Paléoécologie des environnements nordiques anthropisés : une étude comparative entre l'Islande et le Labrador

Thèse

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Résumé

Dans le but de comparer l'impact des fluctuations climatiques et des activités anthropiques sur l'évolution du couvert végétal des environnements nordiques avant et après leur anthropisation, une étude paléoécologique basée sur une approche pluridisciplinaire a été réalisée sur des échantillons prélevés aux alentours de sites archéologiques au nord-est de l'Islande et au nord du Labrador. Les bio-indicateurs qui ont été utilisés incluent les grains de pollen, les macrorestes (plantes et insectes), les diatomées et les cernes de croissance d'arbres. Le Labrador a été occupé par des groupes autochtones depuis 7000 ans; leur économie de subsistance était basée sur la chasse, la pêche et la cueillette de petits fruits. En Islande, la première vague de colons scandinaves est arrivée à la fin du 9e siècle; ils ont apporté avec eux un mode de vie européen continental basé sur un système de subsistance combinant l'agriculture, l'élevage et la pêche.

Tant en Islande qu'au Labrador, nos données paléoenvironnementales montrent une évolution de la végétation similaire qui a été principalement influencée par les conditions climatiques qui prévalaient. À titre d'exemple, la détérioration des conditions environnementales au cours du Néoglaciaire a entrainé un déclin du couvert forestier en faveur des arbustes et des espèces de tourbières. Dans les deux régions d'étude, l'effet principal de l'activité anthropique a été l'introduction et la dispersion de nouvelles espèces de mauvaises herbes et des déchets reliés à leurs activités quotidiennes. Toutefois, au Labrador, l'arrivée des Moraves vers AD 1771 semble avoir entrainé l'ouverture du couvert forestier le long de la côte. En combinant les données paléoenvironnementales et archéologiques, nous avons démontré que les les Inuits et les Moraves du Labrador et les Norois en Islande ont dû faire face à des fluctuations climatiques similaires au cours des derniers millénaires. En particulier, les Norois auraient mis en œuvre des stratégies de gestion des terres pour développer les pâturages à partir de AD 940 et même pendant la période du Petit Âge glaciaire. Pour les Inuits du Labrador, les changements dans l'évolution du paysage sont subtils jusqu'à la fin du 18e siècle, ce qui coïncide avec l'arrivée des missionnaires moraves en 1771. Le besoin récurrent en bois a causé l'ouverture du couvert forestier ce qui pourrait avoir conduit à l'établissement du mélèze.

Abstract

The aim of this study is to compare the impact of climatic fluctuations and anthropogenic activities on the evolution of vegetation cover in anthropic northern environments. Paleoecological studies based on a multi-proxy approach were undertaken on samples taken from archeological sites located in northeastern Iceland and northern Labrador. The fundamental bio-indicators included pollen, macrofossils (plants and insects), diatoms and tree-rings growth. Labrador has been occupied by aboriginal groups for 7000 years BP. Their subsistence economy was based on hunting, fishing and gathering berry picking. In Iceland, the first wave of Norse settlers arrived at the end of the 9th Century. They brought with them a continental European way of life based on a subsistence system combining pasture and fisheries.

The paleoenvironmental data in Iceland and Labrador show a similar vegetation evolution that was mainly influenced by prevailing climate conditions. For example, the deterioration of environmental conditions during the Neoglacial led to a decline in forest cover in favor of shrubs and peatland species. In both of the study regions, the main effects of anthropogenic activity were the introduction and dispersal of new weed species and waste disposal related to their daily activities. However, in Labrador, the arrival of the Moravians at around 1771 seems to have led the opening of the forest cover along the coast. By combining palaeoenvironmental and archaeological data, we have shown that the Inuit and Moravians in Labrador and the Norse in Iceland faced similar climatic fluctuations over the last millennium. In Iceland, the Norse settlers implemented major land management strategies to develop pasture land, which is the primary reason they continued to occupy Svalbard since AD 940 and during the Little Ice Age. In Labrador, there were subtle changes in the landscape at the end of the 18th Century that coincided with the arrival of the Moravian missionaries. In particular, the recurrent need for wood caused an opening in the spruce forest that could have led to the establishment of tamarack.

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Un doctorat est une expérience professionnelle et personnelle d'une richesse inestimable. Au-delà de la découverte des cultures inuite et islandaise, des nombreux voyages lors d'une campagne de terrain (Labrador et Islande), de la réalisation d'un stage à l'international (Islande), d'une assistance de cours (Maroc) ou pour la participation à plusieurs congrès (Chine, Islande, Montréal, Ottawa et Québec), cette thèse reste surtout une succession de merveilleuses rencontres toutes aussi enrichissantes les unes que les autres. Nombreuses sont donc les personnes que je tiens à remercier ici car les travaux présentés dans le cadre de ce doctorat sont le fruit de collaborations multiples.

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AVANT- PROPOS

À l'exception de l'introduction et la conclusion générales écrites en français, cette thèse est présentée sous forme de cinq chapitres-articles rédigés en anglais. Ces cinq chapitres peuvent être lus indépendamment, car chacun répond à différents objectifs spécifiques avec une méthodologie qui lui est propre. Par conséquent, nous prions le lecteur de ne pas tenir compte de certaines répétitions dans le texte, soit la description des sites d'études et/ou la méthodologie. L'auteure de la thèse est la principale rédactrice et auteure de chaque article. Elle a participé à l'élaboration de la problématique, aux collectes de terrain et a effectué les analyses polliniques, macrofossiles et dendrochronologiques ainsi que leur interprétation. Par ailleurs, l'analyse diatomifère a été réalisée par Guillaume Haemmerli alors que l'identification des restes d'insectes a été effectuée par Véroniques Forbes ; ils ont tous les deux contribué à l'interprétation des résultats. En leur qualité de directeurs de recherche dans le cadre de ce doctorat, le Dr Najat Bhiry et le Dr James Woollett ont supervisé l'auteure durant tout le processus de la recherche et de la rédaction. Par leurs nombreux conseils et commentaires, ils ont contribué scientifiquement à la rédaction de la présente thèse et à l'amélioration de son contenu. Enfin, des sections de cette thèse ont également bénéficié des corrections et suggestions des co-auteurs des publications (Ann Delwaide, Guillaume Haemmerli, Véronique Forbes et Reinhard Pienitz).

Cette thèse se compose des sections suivantes:

Introduction générale

Chapitre 1: Roy, N., Woollett, J., Bhiry, N. 2015. Paleoecological perspectives on landscape history and anthropogenic impacts at Uivak Point, Labrador, since AD 1400. *The Holocene*,

Chapitre 2: Roy, N., Bhiry, N., Woollett, J., Delwaide, A., 2015 (sous presse). A 550-year record of disturbance history of white spruce forests near two Inuit settlements in Labrador. *Journal of North Atlantic*

Chapitre 3: Roy, N., Bhiry, N., Woollett, J., (accepté). Reconstruction of vegetation history since the mid-Holocene in northeastern Iceland. *Écoscience*

Chapitre 4: Roy, N., Woollett, J., Bhiry, N., Haemmerli, G., Forbes, V., Pienitz, R. (accepté). Perspective of landscape change following early settlement (Lándnám) in Svalbarðstunga, NE Iceland. *Boreas*

Chapitre 5: Roy, N., Bhiry, N., Woollett, J., (en préparation). Human eco-dynamics in northern environment: a comparative study of Iceland and Labrador.

Conclusion générale

INTRODUCTION GÉNÉRALE

Les régions nordiques sont depuis longtemps considérées comme d'excellents laboratoires pour l'étude des changements climatiques et leurs impacts étant donné leur isolement et leurs écosystèmes fragiles. En effet, selon le Groupe d'experts intergouvernemental sur l'évolution du climat (GIEC), une augmentation de la température moyenne globale de 2°C aurait des conséquences graves étant donné la capacité d'adaptation limitée de certains écosystèmes (p. ex. la banquise) et de beaucoup d'espèces (p. ex. l'ours polaire) habitant les régions arctiques et subarctiques (GIEC, 2014). De plus, avec le réchauffement, certains écosystèmes arctiques courent le risque de subir des changements soudains et irréversibles. Parmi les zones les plus affectées par les changements climatiques, il y a les régions du bassin de l'Atlantique Nord.

1. Le bassin de l'Atlantique Nord

L'Islande et le Labrador sont situés dans le bassin de l'Atlantique Nord (BAN) (Figure 1). Le BAN est directement influencé par plusieurs systèmes de circulation atmosphérique et océanique, en particulier l'Oscillation Nord Atlantique (NAO), l'Oscillation Arctique (AO) et l'El Niño-oscillation australe (p. ex : Hurrell et al., 2001; Way et Viau, 2014). La combinaison de ces systèmes génère des conditions climatiques difficiles et variables (Way et Viau, 2014). À cet égard, les scénarios climatiques du GIEC projettent une hausse des températures mondiales ainsi que des événements climatiques extrêmes (GIEC, 2014).

Plusieurs études ont aussi démontré le rôle non négligeable de ces systèmes sur les changements climatiques passés dans le BAN et leur influence sur l'évolution des écosystèmes terrestres (p. ex : D'Arrigo et al., 1993 ; Dickson et al., 2000 ; Hurrell et al., 2009). À titre d'exemple, dans une étude sur les cernes de croissance de l'épinette blanche effectuée au Labrador, D'Arrigo et al. (2003) ont mis en évidence la corrélation entre un mode de variation significatif d'une durée de 40 à 60 ans entre la largeur des cernes et les variations décennales du NAO. Les températures du Labrador auraient ainsi été influencées par le NAO. Aussi, durant le Petit Âge glaciaire (PAG), ces auteurs ont identifié des périodes froides entre 1600 jusqu'au début de 1700 et de 1800 à 1850, de même que des périodes relativement plus clémentes de 1750 à 1800 et vers la fin des années 1800.

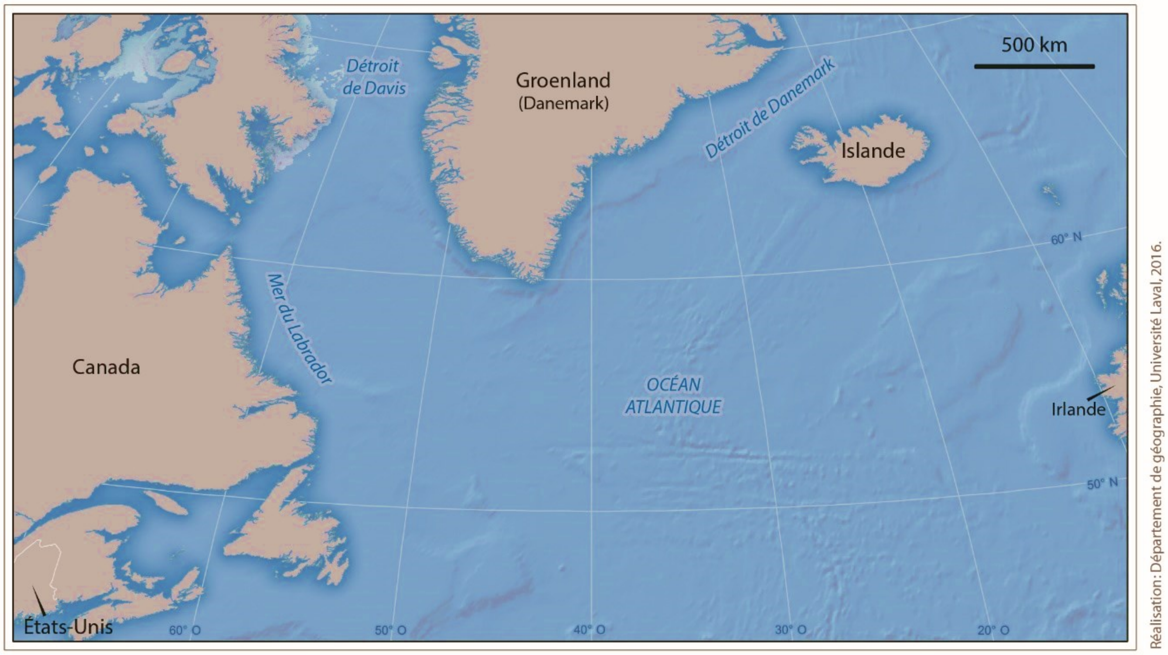

Figure 1: Localisation du Labrador et de l'Islande dans le bassin de l'Atlantique Nord.

D'un autre côté, Ólafsdóttir et al. (2010), dans une étude effectuée au nord-ouest de l'Islande, ont mis en évidence la vulnérabilité des écosystèmes des côtes du nord de l'île en raison de son exposition directe à la mer Arctique. En fait, en utilisant des assemblages de foraminifères benthiques et leur composition isotopique stable sur deux carottes de sédiments marins, ces auteurs ont montré comment l'avancée vers le sud de l'eau douce froide du courant Est du Groenland influence le profil de température des eaux du nord de l'Islande. L'avancée de cette eau douce conduit à la formation de glace de mer le long de la côte nord de l'Islande, favorisant des conditions plus froides l'hiver (Ólafsdóttir et al., 2010). Par exemple, dans les années soixantes, la glace de mer a persisté jusqu'au printemps, causant des températures de l'air beaucoup plus froides que d'habitude, ce qui limitait les activités de pêche (Ólafsson, 1999).

Autres que les systèmes atmosphériques et océaniques tels que décrits ci-haut, certains facteurs naturels et/ou anthropiques peuvent également entrainer une modification des écosystèmes terrestres des régions nordiques.

2. Les facteurs naturels ayant engendré des changements importants dans les écosystèmes terrestres en Islande et au Labrador

Les régions arctiques sont considérées comme étant très vulnérables puisqu'elles se caractérisent par une courte saison de croissance, une faune et une flore peu diversifiées et des sols pauvres (ACIA, 2004). Cette vulnérabilité peut se définir comme étant la prédisposition de ces régions à se détériorer de par leur fragilité et leur incapacité de faire face et de s'adapter (IPCC, 2013).

2.1 Les changements climatiques

L'un des facteurs naturels principaux dans la transformation des écosystèmes terrestres est les changements climatiques. Selon le GIEC (2014), les changements climatiques consistent en la variation de l'état du climat, qu'on peut déceler par des modifications de la moyenne et/ou de la variabilité de ses propriétés et qui persiste pendant une longue période, généralement pendant des décennies ou plus. Les changements climatiques peuvent être causés par des processus internes naturels ou par des forçages externes tels que les modulations des cycles solaires, les éruptions volcaniques ou des changements anthropiques persistants dans la composition de l'atmosphère ou dans l'utilisation des terres.

Ainsi, plusieurs études basées sur des indicateurs biotiques et abiotiques ont permis de reconstituer certains changements climatiques importants au cours de l'Holocène récent, tels que l'Optimum Climatique Médiéval (OCM; AD 800-1100) et le Petit Âge glaciaire (PAG ; AD 1550-1850) (Meese et al., 1994; Ogilvie et al., 2000). L'OCM est connu comme étant une période chaude avec une fourchette de temps plus ou moins synchrone à travers l'Atlantique Nord (Meese et al., 1994). Le PAG, basé sur des données en provenance des carottes de glace des projets GISP2 et GRIP ainsi que des reconstructions dendroclimatiques, a été caractérisé par une variabilité climatique plutôt que par un refroidissement intense et soutenu (Dansgaard et al., 1993; D'Arrigo et al., 1993, Mayewski et al., 1994; Meese et al., 1994). Selon Grove (1988) et Overpeck et al. (1997), la baisse des températures au début des années 1800 et le réchauffement rapide après 1840 sont considérés comme les événements climatiques les plus marquants des derniers 400 ans dans le nord du Labrador. Overpeck et al. (1997) rapportent une augmentation de la température de 0,6°C au début du 20e siècle. Au Labrador, la variabilité climatique de l'Holocène récent a entraîné des changements environnementaux significatifs dans les principaux écosystèmes, notamment l'étendue et la durée de la glace de mer et la répartition et la structure des communautés végétales (D'Arrigo et al., 2003).

En Islande, selon l'étude de Mackintosh et al. (2002) basée sur une reconstruction des avancées glaciaires durant l'Holocène, la période la plus froide aurait eu lieu entre AD 1750 et 1800. Les températures du mois d'août furent alors en moyenne de 1,5°C inférieures à celle de 2005 (Axford et al., 2009). En se basant sur des données historiques d'archives, Ogilvie et al. (2000) a retracé le climat islandais du dernier millénaire, lequel aurait été relativement doux entre les 9e et 13e siècles, lors de l'OCM. Au 16e siècle, de courtes périodes rigoureuses ont eu lieu avec des températures annuelles moyennes de 1 à 2 °C en-dessous de celles du 20e siècle. Toujours selon les archives historiques, de AD 1500 à 1900, le climat était très variable, aux échelles de temps annuelle et décennale, avec une tendance générale au refroidissement (Ogilvie, 1992). Des avancées glaciaires ont eu lieu vers la fin du 18e et au 19e siècle (Dugmore, 1989; Mackintosh et al., 2002.), avancées qui furent similaires à celles survenues dans les Alpes en Europe pendant les 17e et 18e siècles (Grove, 1988).

2.2 Les épidémies d'insectes

Les épidémies d'insectes peuvent jouer un rôle non négligeable dans la dynamique forestière. Plusieurs insectes ont un impact sur la vigueur des arbres, en particulier les insectes défoliateurs qui se nourrissent de la biomasse photosynthétique (feuilles et aiguilles) (Morin et al., 2010). Au Labrador, très peu d'études ont porté sur ce sujet. Selon Payette (2007), le dendroctone de l'épinette (*Dendroctonus rufipennis* Kirby) a provoqué la mortalité d'une proportion relativement importante de la forêt d'épinettes blanches dans la région de Napaktok, au nord du Labrador entre 1989 à 1991. Dans une étude dendrochronologique au centre-ouest du Labrador, Nishimura et Laroque (2010) ont reconstitué une chronologie des épisodes passés d'épidémies de la tenthrède du mélèze (*Pristiphora erichsonii* Hartig) similaires à celle documentée pour l'ouest du Québec (p. ex : Cloutier et Filion, 1991 ; Filion et Cournoyer, 1995). Les épidémies de 1891, 1927 et 1976 semblent avoir été d'échelle régionale, alors que les éclosions ayant débuté en 1877 et 1954 semblent avoir été plus localisées au centre ouest du Labrador (Nishimura et Laroque, 2010).

Dumaresq (2011) a identifié différentes périodes d'épidémies de la tordeuse des bourgeons de l'épinette (*Choristoneura fumiferana*) dans l'est du Labrador. Selon cette étude, les infestations ont été synchrones dans l'ensemble de l'est du Labrador avec des infestations régionales majeures dans les années 1930, 1950 et 1970.

En Islande, la situation est différente étant donné que l'île est dépourvue de grandes forêts matures. Ainsi, à notre connaissance, aucune étude n'a abordé le sujet.

2.3 Feux de forêt

Les feux de forêt sont une perturbation naturelle jouant un rôle majeur dans la répartition, la composition et dans la biodiversité des peuplements forestiers. Il semble toutefois que le Labrador et l'Islande n'aient pas ou très peu été touchés par le feu étant donné l'absence et la rareté de littérature sur le sujet (à notre connaissance). De Lafontaine et Payette (2011) ont utilisé l'analyse des charbon de bois préservés dans les sols minéraux combinée aux études polliniques déjà publiées afin de reconstruire l'historiques des feux de forêt de l'Est du Canada durant l'Holocène. Cette étude a démontré la présence d'une période de plus grande activité du régime des feux dans les sapinières au début de l'Holocène. Au cours du milieu de l'Holocène jusqu'à la période récente, ils ont observé un changement du régime des feux vers une augmentation de leur activité dans la zone de lépinette. Ce changement d'activité s'est produit à 5000 cal. ans BP dans la péninsule du Québec-Labrador. Cette transition serait donc une réponse directe à la fin de l'Optimum Climatique Holocène et au début du néo-glaciaire (de Lafontaine et Payette, 2011).

3. L’antropisation des écosystèmes terrestres dans un contexte de changements climatiques au Labrador et en Islande

Au nord du Labrador, de l’Archaïque maritime (5000-3500 ans BP) au Thuléen (800-350 ans BP) (Labrèche, 2011), l’exploitation des écosystèmes terrestres était sans doute modérée, étant donné que l’économie de subsistance était principalement tournée vers les ressources marines et de la population alors peu imposante et répartie sur le territoire. Selon Kaplan (2009), c’est avec l’établissement des missionnaires moraves vers AD 1771 que l’exploitation des ressources terrestres, particulièrement le bois par les Inuits historiques, s’est intensifiée. Le bois servait principalement à la construction des maisons et de séchoirs à poisson. La tourbe était aussi une ressource importante pour les Inuits; le bois et la tourbe furent très utiles pour la construction des maisons tant au Labrador (Kaplan, 2009; Roy et al., 2012; Lemus-Lauzon et al., 2012) qu’au Nunavik (Steelandt et al., 2013; 2015) et au Nunavut (Alix, 2005). Toutefois, au Labrador, la coupe du bois lors du PAG a eu impact important sur l’écosystème forestier. En effet, les données polliniques de la région de Dog Island (Nain) suggèrent un déclin de l’épinette vers ca. 710 ans étal. BP en faveur du bouleau (Roy et al., 2012). Ce déclin semble avoir d’abord une origine climatique (conditions plus humides), puis anthropique. L’analyse macrofossile de la tourbe accumulée sur une terrasse marine dans laquelle ont été creusées des maisons souterraines au Labrador ont démontré une accélération du processus de paludification (entourbement) (ex : Oakes Bay, Webb’s bay). Le processus de paludification était favorisé par l’action combinée du déboisement par les Inuit et des conditions généralement plus froides du PAG (Roy et al., 2012; Lemus-Lauzon et al., 2016). Dans les environs de Nain, Lemus-Lauzon et al. (2012 ; 2016) ont documenté le déclin de l’épinette noire et sa disparition subséquente aux environs de 170 cal. ans BP (AD 1780) ; période de conditions relativement douces pendant le Petit Âge glaciaire. Cet événement fut suivi par l’installation du mélèze laricin dans la région. Selon ces études, les activités anthropiques seraient responsables de ce changement au sein du cortège floristique. La période autour de AD 1780 correspond à l'établissement des missionnaires moraves sur la côte du Labrador, ce qui a augmenté le besoin en combustible et bois d'œuvre. Des études effectuées sur la dynamique forestière à l’intérieur des terres, au centre-ouest et à l’est du Labrador, n’ont pas démontré un tel scénario d’ouverture du couvert forestier (Nishimura et

Laroque, 2011 ; Dumaresq et al., 2011), ce qui suggère que l'ouverture du paysage autour de Nain est d'origine anthropique.

De ce fait, l'ouverture du couvert forestier, la paludification des milieux forestiers et le déclin de l'épinette sont des exemples concrets de la transformation du paysage naturel le long de la côte dans la région de Nain, Labrador. Mais, est-ce qu'il y a eu des périodes plus marquées que d'autres par de telles transformations ? Y-a-t-il des phases où l'impact du climat fut exacerbé par l'anthropisation, ce qui a conduit à une altération profonde des écosystèmes?

En Islande, les acteurs diffèrent de ceux du Labrador et l'altération du paysage et la transformation des écosystèmes semblent être plus importante. En effet, la colonisation du territoire par les Norois dès la fin du 9e et au début du 10e siècle (Batt et al., 2015) a profondément modelé le paysage. Plusieurs études ont porté sur la relation Homme-Environnement en Islande (ex : McGovern et al., 1988; Dugmore et al., 2006; Dugmore et al., 2007; McGovern et al., 2007; Lawson et al., 2007; Church et al., 2007; Streeter et al., 2015). Dans une étude réalisée au sud de l'île, Dugmore et al. (2006) ont identifié, à l'aide de données stratigraphiques et téphrochronologiques, les facteurs environnementaux ayant contribué à l'abandon d'un groupe de cinq fermes de la région Þórsmörk durant la période médiévale. L'ouverture de la forêt de bouleau pour le développement des pâturages a généré une importante érosion des sols et, par conséquent, l'abandon des fermes entre le 10e et le 13e siècle (Dugmore et al., 2006). De plus, Church et al. (2007) ont étudié les processus? de l'utilisation des forêts et de la déforestation par l'analyse des fosses de production de charbon de bois dans la région de Eyjafjallahreppur, au sud de l'Islande. Deux phases de production de charbon de bois et d'exploitation forestière ont ainsi été mises en évidence : la première entre AD 870-1050 et la seconde de AD 1185 à 1295. Ces phases ont conduit à la déforestation de la région à partir de l'an AD 870 jusqu'à AD 1300 environ.

Dans la région de Mývatnssveit, située au nord, les données polliniques montrent une diminution régulière du pourcentage polliniques du bouleau pubescent (*Betula pubescens*) entre AD 870 et AD 1300 (Lawson et al., 2007). Selon ces auteurs, la forêt de *Betula* *pubescens* à Mývatnssveit s'est ouverte graduellement au cours des 400 années ayant suivi le début de la colonisation, vers AD 870. Cette interprétation diffère de la majorité des sites islandais qui montrent un déclin du bouleau beaucoup plus rapide (environ 100 ans). La répartition spatiale des fosses de production de charbon et la variation dans le temps de leur utilisation laisse croire que le déboisement a été progressif, du moins à certains endroits.

Ce qui est clair cependant, c'est qu'un changement majeur dans l'environnement a eu lieu en Islande autour de l'an 900, lorsque des prairies ouvertes ont remplacé les bouleaux dans la majorité des basses terres (Dugmore et al., 2000, 2005). Toutefois, toutes ces études ont eu lieu dans des régions qui abritaient des forêts de bouleau. Autrement dit, très peu d'études ont été réalisées dans des environnements moins susceptibles d'avoir soutenue de telles forêts (Erlendsson et al., 2009) ou dans les milieux non forestiers tels que le nord-est de l'île (Zutter, 1997; Karslđottir et al., 2014).

Outre le bouleau, la tourbe a aussi été utilisée, et ce, depuis le début l'occupation de l'île. En effet, la récolte de blocs de tourbe en Islande remonte probablement au 9^{e} siècle, puisque elle représentait la principale source de matériaux de construction pendant la période de colonisation et ce, jusqu'au 20^{e} siècle (Sveinbjanarsdottir, 1992).

Au nord-est de l'Islande, plus précisément dans la région de Þhistilfjörður, Zutter (1997) a étudié, par l'entremise de données paléoécologiques et archéobotaniques des sédiments archéologiqus de la ferme de Svalbarð, l'impact des activités humaines sur leur milieu. Les données archéobotaniques démontrent que l'utilisation des terres par l'Homme et l'usage intensif des pâturages ont transformé le paysage naturel en un milieu anthropisé (Zutter, 1997). Toutefois, la reconstitution paléoenvironnementale des 1000 dernières années demeure imcomplète étant donné les activités de récolte de tourbe pour la construction des bâtiments (p. ex. maisons, clôture, enclos) à proximité de la ferme et la difficulté de départager les facteurs climatiques de ceux anthropiques dans l'altération de ces écosystèmes.

Ces peuples (Inuits/Moraves au Labrador et Islandais en Islande), de par l'utilisation de leur envionnement dans lequel ils vivaient et se nourrissaient, semblent avoir contribué significativement à la transformation des écosystèmes terrestres. Mais quels sont les rôles respectifs des facteurs naturels et des facteurs anthropiques dans la modification du cortège floristiquede ces deux régions nordiques et côtières du BAN ?

Le fait que ces régions aient été habitées et exploitées d'une façon significative, il est souvent difficile de distinguer les facteurs climatiques des facteurs anthropiques en cause dans l'altération de l'écosystème. Pour y parvenir, un des moyens adéquats est l'utilisation d'une approche pluridisciplinaire et l'étude des différents écosystèmes adjacents (forêt, tourbière, lac, etc.). À cet égard, le croisement de plusieurs résultats paléoécologiques peut permettre de reconstituer les changements environnementaux survenus depuis la déglaciation, avec une attention particulière portée aux derniers 1000 ans. Les facteurs en cause ont aussi été identifiés grâce au croisement des résultats de plusieurs méthodes paléoécologiques et archéologiques/historiques.

4. Objectifs et hypothèse(s)

4.1 Objectif général

L'objectif principal de cette thèse était de comparer l'impact des fluctuations climatiques et des activités anthropiques sur l'évolution du couvert végétal des environnements nordiques anthropisés au nord-est de l'Islande et au nord du Labrador.

4.2 Objectifs spécifiques

Les objectifs spécifiques consistaient à :

1) obtenir une perspective plus large sur la nature et l'ampleur de l'impact anthropique sur le paysage du Labrador, pendant une période de dynamisme culturel et environnementale importants;
2) documenter l'impact anthropique sur le couvert forestier au nord du Labrador;
3) reconstituer l'histoire de la végétation d'avant, pendant et d'après la colonisation noroise de la partie nord-est de l'Islande;
4) documenter la relation humains-environnement au nord-est de l'Islande dans le contexte des changements climatiques des derniers mille ans.

L'anthropisation du milieu ayant été relativement récente, il nous sera donc possible de déceler son impact sur les milieux naturels plus facilement que dans d'autres régions du monde qui étaient occupées par l'Homme depuis des dizaines de milliers d'années. Les hypothèses testées stipulaient que 1) de par leur impacts sur le couvert végétal, les fluctuations climatiques furent, de manière générale, similaires dans les deux régions, que 2) l'anthropisation a exacerbé l'impact climatique sur les écosystèmes terrestres, et que 3) l'impact anthropique a été plus important en Islande qu'au Labrador.

5. Régions d'étude

Dans le cadre de ce projet, deux régions furent étudiées: le nord du Labrador et le nord-est de l'Islande. Les deux régions sont situées dans le BAN, juste au sud du cercle polaire, à la transition entre les zones arctique et subarctique.

5.1 Labrador : Localisation et caractéristiques générales

Le Labrador correspond à la partie nord-est du Canada. D'une superficie de 294 330 km^2, ce territoire s'étend du nord au sud entre les détroits de Davis et de Belle-Isle, et est bordé à l'est par la mer du Labrador et à l'ouest par la province de Québec. Nous nous sommes intéressés à deux sites archéologiques situés au centre-nord du Labrador : *Oakes Bay 1*

(HeCg-08) situé à Dog Island, à 35 km au large de Nain, et *Uivak Point* (HjCl-9) situé dans la baie de Okak à 125 km au nord de Nain (Figure 2).

5.1.1 Contexte géologique et géomorphologique

La région côtière de Nain consiste en des collines entrecoupées par des vallées glaciaires orientées est-ouest, parallèlement aux systèmes de failles. Le socle rocheux, gneissique d'âge archéen, appartient à la Province de Nain laquelle couvre la majeure partie de la côte nord-est (Green, 1974). La région de Okak est située entre les chaînes de montagnes Kaumajet et Kiglapait. Le relief est modéré, caractérisé par de vastes vallées qui s'étendent vers l'intérieur des terres et qui sont drainées par plusieurs rivières (Woollett, 2003). Le socle rocheux est d'âge archéen et fait partie de la province géologique de Nain et origine de l'orogénèse des Torngat (Ermanovics et Kranendonk, 1998).

Au cours du Wisconsinien supérieur, le centre-nord du Labrador était couvert par le segment Labrador de l'Inlandsis laurentidien (Prest et al., 1968). La déglaciation a eu lieu vers 8500 ans BP selon un axe NE-SO (Clark et Fitzhugh, 1990). Le retrait des glaces a été suivi de la transgression de la mer du Labrador jusqu'à une altitude d'environ 70 m (Clark et Fitzhugh, 1990). La région d'étude se situe à la limite nord de la zone de pergélisol discontinu et dispersé (Ressources naturelles Canada, 2003).

5.1.2 Climat

La région du centre-nord du Labrador se situe dans la zone de transition entre les climats arctique et subarctique. Elle subit une forte influence de la mer du Labrador en raison du courant du Labrador qui est un mélange des eaux froides du courant de Baffin et de l'affluent du détroit d'Hudson (Dickson et al., 1988). Dans la région de Nain, la température moyenne annuelle est d'environ -2.4°C et les précipitations moyennes annuelles varient de 800 à 1000 mm, dont environ un peu plus de la moitié tombe sous forme de neige (Environnement Canada, 2015). Recouverte de neige huit mois par année, la région est caractérisée par une

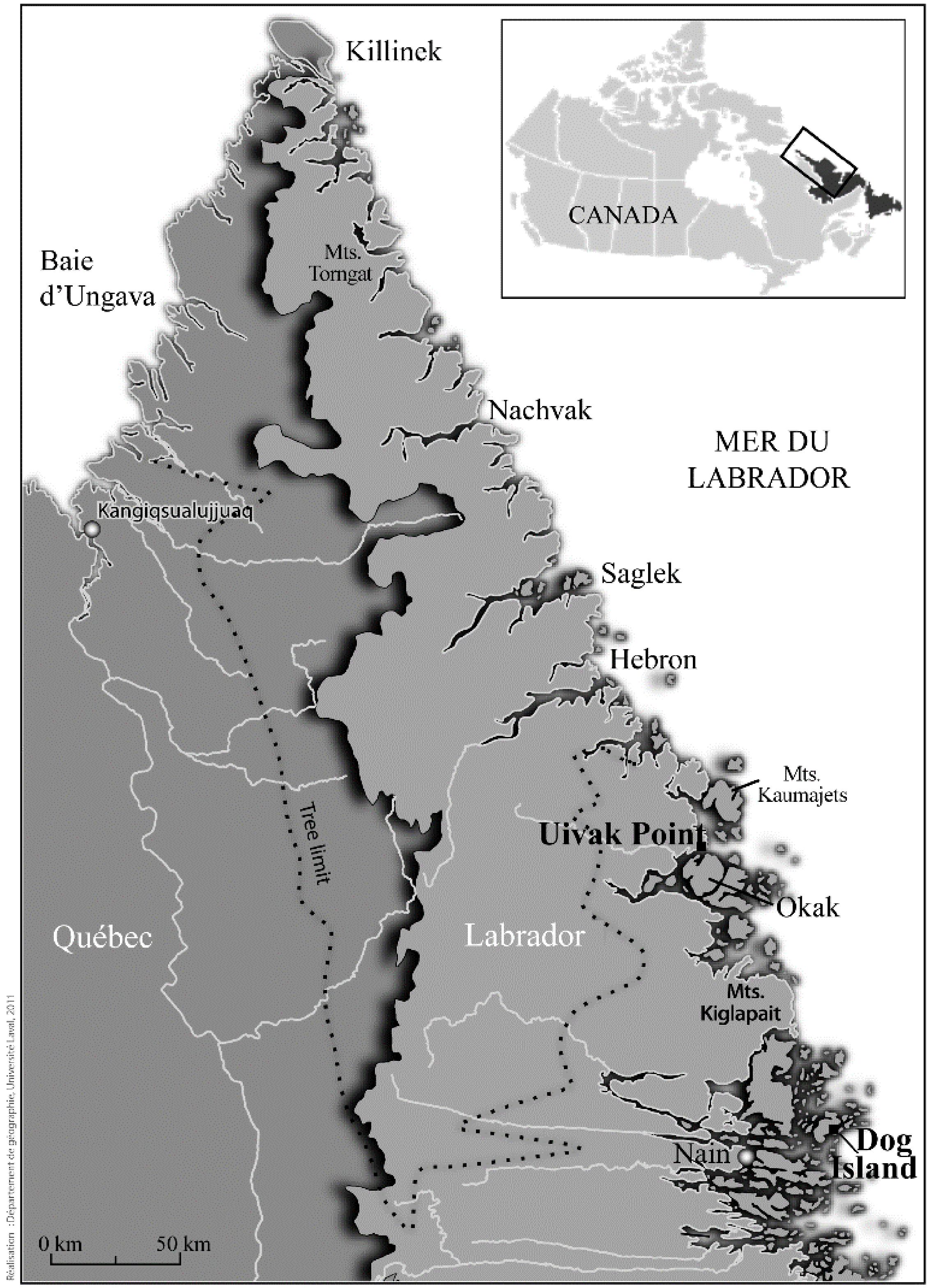

Figure 2: Localisation de la région et des sites d'étude dans le centre-nord du Labrador, Canada

saison hivernale généralement très froide alors que la saison estivale est courte et fraîche le long de la côte avec une température moyenne de juillet de 10°C. Toutefois, la température est relativement plus élevée à l'intérieur des terres (Gouvernement de Terre-Neuve et du Labrador, 2010). La saison de croissance varie de 100 à 120 jours. Le vent en provenance de l'ouest apporte un temps clair et doux, contrairement aux vents de l'est qui sont à l'origine des conditions froides, nuageuses et humides principalement à cause du courant du Labrador.

5.1.3 Couvert végétal

La région côtière du centre-nord du Labrador appartient au domaine écologique de la zone côtière (Gouvernement de Terre-Neuve et du Labrador, 2010). Cette zone, qui s'étend de la baie de Napaktok jusqu'au détroit de Belle-Isle, est caractérisée par une végétation arbustive comprenant, entre autres, *Empetrum nigrum, Rubus chamaemorus, Vaccinium* sp., *Betula* sp., *Ledum* sp., *Alnus* sp. et *Salix* sp. La strate herbacée est dominée par des cypéracées, principalement des carex. Les lichens sont présents dans les sites bien drainés alors que les bryophytes (sphaignes et mousses brunes) se retrouvent principalement dans les dépressions humides. Les vallées sont les milieux où les conditions climatiques et édaphiques sont favorables (zones protégées) à la croissance de l'épinette noire (*Picea mariana*), de l'épinette blanche (*Picea glauca*) et du mélèze laricin (*Larix laricina*) sous leur forme arborescente. En altitude, l'épinette se présente surtout sous forme de krummholz.

5.1.4 Occupation du territoire

L'Archaïque maritime est arrivé au sud du Labrador et à Terre-Neuve entre 9000 et 7500 ans BP (Cox, 1978) (Tableau 1). Ce groupe culturel a atteint le nord du Labrador entre 5000 et 3500 ans, où il a occupé presque toute la côte. Entre 3500 et 2000 ans BP, la culture appelée Indien intermédiaire succède à la culture amérindienne de l'Archaïque maritime. L'Indien intermédiaire est considéré comme une phase de transition culturelle entre les peuples de l'Archaïque maritime et leurs descendants, les Innus actuels (Cox, 1978). Les Prédorsétiens, peuple d'une culture paléo-esquimaude, sont arrivés au Labrador vers 4000 ans BP et ont formé un peuple distinct jusque vers 3000 ans BP. La culture Groswater a succédé à la culture pré-dorsétienne vers 2800 ans BP (Cox, 1978). Il s'agit d'une phase de transition du Prédorsétien vers le Dorsétien. Le Dorsétien est une culture qui a occupé la région de 2600 à environ 800 ans BP, principalement la côte et les îles (Brice-Bennett, 1977).

Originaires du nord du détroit de Béring, les Thuléens sont arrivés au Labrador entre la fin du 13e siècle et le début du 15e siècle, une date encore sujette aux débats (Fitzhugh, 1994; McGhee, 1999; Raghavan et al., 2014). Les sites d'occupation sont généralement datés entre le 13e et le 17e siècle et s'étendent de Killinek, à environ 500 km au nord de Nain, jusqu'à Sandwich Bay, à environ 335 km au sud de Nain (Brewster, 2005). Comme ailleurs en Arctique, les Thuléens du Labrador ont habité dans des maisons semi-souterraines construites d'une structure en bois ou d'os de baleine, de blocs de tourbe et de roches. Ces maisons constituaient des habitations d'hiver de forme sub-rectangulaire à sub-arrondie et comportaient généralement une ou deux pièces adjacentes qui partagent la même entrée. L'économie de subsistance des Thuléens fut principalement basée sur la chasse à la baleine et aux autres mammifères marins tels que le phoque annelé, le phoque du Groenland, le phoque commun et le phoque barbu (McGhee, 1996). Le caribou constituait aussi une source de nourriture importante, en particulier pendant l'automne (McGhee, 1996).

Tableau 1: Séquence culturelle au Labrador

C \ D	Amérindiens			Paléo-esquimaux			Néo-esquimaux	
	Archaïque maritime	Indien intermédiaire	Innu	Prédorsétien	Groswater	Dorsétien	Thuléen	Inuit
A	5000-3500	3500-2000	2000-	4000-3000	2800-2100	2400-800	800-350	350-

C : Culture
D : Date
A : Âge (ans BP)

Source: adapté de Labrèche (2001)

Les Inuits sont les descendants des Thuléens; ils occupent actuellement le nord de l'Alaska, le nord du Canada et le Groenland. Au Labrador, la transition culturelle entre les Thuléens et les Inuits est datée au 17e siècle (Kaplan, 1983). Le développement de la culture inuite s'est effectué en trois phases. La première phase (de AD 1450 à 1700) est caractérisée par plusieurs similitudes avec la culture thuléenne (ex : type d'habitation) (Labrèche, 2001) mais s'en distingue par une spécialisation linguistique et économique variant selon les régions. La seconde phase (AD 1700 à 1850) fait suite aux premiers contacts avec les Européens lors de leur établissement le long de la côte du Labrador. Ces contacts se sont traduits par des changements sociaux et économiques chez les populations autochtones. À titre d'exemple, les habitations d'hiver du 18e siècle sont devenues de grandes maisons multifamiliales (Taylor, 1974; Schledermann, 1976; Kaplan, 1983; Labrèche, 2001). Durant la dernière phase (AD 1850 à aujourd'hui), la taille des maisons a diminué n'abritant qu'une seule famille. Les maisons semi-souterraines traditionnelles ont alors été remplacées par les maisons en planches de bois de style européen. L'établissement de postes de traite le long de la côte et des missions moraves dans le nord du Labrador a augmenté les opportunités d'échange entre Inuit et Européens (Brice-Bennett, 1977).

5.1.5 Sites d'étude

Au Labrador, ce sont les sites archéologiques *Oakes Bay 1* (HeCg-08) et *Uivak Point* (HjCl-9) qui ont fait l'objet de cette étude. Oakes Bay (56°40.06' N, 61°08.24'W) est située à Dog Island qui fait partie de l'archipel de la baie de Nain. Dog Island se trouve à 35 km au large de Nain, actuellement la plus grande communauté Inuit du Labrador. Nain a été établi en 1771 par les Moraves, sous la direction de l'Agence missionnaire danoise Christopher Brasen (Demaré et Ogilvie, 2008). En 2006, Nain comptait environ 1034 habitants (Statistiques Canada, 2012). Ce village est actuellement le siège administratif du Gouvernement du Nunatsiavut, gouvernement inuit du Labrador. Pour sa part, le site archéologique de *Uivak Point* (57°37.2' N, 61°54.5' W) est situé dans la baie de Okak à environ 125 km au nord de Nain. *Uivak Point* est à 8 km au nord du village de Okak qui a été établi par des missionnaires moraves en 1776, mais fut abandonné en 1919 à la suite d'une épidémie de grippe espagnole (Taylor, 1974).

5.1.5.1 Oakes Bay 1 (HeCg-08), Dog Island

Oakes Bay (Baie de Oakes), orientée est-ouest, est l'une des principales baies de Dog Island (Figure 3). Le site *Oakes Bay 1* (HeCg-08) est circonscrit, au sud, par le littoral de la baie de Oakes, à l'est et à l'ouest par deux ruisseaux et au nord par le versant sud du mont *Alagaiai,* lequel est colonisé à la base par l'épinette. Le site archéologique se trouve sur une terrasse marine sableuse d'une altitude de 6 m (Figure 4) qui aurait émergé lors de la régression de la mer du Labrador vers 3500 ans BP (Clark et Fitzhugh, 1990; Roy et al., 2012). Cette terrasse dont la partie sommitale a été pédogénéisée (sol podzolisé) fut entourbée vers 1000 ans étal. BP (Roy et al., 2012). *Oakes Bay 1* comprend les ruines de sept maisons semi-souterraines de grandeurs diverses. Les maisons sont de forme sub-rectangulaire à rectangulaire et comportent une seule pièce (Tableau 2) (Woollett, 2003). Les murs ont été construits à l'aide de pièces de bois et de blocs de tourbe, lesquels auraient été prélevés à même le site afin d'isoler la maison du froid pendant l'hiver. L'intérieur des maisons est caractérisé par une

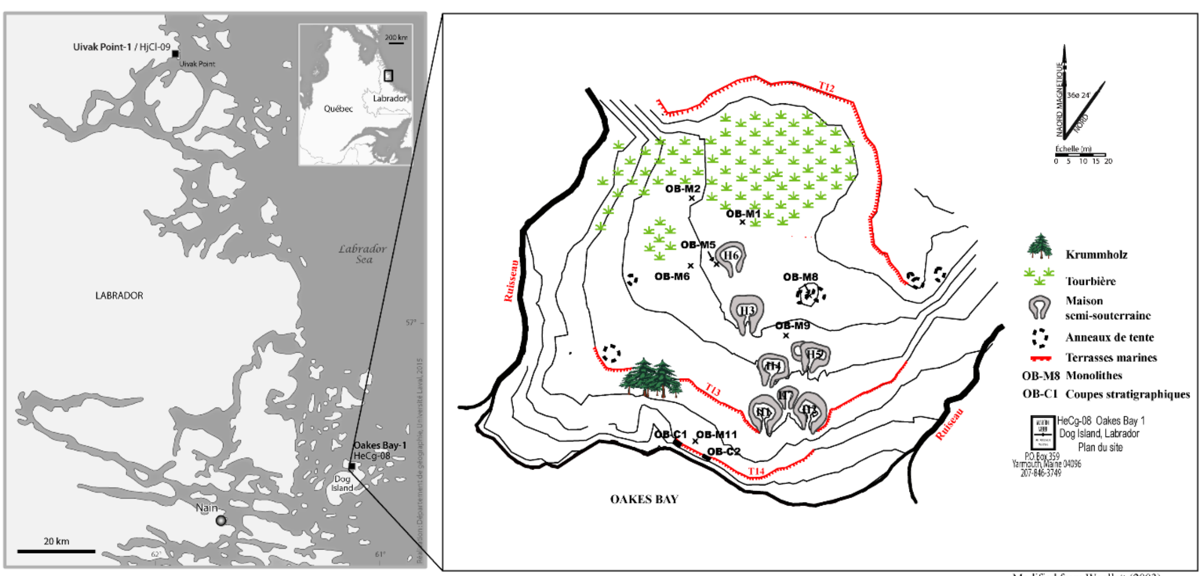

Figure 3: Localisation du site de Oakes Bay, Labrador.

Figure 4: Site archéologique de Oakes Bay 1 (flèche noire), Dog Island, Labrador.

Tableau 2: Synthèse des caractéristiques des maisons semi-souterraines du site archéologique Oakes Bay 1, Dog Island

Maison	L (m)	l (m)	C (m)	forme	Catégorie	Date (siècle)
H1	10	7	10	sub-rectangulaire	multifamiliale	mi-tardive 18e
H2	11.5	7	9	rectangulaire	multifamiliale	mi-tardive 18e
H3	9	5.5	9	-	multifamiliale	mi-tardive 18^{e}
H4	9	5.5	6	sub-rectangulaire	unifamiliale	fin 17^{e} à début 18e
H5	2	3	7	rectangulaire	unifamiliale	fin 17^{e} à début 18e
H6	7	4.5	6	rectangulaire	unifamiliale	-
H7	-	-	-	ovale	unifamiliale	-

Données de Taylor (1974) et Woollett (2003, 2010)

L : longueur
l : largeur
C : longueur du couloir

plateforme surélevée, le long du mur (dominant le plancher) et par un emplacement pour la lampe de stéatite pour procurer chaleur et lumière. Un long couloir muni d'une trappe d'air froid constitue l'entrée de chaque maison, laquelle est orientée vers le sud (vers la baie). Ainsi, la maison est protégée des forts vents d'ouest, en provenance du continent, et des vents d'est, en provenance de la mer du Labrador. À l'extérieur de l'entrée de chacune des maisons se trouve un dépotoir. D'après les données archéologiques, il y aurait eu deux phases d'occupation successives du site datées respectivement de la fin du 17ᵉ siècle et du début du 18ᵉ siècle (Woollett, 2003; 2010). Le rapport historique des missionnaires moraves de Nain indique une dernière occupation pendant l'hiver de 1771-1772 (Taylor, 1974).

5.1.5.2 Uivak Point (HjCl-9)

Le site de Uivak Point comprend les ruines de neuf grandes maisons semi-souterraines datées du 18ᵉ siècle (Figure 5). Ces maisons multi-familiales sont de formes variées (Tableau 3). Elles ont été construites dans le talus séparant deux terrasses marines d'une altitude respective de 8 et 11 m (Figure 6) (Tableau 3). La terrasse de 11 m d'altitude est surmontée de tourbe dont l'épaisseur varie entre 12 et 28 cm. Les données historiques des missionnaires moraves révèlent que plusieurs maisons étaient occupées simultanément et que près de 125 résidents occupaient le site de *Uivak Point* à la fin du 18ᵉ siècle. Il s'agissait de l'une des deux plus grandes communautés de la région de la baie de Okak (Taylor, 1974; Taylor et Taylor, 1977). Selon ces auteurs, le site fut occupé chaque hiver entre 1776 et 1798 et entre 1800 et 1807. *Uivak Point* constituait un important site de chasse à la baleine et aux mammifères marins. L'occupation du site a pris fin au printemps 1807 (Taylor, 1974; Taylor et Taylor, 1977).

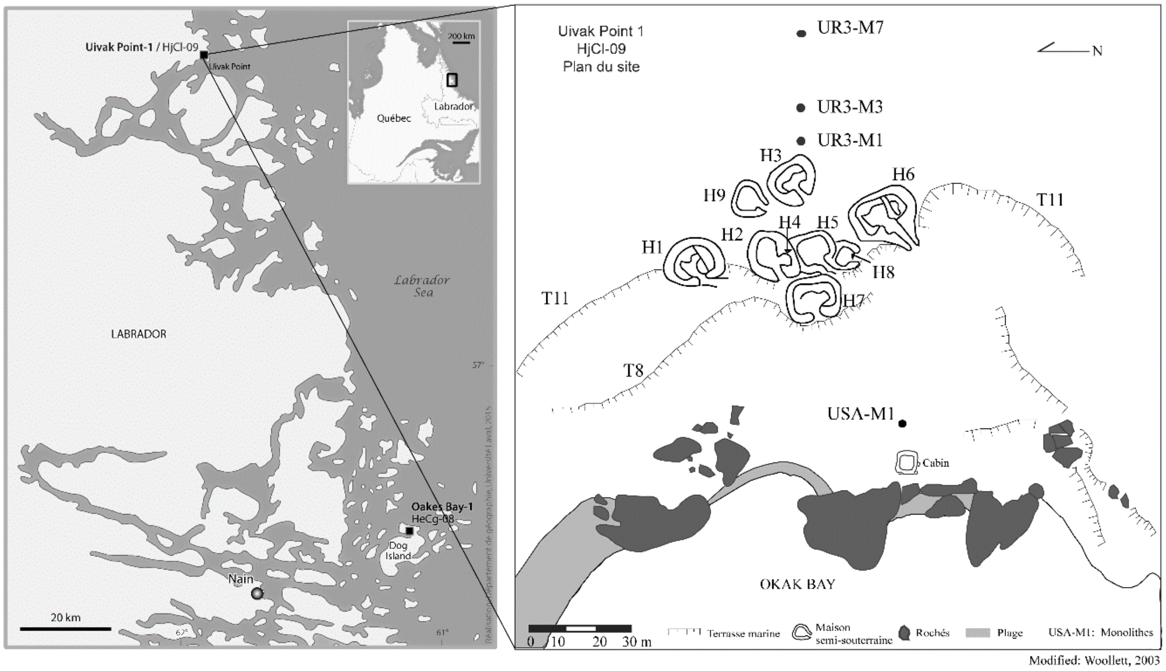

Figure 5: Carte de localisation de Uivak Point, Labrador.

Figure 6: Site archéologie de Uivak Point, Labrador.

Tableau 3: Synthèse des caractéristiques des maisons semi-souterraines du site archéologique Uivak Point, Labrador

Maison	L (m)	l (m)	C (m)	Forme	Catégorie	Date (siècle)
H1	12	8	4	trapèze à ovale	multifamiliale	18^e
H2	8	6	4	rectangulaire	multifamiliale	18^e
H3	9.5	5	4	sub-rectangulaire	multifamiliale	18^e
H4	4	3	-	rectangulaire	chambre ou vestige	18^e
H5	9	7	7	sub-rectangulaire	-	-
H6	13	8	9	rectangulaire	multifamiliale	18^e
H7	11	8	3	rectangulaire	-	-
H8	6	5	-	ronde	chambre ou vestige	-
H9	7	6	4	ronde	-	-

Adapté de Woollett (2003)

L : longueur
l : largeur
C : longueur du couloir

5.2 Svalbarðstunga, nord-est de l'Islande : localisation et caractéristiques générales

L'Islande, d'une superficie de 103 000 km^2, est située dans l'océan Atlantique Nord entre 13° et 24° O et 63° et 66° N, juste au sud du cercle polaire arctique. Le Groenland est à 300 km à l'ouest, alors qu'à 1000 km à l'est se trouve la Norvège. Les sites à l'étude se situent sur les terres de la grande ferme de Svalbarđ, aussi appelées Svalbarðstunga. Svalbarðstunga borde la rive sud-ouest de la baie de Þistilfjörður, au nord-est de l'Islande, et s'étend jusqu'à environ 20 km à l'intérieur des terres. Svalbarðstunga correspond à la langue (tunga, en islandais) de terre comprise entre les rivières de Svalbarđsá et de Sandá (Figure 7). Les installations humaines sont principalement des maisons, des bâtiments de fermes (laiterie, bergerie et étable), des enclos à bétail, des clôtures, des shieling, des cabines de pêche, une église, une fosse à charbon et des fossés de drainage.

5.2.1 Contextes géologique et géomorphologique

Formée il y a environ 60 millions d'années, l'Islande est une terre jeune et très active en termes géologiques. L'Islande est située au milieu du BAN sur la dorsale médio-atlantique et comprend deux formations géologiques principales: une formation de basalte d'âge tertiaire et une formation volcanique de palagonite mise en place lors du Pliocène-Pléistocène (Thorarinsson, 1968). L'Islande est essentiellement montagneuse; les basses terres sont principalement côtières et représentent moins de 35 % de la superficie de l'île. Les glaciers, les rivières et les lacs couvrent environ 20 % de la superficie totale de l'île. Un quart de la superficie de l'Islande est végétalisé, principalement en dessous de 200 m d'altitude et environ 2 % est cultivé (Thompson, 2003).

