017).

Owing to the dynamic dune systems in the area, the headland adjacent to Tràigh na Beirigh beach was surveyed over consecutive years, from 2011-2013. In the first year, nothing was observed. However, in 2012 a shell midden and buried soil horizon (TnB2) was seen underlying the eroding machair dune (fig. 3-B). Mesolithic occupation at this site dates to 4540-4470 cal. BC (Church et al., 2012b; Bishop et al., 2013; Ascough et al., 2017). Repeated survey alongside further excavation of TnB2 identified several more exposures of shell midden deposits, another of which dates to the late Mesolithic (TnB9), with two others containing undiagnostic knapped quartz (fig. 3-A; Snape-Kennedy et al., 2013; Piper, 2016). These sites were revealed due to the dry summer and aggressive autumn storms that affected the area in 2012. An additional eroding Mesolithic midden was recorded on the neighbouring island of Pabaigh Mòr, following a report by a local resident (Church and Rowley-Conwy, 2013).

Fig. 2 – A: The eroding Mesolithic ground surface and overlying later prehistoric deposits at Northton, Harris (trench extent indicated by the dashed line). B: Sampling underway at Tràigh an Teampuill (photos P. Rowley-Conwy).

***Fig. 2** – A : Surface d'occupation mésolithique en cours d'érosion et dépôts préhistoriques ultérieurs qui la recouvrent, Northton, Harris (la zone de fouille est indiquée en pointillés). B : Échantillonnage en cours à Tràigh an Teampuill (clichés P. Rowley-Conwy).*

Fig. 3 – A: The cliff-face location of three eroding Late Mesolithic shell middens at Tràigh na Beirigh, peninsula, Lewis (photo P. Rowley-Conwy). B: Tràigh na Beirigh 2 under excavation. The Mesolithic ground surface is sealed below substantial machair formation (photo M. Church).

Fig. 3 *– A : Emplacement à flanc de falaise des trois amas coquillers du Mésolithique tardif, en cours d'érosion à Tràigh na Beirigh, Lewis (cliché P. Rowley-Conwy). B : Tràigh na Beirigh 2 en cours de fouille. La surface d'occupation mésolithique est scellée sous une importante formation de machair (cliché M. Church).*

The occupation surfaces on Harris and middens on Lewis present distinctly different site types, separated in time by almost two millennia. Despite this, they share two features that are invaluable to building a methodology by which other sites may predictably be found. Firstly, their topographic location on headlands associated with sheltered bays. These are analogous to scenarios *C* and *D* of the Danish "fishing site location model" (fig. 4; Fischer, 1995, p. 373-374). Although this model cannot be directly exported to western Scotland due to the differences between the coastal landscapes, and its origins in favoured present-day passive fishing locales, a similar model may be developed for Scotland based on local conditions. Second is their geomorphic position. The relic ground surfaces are preserved atop steep, rocky platforms, thus far guarding against inundation. Apart from TnB1, machair formation has generally protected against later disturbance, and offers alkaline conditions that favour organic preservation (Barber, 2011, p. 50).

2.2. Early Prehistoric maritime communities of western Scotland, Muck, Small Isles

The isle of Muck, Small Isles, presents a very different environment to much of the Highland and island region, instead dominated by rich soils that have been extensively cultivated. Whilst retaining the strategy developed in the Western Isles of targeting several coastal embayments, the project implemented systematic test-pitting, over three seasons from 2016-2018 (Piper et al., 2019). One inland location was also chosen based on prior known later prehistoric lithics (NMR: NM48SW 48-50) and a Bronze Age sword (HER: MHG3982).

The lithic and pottery assemblages recovered from the test pits indicate Mesolithic and Neolithic-Bronze Age presence, consolidating the evidence for prehistoric activity on the island across a wider area than previously recognised. The low concentrations within a homogenous sub-soil horizon appear to represent "background noise" however, rather than definitive activity areas. Without the protective coverage of peat or machair, and the islands' long history of cultivation, it seems any prehistoric sites have been substantially disturbed.

The presence of worked Rùm bloodstone within the lithic assemblages demonstrates connections between Muck and its larger island neighbour for the supply of lithic raw material and supplements the evidence for regional distribution of this raw material during early prehistory (fig. 5; Ballin, 2018; Piper et al., 2019)

2.3. Coastal Archaeology and Erosion in Wester Ross

Project CAERoS (Coastal Archaeology and Erosion in Wester Ross, Scotland) was initiated in 2019 with the aims of establishing the potential of eroding coastlines to yield new early prehistoric sites and contribute to monitoring of archaeological sites at risk of erosion (Piper et al., 2020; Piper, forthcoming). The targeted area encompasses three peninsulas from Gairloch to Ullapool, between the areas surveyed by the SFS project and the Ullapool-Lochinver CZAS (fig. 6). Both surveys have documented buried and upstanding sites of prehistoric date (Long, 1996; Hardy and Wickham-Jones, 2009), however desk-based assessment of the Historic Environment Record (HER) indicated few records exist for early prehistoric occupation in this region. This suggested high potential for CAERoS to fill a significant gap in the known distribution of prehistoric sites along the coastline of the Highlands.

