Einar Kristensen

In search of 'lost' arrows

A metal-detector survey of the Storbreen ice-patch, Oppdal, Norway

Master's thesis in Archaeology
Supervisor: Martin Callanan
Trondheim, May 2017

Norwegian University of Science and Technology
Faculty of Humanities
Department of Historical Studies

NTNU
Norwegian University of
Science and Technology

Cover photo: Storbreen, as seen on 18.08.2016. Photo: Andreas Alsaker.

Sammendrag

Denne masteroppgaven tar utgangspunkt i en ulikhet i den kronologiske fordelingen av pileskaft og pilspisser mellom to nærliggende soner i høyfjellsområdene rundt Oppdal kommune, Sør-Trøndelag. Det dreier seg om artefakter funnet i tilknytning til de funnførende arkeologiske snøfonnene i området. Disse snøfonnene har vært en arena for pil-og-bue jakt på villrein siden neolittisk tid. Den østligste sonen, Knutshø, har et betydelig innslag av artefakter fra middelalder og historisk tid. På den andre siden av Drivdalen, i Snøhetta-øst, er det ingen artefakter som med sikkerhet kan dateres til disse periodene; her er det artefakter fra folkevandringstid som dominerer materialet.

Det foreligger i litteraturen to forklaringsmodeller på denne krono-geografiske fordelingen av artefakter. Det kan tenkes at ulikheter ved snøfonnenes egenskaper har en direkte innvirkning på den observerbare fordelingen, ved at gjenstander avsatt i snøfonnene i de ulike periodene, også smelter frem igjen på ulike tidspunkter. Her er igjen to mulige scenarioer skissert i litteraturen, avhengig av hvorvidt iskjernen i de ulike fonnene har vært i bevegelse eller ikke. Dersom det ikke har vært bevegelse i iskjernen, ser man for seg et *sist inn – først ut* scenario. I henhold til denne forklaringen vil piler mistet i middelalder smelte ut før piler avsatt i folkevandringstid. Hvis så er tilfellet, kan mangelen på artefakter fra middelalder skyldes at disse smeltet ut av fonnene i Snøhetta-øst før arkeologiske undersøkelser av fonnene ble aktuelt. Mye av det postulerte middelaldermaterialet kan i henhold til dette ha gått tapt, da gjenstander utsettes for en hurtig nedbrytning når de først kommer i fornyet kontakt med elementene. Dog kan det tenktes at noe av materialet, først og fremst jernspisser – da disse er mer resistente enn treskaftene – kan ha blitt bevart. Særlig dersom de i løpet av kort tid har blitt begravde i avrenningsmaterialet fra snøfonnene. Hvis så er tilfellet skulle det være mulig å påvise denne grupperingen av artefakter ved hjelp av en spesialisert undersøkelse.

Den andre forklaringsmodellen baserer seg på at det observerte mønsteret i snøfonnmaterialet reflekterer en kulturhistorisk realitet. Med dette menes det at den krono-geografiske fordelingen av artefakter er reell, og at det har vært en forskjell i graden av bruk av de ulike sonene oppigjennom historien.

For å undersøke disse to forklaringsmodellene nærmere, ble det gjennomført et arkeologisk feltarbeid ved snøfonna Storbreen i Snøhetta-øst. Undersøkelsen baserte seg på å bruke metalldetektorer til å gjennomsøke et område i nedkant av snøfonna, da eksisterende hypoteser vedrørende glasiologiske aspekter ved snøfonnene tilsier at det er i dette området eventuelt materiale fra middelalder vil kunne gjenfinnes.

I løpet av ti dager med feltarbeid, fordelt på to sesonger, ble et område på ca. 60000m^2 systematisk gjennomsøkt med metallsøker. Resultatet av undersøkelsen ble funn av fire pilspisser og ett -skaft fra folkevandringstid, i tillegg til tre udaterte skaftfragmenter og en rekke funn fra nyere tid.

På bakgrunn av undersøkelsens resultater argumenteres det for at forklaringsmodellen basert på glasiologiske prosesser er svekket. Det er med andre ord en økt sannsynlighet for at det observerte krono-geografiske mønsteret har en forankring i kulturhistoriske realiteter. Oppgaven går videre med å diskutere ulike kulturhistoriske faktorer som kan tenkes å ha ført til en endring i graden av bruk mellom de to sonene. Det konkluderes med at en rekke slike faktorer er tilstede, og at det krono-geografiske mønsteret i snøfonnmaterialet trolig er et resultat av samspill mellom flere av disse faktorene.

Acknowledgements

First and foremost, to my supervisor, Martin Callanan; It has been a privilege and a pleasure having you as my guide through the process of writing this thesis. You are a great teacher and a fantastic motivator. I can only hope that you will continue to inspire countless more students, in the years to come.

Thanks to;
Arne Anderson Stamnes, for lending me his tried and tested metal-detector.

Thomas Heggem, for assistance with artefact photography.

Leena Aulikki Airola, for providing me with materials and tips for the secure transportation of artefacts from the field to the laboratory, and for providing me with access to the artefacts when needed.

Frode Lindgjerdet, for assistance with the identification of the modern hunting projectiles.

All the lecturers on the master program in archaeology, in particular to Axel, Hein, and Marek, for valuable inputs and feedback during the student seminars.

To my fellow students on the master-program in archaeology; Three years is too short a time to live and work among such excellent and admirable students. I don't know half of you half as well as I should like; and I like less than – well, you know how it goes…

Additionally I would like to extend my gratitude to my friends and family, who have – with varying degree of interest - been patient and indulgent, while listening to me speak of reindeer, arrowheads, and ice-patches.

A special thanks to;
My parents, for their support and understanding,
My brother Eirik, for providing me with coffee, clothes, and company.

Table of Contents

Figures

List of tables

1. Introduction

The hunting of wild reindeer on ice-patch sites in the mountains of central Norway is a tradition with deep roots. Fifty meters away from a modern rifle-round casing and the remains of a freshly butchered reindeer carcass, we discover an iron arrowhead dating to the Migration period. At the same site, there have previously been found artefacts dating back to the Neolithic period (Callanan, 2013).

During warm summer days, wild reindeer reliably congregate on ice-patches. There are two aspects of reindeer behaviour that are usually cited with the aim of explaining their tendency to do so; thermoregulation (Anderson & Nilssen, 1998) and relief from insect harassment (Hagemoen & Reimers, 2002). There is some uncertainty as to which of these constitute the main behavioural trigger, but from a purely archaeological point of view, determining this is not that relevant. What is important is that the animals do indeed seek out these places with a degree of predictability that would have been as obvious to (pre)historic hunters as it is to the hunters of today.

This particular behavioural trait has been made use of by peoples across time and space. This is evident in that hunters from vastly different cultural technological frameworks have made use of the ice-patches as hunting sites in comparable ways.

Figure 1: Storbreen (01.08.2015). The dark line on the right-hand side is made by reindeer tracks. Photo: Einar Kristensen

Here we see one activity being practised at the same locale from pre-history and into modern times. There is a depth of time on these sites that – combined with the excellent preservative conditions within the ice-patches – presents unique opportunities for archaeologists to ask questions about the developments of hunting technology and the practises of the hunt, and their further implications for past societies in general.

The first artefacts originating from an ice-patch context within central Norway entered the archaeological record in early 20th century. By 2011, the material from the region totalled 234 artefacts, recovered from 28 ice-patch sites (Callanan, 2014b, p. 116). The dataset is made up almost exclusively of artefacts related to hunting; arrowheads of stone, bone, antler, iron, and even shell, as well as arrow-shafts. Many of these are very well preserved. Most of the artefacts have been discovered by way of visual surveying on the sites, during the months of August and September, when the ice-patches are in the most contracted state of their annual cycle.

Whilst we are starting to get a good overview of the existing data, and good routines for archaeological surveying of these sites are in place – at least in some areas – there are still many unanswered questions when it comes to the significance of the ice-patch material, and the culture-historical implications they entail. Oddmunn Farbregd (1983, p. 40) highlighted the potential of the ice-patch dataset to further our knowledge of culture-historical changes in central Norway. There certainly is great potential here for archaeologists to ask questions that reach beyond the mountain locales from where the artefacts emerge.

With the amount of data recovered in recent years, we are now in a better position to attempt to answer some of these questions. As the dataset keeps growing and patterns emerge and solidify, we can begin to explore the trends in the material, and question their origins and their validity. Does the ice-patch material represent a "snap-shot" of the hunting activity that has taken place on these sites at different times throughout (pre)history – or are there sorting-mechanisms occurring as the ice-patches continue to melt, giving us a chronologically weighted dataset, with certain periods being underrepresented?

1.1. Research questions

The main theme of this thesis is related to a question my supervisor asked me when I first started working on this project; *"why are there so few medieval arrowheads in the Snøhetta East zone?"* This question is too unwieldy in and of itself – it has to be broken down into parts, and only some of these can be examined within the rather limited framework of a master-thesis project. This thesis then, seeks to explore some of the sub-questions derived from the main question of *"why"*.

The question is based on a clearly observable difference in the chronological distribution of artefacts between two adjacent zones within central Norway: *Snøhetta East* and *Knutshø* (see fig 2). While projectiles from the Medieval period are absent in the former, they dominate in the latter (Callanan, 2014b, pp. 127-137).

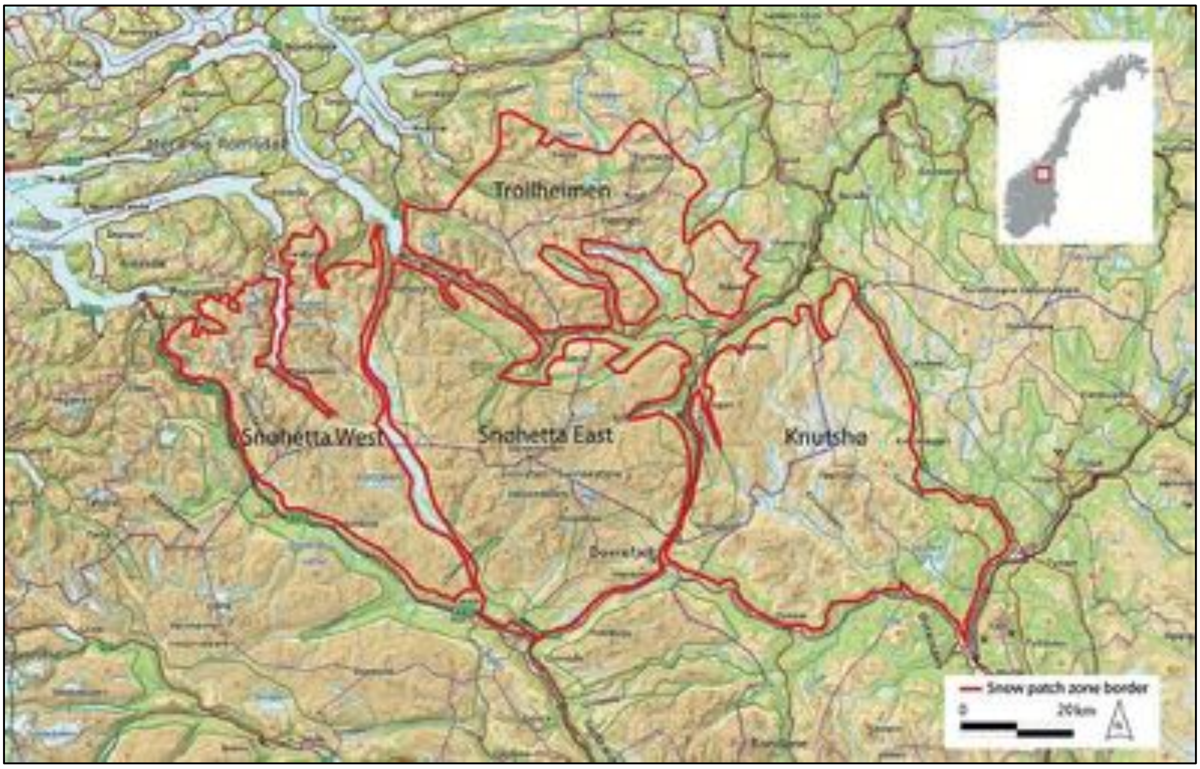

Figure 2: The ice-patch zones of central Norway. (Callanan, 2014 fig. 4.7)

Firstly, the validity of the questions assumption must be examined. *Are there really few medieval arrowheads in Snøhetta East?* This question will be examined by way of a structured metal-detector survey, targeting an area in the fore-fields of the Storbreen ice-patch. Storbreen is the numerically dominant site within the Snøhetta East zone, with 48 out of 91 artefacts (53%) recovered from the zone up to 2011 originating from the site. Because Storbreen seems to have been the most utilized site in Snøhetta East up until the Medieval period, it is considered the most suitable candidate for the recovery of finds from subsequent periods as well.

The survey targets the areas that could be expected to yield finds from the Medieval and Modern periods, based on current hypotheses regarding sorting processes within the ice-patches themselves (Martinsen, 2012, pp. 69-71) and the changing extent, due to variations in climate and weather, of the ice-patches at different times (Farbregd, 1983, p. 39). The main hypothesis underlying the fieldwork is that there are no medieval or modern artefacts on the site. The recovery of any artefacts dating to these periods will serve to falsify this hypothesis.

Should the chrono-geographic pattern remain unchallenged after this extended surveying, its credibility as representative of actual hunting occurrences will be strengthened, and with it the proposition that the chronological dispersal of artefacts on a zone level is the result of something other than recovery-bias or sorting processes caused by the ice-patches.

We can then start to explore other possible reasons why this pattern occurs. Could it be the result of changes in past utilization of these sites? If so, what causes could there be for such changes?

Thus, we are left with the following main research questions:

Has the relative frequency of hunting between the two areas undergone some change with time?

1) *Are there comparatively fewer Medieval arrowheads in Snøhetta East compared to Knutshø?*
2) *What reasons could there be for the apparent abandonment of Storbreen and Snøhetta East as a hunting ground?*

1.2. Chronological and geographic delimitation

This thesis considers all archaeological material recovered from Snøhetta East and Knutshø from 1914 – 2011. More specific focus will be given to the Storbreen ice-patch, and the data from this site will be updated to include finds made between 2011 – 2016.

However, as the focus of the thesis is on the lack of artefacts from the Medieval period, this period will form the basis of the discussion regarding research question 2, in chapter 6.2.

In terms of geography, we are primarily concerned with central Norway, as defined below in chapter 1.3. Data from other ice-patch regions, both elsewhere in Norway and abroad will be included where deemed appropriate, but we are for the most part focused on the two zones Knutshø and Snøhetta East. When treating research question 2, however, the focus will be lifted to a regional, and to a lesser extent national, level. Here the whole of the Oppdal region will be in focus.

1.3. Terms and definitions

Ice-patch – the term is used in reference to perennial patches of snow and ice, possessing an ice-core, that are archaeologically active; meaning that archaeological artefacts have been preserved within the core of the patches, and have subsequently been exposed again by melting events.

Chrono-geographic – this term is used throughout the thesis. It refers to differences in the chronological composition of the archaeological dataset from sites in different geographic locations. Within the context of this thesis, it refers to the difference in the chronological distribution of ice-patch artefacts between the zones *Knutshø* and *Snøhetta-east*, unless it is stated otherwise.

Central Norway is used to refer to the four ice-patch zones surrounding the populated areas of Oppdal municipality, as shown in Figure 2. Knutshø, Snøhetta-east, Snøhetta-west and Trollheimen. This terminology is adapted after Callanan (Callanan, 2012)and is used here for consistency.

This thesis makes use of the recovery-phase system as defined by Callanan (2012). This terminology enables the partitioning of the history of archaeological ice-patch research within the region, making it easier to discuss developments and trends in the recovered material over time.

- Phase 1: 1914 – 1943: begins with the first artefact entering the archaeological record, end ends with the last find made by a member of the pioneer group of collectors in central Norway.
- Phase 2: 1944 – 2000: represents a hiatus with regards to artefact recovery, despite continuing surveying activity.
- Phase 3: 2001 – 2011: A period with extensive annual melts on a regular basis. It also marks a period where new artefacts began to be recovered again, in increasingly large numbers.

The chronological framework used throughout this thesis is based on (Bjerck et al., 2008). This is the framework used by Callanan (2014b) and is used here for consistency and convenience.

Table 1: Chronological framework, adapted after (Callanan, 2014) based on (Bjerck et al., 2008).

Stone Age	**Mesolithic Period**	9500-4000BC
	Neolithic Period	4000-1800BC
Bronze Age	**Bronze Age**	1800-500BC
Iron Age	**Early Iron Age**	500BC-AD570
	Late Iron Age	AD570-AD1030
Medieval Period	**Early Medieval Period**	AD1030-AD1350
	Late Medieval Period	AD1350-AD1536
Historical Times	**Historical Period**	AD1536-Present

1.4. Thesis structure

Chapter 2 deals with the history of research relating to the archaeological investigations of ice-patches within central Norway. Primary focus is given to the research into the regional chronological distribution of artefacts. At the same time, most of the remaining research focusing on central Norway is relevant for this thesis. We will also briefly consider the archaeological literature pertaining to ice-patch material emerging from other parts of Norway, and internationally.

In chapter 3, the Storbreen ice-patch is presented in detail. The archaeological ice-patch material from the site, up to and including 2011 will also be presented here, as a prelude for the synthesis and analysis that will follow, pending the results of the metal-detector survey.

Chapter 4 will give a comprehensive account of the fieldwork carried out on Storbreen during the field-seasons of 2015 and 2016. The methodological aspects will be presented along with assessments of the suitability of the surveying framework when it comes to future surveying. The flaws and merits of the metal-detectors and other equipment needed in order to follow the presented surveying technique will be discussed.

Chapter 5 details the results of the metal-detector survey. Here the spatial and chronological distribution of the recovered finds will be presented. In addition to this, the negative evidence generated by the metal-detector survey will be discussed.

Chapter 6 will discuss the relevance of the results from the fieldwork in relation to the research questions posed in chapter 1.1. Here it will be argued that the negative evidence generated by the fieldwork enables us to suggest an answer to research question 1. Following this, factors connected with research question 2 will be discussed.

In chapter 7 we will conclude, based on the discussion in chapter 6. In addition, the authors thoughts and suggestions concerning future research on the themes of the thesis will be presented here.

2. History of research

In this chapter, the publications pertaining to the archaeological research into the ice-patches of central Norway will be accounted for. We start by looking at the earliest publications to deal with this subject, before moving on to research specific to the chrono-geographical distribution of artefacts. Here, we focus on two possible scenarios suggested by Oddmunn Farbregd as explanations for the observed phenomenon that are still central to the discourse surrounding the material today.

Through this review of the history of research, we can see that the central questions of this thesis are centred around questions that have been a part of the archaeological research on the ice-patches of central Norway for over 40 years. The importance and relevance of answering these questions are still paramount. The approach taken in this thesis is a continuation of the research already undertaken throughout the history of research into these themes, based on the numerical increase of artefacts, and methodological developments in ice-patch research in recent years.

2.1. The early publications

At the Museum of Archaeology and Natural History in Trondheim, in the annual museum catalogue describing archaeological finds recovered in 1914, an arrow-shaft with accompanying arrowhead (T.11190) is described, as is the nature of its recovery (Rygh, 1915). This publication, while brief, was the first to deal with archaeological artefacts emerging from an ice-patch context in Norway.

The remarkably well-preserved condition of the artefact is ascribed to its probable embedment within the *"glacier"* itself. That being entombed within the ice and snow can be beneficial with regards to preservation seems to have been immediately understood. The catalogue entry also makes a point out of describing the extent of the ice-patch, of which it is said that *"it has not been this small [in size] for a long time*" (Rygh, 1915, p. 32).

In the 1937 edition of the same catalogue, describing finds from 1936, two complete, fragmented arrowheads are described. An unknown number of "arrow-finds" are also mentioned, but no further information is given (Petersen, 1937).

Bjørn Hougen (Hougen, 1937), in the first volume of the journal "*Viking*", published an article on the discovery of two arrowheads and shafts from the mountain *Storhø* in Lesja. In it he ponders the curiously well-preserved condition in which the artefacts were recovered. He ascribes the preservation to the fact that the artefacts had been buried underneath layers of snow until a short time before their discovery. Their emergence is seen in relation to a series of successive warm summers, indirectly assuming that the artefacts had not previously been exposed to subaerial conditions. This represents the first journal publication of archaeological material emerging from an ice-patch context in Norway.

These early writings have much in common. They focus on the artefacts themselves, making note of the exceptionally good condition in which they were found, and attributes this to the preservative conditions within the snow and ice. Furthermore, they observe that the gradual diminution of ice-patches is a prerequisite for the discoveries. The receding snow and ice is active only in revealing the artefacts as they melt back; they exert no other forces upon the artefacts, beyond preserving them.

Knut Fægri (1938) makes use of the archaeological ice-patch material in a publication describing the annual mass balance of Norwegian glaciers. His treatment of the artefacts as indicative of the ice-patches and glaciers response to changes in climate and weather embodies much of the current focus on multidisciplinary approaches. His article was the first to consider the glaciological forces at play in ice-patches and the possible effect of these forces on the objects they contain, beyond being beneficial for preservation. The article also considers the way in which the artefacts emerge, and how this too might affect the objects themselves.

2.2. Regional chronological and geographic artefact distribution

The first publication to look at the recovered ice-patch materials at a regional level, was in 1972 by archaeologist Oddmunn Farbregd (1972). In this study, Farbregd gathered and catalogued all ice-patch artefacts that had been recovered since 1914 and turned the collection into a cohesive and contextualized archaeological dataset, that although subsequently modified and expanded upon, has been the starting point for all later archaeological ice-patch research done in the region (e.g. (Åstveit, 2007; Callanan, 2010, 2012, 2013, 2014a, 2014b; Martinsen, 2012)].

Using the ice-patch material, Farbregd constructed a typologically based chronology (see fig. 26) that mapped out the changes and developments of arrow-shafts and projectiles during the period c. AD200 – AD1700.

It was through this initial ordering of the material that the chrono-geographic patterns, of primary concern for the present analysis, were made apparent. Farbregd later reconsidered and refined his thinking on the matter in three subsequent publications (Farbregd, 1983, 1991, 2009). However, questions and hypotheses regarding observed differences in the chronological distribution of ice-patch artefacts within the Oppdal region, is a theme that runs through them all.

Farbregd observed that, when viewing the dataset for the whole region as a single unit, the chronological distribution of artefacts seemed evenly spread out; however, when the region was further divided into geographical zones, however, some interesting differences in the chronological distribution between these zones could be seen. (Farbregd, 1983, pp. 10-12)

Farbregd noted that whilst the artefacts from ice-patches in Knutshø numerically tended towards the Medieval and Historical periods, the majority of artefacts from Snøhetta East dated to the Elder Iron Age.

