UMEÅ UNIVERSITY

Blinded by the light:
Developing models of settlement and mobility with the use of spectroscopy and exploratory methods

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For My Mother, My Beacon In The Dark

Contents

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List of papers

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II. *Sjölander, Mattias, Budd, Chelsea, Smeds, Ronny.* 2023. A Point in Time: An evaluation of the bifacial point chronology in Northern Sweden. [Manuscript submitted for publication]

III. *Sjölander, Mattias, Linderholm, Johan, Geladi, Paul, Buckland, Philip.* 2024. Quartzite Complexities: Non-destructive analysis of bifacial points from Västerbotten, Sweden. Journal of Archaeological Science: Reports, 53, 104387.

IV. *Sjölander, Mattias, Buckland, Philip, Linderholm, Johan.* 2024. Straight to the point: Bifacial points and hunter-gatherer mobility in Västerbotten, Sweden. [Manuscript].

Author's contribution

Introductory text

All figures have been created by the author, except where otherwise noted.

Papers

Attribution for each paper is summarised below according to the Contributor Roles Taxonomy (CrediT).

Paper I. Mattias Sjölander – Sole author

Paper II. Mattias Sjölander – Conceptualization, Data Curation, Methodology, Formal analysis, Investigation, Visualization, Writing – Original Draft; **Chelsea Budd** – Methodology, Formal analysis, Visualization, Writing – Original Draft; **Ronny Smeds** – Investigation, Data Curation

Paper III. Mattias Sjölander – Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Validation, Writing - original draft, Writing - Review & Editing; **Johan Linderholm** – Conceptualization, Methodology, Supervision; **Paul Geladi** – Formal analysis, Methodology; **Philip I. Buckland** – Writing – original draft, Writing - Review & Editing.

Paper IV. Mattias Sjölander – Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing - original draft**; Philip I. Buckland** – Conceptualization, Formal analysis, Methodology, Visualization, Writing - original draft**;** **Johan Linderholm** – Conceptualization, Formal analysis, Methodology, Visualization, Writing - original draft

Abstract

In this thesis an exploratory approach has been used to study settlement and mobility among hunter-gatherer societies in Northern Sweden during the 2 000 – 0 BC period. The focus has been on developing the topics of bifacial point use and raw material management of quartz and quartzite materials. The study combines the information generated at multiple analytical scales in order to address knowledge gaps and facilitate new research. The thesis consists of an introductory text and four research papers.

The first paper discusses modelling approaches in archaeology. It stresses the interlinked nature of models that are created at different spatial scales, and that weaknesses in lower-lying models may impact higher-level models in a study. The paper also discusses the question of whether an analysis is better suited for modelling in the "variable space", rather than geographical space, as the data my need to undergo unnecessary simplification that hides certain features.

The second paper is an evaluation of the current dating evidence for bifacial points made of quartz or quartzite in Norrland. The study includes 124 radiocarbon dates from 30 excavated sites with finds of bifacial points or preforms in the County of Västerbotten. Bayesian modelling is used to evaluate the potential for building a chronological model for bifacial point use in the region. The results indicate that few artefacts can be related to a dated feature, with only 3 dates that may be argued to stem from a secure dating context that dates the points. These dates all fall within the 1 900 – 1 700 BC period.

The third paper is a spectroscopic study of quartz and quartzite material. The study is based on a dataset of 126 quartz/quartzite points and preforms from 47 sites along the upper Ångerman River. Non-destructive analysis was performed using three different spectroscopic instrumentations (Near Infrared, Raman, X-Ray Fluorescence). The data were evaluated using Exploratory Data Analysis (EDA). Each instrumentation showed detectable differences in the material, such as the presence or absence of graphite. The study highlights the potential of non-destructive screening methods and lays the foundation for future survey efforts.

The fourth paper is a spatial analysis of the distribution of bifacial points and preforms made of quartz and quartzite within the County of Västerbotten. The Ångerman and Ume/Vindel Rivers exhibit different distribution patterns, with higher proportions of preforms closer to the mountains. The distribution pattern is evaluated using Exploratory Data Analysis, including geostatistical methods. The capacity for previous settlement and mobility models to explain the observed patterns are then discussed in the light of factors such as archaeological survey coverage.

Sammanfattning (Summary in Swedish)

Denna avhandling studerar bosättning och mobilitet bland jakt- och fångstfolk i norra Sverige under perioden 2 000 – 0 f.Kr. med hjälp av explorativa analysmetoder. Fokus har varit att utveckla teorier kring användandet av bifaciala spetsar och råmaterialutnyttjande av kvarts och kvartsit. Studien kombinerar informationen som genererats på olika analytiska nivåer för att diskutera kunskapsluckor och för att främja ny forskning. Avhandlingen består av en introduktion och fyra forskningsartiklar.

Den första artikeln diskuterar modellering inom arkeologi. Den betonar hur modeller producerade på olika rumsliga nivåer är sammanlänkade, och hur svagheter inom underliggande modeller kan påverka modeller på högre rumsliga nivåer. Artikeln diskuterar även frågan om huruvida en analys är bättre lämpad för modellering inom en ”variabel rymd”. Modellering inom en ”geografisk rymd” kan innebära oönskad förenkling av data som maskerar mönster av vikt.

Den andra artikeln utvärderar dateringsunderlaget för bifaciala spetsar tillverkade i kvarts eller kvartsit i Västerbotten. Studien inkluderar 124 radiometriska dateringar från 30 undersökta lokaler med fynd av bifaciala spetsar eller förarbeten. Bayesiansk statistik och modellering användes för att utvärdera möjligheten att bygga en kronologisk modell av användandet av bifaciala spetsar inom regionen. Resultaten indikerar att få spetsar/förarbeten kan kopplas till daterade anläggningar, och endast 3 dateringar kan härledas till säkra dateringskontexter. Dessa dateringar faller inom perioden 1 900 – 1 700 f.Kr.

Den tredje artikeln är en spektroskopisk studie av kvarts och kvartsitmaterial. Studien är baserad på mätningar tagna på 126 kvarts-/kvartsitspetsar och förarbeten från 47 lokaler längs övre delarna av Ångermanälven. Mätningarna utfördes med icke-destruktiva spektroskopiska instrument (Nära Infraröd, Raman, Röntgenfluorescens). Data utvärderades med explorativ dataanalys. Alla spektroskopiska metoder kunde påvisa skillnader i materialet, såsom närvaro eller frånvaro av grafit. Studien demonstrerar potentialen av icke-destruktiva metoder och lägger grunden för framtida inventeringar.

Den fjärde artikeln är en rumslig analys av spridningen av bifaciala spetsar och förarbeten i kvarts och kvartsit inom Västerbottens län. Spridningsmönstret utvärderades med hjälp av explorativ dataanalys, inklusive geostatistiska metoder. Resultaten diskuterades i förhållande till tidigare modeller av bosättnings- och rörelsemönster, och dessas förmåga att förklara de identifierade mönstren.

Glossary of terms

Bifacial

Lithic technique where flakes are removed from both sides of an artefact

Blank

Piece of stone or debitage used in lithic production

Exploratory Data Analysis (EDA)

A collection of techniques used to summarize data properties and identify patterns

in situ

artefact or material of study is in its original place of deposition

Norrland

Administrative region in Sweden consisting of the five northernmost Counties

Percussion flaking

Lithic technique where flakes are removed by striking the blank directly

Point

Collective term for lithic arrowheads and spear heads.

Preform

Lithic artefact representing the processing stage before the finished point

Pressure flaking

Lithic technique where flakes are removed using pressure

Site ID

Site identification in the The Swedish National Heritage Board database (Fornsök)

Spectroscopy

Study of how a material absorbs or emits light and other radiation

Abbreviations

EDA

Exploratory Data Analysis

GIS

Geographical Information System

NIRS

Near Infrared Spectroscopy

PC

Principal Component

PCA

Principal Component Analysis

RAÄ

The Swedish National Heritage Board

VBM

Västerbottens Museum

ED-XRF

Energy Dispersive X-Ray Fluorescence

1. Introduction

Human mobility has long been a central topic of research within archaeology (e.g. Binford 1980; Brantingham 2003; Fitzhugh and Habu 2002; Kelly 1992), most recently reinvigorated by the increased interest in cutting-edge genomic research (Günther et al. 2018; Schmid and Schiffels 2023) (Figure 1). The reasons for people to have moved in the past are plentiful; habitual procurement of resources (Donadei, 2019; Tomasso and Porraz, 2016), trade and exchange (Kahn 2013; Karampas and Falezza 2023; Tykot 2017), migration (Gregoricka 2021; McSparron et al. 2020), and climate and environmental change (Goldstein et al. 2022; Roberts et al. 2018) being some important examples. Although explicit definitions of mobility tend to be uncommon in archaeological research, *"…the equation of mobility with the act of moving, rather than with the ability to move, is implicit in most archaeological discussion of the topic"* (Close 2000:50).

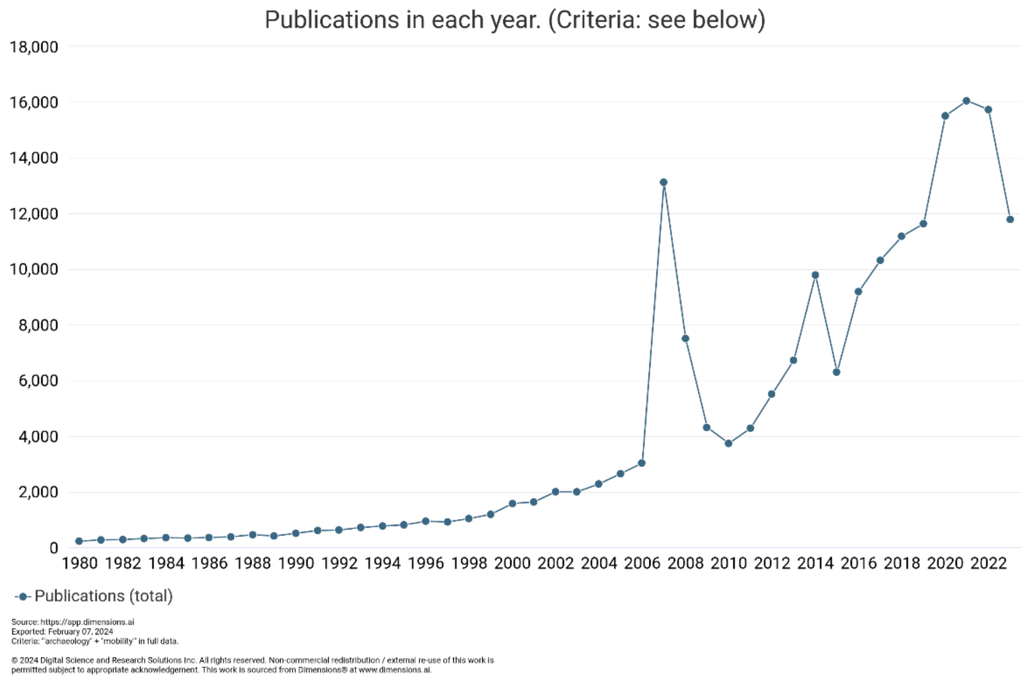


Figure 1 Chart showing publications per year related to search terms "archaeology" and "mobility" between 1980 – 2023 in www.dimensions.ai (© 2024 Digital Science and Research Solutions Inc.).

The appearance of bifacial points made of quartzite in Northern Sweden seems to occur at a time of cultural change among the hunter-gatherer societies (Forsberg 2010, 2012; Forsberg and Damm 2014; Paper II). Bifacial tools have been associated with high levels of residential mobility and logistic organization (Kelly 1988; Kelly and Todd 1988). The material for such tools needs to be sourced from somewhere, however, and depending on availability it may impact the overall pattern of a group. If the archaeological material can be characterised, and potential sources of the same character identified, then a possible link can be established between them (Tykot 2003). This approach, however, is dependent on the geological sources of the material in question being known. What if there is a lack of known sources, or if the material in question is readily available in most of the region? How does one then ascertain the nature of the utilization of this resource?

This thesis will address these questions as part of a study of bifacial tool use among hunter-gatherers within Northern Sweden, mainly during the 2 000 – 0 BC period. The aim is to develop the topic of raw material management of local resources among hunter-gatherer groups and contribute to an increased understanding of how people engaged with their surrounding environment during a period of cultural change.

1.1 Mobility studies in Northern Sweden

In this thesis the Swedish term *Norrland* will be used in place of "Northern Sweden". Although the term "Norrland" has been, and continues to be, used in an administrative capacity to describe the areas north of the Dala River there have also been attempts to describe its borders based on cultural and environmental variables (Loeffler 2005:27-39). Here, Norrland is used according to a more common administrative definition as the five northernmost counties (Edlund and Frängsmyr 1995) (Figure 2).

The view that Norrland was populated fairly late in time was still a common perception held within archaeology as late as the 1960s (Janson and Hvarfner 1960:21). Although archaeological studies of the region can be traced back as far as to the late 1800s it was the hydroelectric development projects in the northern rivers around 1940 – 1980 that highlighted the sheer abundance of archaeological sites (Biörnstad 2006; Loeffler 2005). Following the extensive surveys and excavations undertaken in conjunction with the exploitation of the northern rivers two significant research projects were established (Biörnstad 2006). The *Early Norrland* project (Biörnstad 1967) and *Nordarkeologi* (Christiansson 1980) both endeavoured to properly address the issue of chronology within Northern Sweden, undertaking targeted excavations and sampling of sites that showed promise. The results would be a chronological framework developed by Baudou (1978, 1992), which has largely remained intact since it was published (Table 1).