2.3.1. Walk-over survey

The primary focus of the survey was to identify new prehistoric sites, however archaeological remains of any date within c 50 m of the coastline were also noted in relation to their state of preservation. To maximise the likelihood of identifying buried early prehistoric sites, any area of erosion in this zone was inspected following the methods of the SFS and Western Isles Mesolithic projects. The first phase focussed on the Melvaig and Rubha Mòr peninsulas around Loch Ewe and Gruinard Bay, Gairloch parish.

A total of 25 sites from the HER were visited, ranging from prehistoric hut circles to World War II infrastructure associated with the Russian Arctic Convoys (Chadwick, 2014). None of these sites are at risk of active erosion, however vegetation overgrowth is causing structural instability. The survey also identified several unrecorded sites, predominantly of post-medieval to modern date.

A single site indicating evidence for prehistoric occupation was identified at Uamh Mhòr, Cove. Here, an exposure of burnt material including heat-affected rocks and undiagnostic lithic debris was observed in a sheep "scrape", situated on the eroding edge of a field above a small, sheltered bay facing north-east across Loch Ewe. Aerial imagery from 2014 shows substantial erosion from a recently infilled stream (fig. 7; Piper et al., 2020).

2.3.2. Excavation

A trench contiguous to the eroding edge was subsequently excavated (fig. 8). The curvilinear edge of a dome-shaped deposit of charcoal-rich, black sandy silt was identified overlying a series of sandy-silt deposits with lenses of charcoal and reddened sediment, indicating multiple burning episodes (Canti and Linford, 2000). A thick basal horizon of sterile sand overlies Torridonian sandstone bedrock. This was reached in a 1 m-wide sondage at the south-east extent of the trench; the north-western area is partly truncated by the backfilled stream. A test pit situated 1 m from the south-western corner of the trench confirmed the continuation of the burnt deposit in this direction.

The uppermost burnt deposit comprises frequent heat-affected rolled beach cobbles, a quartz-dominated lithic assemblage, hammerstones, and a small number of minute pottery fragments. Lithics were also recovered from the underlying deposits, in addition to two large pieces of charcoal of a size suggesting possible burnt stakes (Elliott pers. comm.). A fragment from one, iden-