Table 2: Chrono-geographic distribution of artefacts from ice-patches per 1983. Adapted after (Farbregd, 1983 Fig. 2)

	Knutshø	**Snøhetta East**
Early iron age	15	18
Older iron age	4	2
Historical period	36	2

Farbregd ascribes this chrono-geographic pattern to the different nature of the patches: Steep patches, like Brattfonna and Leirtjønnkollen (Knutshø) could accommodate a greater amount of movement, causing a greater rate of material turnover. This could lead to older arrows already being removed from these patches, whilst they could be retained in comparatively flatter sites, such as at Storbreen (Snøhetta East) (Farbregd, 1972, p. 12). Such an explanation Farbregd suggests, indicates that this pattern would be unusable with regards to commenting on changes in human utilization (1972, p. 12). In order to examine this pattern further, more data was required.

In the years between 1972 – 1983, few new finds were recovered from ice-patches in the region, despite continuing survey activity. However, the artefacts that did emerge proved that the melting and processes of emergence were ongoing phenomena. This provided Farbregd with a chance to further investigate the proposed sorting mechanisms.

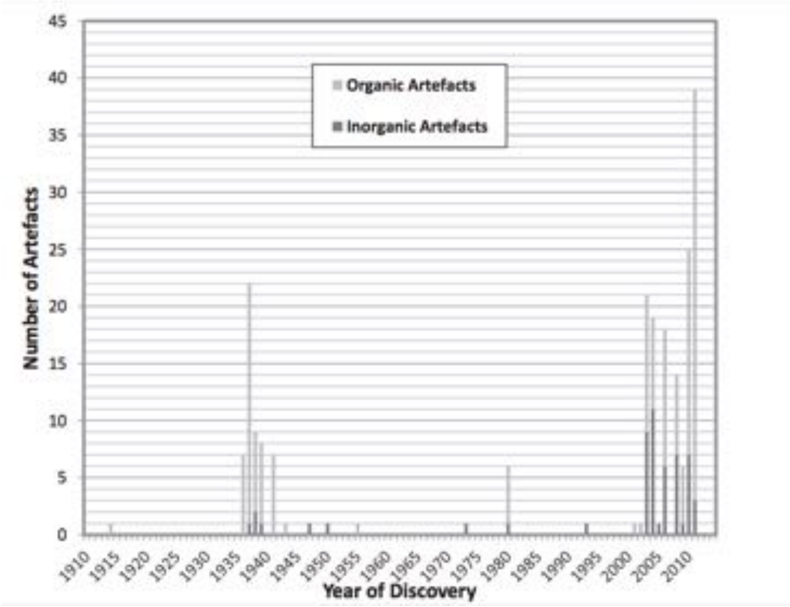

Figure 3: Overview over the year of discovery of ice-patch finds from central Norway (Callanan, 2012, Fig 5)

Based on the total amount of finds from the mountains in Oppdal, both from an ice-patch contexts and stray finds, Farbregd concluded that the chrono-geographic pattern was relatively reliable, and that the clear reduction in finds dating to the Medieval period in Snøhetta East, was an expression of "*culture historic realities"* (Farbregd, 1983, pp. 39-40).

Farbregd (1983, p. 12) proposed alternative scenarios that would result in the observable chrono-geographic distribution of artefacts:

1: The ice patches provide us with a chronologically weighted dataset, representing a source of error. The artefacts are thus not representative of the actual hunting that has occurred.

2: The relative frequency of hunting within the two areas has undergone some change with time. The differentiation resulting from this change is partially visible within the archaeological data.

In the following, for simplicity's sake, these two scenarios will be caricatured. The first will be referred to as the "*glaciological sorting*" scenario, and the second as the "*site abandonment*" scenario.

With regards to the glaciological sorting scenario, Farbregd suggested that selection processes had indeed been occurring in the ice-patches, as these had grown and retracted in response to long-term climatic developments. In relation to this, the question is raised; is it possible that arrowheads melted out during previous melting events, pre-dating archaeological surveying, might still be preserved in a recoverable state below the terminal end of the ice-patches?

Concerning the site abandonment scenario, Farbregd suggested that a transition to pitfall trapping and other "passive" hunting techniques during the late Viking age – early Medieval period, might be part of the explanation (Farbregd, 1983, pp. 35-39). He further suggested that the presence of Medieval projectiles on the ice-patches in Knutshø, was due to the fact that these sites were closer to the contemporary settlements in the valley, and that hunting continued here for purposes of supplementary income and subsistence for local farmers (Farbregd, 1983, p. 39).

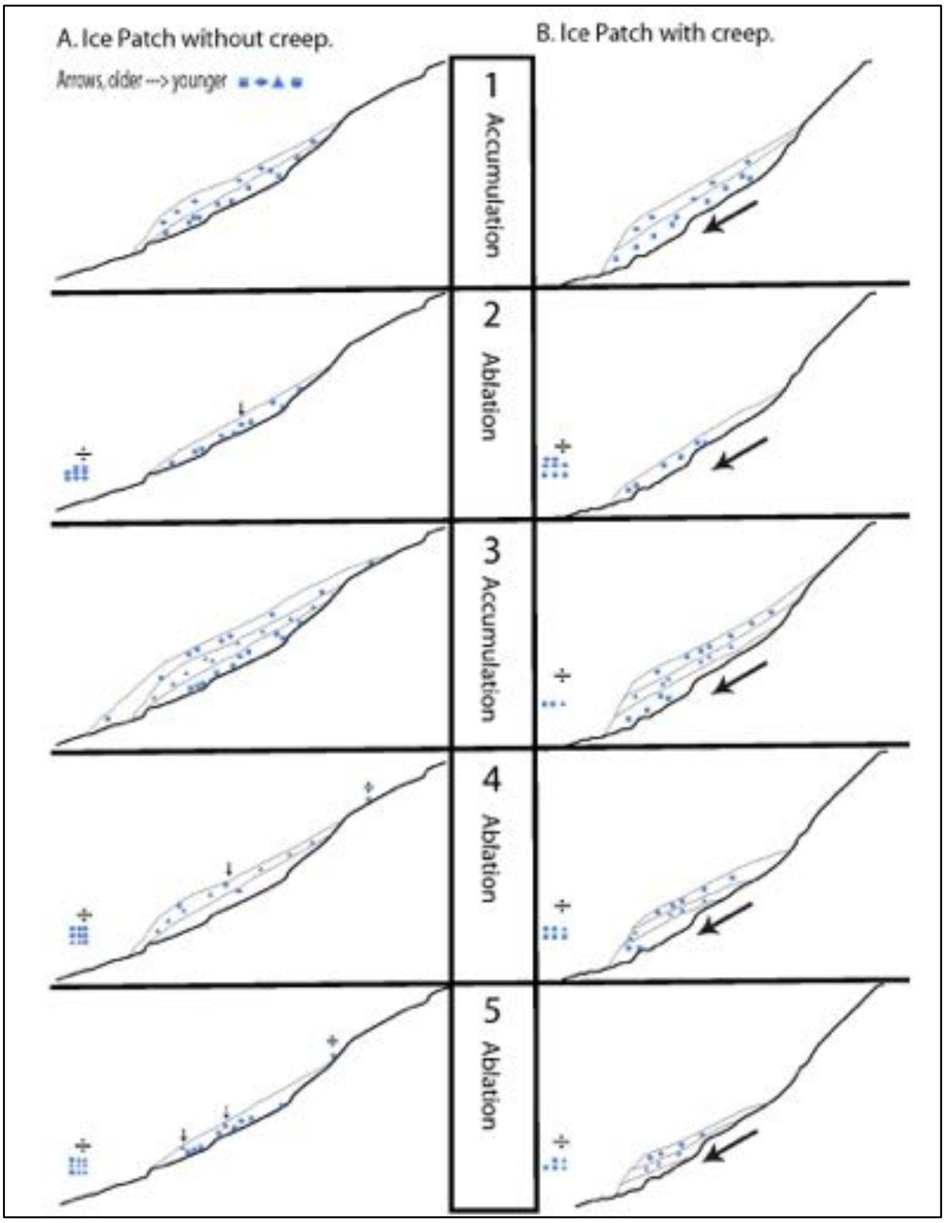

Figure 4: Potential scenarios of artefact emergence, based on ice-patch conditions. (Martinsen, 2012, fig. 6) Redrawn after (Farbregd, 1983, fig. 13)

2.3. Current status

During recovery phase 3 (2001 – 2011) a total of 145 artefacts were recovered from the ice-patches of central Norway. It is evident that we are currently experiencing an unprecedented melting event. Even though there have been years where the patches did not reduce in size and no artefacts were recovered, the general trend is clearly an overall reduction of the ice-cores on most of the ice-patches.

The current focus on global warming has undoubtedly led to a greater interest from the general and academic public alike, in anything relating to melting ice (see Carey (2007) for a discussion on the role of glaciers in a broader western academic discourse). The focus on ice-patches, and the archaeological material emerging from them, as indicators of climatic developments has long been an important focus for much of the research, even more so since the turn of the century.

The archaeological surveying of ice-patches is intimately connected to both climatic trends and year to year changes in weather conditions. Figure 3 shows the amounts of artefacts recovered from ice-patches per year since 1914. In reviewing the variance in artefact recoveries, Callanan (2012) finds that this recovery pattern is not due to reduced surveying activity, but rather it reflects the year by year conditions for melting and artefact recovery on the ice-patch sites.

Knowing where to survey, and when to do so (and when not to) has been to focus for much international research. The development of predicative models for identifying sites (e.g. (Dixon, Manley, & Lee, 2005; Reitmaier-Naef & Reitmaier, 2015; Rogers, Fischer, & Huss, 2014)) has been a focus both in the Alps and in North Amerika, an overview over available GIS tools is given by Rogers (2014). The identification of sites has enabled archaeologists in these regions to focus their surveying activity considerably. Within central Norway, we owe the initial identification and mapping of ice-patch sites to the local reindeer hunters, and the many years of searching and observation made by generations of local collectors in Oppdal. As for when to survey, there are still no good predicative models that can predict the magnitude of the yearly melting on the ice-patches.

Understanding the ways in which ice-patches respond to year on year variations in weather, and to long term climatic trends is paramount to our understanding of the role of these features as shapers of the archaeological dataset. It is also of great importance with regards to the future management of these features in the years to come. In order to efficiently salvage information from the ice-patches, we must understand the mechanisms that underlie their dynamic nature.

The mass balance of the ice-patches is very complex and not yet fully understood. The term mass balance refers to the gain and loss of ice in glacier systems (Benn & Evans, 2014). There has been much research on the subject internationally (e.g. (Fujita, Hiyama, Iida, & Ageta, 2010; Glazirin, Kodama, & Ohata, 2004; Meulendyk, Moorman, Andrews, & MacKay, 2012) ref). Nationally (e.g. (Ødegård et al., 2017)) and locally (e.g.(Rognstad, 2013)). While these results further our understanding of the factors that influence ice-patch mass balance, they are not yet substantial enough for the development of models that can accurately predict yearly melting conditions in advance.

2.3.1. The SPARC-project

The "*Snow patch archaeological research cooperation (SPARC)"* project (2011 – 2017) is an ongoing multidisciplinary research project at NTNU, involving "*archaeology, physical geography, DNA studies, conservation science and cultural heritage management" (Vitenskapsmuseet)*The unifying factor of the project is the ice-patches and the challenges surrounding these features on various levels for the different disciplines.

The project has resulted in numerous presentations and publications, from articles to MA and PhD theses. The research is primarily aimed at increasing our understanding of ice-patches, as physical features of the landscape (e.g. (Kristiansen, 2013; Rognstad, 2013; Rummel, 2013; Slåke, 2015)), as habitats and ecosystems (e.g. (Rosvold, 2016)) as indicators of climatic developments (e.g. (Callanan, 2012)) and as archaeological contexts (e.g. (Callanan, 2014b; Martinsen, 2012))

Of these publications, three are of particular interest for the present thesis. Slåke (2015) studies the landforms on Storbreen. Based on field observations and a review of glaciological literature, he suggests that the observable landforms might have originated beneath a poly-thermal glacier, and that Storbreen is not actively generating such landforms today. At present, Storbreen consists of a cold-ice-mass situated above a permafrost layer; the ice-patch currently shows zero surface velocity (Slåke, 2015, p. 10). He also notes that glacially shaped landforms can only be observed within a 30m wide belt in front the ice-patch. We will return to this in chapter 3.2.

Julian Martinsen's MA thesis in archaeology from 2012 (Martinsen, 2012) represents an attempt at directly investigating the chrono-geographic pattern with which we are here concerned. His approach is inherently multidisciplinary. By measuring changes in the internal temperature of two ice-patches in Knutshø over the course of a year, he demonstrates that these ice-patches are intimately tied to an underlying permafrost layer. Based on these results and a thorough review of the glaciological literature on the theme, he hypothesises that differences in the altitude between the ice-patch sites of Knutshø and Snøhetta East might have resulted in differing sorting processes being present in the two zones during warmer periods in the past. He concludes that "*... sorting processes do take place within ice patches. Gaps in the archaeological record can be the result of ice patch conditions and processes in the past rather than changes in human use of the site*s" (Martinsen, 2012, p. 71). This conclusion is later repeated in a subsequent publication (Martinsen, 2016, p. 70).

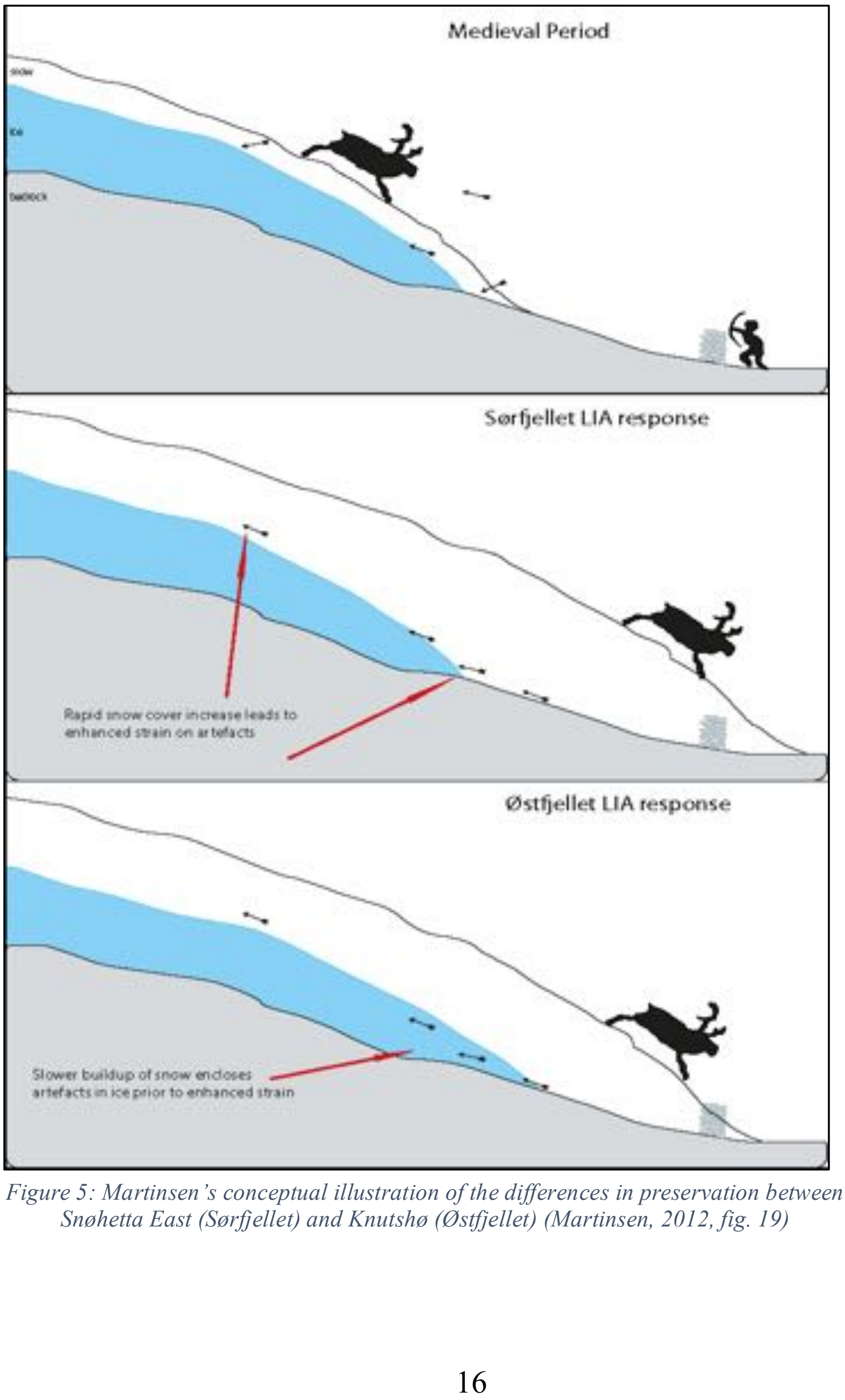

Figure 5: Martinsen's conceptual illustration of the differences in preservation between Snøhetta East (Sørfjellet) and Knutshø (Østfjellet) (Martinsen, 2012, fig. 19)

Martin Callanan (Callanan, 2014b) gives a comprehensive overview over the status of the ice-patch research in central Norway up to 2011, both with regards to the history of research and the present situation. His analysis of the 2011 dataset serves to further cement the chrono-geographic pattern between Knutshø and Snøhetta East. It is this updated dataset that serves as the basis for the themes discussed in the present thesis. The graphical presentation (see Figs 6 and 7) serves as a potent illustration of the differences between to two areas. (Note that Fig 7 is showing finds from Knutshø during recovery phase 3 only, including metal-detector finds, while Fig. 6 shows the finds from all recovery periods in Snøhetta East).

As stated above, Farbregd suggested that sorting processes might lead to a scenario where chronological groupings currently "missing" form certain ice-patches might have emerged during previous melting events, and subsequently been buried below the terminal end of the patches. Furthermore, it is suggested that such artefacts be recoverable, by means of specialised surveying (Farbregd, 1983, p. 15). Artefacts from the Historic periods from Snøhetta east was one such "missing" group. Another was artefacts from ca. AD600-800.

The introduction of metal-detectors in ice-patch surveying, one of the defining characteristics of recovery phase 3, resulted in the recovery of five arrowheads from AD600-800 from ice-patches in the Knutshø Zone (Callanan, 2014b, p. 123). It remains uncertain, however, whether these artefacts did indeed emerge during melting events predating archaeological surveying or not, and when this possible melting event might have occurred.

In total, 34 of the 81 artefacts recovered from the Knutshø zone during recovery phase 3 were fund using metal detectors (Callanan, 2014b table 7.8).This demonstrates the usefulness of metal-detectors in ice-patch surveying. Metal-detectors can observe artefacts that would otherwise be unobservable during visual surveying for objects on the surface. However, the manner in which the metal-detector surveying in Knutshø was carried, has not been described in detail. The arrowheads recovered from Knutshø, especially those dating to AD600-800, demonstrates that the chronological distribution of the ice-patch material can be altered by the inclusion of metal-detectors in the archaeological surveying on these sites. The large number of finds recovered with metal-detectors from Knutshø also lends credence to the assumption that there might be previously unobservable arrowheads present at Storbreen.

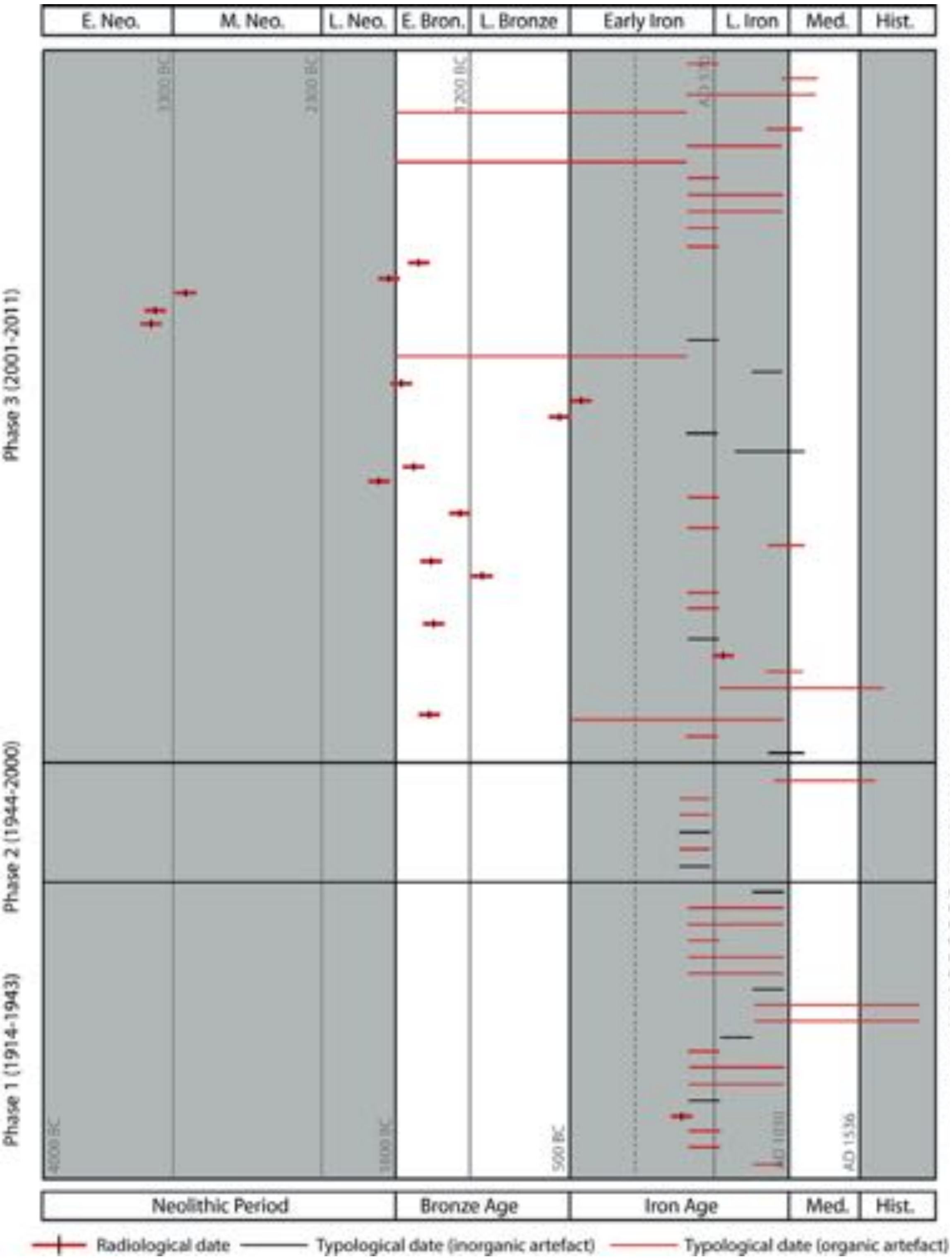

Figure 6: Chronological overview of all dateable finds from Snøhetta-east during all Recovery Phases. (Callanan, 2014, table 7.7)