D'une superficie d'environ 100 km^2, Svalbarðstunga (66°09'N, 15°45'O) est située entre les péninsules de Melrakkaslétta (ouest) et de Langanes (est) dans la région de Þistilfjörður. La région fait partie de la formation géologique Pliocène-Pléistocène composée de brèches de turf brun, riche en verre basaltique hydraté appelé palagonite (Thorarinsson, 1968). La géomorphologie du terrain est influencée par une combinaison de processus volcaniques, éoliens, glaciaires, marins et fluviaux, qui ont créé une variété de formes telles que des terrasses, des eskers, des drumlins et des cônes de colluvions. Des terrasses fluviales étagées sont visibles le long des rives ouest et est de la rivière Svalbarðsá. Elles se sont formées en réponse au relèvement isostatique pléistocène. La genèse des sols a été fortement affectée par un afflux continu de cendres volcaniques (tephra) créant des sols à texture fine, de faible teneur en argile et très sensible à l'érosion (Arnalds, 1987).

5.2.2 Climat

L'Islande se trouve au lieu de convergence où l'air chaud du courant Irminger et de la dérive Nord-Atlantique (deux branches du Gulf Stream) rencontrent l'air froid et le courant polaire de l'Est du Groenland provenant des régions arctiques (Ólafsdóttir et al., 2010). La rencontre de ces deux systèmes engendre l'instabilité du climat islandais qui se traduit par des écarts de température et de précipitations sur de courtes périodes de temps, mais aussi entre le nord et le sud de l'île.

Le nord-est de l'Islande est sous l'influence d'un climat polaire de type Toundra (*ET*) selon la classification de Köppen. Selon les données climatiques de 1950 à 2008 de la station météorologique de Raufarhöfn, située à 25 km au nord-ouest de Svalbarđ, la région de Þistilfjörður est caractérisée par une température moyenne annuelle de 2,6°C et une précipitation moyenne annuelle de 680 mm, dont environ 40-50% tombe sous forme de neige (Veðurstofa Íslands, 2015). Lors des hivers où le couvert de glace de mer est important, le courant Est du Groenland transporte la glace vers les côtes, refroidissant ainsi les températures de l'air (Ólafsdóttir et al., 2010). De manière générale, les températures estivales sont fraîches, limitant la croissance de la végétation, et les hivers sont longs et relativement doux. Cette région est aussi caractérisée par 150 jours sans gel dans les zones sous 200 m d'altitude (Veðurstofa Íslands, 2015).

5.2.3 Couvert végétal

Étant donné son climat rigoureux, ainsi que son isolement au milieu du BAN, la végétation de l'Islande est peu diversifiée (Thompson, 2003). On compte environ 440 espèces de plantes à fleurs et de fougères (Kristinsson, 1998). La flore a une composition originaire du nord de l'Europe et de l'Arctique, bien que plusieurs espèces de l'Ouest de l'Atlantique soient aussi présentes. Les humains ont aussi introduit environ 100 espèces végétales (principalement les plantes cultivées et rudérales) au cours des 1100 dernières années (Steindórsson, 1962).

Certaines distinctions dans la composition de la végétation sont observables entre les basses terres et les hauts plateaux ainsi qu'entre les terres humides et celles plus arides. Avant le neuvième siècle, la flore des basses terres arides était dominée par endroits par une forêt de bouleaux (*Betula pubescens* ou *Bouleau pubescent*) avec une strate inférieure composée d'herbacées et d'arbustes tels que des saules et des éricacées (Thorsteinsson et Arnalds, 1992). Sur les hauts plateaux, *B. pubescens* était remplacé par l'arbuste *Betula nana* (et une variétés d'arbustes (*Salix* sp., *Empetrum nigrum, Calluna vulgaris, Vaccinium myrtillus et Vaccinium uliginosum)* et d'herbacées (*Festuca* sp*, Agrostis* sp*, Poa* sp*, Deschampsia caespitosa* and *Deschampsia flexuosa)*.

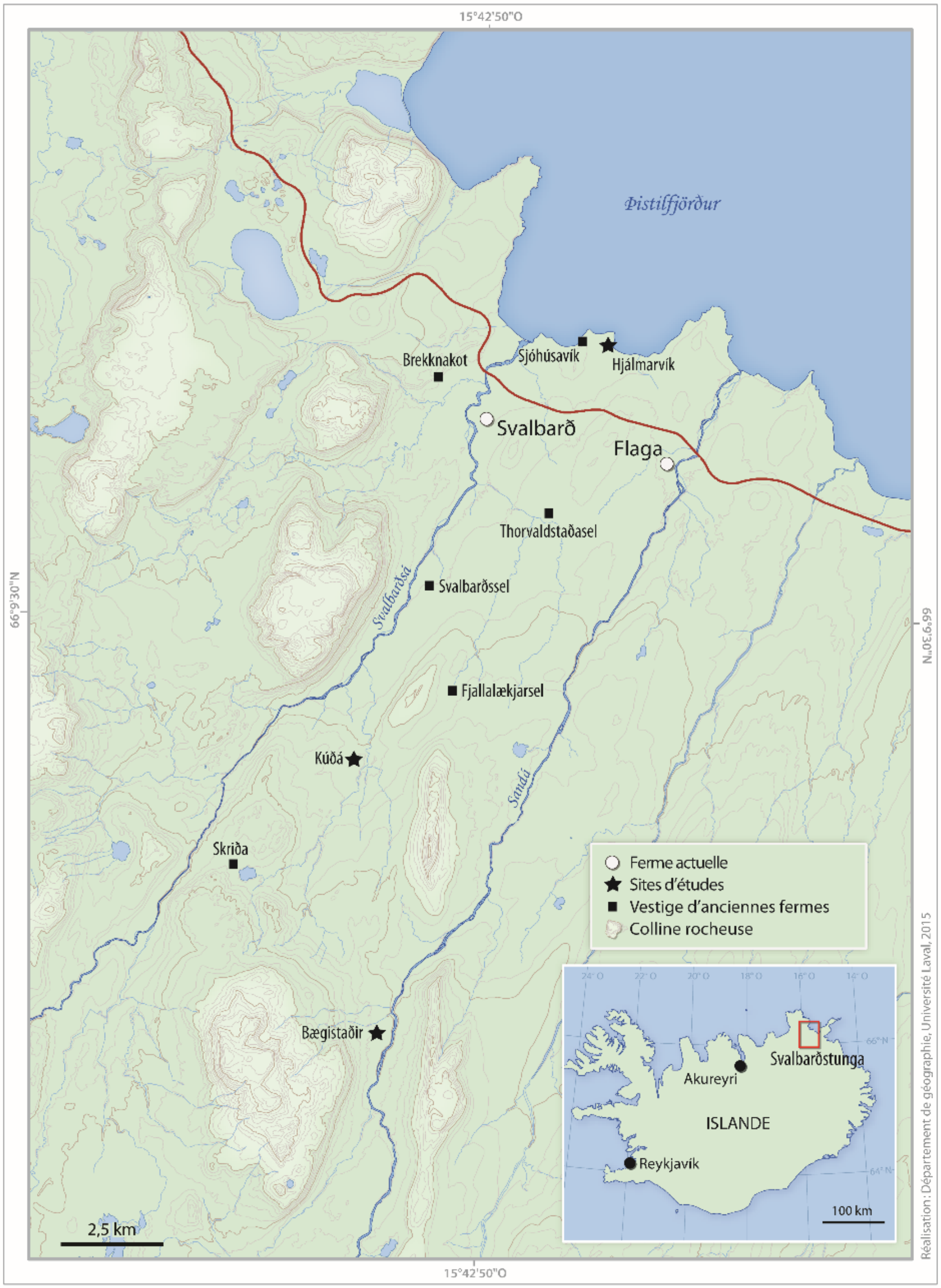

Figure 7: Carte de localisation des sites d'étude Haljmarvík, Kúđá et Baegistađir sur les terres de la ferme de Svalbarð, nord-est de l'Islande.

Les milieux humides, pour leur part, étaient composés par un assemblage floristique de joncs, de carex, de linaigrette et de saules tels que *Equisetum palustre*, *Juncus articus*, *Eriophorum angustifolium*, *Trichophorum caespitosum, Carex rostrata, Carex chordorrhiza, Carex rariflora et Carex lyngbyei*).

5.2.4 Occupation humaine

Les premiers colons de l'Islande provenaient de la Scandinavie. Après une période initiale d'exploration, les Norois ont quitté la côte ouest de la Norvège et des îles du nord de l'Écosse pour coloniser l'Islande vers 870-930 AD (Vesteinsson, 1997). Ils ont alors occupé les fjords et les vallées. Les Norois, les Celtes et leurs descendants (Islandais) sont les seuls peuples à avoir habité l'Islande alors qu'au Groeland, les Inuit occupaient les lieux avant l'arrivée des Norois. Selon Roberts (1987), chacune des générations islandaises aurait façonné le paysage en l'adaptant à de nouveaux besoins au fil du temps, créant ainsi un nouveau paysage différent à celui de leurs ancêtres.

En Islande, le terme « *Landnám* » réfère au début de l'établissement humain sur l'île. Il a été attribué par des archéologues aux premiers signes de l'occupation humaine trouvés immédiatement au-dessus d'une couche de tephra datée à 871 ± 2 AD (Grönvold et al., 1995; Vésteinsson, 1998). Les Norois ont apporté avec eux un mode de vie européen continental basé sur un système de subsistance combinant l'agriculture, l'élevage et la récolte des ressources naturelles. En effet, dès le début de leur établissement, les Norois/Islandais ont défriché les forêts de bouleau pour exploiter des terres pour le pâturage et la récolte de fourrage dans une économie de subsistance de type pastoral. Même si l'élevage des moutons et des vaches pour le lait, la viande et la laine fut important, la pêche fournissait aussi une source alimentaire très significative. De même, ils ont utilisé des quantités importantes de bois de bouleau pour la production du charbon de bois à des fins domestiques et industrielles telles l'extraction du fer des marais (Church et al., 2007). Les Islandais logeaient dans des maisons de tourbe et de bois. Ce bois fut soit du bois flotté, soit du bois de bouleau en provenance de la forêt (Mooney, 2013). La tourbe séchée était aussi utilisée comme combustible pour chauffer les habitations, pour cuisiner et pour alimenter le feu lors de la production de charbon.

5.2.5 Sites archéologiques associés à la ferme de Svalbarð

Svalbarð consiste en un vaste domaine qui, à son apogé, comprenait plusieurs fermes semi-indépendantes (fermes louées), des fermes saisonnières (shielings) ainsi que de vastes pâturages répartis dans presque toute la vallée (Amorosi, 1992; Gísladóttir et al., 2013). D'après les archives historiques, il s'agit de l'une des premières fermes ayant été établi dans la région de Þistilfjörður, vers le milieu du 10e siècle. Svalbarð était considérée comme l'une des plus grandes fermes ovines de la région. Ce domaine représente donc près d'un millénaire d'occupation et d'utilisation des terres (Zutter, 1997). Trois anciennes fermes associées au domaine de Svalbarð font l'objet de cette recherche doctorale. De la côte vers l'intrérieur, nous avons les vestiges des fermes de Hjalmarvík, de Kúđá et de Bægístaðir (Figure 8).

Le site de Hjalmarsvík, qui comprend les vestiges d'une ancienne ferme, est situé le long de la côte sud-ouest de Þistilfjörður à environ 2 km au nord-est de Svalbarđ. Les récentes études archéologiques effectuées à cet endroit ont démontré que la ferme a été occupée peu avant AD 940 jusqu'à la fin du 17e siècle et du milieu du 18e siècle jusqu'à la fin du 19e siècle (Gísladóttir et al., 2013; 2014).

Kúđá est situé à 12 km à l'intérieur des terres (à 10 km au sud-ouest de Svalbarđ) et à 120 m d'altitude. La ferme se trouve sur une colline formée de dépôts glacaires (drumlins) bordée par la rivière Kúđá, laquelle rejoint la rivière Svalbarđsá plus au nord. Le site comprend les ruines de plusieurs maisons et enclos à bétail datant entre le 13e et la fin du 15e siècle (1477) (Gísladóttir et al., 2013; 2014). Une seconde phase d'occupation date du 18e siècle jusqu'en 1966 où la ferme fut abandonnée (Gísladóttir et al., 2013).

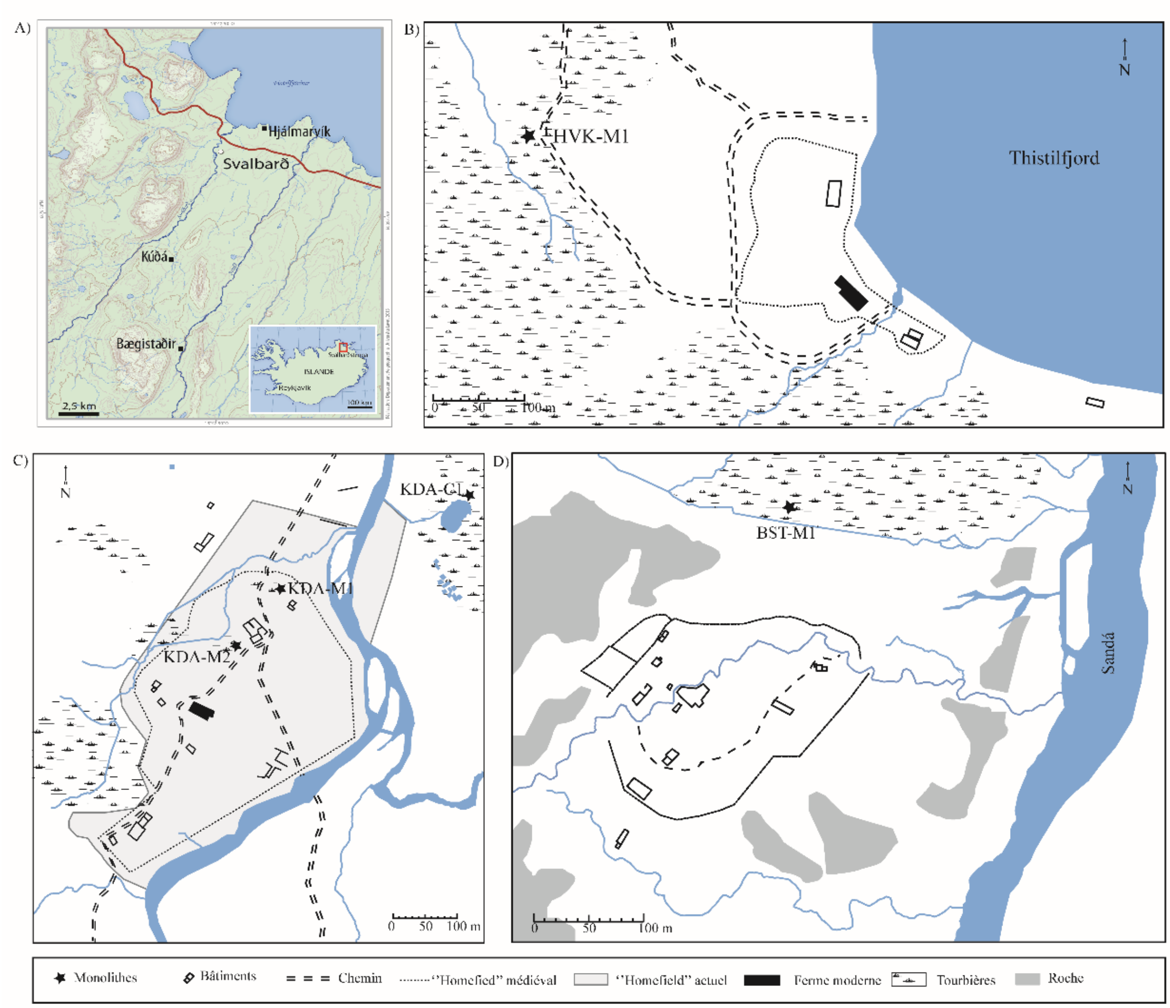

Figure 8: Localisation des sites à l'étude. A) Vallée de Svalbarðstunga, B) Hjalmarsvík, C) Kúðá, et D) Bægístaðir

Le site de Bægístaðir est localisé à 18 km de la côte (15 km de Svalbarð) et à 225 m d'altitude, dans le secteur en amont de la vallée de la rivière Sandá. La région est caractérisée par plusieurs formes glaciaires telles que des eskers, des drumlins et des kettles ainsi que des formes périglaciaires comme des hummocks, des cercles triés et des polygones. Le site de cette ferme ancienne est traversé par un petit ruisseau qui est affluent à la rivière Sandá. Bægistaðir comprend les vestiges d'anciens bâtiments de ferme et d'enclos à bétail (Gísladóttir et al., 2013). La ferme a été occupée vers AD 1300 jusqu'à AD 1477, puis à nouveau entre 1830 et 1928 (Gísladóttir et al., 2013).

6. **Méthodologie**

Tel que démontrée dans plusieurs publications (p. ex. Masson-Delmote et al., 2016), l'étude de la relation entre les humains et leur environnement requiert l'utilisation d'une approche transversale, diachronique et multiscalaire appliquée aux divers écosystèmes situés dans une même région. Dans le cas de notre étude, qui vise à reconstituer l'histoire des paysages côtiers du Labrador et de l'Islande qui ont été affectés par le climat et l'action anthropique, l'utilisation de la paléoécologie (plantes et insectes), de la dendrochronologie, de la diatomologie et de l'archéologie s'avère nécessaire.

6.1 Les méthodes paléoécologiques

La paléoécologie est la science qui étudie les relations entre des organismes vivants fossiles et leurs environnements. Elle a comme principe de base que les exigences écologiques des espèces dans le passé sont les mêmes qu'aujourd'hui. Dans le cadre de cette étude, trois approches méthodologiques complémentaires ont été utilisées : l'analyse macrofossile (plantes et insectes), l'analyse pollinique et l'analyse diatomifère. Un macrofossile ou macroreste est une pièce fossile animale ou végétale visible à l'œil nu préservée dans un sédiment organique ou minéral. La dimension d'un macroreste varie de moins d'un millimètre à quelques centimètres tels que des graines, des feuilles, des aiguilles de conifère (Bhiry et Filion, 2001). Le pollen est émis par les plantes supérieures (Phanérogames). Il est produit dans l'étamine de la fleur et est constitué d'une ou de plusieurs cellules végétatives et d'une cellule reproductrice (Lavoie, 2001). Le spore réfère à une cellule ou un organe (plusieurs cellules) de dispersion et de multiplication végétative ou de reproduction chez les plantes inférieures (Lavoie, 2001). Enfin, une diatomée est une algue unicellulaire siliceuse appartenant à un groupe d'algues brunes, microscopiques, vivant dans un plan d'eau (Pienitz, 2001).

6.1.1 Échantillonnage de milieux humides

Dans le cadre de cette étude, des milieux humides situés aux environs des vestiges des fermes de Hjalmarvík, de Kúđá et de Bægístaðir (Figure 8) ont été échantillonnés.

À Uivak Point (Labrador), trois monolithes (UR3-M1, UR3-M3 et UR3-M7) ont été extraits de la terrasse entourbée sur laquelle ont été édifiées les maisons semi-souterraines. Ils ont été prélevés le long d'un transect de 35 m. Ils ont été échantillonnés à 5 m (UR3-M1), 15 m (UR3-M3) et 35 m (UR3-M7) de distance de la maison H3 (Figure 5). Un quatrième monolithe (USA-M1) a été extrait d'une la terrasse marine entourbée de 3 m d'altitude, près des vestiges d'une ancienne cabine datant de la fin du 19^{e} et du début 20^{e} siècle, et à environ 60 m de la maison H3 (Figure 5). Ces monolithes ont été analysés pour leur contenu macrofossile afin de reconstituer l'évolution de la végétation locale et par le fait-même les conditions hydrologiques du site.

À Svalbarđstunga, à proximté des vestiges d'anciennes fermes, ce sont quatre monolithes de tourbe qui ont été extraits (KDA-M1, KDA-M2, BST-M1 et HVK-M1) afin de reconstituer les conditions envionnementales locales et régionales des environs des anciennes fermes à l'étude. Les monolithes KDA-M1 et KDA-M2 proviennent du ''homefield'' ou ''*tùn*'' de Kúđá et ils ont été extraits respectivement à 10 m au nord et 15 m à l'ouest des vestiges archéologiques. Le *tùn* réfère au champ adjacent à la ferme qui était légèrement aménagé afin de favoriser la croissance du foin. Celui-ci était habituellement récolté à la fauche et clôturé afin de le protéger du broutage par les animaux. À Bægístađir, le monolithe BST-M1 a été extrait d'une zone entourbée située dans la prairie, communément appelée ''hayfield'', laquelle est adjacent au *tùn* ou ''homefield'' de la ferme de Bægístađir. Le monolithe HVK-M1 a été extrait dans la tourbière à 350 m à l'ouest des vestiges de la ferme de Hjálmarvík dans le ''hayfield''.

6.1.2 Analyse macrofossile

Le traitement et l'analyse des échantillons ont été réalisés selon la méthode de Bhiry et Filion (2001). Les échantillons ont été coupés en tranches de 1 cm d'épaisseur. De celles-ci, une quantité d'environ 50 cm^3 a été prélevée et portée à ébullition durant 2 ou 3 minutes dans une solution composée de 200 ml d'eau et de 50 ml de KOH à concentration de 5 %. Ce traitement permet la défloculation de la matière organique et facilite l'observation et l'identification des pièces macrofossiles. Les échantillons ont ensuite été rincés et tamisés dans une colonne de trois tamis de maille de 850, 425 et 180 µm et conservés au frais et à l'abri de la lumière jusqu'à l'étape de l'analyse. L'identification des pièces fossiles a été réalisée sous une loupe binoculaire à un grossissement variant entre 16× et 40×. Les restes de mousses brunes et de sphaignes ont été identifiés à l'espèce au microscope optique. La représentation en pourcentages des différentes espèces de bryophytes a été déterminée sur la base d'un sous-échantillon de 100 feuilles. Les résultats ont été compilés et présentés sous la forme de diagrammes macrofossiles à l'aide du logiciel Paleo Data Plotter (Juggins, 2002). La collection de référence du Laboratoire de paléoécologie terrestre du Centre d'études nordiques (CEN) et des guides d'identification (Montgomery, 1977; Crum et Anderson, 1981; Porsild et Cody, 1980; Ireland, 1982) ont été utilisés.

Les restes d'insectes ont également été récupérés à partir des échantillons des monolithes KDA-M1 et KDA-M2 au même temps que l'identification et le dénombrement des macrorestes végétaux. Ils ont été identifiés grâce à des comparaisons avec des spécimens de référence modernes islandais et de publications entomologiques (Séguy, 1944; Lindroth, 1969; Bousquet, 1990). Les macrofossiles de plantes vasculaires, d'insectes et les écofacts sont exprimés en nombre de macrofossiles par 50 cm^3 de sédiments. Un écofact est un reste de végétal ou d'animal associé à l'occupation humaine. Il peut s'agir de fragments d'os, de mousses brunes brûlées, de graisse brulée ou du charbon.

En ce qui concerne le charbon de bois, des fragements ont été récupérés dans le tamis de maille supérieure à 850 µm de diamètre. Ceux trouvés dans les tamis de maille 425- et 180-µm étaient rares. Ohlson et Tryterud (2000) ont démontré que les charbons ⩾0.5 mm (ou

⩾500 µm) dans des sédiments sont généralement d'origine locale puisqu'ils sont trop lourds pour être transportés par l'eau et le vent. En conséquence, il est fort probable que les fragments de charbon de bois trouvés dans cette étude sont issus des activités humaines qui ont eu lieu directement ou près des sites archéologiques.

6.1.3 Analyse sporopollinique

Au Labrador, l'analyse sporopollinique a été effectuée sur le monolithe UR3-M7 prélevé à 35 m de la maison H3 du site de Uivak Point. Le choix de ce monolithe s'explique par le fait qu'il représente la plus grande accumulation de tourbe et par conséquent, possiblement, la plus grande fenêtre de temps. À Svalbarðstunga (Islande), l'analyse sporopollinique a été effectuée sur la carotte KDA-C1 en provenance de Kúðá et sur la carotte HVK-C1 en provenance de Hjalmarvík. Les lieux de carottage ont été choisis en fonction de leur proximité des vestiges de fermes. De plus, la grande accumulation de tourbe assurait une reconstitution de l'histoire de la végétation avant l'arrivée de l'Homme grâce à la présence de téphras volcaniques qui permet de dresser un cadre chronologique.

En suivant la méthode de Faegri et al. (1989) et de Lavoie (2001), le traitement chimique des échantillons a été effectué sur un volume de 2 cm^3 prélevé à un intervalle de 1 cm pour UR3-M7, étant donné la faible épaisseur de tourbe (21 cm), et à un intervalle de 4 cm pour les échantillons en provenance de l'Islande. Le traitement consiste en la destruction des sédiments organiques et minéraux à l'aide d'acides et de bases dans le but d'extraire les grains de pollen et les spores. Un volume connu d'une suspension de grains de pollen d'*Eucalyptus globulus* (pollen exotique), dont la concentration avait été préalablement déterminée, a été ajouté à chaque échantillon au début du traitement afin de calculer ultérieurement les concentrations polliniques (grains/cm^3). Les échantillons ont ensuite été colorés grâce à l'ajout de rouge neutre puis montés entre lame et lamelle. L'identification et le dénombrement des grains de pollen et des spores ont été effectués au microscope optique à un grossissement de 400×. Un minimum de 500 grains de pollen de plantes vasculaires terricoles a été compté. La collection de référence du Laboratoire de paléoécologie terrestre du CEN et des ouvrages de référence (Richard, 1970; McAndrews et al., 1973) ont été utilisés comme guides de référence pour l'identification des grains de pollen.

Pour chaque niveau analysé, l'identification à l'espèce des grains de pollen de bouleau provenant des échantillons islandais a été effectuée sur la base de mesures de diamètre de cinquante grains de pollen afin de faire la distinction entre *Betula pubescens* Ehrh. et *Betula nana* L. (Birks, 1968). De plus, un référentiel moderne élaboré à partir des échantillons de surface a été créé. Pour ce faire, 100 grains de pollen de bouleau ont été mesurés afin de déterminer la taille moyenne actuelle des grains du bouleau. Ces mesures ont permis d'établir une taille moyenne pour *Betula nana* qui est l'espèce dominante de la région aujourd'hui. La valeur obtenue est similaire à celles présentées par Caseldine (2001) et Karlsdóttir et al. (2014). Finalement, les résultats ont été compilés et présentés sous la forme de diagrammes sporopolliniques à l'aide du logiciel Paleo Data Plotter (Juggins, 2002).

6.1.4 Analyse des diatomées

L'analyse des diatomées a été effectuée à intervalle de 2 cm sur le monolithe KDA-M1 en provenance de Kúðá. Pour chaque niveau, entre 0,035 et 0,05 g de sédiment lyophilisé ont été traités selon le protocole de Pienitz (2001). Des microsphères de volume et de concentration connus ont été ajoutées à chaque échantillon avant la préparation pour calculer la concentration des diatomées. Un minimum de 300 diatomées a été compté dans chaque échantillon. Leur identification a été possible grâce à des guides de référence (p. ex : Antoniades et al., 2008; Bathurst et al., 2010). Les résultats ont été compilés et présentés sous la forme de diagrammes en utilisant le logiciel Paleo Data Plotter (Juggins, 2002).

6.1.5 Datation ^{14}C

Au total, 26 échantillons, neuf en provenance de Uivak Point, Labrador, et 17 des sites islandais, ont été datés par datation SMA (spectrométrie de masse par accélérateur) au laboratoire de radiochronologie du CEN à l'Université Laval (UL), et au laboratoire Keck à l'université de la Californie à Irvine (KIU). Les échantillons ont préalablement été nettoyés de matériel récent afin d'éviter la contamination par de la matière organique contemporaine. Les matériaux datés sont des pièces aériennes incluant des graines, des feuilles de mousses et des charbons de bois. Les dates ^{14}C ont été étalonnées (2 sigma) à l'aide du logiciel Calib 6.0 (Stuiver et al., 2011). Toutes les dates présentées dans ce travail, sauf indication contraire, sont exprimées en années étalonnées avant l'actuel (étal. BP) ainsi qu'en années BC/AD.

6.2 Les méthodes dendrochnologiques

La dendrochronologie est une approche de reconstitution des paléoenvironnements par l'étude des cernes annuels de croissance des arbres (Fritts, 1976; Schweingruber, 1988). Elle a été utilisée dans le cadre de cette étude dans le but de reconstituer le patron d'évolution de la forêt entourant les sites archéologiques de Uivak Point et de Oakes Bay. En analysant les variations de la croissance radiale des cernes de croissance des arbres, il est possible déduire les conditions environnementale dans lequel l'arbre a évolué. La dendrochronologie est utile dans les études climatologiques et écologiques, car pour chaque cerne de croissance une information environnementale est enregistrée. Cette information est particulièrement utile pour les sites éloignés et pour les périodes temporelles ayant précédé les enregistrements instrumentaux.

6.2.1 Échantillonnage pour analyse dendrochronologique

Aux sites de Uivak Point et de Oakes bay (Labrador), 154 échantillons de bois ont été prélevés à l'aide d'une sonde de Pressler sur des arbres vivants (56 carottes) et à l'aide d'une scie sur des arbres morts (98 galettes) lors d'une campagne d'échantillonnage sur le terrain menée aux mois de juillet et d'août 2010.

À Uivak Point, la zone d'étude a été définie après la découverte, dans une vallée à 500 m au nord du site archéologique, de vieilles souches portant des marques de coupe à la hache (Figure 5). Elle comprend des arbres solitaires, très dispersés ou issus de petits peuplements d'arbres. Compte tenu de la très faible densité du couvert forestier, tous les arbres ou krummholz pouvant être échantillonnés ont été sélectionnés. Au total, 15 carottes et 6 galettes ont été prélevées. Enfin, neuf pièces de bois, dont huit pièces d'épinette et une de mélèze, ont été récupérées de tranchées creusées dans les maisons H6 et H7 de Uivak Point (Figure 5). Seule la pièce de bois de mélèze s'est révélé être suffisamment bien conservé sur toute la largeur du tronc pour être daté. Celle-ci consiste en une poutre en provenance du tunnel d'entrée de la maison H6 qui avait été extrait du pergélisol.

Dans les environs de Oakes Bay 1 à Dog Island, l'étude du couvert forestier a été réalisée le long d'un transect de 2 km : 1 km de part et d'autre du site archéologique, vers l'ouest et vers l'est. Ce transect comprend vingt transects perpendiculaires (nord-sud) de 100 mètres de long et de 10 m de largeur. Chaque arbre et krummholz ayant un diamètre supérieur à 15 cm a été échantillonné. Pour les arbres morts, chaque souche pouvant être récoltée (non enterré ou décomposée) a été échantillonnée. Un total de 133 échantillons a été récupéré, dont 41 échantillons de carottes d'arbres vivants et 92 sections de bois mort. En outre, quatre morceaux de bois exposés lors de la fouille de la maison 2 du site archéologique Oakes Bay 1 ont aussi été prélevés.

6.2.2 Datation des bois actuels et archéologiques

L'interdatation est un principe fondamental en dendrochronologie, car elle assure le bon positionnement dans le temps de chaque cerne annuel de croissance (Fritts, 1976). Elle s'effectue par comparaison du patron de croissance d'un arbre avec une série de référence établie dans la même région d'étude que les échantillons analysés. L'interdatation dendrochronologique est possible lorsque ce sont les mêmes conditions environnementales qui ont influencé la croissance radiale d'un grand nombre d'arbres. Lorsque les fluctuations interannuelles d'un même facteur environnemental limitant sont similaires d'un site à l'autre, une réponse synchronisée et équivalente est enregistrée dans la structure des cernes annuels de croissance (Fritts, 1976). Ainsi, la structure des cernes annuels est propre à une région bioclimatique donnée. De plus, une attention particulière a été portée aux cernes diagnostiques, plus particulièrement les cernes pâles, car ils sont reliés à des évènements climatiques exceptionnels. Les cernes pâles sont le résultat d'une saison de croissance fraîche qui n'a pas permis la formation de bois final (Filion et al., 1986). C'est la formation récurrente des cernes diagnostiques chez plusieurs individus au cours de la même année qui permet de dater les cernes de façon précise.

Les échantillons récoltés à Oakes Bay et à Uivak Point ont été sablés afin de rendre visibles les cellules du bois et de pouvoir identifier les cernes annuels de croissance. Les cernes ont ensuite été comptés et pointés. Leur largeur a été mesurée sous la loupe binoculaire à l'aide d'un banc de mesure micrométrique Velmex relié à un ordinateur afin de dresser un patron de croissance pour chaque échantillon. Le cerne a été mesuré perpendiculairement à une tangente, en suivant l'axe de croissance des cellules (Schweingruber, 1988). Ensuite, une synchronisation des patrons de croissance des arbres morts a été effectuée avec ceux des arbres vivants afin de déterminer leur âge (Baillie, 1982). Toutefois, cette étape est possible à la condition que les périodes de vie des arbres vivants et des arbres morts se chevauchent suffisamment (minimum de 80 ans). Les séries de référence de cernes pâles L2 (1680-1922) et *Oakes Bay* (1620-1978) disponibles au laboratoire de dendrochronologie du CEN ont été utilisées comme outil de validation. Cette opération a permis de reculer dans le temps et d'obtenir l'âge relatif des bois archéologiques. L'interdatation a également été vérifiée en utilisant le programme COFECHA (Grissino-Mayer, 2001; Holmes 1983).

6.2.3 Analyse dendroécologique

Fonction de réponse : En dendroclimatologie, « l'analyse de la fonction de réponse » est utilisée pour définir la corrélation entre la largeur du cerne de croissance et une variable climatique particulière influençant la croissance telle que la température. Les données de température de la station météorologique de Goose Bay (Environnement Canada, 2015), situé à environ 300 km au sud de Oakes Bay, ont été utilisées pour le calcul de fonctions de réponse. Plus particulièrement, il s'agit des températures moyennes mensuelles au cours de l'année en cours et de l'année écoulée à partir de septembre (n-1) à décembre (n-1). Le programme CALROB de l'ensemble PPPHALOS (Guiot, 1991) a été utilisé pour calculer les fonctions de réponse de la croissance de l'épinette blanche. La méthode bootstrap (Efron, 1979 ; Guiot, 1991) a été utilisée pour les fonctions de réponses basées sur le calcul répétitif (500 simulations) des régressions multiples sur le même ensemble de variables climatiques. Dans cette étude, les fonctions de réponse ont été calculées suivant les méthodes décrites par Guiot et Nicault (2010).

Évènements de perturbation : Dans une étude effectuée dans la région de Whapmagoostui-Kuujjuarapik sur la côte de la baie d'Hudson, Delwaide et Filion (1988) ont utilisé la croissance relative des cernes afin d'identifier et de dater des perturbations anthropiques. Leur étude a permis de démontrer différentes périodes de récolte de bois dans les zones occupées par les peuples autochtones. De ce fait, la croissance relative des cernes peut être utilisée pour identifier et dater la présence de trouées dans la canopée entre les arbres dans un état de surcimage (Payette, 2010). De plus, selon Nowaki et Abrams (1997), Berg et al. (2006), Caccianiga et al. (2008) et Payette (2010), les évènements de détente de la croissance des cernes peuvent être détectés en calculant le rapport entre la largeur des anneaux de croissance des individus par rapport à ceux des dix années précédentes et ceux des dix années suivantes. L'évènement de détente de la croissance est marqué lorsque la croissance est supérieure à 25 % sur 10 ans. Dans le cade cette étude doctorale, les évènements de détente de croissance de chaque arbre ont été calculés selon les travaux de Nowaki et Abrams (1997) et organisés dans des classes de 10 ans. Le pourcentage de changement de croissance (% GC) a été calculé pour chaque cerne de croissance. Chaque valeur de %GC représente une moyenne de croissance de 20 ans de largeur de cerne, ce qui explique l'absence de données de %GC aux deux extrémités de la chronologie.

Compte tenu de l'espérance de vie de l'épinette blanche qui peut atteindre 250-300 ans dans les régions protégées telles que les îles (Zasada, 1984) et les régions nordiques, la sous-estimation de l'augmentation des événements de perturbation basée sur les fréquences de détente est un facteur important à considérer. Ainsi, la tendance à une réduction du nombre d'événements de perturbation dans les structures d'âge de chaque site a été corrigée en utilisant une régression linéaire semi-logarithmique. Cependant, cette analyse suppose une diminution constante des événements de perturbation au fil du temps. Par la suite, les fluctuations dans le nombre d'événements de perturbation sont exprimées par les courbes des résidus de régression. Un événement de perturbation a été ajouté à chacune des classes d'âge pour les événements de perturbation en raison de la présence sporadique d'années où aucun événement n'a été noté. Cette modification était nécessaire parce que la transformation logarithmique est inapplicable lorsque la valeur est 0.

Épidémie d'insectes: Dans cette étude, la présence du dendroctone a été décelée par l'observation directe de marques sur l'écorce des épinettes blanches telle que la présence de trous et de galeries. Les périodes d'épidémie ont aussi été datées grâce à l'identification de champignons (p. ex. *Ceratocystis coerulescens*) et des pochettes de résine. Ces dernières sont des accumulations de résine en forme de croissant observées soit entre deux cernes annuels ou dans un cerne qui est généralement déformé (Caccianiga et al., 2008).

7. Structure de la thèse

La thèse est structurée en cinq chapitres-articles dont deux sont publiés, deux acceptés avec révision et un qui sera soumis prochainement à une revue scientifique.

Le chapitre 1 s'intitule «*Paleoecological perspectives on landscape history and anthropogenic impacts at Uivak Point, Labrador, since AD 1400*». Il présente les données paléoécologiques (pollen et macrofossiles) qui ont permis de reconstituer près de 3000 ans de l'histoire du paysage au Labrador. Une attention particulière a été portée aux traces laissées par l'occupation humaine. Ce chapitre fait donc un portrait de l'histoire de la végétation locale et extra-locale en lien avec les changements environnementaux, compare les résultats avec des études régionales et suggère des liens entre les fluctuations climatiques et l'utilisation du territoire par les Thuléens/Inuit. Cet article a été publié dans la revue *The Holocene*.

Le chapitre 2 s'intitule «*A 550-year record of disturbance history of white spruce forests near two Inuit settlements in Labrador*». Il documente les perturbations naturelles et anthropiques, ainsi que leurs impacts, sur la dynamique forestière dans un contexte archéologique au Labrador. Cet article a été publié dans la revue *Jounal of the North Atlantic.*

Le chapitre 3 s'intitule «*Vegetation history since the mid-Holocene in northeastern Iceland*». Ce chapitre présente une reconstruction paléoécologique de l'histoire de la végétation avant, pendant et après la colonisation noroise au nord-est de l'Islande. Plus spécifiquement, ce chapitre documente la nature et l'ampleur des changements environnementaux (climatique ou anthropique) au cours de l'Holocène moyen et récent. Cet article est accepté pour publication dans la revue *Ecoscience.*

Le chapitre 4 s'intitule «*Perspective of landscape change following early settlement (Lándnám) in Svalbarðstunga, NE Iceland*». Il documente la relation homme-environnement au nord-est de l'Islande depuis l'arrivée des Norois. Plus précisément, il identifie les premiers signes de l'occupation des terres et leur utilisation, et présente l'impact des activités humaines passées sur l'environnement dans le contexte du changement climatique. Cet article est accepté pour publication dans la revue *Boreas.*

Le chapitre 5 consiste en une synthèse des quatre chapitres précédents et s'intitule ''*Human eco-dynamics in northern environment : a comparative study of Iceland and Labrador*''. Ce chapitre intégrateur met en relation les différents volets de la recherche. Il propose une comparaison des changements environnementaux en lien avec les fluctuations climatiques et les activités humaines dans ces deux régions. Cet article sera soumis à la revue *Environmental Archaeology.*

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Chapitre 1

Paleoecological perspectives on landscape history and anthropogenic impacts at Uivak Point, Labrador since 1400 AD

Résumé

Des recherches archéologiques et paléoécologiques ont été entreprises au site de Uivak Point (HjCl-09) situé à Okak Bay, au Labrador. Uivak Point est un campement hivernal inuit comprenant les ruines de neuf maisons semi-souterraines et d'un certain nombre d'anneaux de tente, de caches et d'autres structures. Le site a été occupé au cours de la fin du 18e et au début 19e siècles, bien que la région immédiate ait été utilisée par de nombreux groupes culturels depuis le début de la préhistoire jusqu'au 20e siècle. Nos résultats indiquent qu'entre 3030 et ca. 710 ans étal. BP, les conditions climatiques étaient froides et sèches, correspondant à la période du Néoglaciaire; elles ont induit l'abondance des arbustes de toundra. De ca. 710 à ca. 550 ans étal. BP, les conditions sont devenues relativement plus chaudes et humides, ce qui a favorisé l'expansion des arbres, principalement l'épinette blanche. Depuis ca. 550 ans étal. BP, il y a eu abondance de taxons préférant des conditions envionnementales sèches reflétant ainsi les conditions plus froides du Petit Âge glaciaire. Le réchauffement climatique ultérieur a permis le rétablissement des arbres et des arbustes au cours des 200 dernières années. Nos résultats indiquent également que les Thuléens/Inuit ont utilisé de nombreuses espèces végétales établies dans les environs de Uivak Point, comme nourriture, matières premières et combustible. Par exemple, de nombreux écofacts ou restes anthropiques (graisse brûlée, feuilles de mousse brûlées et charbon) ont été incorporés dans le sol. Les activités au site ont entrainé l'introduction et la dispersion de certaines mauvaises herbes et apophytes telles *Montia Fontana* et *Silene*. Par ailleurs, les données chronostratigraphiques et paléoécologiques suggèrent que le site a été occupé sur une base irrégulière depuis environ AD 1400.

Mots clés : Labrador, changement climatique, occupation du teritoire, paléoécologie, Thuléen/Inuit, Petit Âge glaciaire

Abstract

Archaeological and paleoecological investigations were undertaken at Uivak Point (HjCl-09 located in Okak Bay, Labrador), a site that consists of a winter village comprising the ruins of nine sod houses and a number of tent ring, cache and other structures. The site was occupied during the late 18^{th} to early 19^{th} centuries, although the immediate area has been used by many cultural groups spanning from Labrador's early prehistory into the 20^{th} century. Between *ca.* 3030 and *ca.* 710 cal. yr B.P., cold and dry climate conditions corresponding to the late Neoglacial period generated the abundance of shrub tundra. From *ca.* 710 to *ca.* 550 cal yr B.P., conditions became warmer and wetter, triggering the expansion of trees. Since *ca.* 550 cal yr B.P., there has been an abundance of dry taxa which may reflect the colder conditions of the Little Ice Age. Subsequent climate warming has allowed the re-expansion of trees and shrubs over the last 200 years. Moreover, our results indicate that the Thule/Inuit harvested many plant species that grew in the vicinity of Uivak Point for food, raw material and fuel. For example, many anthropogenic remains (burnt fat, burnt moss leaves and charcoal) were incorporated into the soil. These activities also triggered the establishment of some weeds and apophytes (*Montia Fontana* and *Silene).* Furthermore, our chronostratigraphical and paleoecological data suggest that the site was occupied on an irregular basis since approximately 1400 AD.

Key words: Labrador, climate change, land occupation, paleoecology, Thule/Inuit, Little Ice Age

1. Introduction

In this paper, we present the results of sustained efforts to apply new archaeological approaches to investigate human-environment interactions in northern Canada, with a focus on human resource use and human landscape impacts that are difficult to observe through traditional archaeological methods. Environmental archaeology, defined as the study of historical peoples and their relationship with the environment (Wilkinson and Stevens, 2001), has long been a core feature of archaeological research in the North American Arctic. This is likely due to the prominence that scientists have traditionally accorded to environmental constraints on human societies in the north and also to the fact that organic, sedimentological, geomorphological and other lines of paleoenvironmental evidence are generally well preserved and readily accessible there. Labrador's tradition of archaeological research has seen a particularly strong influence of environmental archaeology since the late 1960's. Notably, William Fitzhugh (1972, 1975, 1977) compared pollen assemblages to large-scale paleoclimate recontructions in order to provide an interpretive framework for prehistoric colonization movements and settlement patterns in Labrador. Fitzhugh's approach stimulated much contemporary and subsequent work as researchers applied these paleoenvironmental reconstructions to new sources of archaeological data, especially to site survey data pertaining to particular regions and time periods (see, for example: Cox, 1977; Kaplan, 1983).

Since the 1990's, the focus of environmental archaeology research has largely shifted to prioritize the examination of culture change though contingencies and *conjonctures* (sensu Braudel, 1972) that derive from the convergence of human-environment relationships and the direct or indirect impact of one of these agents on the other (Crumley, 1994; Balée, 1998; Balée and Ericsson, 2006), rather than in terms of evolutionary adaption. Recent environmental archaeology projects have focused on the detailed reconstruction of specific elements of settlement and land use patterns, economic activities and well-defined environmental variables pertinent to these factors. They have sought to define human-environmental interactions through multidisciplinary histories of particular landscapes as artifacts that have been conjointly shaped by human occupation as well as climatic and ecological processes (Hardesty and Fowler, 2001).

Kaplan and Woollett (2000, see also Kaplan, 2009, 2012) applied this model of environmental archaeology to Labrador in an effort to better understand the complex relationships between environmental dynamics and historical and social processes in relation to Labrador Inuit culture change from the 16th to the late 19th centuries. Their work included the analysis of significant collections of plant and insect macrofossils and vertebrate skeletal remains gathered through detailed, site-oriented excavations at sites such as Uivak Point 1 (HjCl-09) and Oakes Bay 1 (HeCg-08) in northern Labrador (Bain, 2000, 2001; Woollett et al., 2000; Woollett, 2003, 2007, 2011; Zutter, 2009; Kaplan, 2012). These studies were bolstered by the application of dendrochronology as a precise dating method that integrates high-resolution paleoclimate records with environmental archaeology data (D'Arrigo et al., 2003).

While this work has been very productive in defining land use activities and the economic and seasonal particularities of occupation at these sites, adequately defining the subtle complexities of Inuit-Environment interactions has proven to be difficult. Recent ongoing research conducted at these sites (Roy, 2010; Roy et al., 2012; Couture, 2014) has therefore sought to develop archaeological approaches capable of augmenting the detailed reconstructions of land use patterns, chronologies of site occupation, and human impacts on landscapes that are difficult to observe through traditional archaeological methods. This work has relied on a suite of multidisciplinary approaches including pedology and sedimentology, geochemistry and micromorphology, the study of sea level changes and peat formation, and expanded dendochronological analyses of samples found on (and off) archaeological sites. Taken together, these methods provide the means to develop landscape histories for site localities. Such "ecohistories," as defined by Crumley (1994), represent "the material manifestation of the relation between humans and the environment." These artifacts simultaneously reflect environmental processes, human intentions and activities as well as the ecological synergies or fallouts created by their interaction. In the context of the present project, the ecohistory of the study site is realized through the following steps:

a) Characterisation of the physical landscape and biological communities in the vicinity of targeted sites and changes therein;

b) Identification and dating of the presence of humans and the traces of their activities in the landscape outside of recognized sites and features;

c) Broadened and refined reconstructions of land use patterns, especially those related to terrestrial resources. These comprise most notably plants and peat, but include indirect traces of the acquisition and transformation of animal resources such as bone remains and geochemical evidence;

d) Discernment of human impact on the local environment and the extent to which it is an artifact created by human – environmental interactions.

The re-examination of the archeological site at Uivak Point in this study provides an opportunity to gain a broader perspective on the character and scale of Inuit landscape impacts at a significant and already well-studied Inuit site that was occupied during a period of notable cultural and environmental dynamism. Uivak Point is significant as it was a major winter settlement in the late 18th to early 19th centuries that was home to a large population. There is evidence of a “rich” subsistence economy based on harvesting seals and to a lesser degree whales, land mammals and plant foods. A complete ecohistory of the site makes it feasible to compare it to other sites for which similar analyses are available and thereby provide a comparative perspective on the diversity of Inuit winter settlements and environmental interactions.

This study has helped to develop a better understanding of the Inuit occupation of the Uivak Point 1 site and of the activities underlying its occupation, while adding to existing paleoecological and paleoeconomic studies of the site. Where previous work had concentrated upon highly visible archaeological features such as the ruins of dwellings and middens, this study has focused on the immediate local landscape by seeking traces of occupation in un-built areas in the vicinity of the site that typically escape the field archaeologist’s attention. The study also focused on the reconstruction of cultural activities involving the acquisition and transformation of basic organic raw materials such as turf and the consumption of fuels. Finally, the foundation of the study is a reconstruction of the geomorphological, pedological and ecological changes of the site’s landscape based on analyses of the local accumulation of peat and other soils, sediments, pollen and plant macrofossils.

Historical background

Labrador and the north shore of the Gulf of St. Lawrence represent the southeastern limit of the migration of the Thule across the North American Arctic. The Thule are recognized as the ancestors of the modern Inuit and their arrival in northern Labrador has been dated to between the late 13th to early 15th centuries (Fitzhugh, 1994; McGhee, 2000). A set of technological and economic changes observed in the archaeological record are considered to mark the emergence of communities with recognizably modern Inuit identities between the 17th and 18th centuries (Kaplan, 1983). The “prime movers” motivating these cultural changes were likely multiple and complex; however, archaeologists have identified the impact of climate change and the advent of increasingly profound historical contacts with Europeans as key factors. Both of these phenomena likely posed specific challenges to the Labrador Inuit in the reproduction of their communities and the maintenance of long established modes of social organization, economic production and seasonal nomadism.

The Thule arrived in Labrador at or near the beginning of a very significant environmental transition: namely, at the beginning of the so-called Little Ice Age, the most severe and variable cooling episode of the last 6000 years (Meese et al., 1994). The list of documented and potential impacts of climate change on Labrador’s physical and biological landscape is complex. Terrestrial ecosystems saw a construction of the territory that was optimally productive to humans and the plant and animal species that sustained them due to the shortening of the growing season and the downward and southward displacement of the tree line in altitude and latitude respectively, as well as a concomitant aggradation of permafrost (Allard et Séguin, 1987; Payette, 2007; Roy et al., 2012)**.** The alteration of sea ice climatology (including the prolonged accumulation of thickened land-fast ice, eastward displacement of the ice edge and the increased advection of pack ice in the Labrador Current) would in all likelihood have transformed Labrador’s coastal environment. These changes would have excluded some sea mammal species from certain coastal areas during their seasonal migrations and caused the territory suitable for ringed seal pupping to become more widespread. Human travel by foot and dog team may also have become easier.

According to Woollett's zooarchaeological research (1999, 2003, 2011), the Labrador Inuit appear to have been quite capable of coping with changing ice conditions by shifting the strategic focus (i.e. species and age class), technology and location of their hunting activities while they continued to depend on seals as their staple food resource. Nevertheless, while they were adapting, they had to react to new social economic contingencies related to the increasingly permanent and pervasive contacts with European fishermen and traders before the mid-18th century and by the establishment of Moravian missions after the late 18th century. By the early 19th century, Inuit communities were participating in European colonial world systems by trading local products such as whale oil, baleen, fur and fish for foreign goods and as baptized congregations. The net effect of these changes was to alter the strategic priorities of the "traditional" productive economy and to impose new social identities and standards of socio-economic interaction on Inuit communities (Taylor, 1974).

Uivak Point was a community near the center of processes of culture contact in northern Labrador that was particularly vulnerable to climate change due to its association with marine hunting. Uivak Point was also one of the largest winter villages in its region (Okak Bay) in the late 18th century and it figures prominently in historical accounts of the period. It is described as a community with a rich subsistence base and the winter home of people identified as traders and hunters of bowhead whales (Talyor, 1974). With a dense and somewhat extended history of occupation during a socially and environmentally dynamic period and a well-documented archaeological record, the site provides an excellent opportunity for developing an Inuit landscape history.

2. Physical setting

The archaeological site at Uivak Point (HjCl-09) (57 ° 37.2 'N, 61 ° 54.5' W) is located in Okak Bay (Figure 1) about 125 km north of the village of Nain and 8 km north of the abandoned village of Okak (Figure 1.1).

Uivak Point is located between the Kaumajet and Kiglapait mountains of northern Labrador. The bedrock is Archean and is part of the geological province of Nain and the Torngat Orogen (Ermanocs and Kranendonk, 1998). The climate ranges from arctic to subarctic, the annual mean temperature is approximately -4°C and annual precipitation varies from 800 to 1000 mm. The area is covered by the following shrub vegetation: *Empetrum nigrum*, *Rubus chamaemorus*, *Vaccinium sp*., *Betula sp*. *Ledum sp*. *Alnus sp*. and *Salix sp*. The herbaceous layer is dominated by sedges. Lichens are found in well-drained sites, while bryophytes (Sphagnum and brown mosses) are found mainly in moist areas. *Picea glauca* is mainly found in protected areas with favorable soil conditions.

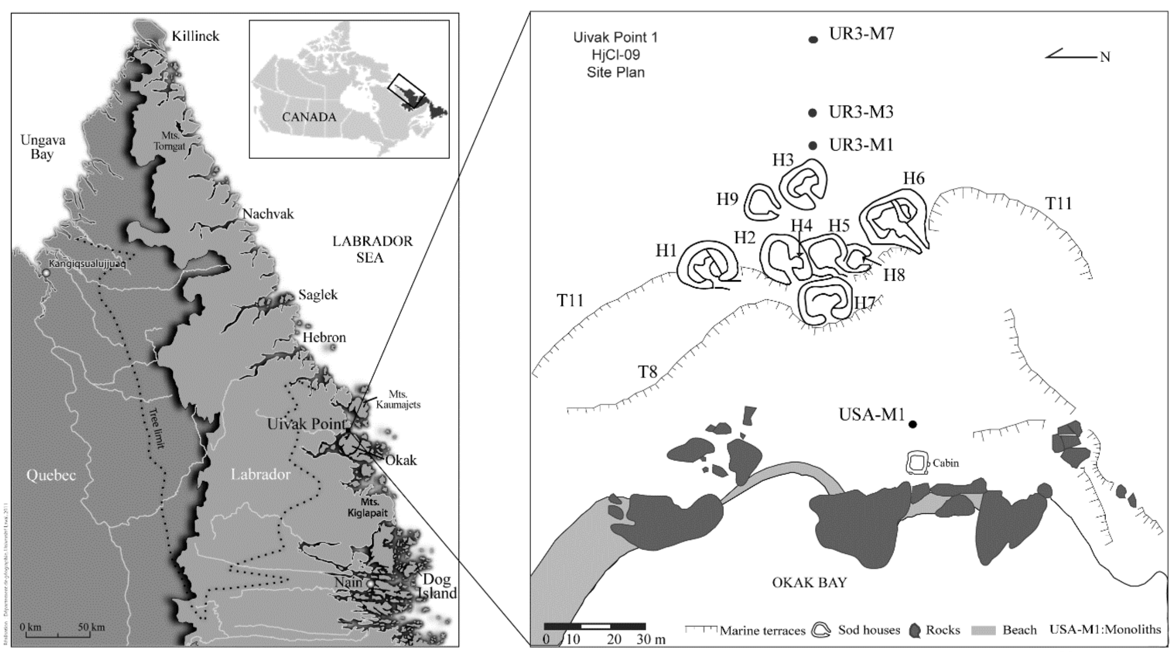

Figure 1.1: Location of the study area and archaeological sites of Uivak

3.1 Archaeology and occupation of Uivak Point 1 (HjCl-09)

The Uivak Point archeological site (HjCl-09) consists of the ruins of nine semi-subterranean sod houses on a slope between two boggy terraces 8 and 11 m asl in elevation respectively (Figure 1.1). The walls of these houses were built using peat, rock, earth, whalebone and wood. A number of tent ring, stone-built cache and grave structures are located on the surrounding slopes while other caches, graves and the foundations of two more recent cabin structures are located on the shore of the adjacent cove. Several surficial distributions of chipped stone tools and tent structures that relate to several prehistoric occupations were also found in the vicinity of the site.