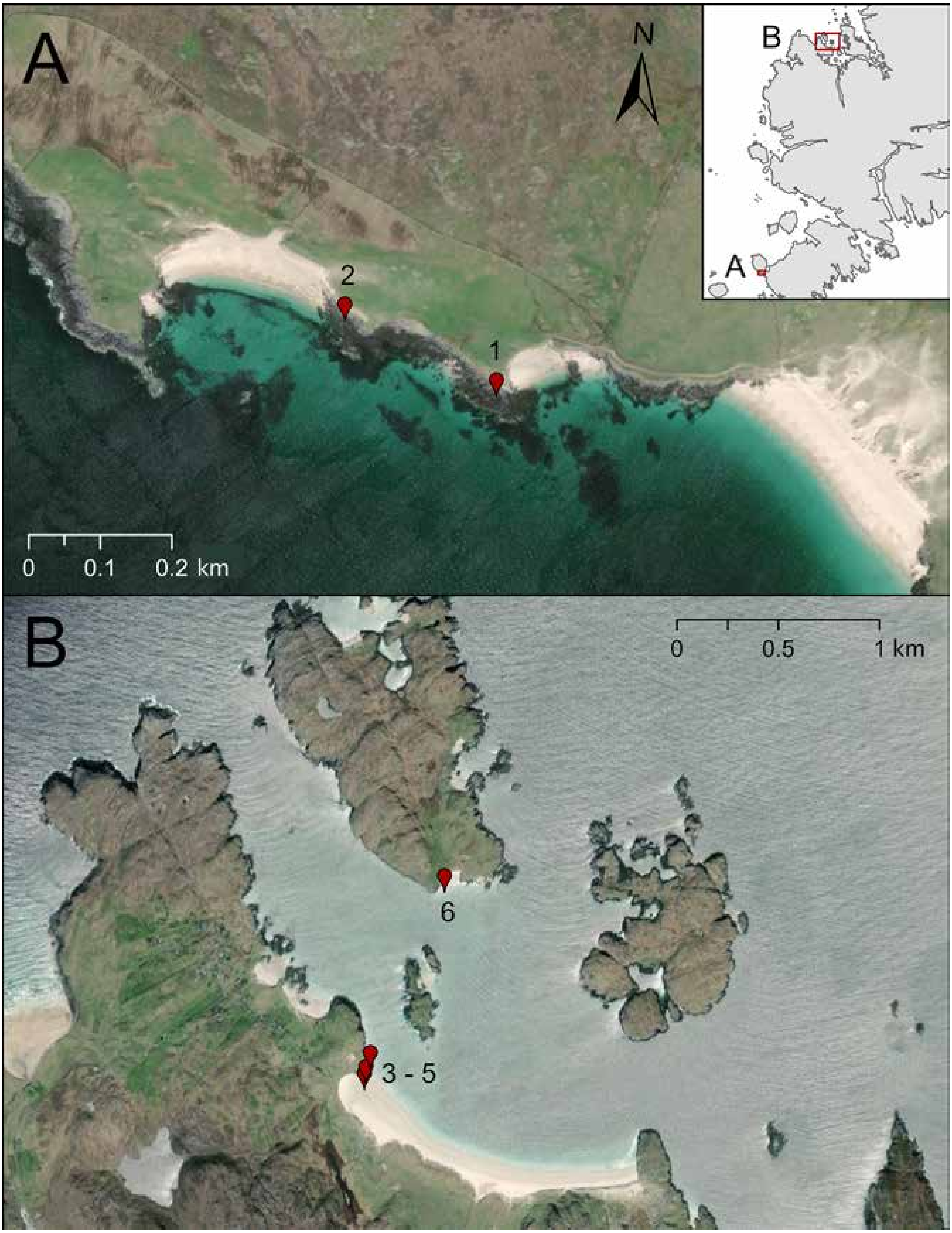

Fig. 4 – Location of the Mesolithic sites in the Western Isles conforms to the Danish "fishing site model". A: Harris, 1 – Northton, 2 – Tràigh an Teampuill; B: Lewis, 3-5 – Tràigh na Beirigh 1, 2 and 9; 6 – Pabaigh Mòr South (Aerial imagery: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

Fig. 4 *– Emplacement des sites mésolithiques dans les Hébrides extérieures, conforme au « Danish fishing site model ». A : Harris, 1 – Northton, 2 – Tràigh an Teampuill ; B : Lewis, Tràigh na Beirigh 1,2 et 9; 6 – Pabaigh Mòr Sud.*