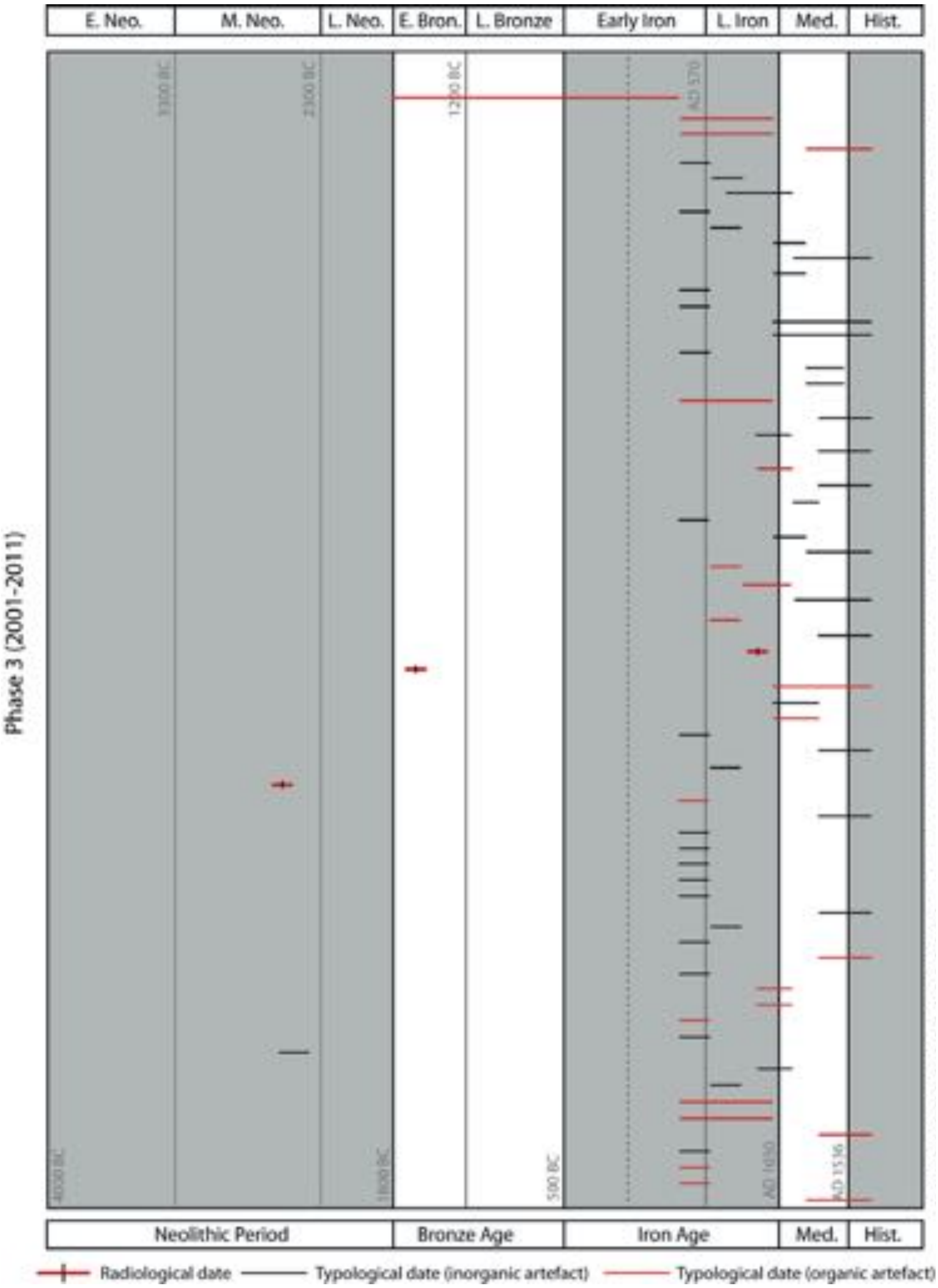

Figure 7: Chronological overview of all dateable finds from Knutshø during Recovery Phase 3. Metal-detector finds included. (Callanan, 2014, table 7.10)

2.3.2. Chronological gaps in ice-patch material outside Central Norway.

Chronological gaps in archaeological ice-patch material is not unique to central Norway. An interesting example is the Schnidejoch ice-patch site in the Swiss Alps (Grosjean, Suter, Trachsel, & Wanner, 2007; Hafner, 2012). The site is located within a transportation corridor, allowing access to the Northern Alps, from Northern Italy. During periods of glacier growth, the ice-mass is considered to have significantly impeded movement of peoples across the pass. Gaps in the archaeological material from the site at Schnidejoch were investigated in relation to these fluctuations in glacier extensions: *"In the light of the large number of dated artefacts the separation of the age cohorts is noteworthy and reflects periods of glacial advance, i.e. times when the route was very difficult to transit"*(Grosjean et al., 2007, p. 206).

With regards to the ice-patch material from central Norway, there are currently no data indicating such a direct relationship between periods of glacial advance and the absence of people on the ice-patches. Rather, the tradition for hunting on these sites seems to have been consistent throughout fluctuations in climatic developments. The differences between central Norway and the Alps in this regard, is probably related to the different activities undertaken at the sites (see Reckin (2013) for an extensive elaboration on these themes, in a global perspective).

In southern Yukon, the dating of archaeological artefacts from ice-patches revealed another interesting chronological pattern; the abrupt transition in projectile technology, from atlatl to bow-and-arrow at around 1200 BP(Hare et al., 2004). The current interpretation of this transition, links the technological shift to the volcanic eruption of Mount Churchill, and the subsequent White River ash fall (Hare et al., 2004; Hare, Thomas, Topper, & Gotthardt, 2012).

Again, we have no parallel to this, which can explain the situation within central Norway. The eruption pf Samalas in Indonesia might have caused crop failures around the middle of the 13th century (see Dybdahl (2016) with references to (Lavigne et al., 2013)) but the impact of this eruption on conditions in central Norway is nowhere near that of the White River eruptions effect in the south of Yukon. It might have had an impact on the weather conditions in the years following it, but it is unlikely that this would have impacted the two bordering zones within central Norway differently, to the degree that the relative hunting frequency between them would be altered.

2.4. Summary

As we have seen, the difference in the chronological distribution of artefacts between Snøhetta East and Knutshø has been part of the academic discourse surrounding the ice-patches in central Norway since made apparent by Farbregd's initial analysis of the ice-patch material on a regional scale, in 1972 and 1983. The chrono-geographic pattern has been solidified by the artefacts that have been recovered since then, and by later research, especially Callanan's analysis of the material up to 2011.

The origin for the chrono-geographic pattern is still not fully understood. Martinsen has suggested that the conditions for different sorting processes on the ice-patches of Knutshø and Snøhetta east might have been present in the past, due to variations in altitude between the two areas, and that this might have resulted in the current pattern.

The multidisciplinary approaches taken since the turn of the century have served to increase our understanding of ice-patches as natural phenomena, and the manner in which glaciological processes might impact the archaeological data. However, we are not yet at a point were our understanding of these glaciological processes enable us to formulate conclusive statements about the archaeological material.

Despite the new discoveries of artefacts and the emergence of multidisciplinary approaches, the persisting question regarding the chrono-geographic pattern in the region, is fundamentally an archaeological question that should be investigated using suitable archaeological surveying methods. Answering the question of whether or not there are iron arrowheads buried below ice-patches in Snøhetta East will be of interest to different disciplines, but it is a question which can only be investigated through specifically targeted and designed surveying by archaeologists in the field.

3. Presenting the case

In this chapter, we take a closer look at the specific case of the Storbreen ice-patch. In addition to the situation on Storbreen with regards to the archaeological material, the ice-patch itself, as well as the landscape to which it relates will be presented.

3.1. Why Storbreen?

Storbreen has a prominent place within the research history of ice-patch archaeology within central Norway. As accounted for in chapter 2, the hypotheses surrounding the chrono-geographic pattern directly relates to this ice-patch, and the way in which it contrasts the numerically dominant ice-patches of the Knutshø zone.

A mentioned in chapter 1.1, Storbreen is one of the most productive ice-patch site within central Norway, with a total of 48 artefacts recovered from the site up to 2011, accounting for 21% of the total amount of finds from the region. Viewing Snøhetta East in isolation, Storbreen accounts for 48 out of 91 finds – 53% (see table 3). This numerical dominance, lends credence to the assumption that Storbreen is the most likely candidate for the recovery of arrowheads from the Medieval periods as well.

Table 3: Artefacts recovered from ice-patches in Snøhetta East up until 2011.
(Callanan, 2014, table 7.6)

	Phase 1	*Phase 2*	*Phase 3*	*Data lost*	*Total*
Storbreen	16	2	28	2	48
Løpesfonna	1	1	16		18
Løftingfonnkollen			2	1	3
Tverrfjellet		1	2		3
Vegskardet		1	3		4
Hesthågåhøa	1				1
Snøhetta		1			1
Kaldvellkinn			3		3
Skiråtangan, Sunndal			1		1
Råstu, Sunndal			1		1
N. Svarthammaren, Sunndal			1		1
Gravbekkfonna			1		1
Namnlauskollen			1		1
Kinnin			1	1	2
Skirådalskardet			1		1
Svartdalskardet			1		1
Håråkollen			1		1
Totals	**18**	**6**	**63**	**4**	**91**

Based on the numerical dominance of the site, the ice-patch is treated here as representative of the whole zone. It should, however, be noted that even if Medieval artefacts were to be recovered from other sites within Snøhetta East in the future, the fact that Storbreen seems to be abandoned would still be very interesting in its own right.

Within the context of this thesis then, Storbreen is viewed as representative of Snøhetta East, and the two terms are used somewhat interchangeably. In other words, when we make statements regarding Snøhetta East, we are here primarily doing so based on the situation on Storbreen.

3.2. Physical properties and location

Storbreen is a mass of cold ice, probably frozen to a permafrost layer, showing zero surface velocity (Slåke, 2015, p. 10). The ice-patch is located within the *Dovrefjell-Sunndalsfjella National Park* at 6914633N – 521143E (EU89, UTM-32), south east of the peak Namnlauskollen (1862m a.s.l). In terms of elevation, the ice-patch stretches from approximately 1730m a.s.l to 1850m a.s.l along its east-west axis. The lower limit of permafrost in on Dovrefjell has been documented to be around 1300m a.s.l on exposed sites (Sollid, Isaksen, Eiken, & Ødegård, 2003). From north to south, the site is approximately 1km long. The ice-patch has an average incline of about 23.5 degrees, with geo-radar surveying showing the ice-core on its southern part to be c. 15m deep. (Slåke, 2015, pp. 7-10)

The age of the ice-core has not been dated by means besides the proxy-data provided by the archaeological artefacts. The oldest artefact from Storbreen, T.25674 date to 3456BC. On Juvfonna in Oppland, ice layers on the bottom of the ice-core has been dated to ca. 7600 calBP (Ødegård et al., 2017, p. 17). It is not unlikely that the lower layers of the ice-core on Storbreen is of a comparable age.

Some years, Storbreen is divided into two parts, as the centre part of the patch completely melts away (see fig. 11), while other years, the two parts remains conjoined (see fig. 10). The partitioning of Storbreen has been observed since 1927, it was commonly divided during the 1970s -1980s (Farbregd, 1983, p. 19) and is due variations in annual weather conditions which affect the ice-patch, as well as climatic developments.

Slåke's (2015, pp. 43-49) investigations into the landforms below Storbreen, showed that these features were limited to a 30m wide belt. Although the area in front of Storbreen is covered in moraine deposits (Slåke, 2015 fig 2.4), there are no moraine features present, which can assist us in determining the former extent of the ice-patch, during the Little Ice Age (LIA) maximum, for example.

Figure 8: View from the top of Storbreen, looking east. Photo: Einar Kristensen

3.3. Archaeological material from Storbreen

The archaeological material from Storbreen characterizes the ice-patch as a hunting site, based around the use of hand bows. The material consists almost exclusively of projectile points and arrow shafts, as well as a few bow-fragments. The archaeological material recovered from Storbreen, from 1914 and until 2016 is presented in its totality in Appendix B.

Up to 2014, a total of seventy archaeological finds originate from Storbreen. Fifty of these have been dated, 14 by radiometric dating and 35 typologically. The single largest chronological grouping is the Migration Period, AD400-600, with 25 artefacts typologically dated to this period. The oldest find so far is (T.25674) is a slate point with accompanying shaft, dated to 3456BC.

No structures, such as hunting blinds or pit-fall traps, have been identified in the immediate area surrounding Storbreen, nor have any sewels (scaring sticks) been recovered. It seems, so far, to be a strictly bow-and-arrow based hunting site.

Table 4: Number of artefacts recovered from Storbreen up to 2014, sorted by year of recovery

Year of discovery	Number of finds
Data lost	2
1936	2
1937	8
1941	6
1950	1
1955	1
2006	2
2008	3
2009	1
2010	10
2011	12
2013	15
2014	7
Total	**70**

Figure 9: Aerial photograph of Storbreen, taken on 14.09.2009. Retrieved from www.norgeibilder.no on 01.05.2017

Figure 10: Aerial photograph of Storbreen, taken on 16.09.2014. Retrieved from www.norgeibilder.no on 01.05.2017

4. Methodology & fieldwork

In order to examine the main research questions posed in Chapter 1.1, a field survey was planned and carried out over two field seasons. The aim of the fieldwork was to answer research question 1; *"Are there comparatively fewer Medieval arrowheads in Snøhetta East compared to Knutshø?",* by investigating the hypothesis that artefacts from the Medieval period might still be recoverable in front of the terminal end of the Storbreen ice-patch.

The data provided by this survey adds to our understanding of ice-patches as archaeological contexts, and sheds light on the main research questions of the thesis. The results are also important for the continuing discussion about what the ice-patch dataset represents, and for our understanding of the origins of the chrono-geographic pattern on a regional scale.

As described in Chapter 2.2, Farbregd presented a hypothetical scenario whereby artefacts from more recent periods might have been sorted out by some of the ice-patches and rendered unobservable to visual inspection. He further suggested the possibility that some of these artefacts might have survived, having been buried in the run-off silt and muck from the ice-patches. But that by means of a *specialized survey* these artefacts might still be recoverable (Farbregd, 1983, p. 15). This proposition is echoed in later literature, (e.g. (Åstveit, 2007, p. 14)). If artefacts have been preserved and subsequently buried in front of the ice-patch then the Medieval period should be overrepresented within this material grouping. The fieldwork presented in this chapter was carried out in order to complete the specialized survey suggested by Farbregd, by way of a structured metal-detector survey.

This chapter accounts for the methodological approaches to the survey, as well as the surveying as it occurred in the field. The methodological choices made and the equipment utilized will be presented. Additionally, the surveying framework that was developed for the purposes of this fieldwork will be described, and its merits discussed with regards to improvements for future metal-detector surveying activity.

4.1. Timeframe and participants

In total, the fieldwork lasted for ten days, stretched out over three sessions, and two field-seasons in 2015 and 2016. 4,5 days were spent actively surveying the site, whilst the remainder were used for transportation to and from the ice-patch. The season for archaeological surveying on ice-patches is usually limited to August and September. This is the period in which the ice-patches are in the most contracted state of their annual cycle, after a summer of melting but before snow starts falling again in the late autumn.

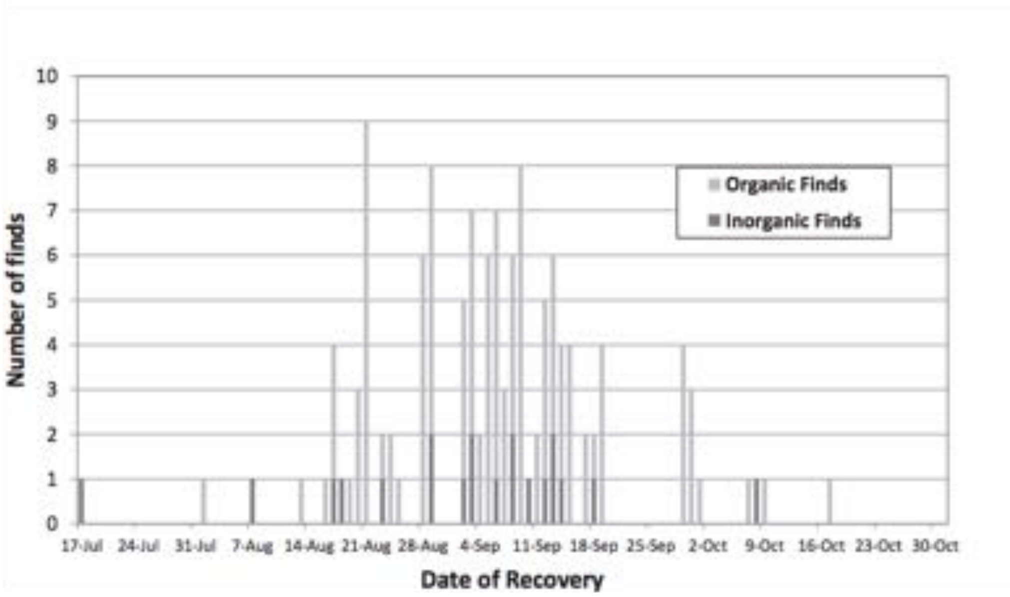

Figure 11: Date of recovery for ice-patch finds in central Norway (Callanan, 2014, fig. 3.6)

As previously mentioned, the year to year recovery pattern of artefacts is dependent on yearly weather patterns, and therefore difficult to predict in advance. Some years the ice-core on the ice patches remains covered by snow for the majority of the melt season. Other years, the old ice is exposed, and artefacts emerge. In 2012, for instance, there were no new artefacts recovered from Storbreen (see chapter 3.3), and in 2015 no finds were made other than the ones from the present metal-detector survey.

Initially it was considered that because we would be surveying the area in front of the ice-patch, looking for artefacts previously emerged, the metal-detecting survey could be initiated earlier than the usual visual inspections. The season of 2015 was, however, characterized by an abnormal amount of persistent snow in the mountains throughout Norway.

Two inspection trips were undertaken in the pre-season of 2015 to assess the conditions on the ice-patch. These trips did not leave us optimistic with regards to an early start to the 2015 season.

For the first inspection on 18.07.2015, we were unable to even approach the site (see fig 14) due to the extent of the late-lying snow. During the second inspection trip, on 01.08.2015 (see fig 15), there was still considerable amounts of snow present on the site, but we could make a close approach and get a first impression of Storbreen.

Figure 13: Eirik Kristensen in front of Storbreen (concealed by fog) on 18.07.2015. Photo: Einar Kristensen

Figure 12: View towards Storbreen on 01.08.2015. Photo: Einar Kristensen

The methodology to be employed for this metal detector survey was not dependent upon advanced melting conditions exposing the old ice-core on the patches, or indeed on new artefacts appearing on site during the project period. However, the weather conditions during 2015 were disruptive to the planned execution of the fieldwork. This demonstrates some of the challenges involved with surveying of high alpine archaeological sites, such as ice-patches.

One of the major challenges with carrying out a fieldwork of this magnitude within the framework of a MA-thesis is the lack of a budget. This fieldwork relied on voluntary labour, and whilst there was no shortage of fellow students interested in joining project, the field-season is short, hectic, and, unpredictable due to the need for favourable weather conditions. In addition, there are requirements to physical health and personal equipment. In the end, the project was carried out by the author with one field assistant (see table 5), except for the last trip on 28-30.08.2016 which EK undertook alone, in order to survey the last remaining part connecting zones A and B.

Table 5: Participants during the fieldwork, 2015 & 2016.

Name	Role	Date	Initials
Einar Kristensen	Field leader	Whole project	EK
Martin Callanan	Field assistant	29.08.15-31.08.15	MC
Andreas Alsaker	Field assistant	15.08.16-18.08.16	AA

4.2. Equipment

"…consumer grade technologies (e.g., GPS and Google Earth) have proven to be less costly and more time- and energy-efficient than professional-grade options such as total stations, GPR, or LIDAR. The potential cost of lower resolution data obtained from these technologies is outweighed by the ability both to transport the equipment into the mountains by foot and to cover more ground with highly reliable equipment performance."(Stirn, 2014, p. 8)

The quote above sums up the criteria by which equipment was chosen for this survey. Lightweight, robust and functional equipment, with which the surveyors had previous experience, was prioritized. In addition, equipment running on of-the-shelves batteries was favoured over those requiring rechargeable alternatives; all the electronic devices utilized ran on standard AA-batteries. This meant that we could reduce the number of back-up batteries carried. On surveys such as this, where everything must be carried to the site in backpacks, every gram counts.

We also opted for a low-tech approach, relying on analogue gear as much as possible. The only electronics used, in addition to the metal-detectors, was a Garmin Oregon 450 handheld GPS device, and digital cameras. The rest of the equipment required for this field survey were two 50m tape-measures, some high-visibility masons line, and plastic road markers which served as surveying poles. Two models of metal-detectors were used; *White's MXT*, and *White's Spectrum*.

In addition, of course, we had to carry all the personal equipment needed for spending a prolonged period of time in the mountains. Due to the unpredictable nature of the high-altitude environment, we carried enough food for three extra days on each trip, as a safety precaution. Good tents, warm sleeping bags and sleeping mats are important, as the temperatures can drop to below freezing at night, even during the main melting season.

Figure 14: Heavy but manageable backpacks. Photo: Andreas Alsaker.

