Universiteit Leiden
The Netherlands

Through the Looking Glass: Using Palaeobotanical Data Analysis from Middle Pleistocene Site Schöningen 12 II 4 to Make Paleoenvironmental Reconstructions and Consider Hominin Behaviour and Landscape Exploitation During Reinsdorf Interglacial

Catalinoiu, Mirela Felicia

Citation

Catalinoiu, M. F. (2024). *Through the Looking Glass: Using Palaeobotanical Data Analysis from Middle Pleistocene Site Schöningen 12 II 4 to Make Paleoenvironmental Reconstructions and Consider Hominin Behaviour and Landscape Exploitation During Reinsdorf Interglacial*.

Version: Not Applicable (or Unknown)
License: [License to inclusion and publication of a Bachelor or Master Thesis, 2023]
Downloaded from: https://hdl.handle.net/1887/3714041

Note: To cite this publication please use the final published version (if applicable).

Through the Looking Glass

Using Palaeobotanical Data Analysis from Middle Pleistocene Site Schöningen 12 II 4 to Make Paleoenvironmental Reconstructions and Consider Hominin Behaviour and Landscape Exploitation During Reinsdorf Interglacial

Jerry Lake. (2010). Sunrise in Langley Park. © Retrieved from https://www.flickr.com/photos/park-pictures/4359592459/in/album-72157623314933121, Accessed: 29-10-2023.

Through the Looking Glass

Using Palaeobotanical Data Analysis from Middle Pleistocene Site Schöningen 12 II 4 to Make Paleoenvironmental Reconstructions and Consider Hominin Behaviour and Landscape Exploitation During Reinsdorf Interglacial

Name: Mirela F. Catalinoiu
Course: Master thesis Archaeological Science
Course code: 1084VTSY
Supervisors: Dr. Michael H. Field and Dr. Gerrit Dusseldorp
Leiden University, Faculty of Archaeology
Leiden 15th of December 2023, Final Draft

Acknowledgments

Mentioning everyone who has played a part in this journey of knowledge, but I will try and do my best to make sure that all the people that played an important role in my journey are mentioned.

The inception of this thesis owes a great deal to the remarkable Dr. Mikael Field. Initially, I thought I had it all figured out when I embarked on my studies, with a specific interest in the Near East and the pre-Neolithic era. But life had different plans for me, leading me down the Middle Pleistocene rabbit hole and the world of micro and macro botanical fossils.

Plants have always held a special place in my heart, but who would have thought that my knowledge about them would find such a meaningful purpose? Pinpointing the exact moment of this transformation is like chasing my own shadow. I will never know, but I think Botany Lab has undoubtedly been a key player. Those spirited discussions over a cup of tea, immersing into anything and everything, and of course botany, created an atmosphere akin to the 'Dead Poets Society' movie. Dr. Field's infectious enthusiasm keeps us returning for more, adding a sprinkle of magic to the journey

Dr. Ilse Kamerling deserves a special mention for her patience and ability to turn pollen and pollen preparation into a delightful stroll in the park. She is the beating heart of the Botany Lab, a helpful, candid, and beautiful soul who embodies the essence of this space.

A heartfelt nod goes to Dr. Gerrit Dusseldorp, who offered guidance when I felt adrift and uncertain. His feedback was the compass that helped me navigate the writing process, providing confidence when it was sorely lacking. I'm grateful for his clarity, constructive feedback, and boundless patience as my supervisor.

Dr. Femke Thomas, our meeting marked an important moment in my life's journey, steering me toward this point. Thank you for your kindness and good advice on how to figure out the maze of master's applications.

Dr. Ivo Verheijen, the untangler of the intricacies of Schöningen landscapes, a big thank you for sharing materials and patiently answering so many questions.

A special mention goes to my friend Andres Madrid Ucha. Your friendship was a refreshing breeze in moments of uncertainty. When we first crossed paths, I had just moved here, ready to rebuild my life from scratch. Thank you for your companionship and the wisdom you shared. Who would have expected such profound insights from someone so young? You are going to do great things, kiddo.

Big thanks to the excellent professors who impacted my academic journey: Dr. Martina Ravello Lami, Dr. Alexander Verpoorte, Dr. Peter Akkermans, Dr. Joanne Mol, Dr. Tuna Kalayci, Dr. Dennis Braekmand, Dr. Maike de Vaal, and Dr. Anne Braysebaert.

Table of contents

Acknowledgments ____ 3

List of Figures and Tables ____ 9

CHAPTER 1: INTRODUCTION ____ 13

1.1 The Research Problem ____ 16

1.2 Research Gap ____ 16

1.3 Research Questions ____ 17

1.4 The Significance of Botanical Macro Remains at Schöningen ____ 18

1.5 Why Hominid Exploitation Strategies in the Middle Pleistocene ____ 19

1.6 Reading Guide ____ 20

1.6.1 Chapter 1 – Introduction 20

1.6.2 Chapter 2 – Background and Site Presentation 20

1.6.3 Chapter 3 - Methodological Approaches for Botanical Macrofossils Analysis on Sediment Sample from Schöningen 12 II 4 21

1.6.4 Chapter 4 - Results 21

1.6.5 Chapter 5 - Discussion 22

CHAPTER 2: BACKGROUND AND SITE PRESENTATION ____ 24

2.1 The Pleistocene Epoch ____ 25

2.2 The Middle Pleistocene Archeology ____ 27

2.3 The Location and Nomenclature ____ 29

2.4 The Geology ____ 32

2.5 The Stratigraphy in Schöningen Open-Cast Mine ______________________ 36

2.5.1 Channel II Reinsdorf Interglacial Stratigraphy 36

2.5.2 The Sedimentary Cycle/Layer 4, Stratigraphy 39

CHAPTER 3. METHODOLOGICAL APPROACHES FOR BOTANICAL MACROFOSSILS ANALYSIS ON SEDIMENT SAMPLE FROM SCHÖNINGEN 12 II 4C ______________ 44

3.1 Introduction ____ 44

3.2 Research Design ____ 44

3.3 Data Collection Procedures _____________________________________ 45

3.3.1 Quantitative Method... 45

3.3.2 Qualitative Methodology... 46

3.4 Data Analysis Procedure ______________________________________ 47

3.5 Considerations____ 48

CHAPTER 4. RESULTS____ 50

4.1 Introduction ____ 50

4.2 Preliminary Results ____ 50

4.2.1 Additional Fossil Discoveries 53

4.3 Considerations in Botanical Macrofossil Analysis ______________________ 54

CHAPTER 5. DISCUSSION ______________________________________ 56

5. 1. Reconstruction of the Paleoenvironment at Middle Pleistocene site Schöningen 12 II during Reinsdorf interglacial, corresponding to sublayer 4c ______________ 57

5.1.1 Middle Pleistocene Environment in Northern Europe during the Interglacial Period.......... 57
5.1.2 Botanical finds from Platform 4, Schöningen 12II-4 sublayer c. Presentation of the Data Set 58
5.1.3 Reconstructing the Hydrophytic Zone/Aquatic Zone 59
5.1.3.1 Reconstruction of the Sediment Layer from the Aquatic Environmental Zone ***60***
5.1.3.2 Reconstruction of the Aquatic Layer from the Aquatic Environmental Zone ***62***
5.1.4 Reconstructing the Lake Margins and the Surrounding Damp Grounds Zone 67
5.1.4.1 Reconstructing the Macrophyte Plant Environmental Zone on the Lake Margins 68
5.1.4.2 Reconstructing the Lacustrine/ Waterside Environment Zone 70
5.1.4.3 The Vegetation Layers of the Lacustrine/Waterside Zone 72
5.1.5 Reconstruction of the Upland Terrestrial Zone 74
5.1.6 The Reconstruction of the Lacustrine Paleoenvironment. Adding together all the Reconstructed Environmental Zones 78

5.2 Hominin Behaviour during the Reinsdorf Interglacial at Schöningen 12 II, Corresponding to Sublayer 4 c ____ 85
5.2.1 Exploring the Plant Tool Crafting... 86
5.2.2. Exploring the Potential of Plant Nutrition 96
5.2.3. Exploring the Potential of Medicinal Plant Use 107

CHAPTER 6. CONCLUSION ____ 117

6.1 Answering the First Research Question______________________________ 117

6.2 Answering the Second Research Question __________________________ 118
6.2.1 Exploring the Plant Tool Crafting.. 119
6.2.2 Exploring the Potential of Plant Nutrition 120
6.2.3 Exploring the Potential of Medicinal Plant Use 121

6.3 Contributions and Considerations __________________________________ 122

6.4 Future Research ____ 123

6.5 Final Thoughts ______ 124

Abstract ______ 125

Bibliography ______ 127

List of Figures and Tables

Figure 1.1 Schöningen position in Europe, map realized with GEP, satellite imagery taken from Landsat/Copernicus, retrieved on 11th February 2023 15

Figure 1.2 Schöningen 13 and 12 positions in the Schöningen open cast lignite mine, map realized with GEP, satellite image taken form Landsat/Copernicus, retrieved on 11th February 2023 15

Figure 2.1 Table representing the marine isotopes stages for different regions, with Schöningen having two interglacial periods, Holsteinian contemporary with 13- I site, and Reinsdorf contemporary with 12-ll and 13-ll, modified from Lang et al. (2015), fig. 2, p 65........................ 26

Figure 2.2 Middle Pleistocene climatic fluctuation with Schöningen corresponding to MIS9, indicating temperature fluctuation. Taken from Lauren &Weiss (2018), fig. 4 p.6...................... 26

Figure 2.3 Middle Pleistocene sites in Northern Europe, from 600 to 300 kay, Schöningen, Mauer, Boxgrove, Swanscombe, Clacton-on-Sea, Lynford- Quarry, Bilzingsleben. The map was made with GEP using satellite imagery from Landsat/Copernicus, data: 23 February 2023 28

Figure 2.4 Vertical Section of the Quaternary sedimentary sequence of Schöningen Tunnel valley and the Vl channels with the star indicating channel ll. Layer 1: Elsterian till; 2: Saalian glacial sediments; 3: Lacustrine sediments; 4: Limnic telmatic sequence; 5: Soil complexes; 6: Loess; 7: Evaporites; 8: Gypsum cap-rock; 9: Buntsandstein; 10: Triassic limestones; 11: Triassic deposits; 12: Paleogene deposits. The red star indicates the location of channel II. Modified from Peters & Van Kolfschoten (2020), fig. 3, p. 3. 30

Figure 2.5 The map contains the position of Schöningen 13-II, the blue square, and Schöningen 12-II on the same channel with the seven plateaus; the black circle is around plateau 4. Drawing: Utz Bohner, modified Serangeli et al. (2015), fig 3, p. 32.. 31

Figure 2.6 Schöningen position of the locality between the maximum southern expansion of the Elsterian and the Saalian and Weichselian continental glaciers is taken from Conrad et al. (2015), fig. 1, page 2. 34

Figure 2.7 Changes in the landscape during the glaciation and interglaciation in the Schöningen area. Taken from Bigga (2018), fig 5, p. 19.. 35

Figure 2.8 B) Paleogeographic reconstructions of the Holsteinian lake. The delta systems were shed by surface run-off from the Elm, probably fed by springs. C) Schematic cross-section of the delta system, illustrating the embedding of the artifacts. Artifacts originate from the activity of early humans on the subaerially exposed delta plain. Subsequent lake-level rise causes the embedding of the artifacts in lacustrine deposits. Modified from (Lang et al. (2015), fig. 6, p23 35

Figure 2.9 Schöningen 12-II 4 80 m deep stratigraphy, 1. Holocene layer, 2. Loess from Weichselian glaciation, 3. Saalian glaciation sand and gravel, 4. Schöningen 12-II 4, 5. Elsterian glaciation sediments, 6. Tertiary lignite. Photo and drawing: Jordin Serangeli. Modify from (Serangeli et al. (2015), fig 3, p. 34 36

Figure 2.10 Schöningen 13 II shows the position of the four preserved sedimentary cycles from the paleolake at Schöningen. Sedimentary cycle 5 was truncated by mining. Photo: J. Serangeli. Modify form Serangeli et al.(2015), fig. 4, p. 35 38

Figure 2.11 Table contains the reference profile from Schöningen 13 II, with sublayers and sedimentology. Acquired form Urban &Bigga (2015), table 1, page 62.......... 39

Figure 2.12 Profile description from Schöningen 12 sublayer II 4 c and b. Acquired from Julien et al. (2015), fig. 3, p. 267.......... 41

Figure 2.13 Table contains the reference profile from Schöningen 13 II, with sublayers and sedimentology. Acquired form Urban &Bigga (2015), table 1, page 62..........42

Figure 2.14 Profile description from Schöningen 12 sublayer II 4c and b. Acquired from Julien Et al., 2015, Fig. 2, p. 267..........43

Figure 4.1 Table containing the identified plant parts according to taxon, taxon family, numbers, percentage from the total without Characeae, and image and its source.Created by MF Catalinoiu 51

Figure 4.2 The table containing the fossils found in Schöningen12 II 4c sediment, Mollusca operculum and shell fragment, Osteichthyes tooth and scale, Ostrocoda carapace, and Coleoptera elythrum. Created by MF Catalinoiu 54

Figure 5.1 Table containing the Lithological description of the profile from Schöningen 13 II, level 4, showing the soil composition on sublayer c. Modified from (Urban & Bigga, 2015), page 62..........61

Figure 5.2 Geochemistry of Schöningen 13 (Reinsdorf Interglacial) profile, level 4 and 5, Modified from Urban &Bigga (2015), fig. 1, page 63 61

Figure 5.3 Schematic representation of vegetation stands with Zannichellia taxa under field conditions. A bay in Finland. B, temporary pool, The Netherlands. C, temporary marsh, Camargue, France. D, former riverbed, Lith, The Netherlands., taken from Van Vierssen (1982), fig. 13, p 431 65

Figure 5.4 Table contains the identified aquatic plants and the depth where they can be found in a lacustrine environment. Created by MF Catalinoiu 66

Figure 5.5 Example of Thypa and Phragmites australis environment on the lake margins on the Vliet The Netherlands, image taken on the 13th of July 2023 by MF Catalinoiu 69

Figure 5.6 Example of a dense thicket of Rubus fruticosus competing for space and light with Rumex and other species of plants on the lake margins in Vlietland, The Netherlands, picture taken by MF Catalinoiu, 13 July 2023 71

Figure 5.7 The layer reconstruction of the lacustrine zone starts with the aquatic area and finishes with the upland terrestrial zone. Graphic by Gerlinde Bigga. Modified from Bigga (2018), fig. 31, page 66 73

Figure 5.8 Schöningen 12 II-4 platform 4 to 6, the position of the identified wood fragments and the type of tree it represents. Taken from Bigga, (2018), fig. 21, page 56 75

Figure 5.9 Pollen diagram of reference profile Schöningen 13 II (2003), layer 4, sublayer c, b, a and layer 5. Where LPAZ - Local Pollen Assemblage Zones; RP-Reference Profile. Modified from Urban & Bigga (2015), fig. 7, page 65 76

Figure 5.10 Local pollen assemblage zones, subzones, vegetational phases, and biostratigraphy of the Reinsdorf Sequence and tentative correlation with the Marine Isotope Stratigraphy (MIS). Modified from Urban et al. (2023), table 1, page 160 80

Figure 5.11 Simulation of landscape reconstruction at Schöningen, corresponding to sublayer II 4 c. It contains flora identified from pollen assemblages LPAZ RP4a and 4b. Taken from Urban et al. (2023), fig. 19, page 170 80

Figure 5.12 The symbols used to represent flora and fauna in the simulation for reconstructing the environment Schöningen after pollen assemblage. Taken from Urban et al. (2023), fig. 11, page 161 81

Figure 5.13 Schöningen 13 II-4. a) Part of spear IV, b) spear V, c) spear/lance VI, and d) spear VII. Photo: P. Pfarr. (Lower Saxony State Service for Cultural Heritage), taken from Schoch et al., (2015), fig. 6, p 221........ 90

Figure 5.14 Table containing the possible cognitive *chaine operatoire* for crafting a spear at Schöningen during Reinsdorf interglacial following Haidle,2009. Created by MF Catalinoiu........91

Figure 5.15 Schöningen 13 II-4: Information on the wooden artifacts containing wood species, age, and the season when it might have been cut, modified from Schoch et al.(2015), table 1, p 216........94

Figure 5.16 Table containing the available types of wood and their properties (density, elasticity MoE, resistance to breakage MoR, resistance to compression Comp) at Schöningen during Reinsdorf interglacial corresponding to sublayer II4c. Created by MF Catalinoiu........95

Figure 5.17 Taste areas: sweet, bitter, sour, salt, umami. Taken from Thomas et al. (2022), page 4........100

Figure 5.18 Table containing the edible plants identified at Schoninger during Reinsdorf interglacial corresponding to sublayer II4c. It includes the scientific and common names, edible parts, and foraging season to which the study belongs and references. Created by MF Catalinoiu 102

Figure 5.19 Table containing the possible medicinal plant from the list of edible plants and their medical effects. Created by MF Catalinoiu........108

Figure 5.20 The table contains possible injuries and diseases that could have affected the hominins at Schöningen 12 II4c and possible natural remedies that could have been used. Created by MF Catalinoiu........112

Chapter 1: Introduction

Schöningen, a small town in the northern reaches of Germany, lies on the southeastern border of the Elm Hills range within the Helmsted district of Lower Saxony (see Fig 1.1). This town boasts a prosperous mining industry that traces back to 1930, when a lignite open-cast mine was first established. The subsequent construction of the Buschhaus Power Station in 1970 marked a significant turning point, further intensifying mining activities and making it a cornerstone of the region's economy. This mining activity has unearthed a treasure of Middle Pleistocene strata, bearing witness to a prehistoric world with well-preserved wooden spears, flint tools, fossilized bones, and botanical macrofossils, all preserved within a waterlogged environment (Schoch et al., 2015, p. 214). This complex of Middle Pleistocene sites, including Schöningen 13 II-4 and Schöningen 12 II-4, belongs to the Reinsdorf interglacial and is correlated with MIS9 (Marine Isotope Stage) (Tucci et al., 2021, p.3).