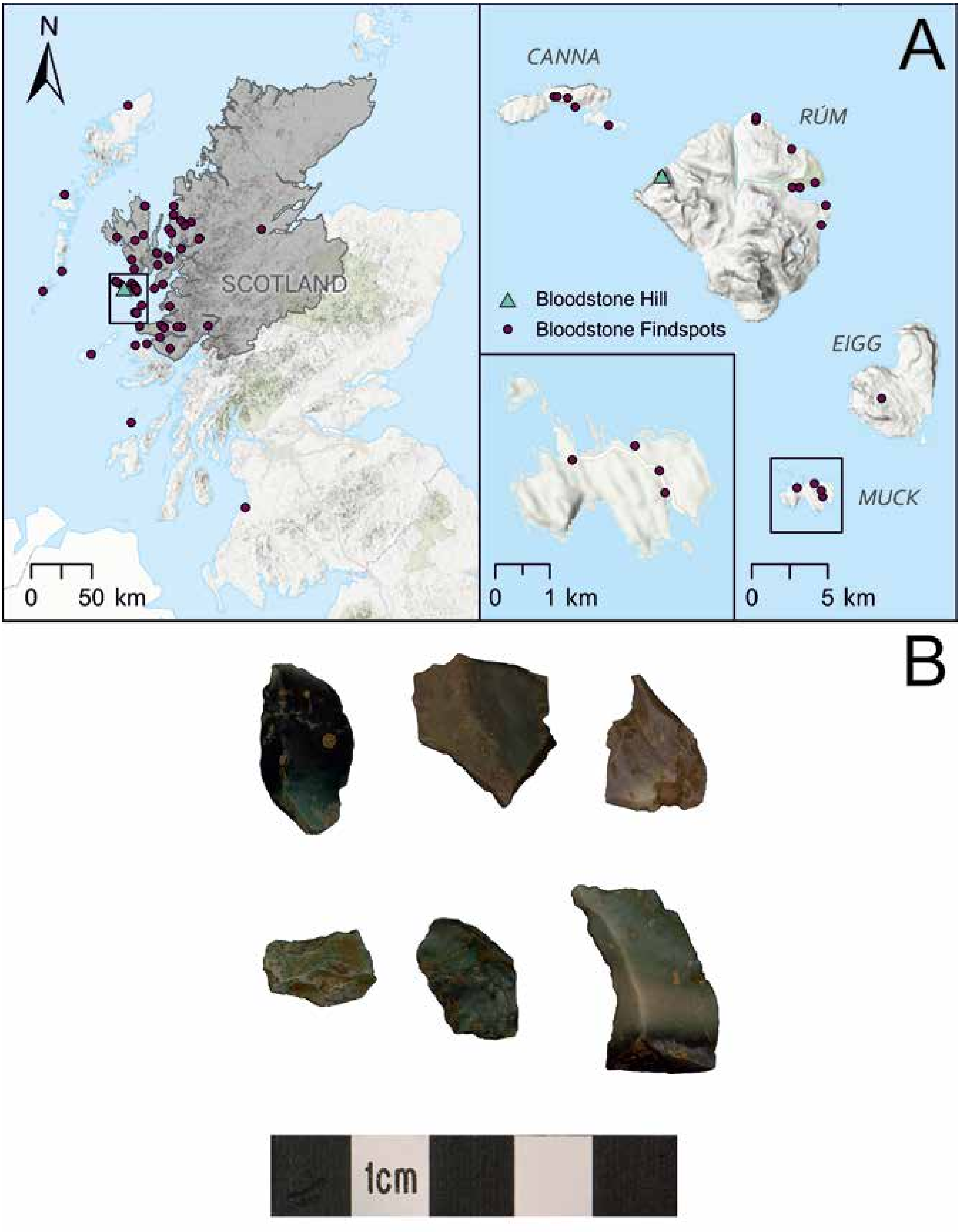

Fig. 5 – A: Regional distribution of bloodstone lithic findspots relative to the source at Bloodstone Hill, Rùm (after Piper, 2016; Ballin, 2018; © Crown copyright and database right 2021 Ordnance Survey). B: Worked bloodstone from Muck (photo N. Gray).

Fig. 5 *– A : Distribution régionale des découvertes d'héliotrope (« pierre de sang ») provenant du gisement de Bloodstone Hill, Rùm (d'après Piper, 2016 ; Ballin, 2018). B : Héliotropes taillées de Muck (cliché N. Gray).*

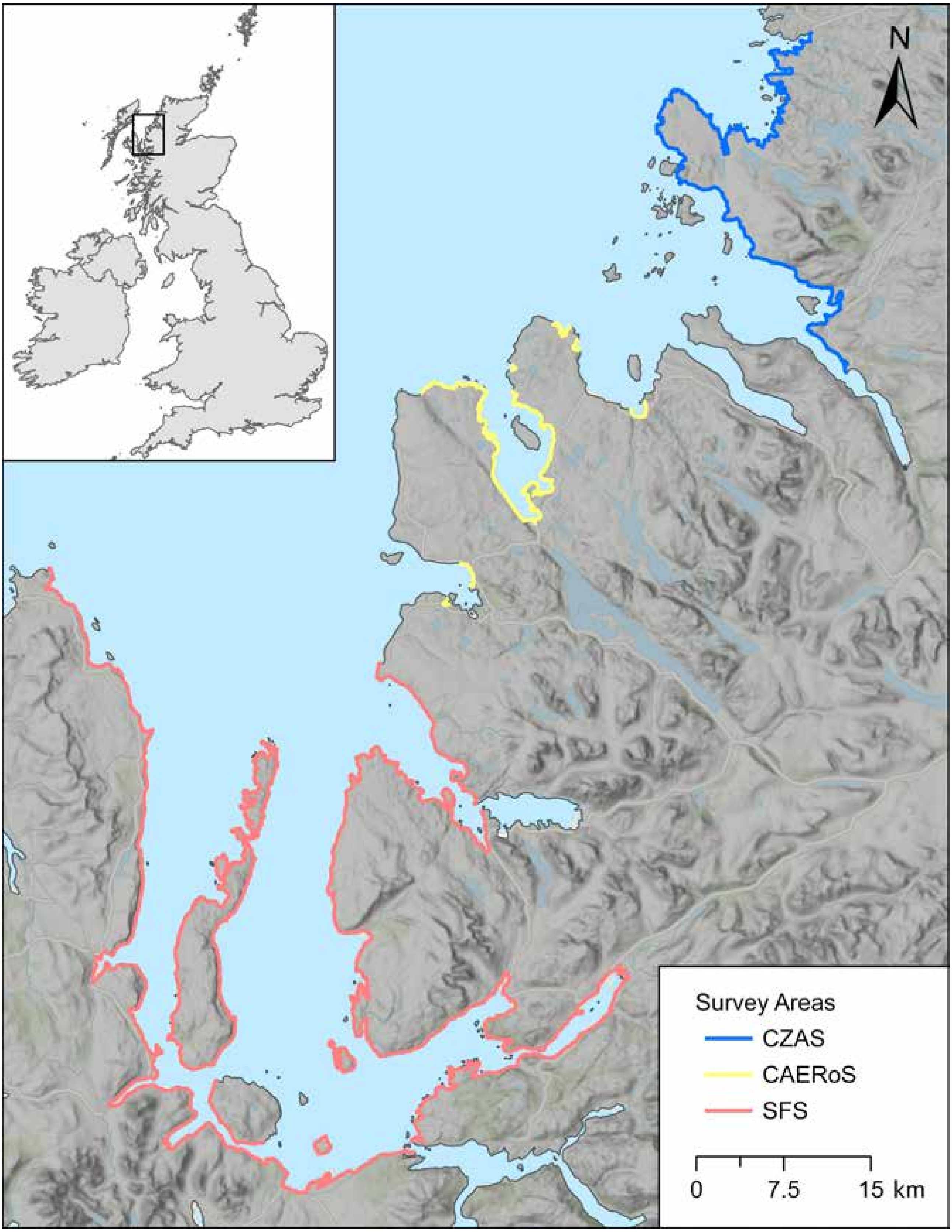

Fig. 6 – Extent of the survey conducted by the CAERoS project, which aims to fill the gap between the Scotland's First Settlers (SFS) and Ullapool-Lochinver CZAS surveys (© Crown copyright and database right 2021 Ordnance Survey).