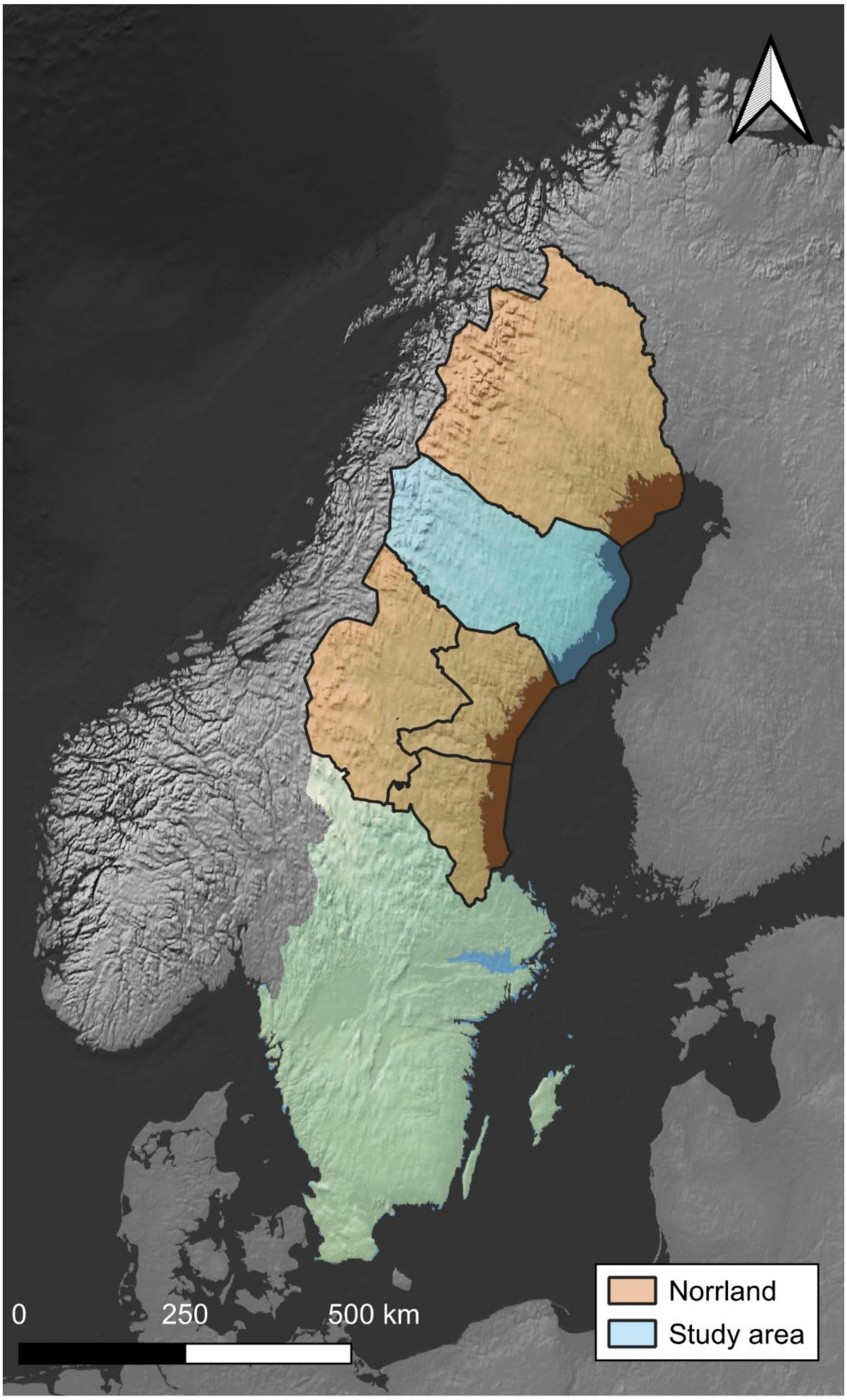


Figure 2 Map of Sweden with the geographical area defined as Norrland highlighted in orange. The study area for the thesis is highlighted in blue. Prehistoric cultural development within Norrland differs from that of Southern Sweden, in terms of raw material use, lithic technology, ceramics, etc. This is exemplified in the area of Northern Uppland where two different bifacial point traditions seem to meet, South Scandinavian pressure-flaking and the North Fennoscandian combined percussion and pressure-flaking technique (Apel and Darmark 2007). Made with Lantmäteriet (CC0) and Natural Earth in QGIS (3.34.2).

One of the main issues of chronological studies within the northern area is the lack of sites with a preserved stratigraphic sequence. There is little organic buildup within the soils due to the widespread moraine and coniferous forests, which makes for short sequences (Linderholm 2010). The low pH of the soils also contributes to poor preservation of unaltered organic material suitable for radiometric dating (Sauer et al. 2007; Schiffer 1987:146-147). Due to this there has been a reliance on relative dating methods, such as shoreline dating and typological comparisons (e.g. Baudou 1978; Broadbent 1979). The isostatic land uplift does not just affect the shoreline of the coastal region, however, but has also been documented to affect inland lakes (Påsse 1998). As the land uplift may not be uniform across a region this can result in different parts of a lake to be uplifted at different rates. This may result in archaeological sites being submerged or the construction of sites in sequence following the regressing shoreline (Bergman et al. 2003).

Indirect evidence of anthropogenic activity can be gleaned via the use of environmental proxies (Reitz and Shackley 2012). Not only does methods such as palynology and palaeoentomology provide useful climate and environmental background data, but certain changes observed in the peat or lake records might be indicative of human impact. Increased erosion (e.g. Lowe and Walker 2013:135-148; Zhao et al. 2023), changes in forest structure, (Bleed and Matsui 2010:361; Dubois et al. 2017; Maezumi et al. 2018), and agricultural pollen taxa could all be indicators of human driven processes. Dating these changes in the peat or lake records can thus provide valuable context for dates obtained at archaeological sites (absolute and/or relative). Palynology in particular has long been integrated with archaeological studies in Northern Sweden (e.g. Engelmark 1978; Miller and Robertsson 1979; Wallin 1996).

Archaeological research within Norrland has largely focused on the cultural development of inland hunter-gatherer communities (Andersson 1999, Bergman 1995; Forsberg 1985; Holm 1991; Lundberg 1997; Spång 1997). As a result, there are now diachronic models that describe the development of settlement and mobility among these groups from the Mesolithic period (ca. 9 600 BC – 4 200 BC) up until around the Early Metal Age (800 BC – 200 AD). In contrast, the cultural development among hunter-gatherer communities along the coastal region has received less attention (Broadbent 1979; Norberg 2008; Forsberg and Damm 2014). For a long time, archaeologists considered the coastal region as being settled by South Scandinavian groups around the late Mesolithic – early Neolithic, due to the presence of flint artefacts made in South Scandinavian sources and style (Halén 1994:115-122; Knutsson 1988). This research depicted a division between South Scandinavian farmers along the coast and Northern hunter-gatherers in the inland. These ideas have received criticism over the years (e.g. Halén 1994), and later studies have argued the presence of South Scandinavian tool types as being more indicative of local traditions engaged in complex trade and exchange networks (Forsberg 2012).

Although there has been considerable development in recent years, settlement and mobility during the Mesolithic is vaguely defined within Norrland. This has in part been due to the lack of known sites dating to this period, and the settlement pattern has as a result been described as flexible and variable (Bergman 1995; Forsberg 1985), made up of smaller groups of hunter-gatherers using short-term campsites. Much emphasis in archaeological research on this period has been the pioneer settlement of the region; when was it possible for people to move into the landscape, and from what directions (e.g. Bergman et al. 2004; Ekholm 2021; Knutsson et al. 2016). Two different lithic traditions can be seen moving into the North Scandinavian region shortly after the deglaciation, the Ahrensburgian from South Scandinavia, moving up along the Norwegian coast, and Butovo/Veretye from Russia (Ekholm 2021). The two traditions seem to meet and mix later during the Mesolithic (Günther et al. 2018), moving into the region of Dalarna in middle Sweden. The details of the pioneer settlement in the upper parts of Norrland are still unclear, but evidence points towards hunter-gatherers of the Butovo/Veretye tradition having a lot of presence in the region (Ekholm 2016, 2021; Knutsson et al. 2016; Riede and Tallavaara 2014).

Around the late Mesolithic (ca. 5 000 BC), the hunter-gatherer communities appear to become more sedentary. Semi-subterranean dwellings, with a lowered floor surface and embankments filled with fire-cracked stones, are constructed in the inland and coast alike (Norberg 2008; Spång 1997). Similar structures can be found in ethnographic comparisons with northern Fennoscandia, Siberia, and North America (Lundberg 1997:87-100), where they have been used as winter dwellings. Lundberg (1997) proposes that the semi-subterranean dwellings were used recurringly during the winter season as part of a semi-sedentary settlement system among the inland hunter-gatherers. Norberg (2008) reached similar conclusions in his study of coastal settlements in the County of Norrbotten, but where the dwellings exhibit less intense use, and a more marine-focused economy from the Neolithic period onwards (4 000 – 1 800 BC).

By 5 300 BC the reindeer seems to disappear from the archaeological record (Ekholm 2021), and the elk (*Alces alces*) takes a central role in the subsistence pattern of the hunter-gatherer communities (Lundberg 1997). The elk seems to have held not just economic value to the Neolithic communities, but also has a symbolic value, as can be implied from its depiction on both tools and in rock imagery alike across Northern Eurasia (Gjerde 2010; Larsson et al. 2012; Ramqvist 1992; Sjöstrand 2011). In her analysis of the inland dwellings Lundberg (1997) draws comparisons with the North American moose (*Alces alces*) hunting groups, outlining a settlement and mobility model where the hunter-gatherers are organized into a semi-sedentary band society moving between seasonal base camps.

The shift from the Neolithic to the Epineolithic (2 000 – 0 BC) has been described by Forsberg (2012:36) as *"…one of the most radical breaks in societal development of Norrland, Sweden"*. One of the most conspicuous changes is the abandonment of the settlement pattern based around semi-subterranean dwellings. This occurs alongside a significant decrease in the amount of elk bones found in the archaeological bone assemblages. This is curious, as the elk seemed to hold such a central symbolic role among the Neolithic communities. Whilst there have been arguments made that there may have been a climatic factor affecting the elk population around this time, this has yet to be conclusively demonstrated (Larsson et al. 2012). Other significant changes that occur around this time, highlighted by Forsberg and Damm (2014:848), includes an increase in the utilization of quartzite (Baudou 1978), the re-introduction of bifacial points (Darmark 2012; Paper II), production of asbestos tempered pottery (Stilborg 2017), and metallurgical developments (Bennerhag 2023; George 2001; Hulthén 1991).

Forsberg (1985; 2012) argues that the inland and coastal communities adopted different settlement systems at around this time. The inland hunter-gatherers were logistically mobile, organised into local societies based around the river valleys and moving seasonally between the inland and the mountain foothills. The coastal communities, however, were more sedentary and formed different local traditions. These could consist of a mixture of incipient agropastoral and/or maritime hunting/fishing subsistence economies (Forsberg and Damm 2014). This settlement pattern seems to persist until the later parts of the Early Metal Age (800 BC – 200 AD).

1.2 Provenance studies and lithics

"Provenance studies" in archaeology typically have the aim of identifying either the place of manufacture of an object or the source of the material used in its manufacture (Waksman 2012). Knowing the source of a material used can provide useful insights into questions of settlement and mobility. Is the material local or foreign to the region? A foreign material appearing in the site assemblage could be indicative of trade. Is it common or limited in its distribution? Material that is readily available in the surrounding environment could be sourced as part of other activities. Is it located within an easily accessible area? Sources that are difficult to reach or require special tools could indicate that special meaning or value is attached to the procurement of the material. Answering these and other questions related to sourcing behaviour can contribute much to the interpretation of the organization of a group of people (Thacker 2006).

European provenance studies have for some time favoured flint and obsidian over other geological materials (e.g. Dixon et al. 1968; Polanyi 1957; Olofsson and Rodushkin 2012; Tykot 2003, 2017; Werra and Siuda 2022). Whilst this has enabled insightful research into aspects such as trade and exchange and societal organization (e.g. Manninen et al. 2003; Terradas et al. 2014; Tykot 2017), it leaves a void in terms of understanding prehistoric societies that relied primarily upon other geological materials (Knutsson et al. 2016; Prieto et al. 2019; Ramacciotti et al. 2019, 2022; Sciuto et al. 2019; Sjölander et al. 2024). As there are no local sources of flint or obsidian in Norrland, slate, quartz and quartzite have been the primary materials exploited by local communities. Despite this there have been few targeted studies of these same materials.

The lithic material recovered during the development of hydroelectric power in Norrland was petrographically characterised as part of the *Early Norrland* research project (Biörnstad 1967). The aim was to establish a system for petrographic classification which could be used by archaeologists. As the system was meant for use by people with no geological background it had to be simplified in such a way as to enable classification based mainly on visual inspection of the material (Baudou 1978:9; Käck 2009:54-55). Initial grouping of the material was performed by archaeologists, after which a geologist was consulted to undertake microscopic analysis in order to define the groups (Åhman 1967). This resulted in a standardised list of terms which could, theoretically, then applied by archaeologists without the assistance of a geologist (Table 1).

Although the manuscript describing the *Early Norrland* petrographic system was never published (Käck 2009;54-55), it remained in use for some time following the project. This system has enabled valuable synthesis studies (e.g. Forsberg 1985; Käck 2009), with some resulting in tentative hypotheses regarding raw material sourcing among hunter-gatherer groups (Bergman 1995; Forsberg 1985, 2010; Lundberg 1997:161-168). The system remains reliant on visual characterization of the material, however, and whilst suited for general overviews and initial classification they are not reliable in provenance studies. In order to reliably link a material to a potential source area microscopic and/or chemical characterization is necessary. Such studies aimed at quartz and quartzite material have been lacking within Norrland.

Table 1 The Early Norrland system for classifying petrographic material in Norrland, Sweden (see Käck 2009:59). This system has seen extensive use in contract archaeology within the region.

Code	***Material groups***
A	Quartz
Aa	Smokey quartz
Ab	Brecciated quartz
	Vein quartz
B	Milky quartz
C	Rock crystal (quartz)
D	Rose quartz
	Jasper
E	Dark quartzite
F	Dark porphyric quartzite
G	Light quartzite
H	Grey slate
J	Red slate
K	*"Hälleflinta"* (Halleflint, a form of tuffite)
L	Porphyric rocks
M	Flint

There are some factors that contribute to this lack of development, most importantly the region's geology (Chapter 2.1). Prehistoric peoples would have been able to source both quartz and quartzite material, that has been transported by glacial and postglacial processes, from riverbeds and moraine formations (Forsberg 2010:132-133). This means that even if a potential source of a specific quartzite type was to be identified it does not rule out the possibility that people sourced that same material from elsewhere. Likewise, quartz is ubiquitous and can potentially be sourced from any exposed vein in almost the entirety of the region (Rankama et al. 2006:249-250). This creates a large number of potential source areas for quartz.

The most recent developments in provenance studies of quartz and quartzite within Norrland have been attempts using non-destructive spectroscopy. Sciuto et al. (2019) applied Hyperspectral Imaging to a dataset of both quartz and quartzite material at a Late Mesolithic site in the parish of Anundsjö, Västernorrland. Using multivariate exploratory methods, the authors distinguished two different types of quartz and quartzite material, which was used to infer chronological changes in raw material use at the site. Even though the provenance of the material remained unknown there was still valuable data that could be gained from grouping the material according to its chemical characteristics.

1.3 Overall thesis objectives and papers

The aim of this thesis is to contribute to the development and advancement of models for settlement and mobility among hunter-gatherers during the 2 000 – 0 BC period in Norrland. Settlement and mobility are well-researched fields in Fennoscandia (Bergman, 1995; Bergman et al., 2004; Broadbent, 1979; Forsberg, 1985, 2010, 2012; Holm, 1991; Knutsson et al., 2016; Lundberg, 1997; Manninen et al., 2023; Norberg, 2008), and internationally (e.g. Binford 1980; Fitzhugh and Habu 2002; Kelly 1988, 1992; Kelly and Todd 1988; Preston and Kador, 2018; Zvelebil 2006). Norrlandic archaeology, however, suffer from a lack of development in terms of data and models for raw material management strategies with respect to quartz and quartzite materials (Baudou 1978; Forsberg 1985; Holm 1991:24; Rankama et al. 2006; Sciuto et al. 2019). As these materials represent a considerable part of the lithic assemblages at archaeological sites, it is likely that they have had a significant impact on the resource procurement strategies employed by the hunter-gatherer communities.

Due to limited amount of previous research, the distribution and character of quartz and quartzite sources are only vaguely understood. Furthermore, the displacement and reincorporation of these materials into alluvial and moraine formations adds an element of uncertainty. There is a lack of data on which to produce a robust provenance model, relating archaeological finds to their raw material sources, due to the paucity of extensive surveys and sampling for reference material. Building theories and models around this lack of data motivates the application of exploratory inductive methods (Jebb et al. 2017), which are suited for such situations. This thesis thus lays the foundation for future provenance studies aimed at quartz and quartzite material within Norrland. It provides an insight into the petrographic variability and distribution of these materials at archaeological sites in the region.