Schöningen 13 II-4, often called the "Spear Horizon," is the most famous among these. It was discovered in 1994 by Dr. Hartmut Thieme, an archaeologist at the Lower Saxony State Heritage Office. The groundbreaking discovery was the nine wooden spears in what appears to be a butchering site in a waterlogged environment. Horse bones bearing cut marks indicating butchering, scrapers, and flint debris were found along the spears, suggesting that hunting and food processing were happening on the site. This shows that the lake margins at Schöningen 13 II-4 were dynamic spaces where early hominins hunted and efficiently processed resources from their environment.

The spears were initially estimated to be 400 ka. However, the optically stimulated luminescence (OSL) dating of the spear`s sediment layer has provided more precise information, suggesting that the sediment sublayer II 4c is approximately 320ka (Conard et al., 2015, p.8). Although the second oldest spears, after the 400ka partial spears made of yew discovered in 1911 at Clacton-on-Sea (Allington-Jones, 2015, p. 274), the completeness of the Schöningen spears makes them ideal for in-depth analysis, both from a technological perspective and in terms of the understanding they offer into the surrounding environment, as evidenced by the choice of wood materials (Schoch et al.,2015, p. 215). Ongoing excavations at the Schöningen 13 II-4 site continue to unearth significant archaeological finds, with efforts underway to secure its designation as a UNESCO World Heritage site. These well-preserved artifacts, dating back to around 330,000 years ago, provide insights into the evolution and behaviour of hominin species that may have inhabited the area during that period.

Another archeological horizon, Schöningen 12 II-4, is positioned on the same channel not far from Schöningen 13 II-4 (Fig 1.2). From 2008 to 2009, it underwent a rescue excavation before being destroyed by mining activities. However, this site yielded remarkably preserved botanical macrofossils, which shed new light on the environment (Bigga, 2018) and the formation of a paleolake in a former tunnel valley (Lang et al., 2015, p.19).

In the academic world, Schöningen role as a Middle Pleistocene site is widely acknowledged as one of the most significant in Northern Europe. This site's critical significance lies in its capacity to unveil the earliest indicators of hominin activity at this latitude, occurring during interglacial periods. The fluctuations of cooling phases (Serangeli et al., 2018, p.140) put to rest the scavenger vs. hunter controversy (Domínguez-Rodrigo, 2007, p. 11) but also add more evidence of plant diet possibility. The discoveries from this site provide a vivid portrait of the hominin cultural landscape and their remarkable ability to adapt to the environment amid significant climate changes. This challenges our *H. sapiens*-centric perspective, suggesting that early hominins were not mindless creatures but could exhibit a more intricate and nuanced behaviour than previously thought. They adapted to new environments (Rodríguez et al., 2016, p. 20) through environmental awareness and strategic resource exploitation. The sophistication of their tool technology indicates a certain level of cognitive ability and implies strategic thinking and problem-solving skills (McNabb, 2005, p. 302). This broadens our understanding of early human capabilities beyond a simplistic view, highlighting their adaptive intelligence and resourceful behaviours in diverse settings. Furthermore, Schöningen archeological finds gave many insights into the region's fauna and flora. The analysis of the fauna and flora has played an important role in understanding the environmental and climatic conditions prevalent in the area during the Lower Pleistocene period.

Figure 1.1 Schöningen position in Europe, map realized with GEP, satellite imagery taken from Landsat/Copernicus, retrieved on 11th February 2023

Figure 1.2 Schöningen 13 and 12 positions in the Schöningen open cast lignite mine, map realized with GEP, satellite image taken form Landsat/Copernicus, retrieved on 11th February 2023

1.1 The Research Problem

Schöningen well-preserved layers can be likened to a rediscovered library, where ancient manuscripts spanning hundreds of thousands of years offer insights into the daily lives of early humans. Schöningen 12 and 13 have complex stratigraphy formed during the most extended interglacial period between Saalian and Emian glaciation, featuring two sedimentation channels, channels I and II (Tucci et al., 2016, p.3). The interglacial corresponding to Northern Europe, particularly Germany, comprised the Holsteinian and Reinsdorf interglacial periods (Lang et al., 2015). Channel I is a sedimentation event in the tunnel valley during the Holsteinian interglacial, correlated to MIS 11(424 to 374 ka). In comparison, channel II represents the Reinsdorf interglacial correlated to MIS 9 (337 to 300 ka), comprising the archaeological horizon of Schöningen 12 II and Schöningen 13 II. Within channel II, layer 4 is particularly intricate, with sublayers labeled from 'i' to 'a', each corresponding to episodes of lake level and climate change (Stahlschmid et al., 2015, p.2). The intricate nature of these factors complicates the precise determination of the context and timeframe for comprehending the interplay between environmental conditions and hominin behaviour. To address this challenge, palaeobotanical data and its interpretation become crucial. Refining the environmental reconstruction to a specific timeframe involves a detailed sediment sample analysis from a particular sublayer. This study aims to identify and specify this timeframe more accurately, focusing on sublayer II 4c.

1.2 Research Gap

The study of botanical macro remains faces several challenges. Firstly, there is a limited number of sites with these well-preserved remains. Even when found, the sample size tends to be small due to the scarcity of botanical macrofossils in places like El Sidrón Cave in Spain (Radini et al.,2016, p. 291) Qesem Cave in Israel (Kovárník & Beneš, 2018, p. 89) or Gesher Benot Ya'aqov (Melamed et al., 2016, p. 141677). Additionally, the taxonomic resolution in identifying plant macro remains often limited, with many studies only being able to classify them at the genus level based on general characteristics. This hinders the ability to provide precise species-level identifications. Moreover, merely identifying plants and making climate inferences is insufficient to reconstruct paleoenvironments (Wolfe, 1978, pp. 313-316). Multiple proxies are necessary to create an accurate picture encompassing various aspects of the environment.

The study of hominin-plant interactions still lingers due to limited evidence, although new findings continue to emerge, clarifying this crucial aspect of human history. When discussing plant-hominin interactions, there is a need for more integrative approaches that combine insights from various fields to provide a comprehensive understanding of hominin behaviour and its relationship with plants in the context of ancient environments. Furthermore, regarding chronological resolution, many studies focus on extensive periods, potentially overlooking variations that may have occurred over shorter periods. Analyzing botanical macro remains can offer finer insights into understanding changes over time.

1.3 Research Questions

While the contemporaneous Schöningen 13 II-4 site has yielded many findings, Schöningen 12 II-4 has received less attention, and its environmental context remains unclear. Therefore, the first question is:

What is the detailed reconstruction of the lacustrine paleoenvironment at the Reinsdorf interglacial site Schöningen 12 II, corresponding to sublayer 4c? How can we characterize the paleolake's water chemistry, depth, and speed during this specific timeframe?

To address this, botanical remains in a sediment sample from Schöningen 12 II-4 will be analyzed to reconstruct the lacustrine environment and its connection with hominin behaviour. Questions will be explored, including whether Schöningen 12 II-4 was situated on the lake margins or farther away, and if so, what insights can be drawn regarding water depth, suspended sediment, velocity, chemistry, and substrate. Utilizing seed identification data from the sediment sample of Schöningen 12 sublayer II 4c, a local environmental reconstruction will be conducted, supplemented by information gathered from a literature review from Bigga (2018) and Bigga, Schoch, Urban (2015). With a clearer understanding of the paleoenvironment, the research will address the following question:

What insights can we derive from vegetation reconstruction about potential plant use, hominin behaviour, and exploitation strategies at the middle Pleistocene site Schöningen 12 II during Reinsdorf interglacial corresponding to sublayer 4c?

Therefore, I will explore the hominins' relationship with their surroundings and how they managed available resources, especially plants and wood. This exploration will investigate the hominins' activities at the site, whether they were hunting or foraging for fruits, nuts, and edible plants, and how these elements factored into their dietary habits. By scrutinizing the dynamic between hominins and their environment, we aim to understand better how these early humans adapted and thrived in a world marked by constant change.

1.4 The Significance of Botanical Macro Remains at Schöningen

The preservation of botanical macrofossils in Schöningen is notably exceptional, owing to their incorporation within waterlogged sedimentation. The advantage of using the botanical macro remains to reconstruct the vegetation and ecosystem of the Middle Pleistocene period at Schöningen is that by analyzing these remains, the identification can be made at the species level (Azaele et al., 2010). The information it provides enables a local environmental reconstruction since botanical macro remains generally do not travel too far from where they were first deposited. On the other hand, the pollen can be carried by wind further away; therefore, when pollen data is added to the study about the paleoenvironment, the reconstructions can be made on a regional scale. This information aids in understanding the climatic conditions, vegetation structure, and ecological context in which hominins lived.

Botanical remains from Schöningen corresponding to sublayer II 4c can provide data on paleoenvironmental conditions, including temperature, precipitation, water chemistry, and water depth (Smart & Barko, 1988, pp. 3-5). Some aspects of the paleoclimate, hydrology, and landscape dynamics can be inferred from examining the composition and distribution of plant species. These data can contribute to our understanding of how environmental factors influence hominin behaviour and adaptation—offering clues about hominin subsistence strategies during the Middle Pleistocene. Analysis of these remains can reveal evidence of plant gathering and exploitation. By identifying edible plant species and examining their quantities and distribution, we can theorize about the role of plants in the hominin diet and their contribution to overall subsistence strategies.

1.5 Why Hominid Exploitation Strategies in the Middle Pleistocene

Studying the hominid exploitation strategies at Schöningen brings new information on hominin behaviour and their hunting techniques, subsistence strategies, and interactions with the landscape, which can explain their resource exploitation patterns and cultural practices. Their toolmaking and tool-use skills and the technological innovations developed to support their subsistence activities can bring new information on Middle Pleistocene hominin cognitive abilities and problem-solving capabilities (Birch, 2021, pp. 3-6). The Palaeoecological context can be inferred based on the ecological conditions, the availability of fauna in the landscape, and the interaction between hominins and their ecosystem.

The subsistence and survival strategies through exploitation strategies employed by hominins at Schöningen reflect their subsistence and survival strategies to ensure their survival in the Middle Pleistocene environment. Also, by examining the continuity or changes in exploitation strategies over time, we can make inferences on the transmission of cultural practices, technological innovations, and adaptive behaviours across generations.

1.6 Reading Guide

1.6.1 Chapter 1 – Introduction

Chapter one introduces the Middle Pleistocene, highlighting the research problem: the unknown environmental context of Schöningen 12-II 4 and its link to hominin behaviour. It stresses the importance of botanical macro remains for local and regional reconstructions, providing insights into paleoenvironmental conditions and hominin subsistence strategies. The chapter underlines the significance of studying Middle Pleistocene hominin exploitation strategies, addressing behaviour, technology, paleoecology, subsistence, cultural transmission, and comparative studies. Research gaps include sample size limitations and the need for interdisciplinary and chronological studies. The research questions focus on local and regional environmental reconstructions, hominin behaviour, and exploitation strategies.

1.6.2 Chapter 2 – Background and Site Presentation

Chapter 2 highlights the Schöningen site's importance in Northern Europe for understanding the Middle Pleistocene and hominin behaviour. It explores the Pleistocene Epoch's impact on species evolution, including hominids, and delves into Middle Pleistocene Archaeology, citing sites like Lynford Quarry, Boxgrove, Mauer, Clacton-on-Sea, and Swanscombe. Challenges in identifying specific hominin species due to limited DNA preservation are noted. The chapter discusses Schöningen geology and geography, emphasizing its basin-fill nature and lignite formation over millions of years. It explores glacial and interglacial periods, detailing Schöningen stratigraphy during the Reinsdorf interglacial. The transition from warmer to cooler climates and its impact on the environment and hominin remains' preservation are discussed. The significance of Schöningen 12-II 4 and Schöningen 13-II 4, focusing on complex nomenclature, is highlighted in understanding Middle Pleistocene hominin behaviour.

1.6.3 Chapter 3 - Methodological Approaches for Botanical Macrofossils Analysis on Sediment Sample from Schöningen 12 II 4

The methodology focuses on the unique preservation of Middle Pleistocene organic remains at Schöningen 12 II-4. Well-preserved botanicals in a waterlogged environment were extracted from platform 4, sedimentary cycle 4, layer c. Due to the rescue excavation, on-site sieving used a 500-micron mesh sieve. The mixed-method approach incorporates quantitative and qualitative methods. Data collection involves botanical macrofossil extraction, identification, and a literature review on ecological tolerances. Hominin behaviour data come from an extensive literature review. Data analysis includes quantitative assessment of botanical macrofossils and qualitative analysis through literature research, addressing environmental and hominin behaviour. Recognizing limitations, such as rescue excavation constraints, specific sieving mesh, potential biases, limited contemporaneous sites, and small-scale excavations, the study aims to interpret the environment and hominin behaviour.

1.6.4 Chapter 4 - Results

This section presents key findings from analyzing botanical macrofossils, excluding Characeae, found in the Schöningen 12 II-4 site sediment. The study identified three major categories: Obligated Aquatic (62.44%), Unclassified (16.80%), and Waterside & Damp Ground (20.72%). It acknowledged limitations due to on-site sieving and potential fragmentation of delicate specimens. Visualization tools and taxon classification were used to present the data. In summary, the study provides insights into seed distribution and highlights the significance of the Potamogetonaceae family.

1.6.5 Chapter 5 - Discussion

This chapter is structured into two distinct sections, each contributing to our understanding of the ancient environment and the behaviour of hominins within it. The first part of the chapter is dedicated to reconstructing the paleo-lacustrine environment layer by layer. It starts at the very bottom of the lake, examining the sediment/substrate layer and its composition. This layer provides information on water geochemistry and sediment deposition. Moving upward, the focus shifts to the aquatic area of the lake, which features alkaline and eutrophic waters. This environmental zone offers clues about the water chemistry, the types of aquatic life that may have existed, and the overall health of the lake ecosystem.

The reconstruction continues with the lacustrine (lake margins) area, a critical zone along the water's edge. Here, we encounter macrophyte plants, trees, and shrubs that would have played a vital role in shaping the landscape and influencing the interactions between the aquatic and terrestrial environments. Additional evidence in the form of pollen and botanical macrofossils helps us piece together the characteristics of this lacustrine zone. The final layer of reconstruction takes us to the upland terrestrial area. This phase reveals an open woodland landscape, introducing types of vegetation and ecosystems that extend beyond the lake's immediate surroundings. It provides context for understanding the broader environmental conditions during the Middle Pleistocene period.

In the second part of the chapter, attention shifts toward populating the newly reconstructed paleoenvironment with hominins. Various aspects of hominin behaviour within this landscape are explored, focusing on sustainability and foraging habits. The examination delves into how hominins potentially interacted with their surroundings to secure food and resources. This involves exploring the craftsmanship of tools from available materials, emphasizing wood on selection. Additionally, the chapter investigates the potential role of plants in the hominins' diet, exploring how they might have supplemented their nutrition with plant-based foods by considering the availability of edible flora in the environment. This dietary aspect is crucial for understanding the overall nutritional strategies of the hominins. The chapter dives into the potential use of plants for medical purposes. This includes examining plants that might have been used for their medicinal properties, indicating an early form of medical knowledge and practice among hominins. By dissecting and comprehensively exploring these two interconnected parts, the chapter provides a holistic view of the ancient environment and the intricate behaviours of the hominins who inhabited it during the Middle Pleistocene period.

1.6.6 Chapter 6 – Conclusion

This chapter will summarize the key findings from the preceding Discussion chapter. The palaeobotanical dataset from Schöningen 12-II 4 reveals a Middle Pleistocene environment characterized by open woodlands surrounding a lake. Hominins displayed adaptability through resourceful exploitation strategies, crafting spears from specific trees for hunting large game. Dietary plant use strategic adaptation to seasonal availability, focusing on lake margins for foraging. Additionally, plant medicinal use highlighted hominins' understanding of medicinal plants for addressing various health issues. These behaviours demonstrate adaptability, resourcefulness, and a profound connection with the environment, enriching our understanding of early human evolution.

Chapter 2: Background and Site Presentation

Schöningen is significant in Pleistocene archaeology due to its exceptional preservation of archaeological artifacts and the discovery of wooden spears, some of the oldest known to us. Examining faunal and floral assemblages has provided an understanding of the behaviour of early humans and their interactions with the environment and resource management practices. In light of this significance, this chapter aims to provide a foundational overview of Schöningen archaeological sites, specifically Schöningen12 II 4 and Schöningen13 II 4.

The existing data from Schöningen 13 II 4 complements Schöningen 12 II-4 data, where resolution is impaired because it was subject to rescue excavation necessitated by impending mining activities. Regrettably, the site no longer exists today, as all the strata were removed during mining operations. Although the excavation had a brief duration, it produced valuable discoveries. These findings encompassed animal bones from species like aurochs, giant deer antlers, and a water buffalo skull, along with flint tools and potentially bone tools (García-Moreno, 2021, pp. 5-7). However, the quantity of bones and tools recovered is significantly smaller than those found at Schöningen 13 II-4, primarily due to time constraints.