Historical census records compiled by Moravian missionaries indicate that sod houses were occupied virtually every winter between 1776 and 1807. A number of spring, summer and fall tent camp occupations were also noted, extending well into the 19^{th} century (Taylor, 1974; Taylor and Taylor, 1977). According to the Moravians, the site was one of the most important winter settlements in Labrador, having up to 125 occupants, and it was regarded as one of the more successful whaling hunting communities in Labrador (Woollett, 2003). Uivak Point was thus one of three principal communities in the Okak Bay region. It is located within 10 km of the village of Kivalek and the settlement of Okak, which superseded Kivalek. Okak was a village established by Moravian missionaries in 1776 and it became the largest community in Labrador until its abandonment in 1919 following the catastrophic 1918 Spanish flu pandemic (Taylor, 1974).

Archaeological excavations conducted at the site from 1993 to 2000 (Kaplan and Woollett, 2000; Woollett, 2003; Kaplan, 2012) documented the architecture and history of occupation of one of the sod houses as well as three middens containing household refuse deposits. Midden deposits preserved in the wet and frozen ground contain dense concentrations of artifacts and animal bones (such as seal, whales, dogs, foxes, caribou, mussels and other species (see Woollett, 2003, 2008)) as well as rich inventories of plant macrofossils (such as edible berries, fuel, craft wastes, and bedding material (see Zutter (2009)), and insects. These deposits relate to the occupation of the house and its reclamation following its abandonment and yield clues about the storage of meat and the disposal of household wastes (Bain, 2000, 2002). The artifacts and the dendrochronological and radiocarbon dates point to the occupation of the excavated house possibly as early as the mid 18th century and continuing into the early 19th century. The most important occupation deposits date from the 1770's to at least 1807 (Woollett, 2003; Kaplan, 2012).

While the historic Inuit occupation is by far the most important in terms of the density of cultural materials and living structures, the site has a much longer, if as yet poorly understood, history of occupation. Several surficial distributions of chipped stone tools and tent structures that relate to several prehistoric occupations (notably, Maritime Archaic, Pre-dorset and Point Revenge/Intermediate Indian) were also found in the vicinity of the site. An additional and ambiguous aboriginal occupation of the area is indicated by the presence of out-of-context chipped stone tools in the 18th century Inuit excavations that originate from the Intermediate Indian period. Thule occupation (between approximately the 15th to 17th century) may also be vaguely and indirectly indicated by the presence of a small number of fragments of ground slate tools and tool production waste in deposits associated with the 18th century houses and middens. If that is the case, then these artifacts are also detached from their original archaeological context. Finally, two recent Inuit cabin foundations dated to the late 19th to early 20th centuries are located on the edges of the site (Woollett 2003).

3. Methods

Pollen analysis and macrofossil analysis were used in order to reconstruct the environmental conditions surrounding the archaeological site and to obtain a better understanding of Inuit occupation and related activities. Pollen records helped us to retrace the evolution of the regional and extra-local vegetation, while macrofossil analysis was used to evaluate local hydrological changes and human disturbance around the archaeological site. Larouche (1979) demonstrated that macroscopic vegetal remains (seeds, bark, needles, stems, etc.) are generally found within about 20 m of their place of origin. They are, accordingly, ideal for local-scale reconstructions of vegetation (Bhiry and Filion, 2001).

The organic matter (OM) layer of an 11 m high sandy terrace was selected for stratigraphic, macrofossil, spore and pollen analyses. Several sod houses are located on this terrace on the Uivak Point archaeological site. The vegetation type dominating the site is arctic tundra and includes *Salix* sp., *Betula glandulosa, Ledum decumbense, Vaccinium uliginosum* and *Vaccinumvitis-idea*. Brown mosses such as *Polytrichum piliferum, Aulacomninium turgidium* and *A. palustre* are also present, but there are no trees near the site except for some krummholz of *Picea glaca* on the hills.

3.1 Spore and pollen analysis

Spore and pollen analyses were performed at 1 cm intervals on a 21 cm long monolith (UR3-M7) extracted from the peaty terrace around the archaeological site. We focused on the UR3-M7 sample because OM accumulated earlier in the sampled point, at about 3030 cal yr B.P., as opposed to 1130 cal yr B.P. for UR3-M3 and modern times for UR3-M1. For each level, 2 cm^3 of sediment was processed following the procedures of Faegri and Iversen (1989) and Lavoie (2001) (using chemical treatments of 10% KOH, HCl, and HF, and acetolysis). A *Eucalyptus globulus* pollen suspension of known volume and concentration was added to each sample to calculate pollen concentration (grains/cm^3) (Benninghoff, 1962). At least 500 pollen grains of terrestrial vascular plants were counted for each sample (pollen sum). Pollen and spore identification followed Richard (1970, 1981) and McAndrews, Berti, and Norris (1973). The pollen collection at the Centre d’études nordiques (CEN) was used as a reference for the identification of problematic specimens. Pollen diagrams were drawn using Palaeo Data Plotter software (Juggins, 2002).

3.2 Macrofossil analysis

Four OM monoliths were sampled for stratigraphic analysis, macrofossil analysis, and radiocarbon dating (Figure 2). Three of them (UR3-M1, UR3-M3, UR3-M7) were extracted from the 11 m high paludified terrace (T11), while one (USA-M1) was sampled from the 3 m high terrace (T3) located about 60 m south of House 7 (H7) and adjacent to the present beach (Figure 1). The monoliths were between 12 and 35 cm thick.

Monoliths UR3-M1, UR3-M3 and UR3-M7 were selected along a 35 m long transect at a distance of 5, 15 and 35 m from House 3 (H3) in order to distinguish changes in the stratigraphy and plant succession. The analysis was conducted at 2 cm intervals following the protocol outlined by Bhiry and Filion (2001). Each sample consisted of 50 cm^3 of sediment. Sediments were treated with a weak 5% aqueous KOH solution and boiled for a few minutes to deflocculate. The material was then wet-screened through a series of sieves (850, 425, and 180 μm mesh) and the macrofossils were identified under binocular and light microscopy. References used to identify plant remains included Montgomery (1977), Porsild and Cody (1980), Crum and Anderson (1980), Ireland (1982), and the CEN collection at Laval University. The macrofossils of vascular plants and other anthropogenic ecofacts (charcoal, animal bones, burnt brown mosses and burnt fat) are expressed in terms of the number of macrofossils per 50 cm^3 of sediments. Recovered charcoal fragments were generally larger than 850 µm in diameter, which corresponds to the largest mesh size used here (850, 425, and 180 μm mesh sieves). Charcoal fragments found in the 425 and 180 µm mesh were rare. Ohlson and Tryterud (2000) have shown that charcoal fragments ≥0.5 mm (or ≥500 µm) in sediment samples tend to be of local origin due to the difficulty of their transport. Accordingly, it is likely that the charcoal fragments observed in this study are residues of human activities that took place at the archaeological site itself. For mosses, the percentage of each species was determined based on a subsample of 100 leaves. Palaeo Data Plotter software was used to construct the macrofossil diagrams (Juggins, 2002).

3.3 Radiocarbon dating

Nine organic samples were dated with accelerator mass spectrometry (AMS) at CEN's laboratory and at the Keck Laboratory at the University of California, Irvine (UL-KIU). Samples consisted of plant macroremains (leaves, seeds, etc.). Dates were calibrated using the Calib 6.0 program (Stuiver et al., 2011) and midpoints were obtained using the weighted median method (Telford et al., 2004; Stuiver et al., 2011). Calibrated ages (cal. yr B.P.) were rounded to the nearest decade and the results are presented in calibrated years.

4. Results

4.1 Pollen and spore data from Uivak Point

Three zones were delineated based on the pollen assemblages (P-I, P-II, and P-III) of the UR3-M7 monolith, which was extracted from the peaty terrace near the archaeological site (Table 1.1, Figure 1.2).

Table 1.1: Radiocarbon and calibrated ages of the monoliths sampled at Uivak Point, Labrador

Sample	Lab. number	Age (yr BP)	Age AD. BC. (2 σ)	Age (cal yr BP) (2 σ)	Midpoint calibrated age (cal yr BP)	Dated material
UR3-M1 (14-15 cm)	ULA-3297	modern	-	-	-	Organic matter
UR3-M3 (7-8 cm)	ULA-4054	495+/-30	1401-1449 AD.	501-549	530	Wood fragments
UR3-M7 (3-4 cm)	ULA-4051	195+/-30	1729-1811 AD.	139-221	180	Leaves
UR3-M7 (9-10 cm)	ULA-4052	450+/-30	1415-1478 AD.	472-535	510	Wood fragments
UR3-M7 (13-14 cm)	ULA-4053	745+/-30	1223-1288 AD.	662-725	660	Wood fragments
UR3-M7 (20-21 cm)	ULA-3296	2900+/-15	1129-1013 BC.	2962-3078	3030	Organic matter
USA-M1 (17-18 cm)	ULA-3025	115+/-15	1685-1953 AD.	*0-265	110	Seeds
USA-M1 (25-26 cm)	ULA-3026	345+/-15	1472-1633 AD.	317-478	380	Seeds
USA-M1 (33-34 cm)	ULA-3027	1015+/-15	992-1028 AD.	925-958	940	Wood

Zone P-I: 21–14 cm (from 3030 to ca. 710 cal yr BP). Zone P-I is composed of sand and organic matter overlain by highly decomposed brown OM. The average rate of sediment accumulation is low (0.003 cm/yr) (Figure 1.3). Pollen concentration is high at the base of the core (750 000 grains/cm^3) but decreases progressively and significantly thereafter. This zone is also characterized by an abundance of pollen from *Ericaceae*, which suggests that the conditions were well drained and facilitated the development of shrub tundra. Indeed, pollen from several shrub species (e.g. *Betula sp., Alnus sp.,* and *Salix sp.*) were found in small quantities (less than 20%), indicating their gradual establishment in the region. The presence of *Lycopodium* and *Sphagnum* spores, albeit in small quantities, indicates that the local conditions were often wet. The pollen influx is relatively low, except for *Ericaceae*, which decreases to the end of this zone (Figure 1.4).

Zone P-II: 14-10 cm (from ca. 710 to ca. 570 cal yr BP). Zone P-II is composed of highly humified brown OM. The average rate of sediment accumulation is significantly higher than in the P-I zone (0.027 cm/yr). This zone is characterized by an abundance of pollen from *Picea* sp. The sharp increase in *Picea* sp. pollen to 39% indicates that the conditions were clement and that trees were colonizing in proximity to the archeological site. One of the most remarkable features of this zone is the peak of the pollen influx of species observed between 14 and 12 cm, dating to ca. 660 cal. yr B.P. Taking into account the short intervals, the peak influx may be explained by a significant expansion of the species in the region. This interpretation is supported by the increase in pollen from other tree species such as *Abies* sp. and *Pinus* sp. The *Poaceae* pollen percentage (1-5%) is low and may be indicative of grasses growing in scrub and heath or minor grassland/herb slope communities. *Ericaceae* comprises approximately 60-70% of the total pollen assemblage.

Zone P-III: 10 to 0 cm (from ca. 570 cal yr BP to present). Zone P-III consists of fibrous light brown OM. The average rate of sediment accumulation is about 0.018 - 0.017 cm/yr. Two subzones were identified based on the pollen assemblages: P-IIIa and P-IIIb.

In subzone P-IIIa, there was a decrease in pollen percentages of *Picea* sp. and *Pinus* sp., while *Cyperaceae* pollen percentages rose from 10% to 40%. This finding suggests an opening of the canopy, which could have been caused by the deterioration of climate conditions or by anthropogenic impacts (given that we know that Uivak Point was occupied by Inuit and by Moravians during this time). *Epilobium latifolium* and *Silene* sp. were prevalent, which is significant because these taxa are known to grow on sites that have been disturbed by human activity (Blondeau and Roy, 2004).

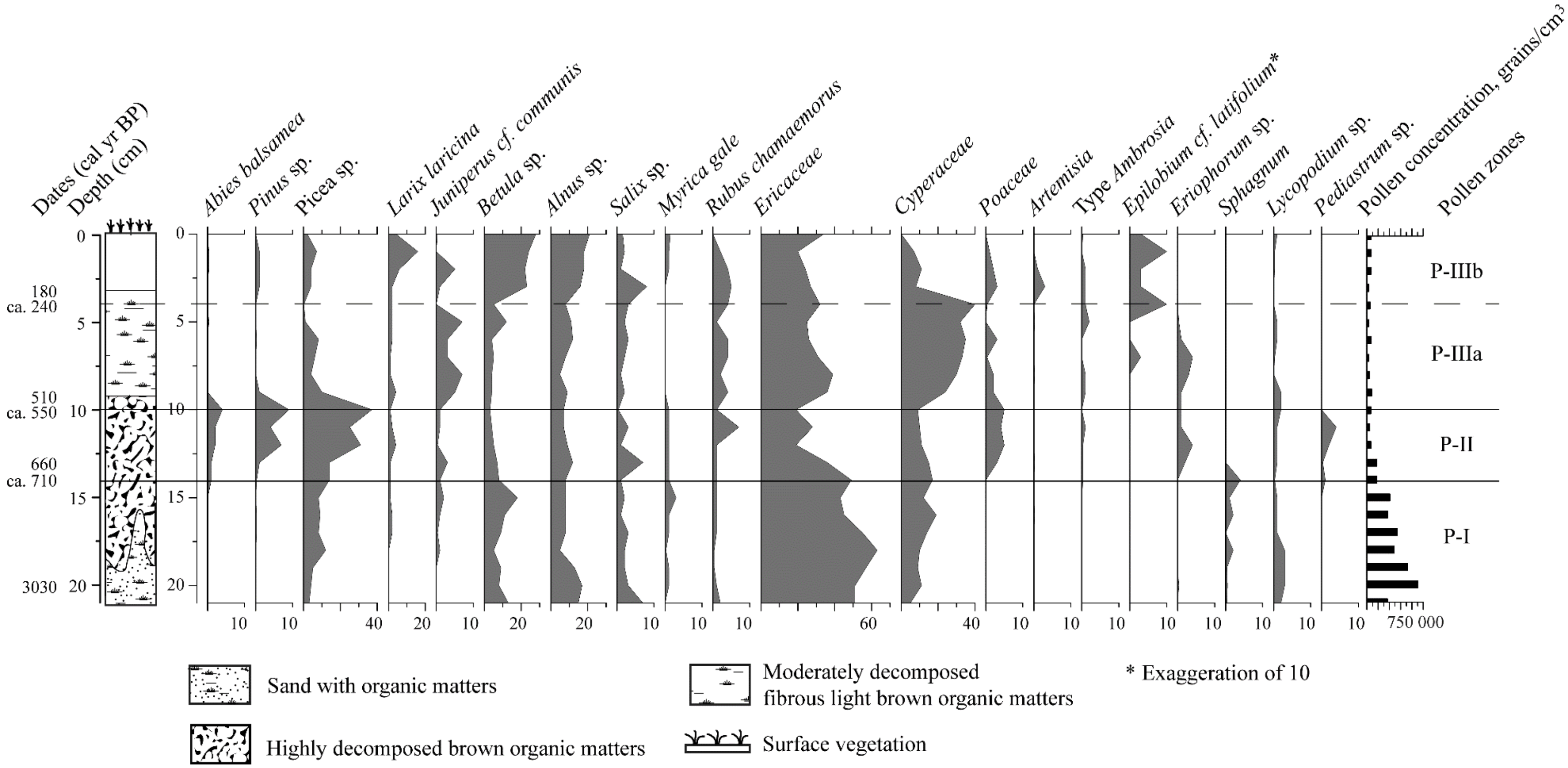

Figure 1.2: Pollen diagram of a monolith (UR3-M7) extracted from the peaty terrace around the archaeological site

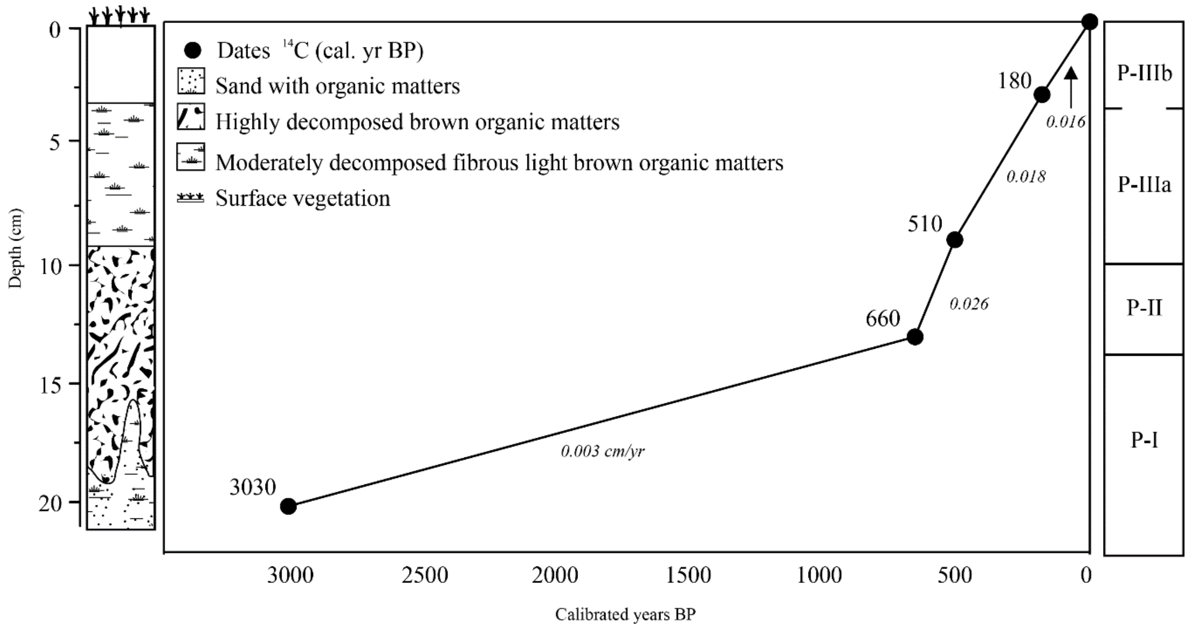

Figure 1.3: Age-depth model of the monolith UR3-M7, Uivak Point. Stratigraphy (left) and pollen assemblage zones (right) are also illustrated.

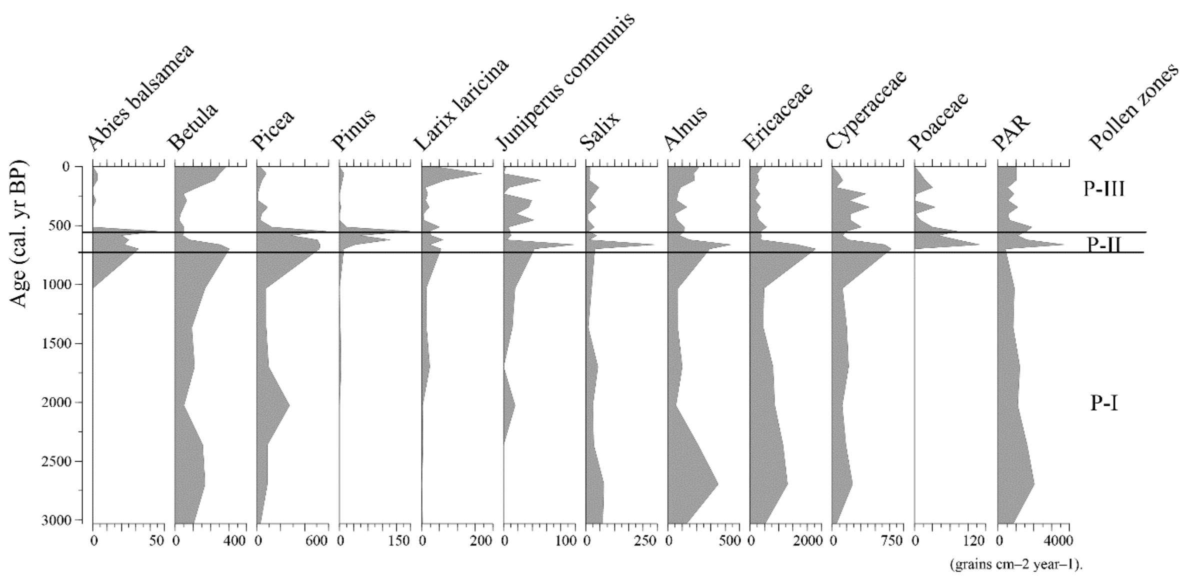

Figure 1.4: Pollen accumulation rate diagram of dominant species from monolith UR3-M7, Uivak Point.

Subzone P-IIIb is characterized by the sharp decline of *Cyperaceae* pollen (down from 40% to 1%) and a rise in pollen from *Salix* sp. and *Picea* sp. (rising to 10%). These patterns are also reflected in the pollen influx data. The pollen percentage and the pollen influx data indicate a significant increase in pollen from *Betula sp., Alnus sp.* and *Larix laricina*, which is indicative of an expansion of these taxa.

4.2 Uivak Point Monolith Stratigraphy and Macrofossil Data

The stratigraphy of all of the monoliths from Uivak Point (UR3-M1, UR3-M3, UR3-M7) is characterized by a brown coarse sand with organic matter (B-horizon) capped by an organic matter layer (OML) 15 to 20 cm thick. This OML is formed by highly decomposed black to brown OM overlying a moderately decomposed, fibrous, light brown OM. The detailed stratigraphical description of each monolith is included in the legend of the corresponding figure.

Although all of the monoliths were taken from the same terrace along the 35 m transect and were separated by only a few meters, radiocarbon (^{14}C) ages for the mineral-organic transition differ from one monolith to another (Table I; Figure 1). This transition was dated *ca.* 780 and *ca*. 980 cal. yr B.P. in monoliths UR3-M7 and UR3-M3 respectively. Monolith UR3-M1 is located in proximity to the houses (H3) and is significantly more recent, dating to modern times.

Macrofossils in Monolith UR3-M1

Two macrofossil zones were identified based on the assemblage of plant remains (M-I, M-II) (Figure 1.5). This monolith is of recent age, with modern dates obtained at a depth of 14 -15 cm.

Zone M-I: 16-9 cm. Zone M-I is dominated by the remains of *Montia fontana*, which usually grows on sites that have been disturbed by human activity (Blondeau and Roy, 2004). Human activity is further indicated by the presence of *Polytrichum piliferum*. This plant grows on open and sandy to gravelly soil and it is often the first to grow on dry, sterile and disturbed sites (Crum and Anderson, 1980; Ireland, 1982) (Figure 1.5).

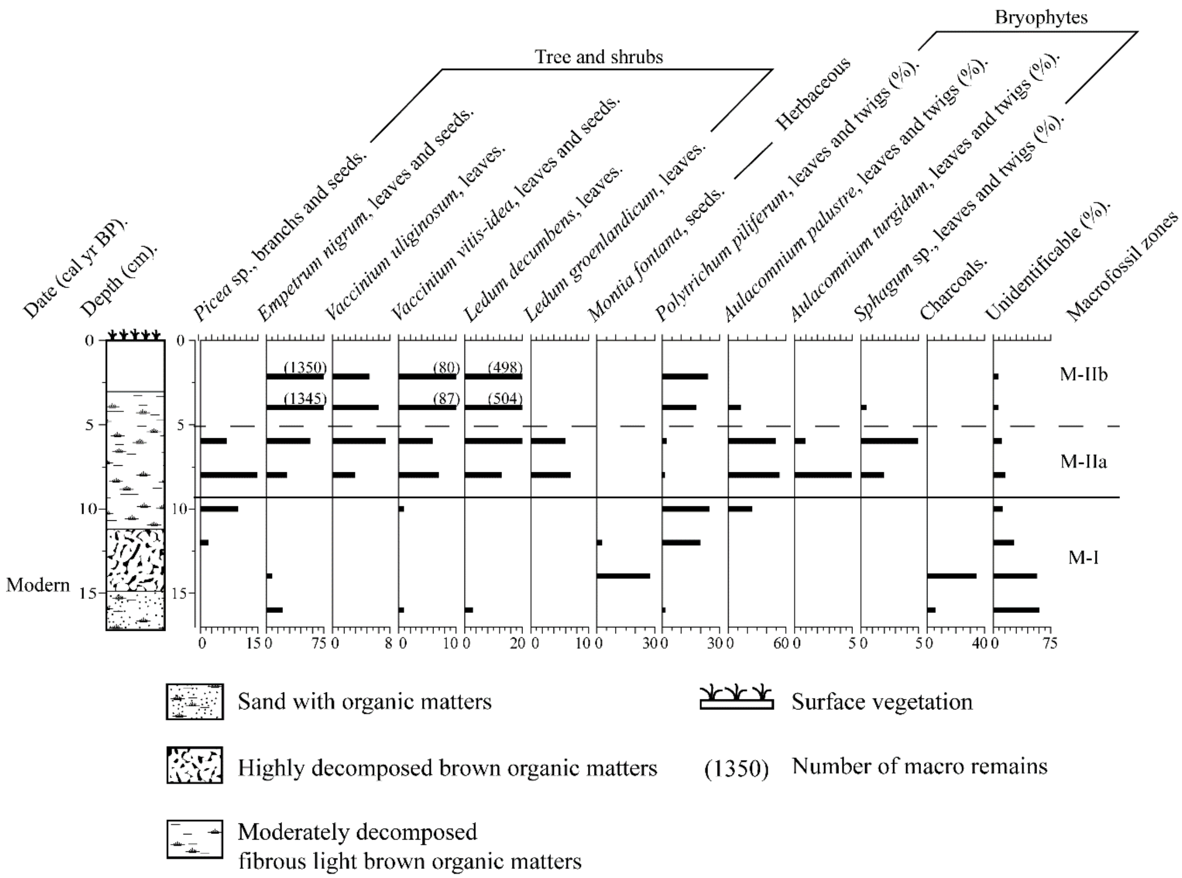

Figure 1.5: Macrofossil diagram of UR3-M1 monoliths sampled at Uivak Point (number of macrofossils per 50 cm3).

Zone M-II: 9-0 cm. Two subzones were identified in this zone: M-IIa and M-IIb. Subzone M-IIa is characterized by diversified vegetation such as *Picea sp., Empetrum nigrum, Vaccinium uliginosum, Vaccinium vitis-idea, Ledum groenlandicum* and *Ledum decumbens.* The abundance of bryophytes in this subzone suggests that conditions were wetter than in zone M-I. Subzone M-IIb contains the remains of current vegetation including *Empetrum nigrum, Vaccinium uliginosum, Vaccinium vitis-idea, Ledum decumbens* and *Polytrichum piliferum.* The disappearance of *Aulacomnium palustre*, *Aulacomnium turgidum* and

Sphagnum sp. could indicate that environmental conditions changed from wet to well drained.

The monolith was extracted 5 m from House 3 (H3) at Uivak Point. The base if the UR3-M1 monolith contains *Montia Fontana* and *Polytrichum piliferum,* which typically colonize open sandy areas that have been altered by human activity and precede the diversification of the vegetation.

Macrofossils in Monolith UR3-M3

Two macrofossil zones were identified based on the assemblage of plant remains (MI, M-II) (Figure 1.6).

Zone M-I: 15-6 cm (from ca. 1130 to ca. 450 cal yr BP). Identifiable and well-preserved plant remains are scarce in this zone. Only a small number of *Empetrum nigrum* pieces and wood fragments were identified. However, we do know that *Empetrum nigrum* was used by Inuit and their ancestors for food, fuel, in mattresses and for medicine (Blondeau and Roy, 2004). Charcoal, some masses of burnt fat and burnt brown moss fragments were also found at a depth of 7 - 13 cm.

M-II zone: 6-0 cm (from 450 cal yr BP to the present). This zone has a diverse range of vegetation: *Empetrum nigrum, Vaccinium uliginosum, Vaccinium vitis-idea, Polytrichum piliferum, Aulacomium palustre* and *Aulacomnium turgmidiu*. The presence of these plants shows that the environment was wet, acidic and open (Porsild and Cody, 1980; Crum and Anderson, 1980; Ireland, 1982). *Polytrichum piliferum* is a particularly significant find as it is a brown moss that typically grows on disturbed sites (Ireland, 1982).

This monolith was extracted 15 m from House 3 (H3). Charcoal and anthropogenic remains (e.g. burnt brown mosses and burnt fat) were found at a depth of between 13–6 cm. This finding suggests that the site was impacted by humans at ca. 980 - 530 cal yr BP (from about

970 to 1420 AD) with greater human activity at ca. 680 cal yr BP (1270 AD) (between 9–10 cm).

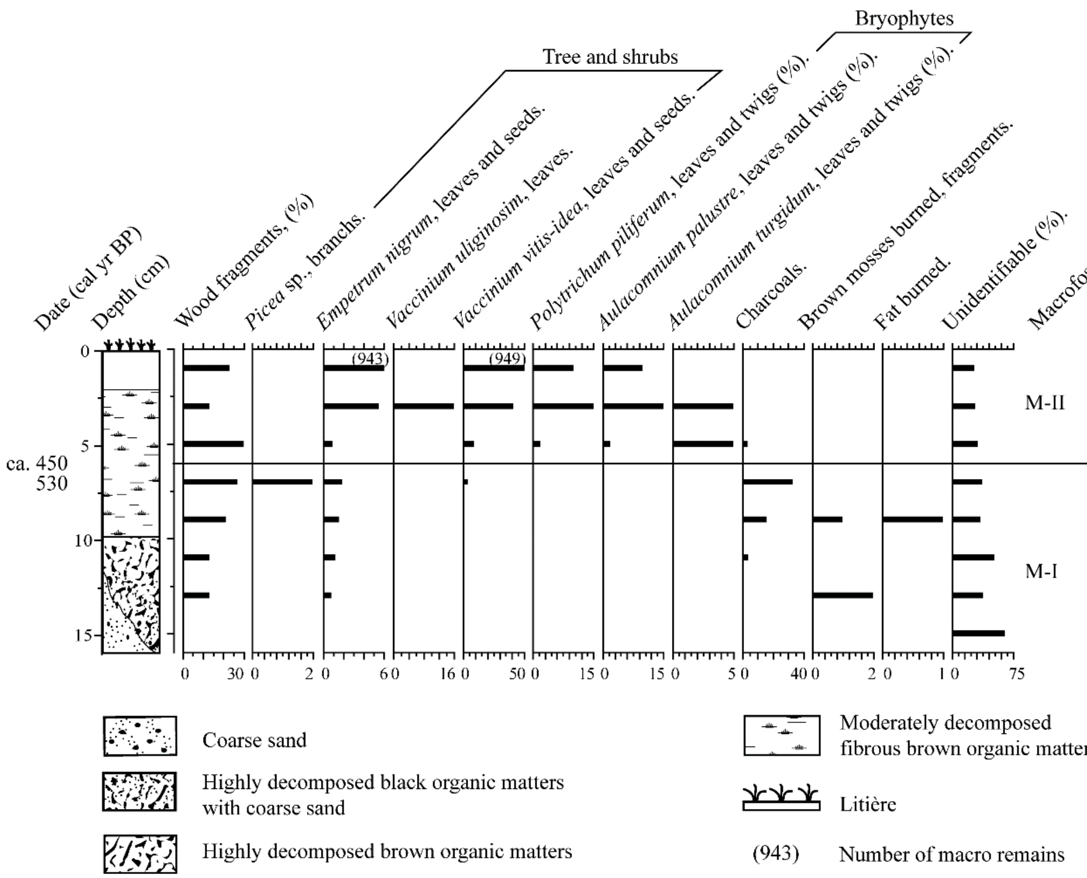

Figure 1.6: Macrofossil diagram of UR3-M3 monoliths sampled at Uivak Point (number of macrofossils per 50 cm3).

Macrofossils in Monolith UR3-M7

Three macrofossil zones were identified based on the assemblages of plant remains (MI, M-II, M-III) (Figure 1.7).

M-I zone: 21-9 cm (from 3030 to 510 cal yr BP). Zone M-I has a high degree of OM decomposition and a scarcity of identifiable plant remains. The only identifiable ecofacts in the zone include a small number of *Empetrum nigrum* macrofossils, wood fragments and charcoal fragments.

M-II zone: 9-0 cm (from 510 cal yr BP to the present). Zone M-II was subdivided into two subzones: M-IIa and M-IIb. Subzone M-IIa (9-3 cm) is characterized by a diverse range of plants including *Vaccinium uliginosum, Vaccinium vitis-idea, Ledum decumbens, Polytrichum piliferum, Aulacomnium palustre* and *Aulacomnium turgmidium*. As noted above, the presence of these taxa shows that the environment was wet and acidic (Porsild and Cody, 1980; Crum, 1981; Ireland, 1982). In the north, *Vaccinium vitis-idea* is a dominant plant in open and turfy areas (Porsild and Cody, 1980). This plant has been used by Inuit and their ancestors as a medicinal plant and as a form of tobacco (Blondeau and Roy, 2004). *Polytrichum piliferum* is most commonly found on disturbed, acidic sands and gravels and on bare patches in sandy, heathy grassland in the lowlands. It is sometimes found on dry peat as a colonist of burnt moorland (Ireland, 1982).

Subzone M-IIb (3-0 cm) is characterized by the dominance of *Aulacominium turgidium*, which grows on dry tundra (Crum and Anderson, 1980). This change may indicate a drier environment, which would also explain the decrease of *Aulacomnium palustre* and *Vaccinium vitis-idea*, two species that thrive in swampy habitats (Porsild and Cody, 1980; Crum and Anderson, 1980). Near to the surface (at a depth of 2 cm), we found several fragments of branches from *Picea sp.* Assuming that *Picea* trees never grew in the immediate vicinity of the archaeological site, this finding suggests that people brought *Picea* branches and trunks to the site for use in beds, as fuel for fire, or as building material. Kaplan (1983) and Kaplan and Woollett (2000) both note the use of very substantial straight and krummholz of *Picea* sp. in the construction of buildings at the site.

To summarize, the macrofossil data from monolith UR3-M7 reveal that the site has been affected by human activities over a long duration, but that these activities intensified between 510 and 180 cal yr BP (1440 to 1770 AD) as well as after 1770.

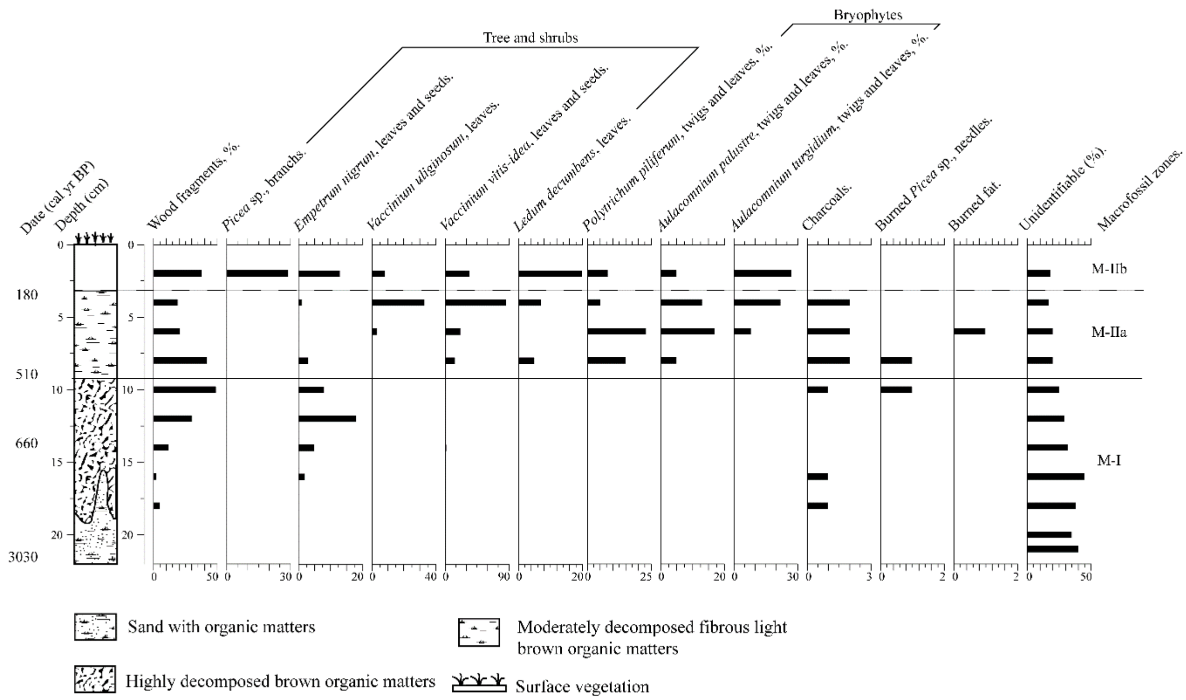

Figure 1.7: Macrofossil diagram of UR3-M7 monoliths sampled at Uivak Point (number of macrofossils per 50 cm3).

Macrofossils in Monolith USA-M1

Three macrofossil zones were identified based on the assemblages of plant remains (MI, M-II, M-III) (Figure 1.8).

M-I zone: 34-29 cm (from 940 to ca. 660 cal yr BP). Zone M-I is marked by a high degree of decomposition and the scarcity of plant remains. Indeed, a large number of wood fragments and some fragments of herbaceous plants were the only remains found here. This reflects a well-drained site or a site that has been altered by human activity.

M-II zone: 29-6 cm (from ca. 830 to ca. 50 cal yr BP). This zone is characterized by a diversity of taxa such as *Vaccinium vitis-idea, Empetrum nigrum* and *Epilobium latifolium*. All of these species have a large ecological spectrum but they are commonly found near marshes (Porsild & Cody, 1980; Blondeau, 1986; Marie-Victorin, 1995). Furthermore, according to *Flora of the Canadian Arctic Archipelago* (2011), *Epilobium latifolium* is a species that tends to rapidly colonize open areas where there is little plant competition, such as burn sites. The abundant remains of *Montia fontana*, as well as the presence of charcoal, burnt fat and burnt mosses, are highly indicative of human occupation. Baleen whale fragments were found at two levels dated to 380 and 110 cal yr BP.

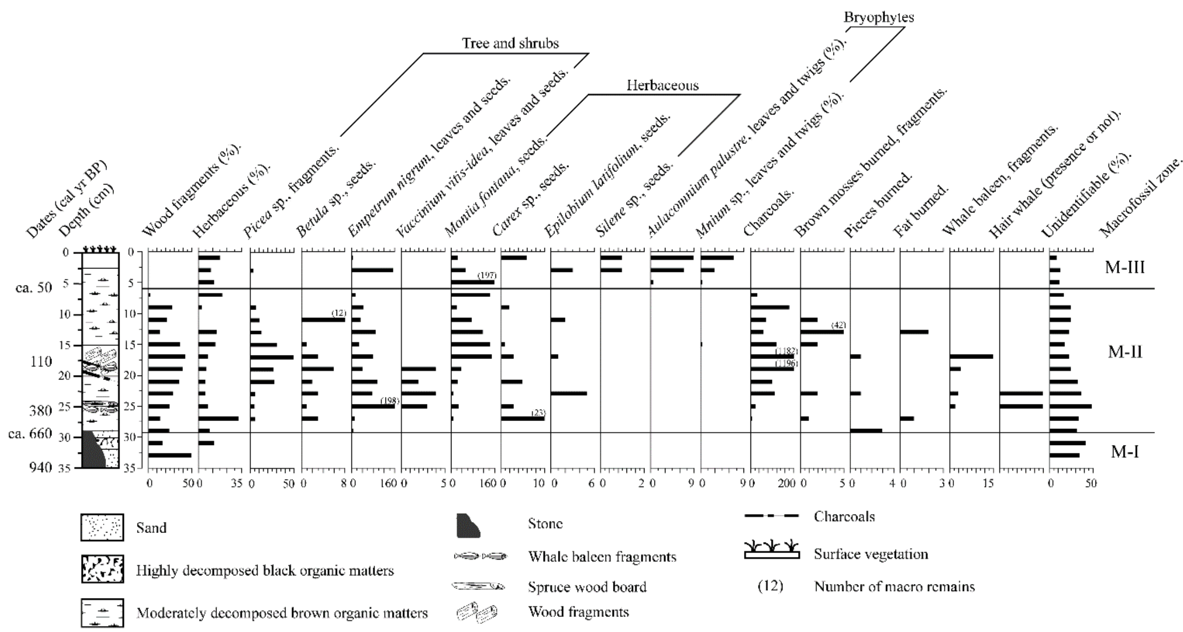

Figure 1.8: Macrofossil diagram of USA-M1 monoliths sampled at Uivak Point (number of macrofossils per 50 cm3).

M-III zone: 6-0 cm (from ca. 50 cal yr BP to the present). Zone M-III contains herbaceous surface vegetation such as *Carex sp., Epilobium latifolium, Montia fontana* and *Silene sp*. The presence of *Aulacomnium palustre* and *Minium sp.* indicates wet and ombrotrophic conditions (Crum and Anderson, 1980; Ireland, 1982). The abundance of *Montia fontana* also supports the conclusion that the site was affected by human activity.

Monolith USA-M1 was sampled from terrace T3, situated at an altitude of 3 m and approximately 60 m west of the archaeological site. This monolith is characterized by the high concentration of charcoal at a depth of 29-6 cm (ca. 830 - ca. 50 cal yr BP) as well as the presence of many archaeological ecofacts such as burnt fat remains. The two levels of whale remains (fragmentary strips of baleen) dated to approximately 380 cal yr BP and 110 cal yr BP confirm that the site was occupied and used by Inuit, possibly during occupations that were not directly related to those of the nearby winter sod houses.

5. Discussion

It is often difficult to distinguish the effects of climate from anthropogenic factors on the evolution of vegetation in an archeological site such as Uivak Point. However, by taking into account the archaeological context (Woollett, 2003), the archaeobotanical data of the site (Zutter, 2009) and the paleoenvironmental data of the region (this study), it is possible to reach several conclusions (Figure 1.9).

Changes in Vegetation Cover at Uivak Point in Response to Climate Change

The stratigraphy of the monolith profiles and the temporal development of past plant communities deduced from the pollen, spores and the macrofossil records allow us to identify three major developmental stages within the Late-Holocene history of the Uivak Point.

Tundra stage: 3030 – ca. 710 cal yr BP. Plants began to be established on the 11 m terrace at about 3030 cal yr BP. Between then and *ca.* 710 cal yr BP, the region was covered by shrub tundra dominated by *Ericaceae*, *Betula* sp., *Alnus* sp. and *Cyperaceae*. The spruce forest cover *Picea* sp. was likely open during this stage, based on the fact that the *Picea sp.* pollen percentage was low (6 – 20 %). At the local scale, vegetation was scarce. In fact, very few *Empetrum nigrum* seeds and leaves were found before 710 cal yr BP (UR3-M7, UR3-M3). These findings indicate a cold and dry climate that could be associated with the Neoglacial period. In part, this matches the finding of Lamb (1980) and Engstrom and Hansen (1985), who showed that climate conditions deteriorated at the regional scale in southeastern Labrador between 4250 and 2500 cal yr BP. In Newfoundland, this climate deterioration occurred between 3000 and 2500 cal yr BP (Davis, 1984). Our data suggest that cold and dry conditions lasted from 3030 to *ca.* 710 cal yr BP in the Okak Bay region (northern Labrador).

Clement conditions and the expansion of trees: ca. 710 to ca. 570 cal yr BP. Only a few macro-remains were found at the site. This could be explained by the alteration of the soil vegetation by natural oxidation or by trampling between ca. 710 to ca. 570 cal yr BP. At the same time, there was a change in the pollen record: pollen from *Picea* sp. increased to as much as 40% and *Abies balsamea* and *Pinus* grains appeared in the pollen assemblage. Such changes could be explained by an improvement in the climate. This interpretation is supported by the local establishment of *Pediastrum* sp. and *Eriophorum* sp., which are associated with elevated humidity (Warner, 1990). Our findings are also corroborated by a palynological study conducted 100 km south in the Dog Island region (central Labrador). In fact, at ca. 1000 cal yr BP, humid conditions triggered the establishment of hygrophilic species and *Larix laricina.* In addition, the paludification of sandy terraces began after this date (Roy et al., 2012). In similar fashion, climatic conditions were mild at Drayton Island along Hudson Bay between 960 and 510 cal yr BP, which promoted the establishment and diversification of vegetation (Lemieux et al., 2011). On the south shore of Hudson Strait, Ouzilleau et al. (2010) also observed pollen assemblages indicative of warm and humid conditions between 870 and 670 cal yr BP.

Cold and dry conditions followed by recent warming: From ca. 570 to about 180 cal yr BP, the decline of *Picea* sp. in conjunction with the increase of Cyperaceae indicates that conditions became colder and drier. At the local scale, tundra shrubs and some mosses were dominant (UR3-M3, UR3-M7, USA-M1). This period corresponds to the Little Ice Age (LIA; AD. 1500 – 1870). Subsequently, climate warming conditions favored the increase of regional and local trees and shrub species. Pollen from *Pinus sp., Picea sp. Larix laricina, Betula* and *Alnus sp*. and the high representation of very low pollen producers such as *L. laricina* may be indicative of wetter conditions at the site and at the regional scale. The recent increase in *L. laricina* pollen was also observed by Roy et al. (2012) in the Dog Island area, starting from 1140 cal yr BP.

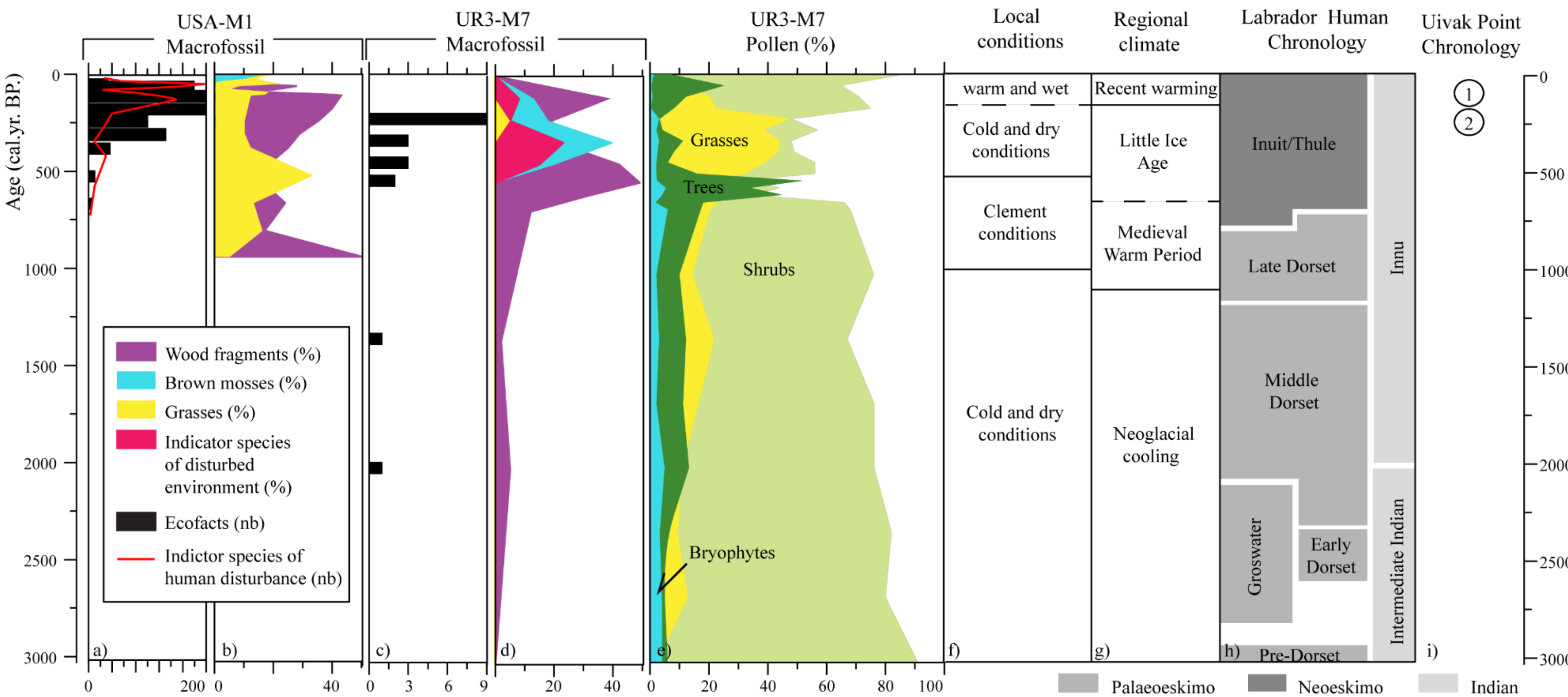

Figure 1.9: Correlation diagram for the last 3000 years. Macrofosils analysis results from monolith USA-M1 and UR3-M7 (a, c) number of ecofacts found and (b, d) pourcentage of vegetation groups. e) Summary of Pollen analysis from UR3-M7 monolith type in four groups: Trees (dark green), Shrubs (light green), Grasses (yellow) and Bryophytes (blue). f) local vegetation interpretated from pollen analysis (this study); g) Regional climate (Meese et al, 1994), h): Labrador Human Chronology (Brice-Bennett, 1977; Fitzhugh, 1977; Cox, 1978; McGhee, 1999; Park, 1999), and i) Uivak Point archaeological site occupation (Taylor, 1974; Kaplan, 1983; Wollett, 2003) - 1: 1776: Moravian establishment, 2: 1770 - 1807: Winter Inuit settlement occupation

Changes in Vegetation Cover in Response to Human Activities

The earliest Thule sites are found in the far north of Labrador at places such as Killinek Island and Staffe Island and date to 700-650 BP (1250 - 1300 AD) (Fitzhugh, 1994). By the 16th century, they had established settlements in the Nain-Hopedale region and Inuit were present in southern Labrador by the 17th century (Figure 1). Oakes Bay 1 (HeCg-08), located on Dog Island (Nain archipelago), seems to have been occupied on a regular basis between the late 17th century and 1772 (Taylor and Taylor, 1977; Woollett, 2010). Paleoecological data suggest that anthropogenic impacts at this site started soon after ca. 610 cal yr BP (1309–1361 A.D.) and lasted until ca. 300 cal yr BP (Roy et al., 2012). Similar circumstances apply to Uivak Point. In fact, historical records kept by Moravian missionaries and other archaeological studies (Woollett, 2003) revealed that the site was occupied in winter between 1776 and 1798 and between 1800 and 1807 (Taylor, 1974; Taylor and Taylor, 1977). Our paleoecological data from monolith USA-M1 suggest that human activities disturbed this sampling location as early as approximately 1520 AD. In fact, several whale baleen fragments, burnt fat and charcoal were found that date to between 1520 and 1840 AD. In the UR3-M3 monolith, the presence of burnt fat, charcoal and burnt brown moss leaves interpreted as fuel waste dated to 1440 AD, which would be chronologically consistent with a Thule period occupation. This date is corroborated by results from monolith UR3-M7, in which we found charcoal, burnt needles of *Picea* and burnt fat between 1400 AD and 1770 AD. Some of the wood dates may overestimate the date of archaeological occupation if the sample was old wood (heart wood or drift wood). Unlike the previous monoliths (UR3-M3 and UR3-M7), no ecofacts (e.g. burnt fat, burnt needles, and burnt mosses) were found in monolith UR3-M1. However, its modern age is indicative of human activity on the site. The most plausible explanation is that the vegetation re-established itself after the OM layer was removed by the inhabitants for construction of houses. Furthermore, activities carried out on the terrace would certainly have limited the accumulation of organic material. This means that Uivak Point was occupied earlier, possibly even substantially earlier, than archaeological research had previously suggested. However, there is as yet no other visible archaeological trace of earlier occupation and these fuel wastes do not in themselves prove that this occupation had a long duration.

According to the archaeobotanical analysis conducted by Zutter (2009) of House 7 at Uivak Point, (Figure 2), the Inuit who lived in this settlement in the 18th century used taxa such as *Empetrum nigrum* and *Vaccinium* sp. in their diet. *Carex* sp. and *Eriophorum* sp. were used as lamp wicks, bandages, woven mats and as floor coverings. *Betula* sp. was probably used as fuel, bedding or as woven mats. The Thule/Inuit harvested taxa that were growing in the vicinity of the site as indicated by our paleoecological data. During harvesting and as a consequence of the trampling of house floors, anthropogenic remains such as burnt fat, burnt leaves of mosses and charcoal were inserted into the soil. This kind of human activity likely aided the establishment of some weeds and apophytes such as *Montia fontana* and *Silene*, as argued by Zutter (2009) and as supported by the finding of this study.

The *Picea* sp. remains are a very significant finding. According to Lepofsky et al. (1996) and Zutter (2009), the collection of conifer branches and other woody twigs for insulation and comfort on sleeping areas is still a common practice for Arctic peoples and other aboriginal groups. Spruce needles may also be used as cough medicine (Moerman, 1998). Assuming that there were no trees on the archaeological site, *Picea* sp. trunks and branches must have been carried by people from the nearby hillside or the valley located about 1 km from the site.

6. Conclusion

Paleoecological data from Uivak Point houses indicate that temporal changes in vegetation were triggered by climate as well as by human activities. Between 3030 and ca. 710 cal yr BP, the region was covered by shrub tundra dominated by *Ericaceae*, *Betula* sp., *Alnus* sp. and *Cyperaceae*. The spruce forest cover (*Picea* sp.) was open, which is indicative of a cold and dry climate such as that which occurred at the end of the Neoglacial period. For a brief period from ca. 710 to *ca.* 570 cal yr BP (140 years), conditions became warmer and wetter, triggering the expansion of trees and the diversification of shrubs and herbs. From *ca.* 570 cal yr BP onward, by contrast, there is an abundance of dry taxa. This change may reflect the

Little Ice Age, when conditions were drier and colder in the Arctic and Subarctic (particularly between 500 and 100 cal yr BP). Recent climate warming subsequently induced the abundance of trees and shrubs at regional and local scales.