The thesis is an inquiry into the topic of raw material management and mobility at different levels of analysis. Modelling human behaviour is an act of modelling a multi-scale system, as large-scale patterns are an expression of decisions made at different spatiotemporal scales (e.g. Brouwer Burg, 2017; Close 2000; Nakoinz 2018; Paper I). This is exemplified in the thesis by each paper approaching the topic of hunter-gatherer mobility at a different level of analysis and data aggregation. The period of interest is the Epineolithic – Early Metal Age period (2 000 BC – 200 AD), which has been described as a time of cultural change among the hunter-gatherer societies in Norrland. Constraining the study temporally is challenging, however, due to the difficulties with developing a chronological framework for the region (Baudo 1978). The study thus chose to focus on bifacial points, which have been used as a temporal indicator for the period of interest (Forsberg 1985, 2010; Paper II). This assumes that the find category is truly representative of the more than 2 000 years of human development, and as this thesis shows, may not be entirely accurate.

Questions discussed in this thesis include: How do we model data in a way that ensures transparency at multiple analytical levels? What is the potential of non-destructive spectroscopy in the characterisation of quartzite? How reliable is the dating evidence upon which the relevant chronologies are based? How do we assess the human influence on the material flow of quartzite within the Norrlandic region?

- Paper 1: "Non-Spatial Data and Modelling Multiscale Systems in Archaeology"
    - A discursive paper on modelling in archaeology and approaches to large-scale multivariate datasets. The focus of the discussion is on the relationship between high-resolution data at a smaller scale and how this is visualised in aggregated form at regional scale.
    - Published in *Open Archaeology, 2022, vol.8,* https://doi.org/10.1515/opar-2022-0250
- Paper 2: "A Point in Time: An evaluation of the bifacial point chronology in Norrland"
    - A chronological analysis of bifacial point finds in Västerbotten, Sweden. The paper evaluates radiocarbon data sampled from sites with bifacial points. The focus of the discussion is on the potential for building a reliable chronology for bifacial points in the region using the evidence currently available.
    - Submitted for publication
- Paper 3: "Quartzite Complexities: Non-destructive analysis of bifacial points from Västerbotten, Sweden"
    - A non-destructive multi-spectral analysis of bifacial points made in quartz/quartzite material. The aim of the paper is to make an assessment of

    - the petrographic variability of the material, and discuss the potential for future provenance studies.
    - Published in *Journal of Archaeological Science: Reports, 2024, https://doi.org/10.1016/j.jasrep.2024.104381*
- Paper 4: "Straight to the point: Bifacial points and hunter-gatherer mobility in Västerbotten, Sweden"
    - An exploratory spatial analysis of the distribution of bifacial points and preforms within Västerbotten, Sweden. The paper discusses settlement and mobility among hunter-gatherers in relation to bifacial technology, and the geological and data landscapes behind it.
    - Manuscript

2. Materials and Methods

There are two central concepts that permeate this thesis: *non-destructive* and *exploratory*. The former alludes to the application of spectroscopic techniques which cause no physical damage to the material to which they are applied. The main motivator for this was the potential this offers in terms of building a large and diverse dataset. Museum collections represent a valuable repository of information which has been collected from a wide geographical region. Non-destructive spectroscopy makes it possible to access this information far more easily, as destructive methods would not be permitted to the same extent due to their potential impact on the archaeological material.

The *exploratory* concept alludes to the data mining which then is performed on the dataset resulting from the non-destructive analysis, as well as other data and metadata of relevance to the interpretation of the archaeological finds. 'Exploratory Data Analysis' (EDA) refers to a collection of inductive approaches with the aim of summarising data properties and identify patterns within the data so as to gain a better understanding of the structure of a dataset (Jambu 1991; Haining 2003). The techniques encompass univariate, bivariate and multivariate analysis, with the emphasis being placed on hypothesis generation rather than hypothesis testing (Jambu 1991).

Considering the state of research on quartz and quartzite material within the region the above approaches were deemed central to developing models of settlement and mobility among hunter-gatherers. However, petrographic analysis is merely one component of the analysis of raw material management, and the same exploratory approach may be extended to investigate other aspects of human activity in space and time.

2.1 Study area

The focus of this thesis is the present-day County of Västerbotten, Sweden (Figure 2). The two main reasons for framing the project in this region were: 1) the digitally catalogued and well-structured collections at Västerbottens museum (VBM), and 2) the broad range of environmental contexts in which the sites are located, ranging from the fine sediment plains along the Bothnian coast, to the hilly forest inlands, and the mountainous Scandes (Figure 4-5) (Nordiska Ministerrådet 1984).

2.1.1 Regional chronology

An archaeological chronology is at its core an outline of the order in which a number of cultural events have occurred through time (Niccolucci and Hermon 2015). The term "event" is flexible and can be used to describe large-scale changes, such as regional shifts from a hunter-gatherer economy to agricultural, or small-scale changes, such as the introduction of a new artefact type at an archaeological site (e.g. asbestos tempered pottery). Aside from absolute dating methods (e.g. ^{14}C-dating, Chapter 2.5) archaeologists also make use of relative methods, such as seriation. These methods make observations of the contexts in which artefacts occurs at a number of sites in an attempt arrange them in a chronological order (Renfrew and Bahn 2012:122-128). As an artefact type is constrained temporally by relative and absolute dating methods archaeologists may use their presence at a site in order to place it in a chronological period. As Paper II highlights, the dating foundations upon which these chronologies are based should be open to evaluation and the periods or artefact timings open to revision in the light of new, or discarded, evidence.

Since chronological periods are based on cultural traces, they are not merely temporal markers. There is cultural meaning attached to the period name based on a current understanding of past behaviour (Niccolucci and Hermon 2015:257-271). Forsberg (2012) notes that there has been a "dualistic" perception of cultural development within the Norrlandic region. The coastal societies have been viewed by archaeologists as having been under considerable South Scandinavian influence (through e.g. migration, trade and exchange, material culture), especially as inferred through the presence of flint artefacts in a South Scandinavian material and style, and coastal burial cairns (Baudou 1968; Halén

1994:115-122). This may have contributed to the tendency for archaeologists to apply a South Scandinavian model when discussing chronological developments among the prehistoric Norrlandic coastal societies (Baudou 1992:99-103). In contrast, the inland hunter-gatherers have been discussed more in terms of contacts towards the west and east (e.g. Baudou 1992; Bergman 1995; Forsberg 1985, 2012; Lundberg 1997; Spång 1997). Using the results from the *Early Norrland* project, Baudou (1992:52) outlined a Norrlandic chronological framework based on perceived differences with Southern Sweden, such as the persistent hunter-gatherer economy of the inland societies.

Forsberg (2012) acknowledges that simply unifying the two chronological schemas could be problematic. Furthermore, Forsberg's own study outlines distinct differences in the settlement and mobility strategies used between the coastal and inland societies. It is not within the scope of this thesis to suggest an alternative chronological model for the coastal region. Therefore, similarly to Forsberg, a general South Scandinavian chronology will be used when referring to coastal phenomena, and Baudou's (1992) model will be used for the inland societies (Figure 3).

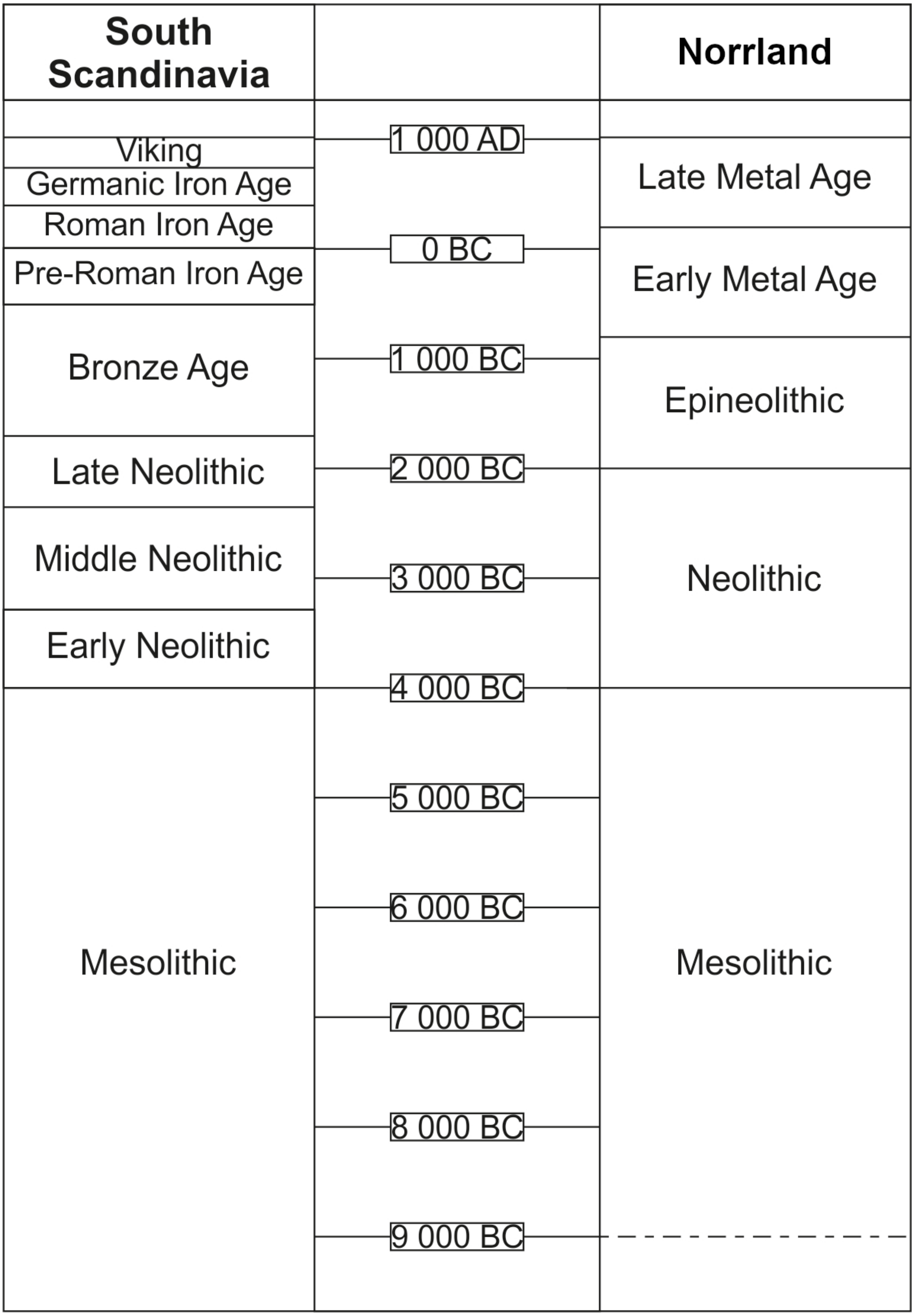


Figure 3 Overview of the chronological schema for South Scandinavia and Norrland, after Price (2015) and Baudou (1992)

2.1.2 Vegetational history and geological background

The present-day environmental setting in Västerbotten can be divided into three general regions (Nordiska Ministerrådet 1984) (Figure 3): 1) A coastal marine setting to the east, with sorted sediments (sand and silt) along with stretches of boulder fields (blocky moraine) and raised beaches, that have resulted from a combination of coastal erosion and land uplift (Stroeven et al. 2016). Due to post-glacial rebound, the shoreline from 2 000 BC was located ca. 5 – 10 km inland from the current coastline; 2) The forest inland, which makes up most of the region, and includes most of the settlements (historical and modern) and agricultural lands. The greatest extent of this area is now (coniferous) plantation woodland. Wetlands (fens and mires) are common in the areas in between the large rivers. Finer sediments suitable for agriculture have largely been deposited along the river valleys; Finally, 3) the Scandian mountain region to the west where alpine birch trees become more common, eventually disappearing as the elevation reaches above the treeline. Exposed bedrock can be seen among the moraine, with glacier ice and permanent snow patches remaining in certain areas.

Geologically, most of the region is made up of Proterozoic rocks part of the Fennoscandian shield (Figure 4). Forming around 1.8 Gya – 1.9 Gya, sedimentary and volcanic rocks are largely found along the coastal region with igneous rocks in the inland (Lax 2005). Gneiss and granite can be found throughout the shield, with slate being more common towards the north eastern Skellefte mining fields (Nordiska Ministerrådet 1984). The Scandian mountains formed from the collision of the Baltica and Laurentia continental plates ca. 490 – 390 Ma. As a result, there is a lot of geological variation. Metamorphic rocks, including mica schists and quartzite, are more common within the Alpine region. A more detailed description of the Scandian stratigraphy, too extensive to summarise here, can be found in Stephens and Bergman Weihed (2020).

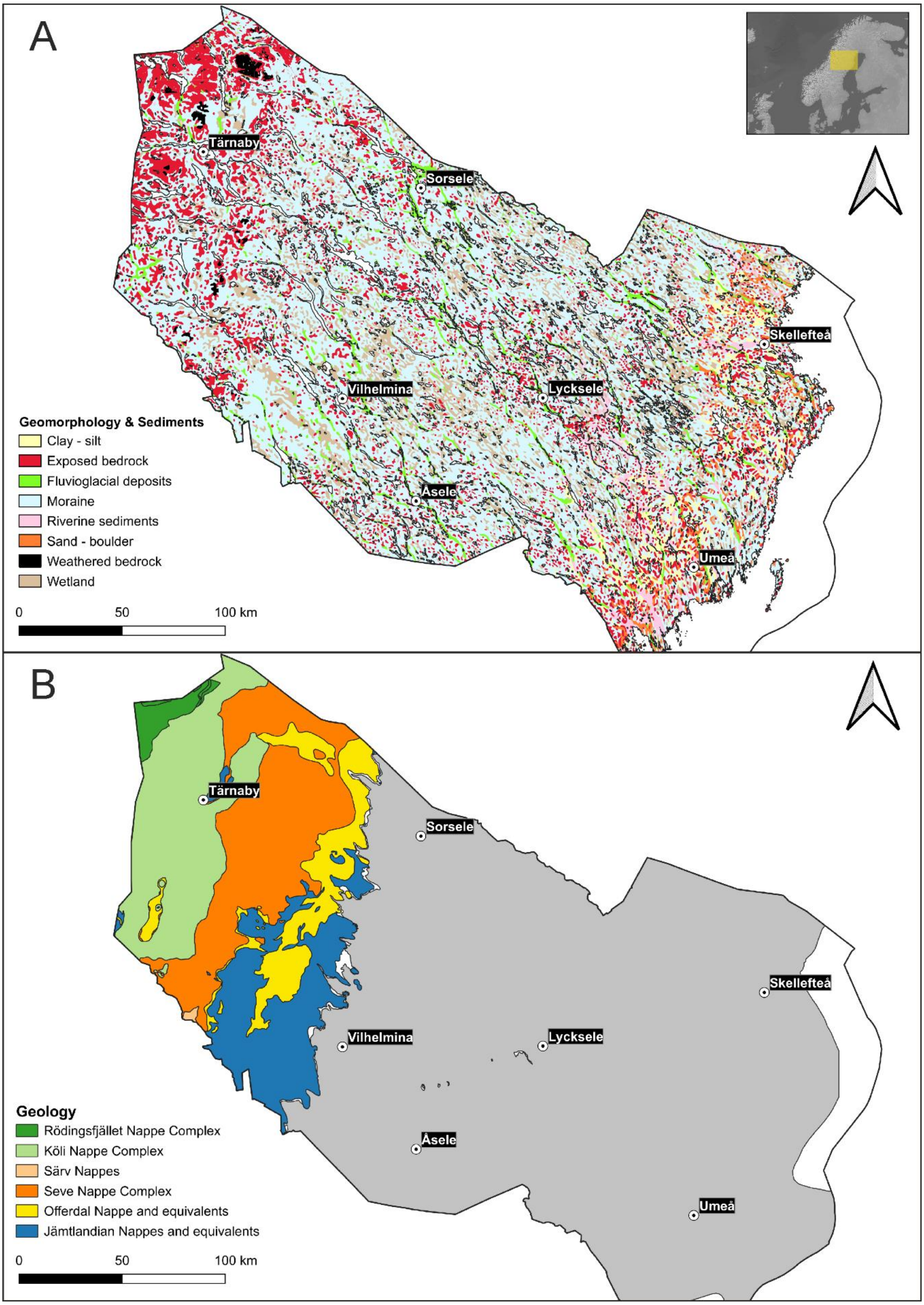


Figure 4 *A) Distribution of sediments in Västerbotten. The glacial impact can be seen in the wide distribution of moraine and fluvioglacial sediments, B) Major geological units in Västerbotten. The Scandes has been subjected to varying degrees of metamorphism, resulting in the formation of quartzite. Made with Lantmäteriet (CC0) and geological data from © SGU in QGIS (ver. 3.30.3).*