***Fig. 6** – Étendue de la campagne menée par le projet CAERoS, destinée à combler le fossé entre les études Scotland's First Settlers (SFS) et Ullapool-Lochinver CZAS.*

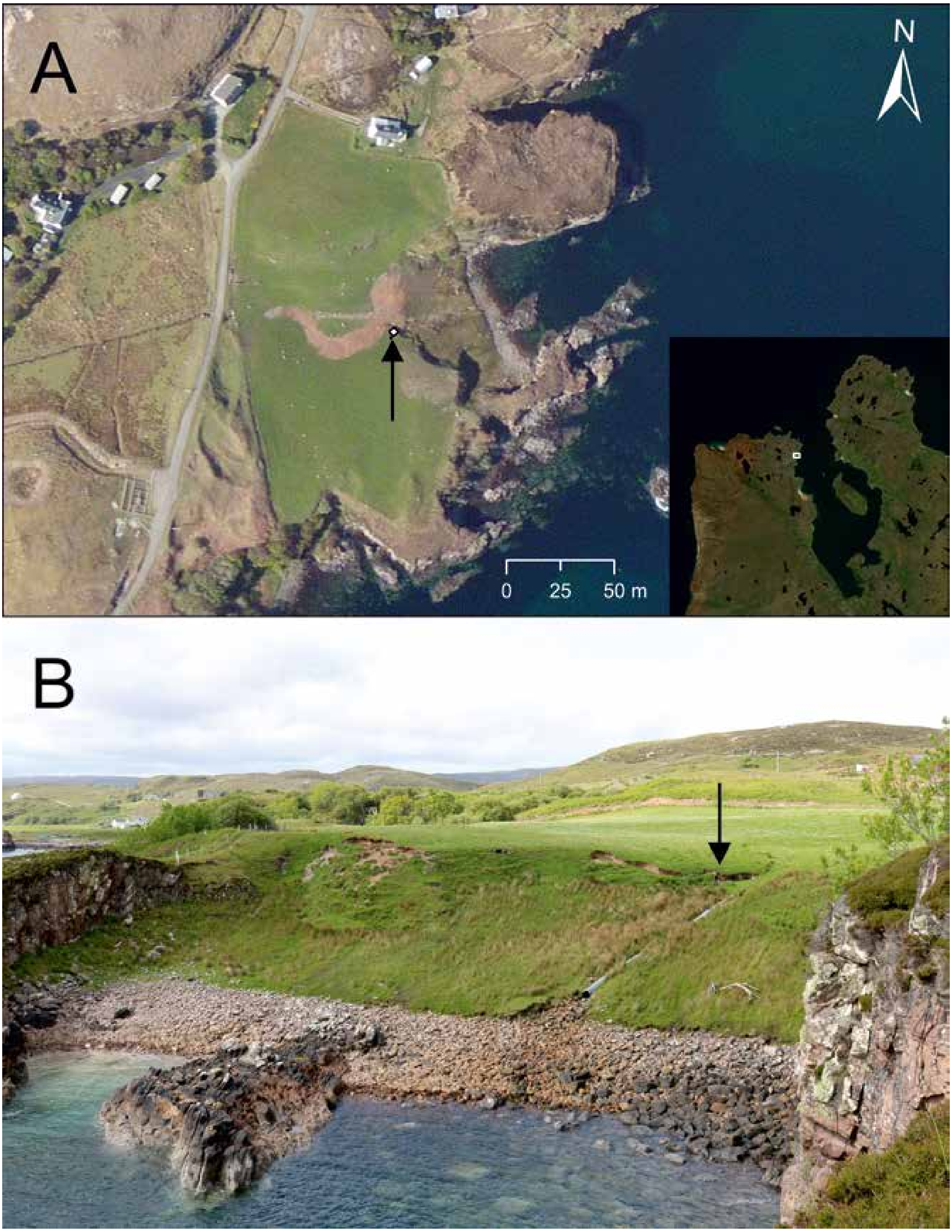

Fig. 7 – Location of the excavation at Uamh Mhòr (arrowed). A: In relation to aerial imagery from 2014 showing the infilled course of the stream (aerial imagery: Esri, DigitalGlobe, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, IGP, and the GIS User Community). B: Along the present eroding edge (photo F. Martínez Sevilla).