4.3. The use of metal detectors

"Arrows which melted out of snow patches in earlier stages have usually ended up some distance away from today's minimal melting fronts. Their organic parts have withered or rotted away. Iron arrowheads my, however, be spotted and retrieved with metal detectors."(Farbregd, 2009, p. 168)

Metal-detector surveys have been included in archaeological investigations on ice-patch sites both in Norway(Callanan, 2012; Wammer, 2007, p. 15) and in the Alps (e.g. (Hafner, 2012) (Bezzi, 2014)). On sites where one could expect metal objects, such as arrowheads, coins, and so on, integrating metal-detectors into surveying can be a time- and cost-efficient way of expanding the capabilities of the survey, with regards to observing such artefacts. The lack of top-soil in these high-alpine environments makes metal-detectors particulary effective with regards to artefact recovery, as there is mostly no need to excavate in order to retrieve the finds. Usually it is simply a matter of locating the metal object amongst the boulders, stones and gravel in the area. A handheld *pinpointer* device was brought along for the survey, but it proved to be unnecessary

The introduction of metal-detectors has been one of the defining features of recovery phase 3, in central Norway. The metal-detector finds from phase 3, stem from five ice-patches, all located in the Knutshø zone: Leirtjønnkollen (12 finds), Brattfonna (11 finds), Kringsollfonna (6 finds), N. Knutshø (4 finds), and M. Knutshø (1 find). On these sites, metal

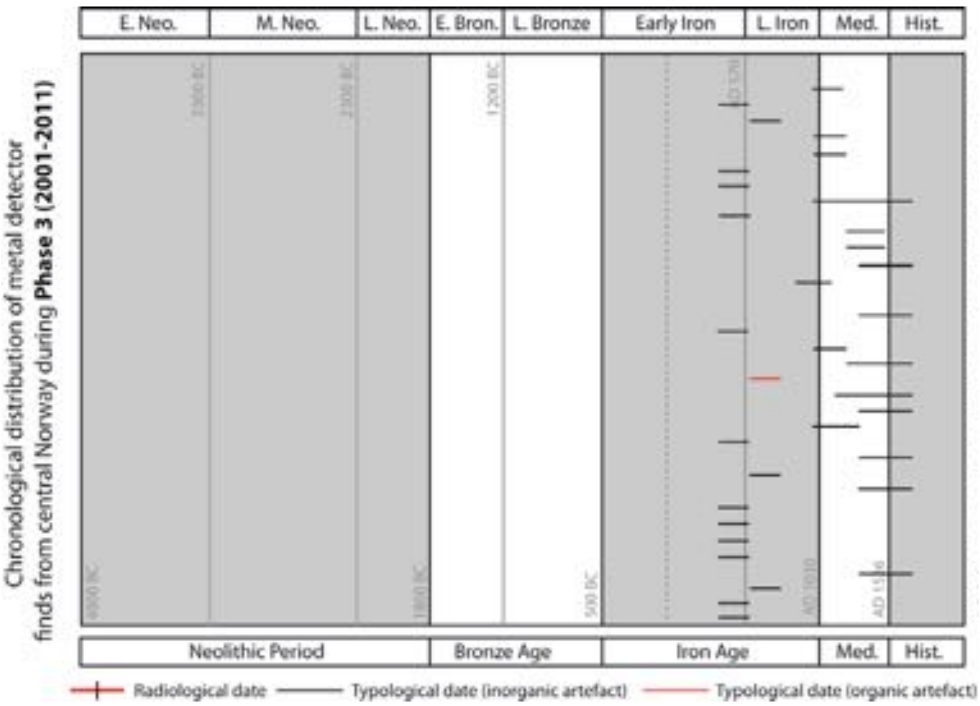

Figure 15: Chronological distribution of metal-detector finds from central Norway during recovery phase 3 (Callanan 2014, table 7.4)

arrowheads have been recovered up to 50m away from the ice-patches annual minimum extent (Callanan, 2012, p. 186). The chronological distribution of these metal-detector finds can be seen above, in Figure 16.

The finds from Knutshø demonstrate that artefacts from the Medieval period have survived prolonged deposition outside the ice-patch with a degree of preservation that renders them observable to metal-detectors. Based on this information, the prognosis for the recovery of artefacts dating to the Medieval period on sites such as Storbreen was viewed as promising, and it was decided that a metal-detector survey would be suitable for the purposes of carrying out the specialized survey as suggested by Farbregd.

4.3.1. Field testing the metal-detectors

To supplement the promising results from the use of metal-detectors in the Knutshø zone and other sites, a field-test of the chosen metal-detectors was carried out. This field-test demonstrated the capabilities of the metal-detectors to observe artefacts under real-life conditions at Storbreen.

Figure 16: Field-testing the metal-detectors. Photo: Andreas Alsaker

The test consisted of burying a replica iron arrowhead at increasing depths, covering the burial site with rocks, and then sweeping the metal-detectors over the site. Both metal-detectors were equipped with a "pinpoint" function that enables the operators to more accurately determine the location of an object. While in "pinpoint-mode" the detectors display gives an indication of the depth at which an object is buried, and it also attempts to identify the kind of metal the object is made of. This information is also given by way of varying audio-signal feedback.

The MXT-pro gave relatively accurate depth measurements and identify the material of the replica arrowhead, when the artefact was buried at 16cm depth, with fist-sized rocks on top. The Spectrum also gave a clear signal at 16cm, but a faulty display meant that we could not check the depth and material readings. However, the audible feedback was unmistakeable and consistent every time the coil was swept over the test-pit. The results of the testing increased our optimism in this regard, as both metal-detectors were capable to observe the replica arrowhead down to 16cm. This depth was deemed satisfactory with regard to demonstrating the capabilities of the metal-detectors, in line with the aims of the survey. Seeing as how both detectors gave strong and consistent feedback down to 16cm, this depth does not represent the maximum extent of their capabilities, rather it serves as a good minimum benchmark; we now know that the instruments can observe artefacts buried at least up to 16cms depth.

Table 6: Results of field-testing the metal-detectors

Depth	Spectrum	MXT-Pro
7 cm + rocks	Clear signal	Clear signal, reading: 4 inches, iron
11 cm + rocks	Clear signal	Clear signal, reading: 5 inches, iron
16 cm + rocks	Clear signal	Clear signal, reading: 6 inches, iron

Figure 17: EK checking and logging the depth readings on the MXT-Pro.
Photo: Andreas Alsaker

4.3.2. Practical experience and observations on the metal-detectors

The MXT was operated in the "relic mode", with the discrimination (dual control) setting set to the lowest value, resulting in no discrimination at all. The dual control setting enables the surveyor to program the device in question to filter out certain metallic signatures. This is useful if one is surveying for coins in park-areas, for example, and do not want the detector to react to the presence of iron (nails) or aluminium (pull-tabs). The Spectrum ran on a user-made program designed for use on archaeological surveys, this program also set discrimination to a minimum. As we were primarily expecting to find iron objects, we had no need to discriminate anything out.

The "TRAC-switch" was set to the "ground" position for the most part, activating the MXTs automatic ground-balancing feature, enabling the device to automatically react to minor changes in background conductivity levels. The Spectrum device did not have this feature, and had to be reset on occasion, in order for proper ground-balance to be achieved. Without proper ground-balance, the devices are more prone to giving false signals due to hot-rocks. Having an automatic ground-balancing feature was advantageous, as the machine was better able to deal with the rapid changes in the magnetic composition of the rocks, causing less interference with the surveying, and less irritation on behalf of the surveyor.

Figure 18: "Overload rock". Photo: Einar Kristensen

The "Gain-control" was set to the recommended pre-set value, with only minor adjustments made underway. The Gain-control switch enables the operator to adjust the signal-strength of the device. Higher signal strength enables the metal-detector to "look" deeper into the ground, however, it set too high the frequency of fake signals increases, as does the probability that the device will "Overload". Overload is a term used to describe what happens when the strength of the signal is of a magnitude that overloads the systems capabilities for accurate metal identification and depth readings. Certain mineralized rocks did cause this to occur, especially within Zone A.

It is strongly recommended to use headphones while surveying, as they enhance the readability of the audio feedback of the detectors and isolates out other distracting sounds, and also increase the life-time of the batteries that power the devices. Over-ear headphones with a built-in volume regulator were the most comfortable during long sessions, but this is down to personal preference.

It is also advantageous to have length-adjustable metal-detectors, so that the devices can be customized to the operator. It was found that adjusting the length of the devices during surveying could to some degree prevent muscle fatigue, as such changes alter the sweeping pattern. Being somewhat ambidextrous also helps in this regard.

4.4. Delimiting the survey area

Before surveying could commence, the area to be surveyed must be delimited. Based on the data published by Callanan (2014b), the spatial distribution of artefacts up to and

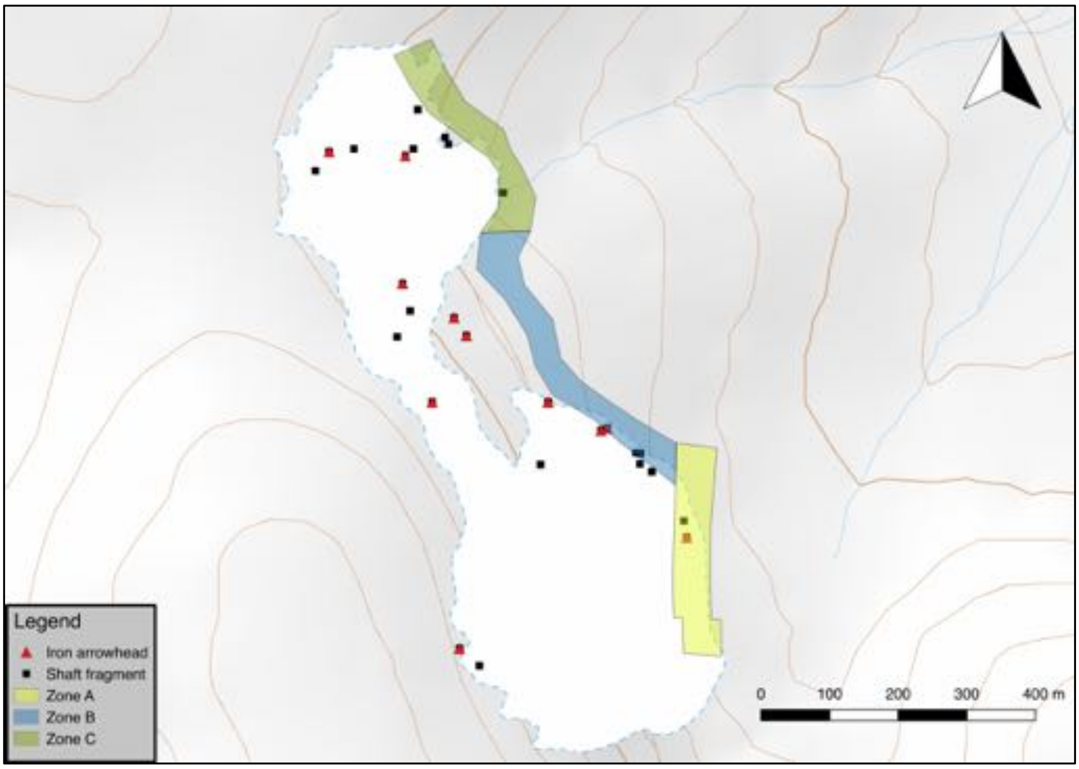

Figure 19: Surveyed area, based on the spatial distribution of artefacts recovered up to and including 2011

including 2011 was mapped out. The artefacts recovered farthest away from the ice-patch served as the starting point for the metal-detector survey (see fig 19). In addition to this, the extent of the ice-patch itself, as it appeared in 2015 and 2016 served as a limiting factor. These two factors were the most important with regards to determining the western boundary of the survey, towards the ice-patch. As can be seen in Fig 19. the artefacts recovered up to 2011 adhere to a relatively narrow corridor, extending outwards from the annual extent of the ice patch, as this varies from year to year. This corridor has been thoroughly surveyed by visual inspection over the years. Including a portion of this visually surveyed corridor in the metal-detector survey, would potentially give grounds for assessing the effectiveness of the visual surveying, should a large number of artefacts be recovered by the metal detectors.

The eastern delimitation of the survey, moving away from the ice-patch, was based assessments and observations made in the field. As stated above, the surveying with metal-detectors in the Knuthsø zone had demonstrated that artefacts on these sites had been deposited up to 50m away from the ice-patches. Based on estimates of what could be accomplished within the timeframe available, when inspecting the conditions on Storbreen in person, it was elected to extent the survey to cover a 60m wide corridor, along the entire north-south axis of Storbreen.

4.5. In the field

Figure 20: Footprints in the snow reveals surveying pattern (31.08.2015). Photo: Einar Kristensen

We started by laying out two 50m tape-measures parallel to each other at 60m apart, with allowance for some variation where the terrain demanded it. A high-visibility guideline was then stretched out between the ends of the two tape measures, at the two-meter mark.

Two surveyors then walked towards each other on opposite sides of the guideline, each sweeping a two-meter wide corridor with a metal-detector. Once both surveyors reached the end of the corridor, the guideline was lifted and moved four meters along the tape-measures. This process was repeated until the entire 50mx60m (3000m^2) rectangle was surveyed. These rectangles constituted the basic unit within the present surveying framework.

The time usage for surveying some of these units was logged. On average, it took approximately 1h 15m to survey one unit (see table 7), though the time used varied greatly depending on whether any artefacts were recovered and on the ground conditions. The time logged does not include setting up the tape-measures and guideline. Once one unit was surveyed, another one was laid out starting from the end of the first. The orientation of the units was determined by a mix of compass direction and the edge of the ice-patch. Generally, surveying snow covered areas more than necessary was avoided.

Zone A was surveyed by EK and MC during the season of 2015 from 29.08-31.0. In total 1,5 days were spent surveying. During the first session of 2016, from 15.08-18.08, EK and AA surveyed the entirety of Zone C, and the majority of Zone B. Additionally, the snow free corridor which almost divides the northern part of the ice-patch in two (see fig 27) was surveyed during this session. This area was surveyed "free-hand", without the guideline system, as an experiment. It turned out it was exceedingly difficult to keep track of where we had and had not surveyed, when operating in this manner. It can therefore not be claimed that we generated any negative evidence (see chapter 5.4), from this experimental surveying.

The last portion of the surveyed area, connecting Zones A and B, was surveyed by EK alone, during the third and last surveying session, from 28.08 – 30.08.2016. The surveying was less time-efficient when operated by a single surveyor, but the surveying framework was functional during solo-surveying as well.

In the introduction to this chapter, it was stated that a total of 4,5 days was spent surveying. It must be clarified, that these are not normal working days. Rather, surveying started immediately after breakfast, and lasted until sunset, which occurred around 21:30. The numbers in table 7, therefore, represents a more accurate basis, around which future surveying time requirements can be estimated.

4.5.1. Weather conditions

The dates for the trips were primarily planned around the long-term weather forecasts, as good weather is a key factor for successful and efficient surveying, and beneficial with regards to safety and morale. The weather can change fast in the mountains, and the severity of bad weather increases with remoteness and altitude. We did experience some fog during the morning of 16.08.2016, and on the last trip some light rain and sleet occurred, but not of a severity that influenced surveying.

The fog can get quite severe on Storbreen (see figure23). During arrival on 15.08.2016, we had to resort to the GPS-device on approaching the camp site. Since, however, we were prepared for such an eventuality, this gave no cause for concern. The tent used is highly visible, and the campsite was logged on the GPS-device in order for us to be able to get back, should the fog return while surveying was ongoing.

Figure 21: EK navigating to the camp-site using the handheld GPS device (15.08.2016)
Photo: Andreas Alsaker

The only weather related issue that interfered directly with surveying was sun exposure. The landscape around Storbreen offers no shade, and on 17.8.2016, after long session of surveying on a cloudless day, EK and AA had to take a mid-day siesta, reapply sunblock, and rehydrate for a while.

The fact that the weather was favourable during the entire survey, and did therefore not impede with the execution of the surveying, should be taken into account with regards to the time used per surveyed unit.

Table 7: Recorded sample of time-use per surveyed unit.

Time used	Objects recovered	Date	Comments
1h23m	No data	30.08.15	Many “hot-rocks”
1h28m	No data	30.08.15	Many “hot-rocks”
1h58m	No data	30.08.15	Many “hot-rocks”
55m	0	16.08.16	Foggy weather
45m	0	16.08.16	
1h12m	1	16.08.16	Difficult terrain
31m	0	16.08.16	Reduced area
52m	0	17.08.16	
1h29m	1	29.08.16	1 surveyor
1h50m	2	29.08.16	1 surveyor
1h6m	0	29.08.16	1 surveyor
1h47m	2	29.08.16	1 surveyor
52m	0	29.08.16	1 surveyor

4.6. Documentation and find treatment

The documentation of the finds was done by logging their position on the handheld GPS device, and photographing the finds *in situ* on a micro and macro level. The surveyed area was mapped by logging the coordinates of the corners of each surveyed unit. The satellite reception on the Storbreen site was generally good. The handheld GPS device provides an accuracy reading for each logged point; this never exceeded 3 meters, and was mostly within 2 meters. This level of accuracy was deemed sufficient with regard to the aims of the survey. Accuracy could potentially be increased by bringing more accurate measuring equipment, but such gear is weighty and bulky, and has higher demands in terms of reception. Cell-phone reception was limited to specific areas of the site, and the quality radio-signal reception was unknown. Satellite coverage sufficient for handheld-GPS devices was known to be present, based on previous fieldwork in the region, and it was also tested for the Garmin Oregon 450 specifically based on the recon-trips undertaken prior to the fieldwork.

The circumference of Storbreen was logged on 31.08.2015 and 16.08.2016, by using the track-logging function of the handheld GPS-device. This was done to provide an as accurate as possible reference point for the logged coordinates of the artefacts and objects recovered. The written account attempts to contextualize the artefacts in relation to distance from the ice-patch edge, but this information is more accurately obtained from the GPS-logged information. The approach to the site was also logged in the same way, as a safety precaution.

Care was taken to provide sufficient photographic documentation of the finds. This includes photos on micro and macro levels. It is important to document the finds in-situ, and if possible show the relation of the finds to the ice-patch. This latter information is, however, more accurately obtained from the geo-referenced data. Good photographic documentation, the GPS coordinates, and written descriptions of the artefacts deposition and condition, is the extent of the meta-data we currently generate for the ice-patch artefacts. This helps with contextualizing them, and preserves the information of their recovery for future research.

Once documented and mapped, the artefacts were prepared for packing and transportation. The shafts were wrapped in plastic foil to keep the moisture content as stable as possible, before being placed in find-bags and labelled. The arrowheads were allowed to dry off, before being wrapped in acid-free paper, and packed in labelled find-bags. On the tang of the arrowhead T.27226 (see Appendix A) some biological material was preserved. In order to prevent this from deteriorating, the tang was immediately wrapped in plastic. The arrowhead was then treated and packed in the same way as the others. The smaller shaft-fragments were,

Figure 22: EK processing T.27222 in preparation for transportation off site. (17.08.2016) Photo: Andreas Alsaker

along with the arrowheads and modern finds, wrapped and packed as stably as possible, in a rigid container, packed securely within the centre of a backpack.
The longer fragments of T.27222 were packed in a pre-cut PVC-pipe, secured with foam-plastic and duct tape. None of the artefacts suffered any perceivable harm during transportation from the ice-patch back to the Museum laboratory.

5. Results

Over the course of the ten days spent in the field, a total area of approximately 60000m^2 was surveyed with a high degree of coverage. The survey covered a c. 60m wide belt along the terminal edge of the ice-patch, along its north-south axis.

The survey resulted in the recovery of four iron arrowheads, one whole fragmented shaft, and three other shaft fragments. Additionally, several modern finds were recovered, including rifle-round casings, a led musket ball, and a horseshoe nail.

This chapter presents the chronological and spatial distribution of these artefacts, and discusses the negative evidence generated by the survey. For a detailed description of the individual artefacts and their context, see Appendix A.

5.1. Chronological distribution

The four recovered arrowheads are all of the *flat tanged* type, akin to R.540 (Rygh, 1999). The flat shape of the tang and means of hafting are carried over from the design of bone points. This style of tang is common throughout the Migration Period, but the tang design changes from AD600, becoming pointed or tapered (Farbregd, 2009, p. 162), at which point it goes out of use, at least on metal projectiles. The transition is quite abrupt, and the flat tang therefore serves as a good means of “no-later-than” dating.

Figure 23: The four flat-tanged arrowheads recovered.

The recovered arrow-shafts have not been dated by radiometric means. The complete shaft T.27222 is, however, of the A1 type according to the typology developed by Farbregd (see fig 26). The A1 type shafts are designed for flat-tanged arrowheads, and therefore considered to predate AD600. The material from Storbreen is presented in its entirety in Appendix B.

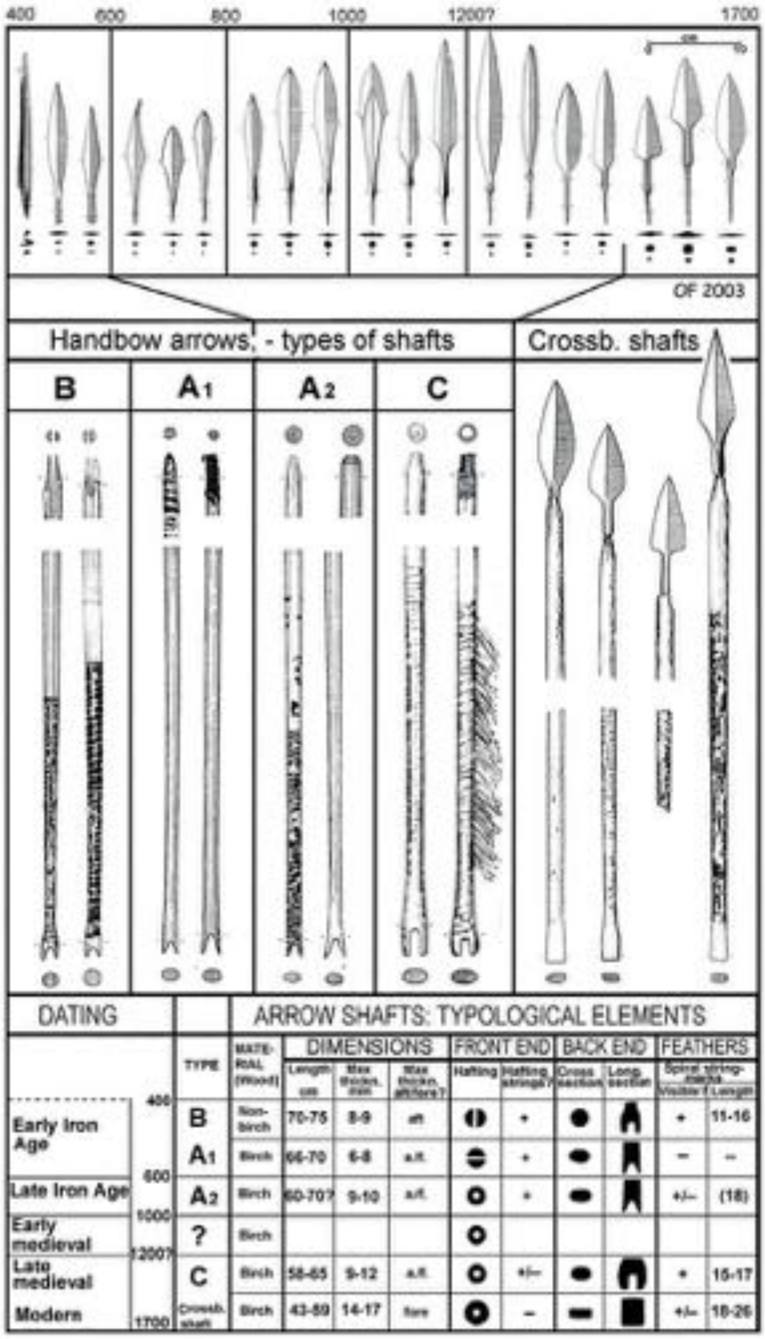

Figure 24:Chronological overview of arrow-shaft types and arrowheads. (Farbregd 2009, Fig. 9)

Artefacts from the Migration Period were numerically dominant in the material from Storbreen up to 2014 (see chapter 3.3). The new dateable finds from the present survey adhere to the existing chronological distribution on the site, helping to accentuate the Migration Period even further. Rather than changing the chronological distribution, they cement them further.