The most common soil in Västerbotten is podzol, which forms in coarse permeable parent material rich in quartz. A characteristic of podzols is the bleached layer that forms from leaching of organic matter, aluminium (Al), iron (Fe), and other elements deeper into the soil profile (Sauer et al. 2007). Apart from calcium (Ca), elements that contribute to a higher pH are removed, resulting in an acidic soil. Due to the acidity unaltered organic material preserve poorly and decompose rapidly. This has had a detrimental effect on dietary and genomic studies as most skeletal material tends to have been burned, or altered in a way that contributes to better preservation (e.g. Ekholm 2021; Fjellström 2021; Larsson et al. 2012, Schiffer 1987). A field of study which has gained increased interest in recent years, in part due to changing climate, is ice patch archaeology (Reckin 2013). Organic materials (bone, textile, wood, etc.) can preserve for up to thousands of years trapped in the ice and snow, but as they thaw out, they are exposed to the elements and risks decay. Surveying the snow and ice patches has resulted in the recovery of valuable organic materials, with the potential for study of paleoclimate and human interaction within high alpine regions (Callanan 2016; Finstad et al. 2016; Rosvold 2015).

The deglaciation of Norrland is a complex process, and the timing of the ice retreat from the Västerbotten region may thus differ slightly depending on which model is used (e.g. Hughes et al. 2016; Stroeven et al. 2016). Glacial refugia, areas where flora and fauna could survive during the ice ages, have also been found among the Scandes, as evidenced by megafossils of pine (Kullman 2002). By around 8 000 BC, however, it seems that the Weichselian ice sheet had mostly retreated from the study area. The Ancylus freshwater lake, a predecessor to the Baltic Sea, reached as far as 100 km further inland than present-day, with the highest ancient shoreline in the study area being ca. 250 meters above sea level (m.a.s.l.) at the time of the glacial retreat (Berglund 2012). As new land is exposed at the coast, herbs, shrubs, and bushes first begin to occupy the area, with nitrogen (N_2) fixating plants like sea buckthorn (*Hippophae rhamnoides*) and *Epilobium* being favoured (Engelmark and Buckland 2005). Recent finds of preserved Scots pine (*Pinus sylvestris*) within the study area, dated to ca. 8 000 BC, further supports the pollen-based evidence that an open-canopy pine (*Pinus*) and birch (*Betula*) forest developed close to the retreating ice sheet (Bergman et al. 2005; Engelmark 1978; Klaminder et al. 2023). The tree limit in the mountain region was at this time higher than it is at the present-day's ca. 750 m.a.s.l. (Kullman 2001).

During the Mid-Holocene (ca. 6 000 BC), the forest is largely made up of pine, birch and alder (*Alnus*) throughout the region (Engelmark 1996). Hazel (*Corylus*) can also be seen establishing as a part of the mixed forest in the coastal region (Barnekow et al. 2008; Engelmark 1996). From 3 000 BC alder becomes relegated to the coastal region with most other broad-leaf trees. The inland forests consist primarily of pine and birch, and in the mountain region birch becomes the prevalent tree species. The presence of spruce (*Picea*) in the central Scandes by the Late Glacial (ca. 12 000 BC) has been evidenced by macrofossil finds and modern DNA studies (Kullman 2002, 2008; Nota et al. 2022). The exact dynamics of the immigration of spruce into Norrland is a contested topic, however, as a continuous presence of spruce in pollen diagrams from the Scandes does not occur until ca. 3 000 BC (Giesecke et al. 2017). In the Late Holocene a new expansion of spruce occurs, moving northwest through Finland and crossing the Baltic Sea, as it establishes along the Bothnian coast ca. 2 000 – 1 500 BC (Giesecke and Bennet 2004; Segerström 1990). Spruce then becomes a major part of the forest structure and continues spreading westward (Engelmark 1996).

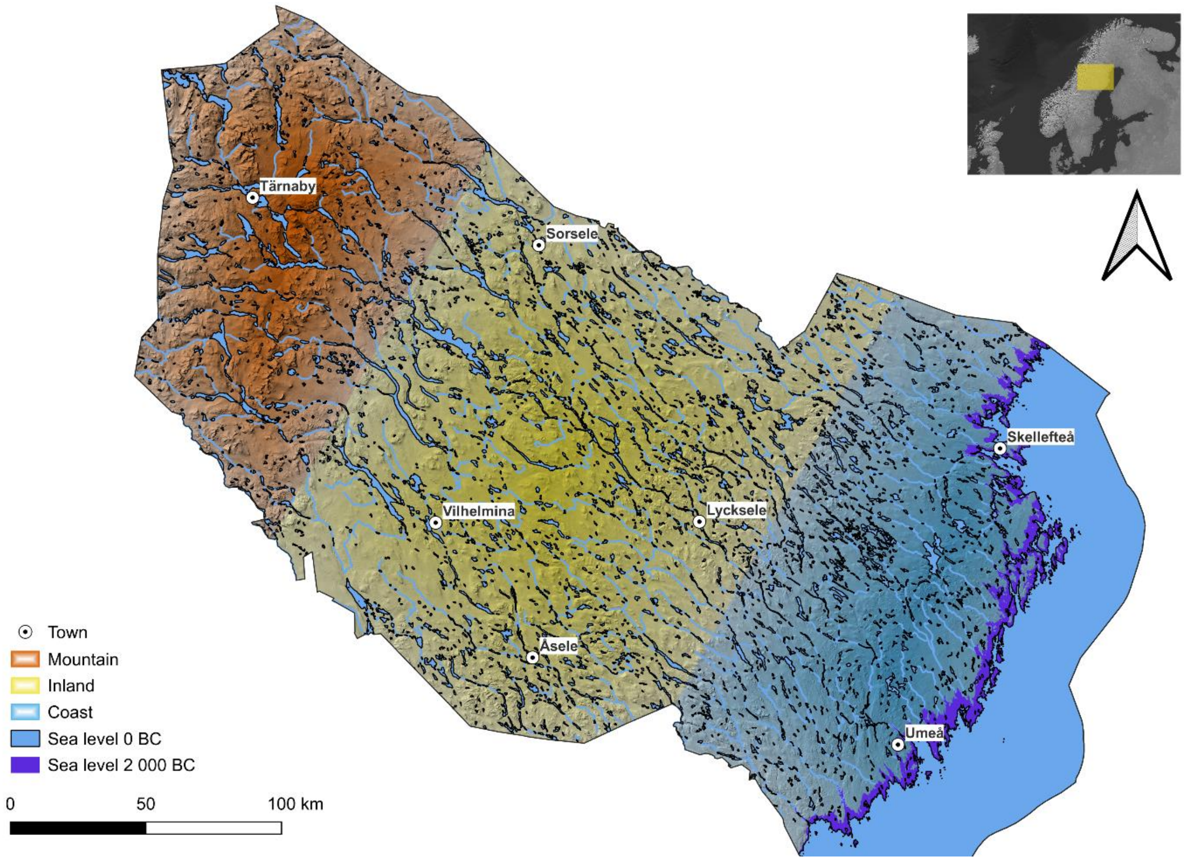


Figure 5 A descriptive division of Västerbotten into three different zones; Mountain, Inland and Coast. The rough border for the coastal region is based on the shoreline ca. 7 500 BC. The border between Mountain and Inland is roughly where the elevation transitions above 700 m.a.s.l. The sea level at 2 000 BC is highlighted for its relevance to the period studied in this thesis. Made with Lantmäteriet (CC0) and Natural Earth in QGIS (3.34.2).

2.3 Dataset

2.3.1 Samples

The artefact types studied in this thesis are referred to as *bifacial points and preforms* (Figure 6). Bifacial technology refers to lithic reduction techniques where a *blank* (piece of stone or debitage) is worked from two opposing sides, gradually thinning the piece to the desired shape (Apel and Darmark 2007). Evidence for the use of this particular technique dates as far back as 1.8 Ma, at the Kokiselei Site Complex in West Turkana, Kenya (Duke et al., 2021). In Northern Fennoscandia the first signs of bifacial point production occur ca. 3 900 BC, during the Comb Ceramic period in Finland (Darmark 2012). These are made using the pressure flaking technique, where a blank (that is already thin) is shaped using a pointed tool of bone or antler (Apel and Darmark 2007). The site of *Lillberget* (Site ID: L1993:4637), in the County of Norrbotten, is one of the few sites in Norrland with bifacial points dating to this period (Halén 1994). The Comb Ceramic bifacial point tradition is short-lived in Finland and seems to disappear 500 years later (Manninen et al. 2003).

Around the early Epineolithic (ca. 1 900 BC) a new form of bifacial point appears in both Norrland and Finland (Forsberg 2010; Paper II). In Norrland these are mainly made of quartz and quartzite materials using a combination of percussion and pressure flaking techniques (Apel and Darmark 2007). In this tradition a blank is first worked using the direct percussion technique, striking the blank directly to create a rough point shape, referred to as a "preform". The preform is then worked using the pressure flaking technique in order to finish the piece.

This thesis is based on a dataset consisting of 1 437 bifacial points and preforms (including fragments) (Figure 6), from 254 archaeological sites in Västerbotten (Figure 7). Most of the artefacts range from ca. 15 mm to 140 mm in their maximum dimension (usually length). All artefacts are stored in the collections at Västerbottens (VBM) (www.vbm.se) and Skellefteå Museums (www.skellefteamuseum.se). VBM supplied an export from their collections database that included all points and preforms made in quartz and quartzite material (including brecciated quartz), where those that included geographic information were added to the dataset. The Skellefteå Museum's online collections database was then queried for the same. Where information on material or lithic technique was missing the author reviewed any available photographic documentation before deciding on whether to include an artefact in the study.

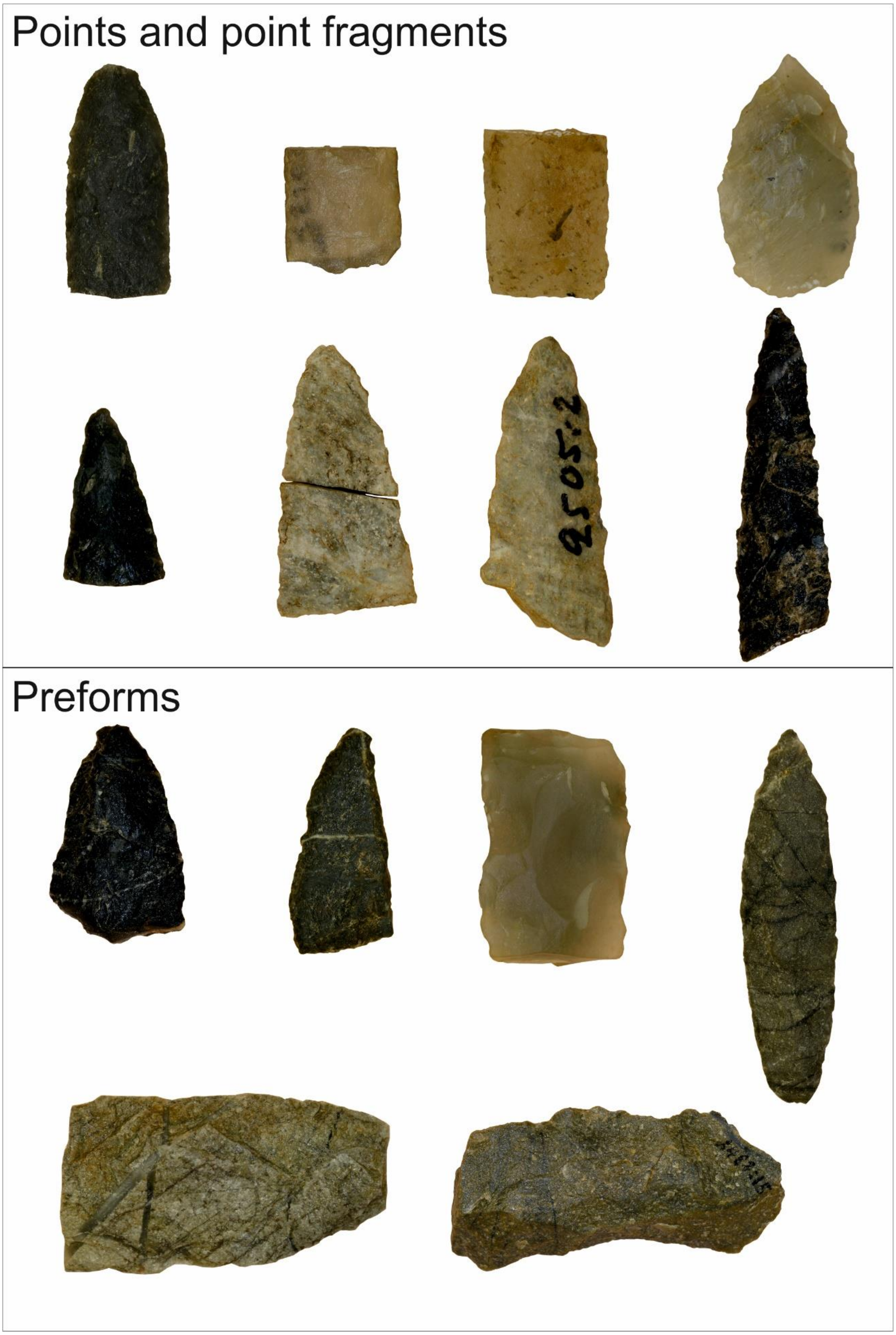


Figure 6 Examples of points and preforms included in the study, showcasing the variability in colour and shape. Classification has been performed by an archaeologist or museum curator. These artefacts are part of the collections at Västerbottens Museum. Photographs by Mattias Sjölander.

2.3.2 Material variability

The dataset includes three main groups of lithic raw materials: brecciated quartz, quartz, and quartzite. The material classifications of the artefacts have been performed by the field archaeologists responsible for collecting them or museum curators.