Both sites, acknowledged as contemporaneous (Serangeli & Conrad, 2015, p. 290), were chosen not only for the importance of Schöningen 13 II-4, celebrated for its spear horizon and its impact on our comprehension of Middle Paleolithic hominin behaviour but also for its extensive studies, from detailed stratigraphy analysis accompanied by geochemical data to comprehensive examinations of tool assemblages, faunal compositions, and palynological studies, offering a significant contribution in achieving a more precise environmental reconstruction and invaluable insights into hominin behaviour.

Schöningen 13 II-4 and Schöningen 12 II-4 are contemporaneous and placed in similar settings, on the same channel, 1000m apart, sharing geology and stratigraphy. The former serves as a foundational context to elucidate the latter's significance within the broader landscape of Pleistocene archaeology. This exploration delves into the interconnection of their stratigraphic and geological underpinnings, which enhances our understanding of sublayer II

4c and its implications. Consequently, Schöningen 13 II- 4 use as a backdrop facilitates a good grasp of the context and significance of sublayer II 4c within the Schöningen site.

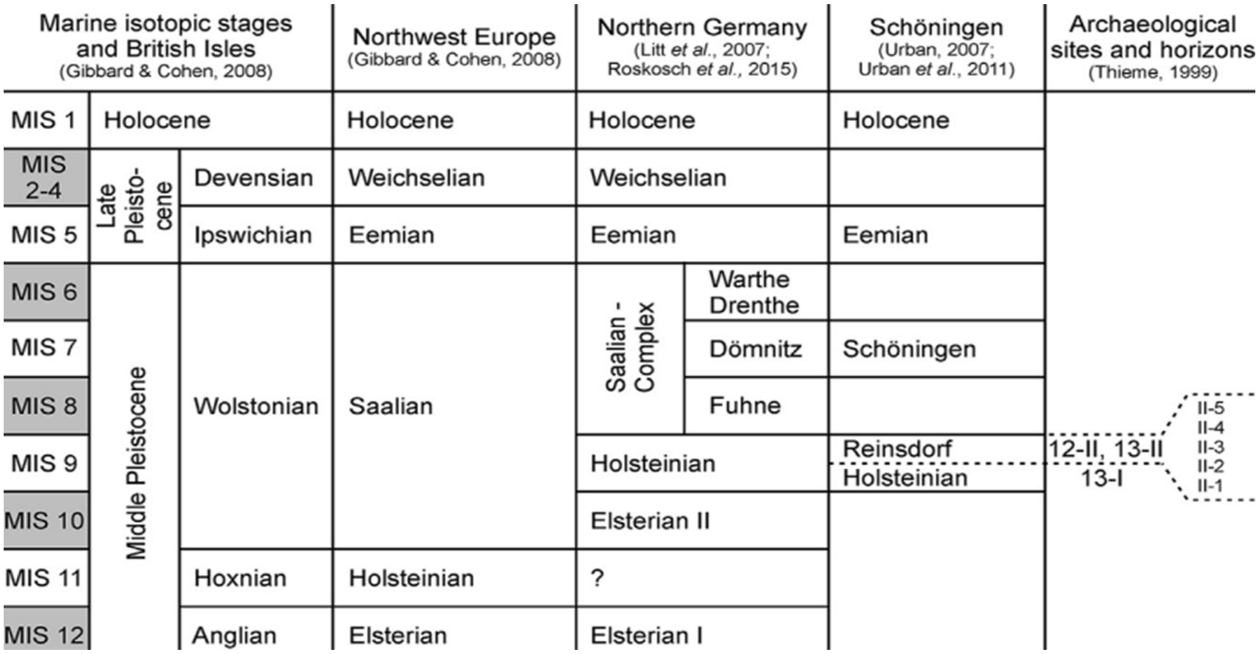
2.1 The Pleistocene Epoch

The Pleistocene epoch, a geological period within the Quaternary period, began around 2.6 million years ago and came to a close after the last glaciation 11,700 years ago. It is a period marked by repeated cycles of glaciation triggered by changes in the Earth's orbital and axial tilt, also known as the Milankovitch cycles, and changes in atmospheric and oceanic currents (Tarling, 2010, pp. 3-6). These shifts in climate forced numerous species, including hominids, to adapt and evolve to survive in changing conditions. During the glaciation periods, the climate was notably cold, forming large ice sheets that covered vast areas of Northern Europe. Conversely, during the interglacial periods, the climate became warmer, leading to the retreat of glaciers (Fig 2.1 and 2.2).

The Middle Pleistocene, a significant epoch within the broader Pleistocene period, spans an extensive timeframe from approximately 761ka to 126ka years ago. This epoch witnessed a series of alternating glacial and interglacial periods.

Of particular relevance to Northern Europe and to sites like Schöningen was the Elsterian glaciation (500ka to 400ka) (Marine Isotope Stage 11), when ice sheets reached their southernmost extent across Europe, notably reaching low latitudes (Fig. 2.2) (Lauer & Weiss, 2018, p.2). In addition to the Elsterian, the Saalian glaciation (300ka to 130 ka) (Marine Isotope Stage 8) shaped the Schöningen environment and hominins' behaviour.

Interglacial periods were between these glacial episodes, marked by milder climatic conditions. Holsteinian interglacial (384ka to 344ka) (Marine Isotope Stage 10) and the Reinsdorf interglacial (347ka to 300ka) (Marine Isotope Stage 9) emerged as significant interludes during this epoch (Lang et al., 2015, p.20).



Marine isotopic stages and British Isles (Gibbard & Cohen, 2008)			Northwest Europe (Gibbard & Cohen, 2008)	Northern Germany (Litt *et al.*, 2007; Roskosch *et al.*, 2015)		Schöningen (Urban, 2007; Urban *et al.*, 2011)	Archaeological sites and horizons (Thieme, 1999)
MIS 1	Holocene		Holocene	Holocene		Holocene	
MIS 2-4	Late Pleisto-cene	Devensian	Weichselian	Weichselian			
MIS 5		Ipswichian	Eemian	Eemian		Eemian	
MIS 6	Middle Pleistocene	Wolstonian	Saalian	Saalian - Complex	Warthe Drenthe		
MIS 7					Dömnitz	Schöningen	
MIS 8					Fuhne		
MIS 9				Holsteinian		Reinsdorf	12-II, 13-II II-5 II-4 II-3 II-2 II-1
						Holsteinian	13-I
MIS 10				Elsterian II			
MIS 11		Hoxnian	Holsteinian	?			
MIS 12		Anglian	Elsterian	Elsterian I			

Figure 2.1 Table representing the marine isotopes stages for different regions, with Schöningen having two interglacial periods, Holsteinian contemporary with 13- I site, and Reinsdorf contemporary with 12-ll and 13-ll, modified from Lang et al.(2015), Fig. 2, p 20.

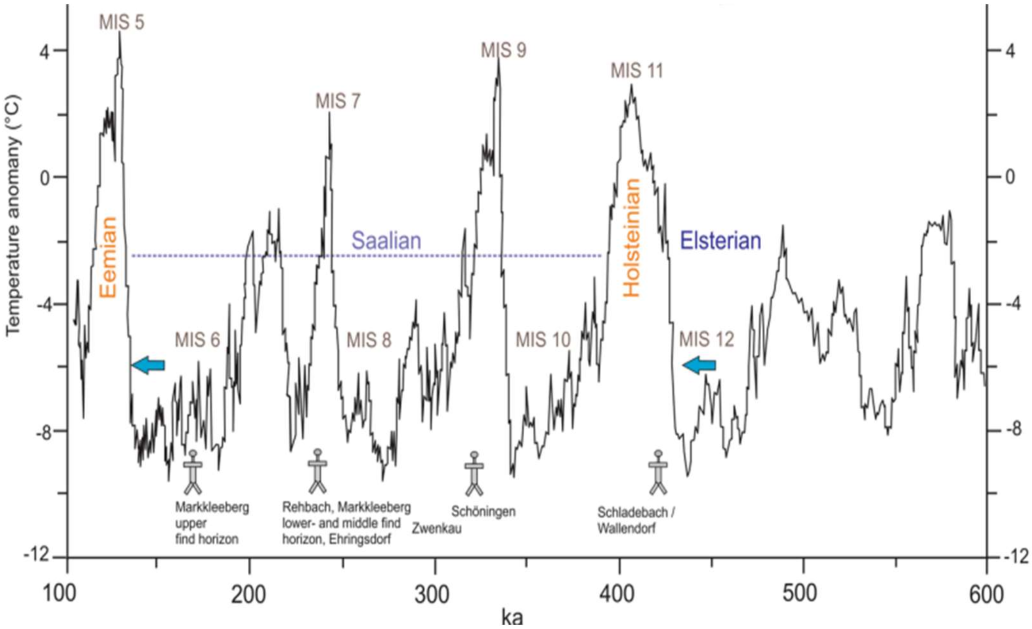


Figure 2.2 Middle Pleistocene climatic fluctuation with Schöningen corresponding to MIS9, indicating temperature fluctuation. Taken from Lauer &Weiss (2018), figure 4. p.6.

These climatic oscillations, characterized by glacial advances and retreats, are integral to understanding the environmental dynamics that prevailed in Northern Europe during the Middle Pleistocene and profoundly impacted the region's landscapes, flora, and fauna.

2.2 The Middle Pleistocene Archeology

The Middle Paleolithic archaeology section in the background presentation brings the context of discoveries leading up to the Schöningen site's dating and its significance within this framework. Understanding the findings that preceded Schöningen and how Schöningen integrates into this narrative is essential.

It is conceivable that several hominin species inhabited Europe during the Middle Pleistocene (Dennell et al., 201, p. 1512). These could be hominid species such as *H. heidelbergensis, H. neanderthalensis, H. erectus*, and other undiscovered species. However, pinpointing the precise hominin species within a specific archaeological site often presents formidable difficulties, even in the presence of hominin fossils. This complexity adds to the challenges researchers face attempting to reconstruct the behaviour and evolution of hominins during this period.

The earliest Middle Pleistocene sites in Northern Europe are in the British Isles and Germany (Fig 2.3). Lynford Quarry has yielded fossils of extinct mammals and stone tools in England. Although no human bones were discovered at this site, these findings have been attributed to *H. heidelbergensis*, which lived between 700ka and 200ka (Boismier et al., 2003, p 318). Boxgrove and Swanscombe, on the other hand, have yielded both human remains and stone tools attributed to *H. heidelbergensis* (Roberts et al., 1986, p. 218) *and H. neanderthalensis* (Paterson, 1940, p. 167). However, DNA analysis was impossible due to the poor preservation of genetic material. These discoveries indicate the presence of hominins at relatively high northern latitudes during a period considered less hospitable for them.

Additionally, with an age of around 450ka, Clacton-on-Sea and Swanscombe share an Acheulian tool technology. What is particularly noteworthy is that Clacton-on-Sea provided the earliest evidence of wooden partial spears—initially thought to be digging sticks due to the belief that hominids lacked the cognitive capabilities to create spears (Allington-Jones, 2015, pp. 274-275; Milks, 2022, p. 12). However, the discovery of Schöningen spears changed the perspective, bringing new evidence into the hunting vs scavenger debate (Domínguez-Rodrigo, 2007, p. 11).

In Germany, the Mauer site, with an estimated age of 500ka, has yielded stone and bone assemblages and a mandible and shin bone as human remains (Wagner, 2011, p. 1465). Bilzingsleben (Fig 2.3), a site dating from approximately 400kay to 330kay, shares similarities with Schöningen 13 II-4, particularly in its use of Acheulian technology featuring hand axes. Skull fragments found at Bilzingsleben have been classified as belonging to *H. erectus* (Mania & Mania, 2005, pp. 100-104), adding complexity to the understanding of the hominin populations in the region during this period.

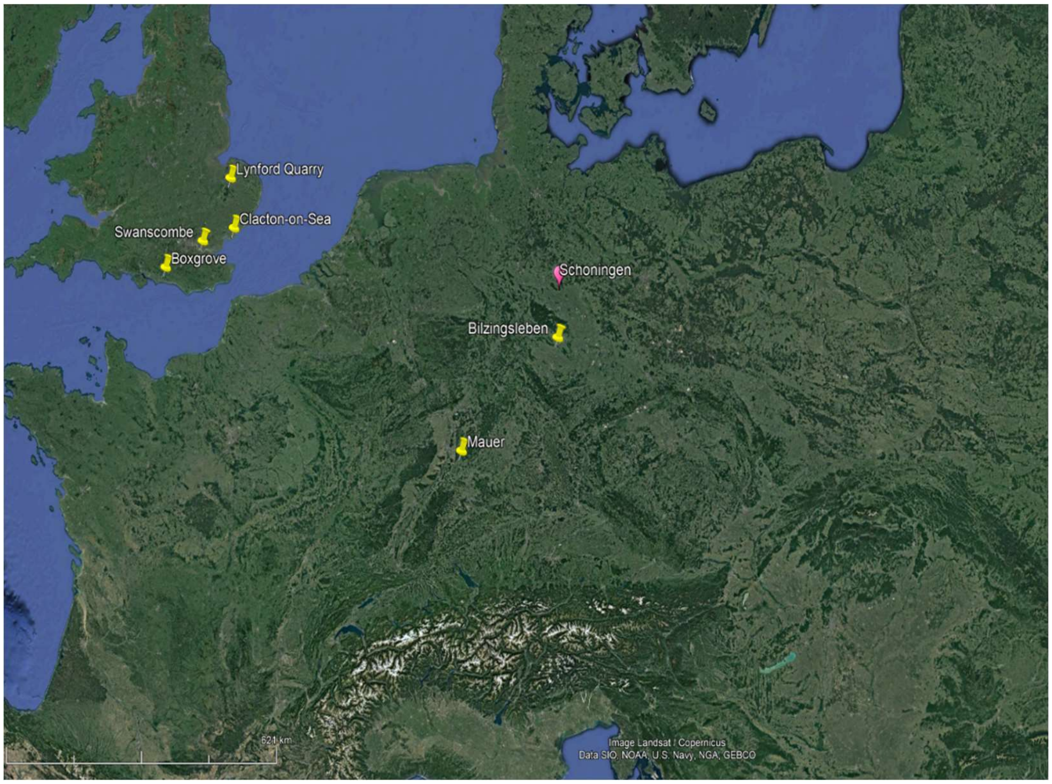


Figure 2.3 Middle Pleistocene sites in Northern Europe, from 600 to 300 kay, Schöningen, Mauer, Boxgrove, Swanscombe, Clacton-on-Sea, Lynford- Quarry, Bilzingsleben. The map was made with GEP using satellite imagery from Landsat/Copernicus, data: 23 February 2023

Schöningen layer 4 sublayer b/c in which the spears were found was established using luminescence dating methodology, which placed the site at 330-300 kay (Sierralta, Frechen & Urban, 2012, p. 146) correlated to Reinsdorf interglacial (MIS 9) (Fig 2.4 and 2.5). However, the initial assumption that Schöningen belonged to MIS 11 has been the subject of ongoing debate (Urban & Bigga, 2015, p. 58). Despite the controversy, the luminescence dating method provided an important tool for accurately determining the age of the Schöningen site.

2.3 The Location and Nomenclature

Schöningen nomenclature may appear intricate owing to its extensive and diverse historical context. Schöningen comprises a complex of sites from the Middle Pleistocene to the Late Paleolithic. The Middle Pleistocene sites are designated by numerals and arranged from North to South. Consequently, Schöningen 12 is situated further North than Schöningen 13, with a separation of nearly 1 km (Fig 2.4).

The Roman numerals I and II correspond to the specific channel in which each site is located (Fig 2.5). These channels, numbering from I to VI, have been sculpted by the flow of meltwater beneath the glaciers, predominantly in a north-south orientation.

Furthermore, within Schöningen 12 II-4, seven plateaus are identified with the prefix 'P' followed by Arabic numerals from 2 to 9. These designations pinpoint the distinct areas within Channel II where excavations have been undertaken.

Hence, Schöningen12 II 4c can be decoded as follows: \`Schöningen\` denotes the specific locality, \`12\` signifies the site's number, \`II\` designates the channel number where the site is situated, \`4\` represents the layer under investigation, and \`c\` denotes the sublayer associated with layer 4. Similarly, Schöningen13 II 4c can be deciphered as: \`Schöningen\` remains the locality, \`13\` identifies the site number, \`II\` specifies the channel number, \`4\` designates the layer number, and \`c\` is indicative of the sublayer aligned with layer 4.