***Fig. 7** – Localisation de la zone de fouille à Uamh Mhòr (flèche). A : Image aérienne de 2014 montrant le tracé du ruisseau remblayé (Esri, DigitalGlobe, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, IGP, et communauté des usagers du SIG). B : Localisation actuelle du site en bordure de la ligne d'érosion (cliché F. Martínez Sevilla).*

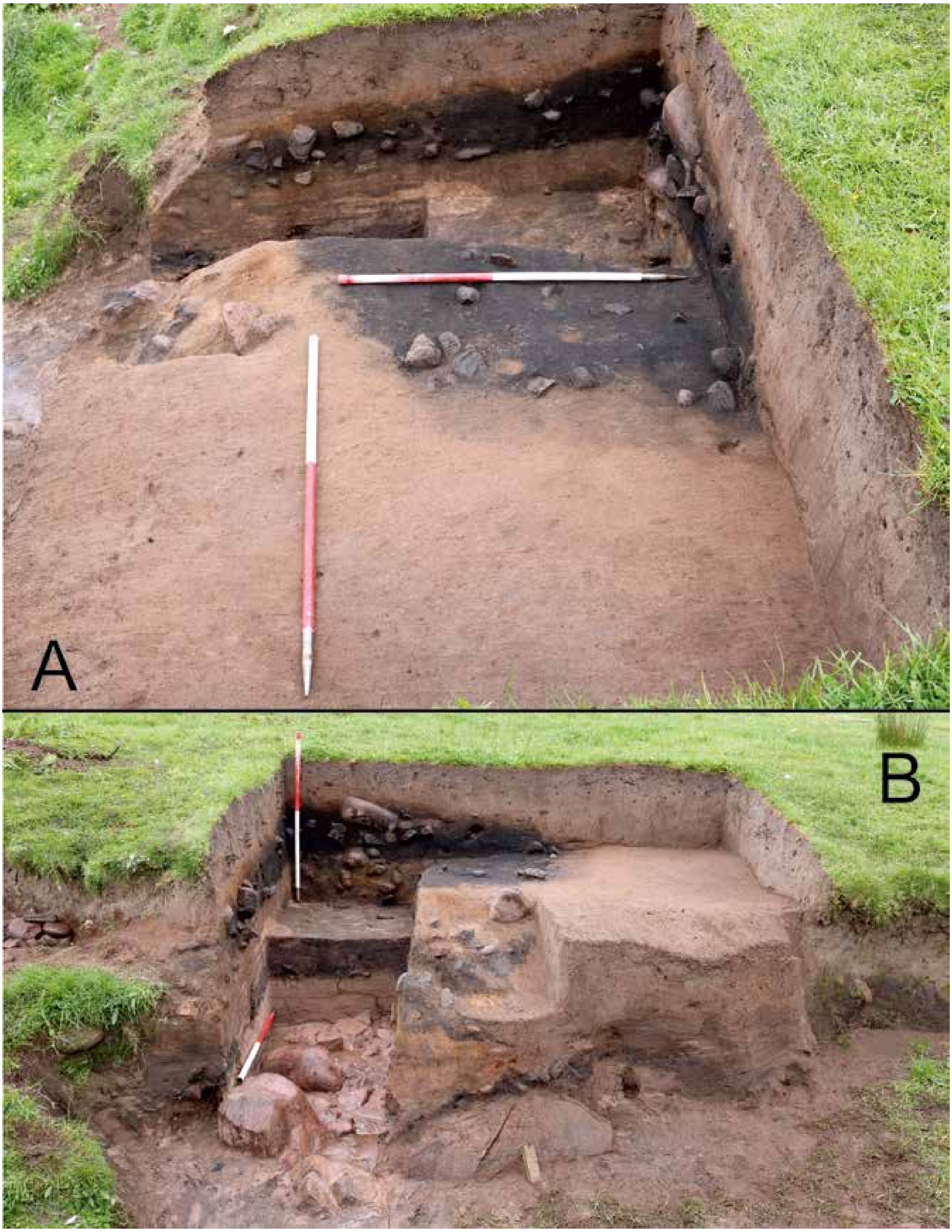

Fig. 8 – Uamh Mhòr under excavation. A: The dark sediment of the burnt mound exposed in the southern extent of the trench, facing south-east. B: Showing the upper deposits of the burnt mound and lower Early Neolithic deposits exposed in the sondage, overlying the sterile basal sand, facing south-west (photos F. Martínez Sevilla).

***Fig. 8** – Uamh Mhòr en cours de fouille. A : Sédiments foncés du monticule brûlé visibles dans la partie sud de la zone de fouille (cliché orienté sud-est). B : Dépôts supérieurs du monticule brûlé et dépôts inférieurs du Néolithique ancien recouvrant le sable basal stérile (orientation sud-ouest ; clichés F. Martínez Sevilla).*

tified as *Alnus glutinosa* was dated 4974 ± 19 BP (3794-3665 cal. BC at 95.4% SUERC-88580 [GU52362]; OxCal v4.4.4, Bronk Ramsey, 2009; IntCal20 atmospheric curve, Reimer et al., 2020). Despite disturbance to some areas of the site through rabbit burrowing, it is highly unlikely the charcoal is redeposited due to its size (c 0.15 m long), positioned at the sharply defined interface of the sterile basal sand and overlying deposits.