Many of the local plant species that were growing in the vicinity of Uivak Point houses were likely used by the Thule/Inuit in their diet or for lamp wicks, bandages, woven mats, floor coverings, as bedding or as fuel. During harvesting and after trampling around the houses, many anthropogenic remains were inserted into the soil in the form of burnt fat, burnt leaves of mosses and charcoal. In this study, no dramatic changes triggered by Thule/Inuit were observed in vegetation or in the environment except for *Picea* sp. remains. These remains are examples of the type of ecofact that results from human activity and the transport of natural resources from the surrounding area to the archaeological site. Human activities also triggered the establishment of some weeds and apophytes such as *Montia fontana* and *Silene.* Finally, the chronostratigraphic and paleoecological data suggest that the site was likely occupied on an irregular basis from as early as 1400 AD. This earlier occupation appears to have left only relatively subtle archaeological traces, perhaps reflecting the use of this location as a transient travelling camp or as a whale or seal hunting and processing site, rather than as a residential site. The 15th century date and the presence of burnt fat provide circumstantial evidence that there was human activity at this site during the Thule period. Further archaeological excavations focused on the un-built areas from which soil the monoliths were extracted are needed in order to confirm this hypothesis.

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Chapitre 2

A 550 year record of the disturbance history of white spruce forests near two Inuit settlements in Labrador

Résumé

Dans cette étude, nous avons documenté par l'entremise d'une analyse dendroécologique, les variations historiques des paramètres environnementaux ayant affecté la croissance des arbres au cours des 550 dernières années de forêts d'épinettes blanches. Ces forêts sont situées près de deux sites archéologiques inuits au centre-nord du Labrador. L'investigation de bois modernes et de bois archéologiques a fourni des données de base pour l'analyse dendroécologique des modèles de croissance et des régimes de perturbations naturelles et anthropiques. Cette analyse a également permis une datation dendrochronologique plus raffinée de l'occupation des sites archéologiques. Alors que les études dendrochronologiques précédentes pour la péninsule Québec-Labrador se sont concentrées sur les agents de forçage climatique, le couplage de l'analyse des cernes de croissance des arbres aux données historiques et archéologiques à l'échelle locale ont facilité l'examen des modèles multi-causals des perturbations sur le long terme. L'étude a permis de démontrer que les intéractions entre les activités anthropiques et l'écosystème forestier ont un impact significatif sur la dynamqiue forestière à l'échelle locale en région subarctique le long de la côte du Labrador. Cet impact devrait être pris en considération ailleurs dans d'autres études.

Mots clés : Labrador, occupation Inuit, dendroécologie, perturbation anthropique, *Picea glauca*, dendroctone.

Abstract

In this study, we documented historical variations in environmental parameters affecting tree growth during the last 550 years in north-central Labrador using dendroecological analysis of white spruce forests near two Inuit settlements. Tree surveys of both modern and archaeological wood samples provided raw data for dendroecological analysis of growth patterns and natural and anthropogenic disturbance regimes. The tree surveys also enabled more refined dendrochronological dating of the occupation of archaeological sites. While previous dendroecological studies for the Quebec-Labrador peninsula have focused on climatic forcing agents, the coupling of annual tree growth records to local-scale historical and archaeological data in this study facilitates the examination of multi-causal disturbance patterns over the long term. Low-intensity human interactions with the forest ecosystem were demonstrated to be significant factors influencing local-scale subarctic forest dynamics in coastal Labrador and they should be taken into consideration elsewhere in other studies.

Keywords: Labrador, Inuit settlement, dendroecology, anthropogenic disturbance, *Picea glauca*, bark beetles

1. Introduction

Several recent studies have used the association of variable tree growth patterns with particular environmental parameters as a cue for assessing the large-scale effects of past and present climate on boreal forest ecosystems (e.g., Caccianiga et al., 2008). In Labrador, tree-ring analyses have been widely used as proxies for climatic conditions such as temperature and for the teleconnections between the atmospheric, oceanic and sea ice forcings that structure the climate system (e.g., D'Arrigo et al., 2003; Dickson et al., 1996). Several studies have also examined climatic influences on Labrador's forests at both local and regional scales, indicating that tree-ring growth records are sufficiently sensitive to record local effects of large-scale atmospheric variations such as the North Atlantic Oscillation (NAO) (e.g., Overpeck et al., 1997; D'Arrigo et al., 2003; Payette 2007). These studies have demonstrated the complexity of the relationship between tree growth and climatic parameters. Very little attention has been paid, however, to the use of dendroecology to identify factors influencing tree growth at the local scale, particularly in relation to forest disturbance processes such as insect outbreak, fire or human activities. In the present study, dendroecological approaches identified significant forest disturbances in areas having prolonged Inuit settlement. While these disturbances appear to be highly localized in the spatial scale, they nevertheless had measurable impacts on the evolution of the forest cover as demonstrated by the frequency of identifiable release events (rapid increase in radial growth).

Dendroecology measures historical variations in radial-growth rates to analyze the impact of environmental changes on tree growth, stand structure, and stand dynamics (Fritts and Swetnam, 1989). Recently, dendroecology techniques have become more important for identifying and documenting historical disturbance regimes in forest stands (Rubino and McCarthy, 2004). Following Nowacki and Abrams (1997) and Payette (2010), tree-rings represent very useful datasets for describing disturbance regimes, especially long tree-ring series that have undergone minimal anthropogenic disturbance.

According to Rubino and McCarthy (2004), a disturbance represents an event of massive mortality in a community of living organisms. However, disturbance may also be seen as a positive process mobilizing vital resources (e.g., light, water and nutrients) to the benefit of survivors or new colonizers that leads to local invigoration of growth (Picket and White, 1985). Disturbance events may be endogenous (i.e., pertinent to growth dynamics of individual stands) or exogenous (i.e., resulting from factors originating outside the stand) and may greatly influence radial-growth rates (Cook, 1987). At the regional scale, a disturbance is usually manifested by the development of canopy-gaps due to windfall, wood harvesting, fire, insect outbreak, or similar events. The presence of a canopy gap induces a release event, a rapid increase in radial-growth in nearby trees that had previously been living in a state of surcimage, i.e., in the absence of light. Disturbance history regimes may be reconstructed by identifying growth release events manifest in radial-growth patterns (Nowacki and Abrams, 1997; Payette, 2010). These methods provide an objective representation of past disturbances when release events are identified according to pre-determined criteria (mean ring-width, percentage growth rate, etc.) (Rubino and McCarthy, 2004).

In order to document anthropogenic forest disturbances and their impacts in northern Labrador, dendrochronological investigations were conducted in two isolated forests surrounded by coastal barrens in the Nain Bay and Okak Bay regions. These studies were undertaken in conjunction with ongoing archaeological research at Inuit winter settlements (Oakes Bay 1 (HeCg-08) on Dog Island and Uivak Point (HjCl-09)) within or adjacent to the forestry study areas.

Arctic and subarctic environments are stereotypically considered to be pristine natural environments lacking anthropogenic disturbances. However, various aboriginal populations, including Maritime Archaic, Paleo-Eskimo and Neo-Eskimo, have called Labrador home during the last 7000 years. All of these peoples have transformed, even if only subtly, the surrounding environment in which they lived by exploiting the available natural resources. Wood was one of the most important plant resources in terms of its diverse and essential roles in daily life and the volume in which it was consumed.

Wood has been an essential resource for Inuit, used as fuel and as raw material for fabricating material culture essential in everyday life such as houses, sleds, boats and tools, both prior to and following the advent of extensive European contacts. According to Kaplan (2012) and Lemus-Lauzon et al. (2012), wood use in the Nain region has changed and adapted to evolving socio-economic conditions accompanying the expansion of the European colonial presence in Labrador. Once centers of colonial exchanges were established in north-central Labrador, such as the first Moravian mission settlements in 1771 to 1783, Inuit resource harvesting became increasingly oriented towards supplying these European bases and markets in exchange for trade goods (Kleivan, 1966; Brice-Bennett, 1977; Kaplan, 1983). By the 19th Century, harvests of wood removed from forest stands in the territories around Moravian settlements, destined for use as fuel and building materials, became one of the local resources Inuit contributed in their market exchanges (Kaplan, 2012).

Inuit wood harvesting had measurable impacts in locales distant from European bases as well. For example, paleo-ecological data published in a recent study (Roy et al., 2012), revealed that the inhabitants of the Oakes Bay 1 (HeCg-08) winter village had considerable impact on the local forest. The discovery of several cut tree-stumps buried in peat, coupled with analysis of spruce macrofossils recovered at the site indicate that, prior to its 17th Century occupation, the site had a cover of spruce trees. By late 20th Century, the perimeter of the site was almost entirely unforested, likely due at least in part to cutting for building materials and fuel. Today, the site is an open peat bog with scattered small stands of spruce and larch, with widespread subfossil spruce remains preserved in peat. Surrounding the site is an open spruce forest which contains numerous subfossil spruce stumps bearing traces of cutting with axes and saws. Given the long history and broad application of Inuit wood harvesting in Labrador, it is necesary to identify the source of disturbances on isolated forest stands such as those at Oakes Bay.

2. Physical setting

The study was conducted in the vicinities surrounding two archaeological sites located on Dog Island and Okak Bay in central Labrador (Figure 2.1). The study area lies in the Coastal Barrens ecoregion of the Labrador coast, which extends from Napaktok Bay south to the Strait of Belle Isle (Government of Newfoundland and Labrador, 2013). The majority of the central Labrador coast is characterized by broad bays and long inlets separated by prominent capes and headlands and screened by clusters of islands. Within the sheltered bays, summers are cool to warm and the growing season are 100 to 120 days (days with temperature over 0°C) (Government of Canada, 2015). Average annual temperature from 1985 to 2012 is approximately –2.4°C and annual precipitation is about 900 mm, of which about 50% falls as snow (Government of Canada, 2015). The dominant vegetation type is *Empetrum* barrens, with black spruce (*Picea mariana* (Mill.) B.S.P.) and white spruce (*Picea glauca* [Moench] Voss) forests occurring in sheltered valleys. White spruce established itself in northern Labrador approximately 6000 years ago in the Nain area, by ca. 3000 cal. yr BP in the Dog Island area, and 4500 years ago in the Okak Bay area, but declined after 2500 years BP (Short and Nichols, 1977; Lamb, 1985; Roy et al., 2012). At sites favorable for spruce, trees 100 to 250 years old are common, while trees 250 to 300 years old may be frequently found in protected and sheltered areas untouched by insect outbreaks and fire such as islands and the nordic region (Zasada, 1984).

2.1 Oakes Bay 1 (HeCg-08), Dog Island

Dog Island is part of the archipelago of Nain Bay (Figure 2.1). This island is located 35 km from Nain, which is currently the largest Inuit community in Labrador with 1188 inhabitants (Statistic Canada, 2012). The Oakes Bay 1 archaeological site (HeCg 08), historically known as Parngnertok (Taylor, 1974), is located on a marine terrace 6 to 8 m asl in a small bay located on Dog Island's western shore. Just north of the site is the steep and cliffy southern slope of Mount Alagaiai that shelters the bay. The slope from about 8 to 180 m asl is colonized by an open forest of *Picea glauca (Moench) Voss* (white spruce). According to

Zasada (1984), relatively wet upland conditions such as those of Oakes Bay are favorable sites for the development of old-growth spruce forest.

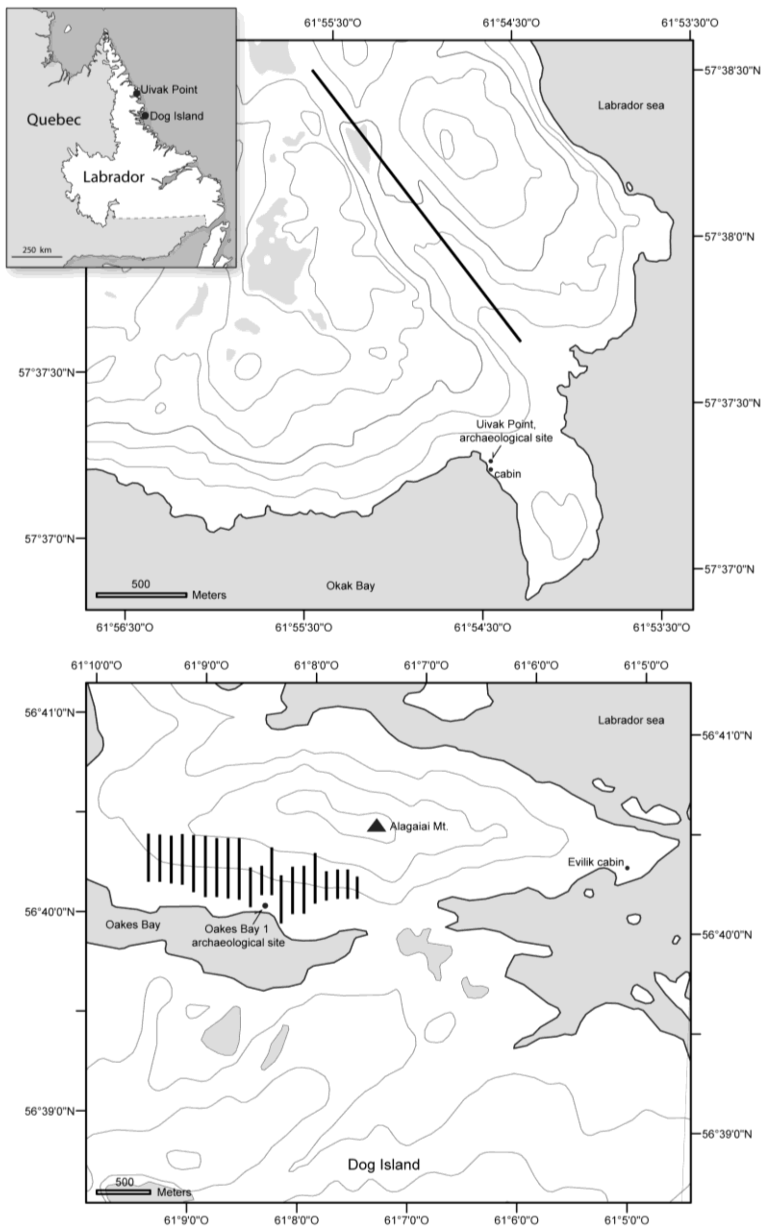

Figure 2.1: Location of the study sites of Uivak Point (upper map) and Oakes Bay, Dog Island (bottom map). In both maps, black lines show transect sampling for the study.

The archaeological site Oakes Bay 1 includes the ruins of seven semi-subterranean sod houses of various sizes. Their floors were dug into sand substrate and their superstructures were built of stacked blocks of peat, piled earth, rock, and wood beams and posts, as was typical of semi-permanent Inuit sod houses used in winter (Woollett, 2010). According to the results of archaeological investigations conducted to date, two successive phases of construction and occupation of sod winter houses can be dated to the late 17th Century to early 18th Century, and to the mid to late 18th Century (Woollett, 2010). Nevertheless, the immediate locality also has a number of tent rings and artifact distributions that demonstrate an ongoing and diverse occupation (apart from the sod houses themselves) stretching from over 2000 BP to the 20th Century. Historical mention of the site's sod houses was made in a census taken by Moravian missionaries in their first winter in the Nain region (AD 1771-1772). This document (summarized by Taylor (1974) and Taylor and Taylor (1977) reported the use of a single house during that winter, but made no further note of the use of the sod houses afterwards, even though subsequent tent camps were reported in the vicinity. While Oakes Bay 1 seems to have been abandoned as an intensively occupied semi-permanent winter village before AD 1780, other winter or year-round settlements were in use on and around Dog Island through the 19th Century until the 1970s.

2.2 Uivak Point (HjCl-9)

The archaeological site of Uivak Point (HjCl-09) is located on the northern shore of Okak Bay (Figure 2.1) about 125 km north of the village of Nain. The site is 8 km north of the village of Okak, which was established by Moravian missionaries in AD 1776 and then abandoned in AD 1919 following the catastrophic outbreak of Spanish flu (Taylor, 1974). The dominant vegetation type surrounding the archaeological site is low arctic tundra, while white spruce occurs sporadically in circumscribed groves of three to ten trees.

The Uivak Point locality has seen repeated occupations in prehistory and during the recent past. Several surficial distributions of chipped stone tools and tent structures found in the vicinity relate to as yet poorly defined occupations ranging from the Maritime Archaic (5000 to 3500 BP) to Intermediate Indian populations, (3500 to 2000 BP) and Pre-Dorset (3800 to

2200 BP) (Cox, 1977). Thule/Inuit used the location on a repeated basis during the 18th, 19th and 20th Centuries (Taylor and Taylor, 1977; Kaplan and Woollett, 2000).

The Uivak Point site is a winter settlement comprising the ruins of nine semi-subterranean sod houses constructed on a slope between two boggy terraces 8 and 11 m asl high respectively (Figure 1). According to Moravian records, Uivak Point was one of the most important winter settlements in Labrador during the late 18th Century and the opening years of the 19th Century, having up to 125 occupants in some years, and it was regarded as one of the more successful whaling communities in Labrador (Taylor, 1974; Taylor and Taylor, 1977; Kaplan and Woollett 2000). Archaeological excavations suggest an initial occupation of some of the sod houses by the mid-18th Century at the earliest and, according to Taylor and Taylor's (1977) synthesis of Moravian census records, the sod house site was occupied every winter between 1776 and 1798 and again between 1800 and 1807. No mention of a subsequent use of the sod houses is reported, although there were tent camps established there in all seasons certainly as late as 1829.

Several groups of tent rings of uncertain date but lacking chipped stone tools distinctive of prehistoric populations are visible around the locality. As well, the foundations of two more recent cabin structures with stone foundations are located on the shore of the cove adjacent to the sod house site. While the dates of these houses' initial occupations are not known, they were used until 1918 (Them Days 11.3).

3. Methods

3.1 Dendroecology analysis

Growth patterns of white spruce stands around Oakes Bay 1 and Uivak Point were studied in a pair of field sampling surveys conducted in July-August 2010. A total of 154 trees were sampled. From living trees, two cores taken perpendicularly were collected using a Pressler increment borer at about 25 cm from the root indent collar. Cross-sections were taken, using a saw, from dead trees at root collar. At Dog Island, the sampling was carried out near Oakes Bay, over a 2 km length comprising twenty individual 10 m wide transects at each 100 m (Figure 1). Each individual tree and krummholz observed along each 10 m wide transect was measured and recorded, but only those having a diameter greater than 15 cm were sampled in order to have a minimum number of 80 growth rings. For dead trees, each stump that could be harvested (i.e., was not buried or decomposed) was sampled. A total of 133 samples were recovered, including 41 core samples of living trees and 92 dead wood sections. In addition, four pieces of spruce wood exposed during the excavation of House 2 at the Oakes Bay 1 archaeological site were collected for analysis.

At Uivak Point, the survey area was defined following the discovery of old stumps that had been cut with an axe in a valley 500 m north of the archaeological site (Figure 1). Unlike the Dog Island study area, this region includes only very scattered solitary trees and small isolated tree stands. Given the low density of forest cover, all trees that could be sampled according to the same criterion given at Oakes Bay were selected, including krummholz. A total of 15 core samples and 6 dead wood sections were taken. Nine spruce trunk specimens were recovered from sampling trenches excavated in Houses 6 and 7 in the Uivak Point archaeological site. A tamarack (*Larix laricina* (Du Roi) K.Koch) beam from the roof of the entrance passage of House 6 that had been extracted from permafrost proved to be sufficiently well-preserved across the breadth of the trunk to justify dendroecological analysis.

Diagnostic light rings, i.e., growth rings with exceptionally few latewood cells, were used to date and cross-date living and dead wood sections (Filion et al., 1986). Archived light ring chronologies derived from the L2 tree-ring sequence (1680-1922) from Okak Bay compiled by Serge Payette and from Oakes Bay, Dog Island (1620-1978) compiled by Natasha Roy, available at the Dendrochronology Laboratory at the Centre for Northern Studies (CEN), Laval University were also used as validation tools. These series allow us to determine the approximate age of the archaeological wood samples. Cross-dating was also verified using the program COFECHA (Holmes, 1983; Grissino-Mayer, 2001). Tree-ring widths were measured with a Velmex micrometer (precision of 0.002 mm) under a binocular microscope at 40X. We retained only highly intercorrelated individual curves to build the chronologies of the Oakes Bay and Uivak Point tree-ring records.

In dendroclimatology, response function analysis is used to define the correlation between ring width and particular climatic variables such as temperature. Temperature data from the Goose Bay weather station (Environment Canada, 2003) were used for the calculation of response functions, in particular mean monthly temperatures during the current year and the past year from September (n-1) to December (n-1). The weather data for the Goose Bay station were preferred to those of the nearby Nain stations since they are more extensive. The CALROB program from the PPPHALOS package (Guiot, 1991) was used to calculate response functions of white spruce growth to climatic parameters at Oakes Bay and Uivak Point. The bootstrap method (Efron, 1979; Guiot, 1991) was used for the response functions based on the repetitive calculation (500 simulations) of multiple regressions on the same set of climatic variables. In this study, response functions were calculated following the methods described by Guiot and Nicault (2010).

3.2 Disturbance events analysis

In Hudson Bay, Delwaide and Filion (1988) identified and dated anthropogenic disturbances such as wood harvesting in areas occupied by aboriginal peoples using dendroecology methods. According to Payette (2010), the relative growth of tree growth rings can be used to identify and date the presence of canopy-gaps between trees in a state of surcimage (in the absence of light). Growth releases were detected for individual trees by calculating the ratio of the width of individual growth rings relative to those of the 10 preceding and succeeding years (Nowaki and Abram, 1997; Berg et al., 2006; Caccianiga et al., 2008; Payette, 2010). A growth release was marked by a percentage growth change exceeding 25% over 10 years. Afterwards, the total growth releases of each tree were arranged in 10-year classes. Percentage growth change (%GC) was calculated in yearly increments across individual tree-ring chronologies. Each %GC value represents a 20-year span of ring width data and empty cells relative to source tree-ring chronologies occur at both ends.

Our data showed that growth releases were recorded as far back as AD 1500. However, old trees samples (those 300 years old and older) are rare (5 of 154), since many of the old trees were too decomposed to analyze or were buried. This may cause an underestimation of disturbance event frequency. Consequently, the low number of disturbance events in the age-characteristic structures of each site was corrected using log-linear regression (Morneau and Payette, 2000). However, this analysis assumes a constant decrease in disturbance events over time. That is why we expressed the fluctuations in the number of disturbance events by using the curves of the regression residuals. To do so, a disturbance event was added to each of the age classes for disturbance events due to the sporadic occurrence of years where no events were noted. This modification was necessary because logarithmic transformation is inapplicable when the value is 0.

We did not have a control site (i.e. a non-disturbed site), but we observed logged stumps throughout the area during initial surveys in the study region. The site studied by Payette et al. (1985) has been preserved from major natural disturbances and could be regarded as a control site. This site has similar ecological characteristics but is located on the mainland.

3.3 Occurrence of insect outbreak

In northeastern Canada, the impact of insects in the forest dynamics ecosystem is largely unexplored and very little is known about insect outbreaks in Labrador. Nishimura (2009) has reconstructed the history of larch sawfly and spruce budworm outbreaks in western Labrador but, to our knowledge, no spruce bark beetle (*Dendroctonus rufipennis* Kirby) outbreak has been documented except for one mentioned by Payette (2007). That outbreak caused a dieback of white spruce in northern Labrador between 1989 and 1991. According to Payette (2007), the spruce bark beetle may also have played a significant role in the past. For example, in western North America, massive outbreaks of bark beetles have infested conifer forests creating extensive mortality of spruce (Berg et al., 2006). Accordingly, bark beetle outbreaks represent an important source of disturbance and must be considered in a study evaluating anthropic impact on forest disturbance. In this study, spruce bark beetle damage was assessed by direct observation of white spruce trees, with a focus on the presence of holes and galleries in the bark. Previous bark beetle attacks were counted and dated by recording resin pockets and blue-stain fungi visible in the wood sections and borer samples. Resin pockets are crescent-shaped resin accumulations that can be found either between two annual rings or within a ring, which is usually deformed (Caccianiga et al., 2008).

4. Results

4.1 Tree-ring width analyses

The overall forest composition at both sites is indicative of a rather stable population in terms of size and structure. The average age of trees in the two study areas is 180 ± 55.12 on Dog Island and 163 ± 61.46 at Uivak Point. Figure 2.2 shows the distribution of years of tree establishment. The forest increased in size after 1780 on Dog Island because many individual trees appeared after that date. At Uivak point, the distribution of years of tree establishment remained constant over time.

Both woodlands are old-growth stands with trees of all sizes and ages, including several 300 year-old white spruce specimens with the oldest being 384 years old. Spruce mortality (as represented by sampled dead wood sections) occurred more or less over the last hundred years in the two study areas and in particular between 1970 and 2000. The oldest dead white spruce trees sampled were established in 1528 and 1666 for the Dog Island and Uivak Point sites respectively. The chronologies extended from AD 1528 to 2009 for Dog Island and from AD 1666 to 2009 for Uivak Point. Mean tree-ring width was similar among the chronologies (0.312 and 0.263 mm, respectively; Table 2.1).

The Dog Island white spruce chronology, spanning AD 1528 to 2009, is one of the longest and oldest presently available in the Nain area, comparable to those of D'Arrigo et al, (2003) from Salt Water Pond (AD 1526-1998) and Eyeglass Lake (AD 1459 – 1960). It is also, at present, the easternmost white spruce chronology for North America and the only one from an island environment.

Table 2.1: Characteristics and statistics of tree-ring series from Dog Island and Uivak Point

Parameter	Dog Island	Uivak Point
Mean ring width (mm)±SD	0.312±0.12	0.263±0.17
Sensitivity	0.23	0.22
First-year autocorrelation	0.72	0.91
Original time series	1528-2009	1666-2009
EPS	0.94	-

The response functions of white spruce to climatic parameters show that tree growth at Dog Island is positively influenced by July mean temperatures. At Uivak Point, response function analyses were insignificant. This is probably due to the small number of samples at Uivak Point (21 samples) as compared to Dog Island (133 samples). When the number of samples is small, there is less chance that the correlation coefficient is high enough to confirm a significant correlation with the temperature data. In general, mean ring widths showed that tree growth was generally low (below average) throughout the period represented by the chronology. However, the two records also indicate that growth rates were not constant over time and there were short periods of notable growth. Mean ring widths for 50-years time intervals at Dog Island show that growth rates were low (below average) during the periods of AD 1551-1600 and AD 1651-1800 (Table 2.2).

Table 2.2: Mean ring width of white spruce for 50 years time periods at Dog Island (DI) and Uivak Point (UP). Mean rin width for Dog Island is 0.312±0.12 and Uivak Point is 0.263±0.17

	Mean ring width (mm)									
Site	**1528-1550**	**1551-1600**	**1601-1650**	**1651-1700**	**1701-1750**	**1751-1800**	**1801-1850**	**1851-1900**	**1901-1950**	**1951-2009**
DI	0.320±0.17	0.230±0.10	0.324±0.17	0.265±0.12	0.230±0.109	0.292±0.14	0.308±0.16	0.332±0.17	0.399±0.22	0.548±0.33
UP	-	-	-	0.209±0.07	0.211±0.14	0.216±0.12	0.201±0.10	0.268±0.15	0.413±0.26	0.502±0.30

At Uivak Point, periods of below average growth were noted during the 18th and 19th Centuries. Furthermore, at both sites, mean ring widths increased during the 20th Century and the growth rate of younger trees increased markedly in this century in contrast to the growth rate of older trees, which was still low. However, at both sites and throughout the chronologies, the mean standard deviation of mean ring width is consistently high, which suggests that values are widely scattered around the average and that growth rates of individual trees were not uniform over time. This suggests that neighbouring trees had variable growth release events in response to forest disturbances. Moreover, dendrochronological dates obtained from wood pieces extracted from House 2 at the Oakes Bay site and House 6 at Uivak Point demonstrate evidence of wood cutting activities corresponding to the timing of the these forest disturbances, although they do not indicate the extent of wood harvesting activities (Table 2.3).

Table 2.3: Dates from archaeological wood pieces

Borden Code	Site	House	ID	Species	Date
HeCg-08	DogIsland	H2	545	Spruce sp.	1634-1764
HeCg-08	Dog Island	H2	OB-1	Spruce sp.	1616-1741
HeCg-08	Dog Island	H2	OB-4	Spruce sp.	1687-1731
HeCg-08	Dog Island	H2	OB-11	Spruce sp.	1618-1681
HjCl-09	Uivak Point	H6	-	Tamarak	1720-1825

4.2 Dendroecology

Growth Release: Growth release episodes occurred with high frequency at Dog Island and Uivak Point. At Dog Island, 70% of the trees sampled showed a minimum of one growth release. At Uivak Point, 62% of trees sampled showed a minimum of one growth release. The highest frequency of growth releases for both sites was recorded at the beginning of the 20th Century (Figures 2.2 and 2.3). Prior to that, growth releases were infrequent, with a small increase around AD 1760 at Dog Island. Between AD 1580-1640 and 1690-1760, many disturbance events occurred.

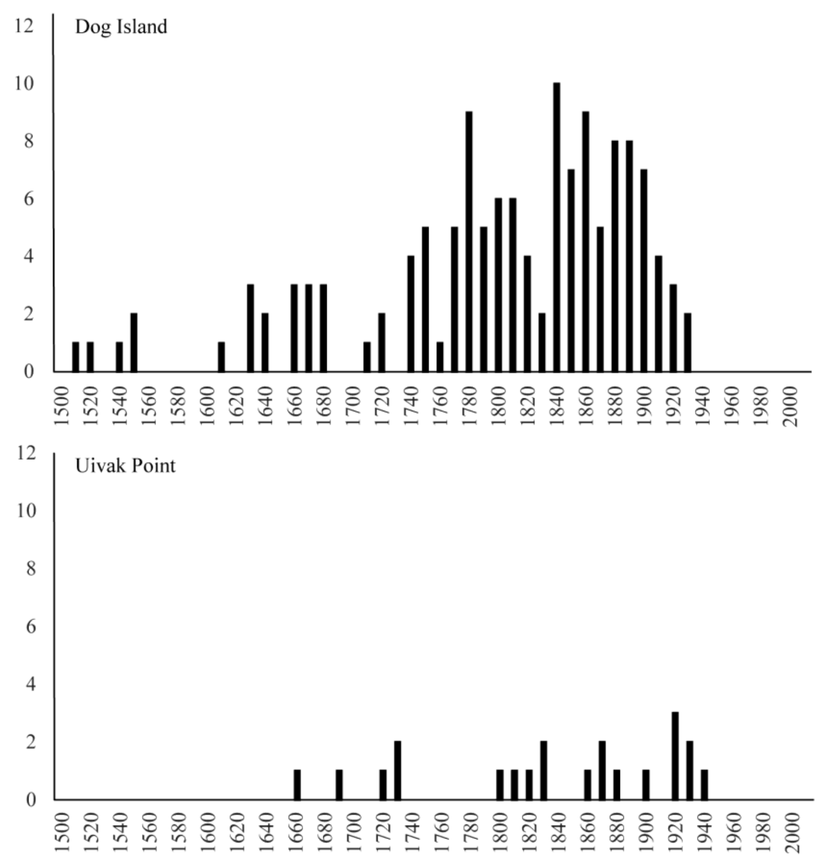

Figure 2.2: Distribution of years of tree establishment that composed the forest structure at Dog Island and Uivak Point. Note that data for the last 100 years are missing due to the sampling methodology (trees smaller than 15 cm diameter were not sampled)

Even though their frequency was low, growth release events extend far back in time to the 16th and 17th Centuries (Figures 2.2 and 2.3). Such a finding is noteworthy because it indicates that forest disturbance is an important process that has influenced forest dynamics since 1600 AD. In addition, there is a close time correlation between the positive residual values and these disturbance events. However, it must be noted that the first and last 10-year periods of each chronology must be excluded in the running mean methodology used in this study.

Long-term reduction in the number of growth releases with age

Age-frequency distributions of growth releases at both sites were characterized by an exponentially decreasing trend over the last 320 and 490 years recorded at Uivak Point and Dog Island, respectively (figure 2.3 and 2.4). According to the residual curve, it seems that the same trends in the frequency of growth release over the last centuries apply to both sites. However, the residual oscillation around the zero value indicates that the frequency of growth release increase was sustained.

Resin pockets and blue-stain fungi

Resin pockets and blue-stain fungi were observed at least once in 35 samples from Dog Island, typically from rings dated after AD 1790. Trees on Dog Island show high concentrations of these marks in AD 1800, 1910 and 1920, with a clustered distribution at the end of the 19th Century and the beginning of the 20th Century. No resin pockets were found after AD 1960. Blue-stain fungi were observed with the highest frequency between AD 1970 and 2000, dates that also coincide with a period of significant tree mortality. Most of the blue-stain fungi were observed in the outermost part of the wood, often associated with holes and galleries in the bark of recently dead trees. However, they were also found inside the wood, indicating that the tree had survived previous bark beetle outbreaks.

5. Discussion

Using the tree-ring chronologies developed in this study, we documented forest disturbance events that occurred with increasing frequency and scale over time. These events were inferred from tree growth releases that occurred when the canopy opened and reduced the competition for resources (e.g. light, growing space) and considerably modified local growth conditions. These disturbance events were less frequent prior to AD 1750 on Dog Island, which could be explain by the scarcity of preserved old trees (which may have been decomposed or buried). A general increase in disturbance events was noted on Dog Island between AD 1750 and 1800, and disturbance events continued to have a frequent and consistent impact upon forest dynamics thereafter. Disturbance events reached their highest frequency after AD 1900 and have remained high since then. The causes of such events may include climate, fire, insects, and human activity.

Climate and forest composition and structure

As has been suggested by Berg et al. (2006), a 10-year mean window for evaluating releases is long enough to smooth periodicity in ring-widths associated with the El Nino-La Nina cycle, which is 3.5 years in Labrador (D'Arrigo et al., 2003). In addition, a 10-year mean window ought to be short enough to avoid correlation with the North Atlantic Oscillation, whose multidecadal waveform variation is about 40-60 years (D'Arrigo et al., 2003). $\delta^{18}O$ proxy temperature data from the GISP2 core in Greenland indicate that there were colder climatic conditions around AD 1200, 1500, after 1750 and 1800, whereas warmer conditions arrived around 1400 and 1700 (Meese et al., 1994). Also, the Labrador tree-ring width record suggests that there were cooling periods in the 1600s to early 1700s and in the 1800s, but a warming period in the middle to late 1700s. A warming trend was also documented from the late 1800s through the mid-20th Century (Overpeck et al., 1997). According to these data, climate does not appear to be a major cause of the growth releases observed in this study. This is because the majority of release events are scattered widely throughout the chronology rather than clustering around phases of temperature change.

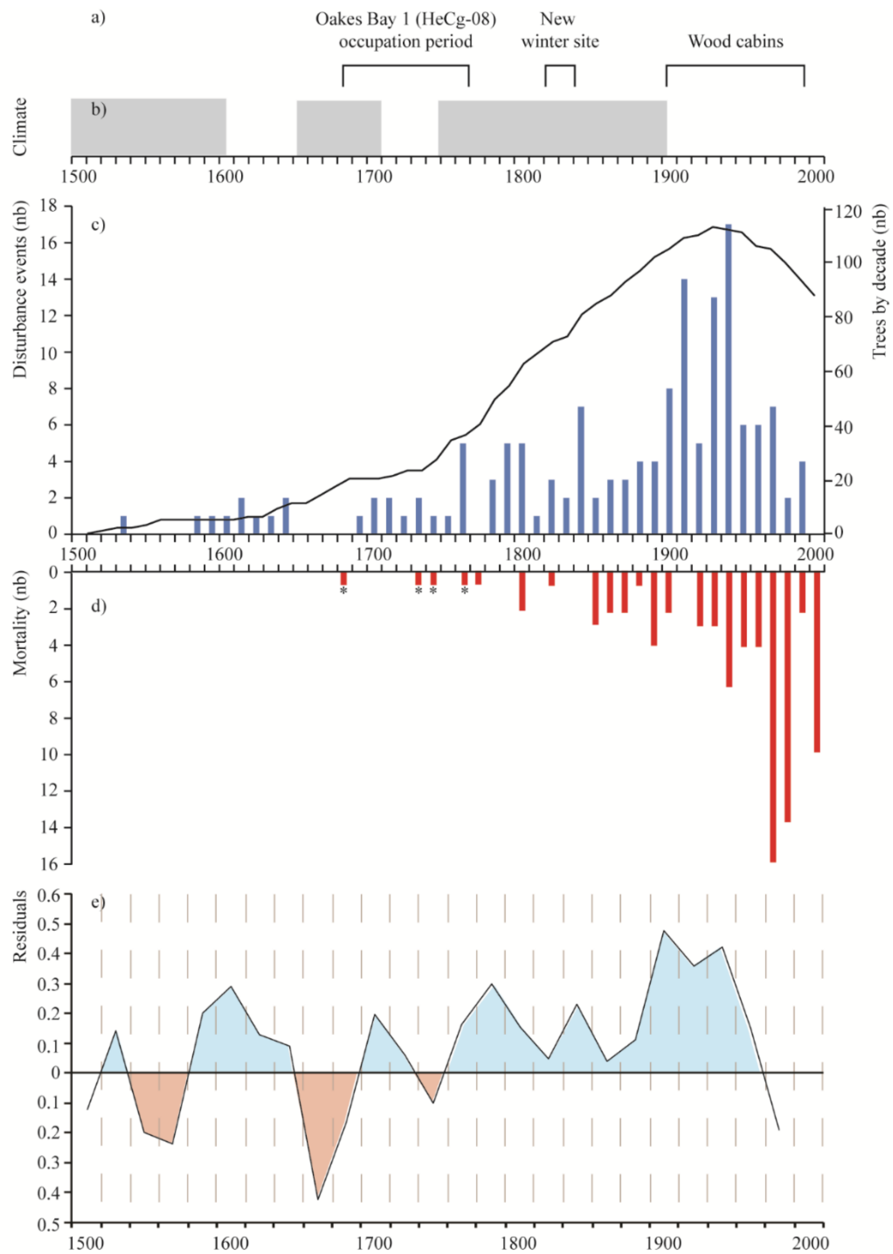

Figure 2.3: Correlation diagram for the last 500 years at Dog Island. a) Occupations periods of the site and surrounding area, b) Cold climate periods (gray bars) from Meese et al. (1994) and Overpeck et al. (1997), c) Frequency distribution of the number (nb) of disturbance events (left, bars) and the distribution of the number (nb) of trees by decade (right, line), d) Frequency distribution of mortality dates, and e) Residuals of the log-linear regression on the age frequency distributions of release events. Dates from archaeological wood pieces are marked by an asterisk.

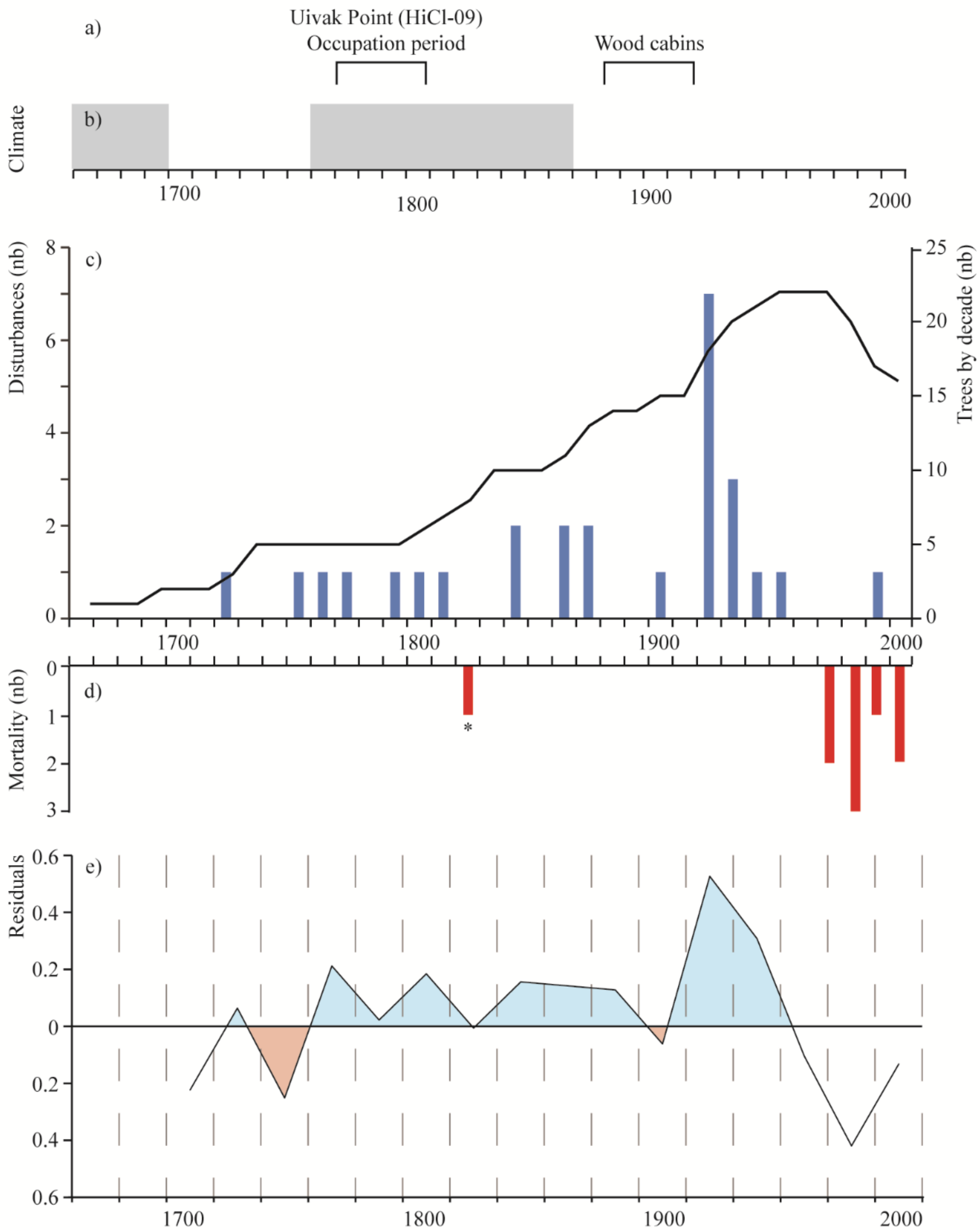

Figure 2.4: Correlation diagram for the last 350 years at Uivak Point. a) Occupations periods of the site and surrounding area, b) Cold climate periods from Meese et al. (1994) and Overpeck et al. (1997), c) Frequency distribution of the number (nb) of disturbance events (left, bars) and the distribution of the number (nb) of trees by decay (right, line), d) Frequency distribution of mortality dates, and e) Residuals of the log-linear regression on the age frequency distributions of release events. Date from an archaeological wood piece is marked by an asterisk.

Non-anthropogenic disturbances impact on forest dynamics

Recent studies of forest dynamics in subarctic Canada have demonstrated the importance of non-anthropogenic disturbances such as fire and beetle outbreak on forest dynamics and tree growth in subarctic Canada, especially in marginal forest contexts (Caccianiga et al., 2008). According to these authors, the role of abiotic and biotic disturbance should not be underestimated. It can play an important role at the local scale on the composition and the structure of woodland stands and must be considered in the study of the dynamics of these marginal forests, especially in the subarctic. We did not find any clear evidence of fire such as a charcoal layer in soil or fire scars on trees in the study sites. However, bark beetle outbreaks were probably involved in forest disturbances in the Dog Island and Uivak Point sites and probably contributed to a number of release event.

Evidence of bark beetle activity was widespread at both sites, but the timing and magnitude of each beetle attack differed. At Uivak Point, only blue-stain fungi were observed and their distribution was concentrated between 1980 and 2000, which is in accordance with Payette (2007). At Dog Island, indices of bark beetle outbreak were more pronounced. Our results suggest that the insect has been present for a long time (since 1790) and that its impact seems to be greater today. The distribution of resin pockets and blue-stain fungi shows an important increase in frequency during the following decades: 1800, 1910, 1920 and between 1970 and 2000. Similar data were obtained on the east coast of Hudson Bay by Caccianiga et al. (2008), who found a high-frequency of occurrence of resin pockets in tree-rings dated to 1861, 1909, 1914 and 1951 and a high-frequency of blue-stain fungi between 1970 and 1990. These authors also showed that bark beetles had been present since the 18th Century and that the activity of bark beetles and related blue-stain fungi became so widespread in the 20th Century that it was linked to extensive waves of mortality that affected the oldest trees in the 1970s, 1980s and especially in the 1990s. Similar bark beetle infestations may also explain the high mortality in our chronology between 1970 and 2000 when blue stain fungi where observed in our samples. In order to distinguish bark beetle disturbance from anthropogenic disturbance, an entomological study of soil and peat sediment in the Oakes Bay forest should be carried out. This would make it possible to determine more precisely when bark beetle outbreaks occurred (e.g. Bhiry and Filion, 1996).

Anthropogenic Disturbances

Disturbances resulting from wood harvesting by humans were documented along the eastern coast of Hudson Bay at Wapmagoostui-Kuujjuarapik by Delwaide and Filion (1988). This study illustrated the significant impact of humans on forest composition and structure in northern environments. The tree-ring study presented here demonstrated that release events have occurred during cold climate periods as well as during clement ones; in other words, the release events had little correlation with climatic trends (Figures 3 and 4). Both of the periods of disturbance (AD 1500 to 1640 and 1690 to 1750) observed in the Dog Island samples coincide with periods when Inuit occupied archaeological sites adjacent to the study area, most notably the Oakes Bay 1 site. While dendrochronological analysis could be performed on only a limited sample of well-preserved archaeological wood specimens, this analysis was enough to demonstrate that the site's occupants probably harvested wood directly from the studied forest.

Dendrochronological dates (Table 3) combined with archaeological artifact dates and historical records related to the occupation of the Oakes Bay 1 site suggest that local tree harvesting could have occurred between the years AD 1681 and 1771. A rather longer history of cutting is in fact likely, due to the presence of other winter settlements and poorly documented seasonal camps in the locality dating between the 15th Century and the 1970s (Kaplan, 1983; Woollett, 2010; Roy et al., 2012), all of which had access to the same forest. The relatively close clustering of these dates (AD 1681 to 1764) leads us to conclude that wood present in the Oakes Bay site was collected from the forest surrounding the archaeological site. If driftwood had been extensively used as a building material, a wider dispersion of tree ages reflective of the more random transport and deposition of flotsam on beaches would likely have been observed, as has been recently demonstrated at the Qijurittuq Site (IbGk-3) on Drayton Island, northern Québec (Lemieux et al., 2011).

The presence of considerable quantities of partially preserved wood throughout the Oakes Bay 1 site (which was unsuitable for dendrochronology) suggests that wood harvesting was a regular and substantial activity. Plant macrofossil analysis has also demonstrated anthropogenic impacts (tree cutting) at the Oakes Bay 1 (Dog Island) site, beginning sometime after circa 610 cal. yr B.P. (AD 1309–1361) and continuing until circa 300 cal. yr B.P. (the late 18th Century) (Roy et al. 2012). This use of the site over the long term had an impact on local wood resources due to the extensive amount of wood required in order to heat and build their houses (Roy et al., 2012).

This study suggests that episodes of growth release documented from AD 1580 to 1750 coincide with anthropogenic disturbances in the form of wood harvesting. Sustained wood harvesting in the relatively sparse local subarctic forest would have quite easily generated a significant canopy gap that likely increased the amount of resources for the remaining trees, especially light. Light is one of the resources that is capable of stimulating growth release events and is widely associated with disturbance events in the forest dynamic (Payette, 2010). Disturbance events occurred frequently after AD 1820, with our data showing a maximum disturbance at the beginning of the 20th Century. These observations suggest that the local forest continued to be harvested, and new release events continued to be generated by the presence of new canopy gaps, well after the Oakes Bay site was abandoned in the 18^{th} Century. This situation can be explained by the construction of a new winter site circa 1820-1830, followed by the construction of wood cabins in the 20^{th} Century at Evilik Bay, located at the eastern extremity of Dog Island (Figure 1). Today, northern Dog Island is still frequented by Inuit for activities such as wood harvesting, fishing and berry picking.

A different scenario of forest disturbance is portrayed at Uivak Point, however. The AD 1720-1825 dates obtained from the wood sample in House 6 at Uivak Point indicate that the structure was built and occupied 18 or more years after the most recent historical mention of the winter village's occupation in Taylor and Taylor's (1977) translation and synthesis of Moravian mission documents. This specimen was recovered from a partially frozen deposit overlying the floor of the entrance passage in House 6. The deposit appears to represent the collapsed roof structure of the most recent phase of construction (and hence occupation) of that house. It was dated using four different unpublished larch chronologies on file at the Dendrochronology Laboratory at the Centre d'études nordiques, Université Laval. All of them indicated a range of 1720-1825, which confirms the best statistical possibilities for the date. This new information suggests that 18th and early 19th Century occupation histories of some Labrador Inuit sites that were gleaned from summaries of Moravian Mission records may be incomplete and need to be verified against independent archaeological, dendrochronological or other pertinent data sources. In this case, artifacts of European origin recovered in earlier test excavations of House 6 are consistent with an occupation dated to 1825 or shortly thereafter, even though they are inconclusive (Woollett, 2003). However, a small number of artifacts recovered in the 2010 excavation that furnished the wood sample also support this interpretation.

At Uivak Point, the frequency of disturbance events seems less significant than at Dog Island due to the low number of wood samples analyzed. However, the data trends in the same direction as the data from Dog Island. In particular, the frequency of disturbance events also seems to correspond to the Inuit occupation period. The beginning of the 20th Century is also marked by high levels of disturbance, which may be linked to the construction of two wood cabins at the nearby Uivak Point archaeological site in the late 19th or early 20th Century (Woollett, 2003).

6. Conclusion

Reconstructing disturbance regimes by using a dendroecological approach can provide valuable data to supplement or substantiate existing information regarding forest dynamics from other palaeoenvironmental sciences. By coupling data from this approach to historical and archaeological data, it becomes possible to document long-term disturbance patterns, even where previous studies have concluded that the forest dynamic is primarily affected by climate. This study demonstrated that the role of anthropogenic disturbance was very significant at the local scale in old-growth forests around the Oakes Bay 1 archaeological site on Dog Island. Wood-harvesting had a great impact on the open forest and should be carefully considered in the study of forest dynamics in the North. Today, the Oakes Bay forest is sparsely treed, open and appears to be, at first glance, a marginal relict forest isolated in a tundra environment. However, our study of tree-ring growth in wood sampled from the forest indicates that this impression is illusory. Dendrochronological analyses date Inuit wood harvesting to periods when the disturbances creating growth releases were initiated. Therefore, the forest dynamics of this particular subarctic forest are dominated by a history of frequent release events that coincide with Inuit occupation and with sustained harvesting and the attendant creation of canopy gaps. Climate change did not have as great impact on forest dynamics as human activities on this site.

This case study provides a useful example of the necessity of adopting broad frame of reference for ecological studies in "pristine" contexts where humans have long histories of occupation. In this case, a bilateral historical ecology perspective (Crumley, 1994) on human environmental interactions provided a fruitful means of understanding the forest dynamics and succession of a coastal subarctic region. The documentation of past disturbance patterns is primordial for understanding how present-day forests developed over the recent past and how they might change in the future.

7. Acknowlegments

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Chapter 3

Vegetation history since the mid-Holocene in northeastern Iceland

Résumé

L'analyse palynologique de carottes de tourbe prélevées près de vestiges de deux fermes de Svalbarðstunga, nord-est de l'Islande, a permis la reconstitution de l'histoire de la végétation depuis la mi-Holocène et la distinction entre les impacts climatiques et les impacts anthropiques sur les écosystèmes terrestres depuis la colonisation de l'Islande. Hjálmarvík, le premier site, est situé le long de la côte alors que Kúđá est situé à environ 12 km à l'intérieur des terres. Nos résultats indiquent que les fluctuations climatiques sont à l'origine des principaux changements écologiques à Svalbarðstunga. De 6310 à ca. 4500 ans étal. BP, les conditions étaient relativement chaudes et humides et le pasysage était dominé par un couvert forestier de bouleau et une toundra arbustive. Entre ca. 4500 ca. 1170 ans étal. BP, les conditions sont devenues relativement plus fraîches et plus humides et ont favorisé l'expansion des tourbières au détriment des forêts de bouleau. Depuis cette période et jusqu'à présent, les prairies et les tourbières caractérisent la région. Selon nos données, les forêts de bouleau ont pratiquement disparu de l'intérieur des terres vers 5910 ans étal. BP et de la côte vers 3340 ans étal. BP; seuls des bosquets isolés persistaient par endroits. À l'arrivée des Norois, *Betula* était donc rare à Svalbarðstunga. L'occupation humaine et le développement de pâturage pour l'élevage pendant et après l'Optimum Climatique Médiéval ont entrainé l'expansion des espèces de *Carex* ainsi que l'introduction de nouvelles espèces de plantes. Toutefois, le degré de changement dans la végétation à Svalbarðstunga, associé à l'arrivée des Norois, semble être plus limité que dans d'autres régions de l'Islande puisque la région était depuis longtemps dominée par les tourbières alors que les forêtes de bouleau étaient rares.

Mots clés: paléoécologie, pollen, Svalbarđ, Islande, changements environnementaux, impact anthropique, Holocène.

Abstract

Palynological analysis of peat cores collected near two abandoned farms in the Svalbarðstunga region of northeastern Iceland was used to reconstruct the mid-Holocene vegetation history and to distinguish climatic and anthropogenic impacts since the colonization of Iceland. Hjálmarvík, the first site, is located along the coast while Kúðá is located approximately 12 km inland. Our data indicate that climate changes triggered the principal ecological changes in the region. From 6310 to ca. 4500 cal yr BP, conditions were relatively warm and moist and birch woodland and shrub tundra communities dominated the landscape. Between ca. 4500 and ca. 1170 cal yr BP, cooler and wetter conditions favoured peatland species while birch significantly declined. From 1170 cal yr BP to the present, grassland and peatland were prevalent in the region. Thus, birch woodland had virtually disappeared from inland areas by 5910 cal yr BP and from the coast by 3340 cal yr. By the time of the initial Norse settlement of the region, *Betula* trees sp. were scarce in Svalbarðstunga and appears to have taken the form of shrubs and isolated trees. Human settlement and the expansion of sheep grazing during and following the Medieval Warm Period promoted the spread of sedge species and facilitated the introduction of new species of plants. The degree of ecological change associated with the Norse landnám is more limited in Svalbarðstunga than in many other Icelandic regions because the valley was dominated by peatland rather than birch.