Quartz is a crystalline mineral composed of silicon-oxygen tetrahedra (SiO_4). It is a common rock forming mineral and can be found in most geological settings. It is widely available throughout the study region in exposed veins. A pure quartz is colloquially referred to as a "rock crystal" (Swe. bergkristall or bergskristall), but a number of quartz varieties can be distinguished via impurities which give rise to different colouring and appearance (e.g. amethyst, milky quartz, rose quartz, smoky quartz) (Henn and Schultz-Güttler 1986; TNC 1988; Tutton 1910).

A true *quartzite* is a type of metamorphic rock that forms when a quartz-rich sandstone (sedimentary rock) is subjected to pressure and heating. The quartz grains in the sandstone recrystallize and interlock, resulting in a very hard rock that fractures through the grains (Howard 2005). Quartzite is notoriously difficult to accurately identify visually, and the term has been used interchangeably with sedimentary orthoquartzite by archaeologists (Prieto et al. 2019:15; 2020:31). Orthoquartzite is a hard unmetamorphosed sandstone that consists primarily of quartz, giving it a similar appearance to that of a metamorphic quartzite.

Although there is no unanimously agreed upon definition of quartzite suitable for field-observations, Howard (2005) defines the material as:

> *". . . a quartz-rich rock (exclusive of chert and vein quartz) that is exceptionally hard and, when broken by a rock hammer, fractures irregularly through both grains and cement (where present) to form an irregular or conchoidal fracture surface."* (Howard 2005:708)

Visual characteristics are typically unreliable, although they can be valuable for a preliminary sorting of material in the field (Howard 2005:708). Microscopic characterization thus seems to be the most reliable method for identification. It is therefore not possible to say whether all samples labelled as quartzite in the study are "true" metamorphic quartzites.

Brecciated quartz is the term used for a quartz-rich, somewhat translucent, material found within Norrland. Visually it appears as an unusually pure quartzite, and functionally it has similar properties. However, the geologist Åhman (1967) identifies it as a type of quartz that has fragmented and later recrystallized, giving rise to its distinct visual features. Artefacts made of brecciated quartz are most common in the inland towards the mountains but can be found at sites as far downstream as Umeå. A possible source of brecciated quartz was recorded by Holm (1991:23-25) during surveys at the Artfjället mountain (near the Rödingsfjället complex), but as no in-depth studies have been undertaken it is difficult to confirm this or say what the distribution of potential source areas is. Although brecciated quartz differs geologically to quartzite, its functional similarities and use in prehistoric tools make it a valuable group to include.

2.3.3 Context and sampling bias

Most of the sites are located in the inland region (Figure 7), mainly along the large river valleys and lakes. Whilst this may be related to the decision making of prehistoric groups, it is also likely to be an effect of modern-day development and survey projects (Andersson 2015). The high site-density areas of Vilhelmina and Åsele were both part of the parishes targeted by a survey project carried out by Västerbottens Museum between 1975 – 1984/86 (Andersson 2015). This large number of sites contrasts considerably with the unregulated (i.e. not developed for hydroelectric power) Vindel River, which is one of four nationally protected rivers (Schäfer 2021:11-14), and which has a substantially lower density of known sites. This potential bias is explored further in Paper IV of this thesis.

The find context in which the bifacial points were initially retrieved include stray finds, surface retrieval during surveys, and excavations. This means that there are varying degrees of contextual information on which to base inferences. Although stray finds are the most uncertain of samples, due to there being little to no contextual information, they still hold some interest for the evaluation of the chemical characteristics of the material itself.

The character of the archaeological sites themselves likewise vary significantly. The most common of sites are the "settlement sites" (Swe. boplats) and "settlement areas" (Swe. boplatsområde). These are standardised terms according to The National Heritage Board's (RAÄ) register of archaeological sites and monuments, which is an open database that has been continually built on since 1937 (Riksantikvarieämbetet, 2016).

A settlement site is defined as a:

> *". . . site from prehistoric times where activities have left objects, raw materials for processing, and/or refuse."* (Riksantikvarieämbetet 2021 p. 12, author's translation).

A settlement area is defined as an:

> *". . . area with remains from prehistoric times of a settlement character, i.e. dwelling features, storage, food preparation or similar as well as tools, raw materials. . ."* (Riksantikvarieämbetet 2021 p. 13, author's translation).

As the definitions are designed to be applicable in a surveying context, they provide little information on the functional aspects of a site. The settlement category in particular can be complex due to the possibility for there to be evidence of human activity at a site dating to different periods, possibly unrelated. Below follows a summary of the different site types present in the dataset.

Composite site

A composite site is here defined as a site with evidence of occupation dating to different periods. It is either unknown as to whether the features are evidence of consecutive occupation by the same group or are unrelated. At these sites it can be difficult to determine what feature(s) the points or preforms are chronologically related to, if any, as they often are recovered from areas in between the features that are dated.

Open-air site

An open-air site is defined as a site with no visible structural remains, mainly identified by a scatter or concentration of fire-cracked stones, lithic remains and/or bone material. Such sites are common in the Norrlandic environment, particularly due to the coniferous forests and its impact on soil formation (Rapp and Hill, 2006:42; Schiffer 1987:146-147). The poor buildup of organic material means that artefacts and features dating as far back as the Mesolithic may be exposed simply by turning over the vegetation layer (e.g. Riksantikvarieämbetet 2020; Sciuto et al. 2019). Open-air sites are frequently registered in conjunction with forestry tilling where lithic scatters are exposed, or along erosion zones next to lakes and rivers.

Rock-painting site

As its name alludes to, a rock-painting site indicates a locale where one or more paintings from prehistoric times have been preserved. These are typically found on rock faces that are somewhat protected from the elements, which means upright or slightly leaning rock faces. Two such sites are included in this thesis. The site of Skellefteå 123 (Site ID: L1937:6996), located on *Finnforsberget* not far from the Skellefte River (Olofsson 2012), and the site of Lycksele 301 (Site ID: L1939:8504) located below *Korpberget* next to the Ume River (Heinerud, pers. comm. 04-02-2024). These sites include imagery which has been related to hunter-gatherer cultures, such as elk, fish, and human figures. Excavations were conducted just below the imagery in both instances, but in the case of Lycksele 301 the report has yet to have been published. At Skellefteå 123 a variety of artefacts were found, including 24 preforms for arrow- and spearheads. This differs from Lycksele 301 where completed arrowheads were found.

Cache

A cache, or hoard, describes a collection of artefacts purposely buried in the ground. Caches can include preforms and/or finished tools and are known to occur from the Stone Age and into the Historical period (Harmon and Quilliec 2008). The current dataset includes one such site, called *Brännraningen* (Site ID: L1937:4256) in this thesis for its location. The find was made in 1940 in the town of Vännäs where the Vindel and Ume Rivers merge (Gullbring 1942). The cache reportedly included 35 bifacial point preforms, of which 28 were eventually deposited at Västerbottens Museum.

Workshop

A workshop is defined as a site for tool-production, as indicated by the presence of concentrations of lithic flakes and/or raw material in a concentrated area. Further indicators, such as preforms may also be present. In this thesis a distinction is not made between early/late stage production as it is not important for the interpretation. Workshop areas have been identified at composite sites, but are then not registered as an individual site.

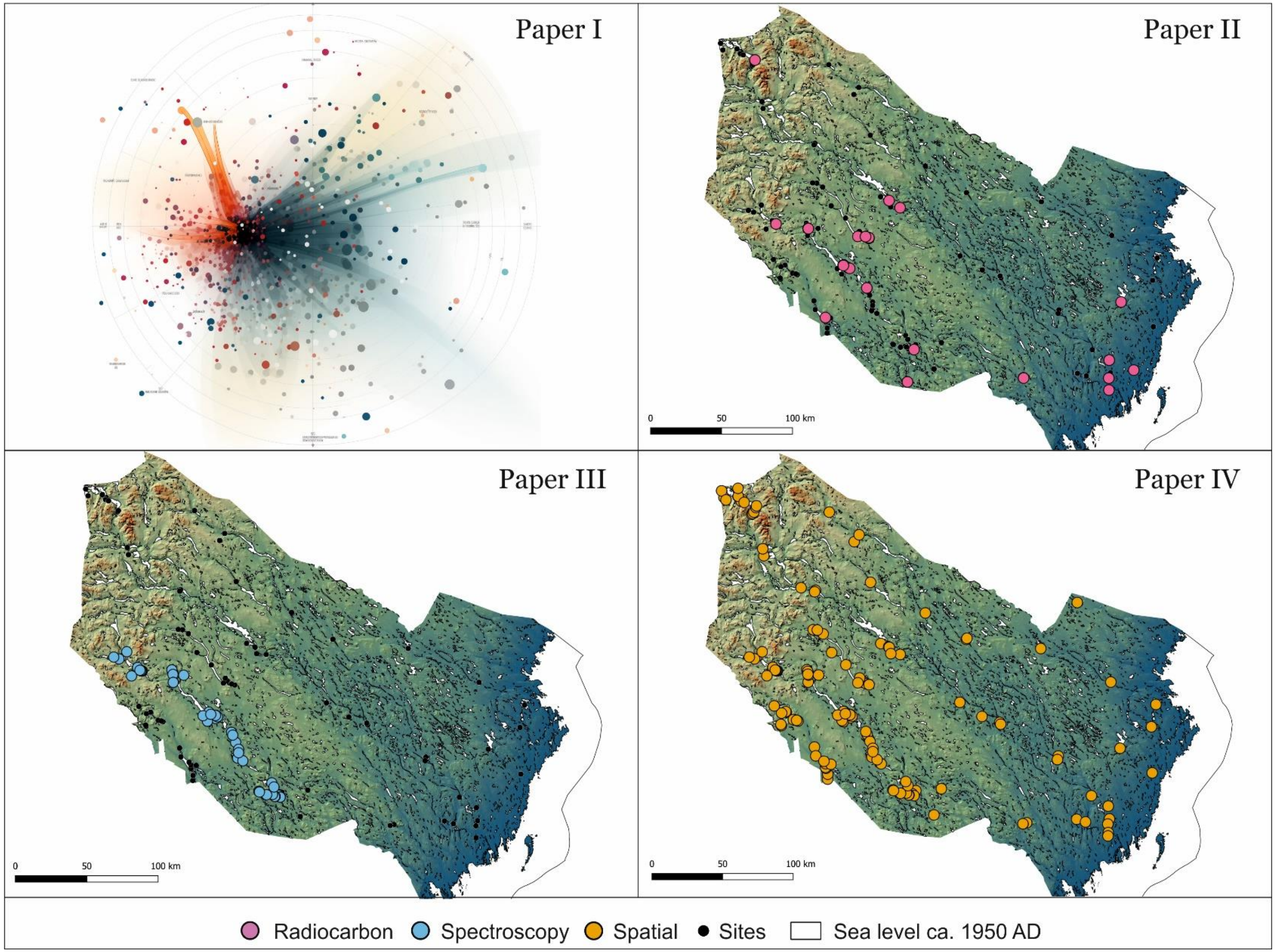


Figure 7 Overview of paper themes and sites included in each study. Paper I is a theoretical discursive paper. Image for Paper I was AI generated from text prompts using Midjourney. Maps for paper II-IV were made with Lantmäteriet (CC0), Natural Earth, and Riksantikvarieämbetet in QGIS (ver. 3.30.3).

2.4 Spectroscopic methods

A novel aspect of this study is the application of multiple spectroscopic screening methods on the same archaeological material. These methods are: Near Infrared Spectroscopy (NIRS), Raman spectroscopy, and Energy Dispersive X-Ray Fluorescence (ED-XRF). All three have been applied non-destructively, i.e. measurements are made on the surface of the artefacts. Non-destructive analysis has the benefit of not only enabling access to sensitive artefact and material collections, but as the techniques are field-applicable *in situ* analysis becomes possible (e.g. Manrique-Ortega et al., 2019). This means that readings may be taken during geological surveys, or as a form of initial screening during excavation. Sensitive geological formations and archaeological monuments (e.g. rock paintings) can also be analysed without the risk of damage (Linderholm et al. 2015), as can items in a museum collection.

In general, spectroscopy works by exposing an object to light (electromagnetic radiation) and measuring how much is absorbed or emitted by the material (Chatwal et al. 2009). The measurements are then visualised as a line referred to as a *spectrum* (Figure 8), where the X axis (horizontal) corresponds to the wavelength (part of the electromagnetic spectrum) and the Y axis (vertical) is the recorded value (e.g. absorbance of light). Increases in the recorded values show as *peaks* in the spectra and depending on what wavelength this occurs at inferences can be made on the molecular/atomic structure of the material.

Spectroscopic measurements typically contain a certain level of “noise”, that is, unwanted signals that may hinder or confound further analysis (Rinnan et al. 2009) (Figure 9). A common cause of noise in the spectra is light scatter caused by the surface of the material. This is managed by a set of different preprocessing methods designed for reducing the level of noise. While some of these methods are common in most types of spectroscopic studies, such as mean-centring, other are more suited for specific instrumentation or tasks. Details on the preprocessing used in this thesis, along with more information on the individual methods, can be found in Paper III.

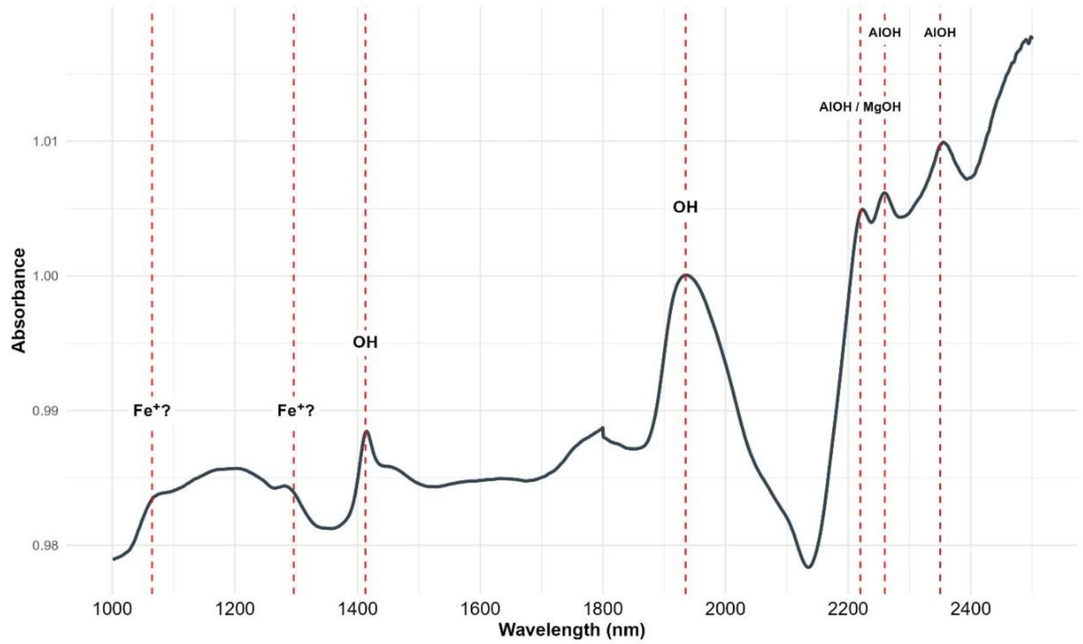


Figure 8 Example of a spectrum representing the average absorbance of 93 dark quartzite samples. The absorbance of light is visualised as a spectral line where peaks indicate energy shifts for different molecular groups. Figure produced in R (R Core Team 2021) using ggplot (Wickham 2016).