5.2. Spatial distribution

The finds recovered are mainly clustered towards the southern part of the ice-patch. The spatial distribution suggests that a widening of the annual zone of visual inspection might be advisable. The distribution of finds up to 2011 shows us that artefacts are generally recovered from a relatively narrow zone. Two, perhaps three, out of the four arrowheads would have, with some luck, been recoverable without metal-detectors. The fact that well-preserved shafts were recovered at up to 50m away from the ice-patch further suggests such an expansion might prove fruitful. However, that the number of finds from the surveyed area is relatively low, lends credence to the assumption that the annual visual inspection is a very effective surveying method on Storbreen, recovering most of the artefacts that emerge from year to year.

The spatial location of each individual artefact is elaborated upon in Appendix A.

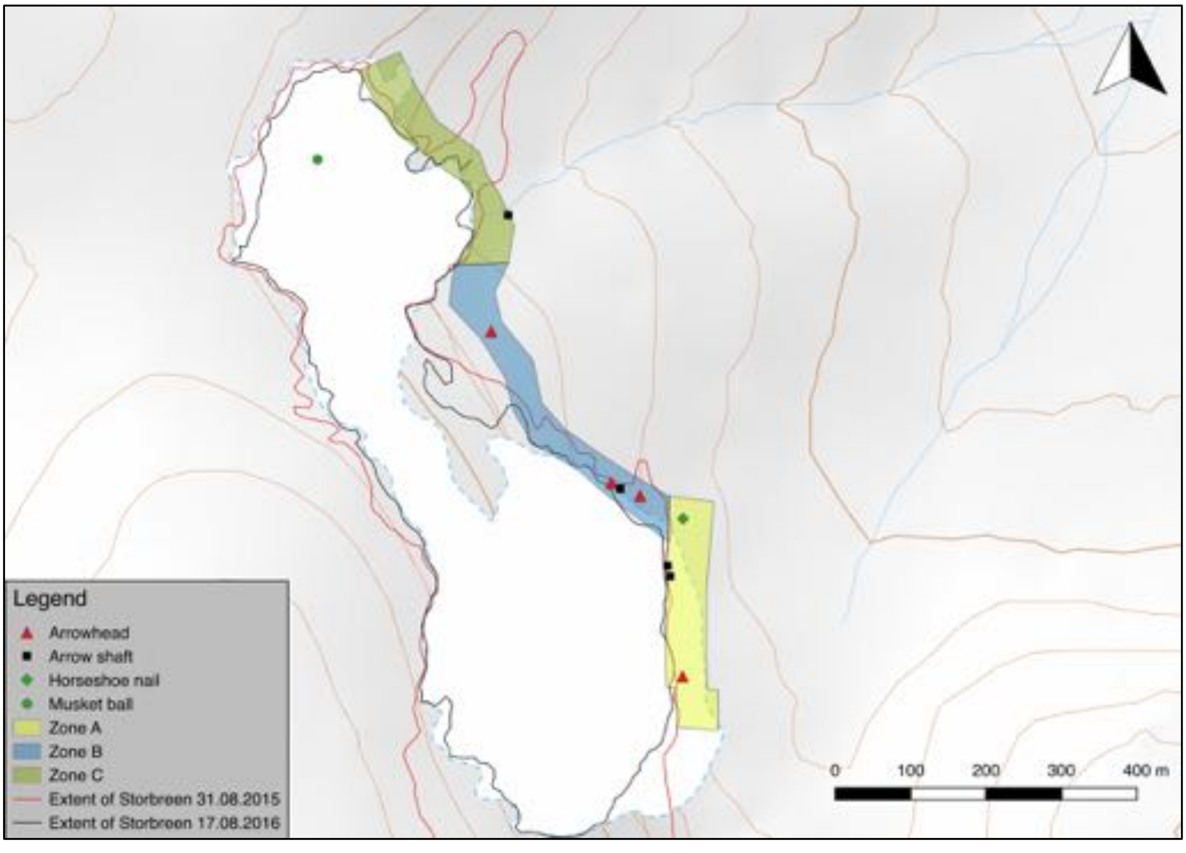

Figure 25: Spatial distribution of finds from metal-detector surveying 2015 & 2016.

5.3. Other finds

Several objects not defined as archaeological artefacts, were also recovered during the survey. Even so, these finds contribute to our understanding of the long tradition of hunting in the region. If metal-detector surveys become more commonplace in the following years, it is advisable that these finds should also be included, as they complement the more ancient objects, and provide interesting data in their own right.

Figure 26: Modern hunting projectiles recovered during the survey.
Photo: Einar Kristensen

These modern objects demonstrate the capabilities of ice-patch finds, with regards to showcasing the development of hunting projectiles. And, furthermore, they highlight the importance of ice-patches as hunting sites, spanning millennia. The addition of these modern finds helps in bringing the past, both ancient and comparatively recent, to life in the present. An arrow lost 5000 years ago, wrapping paper from the nineteen-eighties, equipment from previous surveying, and shell-casings from last year's hunt, are all present at the same site. The landscape in which modern hunting occurs, was also the backdrop in which prehistoric hunters operated.

Within the framework of the present survey, these objects serve mainly to further confirm the reliability of the metal-detectors and their ability to recover even these relatively small objects. Some of the ammunition-casings and bullets were buried beneath rocks and debris, others were visible on the surface – although they were very difficult to spot. The bullets on the left (see fig. 26) are probably related to the Krag-Jørgensen rifle (Hanevik, 1994, pp. 323-326), brass mantled led projectiles. The Krag-Jørgensen magazine-loaded rifle was adopted by the Norwegian army in 1894, and adaptations of it soon became a popular rifle for hunting and sport-shooting as well, throughout the 20th century (Trae, 1996, pp. 30-31).

The musket ball (see fig 28) was recovered from a “*snow-free corridor*” which divides the ice-patch above Zone C almost into two parts. Unfortunately, we were unable to produce a date for the item.

Figure 28: Musket ball in situ. Photo: Andreas Alsaker.

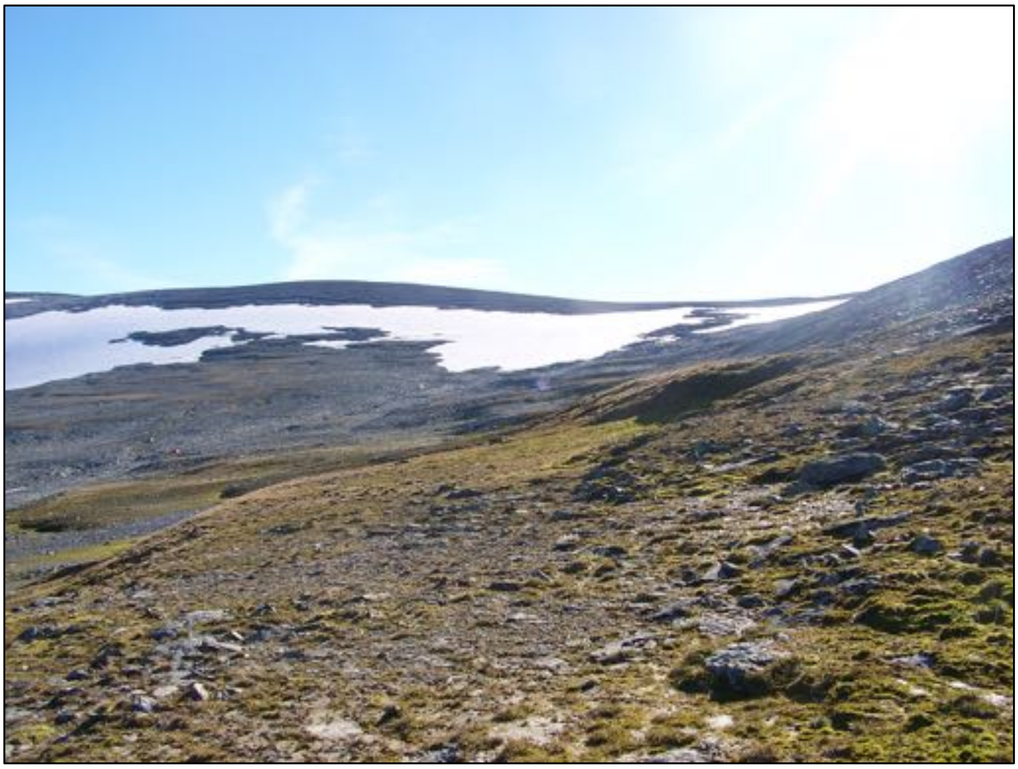

Figure 27: The snow-free "island" above Zone C, on the right-hand side of the picture. Photo: Einar Kristensen

The recovery of a horse-shoe nail (T.26792) was perhaps the most unexpected artefact recovered. There have been no similar finds on ice-patches in the region previously. Storbreen is not a site it makes sense to search out for purposes besides hunting (or recreation, in modern times). It is not “on the way” anywhere. It is therefore probable that the presence of horses, as indicated by the horse-shoe nail, is related to transportation connected with hunting trips, perhaps in order to transport game down off the site. This artefact provides us with an interesting supplementary picture, to the history of hunting on Storbreen. The date of the horse-shoe nail is not known

Figure 29: Horse shoe nail(T.26792.) Photo: Einar Kristensen

5.4. Negative evidence

With regards to answering the main research questions of this thesis, the most relevant category of data generated by this survey, can be termed “negative evidence”. The survey was aimed specifically at investigating the claim that arrowheads from the Medieval Period might have emerged from the ice-patch at an earlier stage, and withstood deterioration to such a degree as to still be observable with the aid of metal detectors. Within the surveyed area, we have demonstrated that there are no such artefacts.

Stone (1981, p. 42) suggest three conditions that might lead to lacunae in archaeological datasets:

"In general, three situations can lead to lacunae in archaeological data: 1) Condition I – the unobserved archaeological phenomenon never did occur; 2) Condition II – the unobserved archaeological phenomenon did occur, but has since been rendered undetectable; and 3) Condition III – the unobserved archaeological phenomenon did and does occur, but the data collection program was not competent to observe it."

Metal-detector surveying is the most competent recovery program available to us at present. The field testing and results from the present survey, as well as the results from previous surveying on Kuntshø, inspire confidence that Condition III does not come into play here.

The results for Knuthsø also reduce the likelihood of Condition II, since artefacts from the Medieval and preceding periods have survived deposition outside the ice-patches for considerable time on other ice patches. It is plausible that Medieval artefacts from Storbreen was deposited outside the surveyed area, but as the location of the surveyed area was based on current hypotheses concerning the probably area in which medieval artefacts would be deposited, this is unlikely, based on the information currently available.

We are then left with Condition I – The unobserved archaeological phenomenon never did occur. This strengthens the *site abandonment scenario*, as described in chapter 2. This will be discussed further in chapter 6.

Additionally, the negative data provides us with a benchmark for mapping the year-of-emergence for future finds with more certainty. Dating the individual artefacts emergence is beneficial when it comes to assessing the climatic "statement" of the ice-patch. The fact that ice-patches investigated in the region display a very fast response-time (Rognstad, 2013, p. 4) enables the year-to-year emergence of artefacts to act as proxy data for climatic development, when viewed over a longer time scale. If, in the next years, metal objects are found within the surveyed area, we can state with confidence that they have emerged after the survey was finished. That is, after 2015 for zone A, and after 2016 for zones B and C. No new metal finds were recovered from zone A during the season of 2016, despite visual inspection of the area. It will have to be considered, when new metal finds do emerge for zone A, if their emergence be set to post-2015 or if the visual inspection overrides the negative evidence provided by the metal-detectors.

Callanan (2012, p. 187) highlights the importance of documenting surveys that do not produce any new finds. I would suggest extending this recommendation to include the documenting of surveyed areas that did not produce new finds on any survey, regardless of whether finds were made overall. This applies particularly to surveys using metal-detectors or other surveying equipment, beyond visual inspection. In theory, the negative evidence generated by metal-detector surveying has, intuitively, more credibility. The instruments themselves will not "overlook" any objects. This increases the verifiability of the negative evidence, and allows for statements based on this data to be made with greater confidence.

5.5. Summary

The results provided by the survey, does not alter the chronological distribution of artefacts at Storbreen. Rather, the new artefacts adhere nicely to existing patterns. The numerical dominance of arrowheads from the Migration Period is further increased. The complete shaft, T.27222 (see Appendix A) is also typologically dated to the Migration Period, based on the shaft chronology developed by Farbregd (see fig. 26).

The recovery of arrowheads, as well as the many modern finds, shows us that the method was competent to recover metal objects. This increases confidence in that the negative evidence produced are valid.

Based on the negative evidence provided, it is no longer a case of surveyors being unable to observe Medieval artefacts because these are buried in the glacial run-off. Rather, we are observing an absence of Medieval artefacts on the site.

6. Discussion

6.1. Research question 1

The results from the fieldwork increase the probability that the regional chrono-geographic distribution of artefacts is the result of the *site abandonment scenario,* rather than glaciological sorting processes or recovery bias. That is not to say that the prerequisites for sorting processes are not present in the ice-patches. Rather, the lack of any hunting projectiles that can be dated to the Medieval period indicates that the prediction that glaciological sorting has caused younger artefacts to become unobservable by visual inspection below the terminal end of Storbreen, is considerably weakened.

If the main cause of the pattern is to be understood in terms of glaciological sorting processes, then there needs to be a hypothesis for means by which iron arrowheads have been deposited outside the surveyed area, or for their total disintegration by corrosion. At the moment, no such hypothesis can be found within the glaciological or archaeological literature.

On average arrowheads from the Medieval and Modern periods are more substantial in term of mass, when compared to for example those from the Migration period. It is, therefore, hard to imagine that such projectiles have completely corroded away on Storbreen, when smaller iron artefacts from the Migration period have survived exposure under the same conditions.

As for deposition outside the surveyed area, it is plausible that a change in hunting tactics could have resulted in a different depositional pattern, but there seems to have been no such change during these periods on other comparable sites. Artefacts from all periods are found intermixed on the ice-patches in Knutshø.

It is also possible that Medieval artefacts have been deposited further away from the ice-patch edge than the area covered by the present survey, but as of now there are no glaciological data to substantiate such a claim. Regardless, it will always be the case that future surveying can lead to new discoveries, that might alter the chronological profile of the various ice-patch sites, as exemplified by the discovery of arrowheads dating to AD600-800 from Knutshø (see chapter 2.3.1). If projectiles from the Medieval period are discovered during Storbreen by future surveying, then the situation will of course have to be reconsidered. The good thing is that the *site abandonment scenario* can be falsified by future investigations. It would be prudent to attempt to do so, by continuing and expanding metal-detector surveying in the future.

Keeping this in mind, the fact that a survey specifically designed with the recovery of Medieval period artefacts in mind did not produce any evidence of their existence, means that we are justified in moving the discussion forward, based on the site abandonment scenario as it stands now.

Research question 1 was: *"Are there relatively few medieval artefacts in Snøhetta East – has the relative frequency of hunting between Snøhetta East and Knutshø undergone some change over time?"*.

Based on the discussion above, we can conclude that based on the evidence produced by the metal-detector survey, the answer to this question is yes. The relative frequency of hunting between the two zones seems to have changed sometime during the transition to the ca. AD1200, as evidenced by the absence of artefacts from this and subsequent periods on Storbreen, until the advent of firearms.

6.2. Research question 2

"What cultural reasons could there be for the abandonment of Storbreen?"

Based on the conclusion above, what reasons could there be for the apparent abandonment of Storbreen and Snøhetta East? The archaeological material demonstrate that the site has been utilized from the Neolithic, through the Bronze age and the Iron age, and in modern times, but not during the Medieval period. In the following several factors that might have caused changes to the relative frequency of hunting between the two areas are discussed.

6.2.1. Changes in hunting tactics and technology.

As described in chapter 2.2, Oddmunn Farbregd suggested that a transition to *passive hunting techniques* might be part of the explanation for changes in the observed chrono-geographic pattern. He considered that the large-scale hunting systems across the Dovre mountain plateau (e.g. (Jordhøy, 2008)) were efficient enough to negate and replace the need for ice-patch hunting in Snøhetta East. Following the same line of thought, the continuing hunting activity within Knutshø is considered to be due to comparatively small-scale hunting by the local farming population, for purposes of satisfying local needs for subsistence or as supplementary income.

Martinsen argues that changes in hunting techniques should not be used as an explanation for changes in one area, and not the other. In reviewing the temporal and spatial distribution of pitfall and corral trapping systems, Martinsen (2012, pp. 65-67) suggests that all reindeer migrating to and from the Knutshø zone would have to navigate some form of trapping system, during the Viking and Medieval periods. This, Martinsen suggests, means that we cannot use the presence of actively used trapping systems as a proxy for reduced ice-patch hunting, since the two techniques coexisted in Knutshø. However, this assumes that the hunting on the ice-patches in the two zones were carried out in a similar way, and for a similar purpose.

Bretten (2003) suggests that large and relatively flat ice-patches, such as Storbreen, would require a different hunting technique than steeper patches. On such sites, therefore, it would be very difficult to get within bow and arrow range of the animals. Bretten suggests that the reindeer might have been driven off the ice-patch, towards awaiting hunters. Reindeer generally tend to run uphill when frightened (Baskin & Skogland, 1997, p. 39) so it is likely that the hunters in this scenario would be waiting above the ice-patch. No constructed hunting blinds have been documented in the vicinity, however.

The large number of sewels found on ice-patches in Oppland, demonstrates that some ice-patch sites has been used for such collective purposes. No sewels have been recovered at Storbreen, but it is plausible that some other form of guiding devices have been implemented (Callanan, 2014b, pp. 23-24) perhaps constructed on the ice-patch itself, by using shovels such as those found at Grovåskardet, in Nesset municipality, Møre and Romsdal county (e.g. (Sanden, 2016, p. 63). Perhaps the hunting on Storbreen should be viewed more akin to corral hunting: a large-scale team effort, requiring some form of organization (Bretten, 2003; Callanan, 2014b, pp. 23-24)?

Viewed in this way the chrono-geographic differentiation makes sense. It is the somewhat collective and organized hunting that was replaced by the, presumably, more efficient corral and pitfall hunting. Whilst the “for local use” hunting, perhaps for salting/preserving as food for the winter (Mikkelsen, 1994, p. 97) – or perhaps selectively hunting for bucks (see (Martinsen, 2012, p. 68) with references to (Mikkelsen, 1994, pp. 63-64) continues in Knutshø, closer to the habitation centres around the Oppdal valley.

Up to the full-scale utilization of the large trapping systems, the hunting of wild reindeer represents an adaptation, on behalf of the hunter, to the movements and behaviour of the animals in relation to the landscape on a local scale. The utilization of sites such as ice-patches, lakes and small scale strategically placed pitfalls, are all examples of hunting adapting to the landscape, using the natural features and knowledge of reindeer behaviour to their advantage. To a certain degree, the large-scale pitfall systems represent a change in this regard; they represent an adaptation of, rather than too, the landscape. Certainly, the mass trapping systems are strategically placed, taking into account the migration routes of the wild reindeer, and making good use of the landscape, but the scale of the endeavour suggests an almost industrial approach to the trapping.

Knutshø and Snøhetta East serves different purposes in the annual migration cycle of the wild reindeer. It might be the case that the differentiation in use of these zones by the animals might have had an impact on the varying degree of human utilization. Within our current climate, Knutshø represents the best winter grazing grounds, whilst Snøhetta East and Snøhetta West represents summer pastures and calving areas (Skogland, 1986). Modern migration patterns usually see the reindeer migrating from Knutshø to Snøhetta East in the early spring. During years with low amounts of snowfall, the animals might spend the winter in Snøhetta East, but usually Knutshø represents more favourable conditions with regards to lichen accessibility.

We know that caribou have been hunted on skis during winter (Spiess, 1979, p. 124).It is possible that reindeer were hunted during winter in central Norway as well, but it is unlikely that we would find traces of this clustered on ice-patches, as the behaviour that drives the reindeer to these sites is usually a attributed to summer conditions (see chapter 1). Reindeer might have spent the summer in Knutshø, but it is unlikely that this would be a favoured period for hunting, since the spring and summer conditions generally tend to involve much work related to farming activities. Additionally, during these seasons, the heard normally occupy the Snøhetta East and Snøhetta West zones. The most likely period for the ice-patch hunting in Knutshø then, is the late summer to autumn, when the reindeer migrate back to the zone and before snow covers the ground. It has also been suggested from North America, that this is the best time to harvest hides to produce clothing (Spiess, 1979, p. 29). Perhaps the hunters would be present at these sites during the same months that are now favourable for archaeological surveying, August – October.

6.2.2. Reduction of the wild reindeer population

The large-scale use of the mass-trapping systems peaked during the 12th century (Mikkelsen, 1994, p. 164). It is difficult to estimate just how extensive this trapping was with regards to the number of animals killed, but it seems it was of a magnitude sufficient to have a dramatic impact the wild reindeer population.

Sometime during between the 11th and 12th century the wild reindeer population decrease rapidly and dramatically. Egil Mikkelsen (1994) suggested such a decline based on a transition from the use of antler to the use of bone in the comb-making industry, as observed in the archaeological evidence from crafting sites in the Medieval towns Trondheim and Bergen. As antler is considered to be the superior and preferred material in this production, Mikkelsen suggested that this transition was rooted in reduced accessibility of antler as a raw material.

Recently, mtDNA analysis from a sample of 104 of ancient reindeer bones from archaeological digs at Tøftom and Vesle Hjerkinn, as well as from ice-patches in the Dovre area, complimented this view (Røed et al., 2014); the mtDNA analysis shows a rapid decline in the female constituency of the reindeer population in the area, during the 11th -12th century. Based on the fact that the population decrease coincides with the assumed peak in hunting activity on the mass-trapping systems across Dovre, the conclusion is reached that there is a direct link between the two(Røed et al., 2014, p. 1137)

6.2.3. Changes in trade-networks

As discussed above, it is probable that the large-scale mass trapping systems across Dovrefjell had a fundamental impact on the bow-and-arrow hunting in Snøhetta East, reducing the need for, and the potential gain from the comparatively small-scale hunting. But if the mass-trapping systems were the main cause for the abandonment of Storbreen and Snøhetta East, why then does the bow-and-arrow hunting not pick up again after the collapse of the mass-trapping?

As we have seen, the reindeer population was probably greatly reduced as a consequence of the almost industrial scale of the mass-trapping systems. However, the population was still sufficient for the ice-patch hunting in Knutshø to be worthwhile, as hunting in this zone continues uninterrupted.