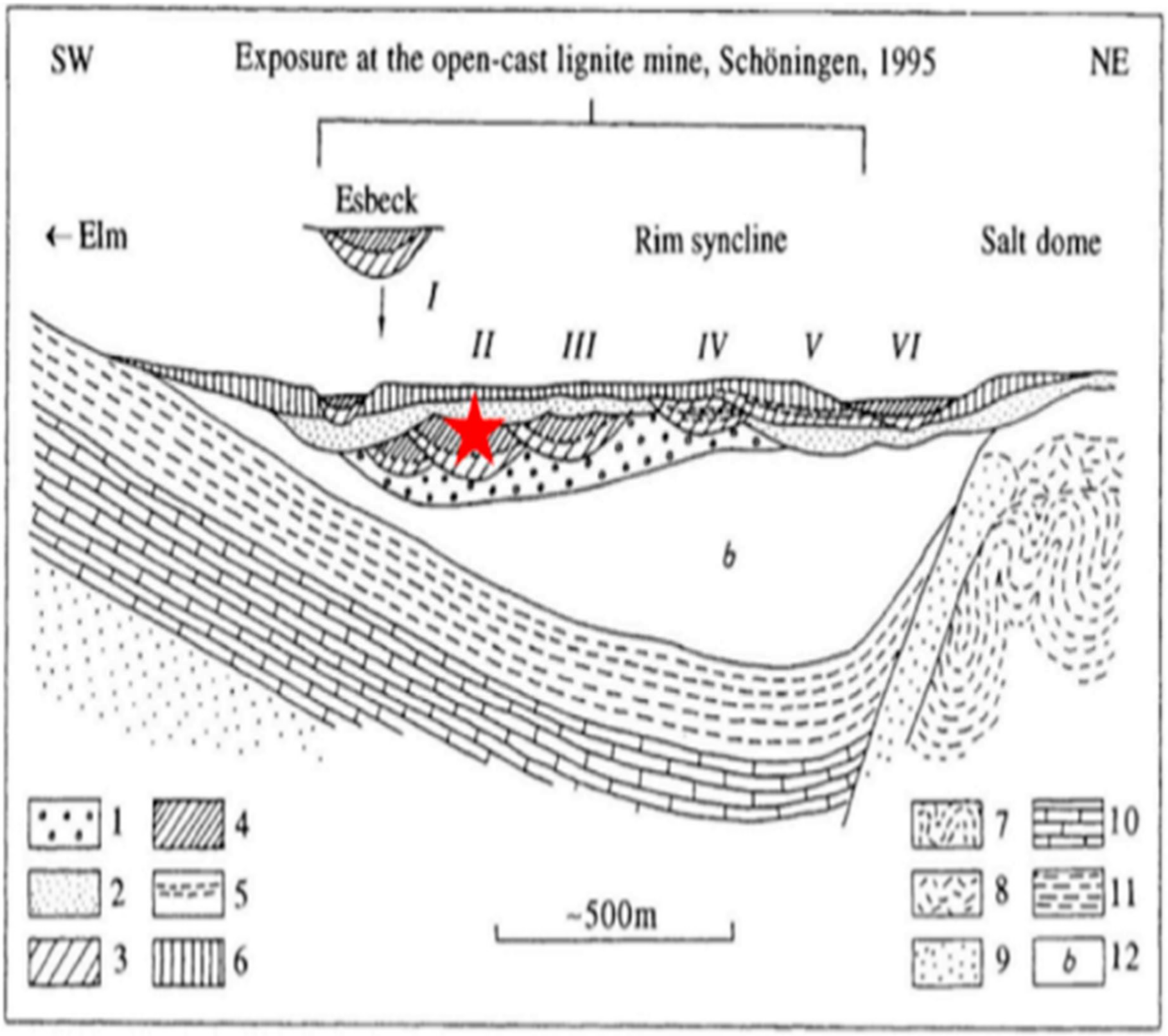


Figure 2.4 Vertical Section of the Quaternary sedimentary sequence of Schöningen Tunnel valley and the Vl channels with the star indicating channel ll. Layer 1: Elsterian till; 2: Saalian glacial sediments; 3: Lacustrine sediments; 4: Limnic telmatic sequence; 5: Soil complexes; 6: Loess; 7: Evaporites; 8: Gypsum cap-rock; 9: Buntsandstein; 10: Triassic limestones; 11: Triassic deposits; 12: Paleogene deposits. The red star indicates the location of channel II. Modified from Peters & Van Kolfschoten, (2020), Fig 3, p. 3.

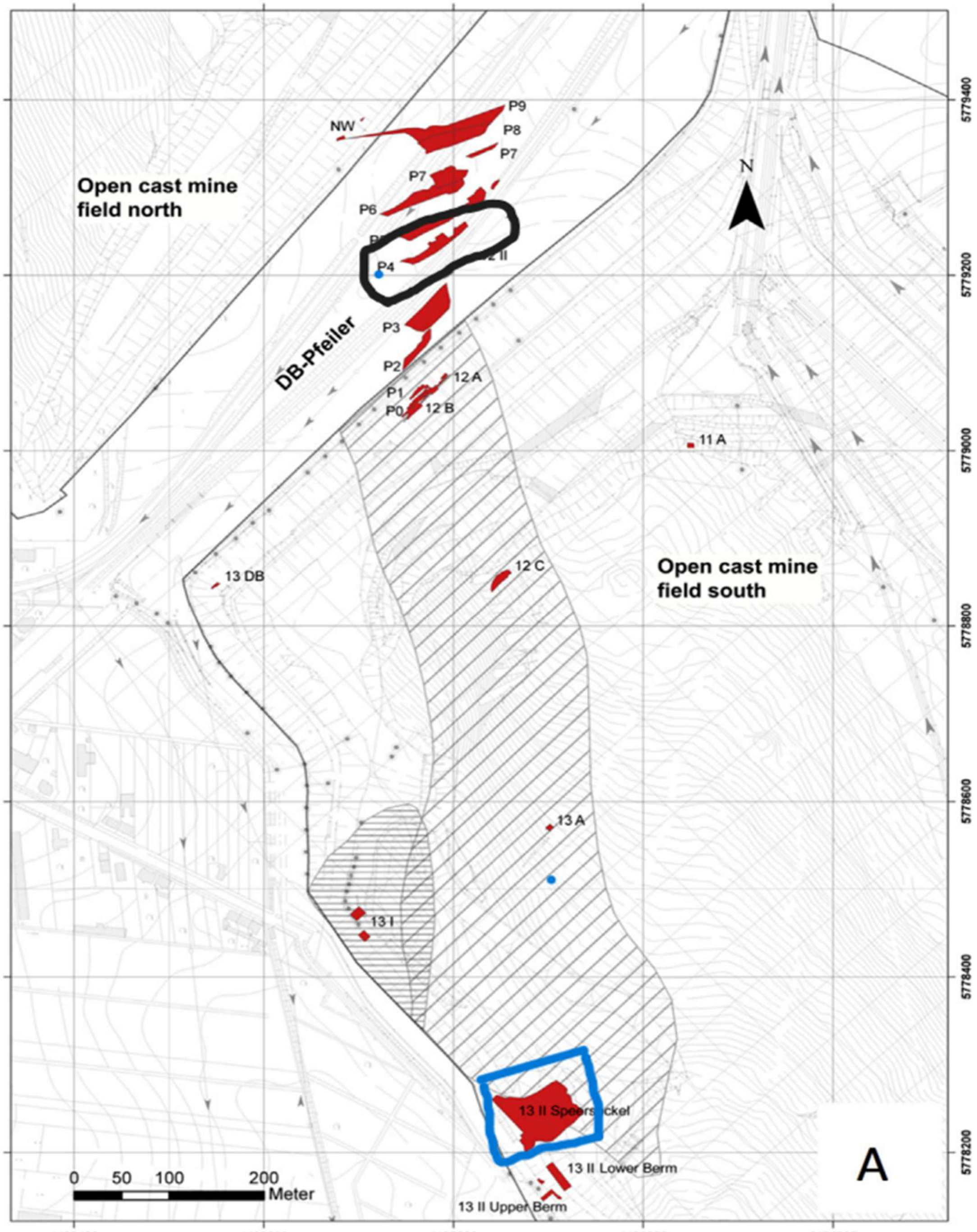


Figure 2.5 The map contains the position of Schöningen 13-II, the blue square, and Schöningen 12-II on the same channel with the seven plateaus; the black circle is around plateau 4. Drawing: Utz Bohner, modified from Serangeli et al. (2015), fig. 3, p. 32.

2.4 The Geology

This section will detail the geological history layer by layer, commencing with the formation of coal layers that unfolded millions of years ago. These coal layers played a role in instigating mining operations and inevitably uncovering Middle Pleistocene artifacts within subsequent layers and sublayers. This exploration will provide information into Schöningen intricate stratigraphy by elucidating the processes that formed these layers. It will show how Schöningen 12 sublayer II 4c and the spear horizon layer came into existence and their synchronicity within this stratigraphic framework. Furthermore, we will delve into how geography has influenced the creation of lakes and the transformative processes at play in this region.

The contemporary landscape surrounding Schöningen is characterized by rounded limestone hills, most notably Elm Hill, 323 meters in elevation, and expansive valleys. These features result from substantial erosional processes and the smoothing effects of moving glaciers over time. Situated between two prominent geological formations, Schöningen lies nestled between the Elm Hill anticline, a 25-kilometer-long ridge of limestone, and the Helmstedt-Staßfurt salt wall syncline, stretching some 70 kilometers in a northwest-to-southeast orientation.

The Schöningen region is essentially a basin-fill, forming a rim syncline(a downward fold in the Earth's crust, and when it's situated near the edge, it's called a "rim syncline") that spans 8 kilometers in length and 3 kilometers in width, with a thickness of up to 366 meters, housing a total of 13 lignite seams (Brandes et al., 2012, p. 670). Above the lignite-bearing strata is a succession of Middle and Upper Pleistocene layers with a collective thickness of up to 45 meters. This sequence contains diverse deposits, including glaciofluvial, glaciolacustrine, and subglacial deposits from the Elsterian and Saalian glacial periods, featuring glacial tills of up to 15 meters. This geological record also incorporates strata related to interglacial periods, such as the Holsteinian and Emian, characterized by lacustrine deposits and Weichselian loess deposits (Peters & van Kolfschoten, 2020, p.3).

The interglacial periods Holsteinian and Reinsdorf, between the Elsterian and Saalian glaciations, deposited a 7.5 m thick layer comprised of a series of lacustrine sedimentary strata deposited in an east-south manner by a propagating delta facilitated by the presence of a tunnel valley formation (Lang et al., 2015, p.20).

A tunnel valley, characteristic of Northern Europe during the Elsterian glaciation, is formed beneath a glacier due to the combined effects of melted water erosion and the carving action of the glacier's movement. The Schöningen tunnel valley, where a sedimentary succession was deposited, measures 840 meters in width and a depth of 40 meters. This valley's formation was made possible by the complete ice coverage of the area during the Elsterian glaciation, which marked the first instance of the ice sheet extending so far southward (Fig 2.6) (Lauer & Weiss, 2018,p.1).

Following the Elsterian glaciation, an interglacial period known as the Holsteinian and Reinsdorf ensued. The previously carved tunnel valley from the Elsterian period was filled with a 45-meter-thick sedimentary sequence composed of lacustrine and deltaic layers (Fig 2.7) containing various artifacts (Lang et al., 2015, p. 22-23). Two sedimentary sequences occurred in the area. The first one, during the Holsteinian, resulted in the formation of channel I. The second sedimentary cycle, during the Reinsdorf period, led to the creation of channel II, where Schöningen 12 II and 13 II are located. The fluctuation in paleolake levels during the Holsteinian and Reinsdorf were attributed to climatic variations associated with a warmer period, and this contributed to the preservation of bone assemblages, botanical remains, and wood and stone artifacts through waterlogging processes (Fig 2.8).

From a palaeobotanical standpoint, the interglacial phases are distinguished by a prevalence of tree species that flourished in the warmer conditions. Pollen records reveal a predominance of tree pollens, encompassing oak, elm, pine, and hazel varieties. These findings imply landscapes characterized by mixed deciduous and coniferous forests (Koutsodendris et al., 2010, p. 3303; Urban et al., 2023, p. 149). Simultaneously, the interglacial circumstances provided a propitious habitat for the flourishing of human populations. The accessibility to a wide array of resources, encompassing a diverse range of plant and animal species, in conjunction with the relatively clement climate (Dennell et al., 2011, p. 1512; Hérisson et al.,2016), undoubtedly played a role in the thriving of hominin species, leaving their indelible mark in the archaeological record.

As the Saalian glaciation arrived, the area was again under ice coverage, resulting in erosion and deformation due to the movement of glaciers (Urban, 1992, pp. 39-40). However, the strata holding evidence of hominin occupation survived, especially in the lower section of the valley. Schöningen indicates early hominin presence at these latitudes during a challenging era (Lang et al., 2015, p. 24). Hinting on possible models of hominid adaptation to their environment and their responses to the environmental challenges they encountered.

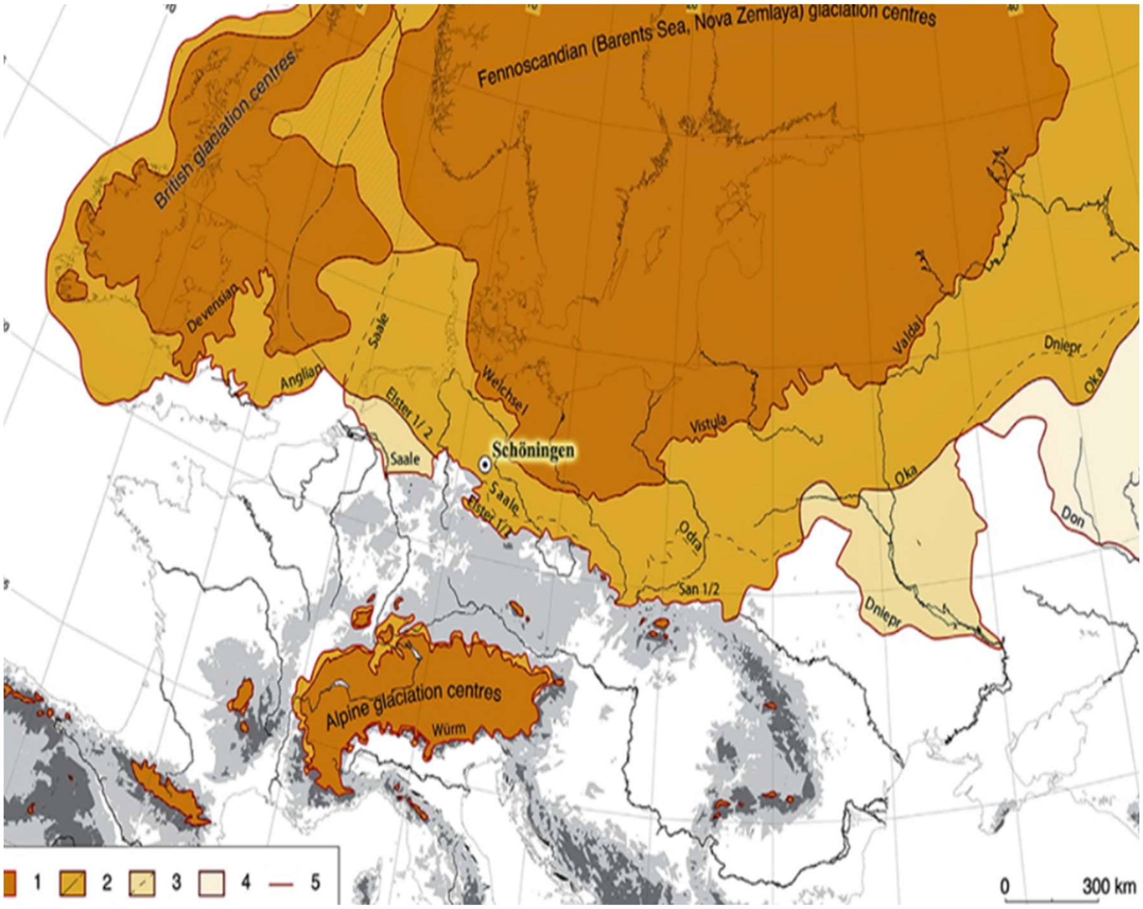


Figure 2.6 Schöningen position of the locality between the maximum southern expansion of the Elsterian and the Saalian and Weichselian continental glaciers is taken from Conard et al. (2015), fig.1, page 2.

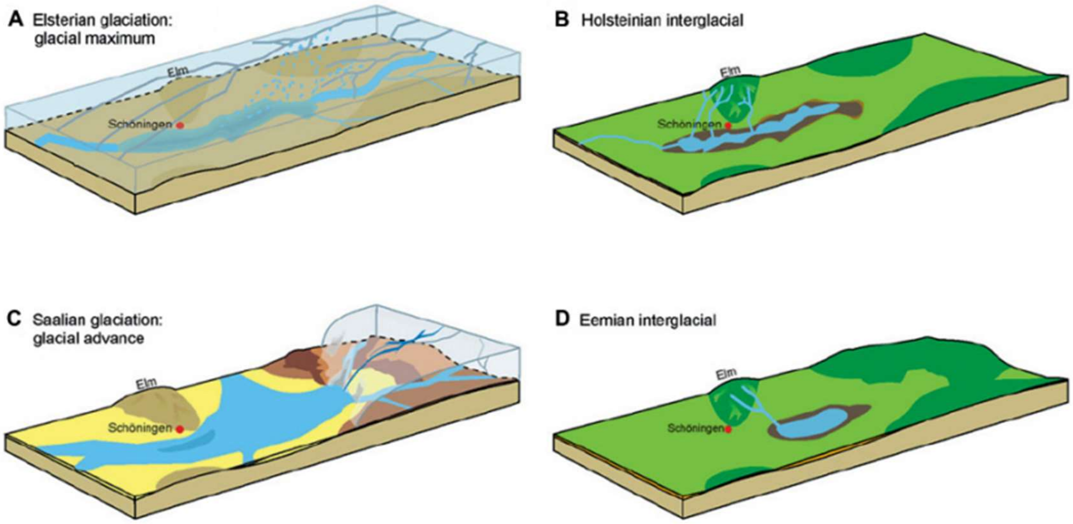


Figure 2.7 Changes in the landscape during the glaciation and interglaciation in the Schöningen area. Taken from (Lang et al. 2015), fig. 5, p. 19

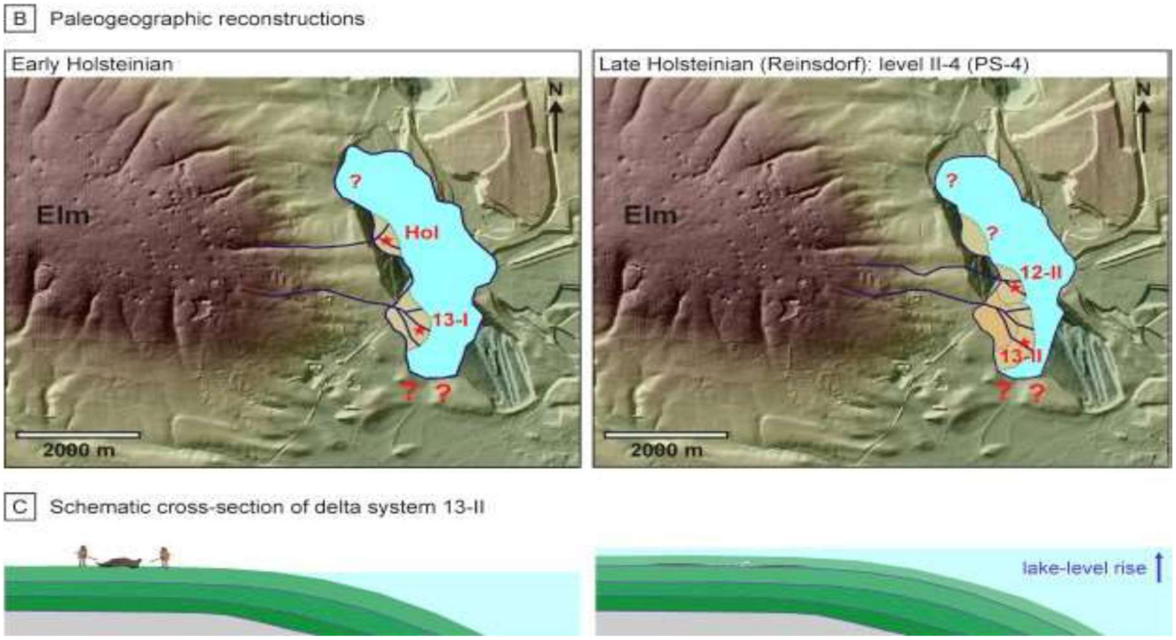


Figure 2.8 B) Paleogeographic reconstructions of the Holsteinian/Reinsdorf Lake. The delta systems were shed by surface run-off from the Elm, probably fed by springs. C) Schematic cross-section of the delta system, illustrating the embedding of the artifacts. Artifacts originate from the activity of early humans on the subaerially exposed delta plain. The subsequent rise in lake level causes the embedding of the artifacts in lacustrine deposits. Modified from Lang et al. (2015), fig. 6, p.23.