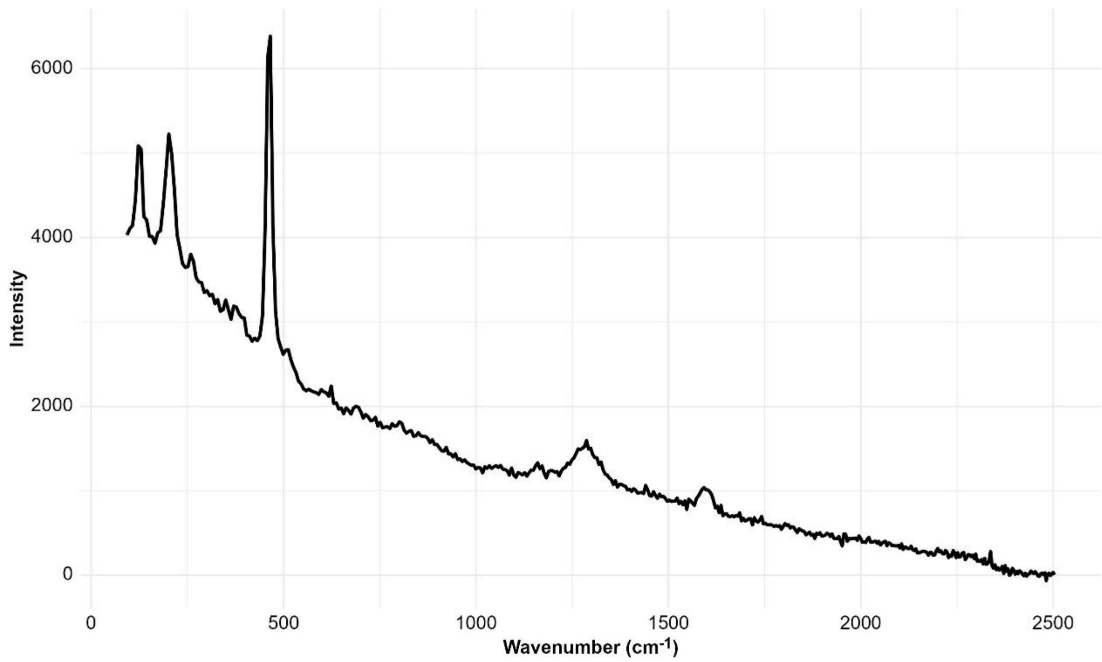


Figure 9 Example of a Raman spectrum from a quartzite. The surface of the material causes scattering effects which contributes to make the spectral line look "rugged". Noise can potentially obscure smaller peaks in the data. Figure produced in R (R Core Team 2021) using ggplot (Wickham 2016).

2.4.1 Near Infrared Spectroscopy (NIRS)

NIRS is based on the vibrational properties of molecules within the near-infrared region of the electromagnetic spectrum (780 nm – 2 500 nm). When molecules, or molecular bonds, absorb the energy emitted by the light source they become "excited" and transition in energy levels in different ways. The central modes of energy transition include **fundamental vibrations**, **overtone vibrations**, and **combination modes** (Ozaki 2021). Fundamental vibrations describe a shift in energy between adjacent energy levels, essentially:

$$v = 0 \rightarrow v = 1.$$

Where v is the vibrational energy of a molecule and 0 and 1 represent the energy levels. It is, however, possible for molecules to transition between higher energy levels, i.e.:

$$v = 0 \rightarrow v = n \text{ (where } n > 1\text{)}$$

This is referred to as an overtone vibration (Ozaki 2021). Finally, a combination band is the result of more than one fundamental vibration occurring simultaneously.

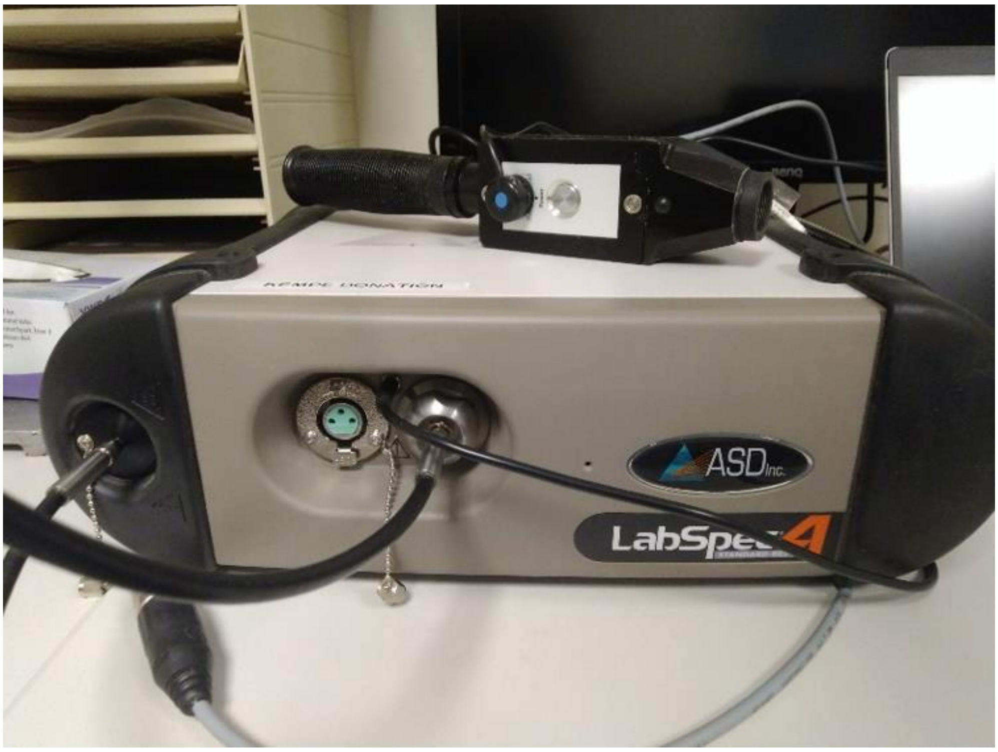


Figure 10 The ASD LabSpec 4 was used for for NIR measurements, with a contact probe for sampling.

These transitions register at different frequencies, depending on the material, and can be used to identify the molecular groups (e.g. OH, CH, NH) (Hunt 1977). The result is visualized as a spectral line, where a peak in the spectra identifies an energy shift for a molecular group. The intensity of the peak is related to the absorbance of the material, and the amount present. In quartz-based materials the most common group detected is hydroxyl (OH), typically related to the presence of molecular water or metal-OH combinations (Hunt 1977, p. 508) (FIG).

In this thesis the Analytical Spectral Device (ASD) LabSpec 4 was used (Figure 10), with sampling undertaken using a contact probe (spot size: 10 mm) (Figure 10). The ASD has a wavelength range of 350 nm – 2 500 nm.

2.4.2 Raman

Raman spectroscopy is a good complement to NIRS as materials that produce weak IR responses will typically result in larger Raman intensities (Chatwal et al. 2008). Like NIRS, the technique is based on the vibrational properties of molecules in the near infrared region of the electromagnetic spectrum, but rather than dealing with light absorption it works on light scattering (Nafie 2001).

A monochromatic laser is used to induce a dipole moment in the molecule, generating the Raman effect. In contrast to NIRS, there is no transition in energy level, rather this shift occupies a quantum state (virtual state). The vibrational energy of the incident photon emitted by the laser is compared to the scattered light. Rayleigh scatter occurs at the same vibrational energy (frequency) as the incident radiation, whereas Raman scatter has shifted in frequency (higher = Stokes scattering, lower = anti-Stokes scattering), indicating that a molecule has absorbed the light from the laser (Dubessy et al., 2012). As the structure of the molecule informs its vibrational mode, the point at which a shift in frequency occurs can be used to identify it and infer the structure of the material (Smith and Carabatos-Nédelec, 2001). A spectrum is drawn using this information but unlike NIRS, which uses wavelength (nm), Raman spectroscopy typically uses wavenumbers (cm^{-1}), which describe the spatial frequency of waves.

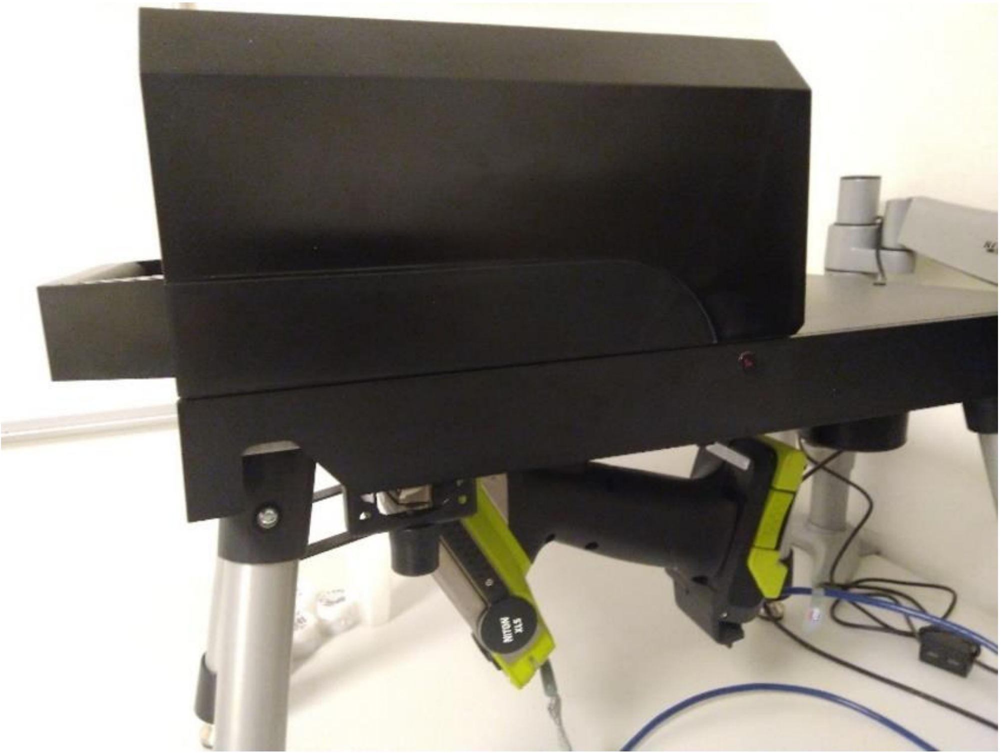
Figure 11 The i-Raman EX was used for Raman measurements, with a 1064 nm excitation laser.

The Raman instrumentation (Figure 11), a portable i-Raman EX featuring a 1064 nm excitation laser (spot size: 8 µm), was supplied by the division of Biomass Technology and Chemistry at the Swedish University of Agricultural Sciences. The spectral coverage is 175 cm^{-1} – 2 500 cm^{-1}, with a resolution of 9.5 cm^{-1}. When sampling the best response was recorded using an integration time of 20 seconds with 30% power.

2.4.3 X-Ray Fluorescence (XRF)

XRF has a long history of use in the characterization of a number of different materials in archaeology (lithics, metals, ceramics, etc.) (Hall 1960; Shackley 2011). Spectral features in XRF spectrometry can be related to certain elements according to Moseley's law (Moseley 1913), which recognizes that the energy of the fluorescence produced when a material is irradiated with high energy particles or photons is characteristic to certain atoms (Thyrel 2014:20–24). As a material is bombarded with high energy photons electrons will be emitted from one of the inner shells (of electrons orbiting the atom's nucleus), causing electrons from outer shells to replace them. The response of different elements is what produces the characteristic fluorescence.

A number of methods have been developed for quantification of the detected elements (Sitko and Zawisza 2012:143–159). In a non-destructive context, where the sample is not homogeneous, it is necessary to correct for matrix effects caused by attributes such as chemical composition, particle size and surface variation (Lu et al. 2022). Portable XRF instruments come prepared with a set of filters calibrated for different mediums (e.g. soil, metals, minerals) which allows the user to focus on a range of elements that are of most interest in different situations (Knight et al. 2021:2).



Figur 12 The portable Energy Dispersive Thermo Scientific Niton XL 5 was used for XRF measurements, attached to a test stand.

XRF measurements were collected using an Energy Dispersive (ED) Thermo Scientific Niton XL5 Analyzer (spot size: 8 mm) (Figure 12), connected to a portable test stand (Thermo Fisher Scientific, 2018). The reference calibration used for element quantification was mining mode (Knight et al., 2021: 2), as this is considered most relevant for geological material.

2.4.4 Sampling and representativity in spectroscopy

Sampling is perhaps the most important factor to consider when undertaking spectroscopic analysis. The sampling strategy will affect not just the quality of the spectra itself, but also how representative the recorded measurements are of the material as a whole. Non-destructive sampling faces challenges regarding how the sample is introduced to the detector.

Arguably, the "best" approach would be to homogenise the sample, depending on how your sample is defined. Still, the heterogeneity of the sample may hold as much importance to the study as the overall bulk chemistry. Bulk analysis methods can include crushing the material into a fine powder, dissolving it in a solution (Olofsson and Rodushkin 2011), or cutting thin-sections on which to take measurements (Prieto et al., 2019, 2020;). Crushing part of the sample would homogenize its fraction size variability and provide better integration between the probe and the material. It would also make it more likely that the distribution of different minerals within the spot size of the probe is more representative of the material as a whole. Likewise, a thin-section provides a better integration surface (i.e. flat surface with no variation) and would enable identification of mineral grains and microscopic structures. The main drawback with these approaches, however, is that they cause irreparable damage to the artefacts, and that this in turn limits their applicability to sensitive museum collections.

In non-destructive spectroscopy there will inevitably be sampling issues. The surface of the artefact varies significantly depending on the material, artefact type, and stage of weathering. Patination, that is fine residue on the surface of the object, may also be picked up by the instrument. These residues may be introduced from time spent in the ground, being exposed to the elements, and time kept in storage (and handling by people) (e.g. Caux et al. 2018). When sampling, the texture of the surface of the object may produce scattering effects, caused by a deviation in the trajectory of light between the sample and the detector. Such effects may lead to saturation and noise in the spectra that masks features of interest (Nardecchia et al. 2021) (Figure 9). In non-destructive analysis this will happen somewhat regularly, with the only real solution being to adjust the settings of the instrument or sample a different part of the surface.

It is therefore important for the analyst to study the spectra during sampling in order to adjust for any potential issues. Ideally, multiple samples should be taken on different parts of the surface so as to collect as representative readings as possible. In this thesis, the general rule was to collect one measurement on each side of the artefact, with extra measurements for difficult objects. The sample point was focused as much as possible on the matrix of the material, avoiding any anomalies. The number of samples was mainly a compromise in terms of the size of the dataset, as any extra measurements would have made the processing too costly in terms of time. XRF measurements in particular had to be limited to one sample per object as a rule, due to the longer measurement times needed by the instrument.

All measurements were taken in a dark room, where the only source of light is the screen of the computer running the recording software. This was to avoid issues related to light pollution and scattering effects introducing noise to the spectra.