Key words: paleoecology, pollen, Svalbarđ, Iceland, environmental changes, human impact, Holocene.

1. Introduction

Northeastern Iceland is a very sensitive region that is highly vulnerable to the effects of climate change. This vulnerability derives from the fact that the region is subject to severe climate conditions generated by the flow of cold Arctic air masses and exposure to cold sea water from the East Greenland Current (Jones et al*.,* 2008). By contrast, the climate in western and southern Iceland is moderated by exposure to the Irminger current, a branch of the North Atlantic drift that carries relatively warm Atlantic water (Hansen et al., 2008). This climatic situation reduces the growing season in northeastern Iceland.

These harsh climate conditions explain the present-day scarcity of woodland in the Thistilfjordur region (northeastern Iceland) and the dominance of peatland. In Iceland, woodland is typically comprised of two birch species: downy birch (*Betula pubescens* Ehrh.) and dwarf birch (*B. nana* L.). Studies conducted in several regions of Iceland have shown that the development of birch woodland versus mires and peatlands was intimately linked to climate conditions after the early Holocene (e.g. Hallsdóttir and Caseldine, 2005). For example, the results of the only two studies conducted in the Thistilfjordur region (Zutter, 1997; Karlsdóttir et al., 2014) indicate an expansion of birch woodland during warm and dry conditions at approximately 7.5-7.1 cal ka BP and 3.3-335 cal ka BP. Between these two periods and after the later period (3.3-335 cal ka BP), there was an opening of the landscape characterized by the expansion of mires and heaths.

The last 1000 years produced a somewhat different situation, as has been shown in studies by Zutter (1997) and Karlsdóttir et al. (2014). Zutter (1997) conducted paleoecological analyses of pollen and macrofossils and archaeobotanical analyses of sediments sampled from drainage ditches near Svalbarð and from a major farm located in the Svalbarðstunga (Þistilfjordur). The data indicated that the initial Norse settlement of the region approximately 1000 years ago included the clearing and burning of wooded areas in order to establish pastures and hay fields. In another study in the region, Karlsdóttir et al. (2014) conducted a palynolgical study of samples extracted from drainage ditches in a pasture at a farm in Ytra-

Áland, 7 km east from Svalbarð. The impact of human settlement was harder to identify since this virtually treeless environment only contained traces of historical forest stands relict forest stands. Both of these study sites are located near the coast (Ytra-Áland is approximately 600 m from the shoreline and Svalbarð is 2.5 km away).

Many studies conducted elsewhere in Iceland have also identified a link between the decline of birch woodland and the sharp decline in *Betula* pollen. These changes occurred after the arrival of the first settlers and the establishment of a pastoral system (e.g. McGovern et al., 1988; Dugmore et al., 2006; Dugmore et al., 2007; Lawson et al., 2007; Church et al., 2007; Streeter et al., 2015). The arrival of the Norse in Iceland in the late 9th Century (Batt et al., 2015) caused the opening of the woodland following the introduction of grazing animals and charcoal production. In addition, overgrazing and intentional deforestation coupled with climate cooling caused run-away extensive local erosion processes, which led to the abandonment of farms in vulnerable areas between the 10th and 13th Centuries (such as in the dry interior Þórsmörk region of southern Iceland) (Dugmore et al., 2006; McGovern et al., 2007; Lawson et al., 2007; Church et al., 2007). These studies were conducted in ancient birch woodland environments. To date, very few studies have been performed in environments that are less likely to have sustained birch woodland (Erlendsson et al., 2009) or in unwooded areas such as northeastern Iceland (Zutter, 1997; Karslđottir et al., 2014).

An attempt to model temperature-treeline relationships for mountain birch globally within Iceland (Wöll, 2008) indicated that the present distribution of birch woodland is far smaller than its potential niche as defined by the territory that is climatically available for birch growth. In addition, we know from the model that the coastal area of Þistilfjordur (and other fjords in the NE) could likely have sustained extensive birch forests at the time of Norse settlement.

The primary aim of this study was to gather paleoenvironmental data from the vegetation record in Þistilfjordur over the last 6000 years in order to present a detailed paleoecological reconstruction of pre- and post-settlement vegetation history. The study is based on the analysis of pollen in cores extracted from peatland located near abandoned farm sites. In addition, we compared land use practices in the more marginal and vulnerable interior sites (as represented by the Kúðá farm site) to the exposed coastal areas (represented by the Hjálmarvík farm site). This comparison complements and expands upon Zutter's original 1997 study of the Svalbarð farm. This paper also offers a regional perspective on the evolution of vegetation spanning the transition between coastal and inland zones in a unique region that has been part of the same land ownership system for over 1000 years.

2. Study region

2.1 Environmental context of the Svalbarðstunga study region

Svalbarðstunga is the local name for the drainage divide that lies between the Svalbarðsá and Sanðá rivers that drain a substantial portion of the coastal plateau and interior highlands of western Thistilfjord in northeastern Iceland (Figure 3.1). A combination of volcanic, wind, ice, marine, landslide and river processes has produced a variety of geomorphological forms such as drumlins and eskers in the upstream portion of the Svalbarðstunga region and debris flows, debris avalanches, grassland, and peatland downstream. The average annual temperature in the region is 2.6°C, based on data for the period of 1931-2008 from the Raufarhöfn weather station located approximately 25 km north of Svalbarð (Veðurstofa Íslands, 2015). Average annual precipitation is 780 mm. As mentioned above, the region is notably colder than southern and western Iceland; for example, the average annual temperature for Reykjavik is 5.2°C for the same period (1931-2008) (Veðurstofa Íslands, 2015). In Iceland, the maritime climate is widespread throughout the coastal plains; summers are cool and winters are mild with relatively high levels of precipitation. The inland regions are characterized by an Arctic climate, with low precipitation (400-600 mm) and cold annual mean temperatures of approximately 2-3°C (lower in the highlands) (Hallsdóttir and Caseldine, 2005). The entire valley is now dominated by heathland, peatland and *thufur* (grassy mound-shaped domes caused by cryoturbation) (see Schunke and Zoltai, 1988).

Figure 3.1: Location of Svalbarðstunga and the study sites (Hjálmarvík and Kúðá); the locations of some satellite farms are also shown.

2.2 Human occupation

The settlement of Iceland (the *landnám* or "land-taking") began at around AD 871 ± 2 in the southwestern region of the island, which is dated by means of a stratigraphic association of a group of volcanic tephras referred to as the Landnam Series Tephras, dating from AD 870 - 940 (Batt et al., 2015). The Norse settlement was initially situated on coastal areas but it then moved to the interior valleys. By around 930, most of the arable land appears to have been claimed (Smith, 1995).

Historically, the entirety of the Svalbarðstunga region belonged to Svalbarð farm. Until its subdivision in the late 19th Century, Svalbarð was a beneficium of the church. The estate comprised several satellite client farms and numerous auxiliary herding installations scattered over the Svalbarðstunga. The Svalbarð farm site itself has been occupied since at least the mid-10th Century (Amorosi, 1992; Gisladottir et al. 2013, 2014) and it remains one of the largest sheep farms in the Þistilfjörður region. Two of Svalbarð's satellite farms (Hjálmarvík and Kúðá) were selected as sampling sites for palaeoenvironmental reconstruction in the present study.

Hjálmarsvík is located about 2 km north-east of Svalbarð near the shore of Þistilfjordur Bay facing the Greenland Sea (Figure 3.1). This site lies on the sheltered eastern side of a headland on a large flat marine terrace dominated by heathland and peatland. Local vegetation includes *Ericaceae, Cyperaceae* (e.g. *Carex* and *Eriophorum*) and bryophytes. The archaeological site at Hjálmarsvík consists of a farm mound, enclosed homefield and clusters of outbuildings including sheep houses, animal pens and a milk fold. The archaeological investigations carried out by Gisladottir et al. (2013, 2014) discovered that the site was occupied prior to AD 940. However, it had an extensive yet apparently diminishing trend of occupation throughout the Middle Ages lasting into the 18th Century. From the 19th Century to the present time, the area has been used as grazing land.

Kúðá is an inland farm located at 120 m asl, approximately 12 km from the coast and 10 km south of Svalbarð. It includes the ruins of a 20th Century house, a substantial medieval and post-medieval farm mound, as well as several outbuildings and cattle pens, the oldest of which were dated to between the 13th and the late 15th Centuries (Gísladóttir et al., 2013). A second phase of occupation lasted from the 18th Century until the farm was abandoned in 1960 (Gísladóttir et al., 2013). To date, there is no direct archaeological evidence of occupation between the 16th and the early 18th Centuries. Historical records report a brief occupation in the 17th Century and the census of 1712 indicated that the site was unoccupied.

3. Methods

3.1 Spore and pollen analysis

One core from each site was extracted and subjected to stratigraphy and spore and pollen analysis. At Kúđá, a 200 cm long core (KDA-C1.IS) was extracted from the peaty margin of a lake located approximately 300 m north-east of the archaeological site (figures 3.2 and 3.3). At Hjálmarvík, a 75 cm long core (HVK-C1.IS) was removed from a small peatland lying approximately 350 m west of the archaeological site (figures 3.4 and 3.5). The vegetation at each site is characteristic of Arctic tundra and includes *Salix sp., Cyperaceae*, *Ericaceae* and brown mosses. Both sites are outside the clusters of ruins that comprise the farm sites.

Spore and pollen analysis was carried out at 4 cm intervals on both peat cores. At each level, 2 cm^3 of sediment was processed following the procedures of Faegri et al. (1989) and Lavoie (2001) (i.e., using chemical treatments of 10% KOH, HCl, HF and acetolysis). A *Eucalyptus globulus* pollen suspension of known volume and concentration was added to each sample before preparation to calculate pollen concentration (grains/cm^3) (Benninghoff, 1962). At least 500 pollen grains of terrestrial vascular plants were counted for each sample (pollen sum). Pollen and spore identification procedures followed Richard (1970, 1981) and McAndrews et al. (1973). The pollen collection at the Centre d'études nordiques (CEN) was used as a reference for the identification of problematic specimens.

Figure 3.2: Aerial view of Kúðá site; red point indicate pollen core sampling and the white rectangle shows the location of the remains of the old farms

Figure 3.3: View from pollen sampling site (red arrow). The black arrow show the location of the remains of the old farm

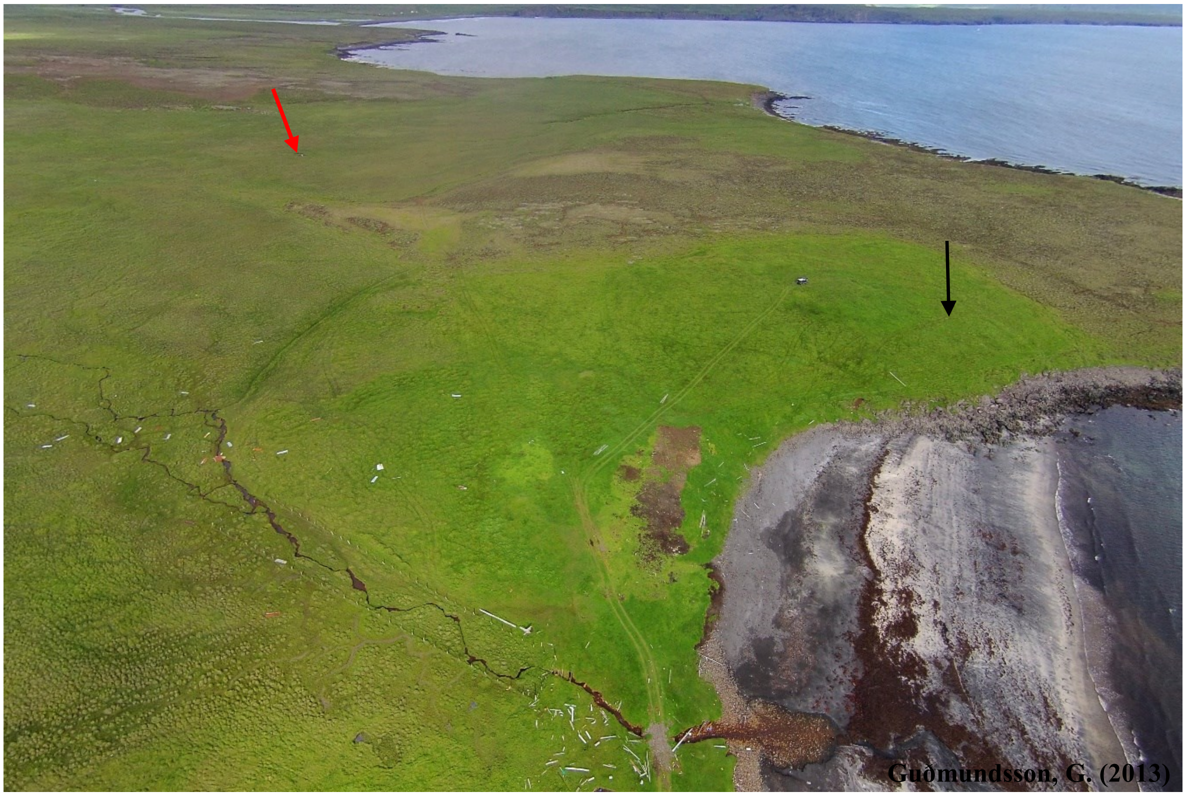

Figure 3.4: Aerial view of Hjálmarsvík site. The black arrow shows the location of the ruins and the red arrow indicates the sampled peatland location

Figure 3.5: Hjálmarvík site; the red arrow indicates the sampled peatland location

We also measured the pollen size of *Betula* in order to distinguish between *B. pubescens* and *B. nana.* To this end, we reviewed several related studies such as Birks (1968), Mäkelä (1999), Caseldine (2001) and Karlsdóttir et al. (2007, 2009). These studies established a mean pollen diameter of 20.42 µm for *B. nana* and 24.20 for *B. pubescens*. The Dividing line between the two distribution curves was 22.1 µm, which means that grains larger than this are *B. pubescens* and those that are smaller are *B. nana*. Thus, for each level we measured fifty *Betula* pollen grains and the results were compared to modern references based on the surface vegetation. In order to determine the median size of the contemporary birch pollen (i.e. *B. nana*), a total of 100 birch pollen grains were measured and a mean pollen grain size of 20.8 ± 1.75 µm was obtained. The pollen diagrams were drawn using Palaeo Data Plotter software (Juggins, 2002).

3.2 Radiocarbon dating

Ten subsamples were dated using accelerator mass spectrometry (AMS) at CEN's laboratory and at the Keck Laboratory at the University of California, Irvine (UL-KIU). Subsamples consisted of aerial pieces of plants such as leaves, seeds and twigs. Dates were calibrated using the Calib 6.0 program (Stuiver, Reimer, & Reimer, 2011) and midpoints were obtained using the weighted median method (Telford et al., 2004; Stuiver et al., 2011). Calibrated ages (cal yr BP) were rounded to the nearest decade. The results are presented in calibrated years and in AD/BC notation. Several tephras such as H4, H3, V-Sv 940, H1300, and V1477 were used to date the primary environmental changes. The tephra were identified in accordance with laboratory protocols established by Magnús Á. Sigurgeirsson (Gísladóttir et al., 2014).

4. Results and interpretation

4.1 Pollen and spore data from Kúðá

Six zones were delineated based on pollen data from the KDA-C1 core from Kúðá: P-I, P-II, P-III, P-IV, P-V, and P-VI (Figures 3.6 and 3.7)

Zone P-I: 200-136 cm (4360 BC – 3960 BC). Zone P-I is composed of highly decomposed black peat containing wood fragments overlain by highly decomposed brown peat. We did not reach the base of the peat (the organic-mineral transition) in this location, but the bottom of Zone P-I was dated to 6310 cal yr BP (4360 BC).The peat accumulation rate is high; this could be explained by the abundance of wood fragments in this zone (Table 3.1, Figures 3.6 and 3.8).

Table 3.1: Radiocarbon and calibrated ages of the samples from Svalbarð

Sites	Samples	Lab. number	Age (yr BP)	Age AD/BC. (2 σ)	Age (cal yr BP) (2 σ)	Midpoint calibrated age (cal yr BP)	Dated material
Hjálmarvík	HVK-C1 (15-16 cm)	ULA-4453	190±20	AD 1740-1810	140-220	180	Leaves
	HVK-C1 (37-38 cm)	ULA-4445	1010±20	AD 990-1040	910-960	930	Seeds, leaves
	HVK-C1 (57-58 cm)	ULA-4446	2425±20	540-410 BC	2360-2490	2440	Seeds, leaves
	HVK-C1 (73-74 cm)	ULA-4436	3110±20	1430-1370 BC	3320-3380	3340	Brown mosses
Kúðá	KDA-C1 (50-51 cm)	ULA-4441	2050±20	AD 0-120 BC	1950-2060	2010	Seeds, leaves
	KDA-C1 (99-100 cm)	ULA-4442	4020±20	2580-2480 BC	4430-4530	4480	Seeds, leaves
	KDA-C1 (135-136 cm)	ULA-4437	5135±20	3980-3940 BC	5890-5930	5910	Seeds, leaves
	KDA-C1 (169-170 cm)	ULA-4443	5475±20	4360-4320 BC	6270-6300	6290	Brown mosses
	KDA-C1 (199-200 cm)	ULA-4444	5530±20	4400-4340 BC	6290-6350	6310	Brown mosses

This zone is distinguished by an abundance of *Betula* pollen, with the pollen influx reaching over 1000 grains/cm^2/year. According to Hicks (2001), a high pollen influx indicates that conditions were favorable for the growth of birch forests in the region (Figure 3.9). The median grain size of birch pollen fluctuates between 23 and 26 µm, which may be an indication of the prevalence of *B. pubescens* (Caseldine, 2001; Karlsdottir et al., 2007, 2014). Histograms of the mean diameters of *Betula* pollen grains support this interpretation but also confirm the presence of *B. nana* (Figure 3.10). Thus, both birch native species are well represented in this zone, but *B. pubescens* was likely more abundant.

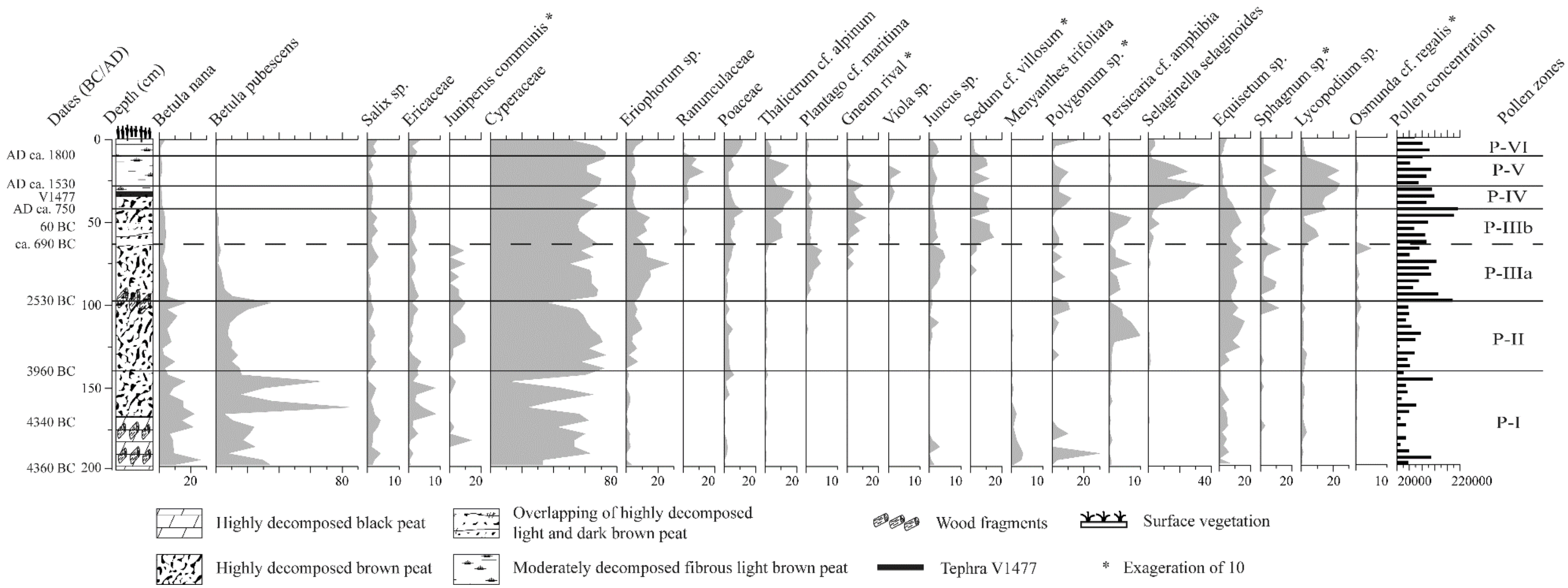

Figure 3.6: Pollen diagram of a core (KDA-C1) extracted from the peaty margin of the lake located approximately 300 m north-east of the Kúðá archaeological site

At the local scale, this zone is characterized by the dominance of pollen from *Cyperaceae*, although it is less abundant than in zones P-II, P-III and P-VI. The presence of pollen from *Salix*, *Ericaceae* and *Juniperis communis* indicates that the birch forest was open. Furthermore, pollen from *Juncus*, *Polygonum, Equisetum*, *Lycopodium* and *Sphagnum* were found in small quantities, indicating that conditions were slightly wet (Porsild and Cody, 1980). The occurrence of *Menyanthes trifoliata* is also suggestive of minerotrophic conditions (Bhiry and Filion, 1996; Godwin et al., 2002).

Zone P-II: 136 - 99 cm (3960 BC – 2530 BC). Zone P-II consists of highly decomposed brown peat. The increase in *Cyperaceaee* pollen in this zone was paralleled by a decrease in *Betula* pollen, except at approximately 2500 BC when the percentage of pollen for this species was higher than in the rest of this zone. The same pattern was also found in the pollen accumulation rate diagram (Figure 3.11). Pollen from *Eriophorum*, *Poaceae* and *Juncus* were also found. The increase in *Juniperus comunis*, which is generally known to inhabit heathlands, lava fields, brushwood, and hill edges in Iceland, confirms an open landscape. The abundant *Equisetum* spores in this zone also suggest the absence of trees (Zutter, 1997). At the local scale, the presence of *Persicaria* cf. *amphibia*, a species that grows in lakes and large ponds, suggests that environmental conditions were wetter than in zone P-I. This interpretation is also supported by the increase in spores of bog species such as *Equisetum* and *Sphagnum* (Porsild and Cody, 1980).

Zone P-III: 99 - 40 cm (2530 BC – AD ca. 750). Zone P-III consists of approximately 40 cm of highly decomposed brown peat overlain by alternating light and dark brown peat that accumulated between 2530 BC and AD ca. 750. This zone was subdivided into two sub-zones: P-IIIa and P-IIIb. In P-IIIa (*2530 – ca. 690 BC)*, the percentage of *B. pubescens* pollen continued to decline (from 10% to 1%). The grain size curve for *Betula* grains also indicates a change in the prevalence of birch species, since the decrease in the median size of *Betula* pollen grains correlates with the dominance of dwarf birch (*B. nana*). The low influx of *Betula* pollen (below 200 grains/cm^3/year) indicates a very open birch woodland in the valley.

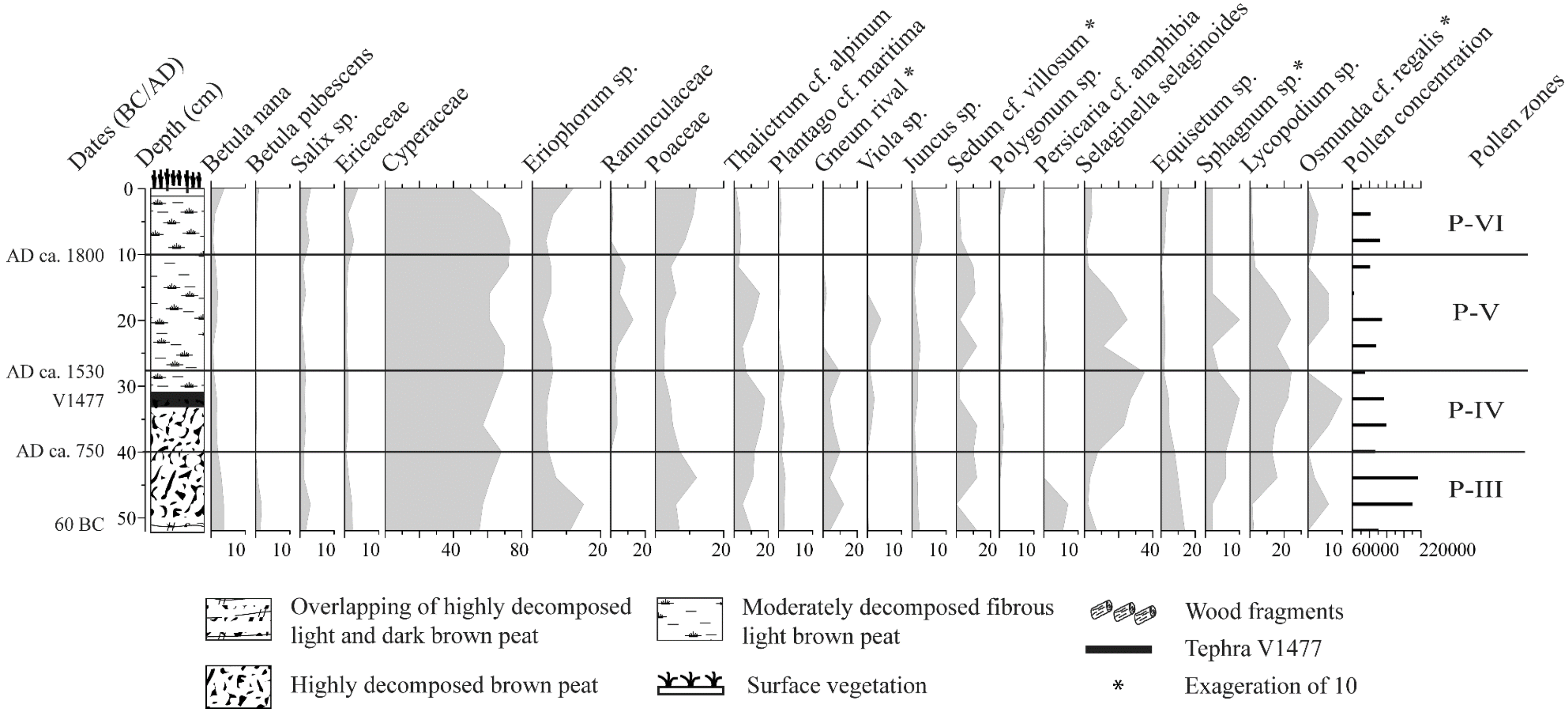

Figure 3.7: Pollen diagram of data from 52 to 0 cm of the core (KDA-C1) extracted from the peaty margin of the lake located approximately 300 m north-east of the Kúðá archaeological site. Figure 3.7 is a close-up view of the top part of Figure 3.6.

At the local scale, sub-zone P-IIIa is characterized by the abundance of hydrophilic herbaceous species such as *Thalitrum* cf. *alpinum*, *Plantago* cf. *maritime*, *Gneum rival*, *Juncus* and *Sedum* cf. *villosum.* Environmental conditions therefore became much wetter, which is also indicated by the persistence (or increase) of *Equisetum*, *Sphagnum,* and *Lycopodium*, all of which grow in peatland ecosystems.

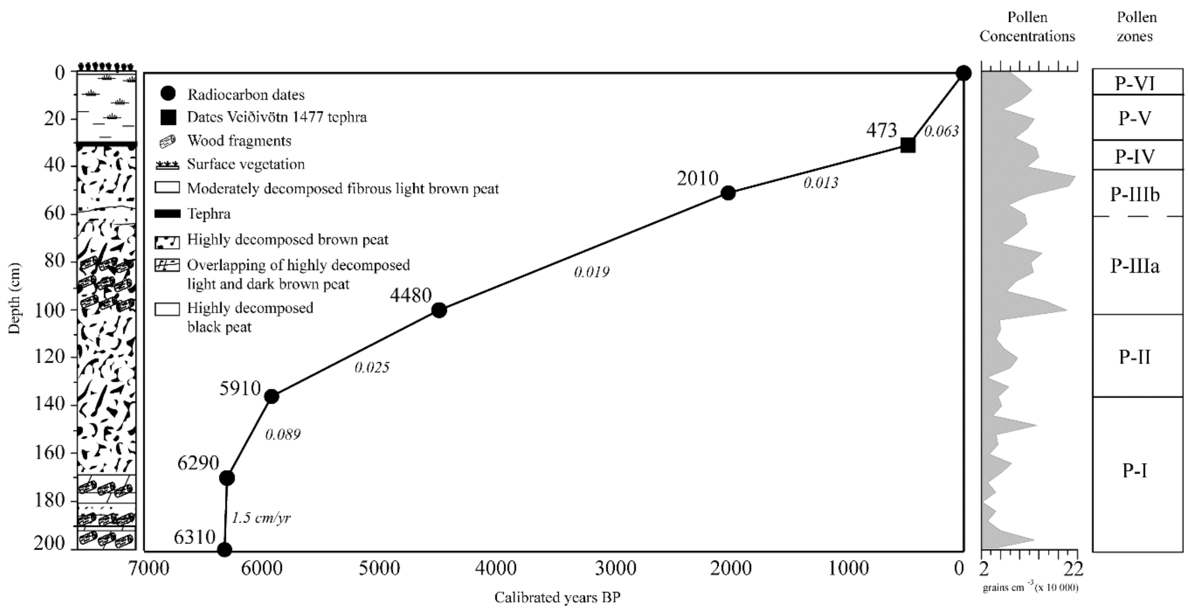

Figure 3.8: Age-depth model of the core KDA-C1, Kúðá. Stratigraphy (left), pollen concentration (curve) and pollen zones (right) are also illustrated.

Sub-zone P-IIIb accumulated between ca. 690 BC and AD ca. 750 and is characterized by the disappearance of *B. pubescens* pollen, which suggests the end of the birch woodland at the regional scale. This sub-zone is also marked by the disappearance of other species such as *Juniperus communis* and *Osmunda cf. regalis*. By contrast, herbaceous species such as *Thalictrum* cf. *alpinum*, *Gneum rival* and *Sedum* cf. *villosum* became more diversified and abundant.

Zone P-IV: 40 - 28 cm (AD ca. 750 – AD ca. 1530). Zone P-IV consists of highly decomposed brown peat overlain by a moderately decomposed, fibrous, light brown peat. There is a slight decrease in the prevalence of *Cyperaceae*, *Poacea* and *Equisetum* pollen, but peatland species such as *Thalictrum* cf. *alpinium*, *Sphagnum*, *Lycopodium*, *Osmunda* cf. *regalis,* and *Selaginella selaginoides* were identified (Figure 3.7). The V1477 tephra lies at a depth of between 31 and 32 cm. At the same level, we also noted a decline of several species (e.g. *Thalictrum* cf. *alpinium*, *Sedum* cf. *villosum*, *Sphagnum* and *Osmunda* cf. *regalis*). These findings illustrate the impact of volcano activity and explain the short-term decrease in the percentage of spores from bryophyte species.

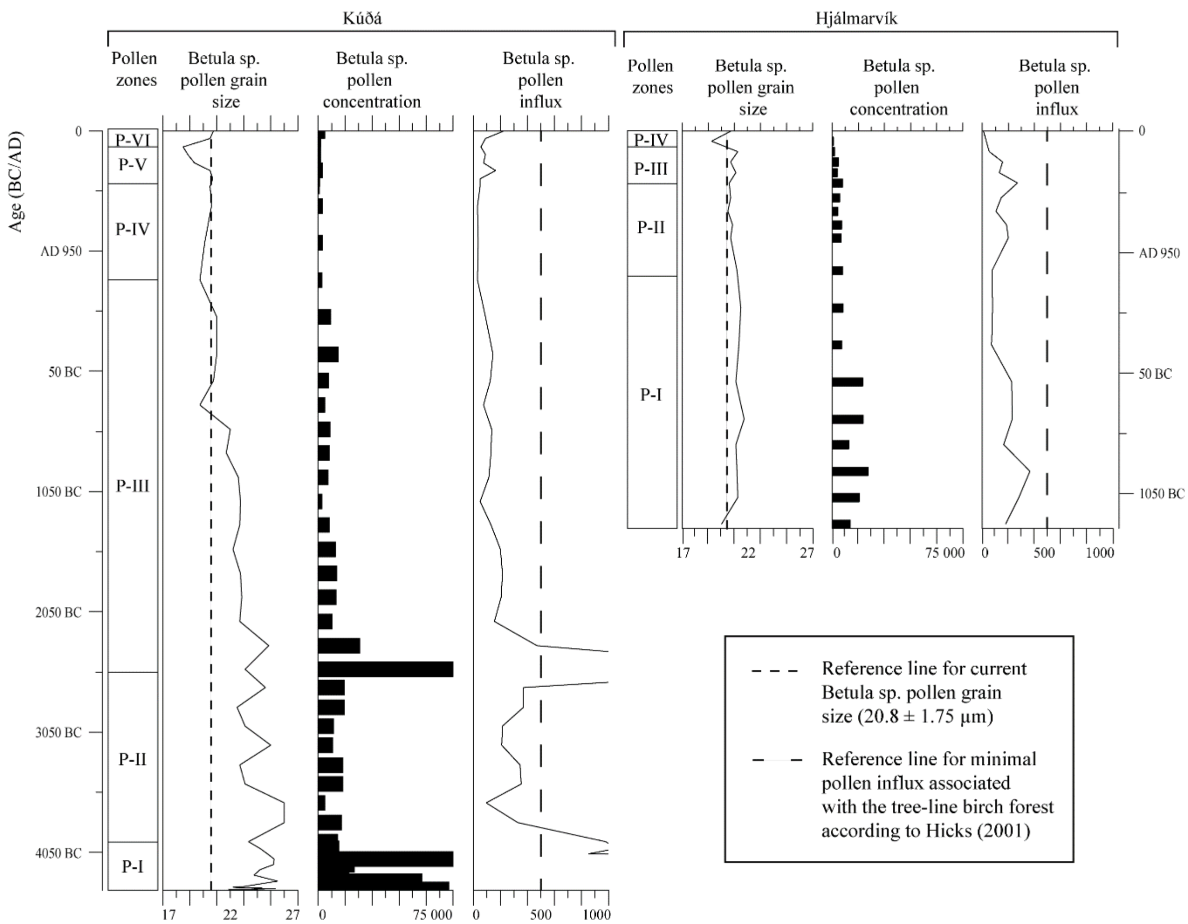

Figure 3.9: Betula pollen data from Kúðá and Hjálmarvík

Zone P-V: 28-10 cm (AD ca. 1530 – AD ca. 1800). Zone P-V consists of a moderately decomposed fibrous light brown peat. Several taxa (e.g. *Ranunculaceae*, *Thalictrum cf. alpinum, Viola*, *Selaginella selaginoides, Sphagnum, Lycopodium* and *Osmunda* cf. *regalis*) were found in this zone that are indicative of wet conditions. These were located at depths

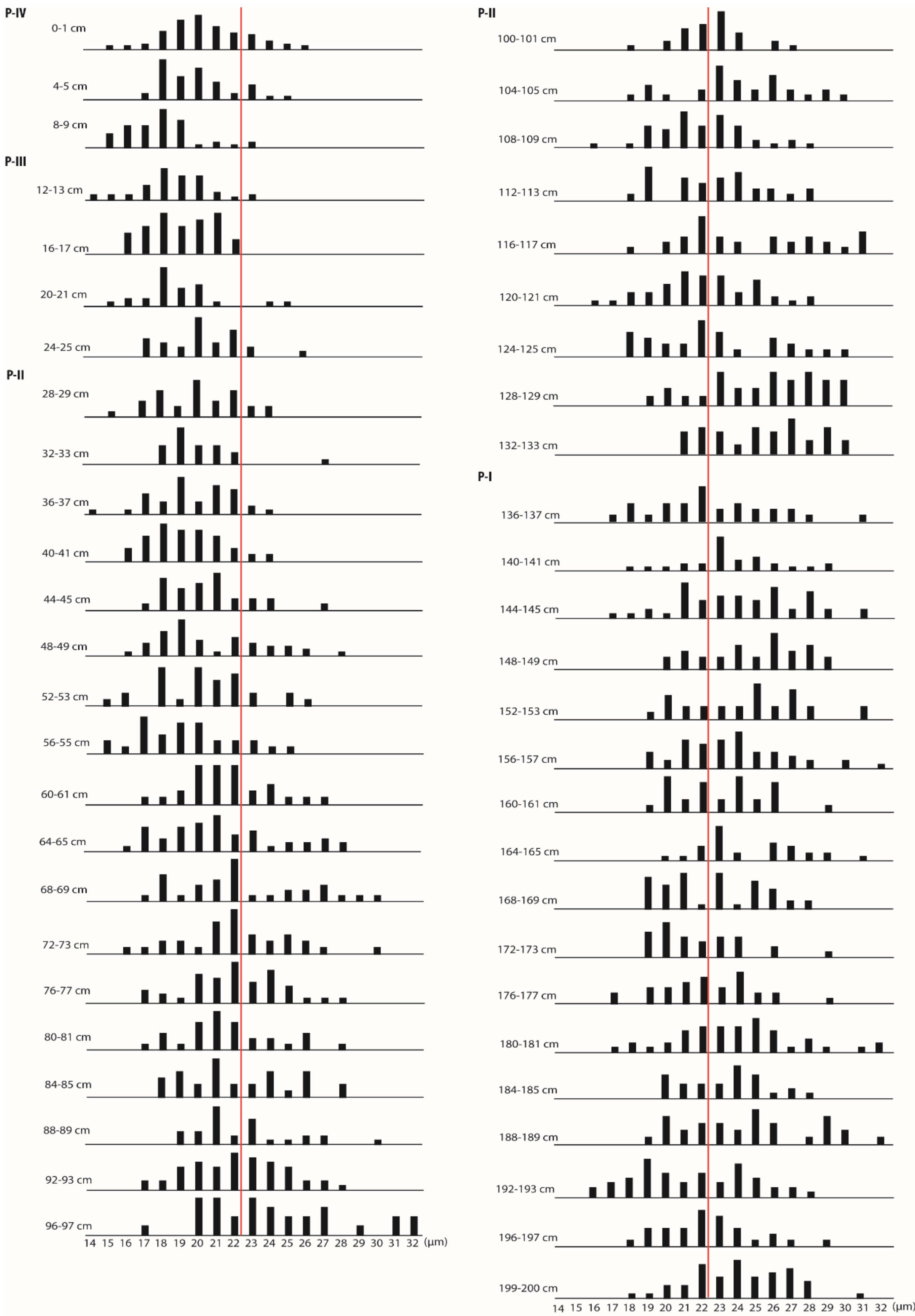

Figure 3.10: Histograms of the mean diameters of Betula grains from the Kúđá core KDA-C1. The red line show the cut-point between both species (B. nana ≤ 22.1 μm, B pubescens > 22.1 μm)

between 24 and 11 cm (AD ca. 1580 – AD ca. 1780). By contrast, at 24-25 cm (AD ca. 1580) and 11-10 cm (AD ca. 1780), several of these taxa showed minimal values that correspond to dry and cold short phases. This zone is also marked by a slight increase in the percentage of *B. nana* pollen, an increased pollen influx and a sharp decrease in pollen grain size (Figure 3.9). These findings could indicate that the greater prevalence of *B. nana* (a species that is tolerant of cold climates) may have been induced by deteriorating environmental conditions or by a change in land use activities. In this regard, zone P-V corresponds to the Little Ice Age (LIA) when conditions were drier and colder in the Arctic and Subarctic, particularly around 1600 and 1800.

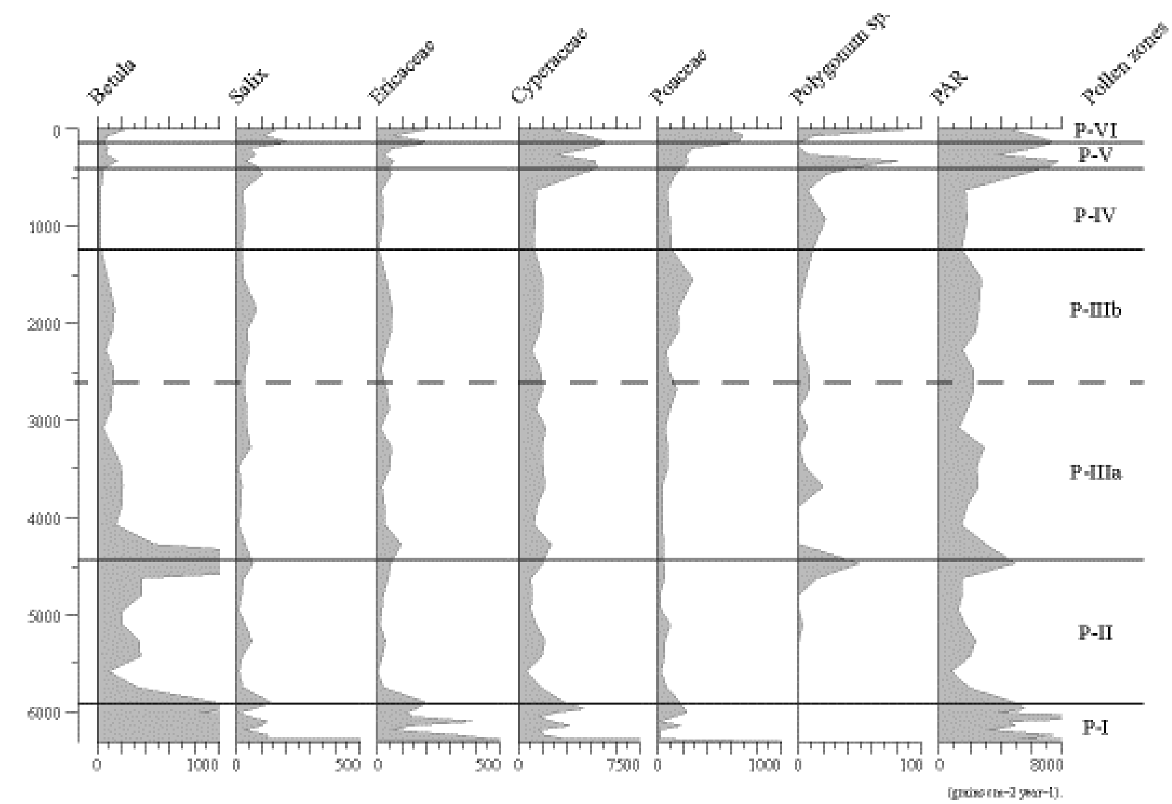

Figure 3.11: Pollen accumulation rates of dominant species of core KDA-M1, Kúðá.

Zone P-VI: 10-0 cm (AD ca. 1800 to the present). Zone P-V contains moderately decomposed fibrous light brown peat. This zone is characterized by the increase in herbaceous species such as *Poaceae* and shrubs such as *B. nana*, *Salix* and *Ericacea*. The data suggest that the regional environmental conditions were clement enough to favour floristic development.

There was also a slight increase in the percentage of spores from *Equisetum* and *Osmunda* cf. *regalis*, which may be a sign of wet conditions at the local scale.

4.2 Pollen and spore data from Hjálmarvík

Four zones were delineated from the pollen assemblages in the HVK-C1 core from Hjálmarvík: P-I, P-II, P-III and P-IV (Figure 3.12).

Zone P-I: 75-41 cm (1390 BC - AD ca. 780). Zone P-I is composed of highly decomposed black peat containing wood fragments overlain by light and dark decomposed brown peat. Pollen from *Betula* (*B. nana* and *B. pubescens*), *Salix*, *Alnus*, *Ericacea* and some hygrophilous taxa were recovered from this zone. Zone P-I was subdivided into two sub-zones: P-Ia and P-Ib.

Sub-zone P-Ia accumulated between 1390 and 610 BC and is characterized by diverse and abundant pollen from shrub species such as *B. nana*, *Salix*, *Alnus* and *Ericaceae*. Both *Betula* species show a general decreasing trend in pollen percentages toward the end of this sub-zone. The histograms of the mean diameter of *Betula* pollen grains reveal the presence of *B. nana* at this level (Figure 3.12). However, given the low *Betula* concentration and the very low *Betula* pollen influx, it is likely that the *Betula* pollen grains that have a large diameter (*B. pubescens*) derive from long-distance transport, either from outside Iceland or from specific regions within Iceland (Caseldine, 2001; Hicks, 2001). At the local scale in sub-zone P-Ia, pollen from peatland ecosystem taxa such as *Eriophorum*, *Juncus, Equisetum* and *Lycopodium* were identified. The abundance of *Equisetum* spores in this zone also indicates an open or treeless landscape (Zutter, 1997). The scarcity or absence of trees at the local scale is also indicated by the presence of *Menyanthes trifoliata*, a pioneer species that colonizes the margins of streams in the north under minerotrophic conditions (Porsild and Cody, 1980; Bhiry and Filion, 1996).

Sub-zone P-Ib accumulated between ca. 610 BC and AD ca. 780. The principal difference between this sub-zone and sub-zone P-Ia was the decline in percentage values for both species of birch: 27% to 5% for *B. nana* and 10% to 2% for *B. pubescens*. Based on these data, we can infer that birch trees were sporadic at the regional and local scales. This interpretation is also supported by the *Betula* influx value of 400 grains/cm^2/year, which is below the 500 grains/cm^2/year characteristic of birch tree-line forests (Hicks 2001) (Figure 3.8). The *Betula* pollen size is similar to that of the contemporary samples taken from *B. nana*. It is possible that this zone (zone P-I from Hjálmarvík) may correspond to the upper part of zone P-III of the KDA-C1 core from Kúðá, since they share a similar pollen assemblage.

Zone P-II: 41 – 20 cm (AD ca. 780 to AD ca. 1510). Zone P-II contained the V1477 tephra and corresponds to zone P-IV at Kúðá. It consists of highly decomposed brown peat overlain by moderately decomposed fibrous light brown peat. The peat accumulation rate is slightly higher comparing to Zone P-I(Figure 3.14). Zone P-II was subdivided into two subzones: P-IIa and P-IIb.

Sub-zone P-IIa was formed between AD ca. 890 and AD ca. 1250. There is a significant decrease in the percentage of *Cyperaceae* pollen (from 71% to 45%) and there is evidence of the establishment and growth of *Poaceae*. According to Zutter (1997), such growth is generally associated with anthropogenic activities and the development of pasture land. This interpretation is supported by evidence concerning the establishment of two distinctive species: *Calluna vulgaris* (which grows on sites used by humans (ISSG, 2010)) and *Polygonum* cf. *aviculaire* (which grows near human settlements (Porsild and Cody, 1980)). Moreover, the presence of pollen from *Eriophorum*, *Juncus*, *Plantago* cf. *maritime, Menyanthes trifoliata* and *Osmunda* cf. *regalis* confirms peatland development/expansion and the existence of wet conditions (Porsild and Cody, 1980).

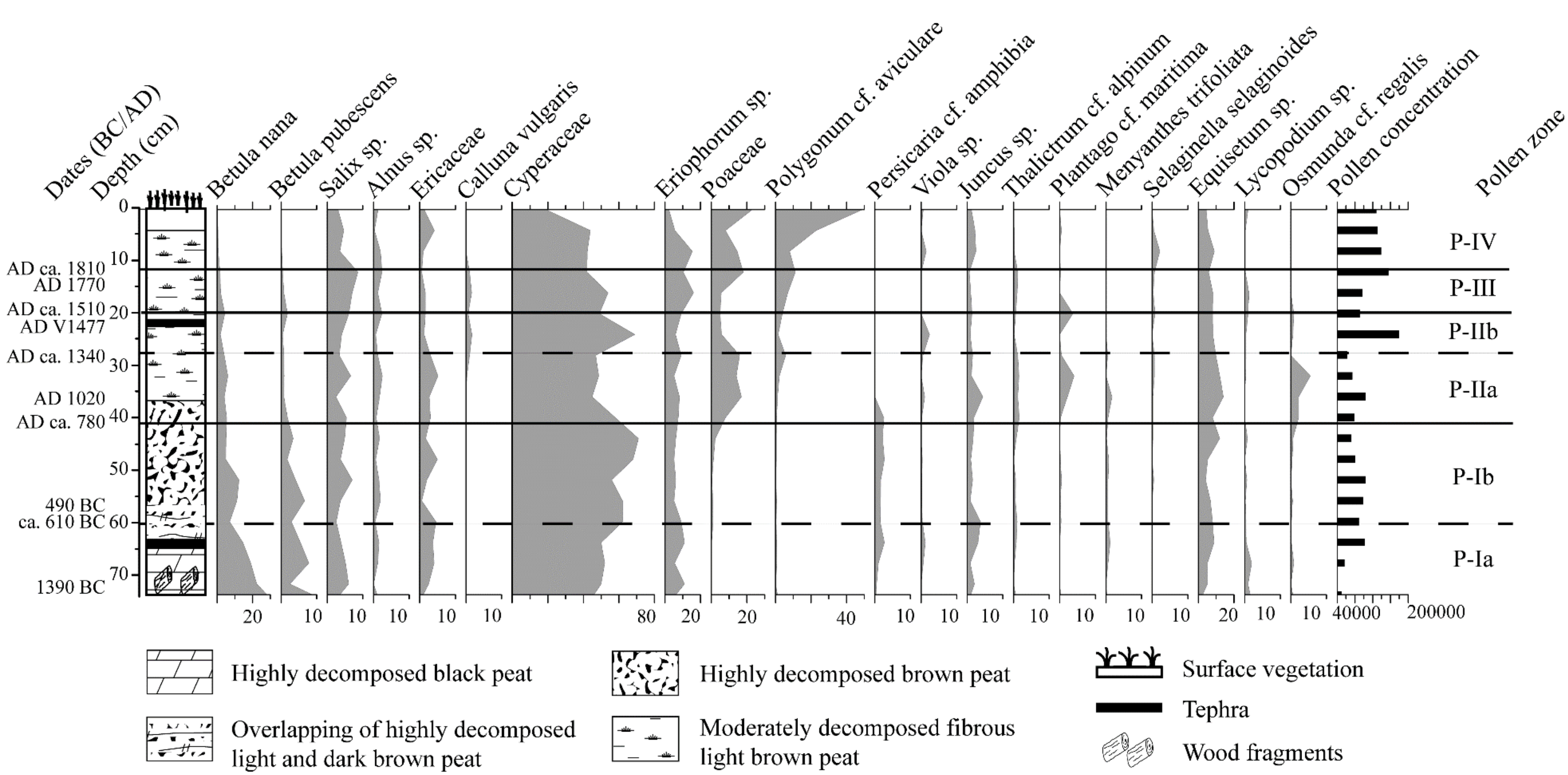

Figure 3.12: Pollen diagram of a core (HVK-C1) extracted from a peatland approximately 350 m west of the Hjálmarvík archaeological site

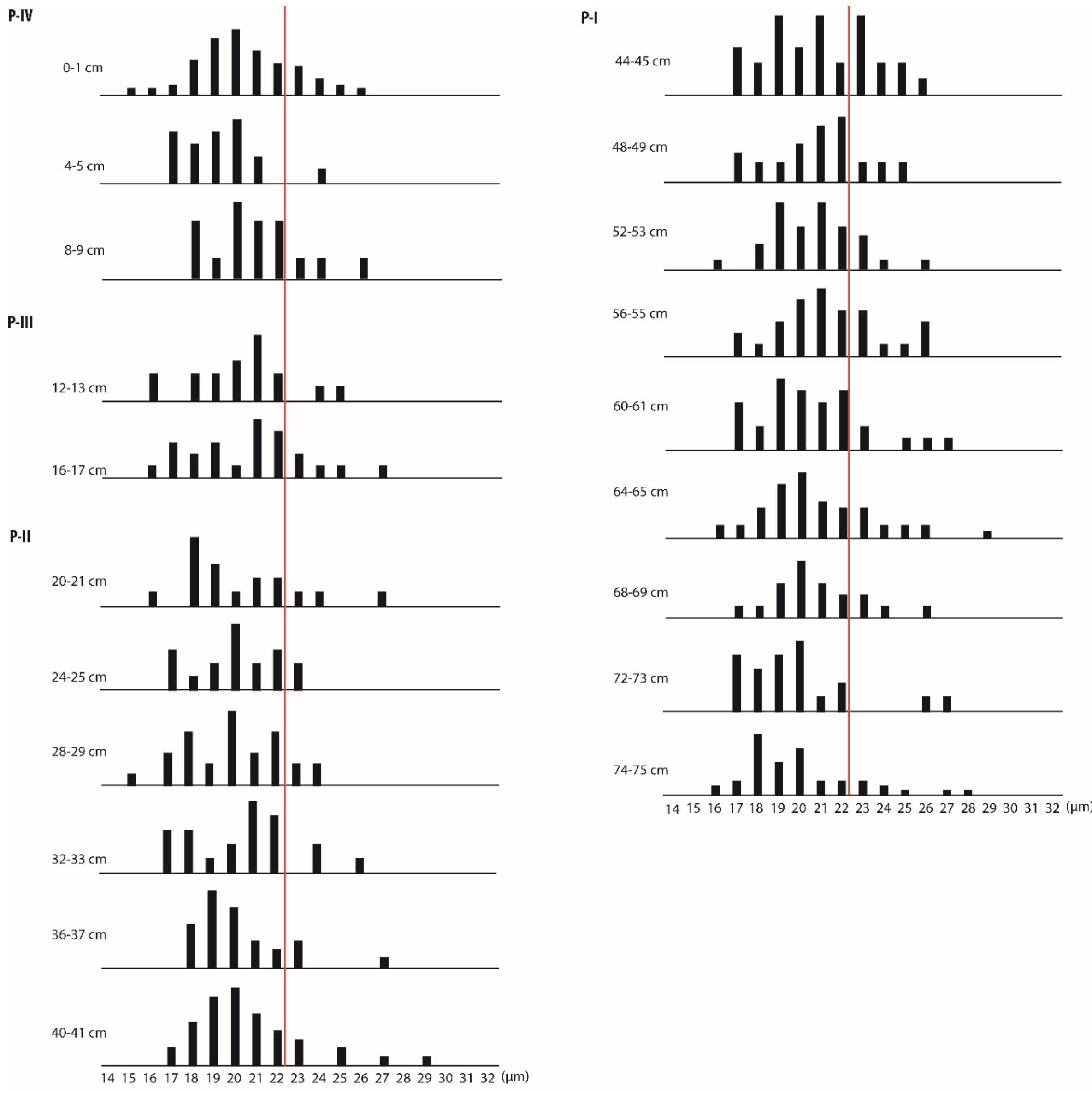

Figure 3.13: Histograms of the mean diameters of Betula grains from the Hjálmarsvík core HVK-C1. The red line show the cut-point between both species (B. nana ≤ 22.1 µm, B pubescens > 22.1 µm)

Sub-zone P-IIb accumulated between AD ca. 1340 and AD ca. 1500 and differs from sub-zone P-IIa by the decline of virtually all taxa except *Cyperaceae*. This could be related to volcanic activity and the accumulation of the V1477 tephra.