2.5 The Stratigraphy in Schöningen Open-Cast Mine

The stratigraphic composition of the Schöningen open cast mine comprises Tertiary layers of lignite and limestone as the foundational base. Overlying these layers is a 15-meter-thick deposit of glacial till, remnants of the Elsterian glaciation. On top of this glacial till are 7.5 meters of sedimentary cycles from interglacial periods, succeeded by Saalian strata, followed by layers formed during the Weichselian and Holocene epochs (Fig 2.9) (Lang et al., 2015, p. 19-23).

Figure 2.9 Schöningen 12-II 4 80 m deep stratigraphy, 1. Holocene layer, 2. Loess from Weichselian glaciation, 3. Saalian glaciation sand and gravel, 4. Schöningen 12-II 4, 5. Elsterian glaciation sediments, 6. Tertiary lignite. Photo and drawing: Jordin Serangeli. Modify from Serangeli et al.(2018), fig 3, p. 143

2.5.1 Channel II Reinsdorf Interglacial Stratigraphy

The examination of interglacial stratigraphy at Schöningen 12 II and 13 II focuses on the period between the Elsterian and Saalian glaciations. During this interval, a deltaic system evolved from the interglacial optimum's inception to the beginning of Saalian (Schreve, 2012, p. 131; Urban et al., 2023, p.148). These deltaic systems were significant silt deposition events that created channels marked as I and II. Channel I originated during the Holsteinian interglacial (MIS 11). While channel II took shape during the Reinsdorf period within the interglacial phase (MIS 9), with Schöningen 12 II and 13 II situated alongside channel II.

Channel II's stratigraphy comprises five distinct depositional layers called sedimentary cycles, each corresponding to variations in lake levels influenced by climatic changes during that period (Fig 2.10). These layers are denoted with level 1 marking the earliest sedimentary cycle, characterized by elevated temperatures during the interglacial optimum, and level 5 representing the final sedimentary cycle, signifying a cooling environment as the prelude to a new glaciation, the Saalian (Gijssel, 2006, pp. 21-22).The transition from warmer optimum temperatures to a cooler climate has embedded its characteristics in each of these depositional layers:

Sedimentary cycle/Layer 1: The first sedimentary cycle occurred during a rapid warming. The sediment contains peaty layers, indicative of organic material accumulation, and grayish-brown mud. These characteristics suggest a high lake level and the presence of swampy forests. It was a time when the climate was amicable for the flourishing of such ecosystems, with a relatively mild environment.

Sedimentary cycle/Layer 2: During the second sedimentary cycle, the trend of warmth continued; the layer was marked by sediments containing peaty layers and dark gray mud. Suggesting swampy and boggy conditions, with a decrease in the dominance of warm-loving tree species. The landscape began to open up during this period as various environmental factors changed.

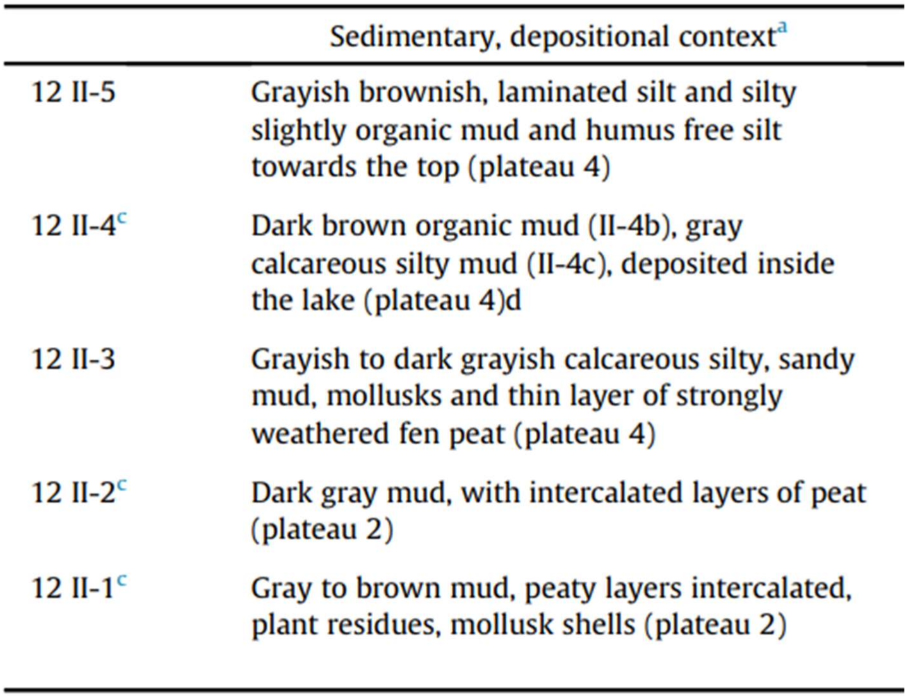
Sedimentary cycle/Layer 3: This phase brought about notable environmental shifts. The sediment in this layer includes silty, sandy, and calcareous mud. Additionally, there is a layer of weathered peat, indicating swampy terrain. Forests still existed along the margins, but there were signs of a climate transition. This period captures moments when the ecological dynamics shift.

Sedimentary cycle/Layer 4 : The 2 -2.5 m thick sediment preserves a detailed record of the environmental shifts driven by climatic changes during the transition from a warmer climate in Layer 3 to a considerably colder one in Layer 5 (Böhner et al., 2015, p. 204) This layer is further divided into sublayers, starting with 'i' as the oldest and 'a' as the youngest, with each sublayer encapsulating the distinct environmental changes that transpired during the respective time intervals. Beginning with sublayer 'i,' we find dark brown organic mud, representing a period when conditions favored organic accumulation. Moving upward in the sequence, we encounter sublayer 'c,' characterized by gray calcareous silty mud. Subsequent sublayers feature a combination of calcareous mud and dark peaty mud ('b' and 'a') (Urban & Bigga, p. 64), indicative of a time when the climate became less favorable, and the landscape underwent significant transformations offering information on this transitional phase's evolving climatic and environmental dynamics.

Sedimentary cycle/Layer 5: The final layer in this sequence is characterized by grayish-brown laminated silt that contains traces of organic matter. It points to the transition to steppe-tundra vegetation, indicating a cooling period and the beginning of a new glaciation known as the Saalian. This layer marks a substantial climatic shift and ecological repercussions, creating a colder and more challenging environment.

Figure 2.10 Schöningen 13 II shows the position of the four preserved sedimentary cycles from the paleolake at Schöningen. Sedimentary cycle 5 was truncated by mining. Photo: J. Serangeli. Modify form Serangeli et al. (2018), fig. 4, p. 144.

These layers provide a chronological record of environmental and climatic changes, each with unique characteristics, offering insights into the region's dynamic history, making possible not only the environmental reconstruction but also the possibility to infer the hominin's behaviour during that time.



	Sedimentary, depositional context[a]
12 II-5	Grayish brownish, laminated silt and silty slightly organic mud and humus free silt towards the top (plateau 4)
12 II-4[c]	Dark brown organic mud (II-4b), gray calcareous silty mud (II-4c), deposited inside the lake (plateau 4)d
12 II-3	Grayish to dark grayish calcareous silty, sandy mud, mollusks and thin layer of strongly weathered fen peat (plateau 4)
12 II-2[c]	Dark gray mud, with intercalated layers of peat (plateau 2)
12 II-1[c]	Gray to brown mud, peaty layers intercalated, plant residues, mollusk shells (plateau 2)

Figure 2.11 Description of the sedimentary deposition corresponding to Schöningen 12 II. Modified from Julien et al. (2015), table 1, p. 267.

2.5.2 The Sedimentary Cycle/Layer 4, Stratigraphy

As discussed in the preceding section (2.3.1), it is evident that Layer 4 exhibits a multifaceted stratigraphy. Considering that the sediment sample I analyzed from Schöningen12 II and the spears from Schöningen13 II both originated from Sublayer II4c, it is crucial to examine the complete stratigraphy of Layer 4 comprehensively. This includes placing Sublayer II4c in its proper context within the larger stratigraphic framework. The climatic transition recorded in Layer 4 is also encapsulated within Sublayer II4c, preserving essential evidence of this climatic shift. Consequently, it is necessary to illustrate its position within the stratigraphic matrix and elucidate the transformations preceding and following this sublayer.

Schöningen12 II was primarily a rescue excavation conducted to locate any potential artifacts before mining activities; therefore, the detailed examination of Layer 4's stratigraphy was conducted at the Schöningen13 II site. The sedimentation profile (Fig 2. 13 & 2.14) illustrates the transition from peaty sediment in the upper Layer 3 to silty and calcareous mud within Layer 4, specifically in sublayer 'i.' This transition is marked by *Characea* and mollusk shells, signifying changes in the lake's margins. It suggests that while during the Layer 3 period, Schöningen13 II may have been situated on the wetlands along the lake margins, by the commencement of Layer 4, it had already shifted its position to an area within the lake, not too distant from the margins (Urban & Bigga, 2015, p. 64).

Therefore, the layer 4 stratigraphy and sediment composition are (Fig 2.11):

- Sublayer 'i' to 'e,' with calcareous and silty calcareous mud, suggests that the location remains within the shallow waters near the margins with shifts in lake levels
- Sublayer 'e' is characterized by clayey muds, clay, clayey-silty muds, and fine-grained sediments, suggesting quieter water conditions. This may indicate a transition to a more stable and less turbulent environment, possibly with a constant water level (Serangeli et al.,2018, p. 144).
- Sublayer 'd' contains sandy, coarse-grained deposits, indicating higher-energy conditions. Coarser grains like sand suggest changes in the depositional environment, possibly due to increased water flow and fluctuating water levels (Urban et al., 2023, p. 152).
- Sublayer 'c,' 90 cm thick, contains calcareous mud and organic calcareous mud deposits, signifying a diverse sediment composition that mirrors fluctuating environmental conditions (Conard et al., 2015, p.8). Within this sublayer are two distinct zones denoted 'c' and 'c/b` (Fig 2.12). This sedimentary makeup captures the progressive decline in lake levels. Moreover, the geochemical data reveal heightened Total Organic Carbon (TOC) and Carbon/Nitrogen ratios, accompanied by increased Fe, Ti, and K mineral concentrations, indicating a progressive reduction in the lake's water level towards

sublayer b. The spears were found on the transition layer between the `c` upper layer and the ` b` sublayer.

- Sublayer 'b' comprises organic silty mud, indicating a predominantly organic composition with fine silty particles. This means sedimentation in an environment with lower energy and likely stable water conditions (Urban & Bigga, 2015, p. 64).
- Sublayer 'a' is characterized by peat, which typically forms under waterlogged conditions and indicates a period of organic accumulation. Its presence suggests lower lake water levels and the presence of wetland vegetation (Urban et al., 2023, p. 152).

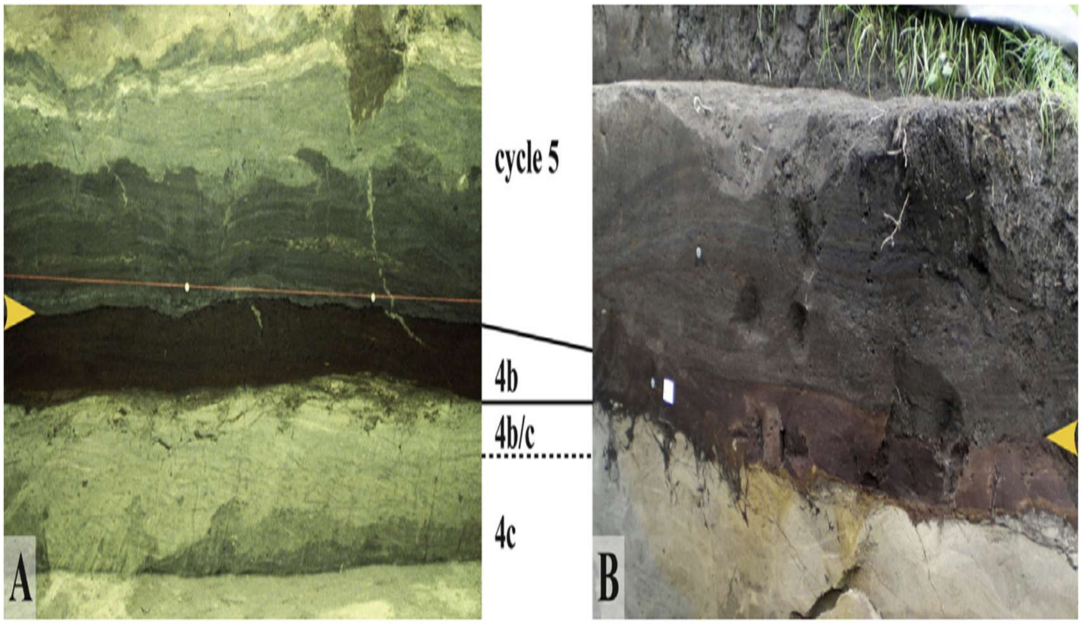
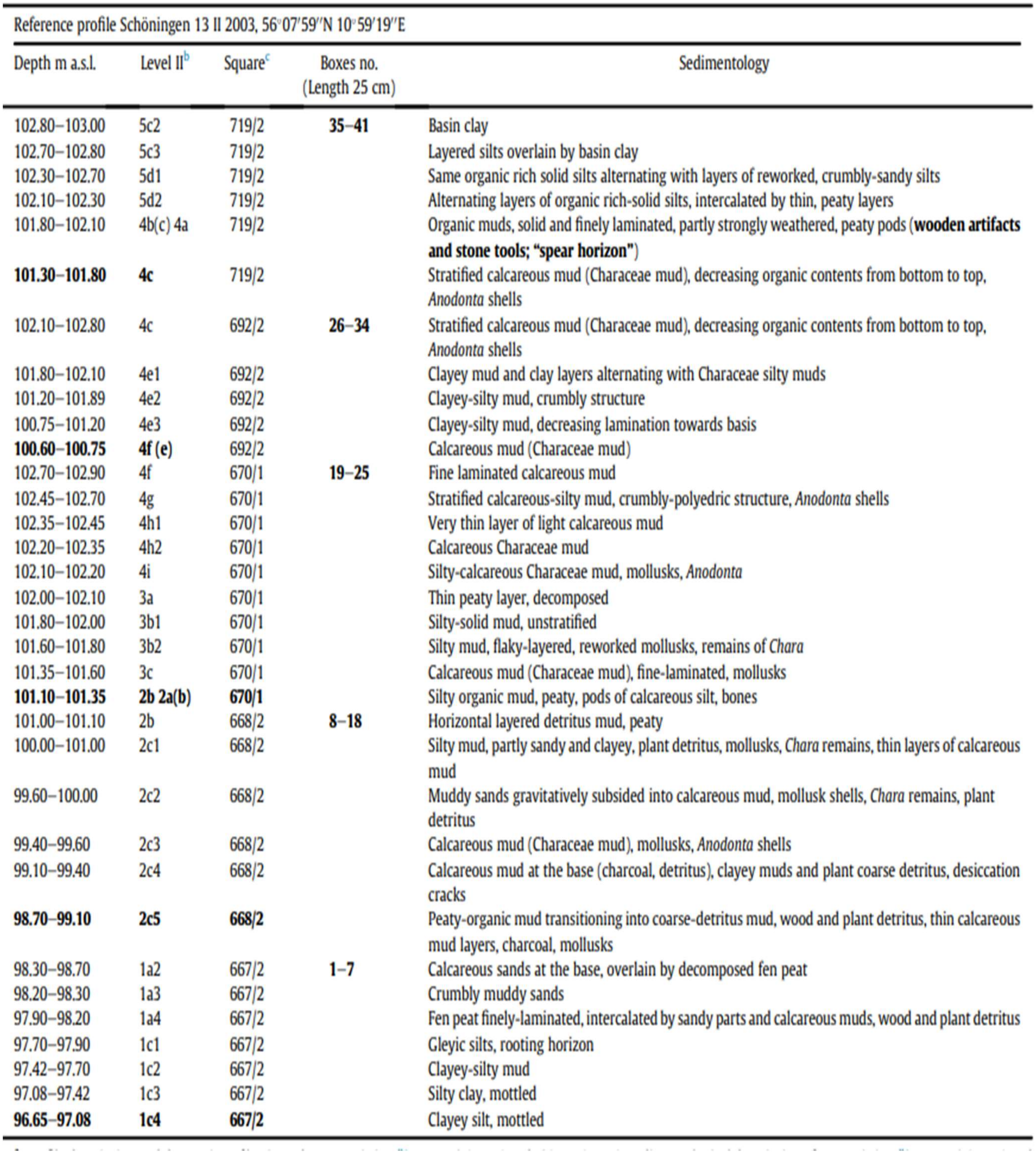