2.5 ^{14}C-data and Bayesian modelling

Radiocarbon dating is a common method for dating organic samples (e.g. bone, charcoal, seeds) found in an archaeological context. It is based on the radioactive isotope of carbon, ^{14}C, which like all unstable isotopes decays at a fixed rate. All organisms incorporate carbon as they live and grow, including both the stable isotopes ^{12}C and ^{13}C and the unstable ^{14}C into their cells. On land ^{14}C is first taken up by microorganisms and plant life (Kandeler et al. 2005), and then moves up through the food chain. This means that the ^{14}C-content in a living terrestrial organism is maintained over the course of its life, and only begins to change once the metabolic process stops (i.e. death) (Taylor and Bar-Yosef 2016). Since only the unstable isotope decays at a fixed rate, the proportion between ^{14}C and ^{12}C in a sample can be calculated, and a radiocarbon age determined. A calibration curve (Figure 13), indicating the expected proportion in the atmosphere over the past ca. 50 000 years, can then be used to convert this into a calendar date (Bronk Ramsey 2009; Reimer et al. 2020).

When analysing a group of radiocarbon dates from a site it is not enough to merely line them up and infer the duration of use as being between the extremes of the calibrated date ranges (Bronk Ramsey 2015). Doing so would typically assign a much wider duration to an event than the true duration. Calibrated dates also feature probability distributions, which means that there are some dates within the range that are more likely to represent the true range than others (Bronk Ramsey 2009). It is therefore preferable to apply statistical approach to try to narrow down the most useful part of the radiocarbon result.

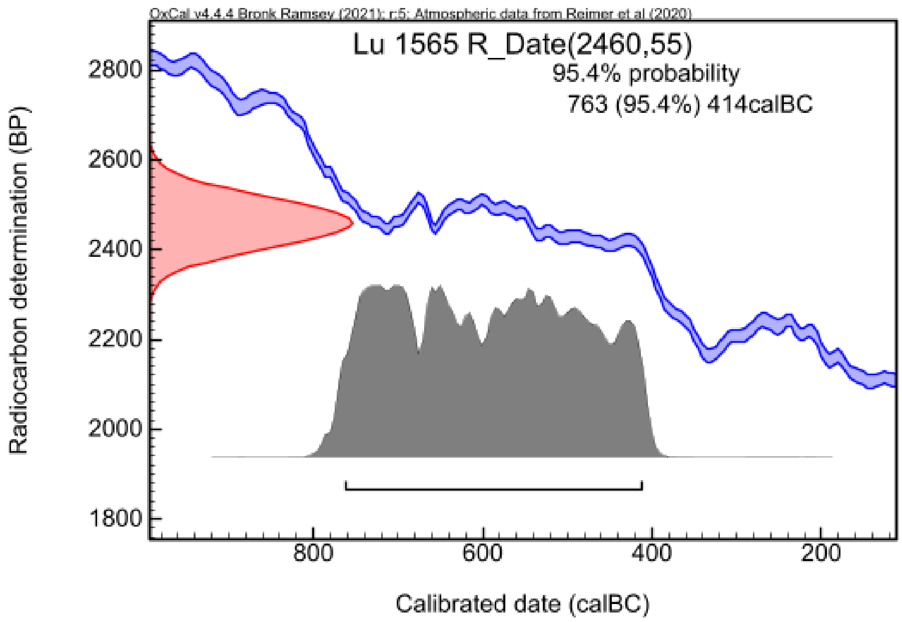


Figure 13 Example of a calibrated radiocarbon date. The Y axis shows the radiocarbon concentration, as years "Before Present" (BP), and the X axis shows the corresponding calendar years. The red curve indicates the concentration of ^{14}C in the sample. Figure produced using OxCal (v.4.4.4) (Bronk Ramsey 2021; Reimer et al. 2020).

Bayesian statistics is a probabilistic method which has been used to model radiocarbon chronologies for some time (Otárola-Castillo and Torquato 2018). Bayes' (1763) theorem consists of a statistical model combined with prior knowledge about the parameters of the model, which can be used to obtain an updated estimate with a higher precision (Buck and Meson, 2015). Put simply, a chronological model could thus consist of a series of ^{14}C-dates from a stratigraphy at a site, with the "prior knowledge" being the relationship between the sampled layers or, if available, other dating evidence with a higher degree of confidence. The known relationships would help constrain the probable use-period of the site, as well as timing of the transitions between the layers.

In this thesis Bayesian modelling was used to test the fit of the radiocarbon data for chronological analysis of bifacial points within Västerbotten (Paper II).

2.6 Exploratory Data Analysis (EDA)

Exploratory Data Analysis (EDA) refers to a collection of (mainly statistical and visualization) techniques used to summarize data properties and identify patterns (Haining, 2003; Tukey 1977). Rather than testing an established model EDA emphasises the generation of new questions and hypotheses (Jambu, 1991). The techniques encompass univariate, bivariate and multivariate data, with the main aim being to gain a better understanding of the structure of the dataset. Examples of univariate and bivariate analysis includes histograms, boxplots and scatter plots, which are all commonly applied techniques for evaluating data.

Archaeology deals with issues of a spatiotemporal nature, and Geographical Information Systems (GIS) have become a central tool for achieving this (Conolly and Lake 2006). In GIS sites and samples are geographically related to each other, which enables a number of different geostatistical analyses to be performed (Gillings et al. 2020). Directs comparisons can be made between the sites and samples themselves, but new values can also be predicted based on existing data by using interpolation or extrapolation (Conolly 2020), making it possible to detect trends in the data. The inclusion of environmental data (e.g. geology, elevation, vegetation) in GIS makes it possible to place people within a palaeolandscape (Brouwer Burg 2013). A common use of GIS has been to calculate least-cost paths through different landscapes, in order to explore possible travel routes of prehistoric peoples (White 2015). More advanced methods, such as Agent-Based modelling and simulation can then be used to further explore human decision making and other scenarios within these landscapes (e.g. Carrignon et al. 2020; Romanowska et al. 2019).

In the case of multivariate data, the primary difficulty is that of representing all of the variables at the same time. This is especially the case when working with spectroscopic data, where a large number of measurements may be collected on a large number of objects. The results of these types of detailed micro-scale analyses are difficult to represent at larger spatial scales without modelling the data beforehand (Paper I). As each wavelength produces a corresponding value, the variables already number in the thousands (Figure 8-9). In order to make sense of the data the only realistic course of action is to apply some form of dimensional reduction technique, where a smaller number of variables can be used to represent different aspects of the overall variation within the dataset. In this thesis Principal Component Analysis (PCA) is used to achieve this.

PCA is one of the most common techniques for dimension reduction, although other similar techniques are available (e.g. Correspondence Analysis, Linear Discriminant Analysis) (Hammer and Harper 2008). During PCA all variables are plotted in a multidimensional space, and a line is fitted in such a way as to maximise the sum of squares of all objects projected onto this line (Geladi & Linderholm, 2020). This line represents the first Principal Component (PC) and is the best estimation of the variance of the dataset. This is then repeated, generating new PCs, until the total variance of the dataset has been captured. The new components can then be used to represent the multivariate dataset in a bidimensional, or 3-dimensional, plot (Figure 14). Within the "variable space" that the score plot represents different attributes can be visualised in order to help detect trends and provide possible explanations for the patterns observed (Paper I).

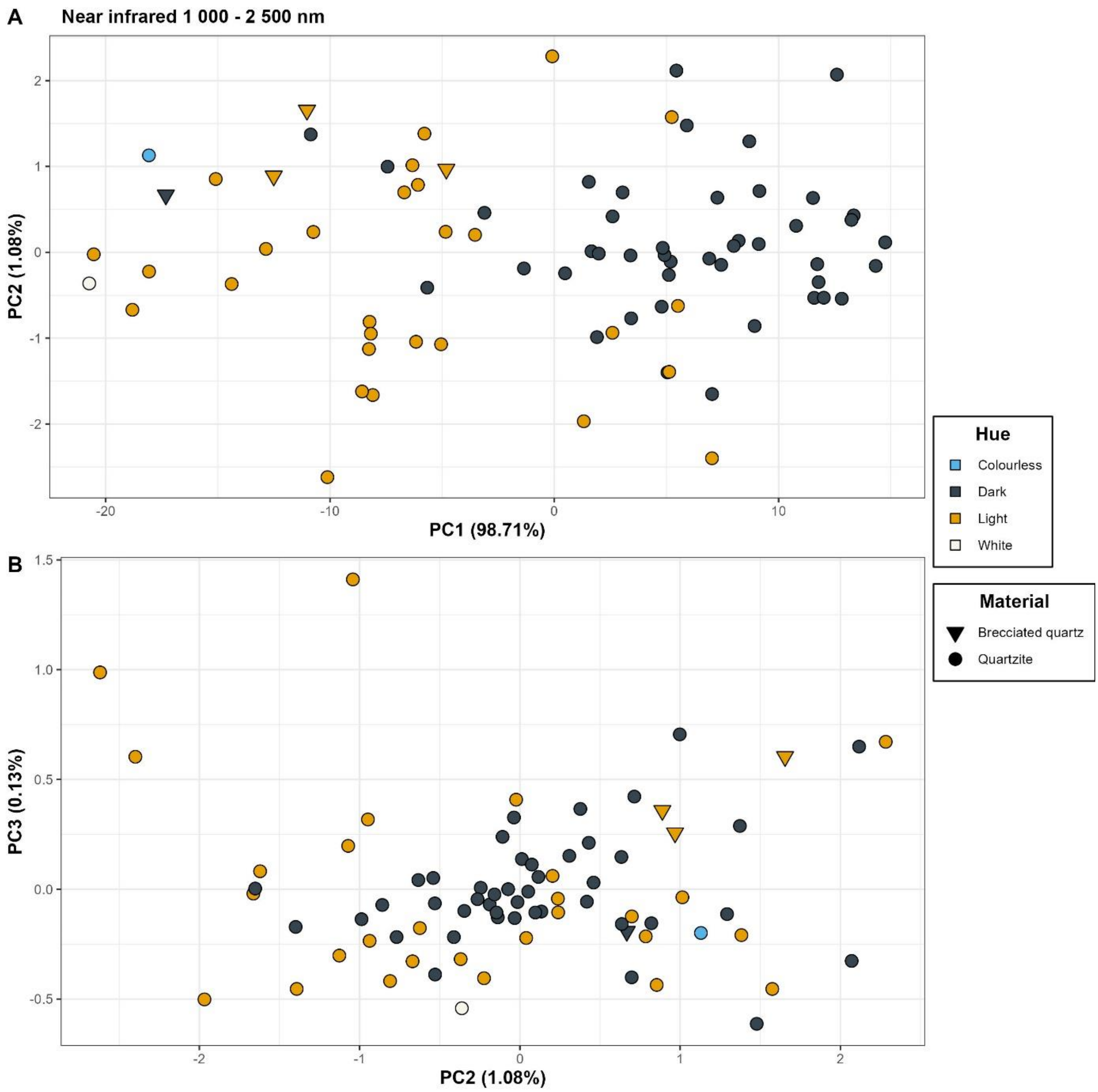


Figure 14 PCA score plots of NIRS absorbance values recorded on brecciated quartz and quartzite artefacts. The PCA model can be explored by adding different combinations of PCs as the axis. Figure made in R (R Core Team 2021) with ggplot (Wickham 2016).

3. Discussion

3.1 Spectroscopic techniques and quartzite

In the process of researching a topic there are moments of insights and progress followed by new challenges to overcome. This project has been no different, and each step taken towards answering the thesis objectives has prompted new questions. It is apparent that there is a knowledge gap in the current understanding of the procurement and management of locally sourced lithic raw materials during prehistoric times in Norrland. The ubiquitous distribution of the raw materials within the landscape (from which the studied artefacts could have been manufactured) makes it difficult to narrow down potential source areas, a component which is central to provenance studies. Materials that are difficult to characterize, such as brecciated quartz and quartzite, have mainly been classified based on visual attributes with little development over the years. This lack of development means that a critical component in our understanding of raw material management among hunter-gatherers in the region has struggled to move beyond the point of a hypothesis (Paper II & IV).

One of the aims of this thesis was to address the above knowledge gap using a quantitative and reproducible approach to the characterization of quartz and quartzite materials. Non-destructive spectroscopy offered this possibility, both in terms of assembling a large and geographically distributed dataset as well as the potential for assessing the chemometric variability of the material. The potential to work with multiple methods further enhanced the study as the different techniques provided insights into different material qualities.

Both NIRS and ED-XRF had already seen some archaeological application on different materials within a Norrlandic environment by the time this project started, thanks to the efforts of the Environmental Archaeological Lab and the MOBIMA project at Umeå University (Sciuto 2018). This was of benefit to the current project, as the previous work highlighted certain spectroscopic features which proved useful for understanding the new materials. This is despite a difference in equipment, in particular the markedly lower resolution of the ADS Labspec 4 (equipped with the contact probe) in comparison to the Hyperspectral camera used in MOBIMA. Despite this, it produced some interesting results within the combination band region (2 000 nm – 2 500 nm).

The main struggle for the ASD Labspec 4 seems to be with the absorption capacity of black materials, resulting in the masking of spectral features (Paper III). Raman faced similar issues with dark artefacts, and has even been known to risk damage of more sensitive materials by heating them to the point of ignition (Wang et al. 2021). Like the ASD the i-Raman instrument is portable, features fast integration, and is relatively easy to use. The usefulness of Raman in general is variable, as not all materials are capable of generating the Raman effect. Although black materials proved difficult to measure, most gave a response. It seems, however, that the information Raman is capable of producing is limited when applied to mainly quartz-based material.

The ED-XRF method is frequently applied in petrographic studies, and its capabilities have been well-demonstrated in this field (e.g. Olausson et al. 2017; Sánchez de la Torre et al. 2017; Sciuto 2018). It is an instrument with a lot of versatility, with the possibility to work with quantitative estimates (Paper III) or with a more qualitative approach using spectra. Most information generated by the ED-XRF pertains to the major elements (e.g. Al, Si, K, Fe), and used in tandem with NIRS there is an interesting avenue for exploring sedimentary/metamorphic quartzite origins. Although dark materials will always prove challenging in NIRS, instrumentation such as Hyperspectral Imaging cameras could be helpful as they capture the full surface of the object. This enables a more dynamic way of assessing the material, making it easier to target parts of the surface that provide more information.

3.2 Data processing and modelling

Spectroscopy produces lots of data, even more so when multiple instrumentations are applied to the same sample. While it is good practice to make a qualitative assessment of the recorded measurements it is not reasonable to expect that any meaningful patterns would be identified at this point. The data need to be processed, and this is a critical step in the analysis. The main aim of the initial processing is to remove noise and other forms of variation that the analyst is not interested in. If left untreated the noise will disrupt the later models, taking focus away from the features of interest. The preprocessing steps vary between the methods used in this thesis, as they all struggle with different sources of variation (Paper III). The Raman data needed to be baseline corrected to make each measurement comparable, whilst the main issue to address with the XRF data was the closed sum effect of calculated estimates. In the case of NIRS Savitzky-Golay filtering proved useful for evaluating what dark samples still exhibited useful information despite the high absorbance, but otherwise minimal preprocessing was used.