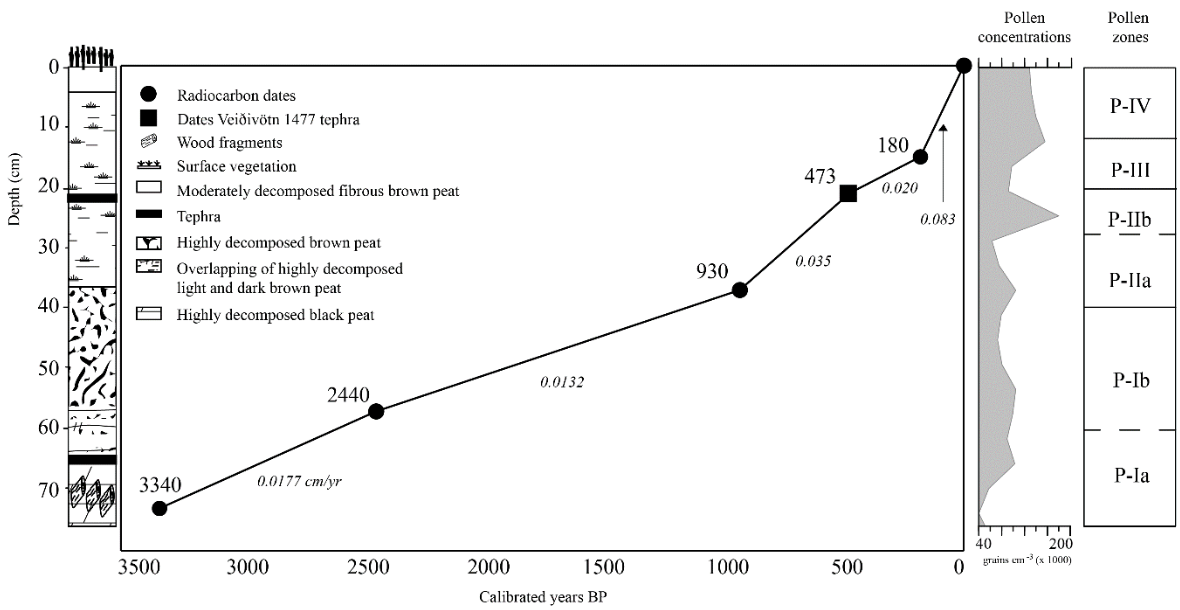

Figure 3.14: Age-depth model of the core HVK-C1, Hjálmarvík. Stratigraphy (left), pollen concentration (curve) and pollen zones (right) are also illustrated.

Zone P-III: 20 – 12 cm (AD ca. 1510 - AD ca. 1810). Zone P-III is characterized by a general trend toward the decline or disappearance of several taxa (e.g. *Betula* sp., *Calluna Vulgaris*, *Thalictrum* cf. *alpinum, Plantago* cf. *maritime*, *Lycopodium* and *Osmunda* cf. *regalis*). Such diminution could indicate a deterioration of climatic conditions that probably became dry and cold. At this time, there was also an increase in pollen grains pourcentage of *Poaceae* and *Polygonum* cf. *aviculare* and the pollen accumulation rate (PAR) (Figure 3.14), which indicates the development of heathland following the establishment of human settlements in the region.

Zone P-IV: 12- 0 cm (AD ca. 1810 to the present). Zone P-IV is characterized by an increase in the abundance of pollen from *Poaceae*, which may indicate the intensification of human activities. This interpretation is supported by the sharp increase in the pollen percentage of *Polygonum cf. aviculare*, a domestic plant that is commonly found throughout inhabited places, paths, and roads (Schofield et al., 2013). Both increases are also observed in the PAR diagram (Figure 3.14). Moreover, the disappearance of *Calluna vulgaris* is notable in this zone, as it is an invasive species that does not support intense pressure from sheep grazing (ISSG, 2010). The abundance of pollen from other shrubs and herbaceous species such as *Ericaceae*, *Juncus* sp., *Selaginella selaginoides* and *Equisetum* suggests that environmental conditions became wetter. This zone corresponds to zone P-VI at Kúðá.

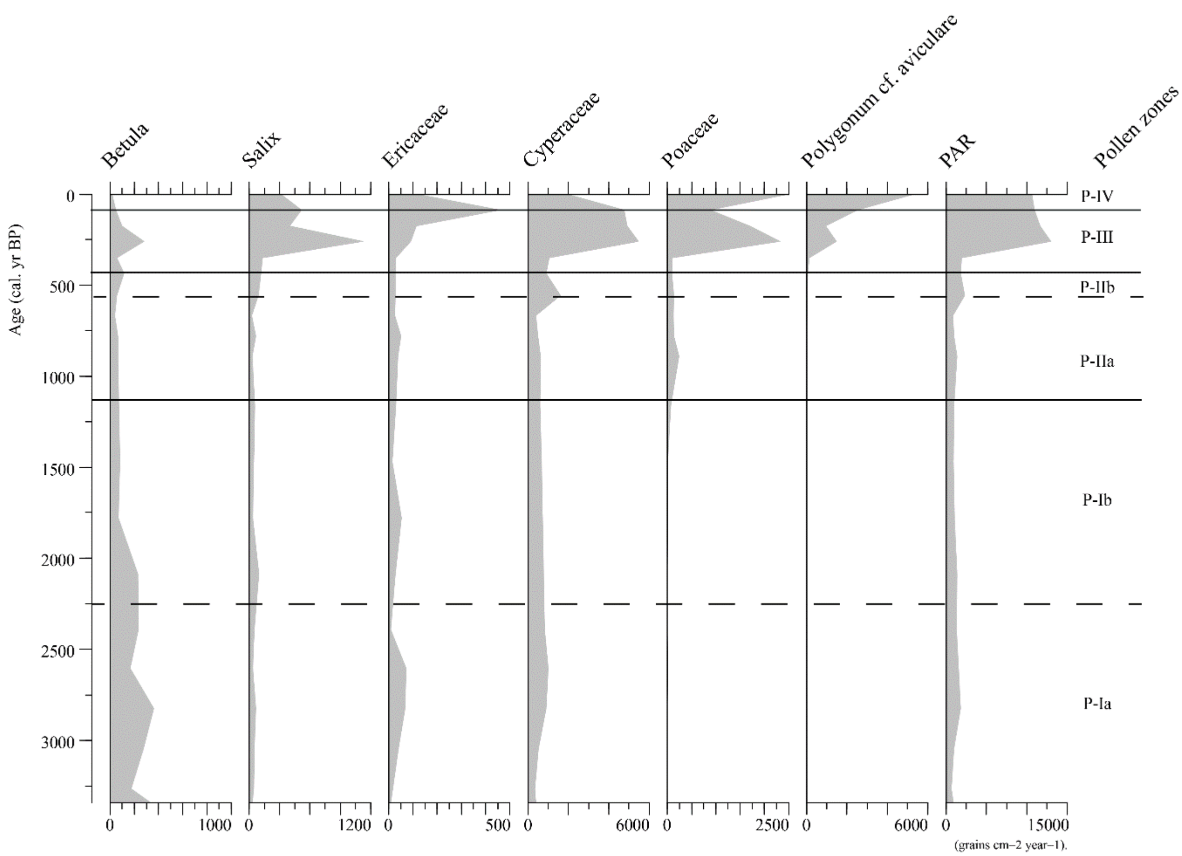

Figure 3.15: Pollen accumulation rate of dominant species of core HVK-C1, Hjálmarvík.

5. Discussion

Environmental and climate changes

Pollen and spore analysis of peat cores sampled from the Kúðá site (12 km inland) and the Hjalmarvík site (on the coast) made it possible to reconstruct the environmental conditions and the development of vegetation in Svalbarðstunga throughout the middle and late Holocene. Figure 3.16 illustrates the key developments that will be discussed below.

Birch forest development and shrub tundra in Svalbarðstunga during the late Atlantic and Subboreal period: from 6310 to 4500 cal yr BP (4300 BC – 2500 BC)

From 6310 to 5910 cal. yr BP at Kúðá, our data indicate that environmental conditions were suitable for the development of a birch forest (*B. pubescens*). This interpretation is supported by the birch pollen influx, which measures at over 1000 grains/cm^2/year and meets the pollen influx threshold for birch forests (i.e., 1000 grains/cm^2/year) (Hicks, 2001). Birch forest development was triggered by high humidity during the Atlantic period in Iceland when the climate in the Northern Hemisphere was warm and wet. Subsequently, *Betula* species significantly declined while shrub species (e.g. *Salix*, *Ericaceae* and *Juniperus communis*, as well as *Menyanthes trifoliata* and *Equisetum)* that frequently grow in wet condition became increasingly abundant. These data are in accord with studies by Halssdóttir and Caseldine (2005) and Karlsdóttir et al. (2014), which showed that there was a retrogressive towards more open birch woodland along with widespread mires and heathland. In other words, the peatland and heath were gaining territory at the expense of the woodland. A second peak of *Betula sp*. occurred at around ca. 4800- 4480 cal. yr BP, which is close to the same period of peak birch pollen detected at the Ytra-Aland farm (8 km east). However, the birch species that increased in that period was *B. nana* (Karlsdóttir et al. 2014), while *in Svalbarðstunga* both *Betula* species sharply increased.

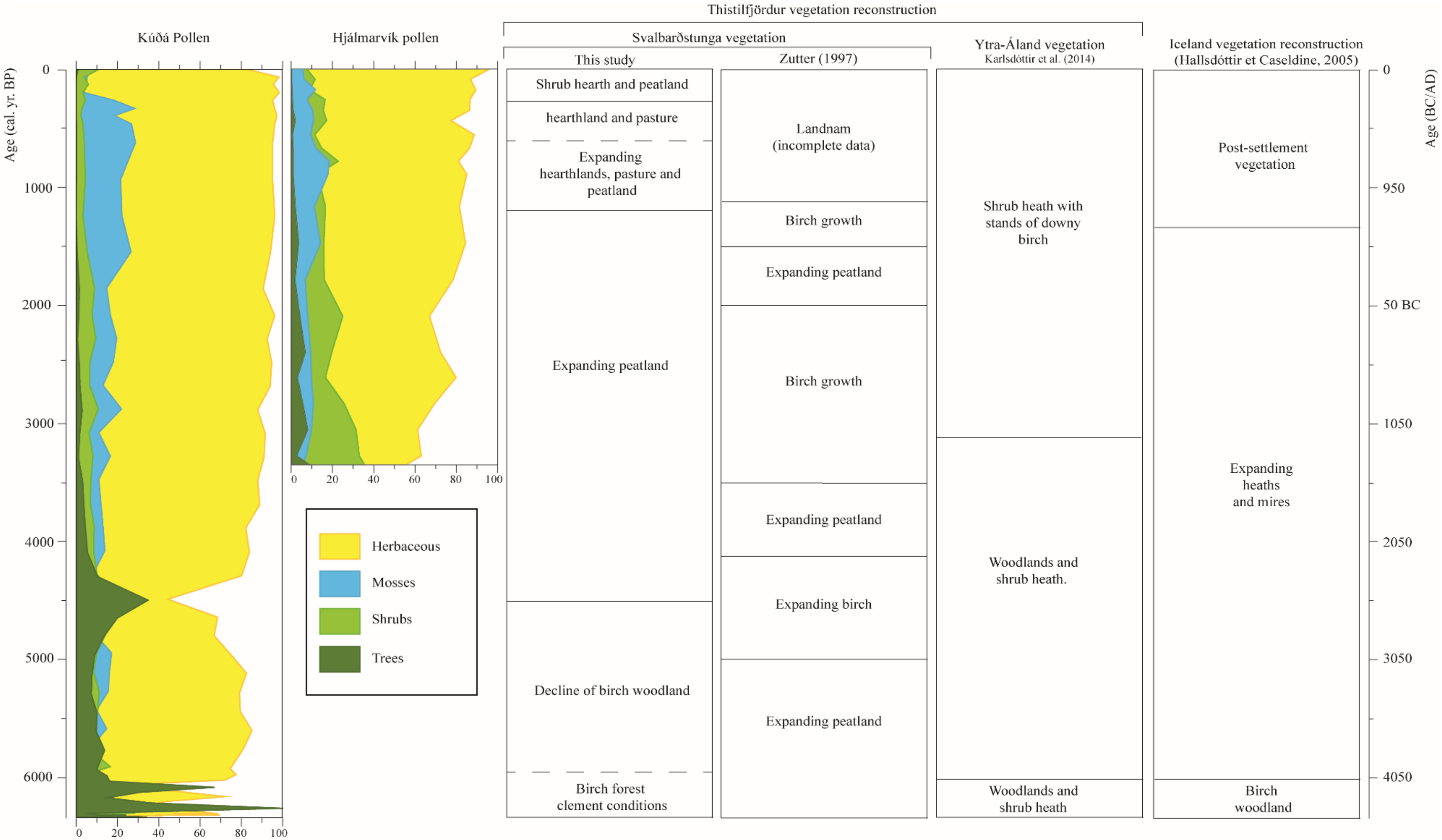

Figure 3.16: Correlation diagram for the last 6300 years based on pollen data from Kúðá and Hjálmarvík with Icelandic Pollen reconstitution and climatic periods.

The comparison of vegetation cover and environmental conditions across the North Atlantic with that of Svalbarðstunga reveals slight regional variations. In general, the climate appears to have been wetter in the most terrestrial regions of the North Atlantic Basin during this period, including at Svalbarðstunga where conditions have been getting cooler and wetter since 6000 cal BP. In eastern Greenland, a study at Geographical Society Ø island detected climatic deterioration and increased precipitation that started in 6500 cal. yr BP. High levels of precipitation continued until 3000 cal. yr BP and were accompanied by a cooling trend starting in 5000 cal. yr BP (Wagner et al., 2000). According to Levac and De Vernal (1997) and Roy et al. (2012), warm and moist conditions promoted the expansion of spruce and caused an increase in the density of vegetation in Labrador from ca. 5700 to ca. 3000 cal. yr BP. In the eastern North Atlantic on the Faroe Islands, Humlum and Christiansen (1998) documented the accumulation of peat from ca. 8000 yr. BP, which then intensified between 5000 to 2500 yr. BP as conditions became cooler and wetter. In fact, conditions have become cooler and wetter in Svalbarðstunga since 6000 cal yr. BP. On the other hand, Massa et al. (2012) documented dry and warm climate conditions in southern Greenland between 8000 to 4800 cal yr. BP. This finding was based on pollen reconstructions that showed an open heath with *Juniperus* and *Alnus* vegetation cover.

Peatland development and birch woodland decline during the Subatlantic period: from 4500 to ca. 1170 cal yr BP (2500 BC – AD ca. 780)

Since ca. 4500 cal. yr BP, *Betula* has been diminishing and has virtually disappeared, while peatland species thrived and contributed to the development of peatland across Svalbarðstunga. These vegetation changes can be explained by the development of moister conditions that decreased the evaporation rate. This decrease allowed moisture to increase (at the local scale at least) and caused the growth of hygrophilous and hydrophilous species at the expense of birch woodland. These results differ from those of Zutter (1997), who found that birch trees were plentiful between ca. 3700 and ca. 2100 cal. yr BP at Svalbarð. This could be explained by slight differences in site topography. At the site studied by Zutter (1997), birch grew on the drier, better drained areas of the mire during a relatively warmer summer. Our study sites consist of flat wetland and peatland. On the other hand, our data are consistent with Karlsdóttir et al. (2014), who showed that birch has been in decline since 4000 cal yr BP. This is significantly different from northern Iceland where, based on pollen data at Mývatnssveit (Lawson et al. (2007)), birch remained stable until the landnám period (c. AD 870), with very little variation in B. *pubescens* pollen percentages. Birch cover began to decline in AD 1050.

Human settlement during the MWP and the subsequent cooling trend known as the LIA

The significant decline in the pollen percentage of *B. pubescens* (2%) at Hjálmarsvík, its disappearance at Kúðá, and the very low *Betula* pollen influx at both sites confirm the nonexistence of birch woodland during the Medieval Warming Period (AD 850 - 1250). In addition, there was a general trend toward the increasing abundance and diversity of a wide range of wild herbaceous and peatland species between AD ca. 780 and AD ca. 1300, suggesting that conditions were probably warm and wet.

At Hjalmarsvík, the increase in *Poaceae* and the establishment of anthropogenic indicators such as *Polygonum* cf. *aviculare* and *Calluna vulgaris* indicates the influence of humans in the valley (Zutter, 1997). However, at Kúðá, the increased growth of weeds and the development of heathland on the inland site occurred before the arrival of man (ca. BC 560 or ca. 2510 ca. yr BP).

There were only scattered birch trees in Svalbarðstunga before humans settled the region, so the clearance of the trees by the new arrivals would have been an easy task. (Zutter (1997) also noted that climate change had dramatically reduced the birch woodland a thousand years earlier.) The case was different in the Faroe Islands, where shrubs and tall herbaceous species disappeared after the Norse arrived with their grazing mammals in the 9^{th} Century and cereals and weeds became abundant (Jóhansen, 1985).

Although there were no drastic changes in vegetation in Svalbarðstunga, there is evidence of a change in environmental conditions in the Hjalmarsvík core in the form of a decrease in

Poaceae and *Polygonum cf. aviculare* at around AD ca. 1340. At Kúðá, there was a general diminution of almost all species between AD ca. 1500 and AD ca. 1800, which could be linked to the cooling conditions of the LIA. Vésteinsson and McGovern (2012) and Vésteinsson et al. (2014) also associated the abandonment of farms with climate fluctuations. They also noted that highland settlements (such as Kúđá) are more vulnerable to changes in climate that affect the length of the growing season and the number of days of snow cover, which may prohibit grazing. In addition to climate change, we cannot rule out the impact of social changes, such as the fact that the church owned most of the farmland in Iceland and secular ownership of land was rare at that time (Gisladottir et al., 2013). The field at Hjalmarvík still appears to have been used by humans despite the difficult weather conditions caused by the LIA. Human activity is indicated by the increase in the *Poaceae* percentage to its maximum value during this period in addition to increases in *Polygonum* cf. *aviculare* and *Calluna vulgaris*.

6. Conclusion

Our reconstruction of the vegetation history has revealed that climate has influenced the primary ecological changes in Svalbarðtunga. From 6310 to ca. 4500 cal yr BP, conditions were relatively warm and moist and the vegetation consisted of open birch woodland and shrub tundra species; this period corresponds to the late Atlantic and Subboreal period. The significant vegetation change began at around ca. 4500 cal yr BP when the peatland species established themselves and birch started to decline. After this time, the landscape was open and mostly covered by grassland and peatland. From ca. 4500 to ca. 1170 cal yr BP, the climate became cool and less evaporation occurred, which led to the establishment and expansion of several peatland and wetland taxa at the local scale. Human settlement during the MWP promoted the growth of sedge species and introduced news herbaceous species. Later, the cold and dry conditions of the LIA led to a slight change in environmental conditions.

This study of two distinctive sites – one inland (Kúðá) and one on the coast (Hjálmarsvík) – provides new data on vegetation changes before and after human settlement. In particular, this study helps to deepen our understanding of the spatial dimensions of birch woodland dynamics. Our research demonstrated that there was no existing birch woodland when humans established themselves in the region. This means that the birch forests did not attract settlers to Svalbarðstunga, contrary to what has been asserted in several studies. At the time of human settlement, the heathland and peatland were already the dominant ecosystems in the landscape, just as they are today. According to our data, it seems clear therefore that no major changes in vegetation or soil erosion accompanied the human settlement of Svalbarðstunga and the impact of land use activities did not reach a catastrophic point, as has been the case elsewhere in Iceland (see Introduction). The apparent resilience of the Svalbarðstunga peatland ecosystem should be considered an important factor contributing to the sustained occupation of the Svalbarð farm for over 1000 years. However, in order to confirm this hypothesis, it would be necessary to conduct further environmental studies focused on property and soil management practices over the last thousand years.

7. Acknowledgements

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Chapitre 4

Perspective of landscape change following early settlement (landnám) in Svalbarðstunga, northeastern Iceland

Résumé

Dans le cadre du projet *"Archaeology and Environmental Archaeology of Settlement and Abandonment of Svalbarð,"* une série de monolithes de tourbe a été collectée des sites de Hjalmarvík, Kúđá et Bægístaðir, trois anciennes fermes abandonnées situées dans la région Svalbarðstunga, nord-est de l'Islande. Il s'agit de petites fermes satellites ou clientes de Svalbarð, le plus vaste domaine de la région ; ces fermes ont toutes connu des épisodes d'occupation et d'abandon. Les changements environnementaux dans les environs de ces fermes ont été étudiés grâce aux assemblages de macrofossiles (plantes et insectes) et de diatomées. Les trois sites d'étude se situent le long d'un transect qui traverse des gradients environnementaux et écologiques différents; ce transect s'étend de la côte à 18 km à l'intérieur des terres et de 2 à 225 m d'altitude. L'analyse multiproxy des monolithes de tourbe a fourni des signes d'occupation et d'utilisation des terres plus anciens que ceux reportés par les archives historiques. De nombreux vestiges anthropiques (ecofacts) tels du charbon de bois et des os brûlés ont également été retrouvés. Les données paléoécologiques démontrent que les changements environnementaux sont principalement associés à l'établissement et aux activités humaines lesquels ont entrainé, entre autres, l'introduction de certaines mauvaises herbes et d'insectes synanthropes. Cependant, certains événements naturels, comme le refroidissement climatique du Petit Âge glaciaire et les éruptions volcaniques, ont exacerbé l'impact humain sur le paysage et ont donc pu influencer l'interprétation du signal d'abandon ou de l'utilisation des terres.

Mots clés : Islande, Norois, paléoécologie, Svalbarðstunga, occupation humaine, paysage

Abstract

As part of the *Archaeology and Environmental Archaeology of Settlement and Abandonment of Svalbarð project*, a series of peat monoliths were collected from Hjalmarsvík, Kúðá and Bægístaðir, three abandoned farm sites in the Svalbarðstunga region of northeastern Iceland. The transformation of landscapes at these sites through direct or indirect environmental and anthropogenic dynamics was studied in assemblages of plant and insect macrofossils and diatoms. The three study sites comprise a transect that crosses environmental and ecological gradients extending from 18 km inland to the coast and at elevations from 2 to 225 m asl. The sites were all small satellite or client farms of the Svalbarð estate, the region's largest landholder, and all had histories of episodic occupation and abandonment. Plant and insect macrofossils and diatoms identified in peat monoliths provided proxy signals of human settlement and land use. Along with archaeological and historical investigation, the study data provide the foundation for regional-scale surveys of trends in settlement and abandonment in Svalbarðstunga and for large-scale processes of landscape change. Palaeoecological data indicate that environmental changes at the archaeological sites were mostly linked to human settlement and activities that triggered the establishment of weeds and synanthropic insects. Moreover, many anthropogenic remains (e.g. charcoal and burnt bones) were also found. However, some natural events such as the Little Ice Age and volcanic eruptions have contributed to environmental changes along with human activities and these have to be factored into the interpretation of the signs of abandonment, occupation and land use activities.

Key words: Iceland, Norse, palaeoecology, Svalbarðstunga, human occupation, landscape

1. Introduction

Iceland, like other islands in the North Atlantic (e.g. Greenland and Faroe), has seen multiple modifications over the last millennium. Notable changes include the clearance of the birch forest, soil erosion linked to anthropogenic activities, and climate change. While the "prime climate suspects" researched to date are the Medieval Warm Period (MWP) (from AD 800 to 1250) and the Little Ice Age (LIA) (AD 1300 - 1850) (Ogilvie, 1992), the ultimate importance of climate change is an open question due to the parallel impact of Norse settlement in the late 9th Century. The first wave of Norse settlers selectively occupied sheltered areas near the coast in order to have access to grazing areas in coastal lowlands and to exploit significant marine resources and birds. The climate conditions during the MWP favored the production of fodder, which was a vital component of the Norse subsistence economy that encouraged the first settlers to manage the environment and promote the growth of sedge and other weeds for grazing. According to Vésteinsson (2000), all of Iceland was claimed and occupied by the end of the MWP. After the 14th Century, Iceland endured the most challenging weather conditions of the historical period (Ogilvie and Jonsson, 2001), as well as several social, political and economic upheavals and several catastrophic events including volcanic eruptions, epidemics, and famines (Karlsson, 2000; Vésteinsson et al., 2002).

The effects of climate change and historical events on the landscape have been studied in several research projects (e.g. Dugmore et al., 2006; McGovern et al., 2007). However, these studies have focused on regions of Iceland that are relatively sheltered from northern climatic influences (such as Þórsmörk, on the south coast) or that are defined by distinctive geographical and ecological features that are difficult to apply to all of Iceland. Svalbarðstunga, located in the Þistilfjörður region, is of considerable interest because its geographical characteristics are different from previously investigated areas. The Þistilfjörður region of northeastern Iceland is highly vulnerable to northern climatic influences due to its direct exposure to the Arctic Sea and its susceptibility to cold water and sea ice carried by the East Greenland current (EGC) that flows along the northern coast (Ólafsdóttir et al., 2010). This freshwater influx contributes to the formation of sea ice along the north coast of Iceland promoting cold winter conditions (Ólafsdóttir et al., 2010). In the 1960s, for example, sea ice remained close to the shore until the spring in the northern coastal region causing much colder air temperatures and limiting fishing activities (Ólafsson, 1999). This region is also unique because of its distinct geography. Heath and peatland have been prevalent for the past 3000 years, primarily at the base of a set of glacial valleys in the western portion (Roy et al., in prep.).

The present study was conducted on the territory of the Svalbarð estate in western Þistilfjörður. Svalbarð, the principal farm on its eponymous estate, has been occupied continuously since at least the middle of the 10th Century (Gísladóttir et al., 2013). Its territory extends roughly 150 km^2 inland form the coast and includes ten satellite client farms. Given that it represents almost 1000 years of land use practices by humans, the region is an excellent location for conducting paleo-environmental studies of the human-environment interrelationship.

The main objective of the present study was to document the human-environment relationships in northeastern Iceland since the beginning of Norse settlement. More specifically, it sought to: 1) pinpoint the first signs of land occupation and land use and 2) document the anthropogenic impact on the environment in the context of climate change. This study focuses on the Kúðá site, which includes an abandoned farm that was historically used as an auxiliary farm attached to the Svalbarð estate. Two other sites, Bægistadir and Hjalmarsvík, served as comparison sites. Taken together, the three study sites (Hjalmarsvík, Kúðá and Bægístaðir, respectively) comprise a transect that crosses environmental and ecological gradients extending from the coast to inland. This transect strategy provides a unique vantage point on the human-environment relationship and illustrates the pattern of human settlement and land use in a distinctive region of Iceland. By using a multidisciplinary methodology that combines the analysis of plant and insect macrofossils and diatoms (microscopic algae) with existing archaeological and palynological data, the present study tries to reconstruct the effects of land use practices, natural processes such as the deposition of volcanic tephra, and climate change on local landscape evolution.

2. Study region

2.1 Environmental context of the Svalbarð farm study region

Svalbarðstunga is the local name for the drainage area between the Svalbarðsá and Sanðá Rivers (Figure 4.1). The upstream portion of the Svalbarðstunga region is dominated by glacial landforms such as drumlins and eskers, while debris flows, debris avalanches, grassland and peatland characterize the downstream portions. Þistilfjörður is notably colder than southern and western Iceland. For example, the average annual temperature and precipitation in Reykjavik and vicinity are 5.2° C and 830 mm, while in Raufarhöfn (which is located approximately 25 km north of Svalbarð) they are 2.6° C and 780 mm for the period of 1931-2008 (Veðurstofa Íslands, 2015).

The regional vegetation has been influenced by climatic conditions that have established distinct plant communities such as coastal meadows comprised primarily of sedges and the inland region characterized by diverse shrubs (e.g. dwarf birch, dwarf and arctic willow). Nevertheless, the Svalbarðstunga region is somewhat exceptional in Iceland due to the virtual absence of birch forest over the past 3000 years along the coast (and for over 5500 years 12 km inland), with the exception of some isolated areas such as the high interior hillsides and mountain sides (Chapter 3). In fact, the local landscape was shaped by peatland and heathland long before the arrival of humans in the region, as was shown by recent palynological data. This region contrasts strongly with other areas in which birch was a key component of the vegetation (Dugmore et al., 2006; Lawson et al., 2007; McGovern et al. 2007). However, Svalbarđstunga is comparable to Ketilsstaðir in southern Iceland, where high-resolution pollen profiles of this exposed coastal location indicate a largely unwooded pre-settlement environment (Erlendsson et al., 2009). In this regard, the Svalbarðstunga study complements previous studies by adding a different environmental context and provides a better understanding of the richness and variety of the Icelandic landscape.

2.2 Human occupation

Recent archaeological research (Gísladóttir et al., 2013) has cast light on the initial settlement of this region, providing information that is absent from the historical record regarding the Iceland landnam. Svalbarð and Hjálmarvík are the oldest farms in the district with archaeological evidence of occupation in the 10th Century contemporary with the first generations of Iceland settlement. By about AD 1300, virtually all of the Svalbarðstunga region belonged to the estate of Svalbarð, the region's central farm, which was itself a beneficium of the Church (Gísladóttir et al., 2013). Eight smaller satellite farms shared the outlying parts of the Svalbarðstunga territory and were clients of, or owned and rented by, the Svalbarð estate until the late 19th Century. At that time, the estate was broken up and the remaining small farms became freehold farms. All of these small farms have been abandoned periodically in the past; only three remained in use into the mid-20th Century. Recent archaeological surveys have identified at least seven additional sites that served as very small farms or seasonal shielings used for dairy or herding (Gísladóttir et al., 2013, 2014). The Svalbarð central farm is currently the largest farm in the locality and one of the largest in Þistilfjörður.

The present study focusses on the three satellite farms of Svalbarðstunga with the most substantial archaeological traces of occupation: Hjálmarvík, Kúðá and Bægístaðir. Together, these sites form a transect stretching from the coast to 18 km inland and at elevations from 2 to 225 m asl. The transect strategy offers an original perspective on land settlement and management from the beginning of occupation until the present day, in which the main farm is still in use. Kúðá was chosen as the principal study site because it is larger and was more frequently occupied than Hjálmarvík and Bægístaðir, which will be used as comparators.

The Hjálmarvík site consists of the remains of a secondary farm located about 2 km north of Svalbarð and the ruins of recent sheep houses (Figure 4.1). It is situated close to the shore on a flat and wide terrace dominated by dry heathland and bog. Recent archaeological studies of the site demonstrated that the site was occupied prior to AD 940, but it had an extensive yet apparently diminishing trend of occupation through the Middle Ages lasting into the 18th Century (Gísladóttir et al., 2013, 2014). The farm site itself was partially bulldozed in the 20th Century; however, portions of the farm mound dating to the 17th Century and earlier remained intact. The homefield and its walls also still exist. The middens and architectural remains associated with the farm mound were the subject of archaeological investigations as reported in Gilsadottir et al. (2011-2014).

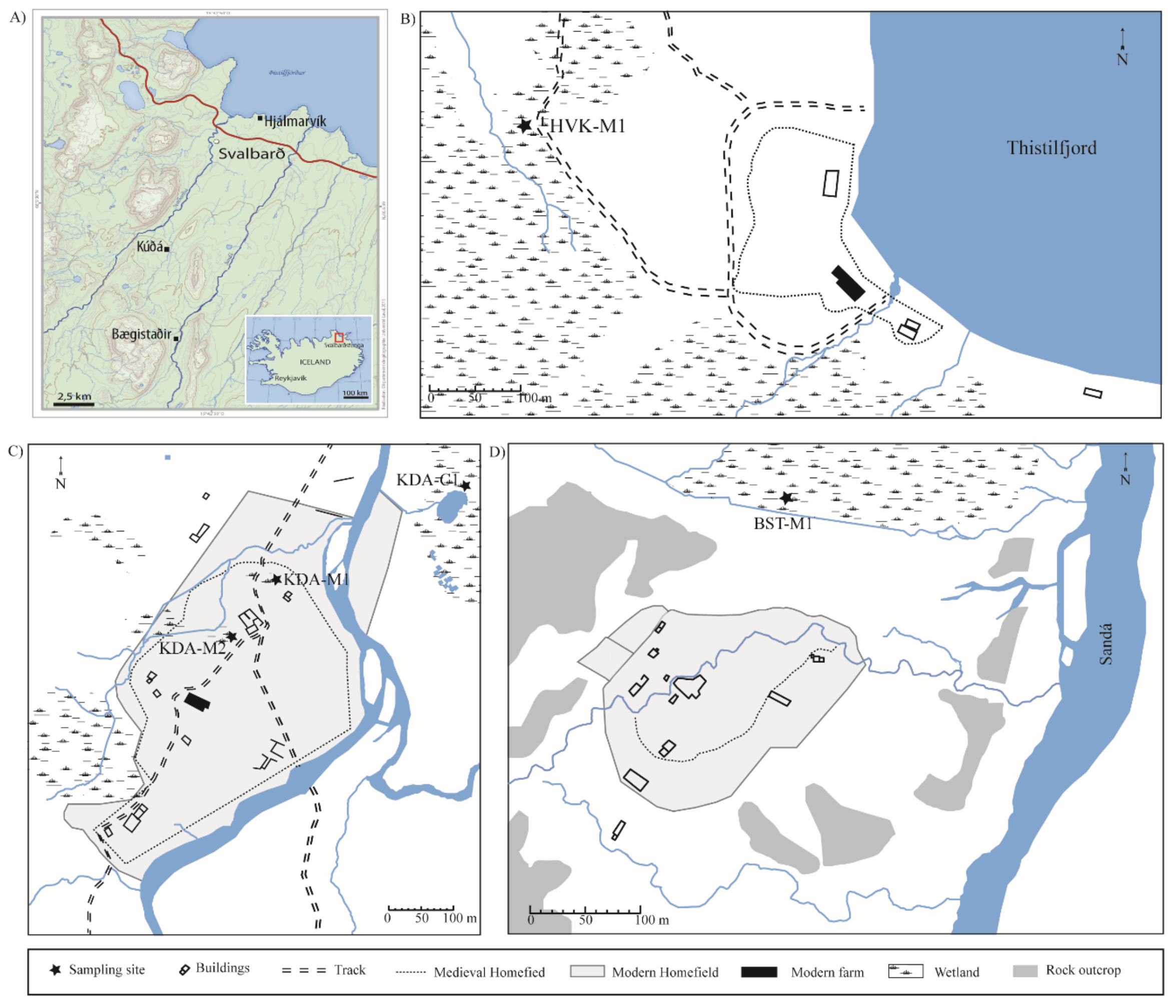

Figure 4.1: Location of the Svalbarðstunga (A) and study sites of Hjálmarvík (B), Kúðá (C) and Bægístaðir (D)

Kúðá is located approximately 12 km inland from the coast at an elevation of 120 m asl and about 10 km southwest of the Svalbarð farm (Figure 4.1). The Kúðá farm is situated on a hilltop in the middle of a glacial valley overlooking the Kúðá River. The archaeological ruins of the farmstead include a substantial farm mound, two farm houses and several outbuildings, the homefield and homefield walls. Archaeological excavations of the farm mound revealed buildings that had been constructed and occupied between the 13th and the late 15th Centuries. These structures overlie midden deposits which, though older, are of uncertain date. A second phase of occupation and construction was initiated in the 17h and 18th Centuries, and the farm remained in use between AD 1814 and 1966 (Gísladóttir et al., 2013, 2014).

The Bægístaðir site is located further inland, approximately 18 km from the coast and 15 km from Svalbarð at an elevation of 225 m asl. The site is located upstream of the glacial Sandá Valley and the surrounding area is characterized by glacial forms such as eskers, drumlins and kettles and periglacial forms such as hummocks, circles and polygons. A small stream crosses the site that reaches to the Sandá River and traverses the southern side of the valley. The Bægistaðir site also consists of well-preserved turf boundary walls, ditches, several turf outbuildings and a farm mound (Gísladóttir et al., 2013). The farm was occupied by about AD 1300, if not earlier, and remained so until sometime after AD 1477. Historical sources report it as having been abandoned for a considerable time but was in use again from AD 1830 to 1928 (Gísladóttir et al., 2013, 2014).

3. Material and methods

3.1 Soil sampling

Four peat monoliths (KDA-M1, KDA-M2, BST-M1 and HVK-M1) were sampled for stratigraphic analysis, macrofossil analysis (plants and insects), diatom analysis and radiocarbon dating. The objective was to determine the impact of anthropogenic activities on the local environment around the farm ruins.

Monoliths KDA-M1 and KDA-M2 were extracted approximately 10 m north and 15 m west of the homefield close to the Kúđá ruins. Both monoliths are 50 cm long and were examined for macrofossil content and insect remains. Diatom analysis was also performed on the KDA-M1 monolith in order to complete the profile of macroremains and to test whether diatoms may provide additional information on human land use. Their emplacement south of the old turf house ruins, served as an ecofact trap directly. This choice of sampling location also increases the likelihood of obtaining the first anthropogenic signals in the immediate landscape surrounding the Kúđá farm.

The BST-M1 monolith is 30 cm long and was extracted from a paludified zone in the hayfield close to the homefield at Bægístađir farm (i.e. 300 m away). Bægístađir is intersected by several small streams, ensuring that the site is relatively well drained, thus limiting the development of peat. The HVK-M1 monolith is about 27 cm long and was sampled from a peatland located in the hayfield about 350 m west of Hjálmarvík. The Hjálmarvík homefield is vast and was carefully managed, which led to a disturbed accumulation of natural and anthropic materials in the immediate environment of the site. Monoliths BST-M1 and HVK-M1 were studied for their plant macrofossil content.

3.2 Macrofossil Analysis

Macrofossil analysis was performed at 2 cm intervals following the protocol outlined by Bhiry and Filion (2001). Each sample consisted of 50 cm^3 of sediment. Sediments were treated with a weak 5% aqueous KOH solution and boiled for a few minutes to deflocculate. The material was then wet-screened through a series of sieves (850, 425, and 180 μm mesh). Macrofossils were identified under binocular and light microscopy. References used to identify the plant remains included Montgomery (1977), Porsild and Cody (1979), Crum and Anderson (1980), Ireland (1982), and the collection at the Centre d'études nordiques (CEN) at Laval University. The macrofossils of vascular plants are expressed as number of macrofossils per 50 cm^3 of sediments. For mosses, the percentage of each species was determined based on a subsample of 100 leaves. Insect remains were also recovered from the KDA-M1 and KDA-M2 monoliths while sorting for plant macrofossils. Insects were identified through comparison with modern reference specimens of Icelandic insects and also with the aid of entomological publications (Séguy, 1944; Lindroth, 1969; Bousquet, 1990). Macrofossil (plant and insect) diagrams were constructed using Paleo Data Plotter software (Juggins, 2002).

3.3 Diatom Analysis

Diatom analysis was performed at 2 cm intervals on peat monolith K-M1 from Kúđá. For each level, between 0.035 and 0.05 g of lyophilized sediment was processed following the procedures of Pienitz (2001) (i.e., chemical treatment with HCl 10%, and H_2O_2 30%). Microspheres of known volume and concentration were added to each sample before preparation to calculate diatom concentration. A minimum of 300 diatoms were counted in each sample. The identification of diatoms was completed with reference guides from the Aquatic Paleoecology Laboratory at CEN (e.g. Antoniades et al*.,* 2008, Bathurst et al., 2010). The saprobic taxa was used as a biological determination of water quality induced by pollution with decomposable organic substances. Saprobity is the state of an aquatic ecosystem resulting from the introduction, decomposition and removal of organic matter (Tagliapietra et al., 2012). Diatom diagrams were drawn using Paleo Data Plotter software (Juggins, 2002).

3.4 Radiocarbon Dating

Seven organic samples consisting of decomposed plant remains, leaves of brown mosses or charcoal were dated using accelerator mass spectrometry (AMS) at CEN's radiocarbon laboratory and the Keck Laboratory at the University of California, Irvine (UL-KIU). Dates were calibrated using the Calib 6.0 program (Stuiver, Reimer and Reimer, 2011) and midpoints were obtained using the weighted median method (Telford, Heegaard and Birks, 2004; Stuiver, Reimer and Reimer, 2011). Results are presented in calibrated years as well as in AD/BC notation in Table I. In addition, tephra deposits were used as stratigraphic and chronological marker levels to correlate peat sequences across Svalbarðstunga (Lane et al., 2014). Tephras H4, H3, V-Sv 940, H1300 and V1477 were identified visually and compared with tephras identified in the laboratory by Magnús Á. Sigurgeirsson (Gísladóttir et al., 2014).

4. Results and interpretation

In this section, we present the results from the main study site, Kúðá, followed by the results from Hjálmarvík and Bægístaðir.

4.1 Macrofossil (Plants and Insects) and Microfossil (Diatoms) Data from Kúðá

The base of monolith KDA-M1 (50-40 cm) is composed of silt and organic silt layers. This layer is overlain by highly decomposed orange colored peat (26 cm thick) that includes a tephra layer (V1477). This second layer is overlain by 10 cm of moderately decomposed brown peat. KDA-M2 is formed of a 35 cm thick layer of highly decomposed orange colored peat, a tephra layer (V1477) at 22-25 cm, and a layer of moderately decomposed brown peat.

Plant and Insect Remains from Monolith KDA-M1

Based on the macrofossil (plant and insect) assemblages from the K-M1 monolith, three macrofossil zones were distinguished: M-I, M-II and M-III (Figure 4.2).

Zone M-I: 50-39 cm (Before AD 1030): Zone M-I accumulated before AD 1030 and consists of a silt layer that is rich in organic matter (Table 4.1). This zone is characterized by a high degree of peat decomposition and the presence of wood fragments. No identifiable plant or insect remains were found. Such characteristics are indicative of well-drained local conditions and the humification of plants by means of natural oxidation.

Zone M-II: 39 - 7 cm (AD 1030 - ca. 1760): At first sight, zone M-II appears to be dominated by macrofossils related to human land use since it contains many ecofacts. It is composed of highly decomposed and oxidized brownish peat and was subdivided into three subzones: M-IIa, M-IIb and M-IIc.

Subzone M-IIa accumulated at a depth of 39-23 cm between ca. AD 1030 and 1160. This subzone is discernable by the abundance of ecofacts and the presence of outdoor insect fauna. Ecofacts found in this subzone included charcoal, burnt bones and fish bones, suggesting human occupation of the site at this time. Some of the insect remains were identified as beetles, specifically *Patrobus* sp. and *Otiorhynchus nodosus*. The genus *Patrobus* is typically found in open environments on moist soils (Lindroth, 1969). Two species are present in Iceland: *Patrobus atrorufus* and *Patrobus septentrionis* (Ólafsson, 1991). *P. atrorufus* is only found in the southernmost parts of the island (Larsson and Gígja, 1959), while *P. septentrionis* is very common in Iceland and is found in wet meadows and homefields. The species is macropterous, meaning that it has large wings and can fly (Larsson and Gígja 1959). *O. nodosus* is very common in Iceland and is found in dry biotopes such as grasslands and heaths. However, this species has poor dispersal capacities and is unable to fly (Larsson and Gígja, 1959).

Only a few plant macrofossils were identified. *Stellaria media* seeds were found, which is a species that is frequently found on fertilized soils and is usually associated with animal feces (commonly found along sheep paths) (Kristinsson, 2010). Spores of *Selaginella selaginoides* were also found, which is commonly found in pastures and heaths in Iceland (Erlendsson et al., 2009).

Subzone MII-b corresponds to the V1477 tephra deposit which contains very few identifiable macrofossils and no ecofacts. This subzone indicates a change in the environmental conditions and the abandonment of the farm following the volcanic eruption.

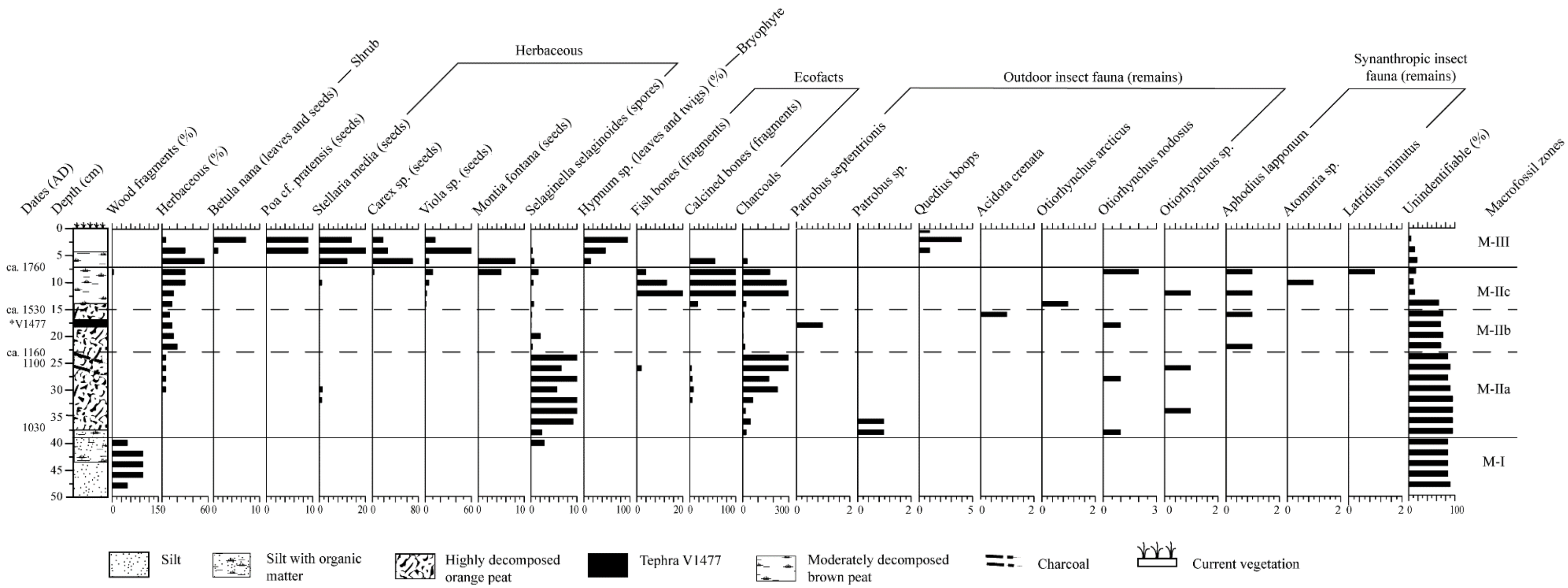

Figure 4.2: Macrofossil (plants and insects) diagram of the KDA-M1 monolith sampled at Kúðá (number of macrofossils per 50 cm3).

Table 4.1: Radiocarbon and calibrated ages of the samples from the archaeological sites

Sites	Samples	Lab. number	Age (yr BP)	Age AD. BC (2 σ)	Age (cal yr BP) (2 σ)	Midpoint calibrated age (cal yr BP)	Dated material
Kúðá	**K-M1 (12-13 cm)**	ULA-4435	20±20	-	-	modern	Brown mosses
	K-M1 (24-25 cm)	ULA-4438	950±20	1080-1150 AD	796-875	850	Charcoal
	K-M1 (36-37 cm)	ULA-4050	995±30	990-1050 AD.	900-960	920	Charcoal
	K-M2 (18-19 cm)	ULA-4440	235±20	1640-1670 AD	280-310	290	Charcoal
	K-M2 (30-31 cm)	ULA-4439	930±20	1040-1160 AD.	790-910	850	Charcoal
	K-M2 (46-47 cm)	ULA-4452	1340±20	650-690 AD.	1260-1300	1280	plant pieces
Hjálmarvík	**HVK-C1** (15-16 cm)	ULA-4453	190±20	1740-1810AD	140-220	180	plant pieces
Bægistaðir	**B-M1** (29-30 cm)	ULA-4454	475±20	1420-1450 AD	500-530	520	plant pieces

Subzone M-IIc accumulated at a depth of 15-7 cm between ca. AD 1530 and 1760. This subzone is characterized by a greater number of ecofacts such as charcoal fragments, burnt bones, and animal and fish bones. Moreover, there are seeds from *Montia fontana*, a plant species that usually colonizes habitats disturbed by humans (Blondeau and Roy, 2004) in addition to wet areas in natural settings (Payette, 2015). Some remains of synanthropic insects such as *Aphodius lapponum*, *Atomaria* sp. and *Latridius minutus* were also identified. All of these insects are connected to human activities. According to Larsson and Gígja (1959), Buckland et al. (1991) and Forbes (2013), *Atomaria* sp. and *L. minutus* are most commonly found in hay stores in buildings. *A. lapponum* lives in open environments and is dependent on livestock, since it breeds on the dung of large herbivores such as sheep, horses and cattle (Larsson and Gígja, 1959).

Zone M-III: 7 - 0 cm (ca. AD 1760 - present): Zone M-III is notable for having a greater diversity of species. The remains of *Betula nana*, *Viola* sp. and *Carex* sp. were found. In addition, seeds of *Stellaria media* and *Poa* cf. *pratensis* were identified, which suggests that the soil had been disturbed. In Iceland, both of these plants are known to grow on fertilized soil such as that found at the homefield (Kristinsson, 2010). *Quedius boops*, which prefers drier environments, was also found (Larsson and Gígja, 1959).

Diatoms from Kúðá: Monolith KDA-M1

Four zones were identified based on changes in the composition of the diatom assemblages: D-1, D-2, D-3 and D-4 (Figure 4.3). Zones D-2 and D-4 were further divided into subzones using Coniss software.

Diatom species appear in the diagram according to the degree to which they require a water environment (Figure 3). Five groups were differentiated: Group 1 includes species that rarely live outside of the water (aquatic species); Group 2 includes species that primarily live in the water, but which may also be found in humid zones (subaquatic species); Group 3 includes species that primarily live in the water, but which are often found in humid zones (hygrophilous species); Group 4 includes species that primarily live in humid zones, but which are also found in well drained conditions; and Group 5 includes aerophilous species.

Zone D-1: 48-39 cm (Before AD 1030): Zone D-1 is mainly characterized by acidophilic taxa, such as *Pinnularia notabilis* Krammer, *Chamaepinnularia krookii* Grunow and *Chamaepinnularia mediocris* Krasske. These taxa are regularly found in wet areas as well as in temporarily dry areas (Group 4). The first two species are often associated with brown mosses and oligotrophic environments (Lange-Bertalot, 1999). However, no brown moss remains were found, which could be explained by the high degree of decomposition of the organic matter. Some species belonging to Group 3 (e.g. *Nitzschia acidoclinata* Lange-Bertalot, *Brachysira brebissonii* Ross and *Pinnularia microstauron* Ehrenberg) were also present. The presence of *Encyonema lunatum* (W. Smith) Van Heurck and *Eunotia praerupta* Ehrenberg at the base of this zone (both of which belong to Group 3) is indicative of a favourable ecological context that was well oxygenated, low in organic matter and low in nutrients (Van Dam et al., 1994). Their disappearance in the second half of the zone could indicate a deterioration of the environment, since these species are sensitive to pollution (Bey and Ector, 2013b). Such deterioration could be caused by the addition of organic matter such as household waste, which would have been foreign to the original environment.

Zone D-2: 39-21 cm (AD 1030 - ca. 1290): Zone D-2 consists of highly decomposed and oxidized brownish peat and includes an abundance of species that live at different moisture levels. Using Coniss software, the zone was divided into subzones D-2a, D-2b and D-2c. Subzone D-2a is characterized by the establishment of taxa that proliferate in water such as *Fragilaria tenera* [W. Smith] Lange-Bertalot and *Fragilaria exigua* Grunow (from Group 2) and by the decline of taxa that are linked to drier conditions. These Group 4 taxa include *P. notabilis*, *C. krookii* and *C. mediocris*. *Achanthes minutissima* Kützing (from Group 3) was identified in this zone (and only here) and so it indicates a decrease in water quality and/or increased acidity.

Subzone D-2b is characterized by a higher proportion of planktonic diatoms, such as *Aulacoseira* cf. *ambigua* (Grunow) Simonsen (Bey and Ector, 2013a) and *Aulacoseira* cf. *islandica* (O. Müller) Simonsen. According to Van Dam et al., (1994), both taxa are rarely (if ever) found outside of a body of water (Group 1) and their presence indicates an increase in the water level. The presence of *Meridion circulare* (Greville) C.A. Agardh, which is usually found in riverine ecosystems, supports this interpretation and could reflect the warm and wet conditions of the MWP (Fukumoto et al., 2012).

In subzone D-2c, the reappearance of *Pinnularia* sp. and *Chamaepinnularia* sp., combined with the reduction (or absence) of *Aulacoseira* sp. and *Fragilaria* sp., suggests a gradual return to an acidic environment rich in macrophytes but low in minerals (Rühland et al., 2000). In addition, the presence of *B. brebissonii* and *E. lunatum* supports this interpretation. These are both acidophilic species belonging to Group 3 that are usually found in oligotrophic environments (Van Dam et al., 1994; Bey and Ector, 2013c, 2013e). At the edge of this subzone, freshwater taxa such as *Aulacoseira* sp. and *Fragilaria* sp. decreased or disappeared in favor of aerophilic species from Group 5 such as *Pinnularia borealis* Ehrenberg and *Hantzschia amphioxys* [Ehrenberg] Grunow.

Zone D-3: 21-15 cm (ca. AD 1290-1710): Zone D3 is composed of highly decomposed and oxidized brownish peat and contains the V1477 tephra layer between 18 and 16 cm. This zone is characterized by a decrease in species diversity and frequency. The majority of identified species (such as *E. praerupta*, *Pinnularia intermedia* [Lagerstedt] Cleve and Grunow and *C. krookii*) normally live in wet or temporarily dry environments (Group 4). However, the most abundant species are aerophilic (*P. borealis*, *H. amphioxys* and *Eunotia palatina* Lange-Bertalot & W. Krüger), which could be an indication of the volcanic activity that triggered the deposition of the V1477 tephra. A diverse range of conditions must have existed: aerobic (*P. borealis*), semi-aquatic habitats or fens (*E. palatina*) and temporarily dry habitats (*H. amphioxys*) (Bey and Ector, 2013c). Krammer and Lange-Bertalot (1991) noted that *H. amphioxys* colonizes dry environments that have transitory wet conditions. There was also a sharp increase in *P. borealis*, which suggests a decrease in the availability of water at the site (Pienitz, 2001). The disappearance of *N. acidoclinata* also supports this interpretation.