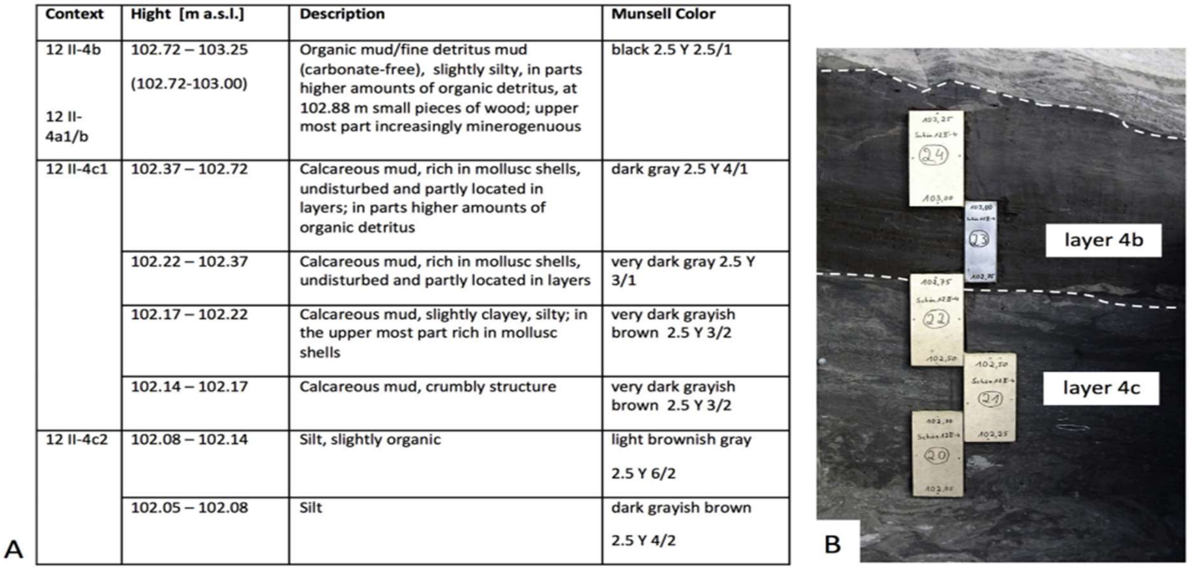
Figure 2.12 Profile photos at (A) Schöningen 13II-4 (photo P. Pfarr ©NLD) and (B) Schöningen 13 II Upper Berm. The sedimentary sequence at Schöningen 13 II-4 and Schöningen 13 II Upper Berm/Spear horizon south consists of four sedimentary layers: gray calcareous marl (layer 4c) at the base, overlain by the gradual transitional layer 4b/c, overlaid by layer 4b. Archaeological finds were retrieved from the contact of layer 4b/c with layer 4b. Retrieved from Stahlschmidt et al., 2015, Fig 3, p 4



Reference profile Schöningen 13 II 2003, 56°07′59″N 10°59′19″E

Depth m a.s.l.	Level II[b]	Square[c]	Boxes no. (Length 25 cm)	Sedimentology
102.80–103.00	5c2	719/2	**35–41**	Basin clay
102.70–102.80	5c3	719/2		Layered silts overlain by basin clay
102.30–102.70	5d1	719/2		Same organic rich solid silts alternating with layers of reworked, crumbly-sandy silts
102.10–102.30	5d2	719/2		Alternating layers of organic rich-solid silts, intercalated by thin, peaty layers
101.80–102.10	4b(c) 4a	719/2		Organic muds, solid and finely laminated, partly strongly weathered, peaty pods (**wooden artifacts and stone tools; "spear horizon"**)
101.30–101.80	**4c**	719/2		Stratified calcareous mud (Characeae mud), decreasing organic contents from bottom to top, *Anodonta* shells
102.10–102.80	4c	692/2	**26–34**	Stratified calcareous mud (Characeae mud), decreasing organic contents from bottom to top, *Anodonta* shells
101.80–102.10	4e1	692/2		Clayey mud and clay layers alternating with Characeae silty muds
101.20–101.89	4e2	692/2		Clayey-silty mud, crumbly structure
100.75–101.20	4e3	692/2		Clayey-silty mud, decreasing lamination towards basis
100.60–100.75	**4f (e)**	692/2		Calcareous mud (Characeae mud)
102.70–102.90	4f	670/1	**19–25**	Fine laminated calcareous mud
102.45–102.70	4g	670/1		Stratified calcareous-silty mud, crumbly-polyedric structure, *Anodonta* shells
102.35–102.45	4h1	670/1		Very thin layer of light calcareous mud
102.20–102.35	4h2	670/1		Calcareous Characeae mud
102.10–102.20	4i	670/1		Silty-calcareous Characeae mud, mollusks, *Anodonta*
102.00–102.10	3a	670/1		Thin peaty layer, decomposed
101.80–102.00	3b1	670/1		Silty-solid mud, unstratified
101.60–101.80	3b2	670/1		Silty mud, flaky-layered, reworked mollusks, remains of *Chara*
101.35–101.60	3c	670/1		Calcareous mud (Characeae mud), fine-laminated, mollusks
101.10–101.35	**2b 2a(b)**	**670/1**		Silty organic mud, peaty, pods of calcareous silt, bones
101.00–101.10	2b	668/2	**8–18**	Horizontal layered detritus mud, peaty
100.00–101.00	2c1	668/2		Silty mud, partly sandy and clayey, plant detritus, mollusks, *Chara* remains, thin layers of calcareous mud
99.60–100.00	2c2	668/2		Muddy sands gravitatively subsided into calcareous mud, mollusk shells, *Chara* remains, plant detritus
99.40–99.60	2c3	668/2		Calcareous mud (Characeae mud), mollusks, *Anodonta* shells
99.10–99.40	2c4	668/2		Calcareous mud at the base (charcoal, detritus), clayey muds and plant coarse detritus, desiccation cracks
98.70–99.10	**2c5**	**668/2**		Peaty-organic mud transitioning into coarse-detritus mud, wood and plant detritus, thin calcareous mud layers, charcoal, mollusks
98.30–98.70	1a2	667/2	**1–7**	Calcareous sands at the base, overlain by decomposed fen peat
98.20–98.30	1a3	667/2		Crumbly muddy sands
97.90–98.20	1a4	667/2		Fen peat finely-laminated, intercalated by sandy parts and calcareous muds, wood and plant detritus
97.70–97.90	1c1	667/2		Gleyic silts, rooting horizon
97.42–97.70	1c2	667/2		Clayey-silty mud
97.08–97.42	1c3	667/2		Silty clay, mottled
96.65–97.08	**1c4**	**667/2**		Clayey silt, mottled

Figure 2.13 Table contains the reference profile from Schöningen 13 II, with sublayers and sedimentology. Acquired form Urban &Bigga (2015), table 1, page 62.



Context	Hight [m a.s.l.]	Description	Munsell Color
12 II-4b 12 II-4a1/b	102.72 – 103.25 (102.72-103.00)	Organic mud/fine detritus mud (carbonate-free), slightly silty, in parts higher amounts of organic detritus, at 102.88 m small pieces of wood; upper most part increasingly minerogenuous	black 2.5 Y 2.5/1
12 II-4c1	102.37 – 102.72	Calcareous mud, rich in mollusc shells, undisturbed and partly located in layers; in parts higher amounts of organic detritus	dark gray 2.5 Y 4/1
	102.22 – 102.37	Calcareous mud, rich in mollusc shells, undisturbed and partly located in layers	very dark gray 2.5 Y 3/1
	102.17 – 102.22	Calcareous mud, slightly clayey, silty; in the upper most part rich in mollusc shells	very dark grayish brown 2.5 Y 3/2
	102.14 – 102.17	Calcareous mud, crumbly structure	very dark grayish brown 2.5 Y 3/2
12 II-4c2	102.08 – 102.14	Silt, slightly organic	light brownish gray 2.5 Y 6/2
	102.05 – 102.08	Silt	dark grayish brown 2.5 Y 4/2

Figure 2.14 Profile description from Schöningen 12 sublayer II 4 c and b. Acquired from Julien et al.,2015, fig 2. p. 267.

Chapter 3. Methodological Approaches for Botanical macrofossils analysis on sediment sample from Schöningen 12 II 4c

3.1 Introduction

This paper aims to reconstruct the paleolake environment and draw insights into hominins' land exploitation and behaviour by analyzing plant usage in hunting, diet, and self-treatment. Schöningen is a unique Middle Pleistocene site with remarkably well-preserved botanical macrofossils due to their preservation in waterlogged conditions. The sediment used in our study is sourced from platform 4, sedimentary cycle 4, and layer c of this site. It's essential to highlight that, given the context of a rescue excavation, the sediment was sifted on-site using a 500- µm (0.5mm) mesh sieve.

3.2 Research Design

This study used a mixed-methods approach to analyze botanical macrofossils in a sediment sample, efficiently addressing specific research questions. For questions on environmental reconstruction, quantitative methods analyzed data from the Schöningen II sublayer 4c sediment sample (Field et al., 2000; Birks, 2019). Focusing on this sublayer narrowed the timeframe, aiding the precise identification of environmental conditions and associated hominin behaviours. Detailed plant species identification was crucial in establishing the environmental context, as Bigga et al (2015, p.93) and others showed.

For the subsequent research question, a qualitative approach delved into various aspects of hominin behaviour, including plant use for toolmaking, hunting, diet, and medicinal purposes. Evidence was drawn from an extensive literature review covering studies on hominin behaviour s during the Middle Pleistocene era. This encompassed research on Schöningen 13, medical studies, investigations into medicinal plants, analyses of plant-based diets, and palynological studies. This methodological approach efficiently addressed research questions, combining quantitative rigor with qualitative insights from various academic sources.

3.3 Data Collection Procedures

3.3.1 Quantitative Method

Schöningen 12 II, layer 4, sublayer c, platform 4, over two months in the Botany Lab of the Faculty of Archaeology at Leiden University. The sediment underwent on-site sieving through a 500-micron (0.5mm) sieve without additional preparation. The procedure included:

- Pick botanical macrofossils under a microscope (Leica S6, 3-40x magnification) and categorize them based on morphological similarities (Motuzaite Matuzeviciute, 2021). Only seeds with distinct diagnostic characteristics were identified at the species or genus level during archaeobotanical identification. Oospores (spores) from *Characeae* sp. (Algae) were excluded due to their high number, which could introduce bias into the results by overrepresentation and skewing the balance toward the presence of aquatic plants.
- Identifying botanical macrofossils following Duistermaat, L. (2020) "*Heukels' flora van Nederland*." Genus-level identification was applied when species couldn't be determined, and species-level identification was chosen with high certainty.
- Counting seeds to assess the representation of each species or genus, aiding in environmental reconstruction (Bigga et al., 2015, p.93), and determining the approximate location of the sample within the lake margins.

These steps were integral in the quantitative data collection process, ensuring a detailed analysis of botanical macrofossils in the sediment sample (Andrieu et al.,1997, pp. 310-317).

3.3.2 Qualitative Methodology

In this thesis, qualitative methods systematically analyzed and interpreted non-numeric data from previous research papers and studies. This approach expanded data depth, grasped the theoretical context, and explored intricate aspects of hominin behaviour, diet, and tool use by scrutinizing information from various qualitative sources.

To broaden the research scope, I conducted searches using keywords:

• For additional data: "Schöningen 13 II 4," "Schöningen 12 II 4," "pollen and botanical macrofossils analysis." • For a comprehensive research context: "Middle Pleistocene Hominins AND Northern Europe," "Middle Pleistocene AND climate," "Middle Pleistocene AND Schöningen," "Middle Pleistocene AND plant diet," "Middle Pleistocene AND fire," "Middle Pleistocene AND hunting," "Middle Pleistocene AND hominin behaviour." • Identifying gaps and research questions: "paleoenvironmental analysis," "sediment analysis," "plant macrofossils," "Middle Pleistocene," and "Schöningen site." • Investigating hominin behaviour: "paleoenvironmental analysis," "sediment analysis," "plant macrofossils," "Middle Pleistocene," "Schöningen site." • In Paleobotany and Tool Use: "paleobotany," "plant remains," "tool use," "archaeological evidence," "Schöningen artifacts." • For Comparative Analysis: "comparative analysis," "Middle Pleistocene sites AND fire," "behavioural studies," "paleoecology," "Schöningen 13 II 4 AND Schöningen 12 II AND fire use."

For developing the theoretical framework:

• Identifying Relevant Theories: "Middle Pleistocene hominin behaviour theories," "Theoretical framework development in archaeology," "Conceptual framework for paleoenvironmental studies," "Behaviour al ecology frameworks in anthropology." • Reviewing Key Concepts: "Middle Pleistocene hominin behavioural concepts," "Interdisciplinary theories in archaeology and botany." • Synthesizing Information and

Defining Key Variables: "Synthesis of Middle Pleistocene behavioural theories AND key variables."

For Data Collection and Interpretation:

- "Data collection methods in paleoanthropology," "Paleoenvironmental data interpretation," "Sediment analysis techniques," and "Archaeobotanical data collection Supporting hypotheses and arguments:
- "Medicinal plants use Middle Pleistocene," "Plant diet Middle Pleistocene," "Plant diet Schöningen 13 II 4," "Medicinal plants Schöningen 13 II4," "(plants from my list) usage," "(plants from the list) medicinal use," "fire," "fire ignition," "fire usage," "Middle Pleistocene fire," "fire evidence," "plant diet evidence," "Middle Pleistocene plant diet evidence," "hunting strategies," "hunting tools," "hunting vs. scavenging theory," "hunting Schöningen 13 II4," "Middle Pleistocene spears."

Leiden University Library and Google Scholar were used for the literature review. The former located reliable studies based on targeted keywords and discovered additional sources on fire usage in the Pleistocene, Neanderthal diet, Pleistocene archaeology, and specific Northern European archaeological sites.

3.4 Data Analysis Procedure

Quantitative data from Schöningen 12 platform 4, sublayer II 4c, including counts and percentages of identified plant taxa (species or general level), were categorized by habitat in an Excel spreadsheet. This categorization facilitated chart creation, visually representing data. Constructed by category, charts highlighted specific plant species prevalence, aiding environmental zone interpretation. The primary spreadsheet was transformed into a table, and microscopic seed images were included.

Simultaneously, a literature review gathered information on identified plants' ecological tolerances and reproductive strategies. This additional data is crucial for environmental reconstruction, addressing potential biases, and complementing sediment sample data. Bigga (2018) and Bigga, Schoch, and Urban (2015) studies provided significant supplementary data.

The literature review on hominin behaviour analyzed papers on Middle Pleistocene excavations, primarily in Northern Europe. The goal was to understand hominin behaviour in northern latitudes, contextualizing hominin presence on lake margins during sublayer II 4c. Intertwined with environmental data, this research addresses questions about hominin activities, including hunting or using fire. Archaeobotanical studies connect the presence of edible plants and possible medical use. It also explores hominins' interaction with and management of their environment, elucidating cognitive capabilities within the Middle Pleistocene context.

3.5 Considerations

In scientific research, acknowledging a study's limitations and biases is customary, mainly when working with samples from old waterlogged environments like Schöningen. Chemical processes and sample size can influence the representation of botanical macro remains. Smaller samples may underrepresent taxa with larger-sized remains (Antolín et al., 2017, p. 331). To prevent bias, caution was exercised to avoid overrepresenting aquatic plants, mainly by not picking *Characeae* oospores. The abundance of robust spores produced by *Characeae*, composed of calcium carbonate, could influence results. Steps were taken to minimize this potential impact.

Another limitation concerns the Schöningen 12-II4 site due to time constraints during excavation, necessitating on-site sediment sieving and using a 500-micron mesh sieve retained only larger seeds and botanical remnants, causing the loss of smaller fragments during screening. Additionally, the wet-sieving method could damage more delicate remains, leading to the survival of only hardier seed types during screening, possibly in reduced numbers (Hosch & Zibulski, 2003). This bias becomes evident when comparing the number of identified plants in my sediment sample to those in samples containing wood from Schöningen12 II 4c (Bigga, 2018p.59) and Schöningen 13 II 4 (Bigga et al., 2015, pp. 99-100), where both macrofossil and palynological analyses were employed. Data derived from palynological and macrofossil studies conducted by Bigga (2018) and Bigga et al. (2015) will be added to enhance the precision of the environmental reconstruction.