There are also overarching changes occurring in the societal organization occurring during the late 1200. With regards to trade, Egil Mikkelsen (1994, p. 165) suggests that the end of the peak in activity on the large-scale mass-trapping systems in the second half of the 13th century, might be related to the establishment of a trading port in Novgorod, by the Hanseatic league. In addition to the reduction in the reindeer herd reducing the output of the facilities, this shift in the market might have had a profound impact on the profitability of the trapping systems. However, it is less likely that this would have a similar impact on the for-local-use ice-patch hunting, as this was aimed primarily at satisfying local needs.

Changes in social organization and trade markets probably had an impact on the large-scale hunting of reindeer that occurred in the mass-trapping systems. However, it is more doubtful that overarching changes like this would directly impact the for-local-use bow and arrow hunting tradition in communities such as Oppdal. Regardless of the changes in the large interregional and international trade, the resources provided by the reindeer would still be as important as previously on a local scale. The kind of occurrences most likely to directly impact the local hunting tradition, are changes which directly and fundamentally impact the day to day lives of the local people.

6.2.4. The Black Death and subsequent depopulation

It is not known precisely when the Black Death reached Oppdal, but after being introduced to Norway in 1348-1349, it spreads rapidly throughout the Trøndelag region, both along the coast and in the interior, decimating the population (Dybdahl, Bull, & Moe, 2005, p. 15). Even though there are no contemporary written sources that elaborate on how the plague affected Trøndelag (Dybdahl et al., 2005, p. 15), its impact on the population has been estimated on the basis of a number of indirect historical sources.

In general, it seems that remote or otherwise marginal settlements generally shows higher abandonment percentages that, for example, the fertile agricultural settlements around Trondheimsfjorden (e.g. (Sandnes, 1971, p. 165). This is not necessarily a result of more people succumbing to the plague in remote settlements, rather it reflects a subsequent movement of peoples towards the larger central farms, with good fertile soil. In a sense, this represented a tempting opportunity for the survivors, providing people with access to better farmlands. In addition, the abandoned farms themselves could also provide a valuable resource for the survivors, as additional grazing grounds, or by providing access to outfield resources such as fresh water for fishing (Dybdahl et al., 2005, pp. 24-25)

There are also data indicating a worsening climate during this period. This would also affect the already marginal farming communities disproportionately, and could have accentuated the depopulation of such areas further. It is argued that the process of abandoning marginal farms began before the Black Death impacted the population. From around AD1250 and again around AD1330 there are evidence for the existence of abandoned farms within Trøndelag (Sandnes, 1971, pp. 211-212).

Dybdahl et .al (2005, p. 34) suggests that the large population pressure in the Early Middle Ages might have resulted in poor general health in the population, setting the stage for the massive impact of the Black Death in Norway. Additionally, a worsening climate has also probably had an impact on the processes of population decrease and farm abandonment before the onset of the Black Death (Dybdahl, 2010, 2012, 2016)

Figure 30: Populated areas of the Trøndelag region in AD1520. The black areas are populated, the dotted areas are abandoned. (Sandnes, 1971, p. 165)

With regards to the situation in Oppdal, the work of *"The Scandinavian Research Project on Deserted Farms and Villages" (Sandnes & Salvesen, 1978),* estimates a reduction in *"named farms"* from 80 to 21, an abandonment percentage of 74%, in the period AD1330 – AD1520 (Sandnes, 1971, p. 74). For the Trøndelag region as a whole, the abandonment percentage is estimated to 56%.

During the Early Medieval Period, there were inhabited farms spread throughout Oppdal, many of which probably, based on farm-name studies, originated in the pre-Christian times (Sandnes, 1971, p. 162). But after the plague people who remained in seems to have clustered together in specific locations, such as *"Blankbygda"*(Sandnes, 1971, pp. 162-163).

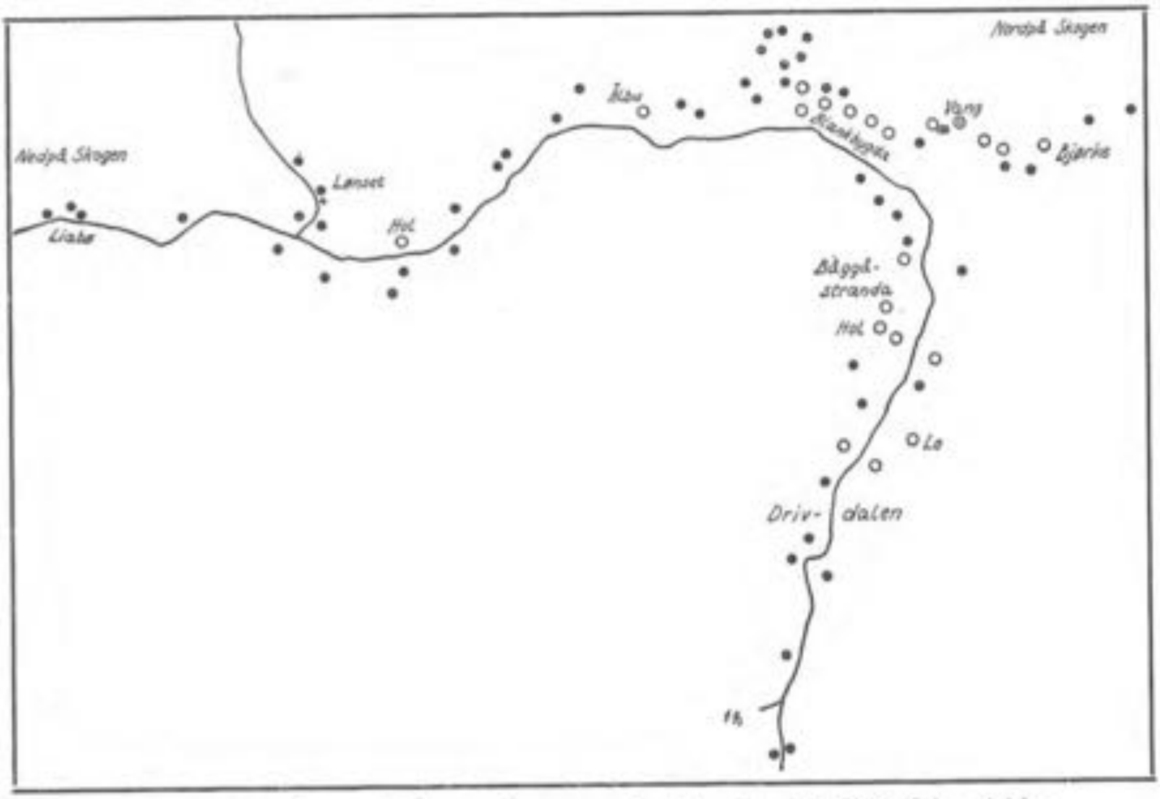

Figure 31: The settlement situation in Oppdal in 1520. The white circles symbolize inhabited farms, the black circles symbolize abandoned farms. The black line is the river Driva. (Sandnes, 1971, p. 163)

Oppdal is counted among the marginal settlements, and would have suffered population loss both from the plague directly, and from the subsequent movements of peoples towards better farm land along the coast. Additionally, the worsening climate would have been felt more extremely in Oppdal, than many other places. These factors must have had a dramatic impact on day to day life for those who survived, and remained settled within the community.

It is difficult to ascertain the degree to which specific local traditions would be affected by such drastic changes in human population. However, the population decrease did clearly have a direct negative impact on the scale of human hunting activities.

As the population declined and the settlements contracted, the primary and secondary demand for reindeer products such as antler, meat and skins were also reduced, there were simply less mouths to feed locally, and probably also a dramatically reduced market regionally.

The people who remained in Oppdal clearly still had a need for the resource provided by the reindeer, but it seems that these needs could be satisfied by hunting on the ice-patches in Kuntsø, closer to the habitation clusters (see fig. 32). The need for these resources then, while reduced, was still present. Among those who remained, there would also be fewer who could partake in the hunt. The plague did not discriminate in terms of gender or physical conditioning. In addition, it is likely that those who did survive would have to work harder to keep the farms up and running. Perhaps there were simply not enough able-bodied people left, to launch hunting expeditions from the settlements around Blankbygda, to relatively remote sites such as Storbreen.

There are many factors that come into play here; the situation is complex and multi-faceted, but we can to a certain extent observe the consequences of these changes with regards to the hunting activity on the ice-patches around Oppdal. The current chrono-geographic patterns in the ice-patch material from central Norway, shows that the hunting activity in Snøhetta East is greatly reduced. Just as the survivors of the black plague experienced the mixed blessing of being abandon marginal farms, and move towards more fertile farmlands along the coast, so those who stayed in Oppdal could afford to be picky with regards to the ice-patch sites. We do not know by what criteria sites were deemed favorable but the end result of their selection, it seems, we can observe via the arrows they lost.

7. <u>Concluding remarks</u>

The recovery of archaeological artefacts from melting ice-patches is a cumulative and ongoing process, which to a large degree is at the mercy of the weather, climate and the ice-patches themselves. These are not normal archaeological sites, where the emergence of artefacts is dependent upon the archaeologists' planned excavations. As of yet, there are still no means of excavating an ice-patch site.

Rather, we must inspect the ice-patch sites on an annual basis, looking for any artefacts that might have melted out. So far, these investigations have for the most part been based on visual surveying, and this is likely to continue in the future – which is a good thing. Based on the negative evidence generated by the present survey, the visual inspections of Storbreen over the years appear to have been very effective with regards to recovering metal arrowheads, as they emerge.

However, there is also room for methodological developments in the way we survey the ice-patches of central Norway. The present survey was designed around answering a specific question which has been a part of the archaeological discourse about local ice-patches for more than 40 years. Doing so required the development of a surveying framework capable of observing artefacts that could not be recovered by visual surveying alone, while at the same time generating testable negative data and evidences.

This thesis has shown that specifically designed and targeted surveying, founded on explicit research questions can be implemented into archaeological research on ice-patches in the region. The results of the fieldwork has given us new insight into the nature of the chrono-geographic distribution of artefacts within central Norway. It adds another small piece to a puzzle, to which we do not yet have all the pieces, and more than likely never will.

With regards to research question 1: "*Are there comparatively fewer Medieval arrowheads in Snøhetta East compared to Knutshø?"*. The results from the fieldwork has given us a clear answer. Based on the dataset as it stands after the season of 2016, based on the strength of the negative data generated by the metal-detector survey, the answer is <u>yes.</u>

Research question 2 was formulated as: *"What reasons could there be for the apparent abandonment of Storbreen and Snøhetta East as a hunting ground?"* The discussion in chapter 6.2 has highlighted some central culture-historic factors that, in some way probably had an impact in shaping the chrono-geographic patterns in the region. Such a discussion is very complex, due to the social and cultural framework within which the local ice-patch hunting stands. But, in one way or another, the rise and fall of the large-scale mass –trapping systems across Dovre, and the subsequent dramatic reduction in the wild reindeer population, in addition to a worsening climate, leading to abandonment of farms, and the movement of peoples would surely have been apt to affect the local tradition. Follow this up with the devastation caused by the Black Death, and at least some of the factors influencing the abandonment of Snøhetta East are in place.

And so we reach the end of this thesis, but not the story. The emergence of archaeological material from the ice-patch sites is an ongoing process, and the archaeological investigations of this phenomena is a cumulative process. During the melting seasons of 2015 and 2016, we gathered new pieces of the ice-patch puzzle. But in a few months, the ice-patches will again reach their minimal annual extent – perhaps it will be another year with extensive melting, exposing new archaeological finds to the elements, or perhaps it will be another season like that of 2015. Regardless, we must be ready come august, this year, and the next.

7.1. Future research

The present survey has further demonstrated that metal-detectors can, with ease, be integrated into the surveying of ice-patch sites in central Norway This systematic approach could also be applied elsewhere where there is the possibility of recovering metal objects. Surveying with metal-detectors should not be seen as an alternative to visual surveying, our experience in the field shows the two methods are both compatible and complementary.

Metal-detector surveying do have certain advantages over visual surveying, however. Their ability to detect artefacts invisible to the naked eye is one, and the ease with which negative evidence can be generated is another. Particularly the generating of negative evidence will be important in the future. As ice-patches continue to melt, some of the sites produce less and less artefacts. It is possible that these will sooner or later be "dead patches", that is to say that all the archaeological material which at one time was preserved within their core has been evacuated from within the ice-patch itself. Under such scenarios, metal-detector surveys have the potential to be of tremendous benefit, with regards to producing negative evidence on the site, allowing the "time of death" to be established with a higher degree of confidence.

One of the strengths of the *site abandonment* scenario presented in this thesis is that it can be falsified, as we here have attempted to do. Attempts at falsifying the *site abandonment scenario* should be continued in the future. This thesis has provided new insights into the nature of the chrono-geographic pattern within the region, but there is still much that could be gained by a continuation of integrating systematic and well documented metal-detector surveys as a staple in the ice-patch archaeology of central Norway. In addition to extending the surveying to include other ice-patch sites, both within Snøhetta East and Knutshø, it would be interesting to test this this method on places where ice-patches have completely melted away (Farbregd, 2009, p. 168). Such sites are difficult to survey by visual inspection alone, but as the results from the present survey, and previous surveying in Knuthsø have demonstrated, metal arrowheads can have survived deposition outside ice-patches for a considerable period of time, in a state which metal-detectors can easily observe.

It would also be beneficial to gather the information about stray artefacts recovered from the mountains in the region as a supplement to the ice-patch finds. As Farbregd (Farbregd, 1983) previously showed, this dataset can provide an interesting dataset with witch to complement the ice-patch finds. The potential information from the spatial and temporal distributions of such artefacts would serve to enhance our understanding of the hunting activity in the region.

It has also been demonstrated that the radiological dating of shaft-fragments can alter the chronological pattern of the ice-patch dataset. Dating more fragments in the future, could provide us with the means to supplement and enhance the existing typological chronology of the shafts. This is another route by which the *site abandonment scenario* could potentially be falsified.

The present thesis represents an attempt at directly answering a specific question, by relying on an appropriate surveying methodology. There are many other questions that could be investigate in a similar manner, by using other methods. For example: Storbreen is a relatively remote site. Even when we are able to cover most of the route by car, it is still a long hike from the parking lot into the ice-patch at Storbreen. Most likely, (pre)historic hunters on this site would have had to spend the night in the vicinity, perhaps in a shelter constructed by stones, or perhaps light a fire or knap some lithics for butchering a reindeer? So far almost no trace of human presence at small auxiliary sites has been found around Storbreen or similar icepatches in the region. In the future, it would be extremely interesting to see if it would be possible to develop systematic surveys that might include metal detectors, with the aim of uncovering traces of human activity associated with the icepatch hunt itself. Targeted surveys such as these, based on specific research questions, have great future potential to add to our archaeological understanding of ice patches and the objects that we find there.

References

Anderson, J. R., & Nilssen, A. C. (1998). Do reindeer aggregate on snow patches to reduce harassment by parasitic flies or to thermoregulate? *Rangifer, 18*(1), 3-17.

Åstveit, L. I. (2007). Høyfjellsarkeologi under snø og is. Global oppvarming, fonnjakt og funn fra snøfonner datert til steinalder. *Viking, 70*, 7-22.

Baskin, L. M., & Skogland, T. (1997). Direction of escape in reindeer. *Rangifer, 17*(1), 37-40.

Benn, D., & Evans, D. J. (2014). *Glaciers and glaciation*: Routledge.

Bezzi, L. (Writer). (2014). Arc-Team Langgrubenjoch EN [Video file]. https://www.youtube.com/watch?v=eXPsFIEHsN4&feature=youtu.be: Youtube.

Bjerck, H. B., Åstveit, L. I., Gundersen, J., Meling, T., Jørgensen, G., & Normann, S. (2008). NTNU Vitenskapsmuseets arkeologiske undersøkelser Ormen Lange Nyhamna. *Tapir Akademisk Forlag, Trondheim*.

Bretten, T. (2003). Nye Funn. Flere pilspisser fra Oppdalsfjella. *Spor, 2*, 13.

Callanan, M. (2010). Northern snow patch archaeology. *A circumpolar reappraisal: The legacy of Gutorm Gjessing (1906–1979). BAR International Series, 2154*, 43-54.

Callanan, M. (2012). Central Norwegian snow patch archaeology: Patterns past and present. *Arctic, 65*, 178-188.

Callanan, M. (2013). Melting snow patches reveal Neolithic archery. *Antiquity, 87*(337), 728-745.

Callanan, M. (2014a). Bronze Age Arrows from Norwegian Alpine Snow Patches. *Journal of Glacial Archaeology; Vol 1, No 1 (2014)*. doi:10.1558/jga.v1i1.25

Callanan, M. (2014b). *Out of the ice : glacial archaeology in central Norway.* (2014:306 PhD), Norwegian University of Science and Technology, Faculty of Humanities, Department of Historical Studies, Trondheim.

Carey, M. (2007). The history of ice: how glaciers became an endangered species. *Environmental History, 12*(3), 497-527.

Dixon, E. J., Manley, W. F., & Lee, C. M. (2005). The emerging archaeology of glaciers and ice patches: Examples from Alaska's Wrangell-St. Elias National Park and Preserve. *American Antiquity*, 129-143.

Dybdahl, A. (2010). Klima og demografiske kriser i Norge i middelalder og tidlig nytid. *Historisk tidsskrift, 89*(02), 183-222.

Dybdahl, A. (2012). Climate and demographic crises in Norway in medieval and early modern times. *The Holocene, 22*(10), 1159-1167. doi:doi:10.1177/0959683612441843 %U http://journals.sagepub.com/doi/abs/10.1177/0959683612441843

Dybdahl, A. (2016). *Klima, uår og kriser i Norge gjennom de siste 1000 år*. Oslo: Cappelen Damm akademisk.

Dybdahl, A., Bull, I., & Moe, K. (2005). *Trøndelags historie : B. 2 : Fra pest til poteter : 1350 til 1850* (Vol. B. 2). Trondheim: Tapir akademisk forl.

Fægri, K. (1938). *Forandringer ved norske breer 1936-37*. Bergen: Bergens museum.

Farbregd, O. (1972). Pilefunn fra Oppdalsfjella. *Det Kgl. Norske Videnskabers Selskab, Museet, Miscellanea 5. Trondheim, Norway. 105 – 117.*

Farbregd, O. (1983). Snøfonner, pilefunn og dyregraver. *Det Kgl. Norske Videnskabers Selskab. Museet. Rapport A, 1983*(5), 7-46.

Farbregd, O. (1991). Gamle jaktpiler i snøfonner. Bom i jakta-arkeologisk fulltreffer. *Spor, 2*, 4-10.

Farbregd, O. (2009). Archery history from ancient snow and ice. In Brattli, T. (ed). *The 58th International Sachsensymposium. 1-5 september 2007. Vitark 7. Tapir akademiske forlag.*, 156-170.

Fujita, K., Hiyama, K., Iida, H., & Ageta, Y. (2010). Self-regulated fluctuations in the ablation of a snow patch over four decades. *Water Resources Research, 46*(11).

Glazirin, G. E., Kodama, Y., & Ohata, T. (2004). Stability of drifting snow-type perennial snow patches. *Bulletin of glaciological research, 21*, 1-8.

Grosjean, M., Suter, P. J., Trachsel, M., & Wanner, H. (2007). Ice-borne prehistoric finds in the Swiss Alps reflect Holocene glacier fluctuations. *Journal of Quaternary Science, 22*(3), 203-207.

Hafner, A. (2012). Archaeological discoveries on Schnidejoch and at other ice sites in the European Alps. *Arctic, 65*, 189-202.

Hagemoen, R. I. M., & Reimers, E. (2002). Reindeer summer activity pattern in relation to weather and insect harassment. *Journal of Animal Ecology, 71*(5), 883-892.

Hanevik, K. E. (1994). *Krag-Jørgensen geværet*. Halden: Hanevik våpen ANS.

Hare, P. G., Greer, S., Gotthardt, R., Farnell, R., Bowyer, V., Schweger, C., & Strand, D. (2004). Ethnographic and archaeological investigations of alpine ice patches in southwest Yukon, Canada. *Arctic*, 260-272.

Hare, P. G., Thomas, C. D., Topper, T. N., & Gotthardt, R. M. (2012). The archaeology of Yukon ice patches: New artifacts, observations, and insights. *Arctic, 65*, 118-135.

Hougen, B. (1937). Pilene fra Storhø. *Viking, 1*, 197-204.

Jordhøy, P. (2008). Ancient wild reindeer pitfall trapping systems as indicators for former migration patterns and habitat use in the Dovre region, southern Norway. *Rangifer, 28*(1), 79-87.

Kristiansen, J. (2013). *Fra natur til kart: Veien til 3D-modellering av en isfonn ved hjelp av GIS og geofysiske metoder.* (MA), Norges teknisk-naturvitenskapelige universitet, Fakultet for samfunnsvitenskap og teknologiledelse, Geografisk institutt.

Lavigne, F., Degeai, J.-P., Komorowski, J.-C., Guillet, S., Robert, V., Lahitte, P., . . . de Belizal, E. (2013). Source of the great A.D. 1257 mystery eruption unveiled, Samalas volcano, Rinjani Volcanic Complex, Indonesia. *Proceedings of the National Academy of Sciences, 110*(42), 16742-16747. doi:10.1073/pnas.1307520110

Martinsen, J. R. P. (2012). *Ice patches as archaeological contexts : a multidisciplinary approach.* (MA), Norwegain University of Science and Technology, Faculty of Humanities, Department of Archaeology and Religious Studies, Trondheim.

Martinsen, J. R. P. (2016). Unmoving Ice Patches and Instances of Biased Recovery Patterns. *Journal of Glacial Archaeology, 2*, 51-72. doi:10.1558/jga.v2i1.27173

Meulendyk, T., Moorman, B. J., Andrews, T. D., & MacKay, G. (2012). Morphology and development of ice patches in Northwest Territories, Canada. *Arctic, 65*, 43-58.

Mikkelsen, E. (1994). *Fangstprodukter i vikingtidens og middelalderens økonomi : organiseringen av massefangst av villrein i Dovre*. Oslo: Universitetets oldsaksamling.

Ødegård, R. S., Nesje, A., Isaksen, K., Andreassen, L. M., Eiken, T., Schwikowski, M., & Uglietti, C. (2017). Climate change threatens archaeologically significant ice patches: insights into their age, internal structure, mass balance and climate sensitivity. *Cryosphere, 11*(1).

Petersen, T. (1937). *Oldsaksamlingens tilvekst 1936*. Trondhjem: Aktietrykkeriet i Trondhjem.

Reckin, R. (2013). Ice patch archaeology in global perspective: archaeological discoveries from alpine ice patches worldwide and their relationship with paleoclimates. *Journal of world prehistory, 26*(4), 323-385.