Zone D4: 15-0 cm (ca. AD 1710-present): Zone D-4 consists of moderately decomposed brown peat and was subdivided into two subzones: D-4a and D-4b. Subzone D-4a differs from the previous zone due to the disappearance of *E. palatina* (Group 5), *P. intermedia* (Group 4) and *Eunotia praerupta* (Group 3) and the reestablishment of many taxa such as *C. krookii* that are associated with temporarily submerged moss habitats (Lange-Bertalot and Genkal, 1999). This zone is also marked by an increase in β-mesosaprobic taxa, which suggests that aquatic environmental conditions were moderately productive and slightly oxygenated (*Nitzschia* sp.). The presence of alpha mesosaprobic taxa, which live in water polluted by organic matter (such as ash or household waste) and that is low in dissolved oxygen (*H. amphioxys* and *Navicula cf. recens*), indicates a degradation of the environment due to human disturbance. According to Bey and Ector (2013d), *Navicula* cf. *recens* can tolerate conditions with high nutrient concentrations and moderate organic matter loads.

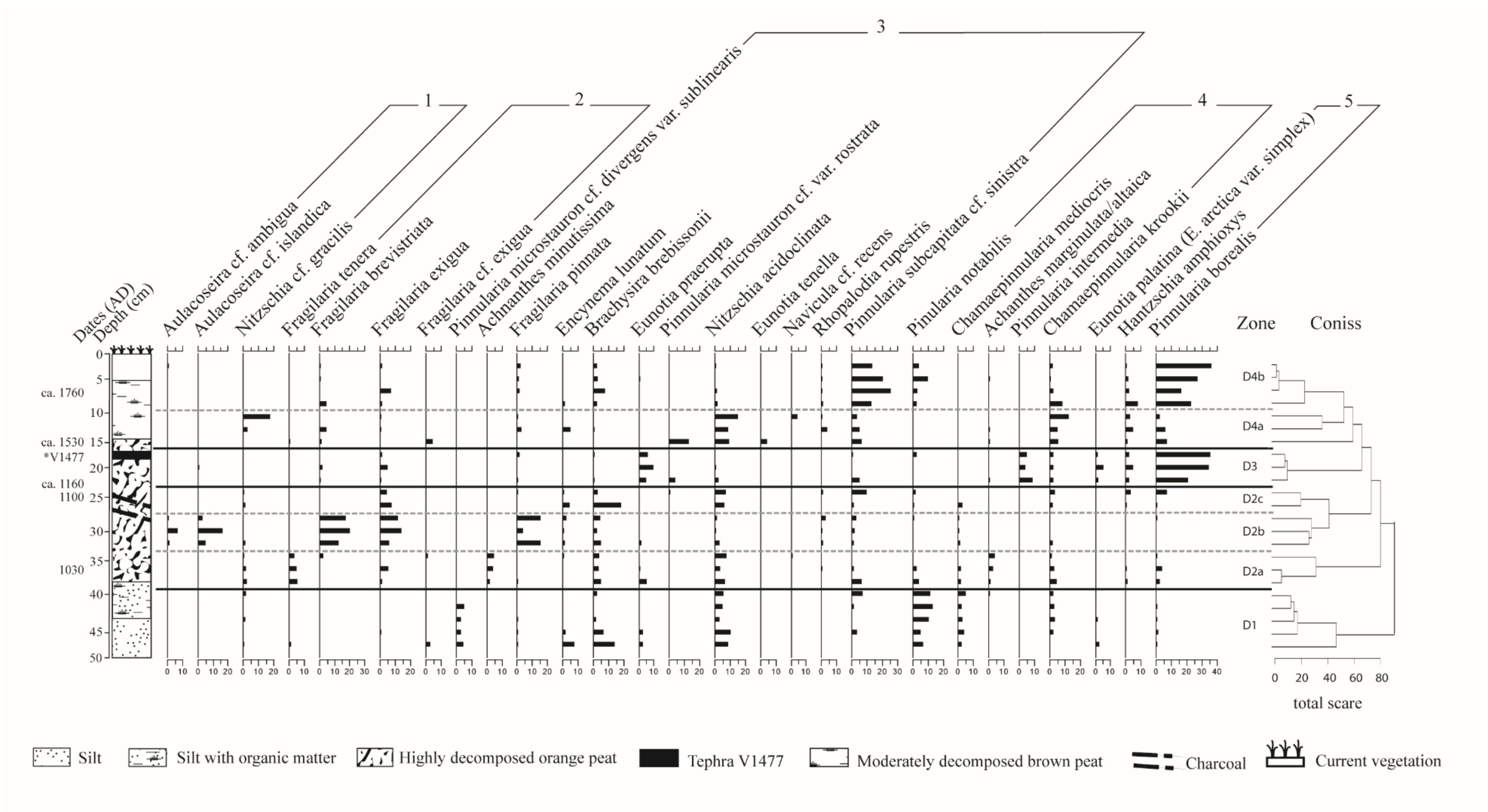

Figure 4.3: Diatoms diagram of the KDA-M1 monolith sampled at Kúðá.

Subzone D-4b is dominated by taxa that primarily belong to Group 5, such as *P. borealis* and *H. amphioxys*. Frustules from *Pinnularia subcapitata* cf. *sinistra* Gregory were also found in high percentages (up to 20%) in addition to frustules from *F. exigua* and *B. brebissonii*. At the same time, many of the taxa identified in subzone D-4a had disappeared or significantly declined. These results suggest a change in the hydrologic conditions of the site toward drier conditions. This interpretation is also supported by the dominance of the aerophilic species *P. borealis* (Pienitz, 2001).

Macrofossil Remains (Plants and Insects) from Monolith KDA-M2

Three macrofossil zones were identified based on changes in the macrofossil assemblages: M-I, M-II and M-III. M-II was further subdivided into three subzones: M-IIa, M-IIb and M-IIc (Figure 4.4).

Zone M-I: 50 - 43 cm (ca. AD 670 - 780): Zone M-I is composed of brownish highly decomposed peat. Consequently, identifiable plant remains are very scarce, but there were some brown moss leaves and some herbaceous fragments. In addition, seeds from herbaceous species such as *Carex* sp., *Stellaria media* and *Poa* cf. *pratensis* were found, which suggests that the environment was open and moist (Porsil and Cody, 1980).

Zone M-II: 43 - 7 cm (ca. AD 780 - 1840): This zone is composed of highly decomposed and oxidized brownish peat overlain by moderately decomposed brownish peat. The abundance of ecofacts at different levels in this zone provides striking evidence of human occupation of the site and/or land use activities. Zone M-II was subdivided into three subzones: M-IIa, M-IIb and M-IIc.

Subzone M-IIa is characterized by the abundance of charcoal as well as by seeds of *Sellaginella selaginoides*, a species that is usually found in pastures and dry heathlands in Iceland (Kristinsson, 2010), but which can also be found in wet environments (Porsild and Cody, 1980). The presence of *Sphagnum* sp. is another sign of wet conditions. Seeds from weeds such as *S. media* and *Poa* cf. *pratensis* were also identified. *Poa* cf. *pratensis* is an early colonizer of disturbed habitats (Aiken et al., 2013). While it is typically found in well-drained and fertilized areas, it can also be found in moist soils and peatland (Kristinsson, 2010). *S. media* grows on cultivated field and pasture soil (Porsild and Cody, 1980). Some insect remains were identified, notably *L. minutus*, which may be a sign of hay stores (Buckland et al., 1991; Forbes, 2013).

Subzone M-IIb accumulated between ca. AD 1380 and 1660 and contains the V1477 tephra layer. This zone is almost devoid of identifiable plant and insect remains. It contains only a few fragments of herbaceous roots and a few spores of *S. selaginoides*.

Subzone M-IIIc (ca. AD 1660 – 1840) is marked by greater species diversity and a higher number of ecofacts and taxa that correspond to human land use. In fact, fragments of charcoal are abundant alongside calcined bones and fish bones. The area surrounding the study site was likely used as pasture, as is shown by the presence of *S. media*, *Poa* cf. *pratensis* and *M. fontana*. Small quantities of specific insect species were also identified. *Acidota crenata* and *O. nodosus* are both outdoor fauna that inhabit dry environments such as grassland, pasture and heath (Larsson and Gígja, 1959). *A. lapponum*, *Cryptophagidae* sp. and *L. minutus* are notable because they are synanthropes that are dependent on human activities.

Zone M-III: 7-0 cm (ca. AD 1840 to the present): Zone M-III is characterized by the disappearance of ecofacts. However, the abundance of seeds from some herbaceous species suggests that the site (and its surroundings) may have been used for pasture. In addition, the disappearance of *Sphagnum* sp. indicates a change to a less humid environment. This shift is also indicated by the presence of *Q. boops*, which lives in well-drained environments (Larsson and Gígja, 1959).

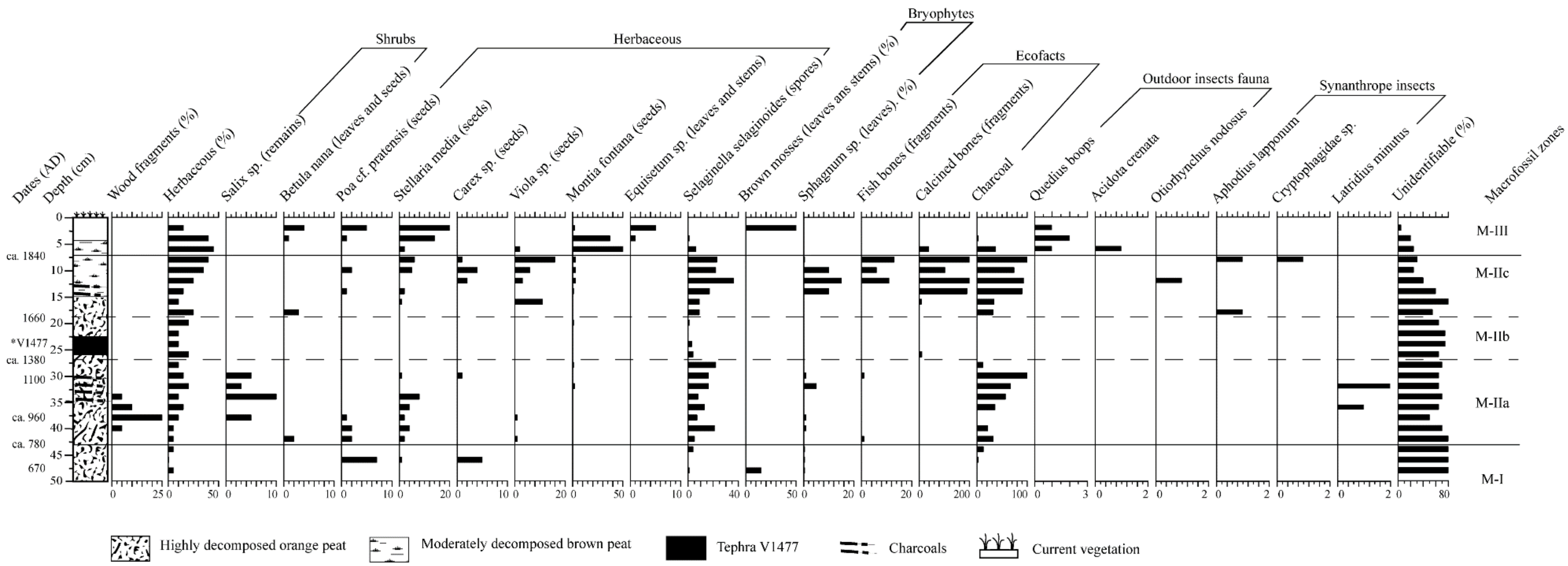

Figure 4.4: Macrofossil (plants and insects) diagram of the KDA-M2 monolith sampled at Kúðá (number of macrofossils per 50 cm3).

4.2 Macrofossils from Hjálmarvík (HVK-M1)

Monolith HVK-M1 is 27 cm thick and consists of a highly to moderately decomposed fibrous light brown peat in addition to the V1477 tephra layer (at 20-22 cm). Three macrofossil zones were identified based on the assemblages of plant remains: M-I, M-II and M-III (Figure 4.5).

Zone M-I: 27-22 cm (ca. AD 970-1477): Zone M-I contains unidentifiable herbaceous remains and wood fragments. It is dominated by brown moss leaves (*Hypnum* sp.), which indicates that the area was open and wet. This interpretation is supported by the few identifiable plant remains that were found, such as shrubs (*Juniperus* sp. and *Empetrum nigrum*) (which may explain the scarcity of wood fragments) and *Poa* cf. *pratensis* (Kristinsson, 2010). These taxa are also found in homefields and fertilized areas along with *Viola* sp. (Porsild and Cody, 1980; Kristinsson, 2010).

Zone M-II: 22-15 cm (from AD 1477 to 1770): The base of this zone includes the V1477 tephra layer. Almost no identifiable plant remains were found except for a few fragments of wood, some herbaceous remains, and a few brown moss leaves.

Zone M-III: 15-0 cm (AD 1770 to present): This zone is marked by a greater diversity of plant species, although herbaceous species (30-50%) and brown mosses (10-30%) continued to dominate the canopy. *Carex* sp. and *S. selaginoides* were also found in zone M-III, both of which are usually encountered in heathland and pasture (Kristinsson, 2010). However, they may also be found in bogs, along the shores of streams, and in grasslands (Porsild and Cody, 1980). At the end of this zone, brown mosses (55%) continued to dominate the plant assemblage at the expense of herbaceous species (10-20%). This situation appears to have developed in response to a wetter climate, which would also explain the increase in *E. nigrum* and *Carex sp.*, both of which thrive in swampy habitats (Porsil and Cody, 1980).

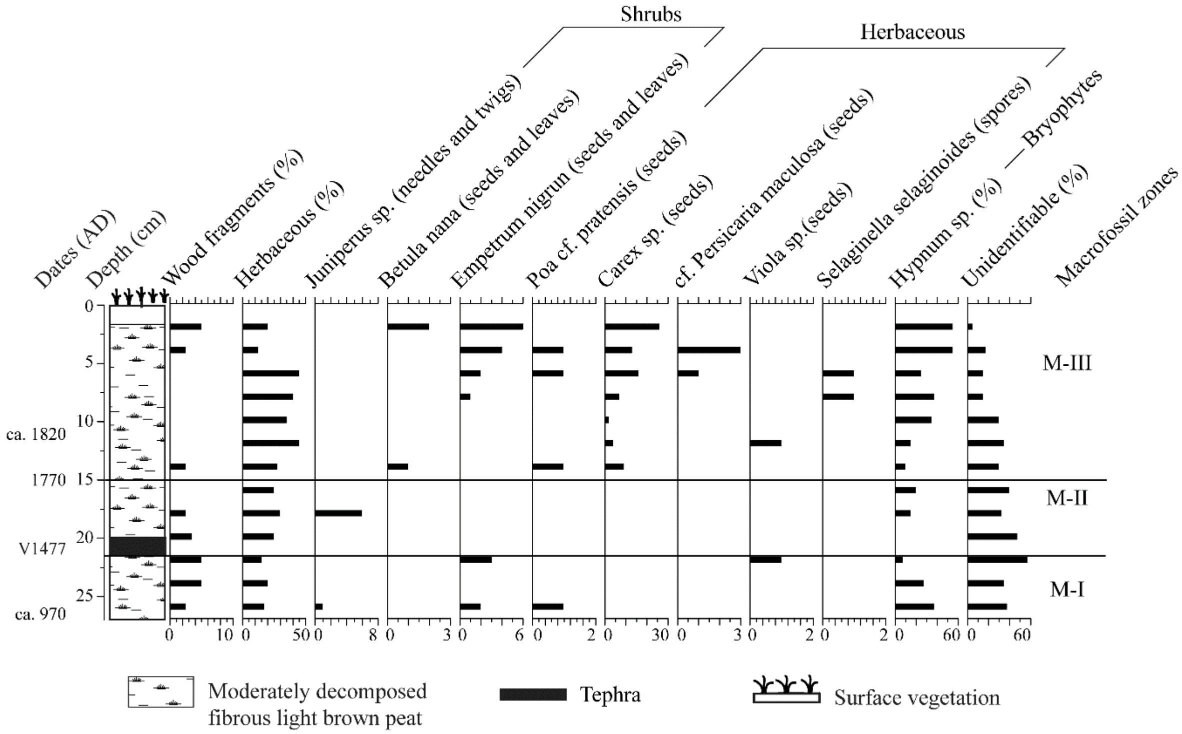

Figure 4.5: Macrofossil diagram of the HVK-M1 monolith sampled at Hjálmarvík (number of macrofossils per 50 cm3).

4.3 Macrofossils from Bægístaðir (BST-M1)

The BST-M1 monolith is 30 cm long. The base of this monolith does not correspond to the mineral-peat transition. As a result, we were not able to find evidence of the initial human settlement. Three macrofossil zones were identified based on the assemblages of plant remains: M-I, M-II and M-III (Figure 4.6).

Zone M-I: 30-15 cm (ca. AD 1430-1470): Zone M-I consists of a highly decomposed brown peat that accumulated between AD 1430 and 1470. Herbaceous remains (roots, rootlets and stems) dominate the assemblage and only a few identifiable pieces of *Poa* cf. *pratensis*, *Viola sp*., *S. selaginoides* and *Carex* sp. were found. As noted above, the first three taxa typically grow in wet conditions, as does *Sphagnum* sp., which was also found here. *Poa* cf. *pratensis* and *S. selaginoides* are also found in grassland and pasture. The recovery of many calcined bone fragments and charcoal fragments suggests that the site was inhabited during this period.

Zone M-II: 15-11 cm (ca. AD 1470 - 1520): Zone M-II consists of a highly decomposed brown peat and includes the V1477 tephra deposit (12 -14 cm). As was true for all of the monoliths, recognizable macrofossils were uncommon: only one or two pieces of *E. nigrum*, *Viola* sp., *Hypnum* sp. and some charcoal fragments were identified.

Zone M-III: 11-0 cm (ca. AD 1520-present): Zone M-III consists of recent, moderately decomposed fibrous light brown peat. There is a great diversity of shrub species (*B. nana,* Ericaceae and *E. nigrun*) and herbaceous species (*Carex* sp., *P.* cf. *pratensis*, *Viola* sp., and *S. selaginoides*), but in low numbers. The sharp increase in *Hypnum* sp. and the establishment of *Meesia uliginosa*, *Calliergon giganteum* and Liverwort indicate wetter conditions. At the end of this zone, a new species, cf. *Persicaria maculosa*, appeared in the assemblage. In the United Kingdom, this taxon is known as a weed that lacks a natural habitat and is always associated with human activity (Simmonds, 1945).

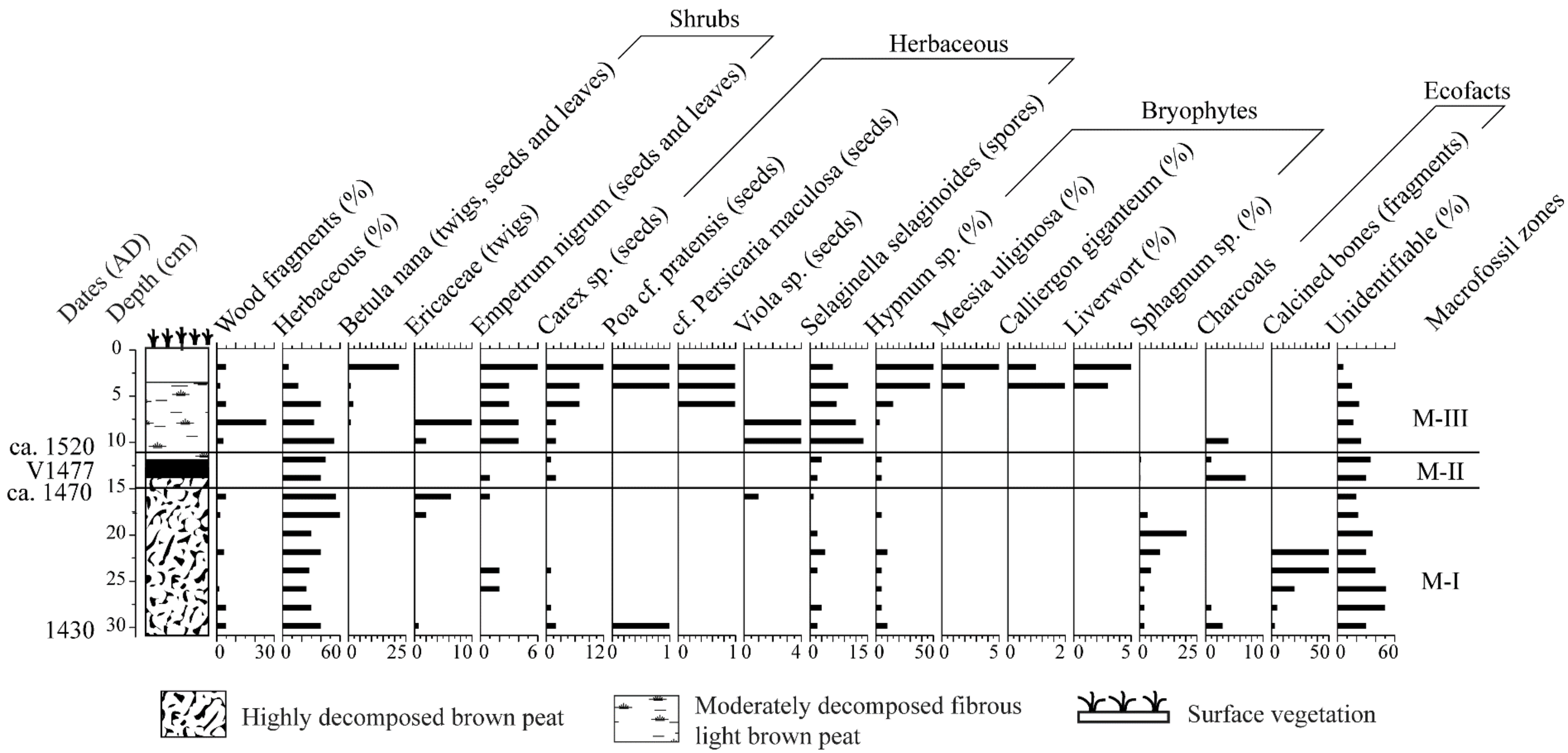

Figure 4.6: Macrofossil diagram of the BST-M1 monolith sampled at Bægístaðir (number of macrofossils per 50 cm3).

5. Discussion

Human settlement and land use activities

Taking into account the presence of ecofacts (e.g., calcined bones, fish bones, and charcoal), specific taxa (e.g., *S. media*) and synanthropic insects, it was possible to pinpoint several periods of land use and/or occupation in and around the study sites (Table 4.2; Figure 4.7).

The macrofossil data indicate that the coastal site of Hjálmarvík has been an open and wet area, such as a wet meadow or peatland, since AD 970. There are some indications that the area surrounding Hjálmarvík was also altered by human activities during this period. Of particular interest is the presence of *Poa* cf. *pratensis* and *S. selaginoides,* which are known to grow in homefields, fertilized areas or pasture land in Iceland. *S. selaginoides* is also well known to grow on disturbed areas rather than boggy environments (Erlendsson et al., 2009). Moreover, this interpretation is supported by a sharp increase in the pollen percentage of *Pocaceae* (Roy et al., in prep.), which is indicative of land utilization. Ongoing archaeological surveys have found that the site has been settled since AD 940 (Gísladottir et al., 2014), which supports our interpretation. In short, the combination of macrofossil, pollen and archaeological data enables us to highlight the consistent occupation and use of the land beginning in AD 970.

At Kúðá, the context is quite different, since there is no basis on which to assert a or continuous occupation or use of the land at this inland site. However, two periods of occupation or land use were identified based on our data: from AD 960 to 1410 and from AD ca. 1650 to ca. 1870. During these periods, the vegetation included herbaceous species that are frequently found in grasslands, heaths and pasture. In particular, there was a sharp increase in *S. media* seeds in the macrofossil assemblages beginning at approximately AD 960. According to Edward et al. (2005), the presence of this weed is consistent with deliberate attempts to improve the fertility and drainage of the soil by means of manuring and plaggening.

Table 4.2 : Characteristics of landscape changes across Svalbarđstunga based on key indicators (plants, insects, ecofacts)

Site	Distance from the coast	AD 940 – 1400	AD 1400 – 1500	AD 1500 – 1800	AD 1800 – today
Hjálmarvík	0	Hypnum sp. E. nigum P. cf pratensis Viola sp. **Synanthropic insects	Hypnum sp. E. nigrum **Synanthropic insects	B. nana P. cf pratensis Carex sp. Viola sp. N/A	B. nana E. nigum P. cf pratensis Carex sp. P. cf maculosa S. selaginoides N/A
*Svalbarđ	2	E. nigrun/E. eamesii Carex sp. Stellaria sp. M. Fontana **Synanthropic insects	Carex sp. Ranunculus sp. S. media **Synanthropic insects	Vaccinium sp. Carex sp. S. media Polygonum sp. **Synanthropic insects	Carex sp. Poa sp. S. media M. fontana Cerastium sp. N/A
Kúðá	12	S. media P. cf. pratensis Synanthropic insects Ecofacts	S. selaginoides	S. media Viola sp. S selaginoides M. fontana Synanthropic insects Ecofacts	B. nana M. fontana S. media P. cf pratensis Synanthropic insects Ecofacts
Bægístaðir	18	N/A	E. nigum Ericales Sphagnum P. cf pratensis Ecofacts	E. nigum Ericales S. selaginoides Viola sp. Ecofacts	B. nana E. nigum Brown mosses P. cf pratensis P. cf. maculosa

*Data from Zutter (1997)
**Data from Forbes (2013)

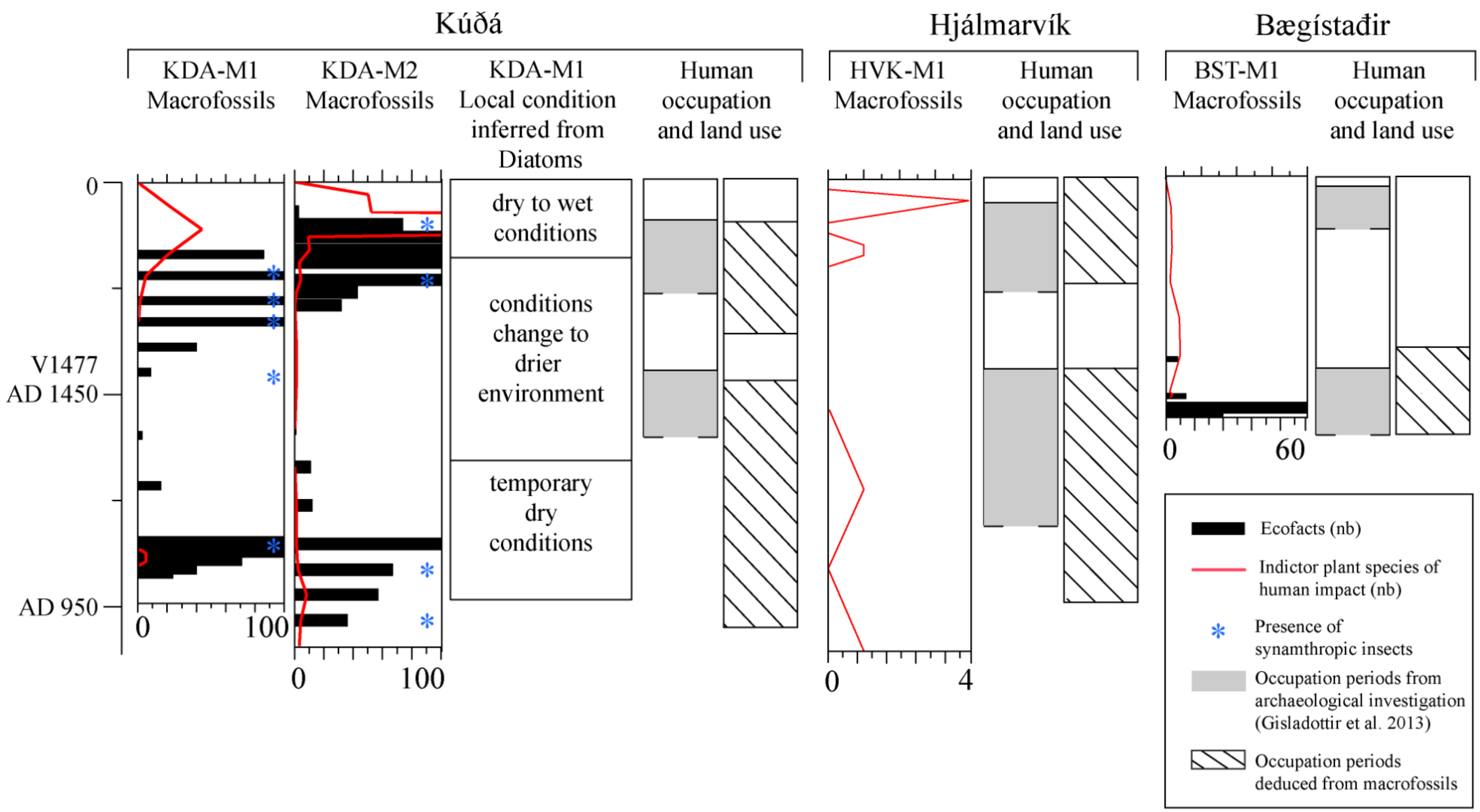

Figure 4.7: Correlation diagram for the last 1000 years – Summary of macrofossil (plants and insects) and diatom data from Hjálmarvík, Kúðá and Bægístaðir and archaeological data used to reconstruct human occupation and land use activities across Svalbarðstunga.

For example, in Iceland the Norse used wet meadows and environments rich in sedges to produce an adequate fodder (Vésteinsson et al., 2002). Such ecosystems are frequently found in the vicinity of Kúðá and were likely managed for fodder production, as suggested by the diatom data and insect identification.

At approximately AD 1030, the diatom data indicate a hydric change to a slightly wetter environment. This change may have been a deliberate human intervention to encourage sedge growth for hay production. Our palynological results (Roy et al., in prep.) from a peatland located nearby Kúðá show an increase in herbaceous pollen, which also supports our interpretation concerning fodder production during these periods. This interpretation is supported by the presence of *L. minutes*, which is usually found inside buildings and is an indication that the fields were used for fodder production and storage. Moreover, the presence of *P. septentrionis* strongly suggests the existence of wet meadows and homefields. Synanthropic beetles recovered from Kúðá would likely have been introduced to the site by the Norse, as was suggested by findings elsewhere in the North Atlantic islands (Larsson 1959; Buckland *et al.* 1991; Sadler 1991; Sadler and Skidmore 1995; Buckland 2000). The same species were also identified in Svalbarđ and Hjálmarvík by Forbes (2013). When viewed together, the insects found in this study can be used as chronological indicators for the initiation of human settlement at Svalbarð. However, it would be necessary to carry out a more extensive collection of insect data in a separate paleo-entomological study at locations external to the archaeological sites in order to track insect fauna changes before and after the arrival of humans. Such a study would provide valuable data that would complement the present study.

Given our findings, it appears that human settlement at Kúðá began ca. AD 960, which appears to be almost as early as at Hjálmarvík (AD 940). This initial occupation period ended at ca. AD 1410. This early date for the settlement of the interior can be explained by the easier access to the land due to the absence of birch forest and the availability of pasture land. The natural landscape was already dominated by peatland and heath, both of which are good resources for grazing. Accordingly, this natural context probably attracted settlers towards the interior. Several signs of hay production also suggest that the site was used as a farm, although there is no archaeological or historical evidence of human settlement and activity at Kúðá as early as the 10th Century. There are ongoing archaeological studies that have identified other zones of midden deposition that may indicate an extended history of occupation at the site prior to 1300 (Gísladóttir et al., 2013).

The environmental context of the second occupation from AD ca. 1650 to ca. 1870 is similar to the previous one. The same ecofacts were found in great quantities, which indicates that the land was used as a farm. However, this interpretation conflicts with existing historical records and archeological findings, which indicate that the site was only occupied between the 13th and the late 15th Century (i.e., between 1494 and 1696) and from the 18th Century until 1960 (Þormóðsson 1970; Woollett, 2011; Gísladóttir et al. 2013). This would mean that Kúðá was unoccupied between these two periods, contrary to our findings.

The lack of evidence of anthropogenic features from AD ca. 1650 to ca. 1870 in our study does not necessarily mean that the site was abandoned at this time. Instead, the macrofossil data yields information about the evolution of the local conditions at the site. During the period between 1650 and 1870, Kúðá could have been used as a summer house or a shieling for the main farmhouse at Svalbarð. This interpretation could explain the fact that the occupation of Kúðá was not mentioned in the land register of 1712 (Þormóðsson 1970). Furthermore, during this period the occupation and land use at Kúðá was probably limited by the cold and dry conditions of the LIA (Wanner et al., 2008). Cryoturbation features have been identified in the upper part of the Svalbarđ midden (above the V1477 tephra) (Zutter, 1997). These features occurred mostly in unconsolidated sediment that is resulting from a deep seasonal frost (French, 2007). The harsh climate conditions after AD 1477 would have limited the growing season and negatively affected the capacity for fodder production, primarily due to the fact that the ground would have been frozen for a much longer period.

A different pattern was observed at Bægístaðir further inland. The base of the monolith dates to AD 1430, but organic material started to accumulate before that date. Our findings indicate that the monolith received waste such as charcoal from the archaeological site between AD

1430-1460 and AD 1480-1560. On the other hand, archaeological data indicates that Bægístaðir was inhabited between 1300 and 1477 and there after, then from the late 19th Century until 1920 (Gísladóttir et al., 2013). There is also a historical record of brief occupation periods during the mid-17th Century (Þormóðsson 1970). While it is likely that the wetland in our study has been used as a hayfield, there was no evidence of land use between the late 19th Century and 1920. This may be explained by the fact that this location had a different function during the late 19th Century.

Farms such as Kúðá and Bægístaðir were characterized in the historical literature as marginal highland settlement areas because of their high elevation (120 m and 200 m asl respectively) and their poor sustainability. According to Rafnsson (1990), Sveinbjarnardóttir (1992), Vesteinsson and McGovern (2012), and Vesteinsson et al. (2014), these high-altitude farms had been abandoned as early as the 13th Century and early 14th Century in Iceland. Farm abandonment was possibly linked to climate fluctuations, especially since highland settlements are more vulnerable to changes in climate that affect the length of the growing season and the number of days of snow cover, which may prohibit grazing. On the other hand, Mairs et al. (2006) have demonstrated that in areas where woodland cover was already sparse (or absent) at the time of settlement (as was true of the sites in this study), resilience to grazing by domestic animals may have been greater despite the less favorable ecological conditions. Given that the landscape of Svalbarđstunga was devoid of birch forest before the arrival of humans, the study by Mairs et al. (2006) provides an explanation for the continuity of land use at the beginning of the LIA (13th and 14th Century) at Bægístaðir and Kúðá, even though marginal highland farms were typically abandoned elsewhere in Iceland. However, the data collected in the present study indicate that there was an abandonment of the farms (or at least significant changes in land use) in the late 16th Century. Weather conditions seem to have been colder at that time, as shown by the pollen data from Kúđá and Hjálmarvík (Roy et al., in prep). At Bægístaðir, the expansion of *E. nigrum* and *Ericales*, taxa that commonly found in Icelandic pollen diagrams post-settlement (Hallsdóttir, 1987; Erlendsson et al., 2009), could reflect the abandonment of the farm in the mid-16th Century.

Anthropogenic and Volcanic Impact on the Environment in the Context of Climate Change

Many studies have shown that paleoenvironmental studies can supplement or offer a new dimension to the chronology revealed by archaeological data (Gauthier et al., 2010; Lemieux et al., 2011; Massa et al., 2012; Roy et al., 2012, 2015). In our study, paleoenvironmental records from intra and extra-site archaeological sites helped us to understand changes in the landscape and land use by identifying traces left by humans in the immediate surrounding environment as early as the first human settlement of the site.

Anthropogenic impact

The paleoecological data revealed that wood fragments (mostly from shrubs) were a significant component of the macrofossil remains before human occupation and declined afterwards, while herbaceous species increased. This change reflects the development of pasture land at the sites. The diatom data revealed that during this time (AD 800-1200), there was a general trend toward the warm and wet climate conditions typical of the Medieval Warm Period (Wanner et al., 2008). Furthermore, the increases in *Poaceae* pollen at Hjálmarvík and *Cyperaceae* pollen at Kúðá during this period suggest deliberate activity by the Norse to structure the landscape in favor of pasture and grazing (Roy et al. in prep.). However, no cereal crop seeds were found at either site.

The diatom data was also very informative. In particular, the occurrence of taxa such as *Pinnularia* sp. and *Chamaepinnularia* sp. indicates a gradual increase in nutrient concentration and acidity resulting from the addition of organic matter to the ecosystem. The Norse practice of spreading domestic ashes for use as a fertilizer is another example of an environmental pollutant that is reflected in the diatom data from the Kúðá homefield.

The impact of the Veiðavötn 1477 volcanic eruption

The tephra of Veiðavötn 1477 (V1477) is evident across Svalbarðstunga. Its distribution and thickness requires us to assess the major impact of the tephra on the landscape, especially with regard to vegetation growth. Eruptions are common in Iceland; there have been approximately 205 eruptions since the settlement of Iceland (Thordarson and Larsen 2007). Occasionally, these eruptions have caused human and animal deaths as well as changes to the environment. For example, out-gassing from the Laki eruption in AD 1783 created a toxic haze that killed thousands of Icelanders as well as livestock, which contributed to an ensuing famine. The major eruptions at Hekla in AD 1300 and Öræfajökull in AD 1362 may have also caused fatalities, but there is no direct evidence for this (Gudmundsson et al., 2008).

Despite its destructive effects, Dugmore et al. (2013) found that vegetation reestablished itself only a few months following the eruption of Eyjafjallajökull in 2010. In addition, the impact of volcanic hazards would have been modulated and exacerbated by other factors, such as severe weather or economic constraints.

Up to now, no evidence of a catastrophic event has been found in relation to the eruption of V1477. This raises the question of whether the impact of the V1477 eruption was exacerbated by the severe climatic conditions of the LIA. At Kúðá, no identifiable macrofossils (plants or insects) or ecofacts were found for the period between ca. AD 1410 and 1530, which suggests that the farm was abandoned. The diatom data from K-M1 also show a sharp increase in aerophilic species (*P. borealis*, *H. amphioxys* and *E. palatina*) at the beginning of the LIA. At Bægístaðir, the abandonment of the site seems to have occurred long after the V1477 at approximately 1560. Along the coast, the deposition of the V1477 tephra at the Svalbarđ and Hjálmarvík sites seems not to have disturbed the use and occupation of the land.

The deposition of the ash layer from the eruption of V1477 appears to have had very little impact on land use in Svalbarđstunga, except at the Kúđá site. Nevertheless, two plagues were identified in the documentary evidence in AD 1402-1404 and AD 1494 in Iceland. These plagues had a severe impact on the northern region of the country (Karlsson, 1996). The population at Kúđá, for example, may have been displaced to more marginal areas such as Bægístaðir, which could explain why this farm was still occupied despite the cold conditions of the LIA.

Given the multiple factors that could lead to environmental changes and land abandonment (i.e., the LIA, the V1477 tephra, plagues and politics), a more precise reconstruction of the chronology and a study of the subsistence economy would be required in order to determine the exact influence of each factor on land occupation in Svalbarðstunga.

6. Conclusion

Multiproxy records of peat monoliths sampled from the vicinity of the Hjálmarvík, Kúðá and Bægístaðir farms in northeastern Iceland supplied clear evidence of early human settlement and land use. These farms are located along an 18 km transect from the coast inland to Svalbarðstunga.

At Kúðá, the first signs of human settlement occurred at approximately AD 960, as revealed by the presence of charcoal, ecofacts and synanthropic insects. The vegetation changed in favor of pasture species such as *Stellaria media*, which would have been linked to human efforts to create grazing land as early as ca. AD 960. All of these indicators help us to reconstruct the early settlement of the inland region of Svalbarðstunga, which would have occurred over a short period of time (perhaps only one generation). By contrast, Hjálmarvík and Svalbarð were settled earlier at around AD 940. At Hjálmarvík and Bægístaðir, the macrofossil data also helped us to document the occupation period and land use activities that had been identified in the archaeological and historical records.

The combination of paleoecological data with archaeological and historical data made it possible to document the history of human occupation in the valley. The present study also showed that changes in land use, volcanic eruption and climate variation each triggered significant changes in the vegetation and landscape. This was especially true during the period spanning 1477 and 1850, which included both a volcanic eruption (during the LIA) and a significant period of land occupation.

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Chapitre 5

Human eco-dynamics in northern environments: a comparative study of Iceland and Labrador

Résumé

Bien que le climat soit considéré le principal facteur des changements environnementaux observés dans le bassin de l'Atlantique Nord (BAN), il n'en demeure pas moins que ce territoire a aussi été habité, utilisé et modifié de façon significative par l'Homme principalement durant le dernier millénaire. Afin d'identifier des changements écologiques temporels dans le BAN, plus spécifiquement en Islande et au Labrador, et de définir les facteurs impliqués, une étude basée sur une approche multi-proxy (pollen, macroreste, bois et diatomée) a été entreprise conjointement à des fouilles archéologiques. L'objectif de cette recherche est de comparer l'évolution du couvert végétal en Islande et au Labrador dans le contexte de changements climatiques et de l'anthropisation. Le Labrador a eu une présence continue de groupes autochtones depuis 7000 ans BP qui avaient une économie de subsistance basée sur la chasse, la pêche et la cueillette. En Islande, la première vague de colons scandinaves est arrivée à la fin du 9^{e} siècle; les colons (Norois) ont apporté avec eux un mode de vie européen continental basé sur un système de subsistance combinant l'agriculture/élevage et la récolte de ressources naturelles. Ces deux groupes culturels distincts se sont installés dans des milieux similaires et ont utilisé les mêmes ressources (bois, tourbe, mammifères marins, etc.) mais de manière et d'intensité différentes. Nos résultats montrent que les principaux changements environnementaux qui ont eu lieu durant les 6000 dernières années dans les deux régions sont similaires et ont été principalement engendrés par le climat. Les impacts anthropiques que nous avons détectés consistent en la modification de la structure de la forêt au Labrador à cause de la coupe récurrente et l'introduction et la dispersion de nouvelles espèces de plantes (mauvaises herbes). D'après nos données, il n'y a pas eu de changements écologiques drastiques causés par les humains, ce qui pourrait être expliqué par la résilience des environnements étudiés en dépit de multiples facteurs impliqués (naturels et anthropiques) dans leur développement.

Mots clés : Islande, Labrador, paléoécologie, Inuit, Norois, impact anthoprique, changements environnementaux

Abstract

Iceland and Labrador are part of the North Atlantic Basin (NAB), a region whose landscape has been significantly impacted by changes in the climate. However, humans have also occupied this region and have also had an impact on the landscape, especially in the last 1000 years. The primary goal of this study was to identify the primary periods of ecological change and to document the factors involved in those changes. Specifically, the objective was to compare the evolution of the vegetation cover in Iceland and Labrador over the last 6000 years in the context of climate change and anthropogenic factors. A multi-proxy approach was adopted that included paleoecological investigations based on pollen, plant macrofossils, wood and diatom analysis. Aboriginal groups have occupied Labrador since 7000 BP, all of whom practiced a subsistence lifestyle based on hunting, fishing and gathering. In Iceland, the first wave of Norse settlers arrived in the late 9th Century and they practiced herding, dairying and fishing in accordance with the European traditions that they brought with them. However, both cultural groups settled in similar environments and used the same resources (e.g., peat, wood, and marine mammals), although they did so in different ways and to different degrees. The paleoenvironmental data show similar patterns of vegetation evolution that were mainly controlled by climatic conditions. No dramatic and irreversible changes in vegetation were detected in either region, which could be explained by the environmental resilience of the study regions despite the multiple factors involved in their development.

Key words: Iceland, Labrador, palaeoecology, Inuit, Norse, anthropic impact, environmental changes

1. Introduction

Northern regions have long been considered excellent laboratories for studying climate change given their relative isolation and their sensitive ecosystems (ACIA, 2004). In addition, many of these regions have only been colonized in the recent past, which makes them unique sites for the study of human-environment relationships. This is the case for Iceland and Labrador (in northeastern Canada).

Iceland and Labrador are located in the North Atlantic Basin (NAB) (Figure 5.1). This region is a crucial climate boundary between the subarctic and arctic climate transition where warm Atlantic and cold Arctic air masses and currents converge. The combination of these factors means that the environment in this region is particularly sensitive to climate change.

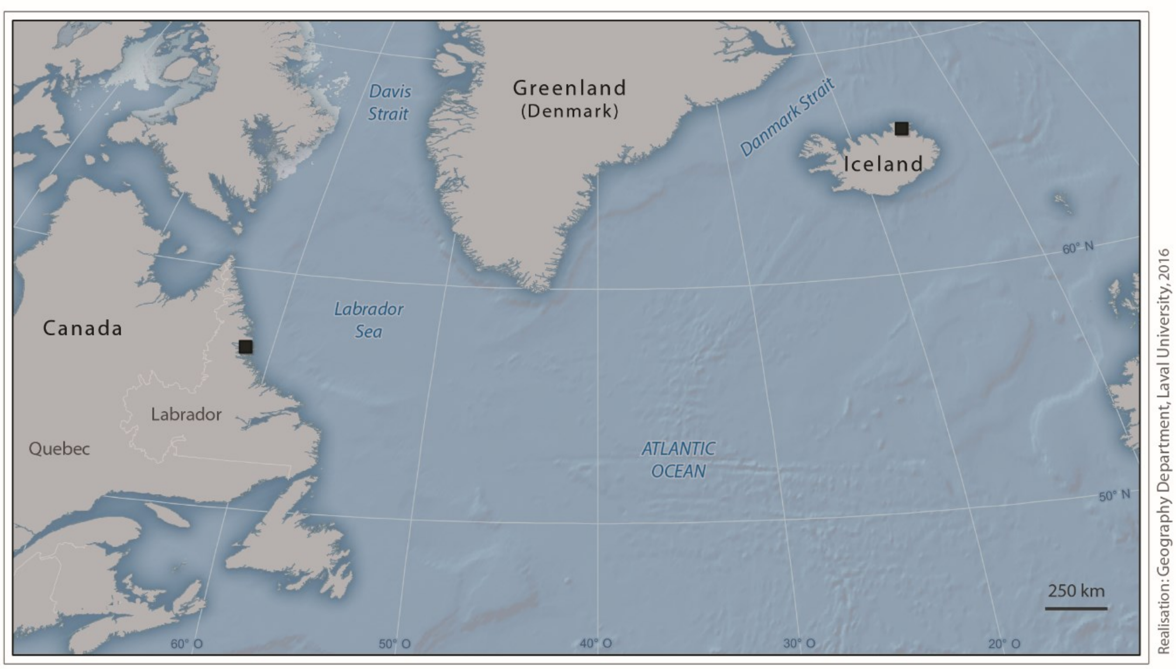

Figure 5.1: Location of study regions in the North Atlantic Basin

The NAB is affected by several atmospheric and oceanic circulation systems, including the North Atlantic Oscillation (NAO), the Arctic Oscillation (AO) and the El Nino-Southern

Oscillation (e.g. Hurrell et al., 2001; Way and Viau, 2014). The combination of these systems generates harsh and variable climatic conditions. As a result, ecosystems in this region bear the impact of climate forcing that links modifications of regional vegetation to changes in NAO phases (see D'Arrigo et al., 2003; Ólafsdóttir et al., 2010; Jessen et al., 2011). The sustainability of living organisms in the Arctic is especially challenging because of the cold climate, poor soil, short growing season and the limited diversity of plants and wildlife (ACIA, 2004). For these reasons, the NAB region is often considered to be a hostile and inhospitable environment even though humans have occupied the region for many years (Þórarinsson, 1958; Vesteisson et al., 2014).

Extensive historical records and archaeological data have enabled researchers to reconstruct past environments, socio-economic systems, and land management practices. In Labrador, archaeological studies have documented a continuous presence of aboriginal groups since 7000 BP (Cox, 1978). All of these groups participated in hunting, fishing and gathering activities as part of a subsistence economy. In Iceland, the first wave of Norse settlers arrived in the late 9th Century (Batt et al., 2015) and they were dependent on herding, dairying and fishing. The subsistence economy in both regions was largely based on the exploitation of natural resources derived from peatland (such as peat, berries and sedges), forest resources, and marine wildlife. The Norse and the indigenous people of Labrador also preferred sheltered areas near the coast. Thus, despite their differences in culture and divergent histories of human occupation, Labrador and Iceland were affected by similar atmospheric and oceanic circulation systems. A comparative study such as ours will allow us to understand the impact of climate and human activities in greater detail.

As articulated in several recent studies (see, for example, McGovern et al., 2007; Woollett, 2010; Roy et al., 2012; Vesteinsson and McGovern, 2012; Vesteinsson et al., 2014), humans have dealt with the impact of climate change in these two regions in different ways. For example, a prolonged phase of climatic cooling at the beginning of the Little Ice Age has been associated with a major phase of farm abandonment and the displacement of settlers in Iceland in the 13th and early 14th Centuries. Some other farms have changed their subsistence economy by specializing in the breeding of sheep instead of cows or their favoured fishing practices (Vesteinsson and McGovern, 2012; Vesteinsson et al., 2014). Contemporaneously, the Inuit and their Labrador ancestors the Thule adapted to the same climate change by increasing their mobility (i.e., by expanding their territory), by exploiting additional natural resources such as wood, or by changing dwelling structures in favor of the longhouse (Kaplan, 1983; Woollett, 2010; Couture et al. 2016; Roy et al., 2017).

This project seeks to identify the main environmental changes in Iceland and Labrador and to identify the principal factors involved over the last 6000 years. In so doing, our research is guided by the following question: what is the level of pressure that sensitive ecosystems such as the sub-arctic and arctic regions can tolerate before reaching the threshold of resilience?

Resilience theory seeks to understand the source and role of changes - particularly transformative changes - in systems that are adaptive (Gunderson, 2000; Holling et al. 2002). According to Scheffer et al., (2009), resilient systems can tolerate a wide range of conditions and still remain in a similar state through time. By contrast, systems with low resilience are more sensitive to changing conditions and are likely to change their state over time (Bhagwat et al., 2012). Changing resilience may explain why some perturbations produce large-scale changes while earlier perturbations of similar magnitude produced little change (Scheffer et al., 2009).

The present study consists of a comparative study of the impact of climate change and human activity on plant cover evolution in northeastern Iceland (NE Iceland) and in northern Labrador from approximately 6000 cal yr BP to the present. Multi-proxy data sets were correlated with major environmental changes using a reliable chronology in order to reconstruct environmental conditions in both regions over the last 6000 years. Particular attention was paid to changes in plant assemblages and to new species that may have been introduced by humans, as identified by indicator species that were discovered in previous studies (Erlendsson et al., 2009; Roy et al., 2012; Schofield et al., 2013). Thus, a key advantage of this approach is that it considers both ecological and human components as well as their interaction. It measures not only ecological variables (e.g., climate impact and vegetation changes) and human activities (e.g., occupation and abandonment of sites), but also variables that link natural and human components (e.g., wood harvesting).

2. Physical setting of the study areas

2.1 Labrador: Location and general characteristics

Labrador is located in northeastern Canada and spans the transition zones between arctic and subarctic climates and between arctic tundra and Boreal forest. It also includes diverse permafrost zones. The weather station in the village of Nain (which is closest to our study sites) recorded an average annual temperature of –2.4°C from 1985 to 2012 (Government of Canada 2015). The average annual precipitation varies from 800 to 1000 mm (Government of Canada, 2015). Winters are generally very cold, while summers are short and cool along the coast (Environment Canada, 2015). Northern Labrador is covered by an arctic tundra that is comprised of shrubs (e.g. *Empetrum nigrum*, *Betula* sp. and *Ledum* sp.) and sedges. Lichen are found in well-drained sites, while bryophytes (*Sphagnum* and brown mosses) are typically found in moist areas. *Picea glauca* is mainly found in protected areas with favorable soil conditions.

Two archeological sites in northern Labrador were studied in order to determine the impact of environmental changes and anthropogenic activities on the landscape: Uivak Point and Oakes Bay.

Uivak Point (HjCl-09): The archaeological site of Uivak Point (57°37.2′N, 61°54.5′W) is located in Okak Bay, which is approximately 8 km north of the abandoned Okak village and 125 km north of the village of Nain (Figure 5.2). The area is one of the most productive in terms of animal and other resources. The site comprises the ruins of nine semi-subterranean sod houses excavated on a slope between two boggy terraces 8 and 11 m a.s.l. in elevation respectively. The houses were constructed of peat, rock, whalebone, and wood. Many other remains of prehistoric occupations were also found in the vicinity of the site including tent rings and chipped stone tools. While the Inuit appear to have used it from the 15th to 21st Centuries, archaeological and historical data point to a particularly intensive period of use between the 18th and 19th Centuries. According to Taylor (1974) and Taylor and Taylor (1977), the site was occupied every winter between 1776 and 1807. Uivak Point was known as one of the most important winter settlements in Labrador and one of the more successful whaling/hunting communities (Woollett, 2003).

Oakes Bay 1 (HeCg-08), Dog Island: Dog Island is located 35 km east of Nain (Figure 5.2). The archaeological site of Oakes Bay 1 (HeCg 08) (56°40’06N, 61°08’24W) (historically named Parngnertok) is located on a marine terrace at an elevation of 6 to 8 m a.s.l in a small bay on Dog Island’s western shore (Taylor, 1974). The site is bordered to the north by of mountain ridge, which is colonized by an open forest of *Picea glauca (Moench) Voss* (white spruce). Oakes Bay 1 includes the ruins of seven semi-subterranean sod houses that were built from stacked blocks of peat, piled earth, rock, wood beams and posts, as was typical of semi-permanent Inuit sod winter houses (Woollett, 2010). Based on artefacts and historical records, Woollett (2010) dated the occupation of the sod winter houses to between the mid-17th to late 18th Centuries. In addition to the sod houses themselves, the site includes a number of tent rings and a significant distribution of artefacts that demonstrate an ongoing and diverse occupation stretching from approximately 2000 BP to the 20th Century (see Woollett, 2003 and Roy et al., 2012).