Uamh Mhòr is interpreted as a burnt mound of probable Bronze Age date, with underlying early Neolithic activity. Burnt mounds are a ubiquitous, albeit poorly understood, prehistoric monument type in Scotland. Dense concentrations exist in the Northern Isles and eastern counties of Caithness and Sutherland, undoubtedly reflecting the surveys of the Royal Commission. Conversely, their distribution in the west is sparse (fig. 9). Only 38 (10%) are in the western Highlands, with five in the CAERoS project area. For this reason, a burnt mound at Ashaig, Skye has recently been Scheduled (HER: MHG5303/SM13721). It is likely "greater concentrations may exist [in the west] than are currently recognised" (Downes, 2012, p. 52). Modelling of C^{14} and thermoluminescence dates from Scottish burnt mounds has also shown that these monuments are not restricted to the Bronze Age and have a wider temporal span (Anthony et al., 2001, p. 922). Future investigation at Uamh Mhòr, including dating of the mound, will contribute valuable information in line with much-needed further research on these sites, particularly in this under-represented area (Downes, 2012, p. 53-54).

The date for the underlying deposits is significant, providing a *terminus ante quem* for activity at the site that falls within the first 200 years of the Neolithic in western Scotland (Whittle et al., 2011; Sheridan and Pétrequin, 2014). Securely dated evidence for Early Neolithic settlement along the north-west mainland is near-absent (fig. 9), therefore Uamh Mhòr has the potential to provide a major contribution to a key research priority for this period in the Highlands (Sheridan and Brophy, 2012, p. 77).

4. REFLECTIONS AND CONCLUSION

Identifying early prehistoric occupation in coastal north-west Scotland is beset by numerous challenges. Despite such complications the results of these three projects demonstrate beyond any doubt that the potential to find new archaeological evidence along its apparently "empty edges" is very high. The present scarcity is clearly due to a lack of targeted research and invisible archaeology, rather than an absence of people in the past. Individually, each project is small in scale, yet in combination, they have substantially increased the prehistoric record in the Highland and island regions.

From a methodological perspective, there are several key findings. At a basic level, the tenets of the Danish "fishing site" model work equally well in predicting onshore locations of prehistoric occupation in the coastal zone. The Western Isles Mesolithic project has shown that local geomorphology is crucial to the preservation of sites. Incorporating this to refine the model should increase the success of its application whilst accounting for local variation. This may be adapted further for submerged sites (Hall, 2014).

Only ground truthing can fully test the viability of these predictive models. The Western Isles Mesolithic and CAERoS projects continue to demonstrate the success of combining the model with intensive erosion survey as a low-cost strategy for the identification of new early prehistoric sites in these areas. Where "blind" test-pit surveys have proven to be somewhat effective on Muck and other islands, this method is more time consuming, and logistically and labour intensive when considering the likelihood of identifying a site (Mithen, 2000, p. 57-58).

Sometimes, fieldwork exposes epistemological flaws. One observation from Muck demonstrated how slight variation in the topography of coasts may influence the desirability for occupation. The bay at Port Mòr faces north-west and is protected by a headland. It yielded a comparatively concentrated lithic assemblage. To the west, Camas Mòr was also targeted as it occupies the same position; additionally, there is a substantial Late Glacial raised beach (Emeleus and Bell, 2005), theoretically making it an equally viable candidate to locate early prehistoric occupation. However, there was very little evidence for human activity of any period. This may be explained by the position of the bay and the sheer cliffs of An Stac that rise to the summit of Beinn Airein, the highest point of the island, at the bays' western edge. These cliffs perfectly channel the prevailing south-westerly onshore wind, resulting in highly exposed and unfavourable conditions as experienced by the Camas Mòr excavation team. In the absence of information pertaining to the local vegetation cover or modelling of weather systems for the area in prehistory, this remains speculative; nevertheless, it highlights the complexities of predictive modelling (Grøn, 2018).

A further issue is that such predictive models have the propensity to reinforce an assumption that prehistoric occupation was primarily coastal, when based on prior successes. This is highly problematic, especially since inland areas of the Highlands are equally under-investigated. Moreover, in some locales the Late Glacial and Postglacial palaeoshorelines, preserved as raised beach deposits, are situated further inland and currently protected from coastal erosion (Johnstone and Mykura, 1989). Good evidence for earlier prehistoric occupation exists in these contexts (e.g. Wickham-Jones and Hardy, 2004; Hardy et al., 2020). Future surveys should take both aspects into consideration, with investigation of the interior region likely to provide much-needed evidence for prehistoric occupation beyond the present and palaeo-coasts.