Reitmaier-Naef, L., & Reitmaier, T. (2015). *cOld Ice: A Survey and Monitoring Programme of High-Alpine Cultural Heritage in the Central Alps, Switzerland*.

Røed, K. H., Bjørnstad, G., Flagstad, Ø., Haanes, H., Hufthammer, A. K., Jordhøy, P., & Rosvold, J. (2014). Ancient DNA reveals prehistoric habitat fragmentation and recent domestic introgression into native wild reindeer. *Conservation Genetics*, 1-13.

Rogers, S. R. (2014). An Overview of Selected GIS Methods Available for Use in Glacial Archaeology. *Journal of Glacial Archaeology, 1*(1), 99-115. doi:10.1558/jga.v1i1.99

Rogers, S. R., Fischer, M., & Huss, M. (2014). Combining glaciological and archaeological methods for gauging glacial archaeological potential. *Journal of Archaeological Science, 52*, 410-420.

Rognstad, A. J. (2013). *En massebalansestudie av to arkeologiske isfonner i Oppdalsområdet.* (MA), Norges teknisk-naturvitenskapelige universitet, Fakultet for samfunnsvitenskap og teknologiledelse, Geografisk institutt.

Rosvold, J. (2016). Perennial ice and snow-covered land as important ecosystems for birds and mammals. *Journal of Biogeography, 43*(1), 3-12.

Rummel, B. (2013). *Investigation of Landsat satellite image change detection of snow and ice cover: A seasonal and multi annual time scale approach to evaluate this technique as a tool for water resource management.* (MA), Norges teknisk-naturvitenskapelige universitet, Fakultet for samfunnsvitenskap og teknologiledelse, Geografisk institutt.

Rygh, K. (1915). *Oversigt over Videnskabsselskabets oldsagsamlings tilvækst i 1914 af sager ældre end reformationen* (Vol. 1914, 4). Trondhjem: Aktietrykkeriet i Trondhjem.

Rygh, O. (1999). *Norske oldsager*. Trondheim: Tapir.

Sanden, G. D. (2016). Villreinfangst i den sørlege delen av Midt-Noreg–ein studie i fordelinga av bågastø, jordgravne og steinmura fangstgroper. *Viking, 79*, 53-74. doi:http://dx.doi.org/10.5617/viking.3904

Sandnes, J. (1971). *Ødetid og gjenreisning*: Universitetsforlaget.

Sandnes, J., & Salvesen, H. (1978). *Ødegårdstid i Norge: det nordiske ødegårdsprosjekts norske undersøkelser*: Universitetsforlaget.

Skogland, T. (1986). Movements of tagged and radio-instrumented wild reindeer in relation to habitat alteration in the Snøhetta region, Norway. *Rangifer, 6*(2), 267-272.

Slåke, L. L. (2015). *En studie om opphavet til landformer ved den kalde ismassen Storbrean.* (MA), Norges teknisk-naturvitenskapelige universitet, Fakultet for samfunnsvitenskap og teknologiledelse, Geografisk institutt.

Sollid, J., Isaksen, K., Eiken, T., & Ødegård, R. (2003). *The transition zone of mountain permafrost on Dovrefjell, southern Norway.* Paper presented at the Proceedings.

Spiess, A. E. (1979). *Reindeer and caribou hunters / an archaeological study*. New York: Academic Press.

Stirn, M. A. (2014). WHY ALL THE WAY UP THERE? *SAA Archaeological Record, 14*(2).

Stone, G. D. (1981). The interpretation of negative evidence in archaeology. *Atlatl*.

Trae, S. V. (1996). *På sporet av norsk forsvarshistorie : fra sverd til Krag-Jørgensen og fra Sten-gun til MP 5 : Notodden heimevernsområde 1946-1966*. Notodden: S.V. Trae.

Vitenskapsmuseet. SPARC - Snow Patch Archaeological Research Cooperation. Retrieved from http://www.ntnu.no/museum/sparc

Wammer, E. U. (2007). Arkeologiske registreringer av fangstrelaterte kulturminner ved snøfonner i Jotunheimen, september 2007. *Oppland fylkeskommune, arkiv.*

Appendix A – artefact descriptions

T.26794

Artefact	Arrowhead
Material	Iron
T-number	T.26794
Dating	AD400-600
Length	13.8 cm
Weight	18 g
Coordinates UTM 32V	N6914340 E0521503
Find date	30.08.15
Found by	M.C

Figure 32: T26794 - after conservation.

DESCRIPTION:

Flat-tanged iron arrowhead, typologically dated to the Migration Period (AD 400-600). Recovered from the surface during surveying with metal detector. Laying on top of a large flat rock, very exposed. Approximately 5m from the edge of the ice patch. In excellent condition with regards to preservation.

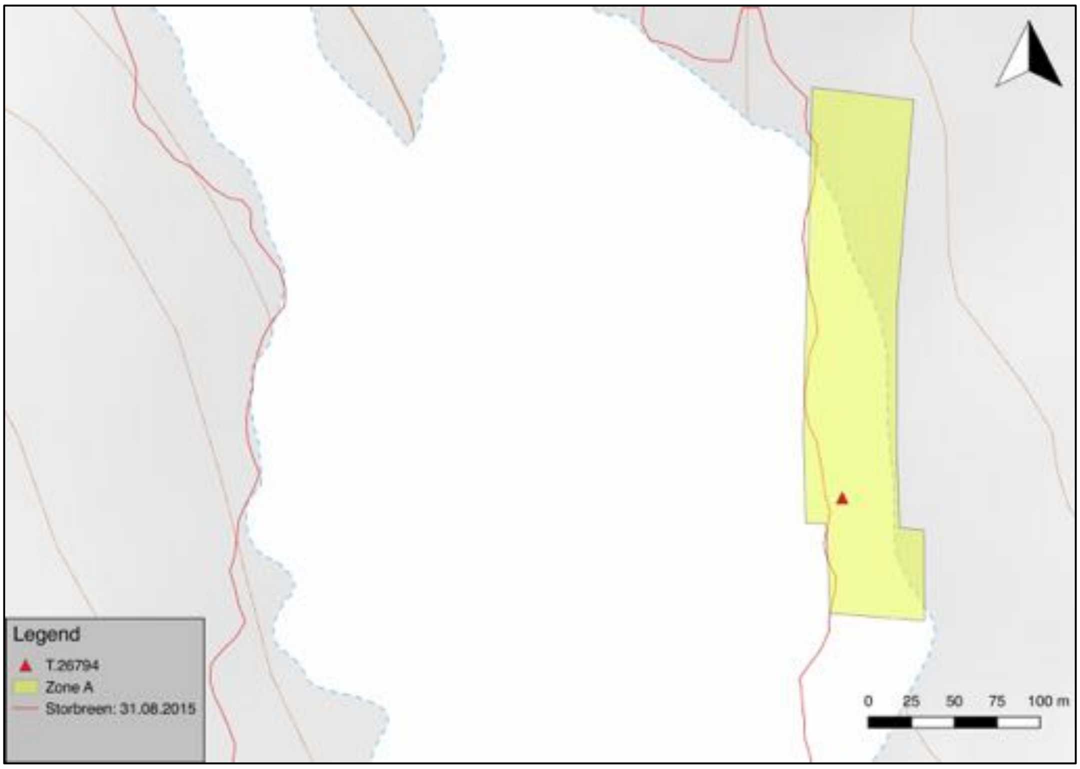

Figure 33: Geographic location of T.26794

Figure 34: T.26794 in situ. Photo: M.C

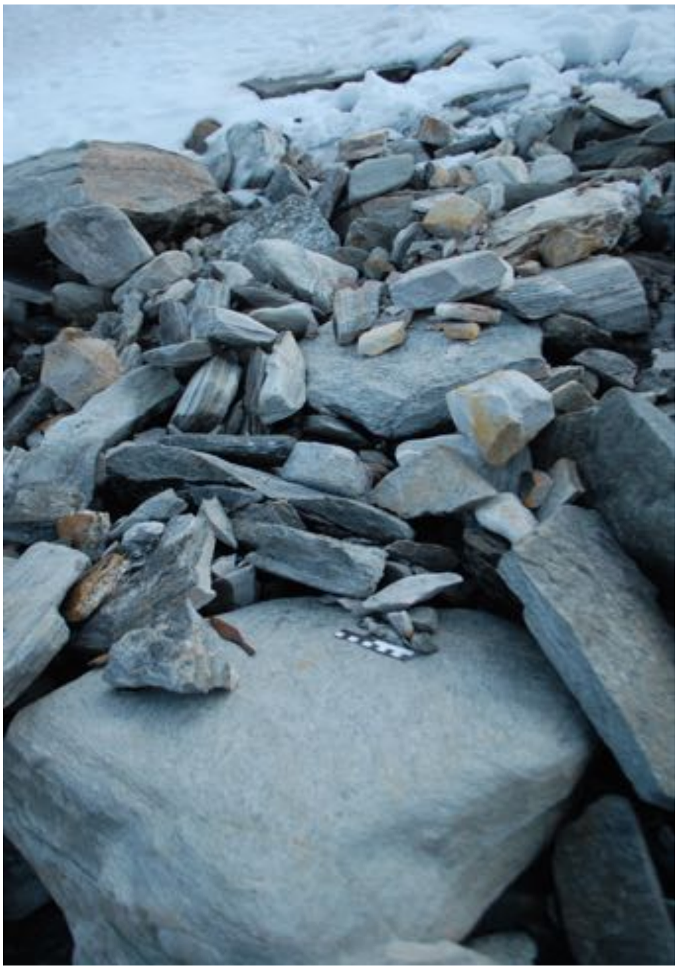

Figure 35: T.26794 in relation to the ice-patch edge. Photo: M.C

T.27221

Artefact	Arrowhead
Material	Iron
T-number	T.27221
Dating	AD400-600
Length	12.5cm
Weight	16g
Coordinates UTM 32V	N6914797 E0521249
Find date	17.08.2016
Found by	E.K

Figure 36: T.27221 - before conservational treatment.

DESCRIPTION:

Flat-tanged iron arrowhead, typologically dated to the Migration Period (AD 400-600). Recovered with metal detector. Found buried 1-2 cm in waterlogged muck and silt: ice-patch run-off. Found approximately 70m from the current edge of the ice-patch, on a large solifluction/gelifluction "terrace". Quite withered and corroded – more so than any of the other arrowheads recovered during the survey. The only arrowhead that it would have been impossible to observe by visual inspection.

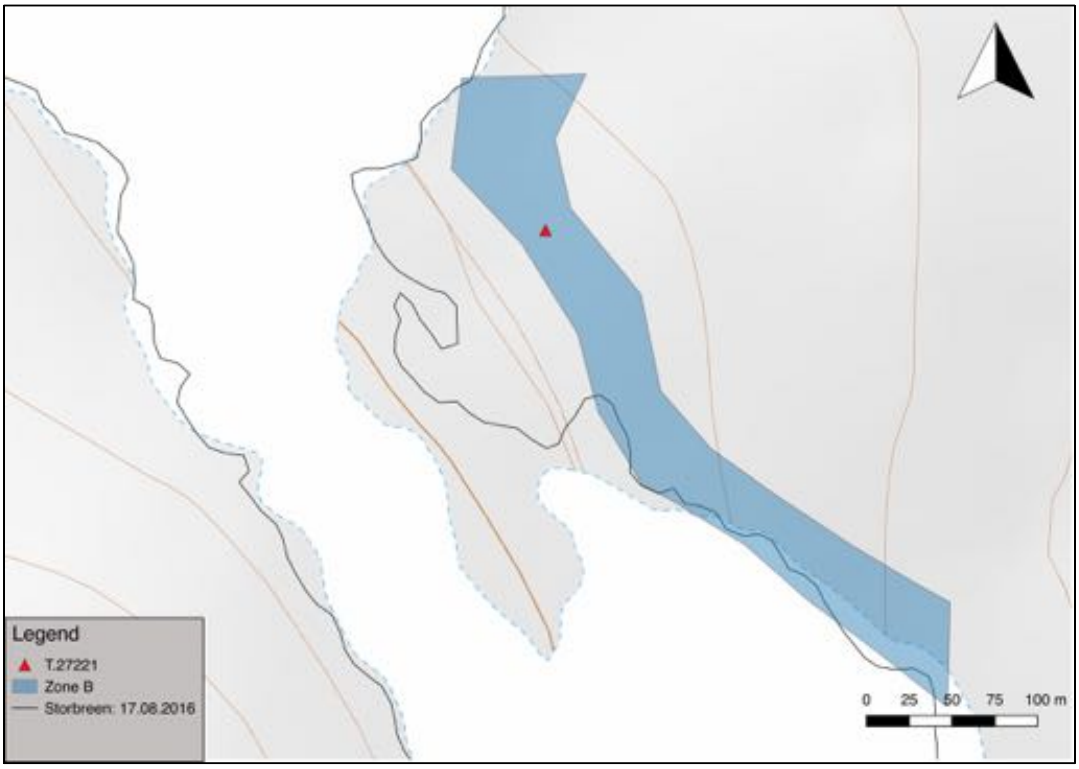

Figure 37: Geographic location of T.27221

Figure 38: T.27221 - in situ, after some debris has been removed

Figure 39: T.27221 - Location in relation to the ice-patch

T.27225

Artefact	Arrowhead
Material	Iron
T-number	T.27225
Dating	AD400-600
Length	12cm
Weight	16g
Coordinates UTM 32V	N6914579 E0521447
Find date	29.08.2016
Found by	E.K

Figure 40: T.27225 – Detail photo

DESCRIPTION:

Flat-tanged iron arrowhead, typologically dated to the Migration Period (AD 400-600). Recovered from the surface during metal-detector survey. Dry conditions, but very much exposed to the elements. Approximately 30m from the ice-patch. A small chip has broken off the tang, this is presumably the metal shard see next to the artefact in picture X. This indicates that some form of trauma was involved with the deposition of the artefact. And also, that either the artefact, or more probably the fragment, has moved since the deposition event.

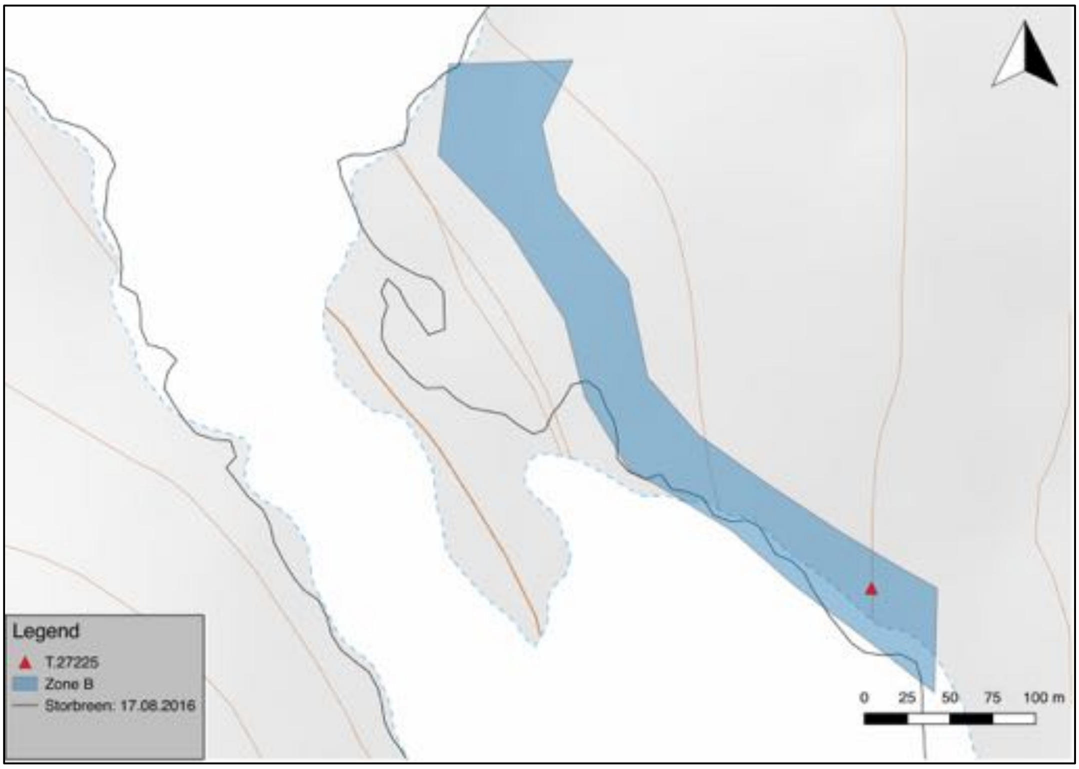

Figure 41: Geographic location of T.27225

Figure 42: T.27225 in situ. Note the metal fragment to the right of the arrowhead.

Figure 43: T.27225 in relation to the ice-patch.

T.27226

Artefact	Arrowhead
Material	Iron
T-number	T.27226
Dating	AD400-600
Length	13.4cm
Weight	21g
Coordinates UTM 32V	N6914596 E0521409
Find date	29.08.2016
Found by	E.K

DESCRIPTION:

Found during metal detector surveying, approximately 10m from the ice-patch. Standing vertically, tang downwards, propped up by rocks in a small "drop off". On the tang, which was covered up by the rocks, some biological material was preserved. Probably this is remnants of the lashing which attached the point to a shaft.

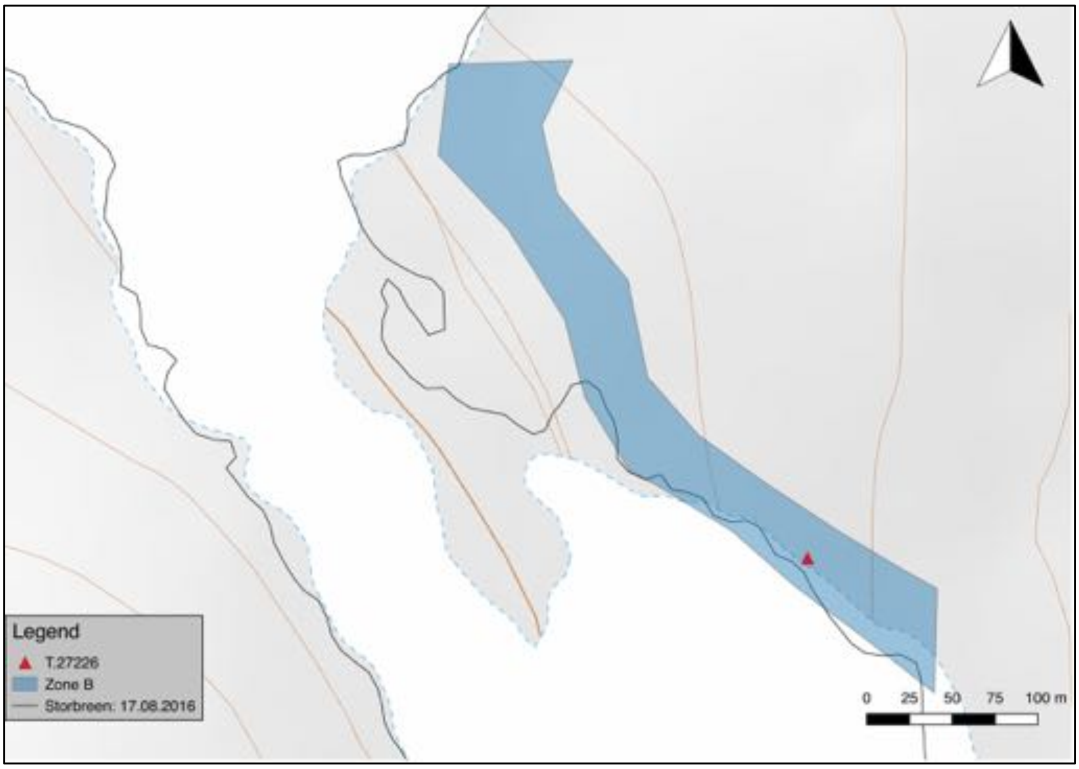

Figure 44: Geographic location of T.27226

Figure 45 – T.27226 in situ, before and after exposing the tang.

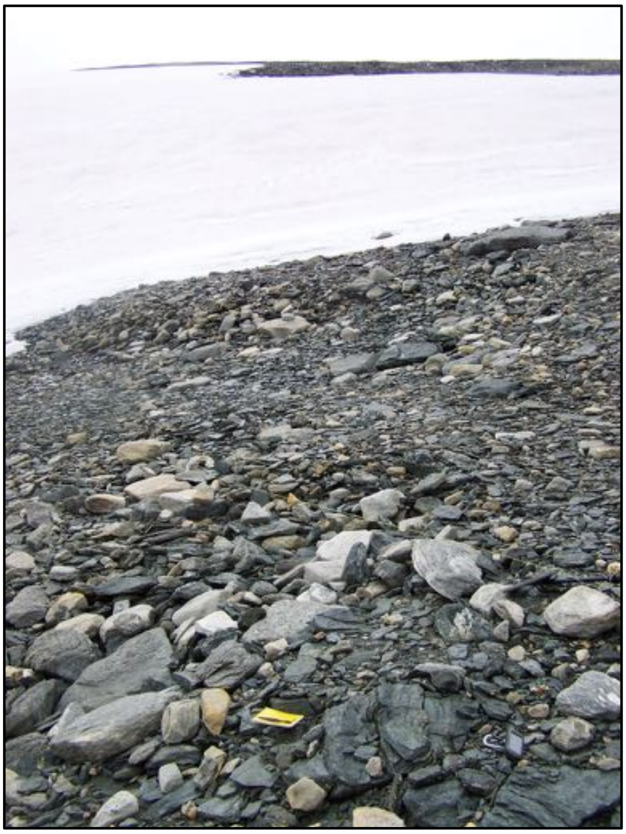

Figure 46 – T.27226 location in relation to the ice-patch

T.26793

Artefact	Shaft fragment
Material	Wood: unknown
T-number	T.26793
Dating	No date
Length	7.5 cm
Coordinates UTM 32V	N6914486 E0521484
Find date	30.08.15
Found by	M.C

DESCRIPTION:

Medial shaft fragment, found during metal-detector surveying. Recovered approximately 1m from the terminal edge of the ice-patch. Moist conditions, amongst rocks, gravel, and sediment run-off. The age of the artefact, and species of wood are unknown at this point.