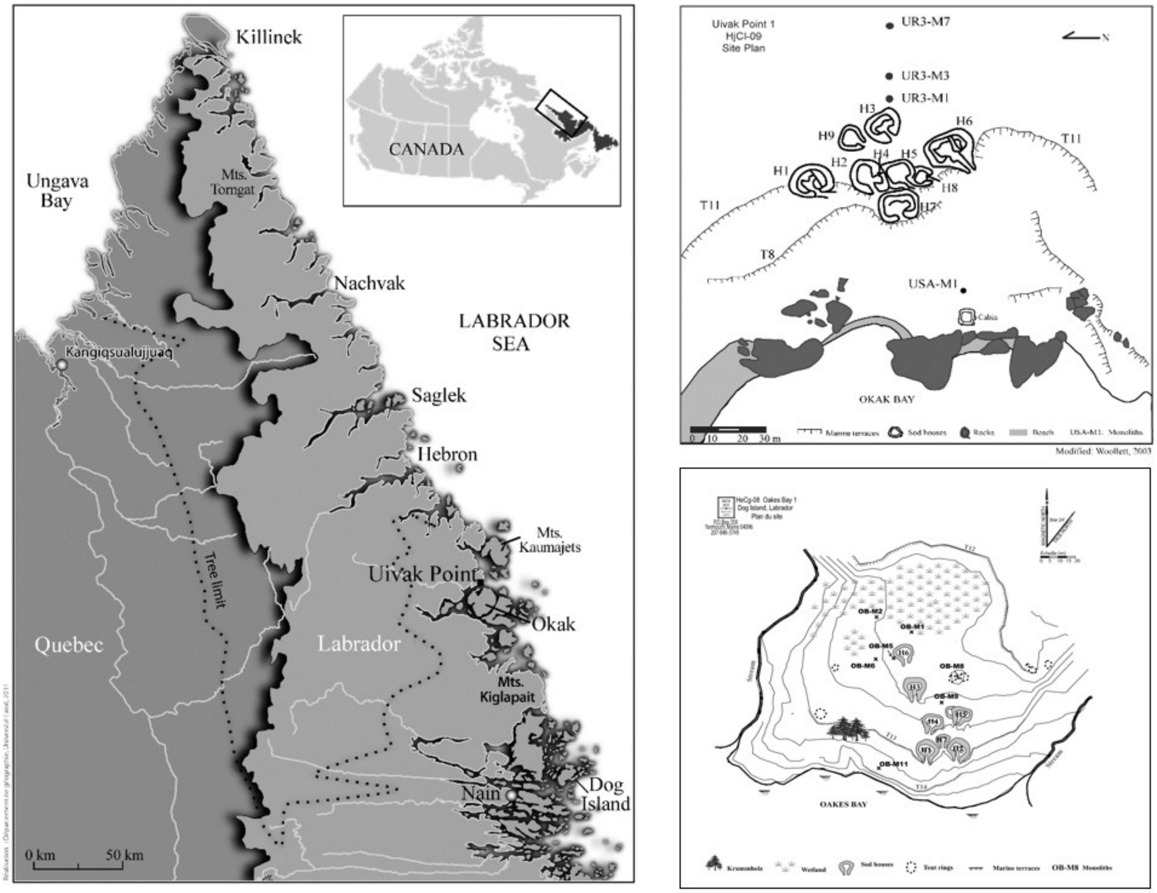

Figure 5.2: Location of archeological sites in northern Labrador

2.2 Þistilfjörður region, northeastern Iceland: Location and general characteristics

The Icelandic study sites are located in the Þistilfjörður region of northeastern Iceland. They are part of Svalbarðstunga, which is 1155 km^2 and sparsely populated (Figure 5.3). The nearest weather station at Raufarhöfn (about 25 km north of Svalbarð) recorded an annual average temperature of 2.6°C in the region and an annual average precipitation of 780 mm (Veðurstofa Íslands, 2015). Along the coast, summers are cool and winters are mild with high levels of precipitation; by contrast, the inland climate is characterized by more seasonally extreme warm summers and cold winters. The vegetation is characterized by distinct zones of plant communities between the coastal meadows and the inland region.

Svalbarðstunga contains many archeological sites: notably, a main farmhouse and several secondary (or satellite farms). Svalbarð is the main farm, dating back to the 10th Century, and has been used continuously since at least the middle of the 11th Century (see Gisladottir et al., 2013). Three satellite farms (Hjalmarsvìk, Kúðá and Bægístaðir) were studied, which, when taken together, form a transect that crosses environmental and ecological gradients extending from the coast to 18 km inland and at elevations from 2 to 225 m asl. The three study sites were all small farms that were satellites or client farms of the Svalbarð estate (the region's largest landholder) and each has had episodic histories of occupation and abandonment (Gísladóttir et al., 2013).

Hjálmarvík: Hjálmarvík is situated on a flat and wide coastal terrace dominated by heath and peatland. It is located about 2 km north of Svalbarð and contains turf boundary walls and farm buildings and at an elevation of 120 m a.s.l. This farm was occupied between the 10th and the end of the 17th Centuries and between the mid-18th and the late 19th Centuries (Þormóðsson, 1970; Gísladóttir et al., 2013, 2014).

Kúðá: Located about 12 km inland from the coast and about 10 km southwest of Svalbarð farm at an elevation of 120 m a.s.l., Kúðá contains the ruins of several houses and farm buildings that were in use between the 13th and the late 15th Centuries and then from the 18th Century until 1960 (Gísladóttir et al., 2013).

Bægístaðir: The Bægístaðir site is located far inland about 18 km from the coast and 15 km south of Svalbarð at an elevation of 200 m a.s.l. The site contains well-preserved ruins of a farm mound, turf boundary walls, ditches and several turf outbuildings (Gísladóttir et al., 2013). Archaeological investigation revealed that the farm was occupied from about 1300 until 1477, then again from the late 19th Century until 1920 (Gísladóttir et al., 2013).

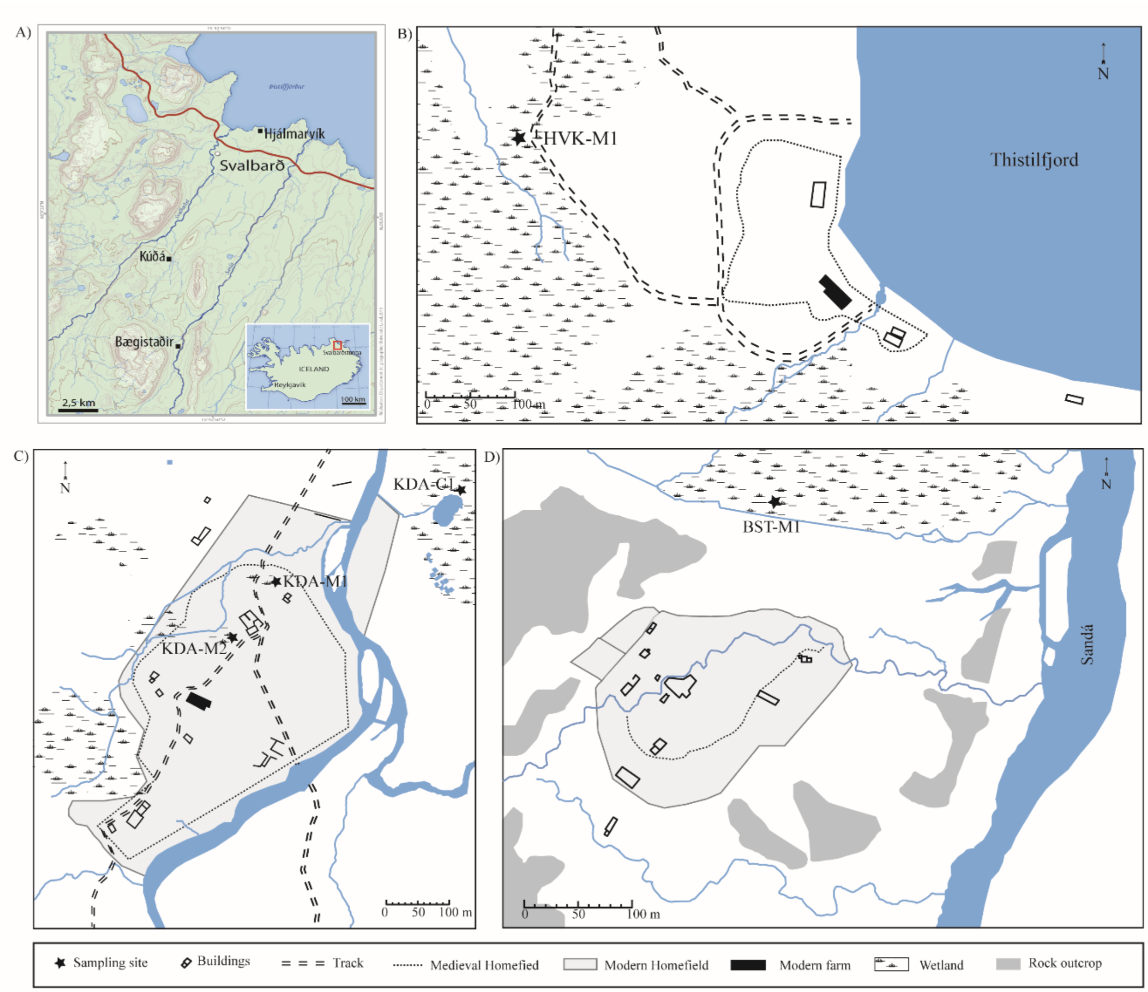

Figure 5.3: Location of the three satellite farms (Hjalmarsvìk, Kúðá and Bægístaðir) studied in Svalbarðstunga, northeastern Iceland

3. Methods

A multidisciplinary investigation was carried out in order to reconstruct the environmental conditions surrounding the archaeological sites and to obtain a better understanding of human occupation and related activities. Pollen records were used to retrace the evolution of the regional and extra-local vegetation, while macrofossil (plants and insects), dendrochronological and diatom analyses were conducted to assess changes in local conditions that could be linked to human occupation of the land.

3.1 Spore and pollen analysis

Spore and pollen analyses were performed at 4 cm intervals on peat cores extracted from Kúđá (KDA-C1.IS) and Hjalmarvík (HVK-C1.IS) and at 1 cm intervals on a monolith (UR3-M7) extracted from Uivak Point. At each level, 2 cm^3 of sediment was processed following the procedures of Faegri and Iversen (1989) and Lavoie (2001) (i.e., using chemical treatments of 10% KOH, HCl, HF and acetolysis). A *Eucalyptus globulus* pollen suspension of known volume and concentration was added to each sample before preparation to calculate pollen concentration (grains/cm^3) (Benninghoff, 1962). At least 500 pollen grains of terrestrial vascular plants were counted for each sample (pollen sum). Pollen and spore identification followed Richard (1970, 1981) and McAndrews et al. (1973). The pollen collection at the Centre d'études nordiques (CEN) was used as a reference for the identification of problematic specimens. To distinguish between pollen of *Betula pubescenss* Ehrh. and pollen of *Betula nana*, we used published records of pollen size measurements (e.g., Caseldine, 2001) as well as our own measurements. The pollen diagrams were drawn using Palaeo Data Plotter software (Juggins, 2002).

3.2 Macrofossil Analysis

Four peat monoliths (KDA-M1, KDA-M2, BST-M1 and HVK-M1) from Svalbarðstunga and four peat monoliths (UR3-M1, UR3-M3, UR3-M7 and USA-M1) from Uivak Point were sampled for stratigraphy, macrofossil identification and radiocarbon dating.

Macrofossil analysis was performed at 2 cm intervals following the protocol outlined by Bhiry and Filion (2001). Each sample contained 50 cm^3 of sediment. Sediments were treated with a weak 5% aqueous KOH solution and boiled for a few minutes to deflocculate. The material was then wet-screened through a series of sieves (850-, 425-, and 180-μm mesh). Macrofossils were identified under binocular and light microscopy. References used to identify the plant remains included Montgomery (1977), Porsild and Cody (1980), Crum and Anderson (1980), Ireland (1982), and the CEN collection at Laval University. The macrofossils of vascular plants are expressed as number of macrofossils per 50 cm^3 of sediments. For mosses, the percentage of each species was determined based on a subsample of 100 leaves. Insects were also recovered from the KDA -M1 and KDA-M2 monoliths while sorting for plant macrofossils. Insects were identified through comparison with modern reference specimens of Icelandic insects and with the aid of entomological publications (Bousquet, 1990; Lindroth, 1969; Séguy, 1944). Macrofossil (plant and insect) diagrams were constructed using Palaeo Data Plotter software (Juggins, 2002).

3.3 Diatom analysis

Diatom analysis was performed at 2 cm intervals on the K-M1 peat monolith from Kúđá. For each level, between 0.035 and 0.05 g of lyophilized sediment was processed following the procedures of Pienitz (2001) (i.e., chemical treatments using HCl 10%, and H^2O^2). Microspheres of known volume and concentration were added to each sample before preparation to calculate the concentration of diatoms. A minimum of 300 diatoms were counted in each sample. The identification of diatoms was performed with reference guides from the aquatic paleoecology laboratory at the CEN (e.g. Antoniades et al., 2008, Bathurst et al., 2010). Diatom diagrams were drawn using Palaeo Data Plotter software (Juggins, 2002).

3.4 Dendroecological analysis

Growth patterns of white spruce stands around Oakes Bay 1 and Uivak Point were studied in July and August of 2010 in a pair of field sampling surveys of living trees (41 core samples from Oakes Bay 1 and 15 from Uivak Point) and dead trees (92 dead wood sections from Oakes Bay 1 and 6 from Uivak Point). The COFECHA program and diagnostic light rings (i.e., growth rings with very few latewood cells (Filion et al., 1986)) were used to date and cross-date living and dead wood sections (Holmes, 1983; Grissino-Mayer, 2001). Tree ring widths were measured with a Velmex micrometer (precision of 0.002 mm) under a binocular microscope at a magnification of 40X.

Disturbance events analysis was performed to identify and date forest disturbances such as wood harvesting in areas occupied by aboriginal peoples or where there had been insect outbreaks. According to Payette (2010), the relative growth of tree growth rings may be used to identify and date the presence of canopy-gaps between trees in a state of surcimage. In this study, growth releases were detected for individual trees by calculating the ratio of the width of individual growth rings greater than 25% relative to those of the 10 preceding and succeeding years (Nowaki and Abram, 1997; Berg et al., 2006; Caccianiga et al., 2008; Payette, 2010). (For more details regarding this procedure, see Roy et al., 2017).

3.5 Radiocarbon Dating

Twenty-six organic samples containing plant remains, brown mosses or charcoal were dated using accelerator mass spectrometry (AMS) at CEN's laboratory and at the Keck Laboratory at the University of California, Irvine (UL-KIU). Dates were calibrated using the Calib 6.0 program (Stuiver et al., 2011) and midpoints were obtained using the weighted median method (Stuiver et al., 2011; Telford, et al., 2014). Results are presented in calibrated years (Table I). In Iceland, tephra deposits were used as stratigraphic and chronological marker horizons to correlate peat sequences across Svalbarðstunga (Lane et al., 2014).

4. Results and discussion

The study of palaeoenvironmental record archives from northern Labrador and northeastern Iceland provided data that were used to reconstruct landscape evolution. As shown in Figures 5.4, 5.5 and 5.6, multi-proxy investigations were used to detect terrestrial ecosystem changes in response to climate fluctuations or anthropogenic activities. We demonstrated that climate changes substantially contributed to significant environmental changes to about AD 1000; afterward, human activities intensified these changes on a local scale.

Vegetation history of northeastern Iceland and northern Labrador throughout the middle and late Holocene

Pollen data from the northern Labrador sites revealed that between 6000 and 4800-4500 cal. yr BP, the study region was covered by shrub tundra (dominated by *Betula* sp., *Alnus* sp., and diverse vegetation) (Roy et al., 2012; Lemus Lauzon et al., 2016; this study). These findings were linked to mild conditions that were suitable for vegetation growth and they are consistent with the results of Short and Nichols (1977) and Lamb (1980). During this same period in northeastern Iceland, our pollen data show that vegetation consisted of birch woodland and shrub tundra species, both of which indicate warm and moist conditions (Figure 4). These results are in agreement with Hallsdóttir and Caseldine (2005) and Karlsdóttir et al. (2014), who demonstrated that the northern Iceland landscape became more open and the birch woodland became sparser. Shade-intolerant herbs and ferns became more prevalent at this time, as indicated by increasing relative values of the pollen and spores for these two groups. In parallel fashion, there was also an expansion of heaths and mires from 6000 to 1200 ^{14}C yr BP, which reinforces the view that there were similar climate conditions in northern Labrador and northeastern Iceland. Gajewski (2015) also demonstrated that in southern Greenland, maximum temperatures were reached between 4000 and 3000 cal. yr. BP and it remained relatively warm in the late Holocene. From 8000 to 4800 cal yr. BP at Lake Igaliku in southern Greenland, the establishment of an open heath with *Juniperus* and *Alnus* also provides evidence of warm conditions (Massa et al., 2012).

From ca. 4800 to ca. 3000 cal. yr. BP, the climate conditions appear to have triggered significant changes in the two study regions. In northern Labrador, according to Roy et al. (2012) and Lemus-Lauzon et al. (2016), the shrub tundra transitioned to tree tundra. In fact, this period is primarily characterized by an increase in the percentage of tree pollen (*Picea* sp.) and by the abundance of shrub species (*Alnus* sp. and *Betula* sp.). Lamb (1980), Payette and Filion (1993), and Levac and De Vernal (1997) have obtained similar results using different methodologies (e.g., palynology and dendrochronology, etc.).

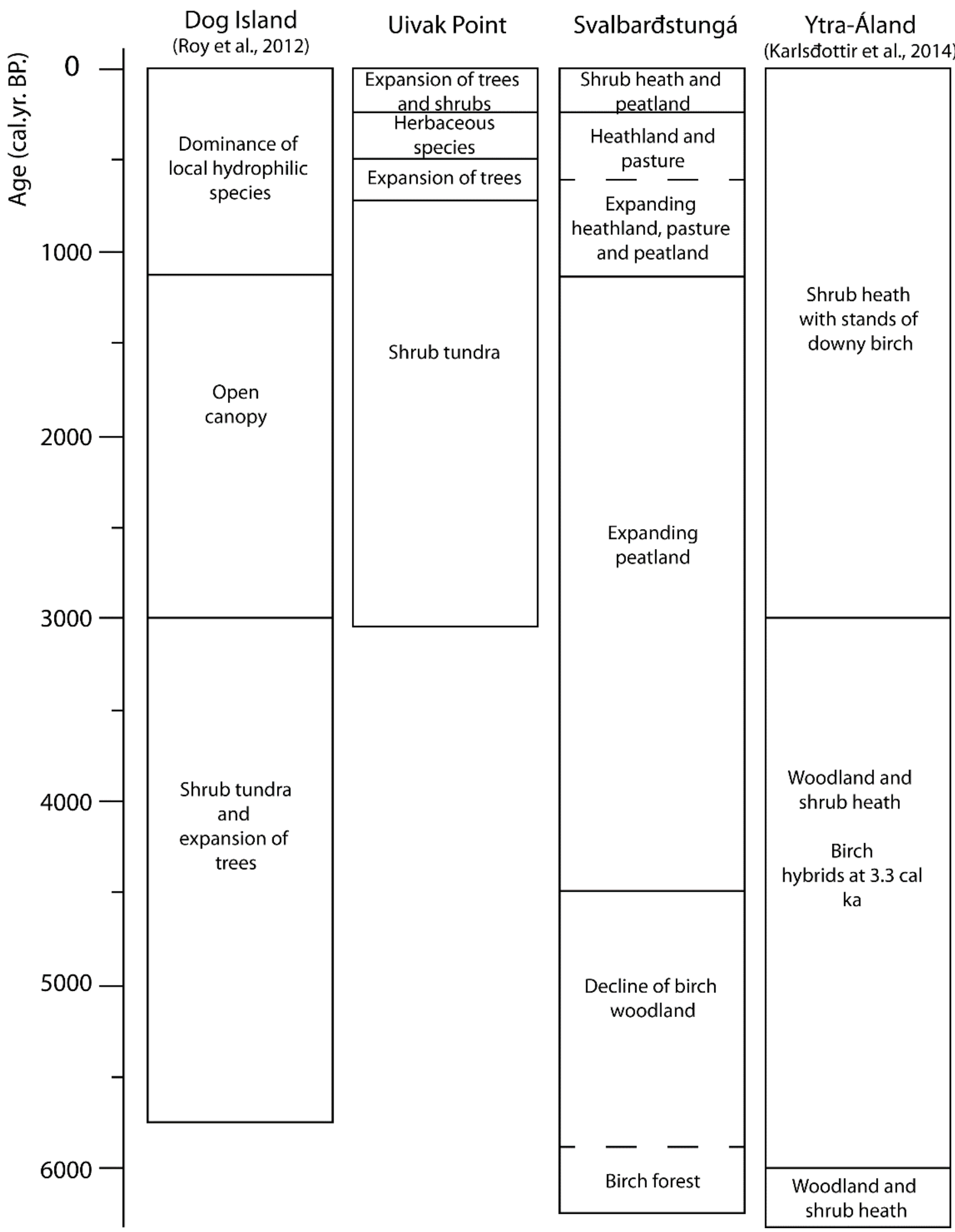

Figure 5.4: Comparative landscape evolution in both study areas

The warm conditions are typical of the Holocene Thermal Maximum (HTM) (or the Hypsithermal). In northeastern Iceland, peatland species thrived, while birch trees declined during this period. According to our data, the birch woodland had virtually disappeared by about 5910 cal. yr BP in the middle of the study valley (Svalbarðstunga) and by about 3340 cal. yr BP on the coast (downstream of the valley). There was also some birch trees scattered across the valley. The extension of peatlands in NE Iceland could be a sign of wetter conditions, but the temperature was probably colder than it had been previously since there was high peat accumulation (less decomposition). This is also what Karsldottir et al. (2014) observed at Ytra-Aland, which is located 7 km south-east of Svalbarđ. Their pollen data indicated that *B. pubescens* almost disappeared from the area at around 3000 cal. yr. Hallsðottir and Caseldine (2005) observed a pronounced *Betula* minimum at around 3300 ^{14}C yr BP that is probably evidence of diminished woodland cover resulting from deteriorating climate. This finding is in contrast with palaeoenvironmental record for Helluvaðstjörn in the Mývatnssveit region of northern Iceland. There, the pollen data suggest that there was a stable birch woodland between 3450 and 900 cal. yr. BP (Lawson et al., 2007). In southern Greenland, pollen data from Lake Igaliku indicate the spread of *B. pubescenss*, a drought intolerant shrub that may signal wetter conditions. These wet conditions coincided with the development of a cooling period, possibly indicating an atmospheric reorganization in the North Atlantic region (Massa et al., 2012).

For the period from about 3000 to 1000 cal. yr. BP, the data from Uivak Point (northern Labrador) point toward an opening of the landscape. This opening is indicated by the decline of white spruce and its replacement by shrub tundra. In fact, the pollen grain percentage of *Picea* sp. significantly decreased, while researchers detected small quantities of pollen (less than 20%) from several shrub species (e.g. *Betula* sp., *Alnus* sp., and *Salix* sp.). Similar data were gathered through palynological studies carried out at the Dog Island and Nain sites that are located approximately 100 km south of Uivak Point (Roy et al., 2012, 2015; Lemus-Lauzon, 2016) (see Figure 2 for locations). We interpreted these changes in vegetation as effects of a transition to the cold and relatively dry climate of the Post-Holocene Thermal Maximum (or post-Hypsithemal). In Newfoundland (close to Labrador), climate change promoted the expansion of peatland between 3000 and 2500 cal. yr BP (Davis, 1984). A recent study by Jessen et al. (2011) on an exotic pollen record from fjord sediments located at Placentia Bay, Newfoundland linked this change to a transition from a dominantly zonal atmospheric circulation (a feature of the positive North Atlantic Oscillation phase) to a more frequent meridional circulation at around 3000 cal. yr BP.

In northeastern Iceland, our data show a significant increase in bryophyte spores, while pollen from shrubs and trees (birch) declined or disappeared at around 3340 cal. yr BP along the coast. This change indicates that peatland development occurred at the expense of woodland and shrubs, likely caused by cold and wet conditions (i.e., wetter than in Labrador). As was noted in southern Greenland, a more significant cooling period was recorded at 3000 cal. yr. BP, with a decreasing pollen accumulation culminating at the end of Little Ice Age (Massa et al., 2012).

Over the last thousand years, the ecosystems of Labrador and Iceland have experienced climate fluctuations as a result of the Medieval Warm Period (MWP), the Little Ice Age (LIA) and the recent global warming. However the impact of these climate fluctuations seems to have been dissimilar. According to our results, the clement conditions of the MWP favored the expansion of spruce trees in Labrador, but in NE Iceland at this time the heathland and peatlands were well-developed across the valley (Svalbarðstunga). During the LIA, conditions in Labrador were favorable to the expansion of hydrophilic species, while in NE Iceland they led to a general decrease in all species except for a few herbaceous species such as Poaceae. Finally, prior to ca. A.D. 650–900 at Igaliku, the low arboreal and dwarf-shrub pollen frequencies at the Norse settlement at Garðar (which is located at the head of the Igaliku Fjord in Greenland) indicate a relatively open landscape. This was followed by a decline of *Betula pubescenss* after A.D. 950, despite the clement conditions of the MWP (Gauthier et al., 2010).

Anthropogenic impact on landscape evolution in northeastern Iceland and northern Labrador in the context of climate change over the last thousand years

Previous studies have profiled the impact of humans on the landscape in different parts of the NAB by identifying indicator plant and insect species linked to human activities and landscape disturbance (e.g. Erlendsson et al., 2009; Roy et al., 2012, 2015; Schofield et al., 2013). Indicator plant species include *M. fontana, S. media, S. selaginoides, P. aviculaire* and the primary indicator synanthropic insect is *L. minutus*. In both of the study regions, peatland ecosystems were used by human populations experiencing different levels of pressure. They used peat blocks to build their houses and they harvested berries or leaves for medicine or other daily activities. In Labrador, for example, Roy et al (2012) demonstrated that *M. fontana* grew on disturbed sites following their abandonment by the Inuit. In Iceland, Erlendsson et al. (2009) interpreted the recovery of shrubs such as *E. nigrum* and Ericales as signs of site abandonment. The pre-landnám placing of the heath species *E. nigrum* (crowberry) and Ericales such as *Vaccinium* in the pollen diagrams is also of note as these taxa commonly expand in Icelandic pollen diagrams post-settlement (e.g., Hallsdóttir, 1987; Erlendsson, 2007; Lawson et al., 2007). Taken together, these findings provide strong evidence of the impact of humans on the landscape and show how humans have influenced the evolution of the ecosystem.

Humans have occupied Labrador for over a thousand years. The Thule, the ancestors of the Inuit, occupied Labrador between the late 13^{th} and mid-15^{th} Centuries. Their winter camps were built on the outer coastal zone in proximity to the open ocean at the edges of the land-fast sea ice (Kaplan 1983). The available natural resources (e.g., trees and peat) would have provided readily accessible construction and heating materials for the occupants of the study sites (Oakes Bay 1 and Uivak Point). Macrofossil results have shown that many of the local plant species that grew in the vicinity of these sites were likely used by the Thule/Inuit in their daily lives. In particular, ecofacts such as burnt brown mosses and a large quantity of *Empetrum nigrum* seeds were identified close to the site (Figure 5). Both species are known to have been used as combustibles and as food respectively by the Inuit and their ancestors. Human activities also triggered the establishment of some weeds and apophytes such as *Montia fontana* and *Silene* (Roy et al. 2015), which is known to grow on sites that have been disturbed by human activity (Blondeau and Roy, 2004). The dendro-ecological data presented in our study and in Lemus-Lauzon (2016) revealed variations in radial growth rates that were identified as growth releases caused by disturbance events such as canopy gaps in the forest (Figure 5). Wood harvesting in the relatively sparse local subarctic forest would have easily created a sizable canopy gap that would have likely increased the amount of resources for the remaining trees, especially light. In this study, we detected episodes of growth release that occurred as early as AD 1580 that coincide with anthropogenic disturbances related to wood harvesting.

Nevertheless, our data suggest that these changes in vegetation and the environment were not as substantial as those that occurred after the arrival of Moravian missionaries in the late 18th Century. At that time, several missions were established along the coast, including one at Nain in 1771. These circumstances would have required a more intensive use of wood to build newly adopted wooden houses for the Moravians and for the Inuit (Lemus-Lauzon et al., 2016; Roy et al., 2017). In addition, the Inuit and Moravians had a greater need for wood as a source of fuel in order to counteract the cold conditions of the LIA (Roy et al., 2012).

Turning to Iceland, the pre-settlement vegetation in Svalbarđstunga was dominated by peatland and heathland. Based on our pollen data, the peatland consisted of a combination of *Equisetum, Juncus* sp.*, Eriophorum angustifolium, Carex sp.* and S*phagnrum* sp. These vegetation communities maintained a relatively stable prevalence from the time of settlement until the 20th Century, at which point drainage improved significantly (Zutter, 1997). The heathland community was mostly dominated by sedges (*Carex* sp.) and other herbaceous species. Overall, the ecosystem was suited for grazing during the settlement period.

When the Norse arrived in northeastern Iceland at about AD 940, birch trees were scarce in Svalbarðstunga (Figure 4). The increase in the sedge population and the appearance of new species reflect the effects of human settlements during the Medieval Warm Period. This explanation is confirmed by macrofossil data (from plants and insects) and diatom evidence obtained from peat monoliths in Kúðá, Hjálmarvík and Bægístaðir (Figure 5).

At Kúðá (our main study site in NE Iceland), the earliest indirect signs of human settlement were charcoal fragments and synanthropic insect remains found in the peat samples that were dated to approximately AD 960 (Figure 6). It appears that there was a shift in the vegetation composition in favor of pasture species such as *S. media* and *P. aviculare*, which reflects deliberate efforts to promote grazing land as early as AD ca. 960. The finding of insect remains from *Latridius minutus*, a coleopteran usually found in hay stores in Iceland, confirms the existence of a human settlement at this time. At Hjálmarvík and Bægístaðir, macrofossil analysis identified dominant species usually found in homefields, pasture land

and fertilized areas such as *Poa cf. pratensis*, *Carex* sp., *Viola sp., Persicaria maculosa* and *Selaginella selaginoides*. Moreover, diatom analysis revealed an increase in organic matter that may reflect the disposal of domestic waste as early as AD 1030.

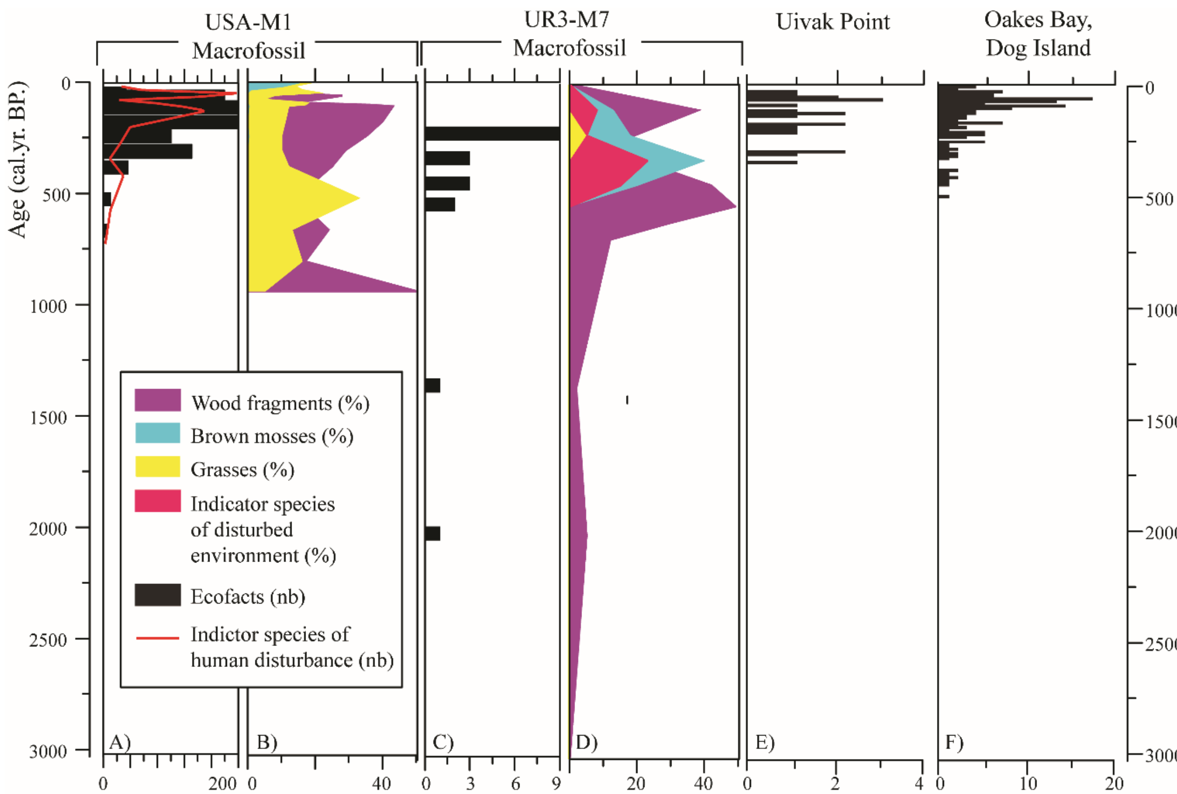

Figure 5.5: Correlation diagram for the last 3000 years based on macrofossil analysis of monoliths USA-M1 and UR3-M7: (A, C) number of ecofacts found and (B, D) percentage of vegetation groups. Frequency distribution of the number of disturbance events from dendroecological analysis (E, F).

Data lead us to conclude that the period of occupation and land use began earlier than had previously been documented in the archeological and historical records. During the LIA, the pollen data show a general decrease in natural vegetation that suggests harsh climate conditions. There was also an increase in weed species and Poaceae, which correlates with the use of the land by humans. This means that despite the unpredictable weather conditions of the LIA, the use of land for grazing still continued across Svalbarðstunga.

The Norse undoubtedly changed their lifestyle in order to cope with the severe weather. Human-environment interactions are influenced by many factors. Climate change is significant, but so too are government policies and contextual factors. The local processes are distinctly shaped by larger-scale and ultimately global-scale processes. All of these factors need to be taken into consideration in order to better understand the human-environment relationship.

Our data reveal that human settlement in Svalbarðstunga (NE Iceland) did not cause dramatic changes in vegetation. This interpretation differs from several studies conducted elsewhere in Iceland. For example, Dugmore et al. (2000, 2004, and 2005) and McGovern et al. (2007) suggested that major environmental changes took place in the south (Þórsmörk) and in the north (Mývatn) of Iceland around AD 900 and centuries after. They claim that birch woodland was replaced by open grasslands and pasture in the majority of the lowland regions. It is also well established that when the Norse settled Iceland, they deliberately promoted the development of pasture land. They also brought many grazing mammals, which inhibited tree and shrub growth and limited their recovery due to grazing in these regions.

Several studies (Gerrard, 1991; Amorosi et al., 1997; Simpson et al., 2001) have discussed the idea of a critical threshold that was breached by the introduction of human populations and their livestock. According to the threshold theory, the ecologically marginal position of Iceland left the country vulnerable to minor shifts in climate. However, researchers have claimed that the arrival of the Norse settlers that finally pushed the system beyond the point of no return.

The paleoenvironmental data presented in this study presents a different scenario. It shows that the vegetation in the Svalbarđstunga region is primarily composed of peatland and grassland, which appears to have remained stable throughout the occupation. The resilience of this type of ecosystem is strong despite the multiple disruptive factors involved.

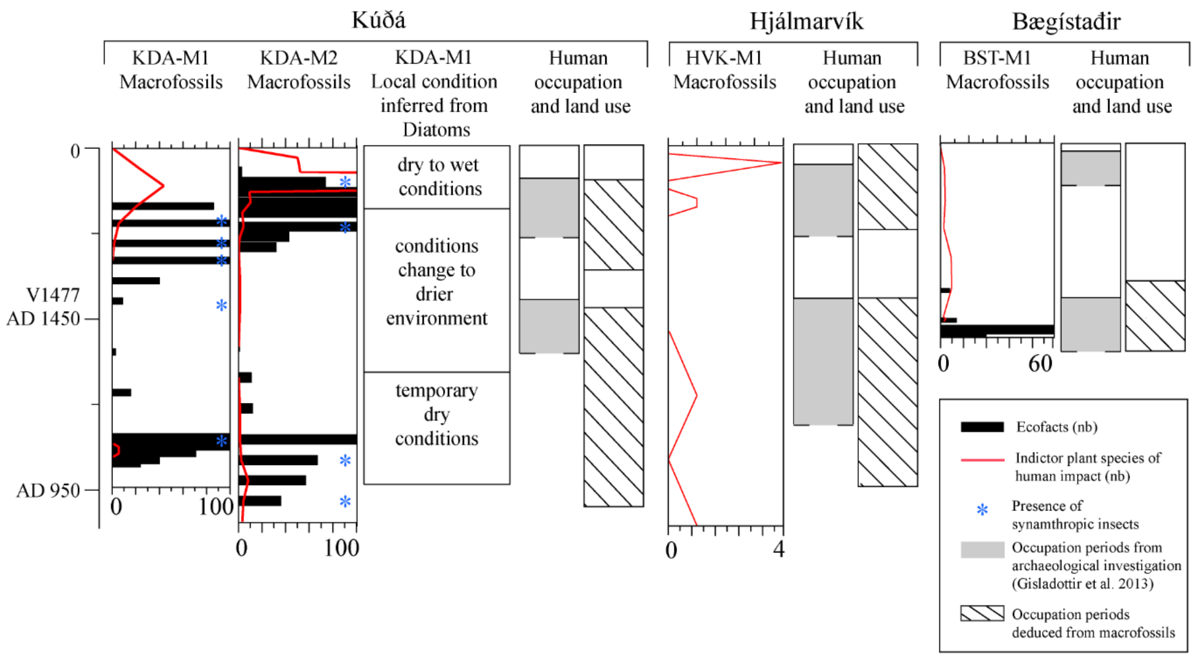

Figure 5.6: Correlation diagram for the last 1000 years based on macrofossil (plants and insects) and diatom analysis at Hjálmarvík, Kúðá and Bægístaðir, including archaeological data used to reconstruct human occupation and land use activities across Svalbarðstunga.

6. **Conclusion**

Multi-proxy palaeoenvironmental archives were used to reconstruct landscape evolution and environmental conditions in the context of climate change and human occupation in Labrador and Iceland from the middle and late Holocene to the present. In both regions, major changes in vegetation were triggered by climate, but during the last thousand years these changes were exacerbated by human activities (notably the decline of *Picea* trees in Labrador). Nevertheless, no irreversible changes in vegetation were detected in either of the study regions. By combining palaeoenvironmental and archaeological data, we found evidence that the Inuit and Norse settlers made adaptations to their environment that prevented long-term environmental instability and an intense reduction in natural resources.

The Inuit and Moravians in Labrador and the Norse in Iceland had to cope with similar climate fluctuations over the last thousand years. In particular, the Norse employed major land management strategies to develop pasture land, which is the primary reason they continued to occupy Svalbard from AD 940 onward. When the first settlers arrived in Svalbarð, the landscape already consisted mostly of peatland and heathland. The primary effect of human activity was the introduction of new weed species. For the Inuit of Labrador, no major changes in the evolution of the landscape were noted until the late 18th Century, which coincides with the arrival of Moravian missionaries in AD 1771.

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CONCLUSION GENERALE ET PERSPECTIVES DE RECHERCHE

Dans cette thèse, nous avons utilisé une approche multidisciplinaire en écologie historique pour documenter et comparer l'impact des humains sur leurs environnements dans deux régions nordiques très sensibles aux changements climatiques. Nous avons étudié trois sites localisés au nord-est de l'Islande et deux autres au nord du Labrador. La culture et le style de vie des peuples qui occupent ces deux régions sont contrastées. Les Inuit et leurs prédécesseurs sont originellement des populations nomades pratiquant la chasse et la cueillette, alors que les Norois/Islandais sont sédentaires et ils ont un mode de subsistance basé sur l'élevage et la pêche. Toutefois, ces groupes culturels se sont installés dans des milieux similaires (subarctiques, maritimes) et ont utilisé les mêmes ressources (bois, tourbe, mammifères marins, etc.), mais de manière et d'intensité différentes.

Les hypothèses qui ont été testées dans le cadre de cette recherche étaient que 1) les fluctuations climatiques, de manière générale, ont été similaires en Islande et au Labrador, que 2) l'anthropisation a exacerbé l'impact climatique et contribué à l'ouverture du paysage des deux régions, et que 3) l''impact anthropique a été plus important en Islande qu'au Labardor.

Les résultats complémentaires obtenus par l'entremise de l'analyse des microfossiles (pollen et diatomées), de l'analyse macrofossile (insectes, plantes) et de la dendrochronologie nous ont permis de confirmer la similitude des fluctuations climatiques dans les deux régions. En résumé, de l'Holocène moyen jusque vers 3000 cal BP, les conditions relativement chaudes et humides ont favorisé l'expansion de l'épinette (*Picea glauca*) et au Labrador et du bouleau (*Betula pubensens* et *Betula nana*) en Islande. Par la suite les conditions plus froides et généralement plus humides ont engendré le développement des tourbières au nord-est de l'Islande et la toundra arbustive au Labrador.

Il s'avère aussi, d'après nos données, que l'impact anthropique a exacerbé l'impact climatique, contribuant ainsi à l'ouverture du paysage au Labrador. À cet effet, l'impact sur la forêt est devenu plus significatif à partir de l'établissement des Moraves. En Islande, le paysage était déjà dépourvu de forêt bien avant l'arrivée de l'Homme. Toutefois, malgré les

conditions froides du PAG, le site de Hjálmarvík semble être en utilisation, alors que les sites de Kúðá et Bægístaðir sont occupés et/ou utilisés à différentes périodes.
Par ailleurs, les divers résultats obtenus ne nous permettent pas de statuer sur un lien direct de cause à effet entre le refroidissement et le changement de stratégie d'occupation dans les deux régions étant donnée l'implication de différents facteurs au même moment (p. ex. volcanisme en Islande).

Évolution de la végétation au Labrador et utilisation des ressources ligneuses par les Inuits. (Chapitres 1 et 2)

Dans le but de reconstituer les changements temporels de la végétation en réponse au climat et aux activités humaines, des analyses paléoécologiques (pollinique et macrofossile) ont été effectuées sur des dépôts organiques prélevés aux environs des maisons semi-souterraines du site à Uivak Point, alors que des analyses dendrochronologiques ont été réalisées sur des échantillons d'arbres près des sites archéologiques de Uivak Point et de Oakes Bay (Dog Island). À Oakes Bay, les données dendroécologiques viennent s'ajouter aux résultats paléoécologiques déjà acquis pour ce site.

Les données polliniques ont permis de reconstituer l'histoire de la végétation des derniers millénaires. Entre 3030 et 700 ans étal. BP., les conditions froides et sèches ont favorisé l'expansion de la toundra arbustive au détriment de la forêt d'épinette. Entre 700 et 550 ans étal. BP, les conditions environnementales plus clémentes (chaudes et humides) ont favorisé l'expansion des arbres. Depuis ca. 550 ans étal. BP, le paysage est dominé par l'abondance de taxons de milieu bien drainés. Ce changement, en particulier entre 500 et 100 ans étal. BP semble refléter les conditions plus froides du PAG. Le réchauffement climatique ultérieur a permis le rétablissement et l'expansion des arbres et arbustes à des échelles régionales et locales. De plus, nos résultats indiquent que les Thuléen/Inuits ont récolté de nombreuses espèces végétales du cortège floristique immédiat au site archéologique de Uivak point. Elles ont été utilisées comme source de nourriture, combustibles ou matières premières pour les activités quotidiennes. Le piétinement autour des maisons a permis d'incorporer dans le sol différents vestiges anthropiques (écofacts) telles que la graisse brûlée, des feuilles de mousses brûlées et du charbon. Ces activités ont également conduit à la mise en place de certaines mauvaises herbes et apophytes tels que *Montia fontana* et *Silene*. En outre, nos données chronostratigraphiques et paléoécologiques suggèrent que le site a été occupé sur une base irrégulière depuis AD 1400. En somme, cette occupation a laissé des traces subtiles, lesquelles reflètent peut-être l'utilisation de cet endroit comme un camp transitoire ou comme un lieu de chasse à la baleine ou au phoque plutôt que comme un lieu d'occupation permanente.

La documentation des effets de la récolte du bois par les Inuit sur la dynamique forestière et la reconstitution du régime des perturbations furent possible grâce à l'étude dendrochronologique de 154 échantillons d'arbres vivants, d'arbres morts et de bois archéologiques. Ces échantillons ont été prélevés à proximité ou à même les sites archéologiques de Uivak Point et Oakes Bay, Dog Island, au Labrador. Les résultats ont permis de définir 550 ans d'histoire de perturbations anthropiques (coupe forestière) et naturelles (épidémie du dendroctone). La dynamique de cette forêt subarctique a particulièrement été dominée par des évènements de détente dans la croissance des arbres (évènements de perturbations) qui coïncident avec l'occupation du site par les Inuits. Ainsi, la création de trouées dans le couvert forestier aurait été engendrée par les activités de récolte de bois, plutôt que d'être en réponse aux changements de climat. Alors que les études dendroécologiques précédentes pour la péninsule Québec-Labrador se sont concentrées sur l'influence du climat sur la dynamique forestière, le couplage de données dendroécologiques à des données historiques et archéologiques à l'échelle locale a facilité dans cette étude l'examen des modèles multi-causals des perturbations sur le long terme de la dynamique forestière. Malgré un impact de faible intensité sur l'écosystème forestier, les données ont démontré que l'Homme a été un facteur important influençant, à l'échelle locale, la dynamique forestière le long de la côte du Labrador. Cette étude de cas fournit un exemple concret de la nécessité d'adopter des cadres généraux de référence pour les études écologiques dans des contextes où les humains ont une longue histoire d'occupation.

En somme, l'approche paléoécologique utilisée en vue de documenter l'évolution de la végétation au Labrador et l'utilisation des ressources ligneuses par les Inuits a permis de suggérer que les principaux changements environnementaux ont été déclenchés par le climat. Les activités humaines au courant du dernier millénaire ont elles aussi eu un influence non négligeable (récolte de bois, introduction de nouvelles espèces de plante) sur le couvert végétal. De plus, nous avons pu également élargir la période d'occupation et d'utilisation des sites par les Thuléens/Inuits; la période d'utilisation du site débute désormais vers AD 1400. Toutefois, d'autres fouilles archéologiques sont nécessaires sur les zones construites (étude de la culture matérielle) et non construites (macrofossile et entomologique) afin de compléter ce dernier résultat.

Évolution naturelle et anthropique du paysage de la région de Svalbarđstunga, nord-est de l'Islande. (Chapitres 3 et 4)

Afin de documenter l'impact des changements climatiques et des activités anthropiques sur le paysage, une étude paléoécologique pluridisciplinaire (pollens, macrofossiles et diatomées) d'échantillons de tourbe prélevés à proximité de trois sites archéologiques a été entreprise conjointement aux fouilles archéologiques effectuées sur les terres de Svalbarðstunga au nord-est de l'Islande. Les trois sites à l'étude se localisent le long d'un transect côte-intérieur des terres où les fermes de Hjálmarvík, Kúðá et Bægístaðir sont respectivement à 0, 12 et 18 km et à 2, 120 et 220 m d'altitude.

Selon nos données, le climat a influencé les principaux changements écologiques à Svalbarðtunga durant les derniers 6000 ans. En effet, les données polliniques montrent que, entre 6300 et 4500 ans étal. BP, les conditions étaient chaudes et humides et que des boisés de bouleau et la toundra arbustive dominaient le paysage. Par la suite, une détérioration des conditions climatiques a engendré le déclin de *Betula pubescens* en faveur du développement et de l'expansion des tourbières et ce jusqu'à environ 1170 ans étal. BP. L'arrivée des Norois au courant de l'Optimum climatique médiéval (AD 850-1250) a eu un impact sur la végétation, marquée par une forte croissance des espèces de Cyperaceae et des Poaceae ainsi que l'introduction de nouvelles espèces d'herbes. Plus tard, les conditions plus froides et moins humides du Petit Âge glacviaire (AD 1500-1870) ont conduit à un changement significatif dans le cortège floristique, illustré par le déclin de l'enssemble des espèces, principalement des plantes hydrophile. Toutefois, à Hjálmarvík, la forte abondance des grains de pollen des Poaceae qui peut suggérer l'utilisation des terres par l'Homme.

À Kúðá, les premiers signes de l'occupation humaine ont été datés à environ AD 960; ces signes incluent des charbons de bois, des écofacts et des pièces d'insectes synanthropes. Le changement de la végétation en faveur des espèces fourragères telles que *Stellaria media* semble être lié à des efforts d'aménagements des terres par les humains pour créer des pâturages dès ca. AD 960. L'identification d'une occupation humaine aussi hâtive à l'intérieur des terres informe sur la colonisation rapide du territoire de Svalbarðtunga puisque la côte semble avoir été colonisée aux environs de AD 940 à Hjálmarvík. La colonisation rapide vers l'intérieur des terres peut s'expliquer par l'absence d'un couvert forestier dense, ce qui limite les efforts nécessaires liés au déboisement pour le développement de pâturage. Entre AD 1410-1650, le site de Kúðá semble toutefois avoir été abandonné, alors que les données en provenance de Bægístaðir indiquent une occupation et son utilisation malgré les conditions sévères du PAG. Cette situation soulève le questionnement quant au rôle du contrôle socio-politique et de l'église à cette époque. Une seconde occupation, basée sur les mêmes indicateurs que l'occupation précédente, a aussi été identifiée à Kúðá entre AD 1650-1870.

En conclusion, l'absence d'une forêt de bouleau peut servir d'explication à l'établissement rapide de la région, mais amène un réel questionnement quant à l'importance d'un accès facile à cette ressource par les Norois. Toutefois, afin de vérifier cette hypothèse, il serait intéressant de mener une étude taxonomique des macrorestes de bois trouvés en contexte archéologique (dans les maisons ou les dépotoirs). Leur identification permettrait de documenter la provenance de la ressource (bois flotté, arbustes, bouleau) et ainsi mieux comprendre l'importance de cette ressource depuis la colonisation. Ceci permettrait également de savoir si *Betula pubescen* (arbre) était la ressource ligneuse principale ou si les arbustes (*Betula nana*, Ericaceae, *Salix*) et bois flottés avaient joué un rôle de premier plan dans la colonisation des terres de Svalbarð.

De plus, tel que démontrée par les données paléoécologiques, l'occupation et l'abandon des terres semblent avoir été un phénomène important du mode d'établissement de la région de Svalbarđstunga. L'introduction et la dispersion de nouvelles espèces (*Stellaria media* et *Montia fontana*) témoigne de l'effort fourni pour l'aménagement de pâturages, écosystèmes essentiels à l'élevage d'animaux. De par les données obtenues dans le cadre de cette étude, il ne semble pas possible de conclure que les conditions climatiques et la détérioration des écosystèmes subséquente aient entrainé l'abandon de la ferme de Kúðá.

Des études environnementales axées sur les propriétés chimiques et la gestion des sols (aménagement, engrais) au cours des 1000dernières années permettraient de comprendre la capacité des sols fertilisés pour des activités agraires soutenues lors de conditions climatiques instables. Aussi, une étude approfondie de l'économie de subsistance depuis le début de la colonisation amèneraient d'excellentes pistes de réponse quant à l'influence socio-politique et le rôle de l'église sur le territoire de par leur gestion et la centralisation des ressources qu'ils imposaient.

Comparer la réponse des écosystèmes face aux perturbations anthropiques et naturelles au cours des 6000 dernières années au Labrador et en Islande. (Chapitre 5)

L'étude paléoécologique comparative entre Islande et Labrador, deux régions situées dans le bassin de l'Atlantique nord, indique que le climat a joué un rôle significatif provoquant des changements majeurs dans la végétation. Par exemple, la détérioration des conditions climatiques et environnementales durant le Néoglacaire ont engendré l'ouverture du couvert forestier, allant même jusqu'à provoquer la disparition de la forêt de bouleau à Svalbarđstunga. Par la suite, au cours du dernier millénaire, les conditions clémentes de l'OCM (AD 800-1250) ont favorisé l'expansion de la végétation, laquelle a été freinée, par la suite, par le refroidissement du PAG (AD 1500-1870).

Les Inuits et les Moraves au Labrador, ainsi que les Norois en Islande ont tous deux dû faire face à des fluctuations climatiques similaires au cours des 1000dernières années. Lorsque les premiers colons sont arrivés à Svalbarð, le paysage était déjà composé de tourbières et de landes. Les Norois ont adopté des stratégies de gestion des terres pour développer des pâturages en favorisant la croissance des herbacées et des graminées (espèces déjà établies) dans les écosystèmes aménagés, ce qui semble être l'une des raisons pour laquelle ils ont continué à occuper Svalbarđstunga depuis l'an 940 malgré les conditions climatiques rudes. Pour les Inuit du Labrador, il n'y a pas eu de changement majeur observé dans l'évolution du paysage jusqu'à la fin du 18ème siècle, période qui coïncide avec l'arrivée des missionnaires moraves en l'an 1771. L'établissement des missionnaires moraves a engendré une exploitation intensive de la récolte de bois afin de construire divers bâtiments (église, maison, écoles, séchoir à poisson), ce qui a contribué à l'ouverture du couvert forestier. De plus, étant donné les conditions climatiques sévères de cette période, la régénération de la forêt fut sans doute ralentie. Néanmoins, aux deux régions d'étude, il a été possible d'observer les effets de l'activité humaine comme l'introduction et la dispersion de nouvelles espèces de mauvaises herbes telles *Montia fontana* et *Stellaria media* en Islande uniquement. Ainsi, il est possible que l'occupation du territoire par l'Homme n'ait pas causé des changements dramatiques dans la dynamique des écosystèmes existants, du moins pas à ces endroits. Selon nos données, il n'y a pas eu de changements irréversibles dans la végétation dans les deux régions à l'étude, ce qui nous permet de déduire que les écosystèmes nordiques subarctiques de ces régions sont résilients.

Pour poursuivre la réflexion sur les interactions entre les humains et leurs environnements et compléter les résultats de cette étude, il serait pertinent d'étendre les recherches à d'autres sites afin de voir aussi, si la réponse aux perturbations climatiques et anthropiques est la même. À cet égard, les établissements de l'ouest et de l'est au Groenland seraient d'excellents lieux de comparaison étant donné que les Inuits ainsi que leurs ancêtres et les Norois ont tous deux habité le même site contrairement à la présente étude.