A combination of erosive factors clearly present threats to archaeology in the respective coastal zones of this under-researched region. In the Western Isles sites are actively threatened by inundation and storms, whereas the CAERoS survey observed little evidence for such. Instead, the mound at Uamh Mhòr was exposed by

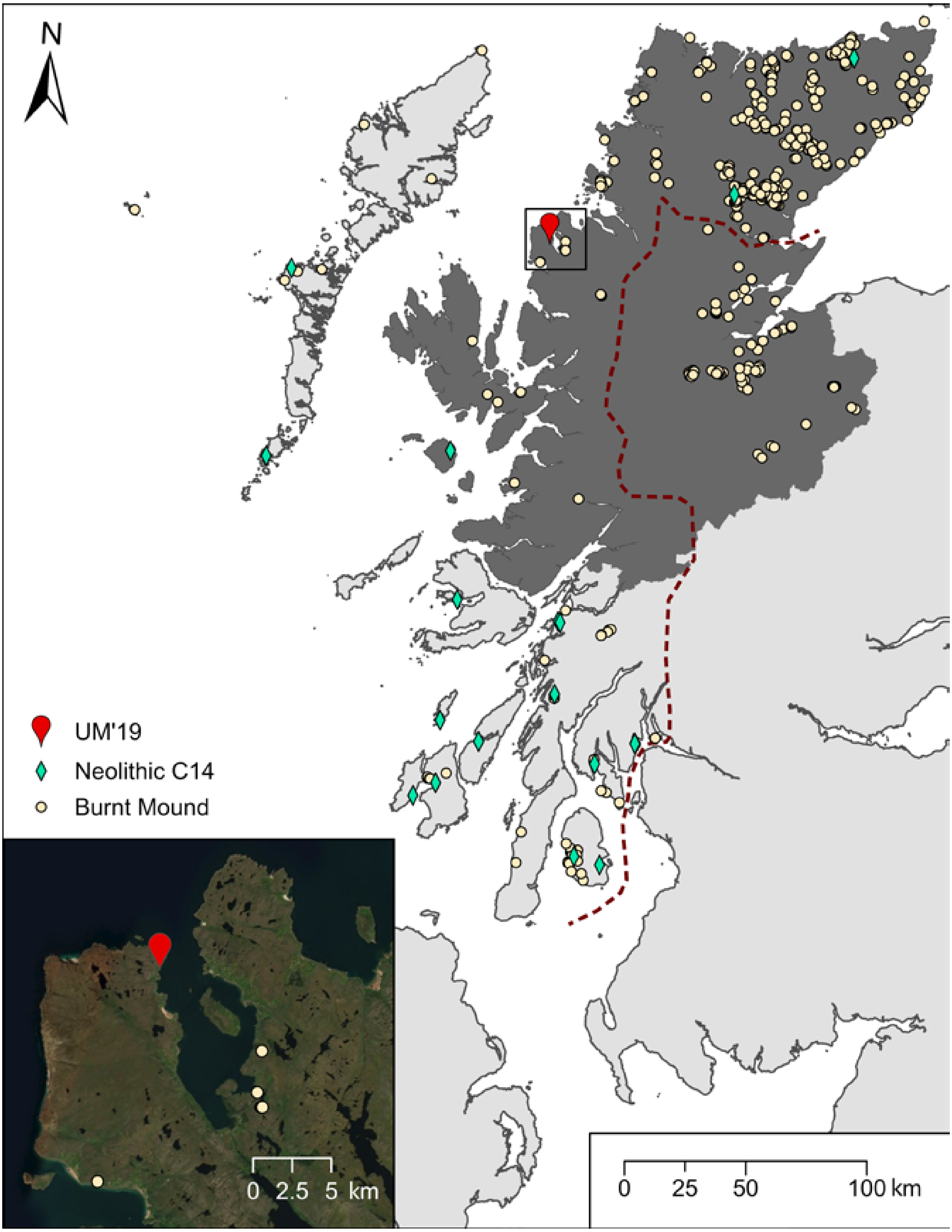

Fig. 9 – Distribution of known and probable burnt mounds, and radiocarbon dated early Neolithic sites in the western Atlantic zone (denoted by the dashed line, sensu Bishop et al., 2010b). All known and probable burnt mounds in the Highlands (dark grey) are included (© Crown copyright and database right 2021 Ordnance Survey; Aerial imagery: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community).

Fig. 9 – *Répartition des monticules brûlés connus et probables, et des sites néolithiques anciennes datés au radiocarbone dans la zone atlantique ouest (indiquée par la ligne pointillée, sensu Bishop et al., 2010b). Tous les monticules brûlés connus et probables dans les Highlands (gris foncé) sont inclus.*

livestock erosion and ground slippage associated with the nearby watercourse. Future research strategies therefore must not only account for the threat from the sea, but to recognise that the coast is also intensely vulnerable from the landward, due to a variety of natural and anthropogenic factors (Harkin et al., 2018).

Erosion is undeniably damaging the natural environment, however the exposure caused by these processes can be used to facilitate investigation of often deeply buried archaeological sites and landscapes that cannot be detected from the surface. Furthermore, whilst the survey strategies that are employed are systematic, the nature of erosion is not. This therefore requires the same regions to be frequently reassessed as further erosion takes place, as the Western Isles Mesolithic project has shown. Understanding of local geomorphology, in combination with knowledge of areas at high risk of erosion, can then be utilised to develop predictive methodologies that facilitate a more targeted investigative approach and active monitoring.

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