A considerable challenge with Paper III was ensuring transparency on the analytical process and making each step of data transformation clear to the reader. Although there is commercial software available that makes the exploration of spectroscopic data easier, there are a number of "black box" moments where the details of how methods are implemented is not fully explained. Embracing the concept of *Open Science* (Marwick et al. 2017), it was therefore decided that all of the steps would be recreated within an open coding environment where the reader had the possibility of reviewing each analytical step. R (R Core Team 2021) is a widely used coding language in the archaeological community, and its use creates the possibility for sharing code and allowing the user to render the entire paper, and its calculations, locally. This was used in Paper III, and means that any reader could use the same data and rerun each step of the analysis, possibly with their own modifications. This methodology thus facilitates both the replication and advancement of science.

Although the deductive approach of hypothesis testing is the more common way in which we engage with modelling (Nakoinz 2018; Popper 1959), Jebb et al. (2017) argues that there should be a balance between inductive and deductive approaches in scientific research. The "bottom-up" approach of methods such as EDA is aimed at pattern recognition and hypothesis generation. These approaches are crucial when engaging with topics which have seen less research, or when faced with an overabundance of data (and at times both). An inductive approach can then help identify variables of interest and lay the groundwork for future research. An added benefit of initiating studies with EDA is that unexpected patterns in the data can form the basis for data-driven hypotheses (Jebb et al. 2017: 271; Spector et al. 2014).

Spectroscopic analysis produces a lot of information, and while a qualitative assessment of the spectra is possible additional analytical methods are needed to fully explore the different patterns. Visualisation is a major component of EDA, and when used wisely can communicate all the information stored within the data in an intuitive way (Li Vigni et al. 2013). Principle Component Analysis (PCA) methodology embraces many of the virtues of EDA as it can be used to represent multivariate space graphically in order to explore trends and patterns within the data. Typically, 3 – 5 PCs are compared by visually inspecting scatterplots to help identify clusters and trends in different combinations of PCs. Not all of the components or combinations will reveal new information, and the analysis can be narrowed to the potentially useful ones. The researcher will most often then try to find explanatory variables (e.g. colour, grain size, presence of certain elements) to help understand the observed relationships in the data. This process was key to identifying statistical similarities in the materials studied in paper III.

When moving between different scales of analysis it is important to be aware of how each transformational step affects the underlying data. As discussed in Paper I, this thesis attempts to navigate analytical scales from the elemental composition of individual artefacts up to regional landscapes. Each model created inevitably results in some loss of detail, as the act of modelling itself is in essence simplification (or abstraction) of data (Nakoinz and Knitter 2016). Large-scale organizational inferences are typically made based on an understanding of local scale (and possibly micro-scale) variations (e.g. Brouwer Burg 2017; Forsberg 1985; Paper IV). Retaining that information and communicating the intricacies of the data to a reader can be difficult, however. One way of addressing this is through the documentation and sharing of code and data, but also making the reader aware of the difficulties involved.

3.3 Confounding factors

The focus of this thesis has included three main directions: 1) exploring the existing theories and approaches to understanding a particular phenomenon in Swedish archaeology, 2) exploring and analysing the different data types available, including the geographic location of bifacial points and preforms, radiocarbon data, and 3) creating and evaluating new spectroscopic data. As previous research on the topic of raw material procurement has been limited, the aim was to fill that void and assess previously proposed models of settlement and mobility, and the implication of these in terms of raw material use and lithic organization. Whilst the thesis provides new information regarding the distribution and variability of bifacial points within Västerbotten, there are a number of confounding factors that affect the potential for interpreting the observed patterns. These are discussed below, and related to an evaluation of available data in (Paper IV).

Data bias and data loss. The distribution of sites within the study area is heavily skewed towards three regions (Dorotea, Tärna and Vilhelmina) (Paper IV), with few sites located along the coastal region. The areas with a higher frequency of sites are also those that have been targeted by extensive survey projects carried out by RAÄ and VBM (Andersson 2015; Roslund-Forenius 1993). Any analysis of spatial trends in the distribution of artefacts and sites thus needs to consider this potential bias. With most sites being located along the shores of lakes and rivers, many of them have suffered, and currently suffer, from erosion to varying degrees (e.g. Andersson 2021; George 2009; Liedgren 2016). Numerous sites have been completely eroded away or submerged following dam constructions (Andersson 2015). Erosion directly damages archaeological features and removes artefacts and other relevant material from their primary depositional context. This limits the potential for both intra-site analysis of different spatial aspects, such as the organization of lithic remains, as well as the analysis of inter-site relationships, such as the procurement of raw materials.

A number of studies have investigated climate change related threats to cultural heritage in Norrland (e.g. Antonson et al. 2021a; Kaiser et al. 2019; Karlsson 2017). However, few projects have directly addressed the extent of the damage caused by erosion (e.g. Andersson 2015, 2021), and the degree to which it poses a threat to the cultural heritage of Norrland is poorly understood. International comparisons suggest there is reason for concern (Antonson et al. 2021b; Hollesen et al. 2018; Sesana et al. 2021). Given the extent of modern development within the river systems of Norrland (Dynesius and Nilsson 1994), including the so called 'green industrialisation' (Näsman et al. 2023), erosion and other forms of damage are progressing as part of both natural processes and as an effect of industrial development. This combination complicates the prediction of impacts, and simple deterministic models based on natural processes will be insufficient. More work is clearly needed in this field if we are to continue to have new archaeological material to investigate the prehistory of Norrland. In other words, it is not entirely certain that more reliable data will be available in the future, as sites are probably being lost (Hollesen et al. 2018).

Trade and exchange. The current narrative of the Norrlandic region at the time of the Epineolithic period shows a complex organization of foragers and farmers (Forsberg 2012). Incipient agro-pastoral and maritime hunter-gatherer communities with lower degrees of mobility are settled along the coastal region. In the inland hunter-gatherers organise along the river valleys, moving seasonally into the mountains to hunt reindeer (*Rangifer tarandus*) and procure lithic raw materials (Forsberg 1985). Living as close as these communities did it is important to consider how their potential interactions may have impacted the observed spatial patterns in the archaeological data (e.g. sites, artefacts, environmental proxies) (Paper IV). Forsberg and Damm (2014) argue that the production of bifacial points may have been related to an intensification of reindeer hunting as a response to trade and exchange of hides and antlers with farming communities at the coast. Evidence of such trade is rare, however, due in part to the poor preservation of unaltered organic materials in the acidic soils (Sauer et al. 2007; Schiffer 1987:163-188). It is also questionable as to whether the radiocarbon evidence available for the period is reliable enough, and gives us the temporal resolution, to expose this kind of trading (Paper II).

It is evident that the capacity to reveal networks of interaction between the different communities inhabiting the Norrlandic region is severely impacted by the variable preservation of the archaeological record. Although organic materials may completely decay, this process will alter the soil chemistry by elevating the levels of certain elements, such as phosphorus (P) or nitrogen (N). These geochemical traces can be used to highlight areas of past activity even when other evidence has disappeared (Linderholm 2010; Jerand 2023). In some cases, the combination of the geology of the region and an intensive use of an area can contribute to better conditions for preservation. This can be seen at the Late Neolithic site of *Bastuloken* (Site ID: L1934:165) where the skin processing of large amounts of elk seem to have taken place (Larsson et al. 2012), as evidenced by soil chemical analysis and the presence of large numbers of unburned bones (Kaal et al. 2019; Linderholm et al. 2019). The scale of production observed at such a site does not imply personal use, which then raises the question of as to whether this was part of a system of trade or exchange of elk products with other communities. A site like *Bastuloken* represent an anomaly in the current state of research, but it is difficult to say whether this was also true during Neolithic times. Nevertheless, the potential to identify such sites is useful and contributes to hypothesis generation and modelling of hunter-gatherer behaviour, especially by introducing empirical data to back a particular theory.

Lithic materials are less susceptible to deterioration than organic material, although they are still affected by different physical and biogeochemical processes (e.g. weathering, freeze-thaw cycles) (Schiffer 1987:151-158). In the case of Norrland brecciated quartz represents a unique type of material, with the only known source being in the Artfjället area in the Scandes (Holm 1991). The presence of brecciated quartz at sites in the coastal region has consequently been taken as possible indications of inland – coastal connections. A Bronze Age grave excavated in the area of Umeå (Site ID: L1938:8246) contained a number of bifacial points, all made in non-local materials, including brecciated quartz, basalt, and (Russian) flint (Lundberg 2005). Given the relatively small number of excavations undertaken in the region, it might be reasonable to expect more of this type of evidence in the future.

Provenance and lack of known sources. Brecciated quartz as a material group is somewhat poorly understood, however, and there is a need for more detailed petrographic characterization (Åhman 1967). It would be beneficial for raw material studies in Norrland in general to engage strategically in the geological survey of potential sources of quartz and quartzite material. These should be sampled and characterised in order to build a reference library so as to enable future provenance studies. This thesis has demonstrated the usefulness of spectroscopic studies on artefacts, but without further studies of the raw material there is a limit to how much can be explained. The geological disturbance in the region and incorporation of such material into fluvioglacial deposits will always add an element of uncertainty, but without the bare minimum it will be difficult to move the field forward.

Chronology. As highlighted in Paper II there is a need for better dating strategies aimed at improving the typological dating of artefacts to a particular archaeological period, such as that for bifacial points. This artefact type has previously been used to assign relative dates to archaeological sites on the basis of its established association with a particular timespan (e.g. Forsberg 1985; Lundberg 1997:141). Given the challenges Norrlandic archaeology faces with the frequent lack of stratification and at times complex palimpsest of prehistoric activities carried out within the same limited area it can be difficult to relate individual finds to a particular date. With Geographical Information Systems (GIS) being as integrated as they are into fieldwork it has become easier to record the observed contextual relationships between features, finds and collected samples. There is also an increased interest for digitizing older data and compiling radiocarbon data in the archaeological community (https://swedigarch.se/) (Bird et al. 2020; Brami and Zanotti 2015; Friman and Lagerås 2023; Manninen et al. 2023; Paulsson 2010; Porčić et al. 2020). This means that there is much potential for future targeted evaluations of different artefact types, distribution patterns, and dating evidence. Research on data from these older studies can benefit considerably from data and GIS analysis methods that were not available at the time of the original data collection.

4. Concluding remarks

Norrlandic archaeology is faced with a number of unique challenges, some of which have been discussed in this thesis. Although this may limit archaeological research in the region to some capacity it has also inspired some novel approaches in order to bridge these challenges and address interesting questions on cultural development (e.g. Forsberg 1985; Jerand 2023; Sciuto 2018). It is hoped that this thesis in turn may inspire future endeavours in the study of hunter-gatherer societies in the Norrlandic region.

Settlement and mobility studies of hunter-gatherer communities utilizing bifacial points made of quartzite material in Norrland, Sweden, are lacking some key components necessary for inferences of lithic raw material management. The focus of this thesis has been the advancement of such models in the area of Västerbotten, Sweden. To achieve this an exploratory approach was used, applying different methods of interrogation at multiple scales of analysis. The results presented in the four papers included herein highlight the challenges archaeologists working within the region are faced with, as well as methods and strategies for overcoming these.

A central challenge to raw material management studies is the lack of information on quartzite variability and potential source areas. It is the conclusion of this thesis that the application of non-destructive spectroscopic methods on quartzite material can help steer future survey efforts aimed at identifying potential sources utilized by prehistoric hunter-gatherers. As discussed in Paper III, they also enable the strategic targeting of material trends identified in the spectroscopic data for more detailed petrographic characterization. These approaches should prove useful in regions such as Norrland, with its geological complexity and, as of yet, untapped potential for scientific provenance studies.

A second challenge, highlighted in Paper II, is the need for artefact chronologies built on a robust empirical basis. Raw material management is intimately linked with lithic technology and organization, and artefact chronologies help us relate the inferences made to human behaviour in time. The re-introduction of bifacial points to the Norrlandic region seems to be concurrent with major changes in the settlement pattern and mobility strategies of hunter-gatherer communities. However, without a good chronological foundation it is difficult to say how representative any potential inferences made of raw material utilization in connection with bifacial points are of the overall raw material strategies. The dispersed nature of radiocarbon data currently presents one of the bigger obstacles to overcome in chronological studies for the region. The current push for digitization and collation of data into larger infrastructures presents a good opportunity for large scale synthesis research and evaluation of the empirical basis of current chronological frameworks (e.g. https://swedigarch.se/).

A third challenge, discussed in Paper IV, is the question of representativity. This is not something new but has long been part of archaeological discussion on Norrland (and the world). The archaeological excavation and survey history of the region affects how we interpret spatial patterns observed in the empirical data. Coincidentally, the areas targeted for later survey projects also featured a higher frequency of sites with bifacial points. Does this then reflect a pattern of use, where areas closer to the major potential geological sources resulted in the deposition of larger numbers of bifacial points and preforms than areas further downstream? Due to the issue of representativity this can be a difficult question to assess. One approach could be the application of agent-based modelling and simulation, wherein different scenarios of raw material use, and lithic production, can be evaluated. The simulated patterns could then be compared with the empirical data in order to provide a better foundation for archaeological inference.

The Epineolithic (2 000 – 800 BC) period in Norrland holds a lot of interest due to the significant changes hunter-gatherer communities seem to undergo around this time. The various artefacts and technologies introduced during this period of time indicate long-distance contacts between the Norrlandic hunter-gatherer communities and neighbouring traditions. There are many questions still left to interrogate on this topic, such as the interaction between inland hunter-gatherers and agro-pastoralists along the coast, and it is hoped that this thesis has contributed to this endeavour by both presenting new insights and facilitating new directions in future research.

Paper summary

Paper I presents the theoretical considerations of working with multivariate data at different scales, and presents a backdrop for the themes discussed in Papers III and IV. The paper discusses the multi-scale nature of modelling prehistoric societies. Landscape-scale spatial analyses (Paper IV) are based on data and inferences made at an artefact level (Paper III). For high-resolution data to be manageable at large spatial scales, however, it needs to be simplified and aggregated, resulting in some loss of information. Not all modelling tasks are of a spatial nature, and by working within the "variable space" it is possible to retain the higher resolution of the data.

Paper II is a chronological study of bifacial points within the Västerbotten region. It compiles ^{14}C-data from archaeological sites with finds of bifacial points in order to evaluate the potential for building a chronology. 124 ^{14}C-dates from 30 sites are included in the study, forming the basis of Bayesian analysis using overlapping model approaches. A number of challenges are highlighted in the study, such as the lack of stratified sites, prevalence of charcoal samples, and tendency for sites to be disturbed (modern and prehistoric). The study finds that there are too few ^{14}C-dates that can be linked to a secure context which dates that bifacial artefact, and thus there is no basis on which to build a chronology.

Paper III presents the spectroscopic approach applied in the thesis. The paper is a case study of 126 quartz/quartzite points from 47 archaeological sites along the upper parts of Ångerman River valley in Västerbotten. The material was analysed non-destructively using NIRS, Raman and ED-XRF. The analysis consists of a qualitative evaluation of the different spectral features recorded by each instrumentation, as well as quantitative exploration using PCA. The study finds that there are a number of spectral features that have potential in guiding future geological surveys and provenance studies. Each instrument showcases the variability of the material, although Raman seems to be more limited than the other two.

Paper IV presents a spatial analysis of the distribution of bifacial points and preforms within Västerbotten. Exploratory Data Analysis (EDA) techniques are used to evaluate the spatial variation in the data at a regional scale. The Ångerman and Ume/Vindel Rivers exhibit different distribution patterns, with higher proportions of preforms closer to the mountains. The capacity for established mobility models to explain the observed patterns are discussed in respect to the geology of the region, archaeological survey coverage and other potentially important variables.

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