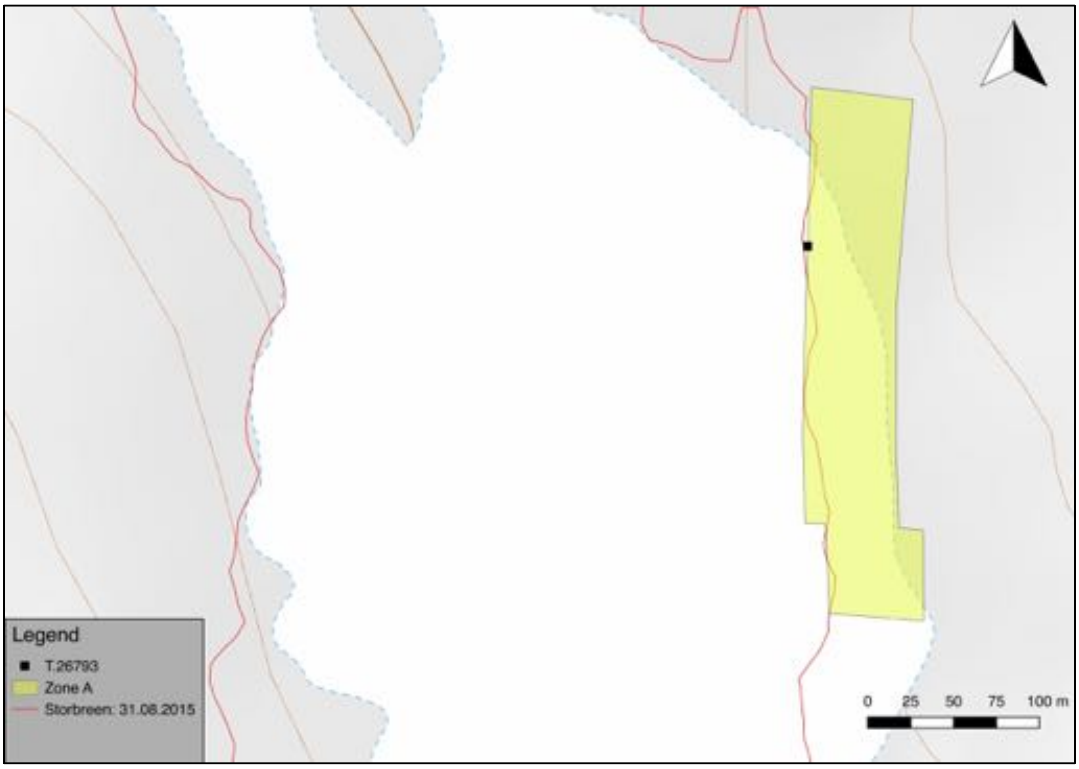

Figure 47: Geographic location of T.26793

Figure 48: T.26793 in situ. Photo: M.C.

Figure 49: T.26793 in relation to the ice-patch. Photo: M.C.

T.26795

Artefact	Shaft fragment
Material	Wood: unknown
T-number	T.26795
Dating	No date
Length	13.5cm
Coordinates UTM 32V	N6914472 E0521487
Find date	30.08.15
Found by	M.C

Figure 50: T.26795 detail photo

DESCRIPTION:

Distal shaft fragment, recovered during surveying with metal-detector. Found in running water, amongst gravel and sediment. Approximately 3 m from the terminal edge of the ice-patch. The artefact has not been dated. The species of wood is unknown.

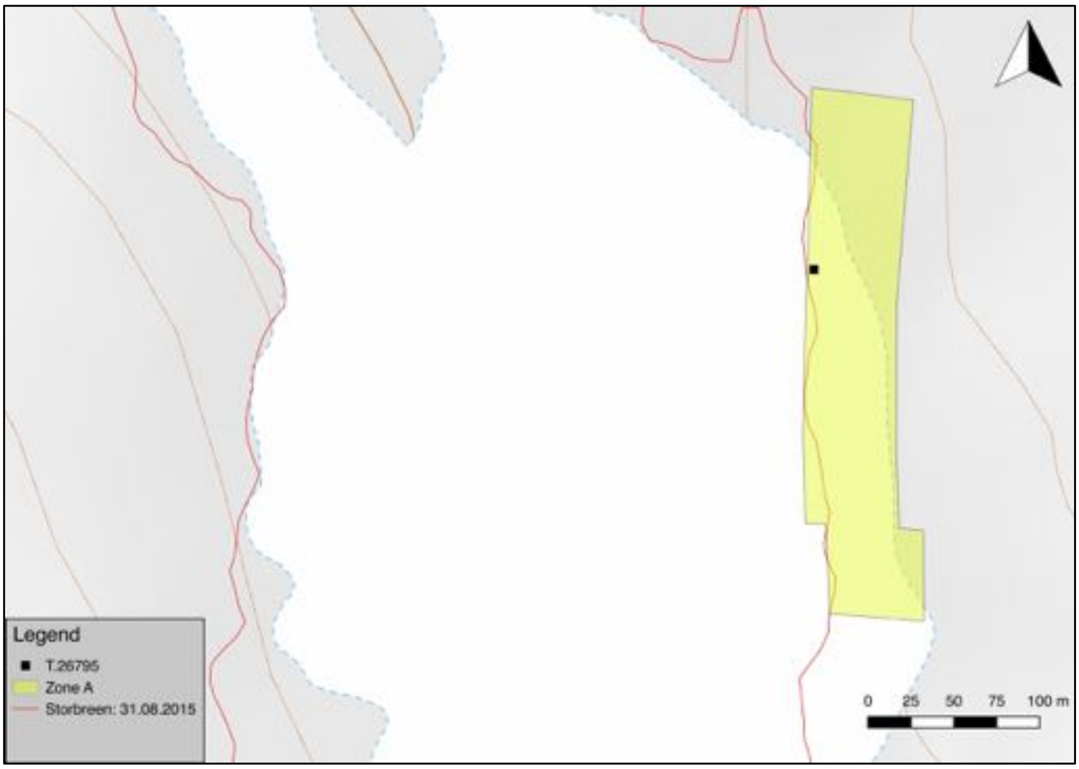

Figure 51: Geographic location of T.26795

Figure 52 – T.26795 in situ. Photo: M.C.

Figure 53 – T.26795, bottom right, in relation to the ice-patch. Photo M.C.

T.27222

Artefact	Arrowshaft: Complete/ fragmented
Material	Wood: Betula[?]
T-number	T.27222
Date-typo	AD400-600
Length	64/60[?]
Coordinates UTM 32V	N6914951 E0521272
Find date	17.08.2016
Found by	E.K

Figure 54: T.27222 – edited by Reidar Øiangen

DESCRIPTION:

Recovered during surveying with metal-detector. Fragmented shaft, seemingly complete. Of the A1 type, typologically dating to the migration period (AD400-600). The fragments were laying in order, indicating that fragmentation has occurred after deposition in current location. Found approximately 50m away from the terminal edge of the ice-patch. Found dry, close to an intersection of two watercourses.

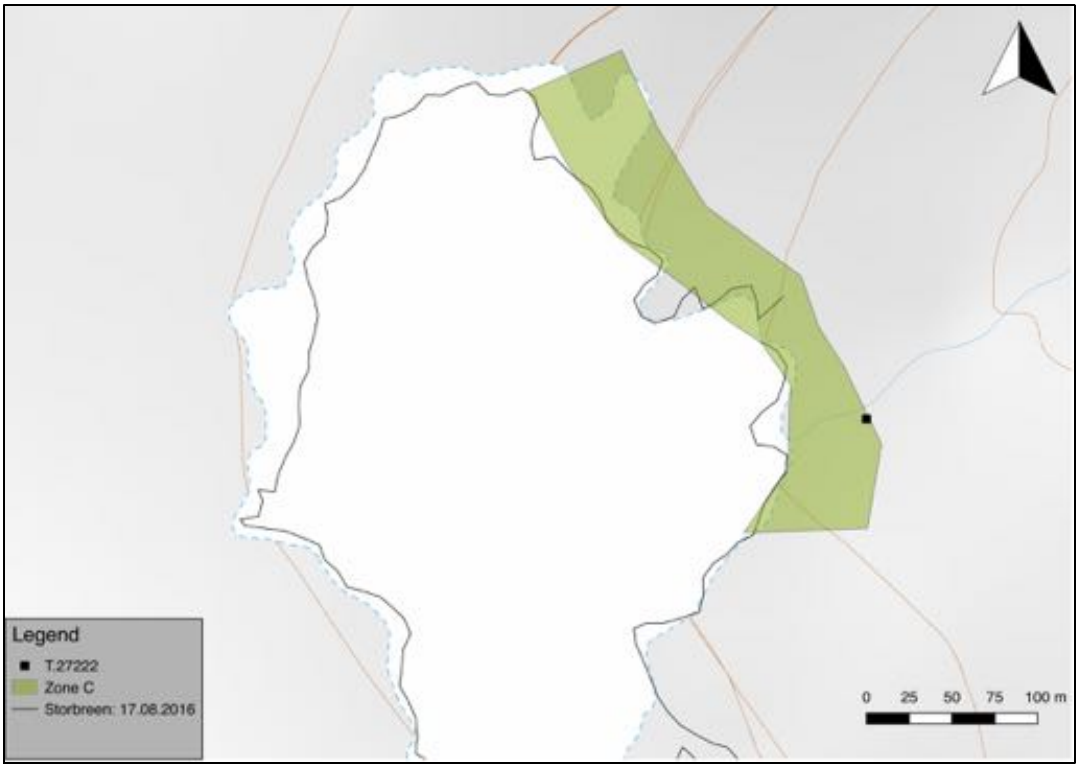

Figure 55: Geographic location of T.27222

Figure 57: T.27222 in situ close-up. Note the small fragment on the centre right, at the 18cm mark.

Figure 56: T.27222 in relation to the ice-patch.

T.27227

Artefact	Shaft fragment
Material	Wood: unknown
T-number	T.27227
Dating	No date
Length	19.8cm
Coordinates UTM 32V	N6914588 E0521420
Find date	29.08.2016
Found by	E.K

Figure 58: T.27227 before conservational treatment

DESCRIPTION:

Found relatively dry, shortly after a light rainfall, approximately 12m from the ice-patch. Dry conditions, directly exposed to the subaerial elements. Lying openly on top small rocks and gravel. Probably belongs to a previously recovered fragment: T.26338.

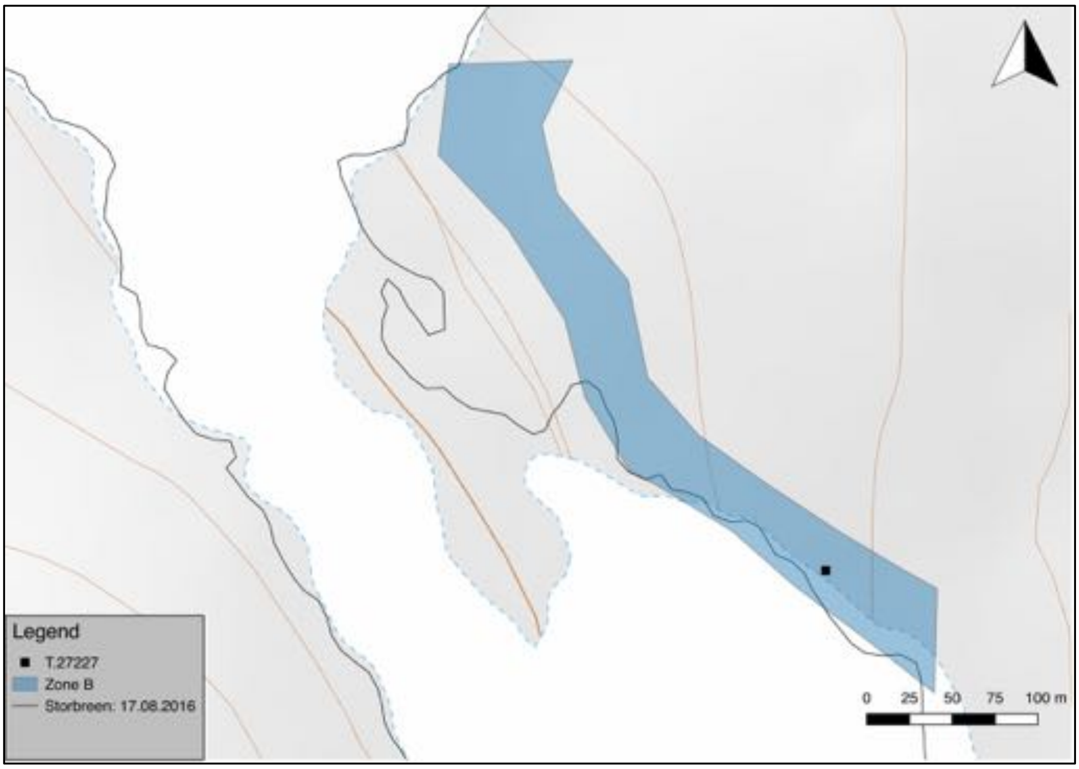

Figure 59: Geographic location of T.27227

Figure 60: T.27227 in situ close-up

Figure 61: T.27227 in relation to the ice-patch

Appendix B – Catalogue

Museum no.	Find Description	Dating	Date Class	Year found	Found by	North	East	Position
T 17687	Iron point	AD400-600	Typo	?	Henry O. Klett	6914638	521298	Estimated
T 17686	Shaft section of Betula	ante AD1000	Typo	?	Peder Fossheim	6914638	521298	Estimated
T 15272	Shaft of Betula	AD400-600	Typo	1936	Gudbjørn Havdal & Hallvard Håker	6914638	521298	Estimated
T 15272	Shaft of Betula	AD400-600	Typo	1936	Gudbjørn Havdal & Hallvard Håker	6914638	521298	Estimated
T 17698,f & T 17694/17698e	Shaft fragment of Betula with bone point	Median AD341	C14	1937	Hallvard Håker	6914638	521298	Estimated
T 17698,c	Iron point	AD400-600	Typo	1937	Hallvard Håker	6914638	521129	Estimated
T 17698,b	Shaft fragment of Betula	ante AD1000 (AD400-600?)	Typo	1937	Hallvard Håker	6914638	521298	Estimated
T 17698,b	Shaft section of Betula	ante AD1000 (AD400-600?)	Typo	1937	Hallvard Håker	6914638	521298	Estimated
T 17698,d	Shaft of Betula	AD400-600	Typo	1937	Hallvard Håker	6914638	521298	Estimated
T 17698,h	Iron point	AD600-800	Typo	1937	Hallvard Håker	6914638	521298	Estimated

T 17698,a	Shaft fragment of Betula	post AD600 (AD1200-1700?)	Typo	1937	Hallvard Håker	6914638	521298	Estimated
T 17698,g	Shaft fragment of Pinus	post AD600 (AD1200-1700?)	Typo	1937	Hallvard Håker	6914638	521298	Estimated
T 16077,c	Shaft section of Betula	ante AD1000 (AD400-600?)	Typo	1941	Hallvard Håker	6914638	521298	Estimated
T 16077,d	Shaft section of Betula	ante AD1000 (AD400-600?)	Typo	1941	Hallvard Håker	6914638	521298	Estimated
T 16077,b	Shaft of Betula	AD400-600	Typo	1941	Hallvard Håker	6914638	521298	Estimated
T 16077,d	Shaft section of Betula	ante AD1000 (AD400-600?)	Typo	1941	Hallvard Håker	6914638	521298	Estimated
T 16077,d	Shaft section of Betula	ante AD1000 (AD400-600?)	Typo	1941	Hallvard Håker	6914638	521298	Estimated
T 16077	Bow fragment of Pinus	N.D.	N.D.	1941	Hallvard Håker	6914638	521298	Estimated
T 18936	Iron point	AD400-600	Typo	1950	Audun Håvimb	6914638	521298	Estimated
T 24761	Shaft fragments of Betula and iron point	AD400-600	Typo	1955	Oddvar Hoel	6914279	521169	Estimated
T 23411	Shaft fragments of Betula	Median 1571BC	C14	2006	Rune Pedersen	6914638	521298	Estimated
T 23412	Shaft fragments of Betula	AD600-?	Typo	2006	Rune Pedersen	6914638	521298	Estimated
T 24140	Shaft of Betula	Median AD618	C14	2008	Martin Callanan	6915007	521102	GPS

T 24137	Iron point	AD400-600	Typo	2008	Ingolf Røtvei	6914997	521090	GPS
T 24141	Shaft fragments of Betula and point of iron	AD400-600	Typo	2008	Martin Callanan	6914735	521179	GPS
T 24981	Shaft fragments of Betula	Median 1569BC	C14	2009	Rune Pedersen	6914943	521233	GPS
T 25165	Shaft of Betula and iron point	AD900-1100	Typo	2010	Ingolf Røtvei	6914597	521375	GPS
T 25166	Shaft of Pinus and iron point	AD400-600	Typo	2010	Ingolf Røtvei	6914600	521384	GPS
T 25167	Shaft of Betula and antler point	Median 1301BC	C14	2010	Tord Bretten	6914975	520959	GPS
T 25168	Shaft of Betula and iron point	AD400-600	Typo	2010	Tord Bretten	6914811	521086	GPS
T 25169	Shaft fragments of Betula	N.D.	N.D.	2010	Tord Bretten	6914563	521433	GPS
T 25170	Shaft fragment of Betula	Median 2056BC	C14	2010	Tord Bretten	6914771	521097	GPS
T 25173	Wooden object of Betula (staff?)	N.D.	N.D.	2010	Julian Martinsen	6914564	521426	GPS
T 25284	Shaft fragments of Betula	N.D.	N.D.	2010	Rune Pedersen	6914943	521232	GPS
T 25285	Iron point	AD400-600	Typo	2010	Rune Pedersen	6914761	521161	GPS
T 25288	Wooden object of Betula (pointed)	N.D.	N.D.	2010	Tord Bretten	6914733	521078	GPS
T 25672	Shaft fragment of Betula	AD800-1000	Typo	2011	Jostein Mellem	6915064	521108	GPS
T 25673	Bow fragments of Pinus	N.D	N.D.	2011	Tord Bretten & Line Bretten Aukrust	6915014	521153	GPS

T 25674	Shaft of Salix and slate point	Median 3456BC	C14	2011	Tord Bretten & LineBretten Aukrust	6914548	521432	GPS
T 25675	Shaft fragmes of Pinus	Median 3447BC	C14	2011	Line Bretten Aukrust & Tord Bretten	6914465	521496	GPS
T 25676	Shaft fragments of Pinus and slate point	Median3206BC	C14	2011	Line Bretten Aukrust & Tord Bretten	6914254	521198	GPS
T 25677	Bow fragments of Ulmus	Median1816BC	C14	2011	Line Bretten Aukrust & Tord Bretten	6914547	521287	GPS
T 25687	Shaft of Betula and iron point	AD400-600	Typo	2011	Tord Bretten	6915003	520979	GPS
T 25688	Shaft fragments of Betula	ante AD1000	Typo	2011	Tord Bretten	6915007	521015	GPS
T 25689	Shaft fragment of Betula	ante AD1000	Typo	2011	Tord Bretten	6914536	521449	GPS
T 25690	Shaft section of Betula and iron point	AD400-600	Typo	2011	Tord Bretten	6914441	521500	GPS
T 25704	Shaft fragments of Betula	ante AD1000	Typo	2011	Hårvard Rønning	6914537	521449	GPS
T 25710	Wooden fragments of Betula	N.D.	N.D.	2011	Tord Bretten	6915024	521148	GPS
T 26108	Antler point	N.D.	N.D.	2013	Tord Bretten	6914467	521509	GPS

T 26110	Leather fragment	FRJA	N.D.	2013	Tord Bretten & Line Bretten Aukrust	6914568	521260	GPS
T 26111	Shaft fragment of betula	N.D.	N.D.	2013	Tord Bretten & Line Bretten Aukrust	6914533	521183	GPS
T 26112	Shaft fragments of Pinus and Iron point	AD400-600	Typo	2013	Greg Hare	6914624	521404	GPS
T 26113	Shaft fragment of Pinus and iron point	293calAD	C14	2013	Martin Callanan	6914534	521186	GPS
T 26114	Shaft fragments of Betula and iron point	AD400-600	Typo	2013	Greg Hare	6914302	521163	GPS
T 26115	Staff of Betula	N.D.	N.D.	2013	Jørgen Rosvold	6914248	521189	GPS
T 26116	Shaft fragments of Pinus and Iron point	AD400-600	Typo	2013	Aud Ingrid, Even og Tyra Bretten	6914605	521419	GPS
T 26118	Shaft fragments of Betula with fletchings and iron point	363calAD	C14	2013	Tord Bretten & Aud Ingrid Bretten	6914985	520940	GPS
T 26119	Shaft fragments of Pinus	N.D.	N.D.	2013	Tord Bretten & Aud Ingrid Bretten	6914626	521241	GPS
T 26120	Shaft fragments of Pinus	N.D.	N.D.	2013	Line Bretten Aukrust	6914641	521229	GPS

T 26121	Shaft fragment of Betula	275calBC	C14	2013	Tord Bretten			
T 26122	Shaft fragmens of Alnus	N.D.	N.D.	2013	Ivar Berthling	6914467	521586	GPS
T 26123	Shaft fragments of Betula	N.D.	N.D.	2013	Arne Johs Mortensen	6914160	521434	GPS
T 26117	Bow fragment	6692calAD	C14	2013	Tord Bretten & Aud Ingrid Bretten	6915022	521150	GPS
T 26348	Slate poin	N.D.	N.D.	2014	Kjetil Haukvik	6914488	521475	GPS
T 26387	Shaft fragments	N.D.	N.D.	2014	Even Bretten	6914490	521468	GPS
T 26388	Shaft fragments	3447calBC	C14	2014	Even og Tord Bretten	6914458	521479	GPS
T 26414	Shaft fragment	N.D.	N.D.	2014	Tord Bretten	6914535	521447	GPS
T 26415	Shaft fragment	N.D.	N.D.	2014	Lars L. Slåke			
T 26416	Shaft of Betula	AD400-600	Typo	2014	Lars L. Slåke			
T 26426	Shaft section of Betula	N.D.	N.D.	2014	Tord Bretten	6922057	499057	GPS
T 26792	Horseshoe nail	N.D.	N.D.	2015	Einar Kristensen	6914548	521504	GPS
T 26793	Medial shaft fragment	N.D.	N.D.	2015	Martin Callanan	6914486	521484	GPS
T 26794	Iron point	AD400-600	Typo	2015	Martin Callanan	6914340	521503	GPS
T 26795	Proximal shaf fragment of Betula	N.D.	N.D.	2015	Martin Callanan	6914472	521487	GPS
T 27221	Iron point	AD400-600	Typo	2016	Einar Kristensen	6914797	521249	GPS

T 27222	Whole shaft of Betula	AD400-600	Typo	2016	Einar Kristensen	6914951	521272	GPS
T 27227	Shaft fragment	N.D.	N.D.	2016	Einar Kristensen	6914588	521420	GPS
T 27225	Iron point	AD400-600	Typo	2016	Einar Kristensen	6914579	521447	GPS
T 26226	Iron point	AD400-600	Typo	2016	Einar Kristensen	6914596	521409	GPS
T 25688	Shaft fragment	N.D.	N.D.	2016	Tord Bretten	6914539	521452	GPS
T 27265	Shaft Fragment	N.D.	N.D.	2016	Tord Bretten			