Identifying a limited number of plants, coupled with a reduction in numbers due to taphonomy processes or sampling biases, may impede attempts at accurate environmental reconstruction (Spicer, 1991). Ecological tolerances can only be ascertained when plant identification is performed at the species level. A limited number of plants identified at the species level may constrain the accuracy of such assessments. Genus-level identification may provide general indications regarding ecology, but it cannot reliably pinpoint a specific climatic event.

Another potential bias arises from the limited number of contemporaneous sites providing additional information about hominin behaviour. Even the current results are based on non-extensive excavations. Given the continuous discovery of new evidence and the frequent alteration of theoretical paradigms, maintaining vigilance is essential, recognizing that many suppositions are often made based on the absence of definitive proof.

Chapter 4. Results

4.1 Introduction

This chapter extensively explores the results of analyzing botanical macrofossils from Schöningen 12 II 4c. This analysis, a central component of the investigation, provides an understanding of this archaeological site's environmental conditions and ecological dynamics during the Middle Pleistocene, specifically within sublayer II 4c.

Botanical macrofossil analysis holds versatility in archaeology and paleoecology (Bigga et al, 2015, p 93). Its primary functions involve reconstructing ancient environments, climates, and ecosystems. It tracks historical climate shifts, reveals information about ancient plant diets and subsistence strategies, and contributes to understanding past biodiversity and its impact on ecosystems. Comparing findings across different sites and periods aids in identifying regional characteristics and broader patterns of environmental change and human adaptation. Integration with other archaeological evidence provides a holistic comprehension of ancient lifestyles and environments.

4.2 Preliminary results

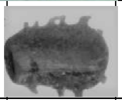
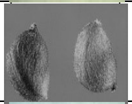
As shown in Fig 4.1, the quantitative breakdown of identified seeds and their categorization is crucial (Field et al., 2000). Here's a summary:

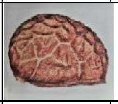
- Obligated aquatic: This category includes 7,427 seeds, constituting 62.44% of the total seeds (excluding *Characea*). It signifies a significant presence of aquatic plant species, indicating a water-rich environment in sublayer II 4c.
- Waterside & Damp ground: 2,464 identified seeds, representing 20.2% of the total seeds (excluding *Characea*), suggest plant species linked to moist habitats, indicating water bodies or damp ground in the archaeological context.

- Unclassified: Additionally, 1,997 identified seeds, equivalent to 16.80% of the total seeds (excluding *Characea),* are unclassified. Further analysis is needed to determine their botanical characteristics and gain insight into the site's environment during the Middle Pleistocene period.

These preliminary results emphasize the dominance of aquatic and moisture-loving plant species. However, further analysis and interpretation are essential for a more nuanced understanding of the environmental dynamics at Schöningen 12 II 4c during the Middle Pleistocene period.

Taxon after Duistermaat, 2020	Taxon Family	Plant part	Number	%	Image	Image source
1. Waterside & Damp ground						
Alnus glutinosa	Betulaceae	Bud	1	0.008		Leica s6 3-40x Microscope
Bidens sp.	Asteraceae	Fruit	1	0.008		Leica s6 3-40x Microscope
Eleocharias palustris	Cyperaceae	Nutlet	1	0.008		Leica s6 3-40x Microscope
Hippuris vulgaris	Plantaginaceae	Fruit	919	7.73		Leica s6 3-40x Microscope
Persicaria cf. hydropiper	Polygonaceae	Nutlet	6	0.05		Leica s6 3-40x Microscope
Ranunculus sceleratus	Ranunuculaceae	Fruit	798	6.71		Leica s6 3-40x Microscope
Rumex maritimus	Polygonaceae	Perianth	26	0.22		Leica s6 3-40x Microscope
Schoenoplectus lacustris	Cyperacea	Nutlet	693	5.83		Leica s6 3-40x Microscope
Sparganium erectum	Sparganiceae	Fruit stone	19	0.15		Leica s6 3-40x Microscope
		Total	**2463**	**20.64**		

2. Obligated Aquatic						
Characeae sp.	Characeae	Oospore	1000+*	N/A		Leica s6 3-40x Microscope
Groenlandia densa	Potamogetonaceae	Endocarp	612	5.15		Leica s6 3-40x Microscope
Myriophyllum spicatum	Haloragaceae	Fruit	2	0.02		Leica s6 3-40x Microscope
Myriophyllum sp.	Haloragaceae	Fruit	45	0.38		Leica s6 3-40x Microscope
Potamogeton alpinus	Potamogetonaceae	Endocarp	522	4.39		Leica s6 3-40x Microscope
Potamogeton crispus	Potamogetonaceae	Endocarp	132	1.11		Leica s6 3-40x Microscope
Potamogetonaceae sp.	Potamogetonaceae	Endocarp	989	8.31		Leica s6 3-40x Microscope
Ranunculus Sect. Batrachium sp.	Ranunculaceae	Fruit	1645	13.8		Leica s6 3-40x Microscope
Sparganium cf. emersum	Sparganiacea	Fruit stone	7	0.06		Leica s6 3-40x Microscope
Stukenia pectinata	Potamogetonaceae	Endocarp	1108	9.32		Leica s6 3-40x Microscope
Zannichellia palustris	Potamogetonaceae	Fruit	2365	19.90		Leica s6 3-40x Microscope
	(*Without *Characeae*)	**Total**	**7427**	**62.44**		
3. Unclassified						
Carex sp.	Cyperaceae	Trigonous Nutlet	1982	16.67		Leica s6 3-40x Microscope
Carex sp.	Cyperaceae	Uticle	8	0.07		Leica s6 3-40x Microscope
Chenopodium sp.	Amaranthaceae	Seed	4	0.03		Leica s6 3-40x Microscope
Ranunculus sp.	Ranunculaceae	Seed	2	0.02		Leica s6 3-40x Microscope

Viola sp	Violaceae	Seed	1	0.008		Leica s6 3-40x Microscope
		Total	**1997**	**16.80**		
4. Woodland & shade tolerant						
Rubus fruticosus	Rosaceae	Seed	1	0.008		Leica s6 3-40x Microscope
		Total	**1**	**0.008**		
	(*Without *Characea*e)	**Total** (1+2+3+4)	**11889**	**100**		

*Characeae numbers are not added because they are too large and can create biases

Figure 4.1 Table containing the identified plant parts according to taxon, taxon family, numbers, percentage from the total without Characeae, and image and its source. Created by MF Catalinoiu

4.2.1 Additional Fossil Discoveries

In addition to botanical macrofossils (Fig 4.2), the sediment in Schöningen 12 II 4c has yielded other fossils that can provide information on the environmental conditions. These fossils include:

- *Coleoptera* (Beetle): The elytra have been identified, offering potential information about the beetle species.
- *Mollusca* (Mollusks): Operculum and shell fragments, these can inform about the types of mollusks, which can indicate environmental factors such as water temperature and alkalinity.
- *Osteichthyes* (Bony fish): Fossils of teeth and scales*, w*hile species identification may not be possible, these remains offer general information about fish presence.
- *Ostracoda* (Seed shrimp): Carapaces, these tiny organisms provide information on the aquatic environment's conditions.

Although not identified at the species level, these additional fossils provide general information (Urban et al., 2023, p. 166), about water temperature, alkalinity, salinity, and the broader ecological context in Schöningen 12 II 4c.

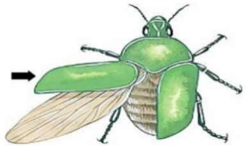
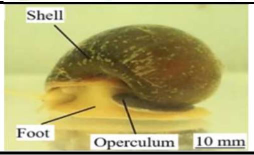
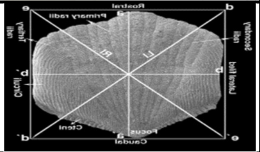
Fossil	**Part**	**Image**	**Image source**
Coleoptera	Elytrum		qizlet.com
Mollusca	Operculum		Xu et al.,2023
Mollusca	shell fragment		
Osteichthyes	Tooth		fossilforum.com
Osteichthyes	Scale		fossilforum.com
Ostracoda	Carapace		Chitnarin, Forel & Tepnarong, 2023).

Figure 4.2 The table containing the fossils found in Schöningen12 II 4c sediment, Mollusca operculum and shell fragment, Osteichthyes tooth and scale, Ostrocoda carapace, and Coleoptera elythrum

4.3 Considerations in Botanical Macrofossil Analysis

While the botanical macrofossil analysis is informative about the Middle Pleistocene paleoenvironment at Schöningen 12 II 4c, recognizing its limitations is essential (Antolín et al., 2017, p. 331). This section outlines key constraints:

- Lack of Species-Level Identification: Inability to identify fossils at the species level, especially evident in *Carex* sp. and *Ranunculus Sect Batrachium* sp. (31% of total), compromises precision in environmental reconstruction.

- Sieving Process Bias: Using a 500-micron mesh sieve may introduce bias, potentially excluding smaller-sized plant remains and impacting species like *Typha* and *Phragmites*.
- Potential for Bias and Fragmentation: The sieving process may damage fragile seeds, complicating identification and affecting the overall interpretation of environmental conditions.
- Limited Scope of Analysis: Primarily focusing on seeds and plant remains limits understanding of the complete paleo ecosystem, with the absence of pollen restricting visualization of the past ecosystem's diversity and dynamics.

Recognizing these limitations is crucial for refining interpretation and planning further research. In the next chapter, collected data will be used to reconstruct the Reinsdorf Interglacial paleoenvironment at Schöningen, focusing on sublayer II 4c. A comprehensive depiction of the past environment will be developed using a systematic layer breakdown.

Chapter 5. Discussion

In this chapter, the environment will be dissected one stratum at a time, only to be reconstructed layer by layer at the end of the section. This meticulous process, guided by data collected from the botanical macrofossil analysis and enriched by insights from relevant literature, specifically from Bigga (2018) and Bigga et al.(2015), will offer a clear image of the paleoenvironment and hominins' behaviour and land exploitation at the Middle Pleistocene site Schöningen during Reinsdorf interglacial, corresponding to sublayer II 4c. This chapter explores the intricate relationship between the environment and hominin behaviour during the Middle Pleistocene at the Schöningen prehistoric landscape. A central focus of our analysis is the important role that plants played in the daily lives of these early humans.

The chapter is structured into two major sections. The first section centers around our primary research question, which concerns the reconstruction of the paleoenvironment. To construct this holistic narrative, I will explore each layer with a critical eye, considering the following:

- Botanical Macrofossils: botanical macrofossils were examined, focusing on dominant plant categories, percentages, and ecological implications. This allows to decode the vegetational composition and the environmental conditions specific to each layer.
- Additional Fossils: Beyond plants, fossils found in the layer, such as *Coleoptera, Mollusca, Osteichthyes,* and *Ostracoda* were investigated. These fossils could provide context on aquatic life, environmental conditions, and potential climatic influences.
- Literature review: Data from Bigga (2018) and Bigga et al. (2015) will be integrated to enrich the environmental reconstruction. These perspectives will help understand the broader context of the findings, placing them within the regional framework.

The reconstruction process unfolds layer by layer, starting from the lake's bottom, analyzing the sediment's geochemistry corresponding to sublayer II 4c, and extending to the upland terrestrial zone. The last layer represents the regional coordinate of the reconstructed environment, and this reconstruction will be realized with additional data from Pollen analysis on Schöningen13 II 4 c from studies by Bigga, et al. (2015), and Bigga (2018). Each layer contributes a piece to the puzzle, culminating in a comprehensive understanding of the environmental context.

In the second section, the second research question, centered on the behaviour of early hominins in a dynamic environment, is explored. Resource management, survival strategies, and the display of cognitive abilities are scrutinized. The inquiry particularly emphasizes using plants for dietary needs, crafting tools crucial in hunting, and potential medicinal uses. This underscores the cognitive capacities of early humans, often underestimated, as evidenced by their intricate knowledge of plants.

5. 1. Reconstruction of the Paleoenvironment at Middle Pleistocene site Schöningen 12 II during Reinsdorf interglacial, corresponding to sublayer 4c

5.1.1 Middle Pleistocene Environment in Northern Europe during the Interglacial Period

Before delving into the environmental reconstruction based on botanical macrofossils analyzed from the sediment of Schöningen 12 II-4 sublayer `c, ` it is important to provide context by discussing the interglacial environment during the Middle Paleolithic and how Schöningen fits into this context.

The Middle Pleistocene in Northern Europe was marked by two notable interglacial periods: the Holsteinian, roughly 400 ka to 325 ka years ago, and the Reinsdorf, around 320 ka years ago, correlated to MIS 9, being the most extended and warmest interglacial periods during the Quaternary period (Kunz et al., 2017, p. 81), with Schöningen 12 II-4 and 13 II-4 corresponding to Reinsdorf Interglacial (Conard et al, 2015, p. 8)

During these interglacial periods, the climate was temperate, causing glaciers to melt. This favorable climate allowed forests to expand, and various species could migrate north.

From a palaeobotanical perspective, the interglacial periods are characterized by tree species that thrived in the warmer climate. Pollen records indicate a prevalence of tree pollen, including oak, elm, pine, and hazel species, suggesting landscapes dominated by mixed deciduous and coniferous forests (Koutsodendris et al., 2010, p. 3303; Urban et al., 2023, p. 149).

Simultaneously, the interglacial conditions provided a favorable environment for human populations to thrive (Parfitt et al., 2010). Access to various resources, including diverse plant and animal species, and the relatively mild climate likely contributed to hominin species thriving and marking their presence in the archeological records. This phenomenon is evident in numerous archaeological sites across Northern Europe, such as Clacton-on-Sea, England; Kesselt-Op de Schans, Belgium; Bilzingsleben, Germany; Pakefield, England, and more (Hérisson et al., 2016, p. 234).

Schöningen aligns with this pattern of interglacial warming and episodic climate changes, which influenced the environment's and landscape's flourishing, allowing human habitation at such a northern latitude (Dennell et al., 2011, p. 1512).

5.1.2 Botanical finds from Platform 4, Schöningen 12II-4 sublayer c. Presentation of the Data Set

Botanical macrofossils are valuable for local environmental insights, as they're typically immobile unless the water is involved. The dataset details Schöningen local environment (sublayer II 4c), and palynological studies at Schöningen 12 II-4 and Schöningen 13 II-4 contribute to regional context understanding.

Identified plants are categorized into four habitat groups:

- Obligated Aquatic: 7,427 seeds (11 taxa)
- Waterside & Damp Grounds: 2,465 seeds (10 taxa)
- Unclassified: 1,997 seeds (5 taxa) • Woodland and shade tolerant: 2 seeds (1 taxon)

This pattern, collected from Platform 4 near the lakeside margin within the shallow lacustrine area, suggests a predominantly lacustrine environment (Conard et al., 2015, p.8). Both abundant and less common seeds contribute to insightful reconstructions in paleoenvironmental reconstruction. Taxa with fewer seeds are crucial for reconstructing specific landscape areas.

The reconstructed environment of Schöningen 12 II-4C involves connected habitats. Three major environmental zones are identified using palaeobotanical data, with two local zones from Schöningen 12 II-4c:

Hydrophytic/Aquatic Environmental Zone: Comprising sediment/substrate and aquatic zones from the Obligated Aquatic category.

Lakeside Environment with Waterside and Damp Ground Environmental Zone: Including Macrophyte and Waterside subzones from the Waterside & Damp ground category. The Unclassified category represents a transitional area between lakeside and upland terrestrial zones.

The third zone is regional, incorporating palaeobotanical data from Schöningen 13 II-4 and Schöningen 12 II-4 studies by Bigga (2018) and Bigga et al. (2015). This extends the environmental reconstruction from lake margins to the "upland" terrestrial zone.

Upland Terrestrial Environmental Zone: Represented by Unclassified category plants and studies on macro and pollen by Bigga (2018), and Bigga et al. (2015).

5.1.3 Reconstructing the Hydrophytic Zone/Aquatic Zone

The Aquatic zone is the first environment layer corresponding to the II 4c sublayer, the lowest layer of the reconstructed environment at Schöningen 12 II-4. This aquatic zone is defined by Submerged and Floating Aquatic plants, which thrive entirely underwater with their roots embedded in the sediment. This zone comprises a sediment layer corresponding to sublayer II4c and an aquatic layer, serving as the medium where these submerged and floating aquatic plants flourish.

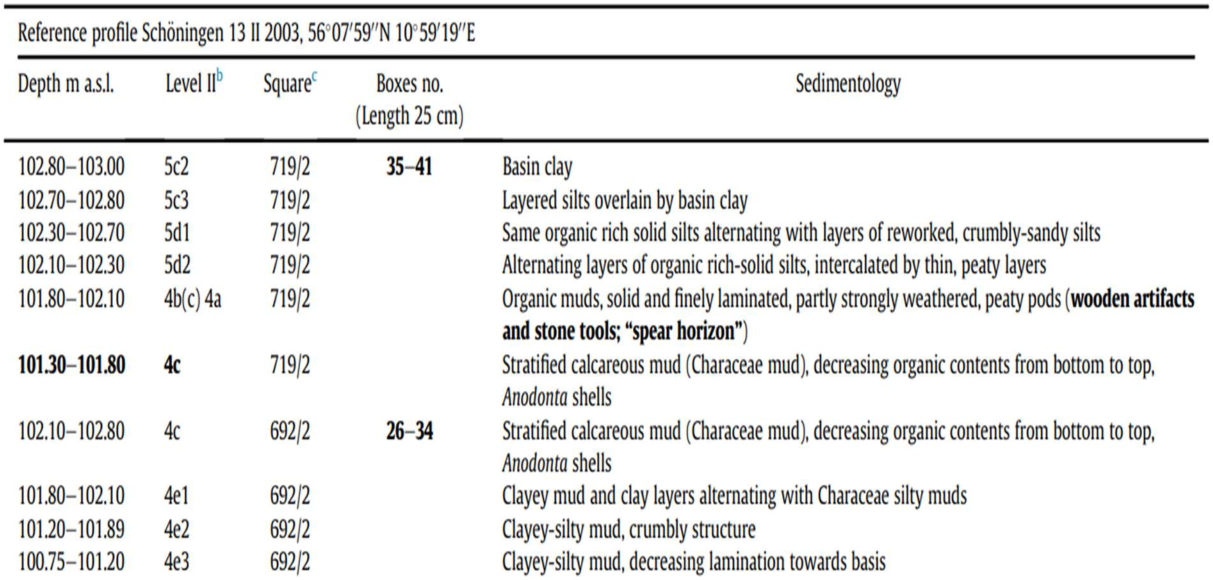
5.1.3.1 Reconstruction of the Sediment Layer from the Aquatic Environmental Zone

The border of the Aquatic plant zone is marked by the sediment/substrate sublayer c, which is part of channel II, layer 4, sedimentation cycle (Fig 5.1). Schöningen 12 II-4 refers to sedimentation cycle 4, and each layer within this sequence reflects fluctuations in the lake levels influenced by climate conditions, from 'i,' the oldest, to 'a,' the youngest. Starting with sublayer 'i,' we find organic silty material and moving upwards through the sequence, we reach sublayer 'c,' which is approximately 90 cm thick and consists of calcareous mud with a notable carbon content, reaching up to 68%. In contrast, sublayer 'b' transitions from calcareous mud to richer organic peaty soil (Urban & Bigga, 2015, p. 64).

Environmental factors that influenced the presence of calcareous mud sediment rich in mollusk shells at Schöningen 12 II 4c during the Reinsdorf interglacial could have been:

- In the lake's water chemistry context, the presence of calcium carbonate can be attributed to the geological composition of the lake's watershed and surroundings (Morse et al. 2007). Elm Hill, a limestone ridge, can release calcium carbonate into the water through weathering and erosion. This geological feature suggests a period of increased water run-offs, possibly due to a lack of vegetation.
- The high alkalinity of the water, influenced by the geological composition, and the simultaneous high levels of oxygen support the precipitation of calcium carbonate (Larson et al., 1942, pp. 1667-1670). This suggests that calcium carbonate in the lake might indicate high-velocity water inputs, most likely caused by increased precipitation. This scenario aligns with the geological influence of Elm Hill, which, through weathering and erosion, contributes to the release of calcium carbonate into the water.
- Eutrophication of the water can lead to algae blooms; when algae die, they release carbon dioxide, increasing the alkalinity and leading to higher calcium carbonate precipitation.
- Mollusks extract calcium carbonate from the water to build their shells; their presence can indicate the presence of calcium carbonate in high concentrations in the water; warm

temperatures increase their metabolism, leading to higher mollusk shell concentration in the sediment.



Reference profile Schöningen 13 II 2003, 56°07′59″N 10°59′19″E

Depth m a.s.l.	Level II[b]	Square[c]	Boxes no. (Length 25 cm)	Sedimentology
102.80–103.00	5c2	719/2	**35–41**	Basin clay
102.70–102.80	5c3	719/2		Layered silts overlain by basin clay
102.30–102.70	5d1	719/2		Same organic rich solid silts alternating with layers of reworked, crumbly-sandy silts
102.10–102.30	5d2	719/2		Alternating layers of organic rich-solid silts, intercalated by thin, peaty layers
101.80–102.10	4b(c) 4a	719/2		Organic muds, solid and finely laminated, partly strongly weathered, peaty pods (**wooden artifacts and stone tools; "spear horizon"**)
101.30–101.80	**4c**	719/2		Stratified calcareous mud (Characeae mud), decreasing organic contents from bottom to top, *Anodonta* shells
102.10–102.80	4c	692/2	**26–34**	Stratified calcareous mud (Characeae mud), decreasing organic contents from bottom to top, *Anodonta* shells
101.80–102.10	4e1	692/2		Clayey mud and clay layers alternating with Characeae silty muds
101.20–101.89	4e2	692/2		Clayey-silty mud, crumbly structure
100.75–101.20	4e3	692/2		Clayey-silty mud, decreasing lamination towards basis

Figure 5.1 Table containing the Lithological description of the profile from Schöningen 13 II, level 4, showing the soil composition on sublayer c. Modified from Urban & Bigga (2015), table1, page 62.

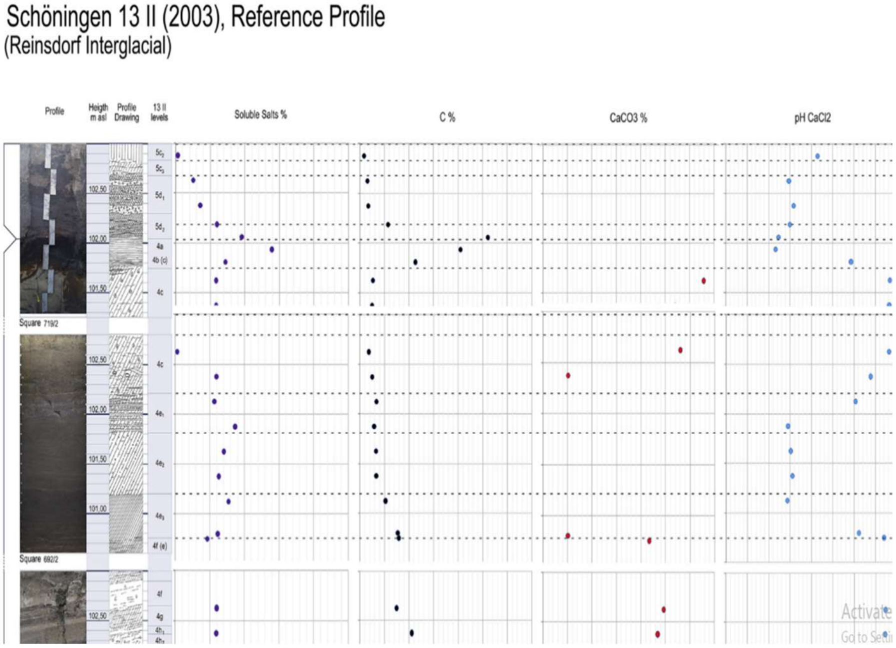


Figure 5.2 Geochemistry of Schöningen 13 (Reinsdorf Interglacial) profile, level 4 and 5, Modified from Urban &Bigga, (2015), fig. 6, page 63.

According to the reference profile geochemistry (Fig 5.2), sublayer `c` indicates water eutrophication with high alkalinity, rich in calcium carbonate**.** Eutrophication is the process by which excessive nutrients, mainly nitrogen and phosphorus, enter water bodies. This leads to the rapid growth of algae and aquatic plants, which consume oxygen when they die and decompose. This can reduce water quality, cause oxygen depletion, and disrupt marine ecosystems, often resulting in algal blooms, fish kills, and other environmental problems. Calcium carbonate in the sediment may suggest heightened erosion of the adjacent Elm Hill. This erosion could be attributed to increased water runoff resulting from the absence of vegetation, signifying open areas and a potential increase in precipitation, correlating with elevated lake levels.

5.1.3.2 Reconstruction of the Aquatic Layer from the Aquatic Environmental Zone

The following analysis will center on the Aquatic zone. This zone is populated by plant species classified as 'Obligated Aquatic' in the dataset, and their roots delve into the substrate/sediment, as explored in the preceding subchapter. Within the Obligated Aquatic category, two subcategories exist submerged aquatic plants with roots anchored in the substrate/sediment and floating aquatic plants (submerged but not fixed by a root system). The submerged aquatic plant species found in this category include *Zannichellia palustris, Stuckenia pectinata, Potamogeton alpinus, Potamogeton crispus, Myriophyllum spicatum*, and *Sparganium cf. emersum*. The 'cf.' notation indicates that the observed plant specimen resembles or is like *Sparganium emersum*, although it may not precisely match all known characteristics of the species. This notation is used when there are uncertainties about identification, often due to variations, environmental factors, or limited information about the specimen. *Groenlandia densa* is the sole representative of floating aquatic plants in this category.

Additionally, some plants were identified at the family level, providing a general understanding of the environment. These include the *Ranunculus Sect. Batrachium sp.,* *Potamogetonaceae sp., and Myriophyllum* sp., with 'sp.' indicating that the specific species is not specified or is being referred to in a general sense.

The presence of these plants in the aquatic environment is helping to make detailed inferences about water chemistry based on the plant species present in the data set belonging to the aquatic environmental zone:

- **Calcium Carbonate and Alkalinity:** A high alkalinity and chemically rich environment that supports the precipitation of calcium carbonate (Larson et al., 1942, pp. 1667-1670) is indicated by the presence of *Groenlandia densa, Characeae* sp., *Myriophyllum,* and *Potamogetonaceae* species *alpinus,* and *crispus*
- **Water Velocity:** The abundant presence *of Zannichellia palustris and Stuckenia pectinata*, both submerged aquatic plants favoring low-velocity environments, suggests that the water in the region exhibited relatively slow movement (Van Vierssen, 1982, pp. 387-388). This observation is further supported by the coexistence of *Groenlandia densa* and *Myriophyllum*, both of which thrive in calm aquatic settings. Potamogetonaceae crispus and alpinus indicate the possibility of diverse velocity conditions, suggesting a nuanced combination of slow to varying water velocities in the historical aquatic environment.
- **Eutrophication and Nutrient Levels:** The presence of *Characeae, Stuckenia pectinata, Myriophyllum, Potamogeton,* and *Ranunculaceae* implies high nutrient levels and eutrophication in the water (Ganie et al.,2016, p. 788). These plants are known to flourish in environments characterized by elevated nutrient content. Their abundance suggests that the water at Schöningen 12 II-4 sublayer c had nutrient-rich conditions, potentially leading to eutrophication, a process in which excessive nutrients, particularly nitrogen and phosphorus, promote rapid growth of algae and aquatic plants. The thriving of these nutrient-sensitive plants further supports the inference of heightened nutrient levels in the paleo aquatic environment (Nichols& Shaw,1986, p. 7).
- **Water Turbidity**: The preference of *Groenlandia densa* and *Potamogeton alpinus* for clear and colder waters, in contrast to the other plants that exhibit a tolerance for some eutrophication and turbidity, suggests that the aquatic environment likely maintained relatively clear conditions (Bayindir, 2020, pp. 125-126). It is conceivable that *Groenlandia*

densa and *Potamogeton alpinus* seeds may have been introduced into the area through the inflow of one of the rivulets. This speculation implies that Platform 4 at Schöningen 12 II could have been situated near the point where a rivulet flows into the lake.

- **Depth and Proximity to Shore:** The dominance of *Zannichellia palustris, Stuckenia pectinata, Characeae sp,* and *Potamogetonaceae* species in specific depths (Fig 5.3 & 5.4) also suggests that the water was likely shallow (Ganie et al.,2016, p. 788; Case &Madsen, 2016, p.22; Nichols& Shaw,1986, p. 7), ranging from 2 to 4 meters deep, and not far from the shore providing clarity into the topography of the lake.
- **Colder Climate Indicators:** Based on the ecological preferences of the identified plant species, the presence of *Groenlandia densa* and *Potamogeton alpinus* and *crispus* which prefer colder waters, suggests a cooler climate in the region (Bayindir, 2020, p. 130). These plants serve as indicators of the environmental temperature conditions.
- **Slightly Brackish Waters:** The detection of *Ostracods* in the sediment indicates colder and slightly brackish water conditions. This observation implies the presence of a water body exhibiting a combination of both fresh and brackish characteristics. Notably, all the aquatic plant species in the environment demonstrate a degree of tolerance to brackish waters. Specifically, *Potamogetonaceae, Zannichellia palustris,* and *Characeae* sp. exhibit heightened adaptability and resilience toward conditions with a slight salinity (Larkin et al.,2018).

With this, the image of the aquatic environment becomes more evident. The sediment/substrate, calcareous mud, indicates calcium carbonate, which shows high alkalinity and pH-water levels. The presence of Potamogetonaceae, Characeae, and Myriophyllum also confirms this. The environment was of high-nutrient waters that cause high alkalinity and pH values, and the presence of carbon in the water typically limits the production of aquatic plants, except for those adapted to survive in eutrophic environments. Also, slow-movement waters with a max of 2 to 4 m depth are probably not far from the shore (Urban & Bigga, 2015, p. 69), with depth dominated by *Zannichellia* and *Potamogetonaceae* (Fig 5.3 & 5.4).

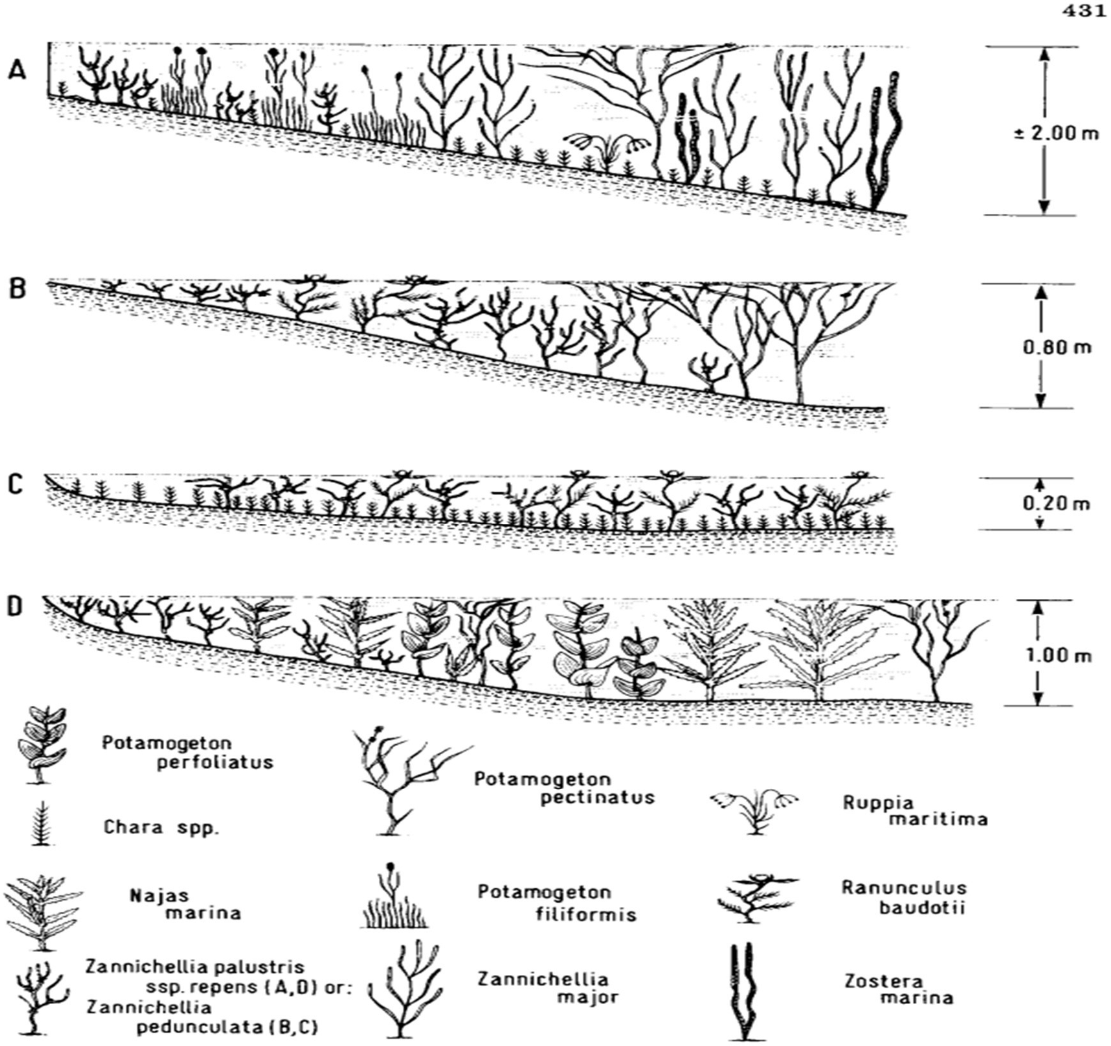


Figure 5.3 Schematic representation of vegetation stands with Zannichellia taxa under field conditions. A bay in Finland. B, temporary pool, The Netherlands. C, temporary marsh, Camargue, France. D, former riverbed, Lith, The Netherlands., taken from Van Vierssen (1982), fig. 13, p 431

The presence of calcareous mud in the lake sediment was also caused by the rivulet channels flowing into the lake, possibly not very far, bringing in the run-off sediment from the side of limestone made Elm Hill, indicating high erosion due to the lack of vegetation. This can suggest that open spaces might have been present in the region, indicating a cooler climate. The *Groenlandia densa* and *Potamogeton alpinus* prefer colder, clear waters, so some were possibly growing in these creeks, and their seeds were brought in by the moving waters and deposited. *Ostracods* in the sediment indicate colder and slightly brackish waters (Quante et al., 2022, p. 716).

The aquatic environment at Schöningen 12 II-4 was not limited to the identified plants. Instead, it constituted a complex habitat that hosted numerous other aquatic plants, which may not have been represented in the sediment sample. This aquatic environment was the main attraction in the region, being not only a water source but also a feeding ground and shelter for a large variety of species of fish (Jackson, 2010, pp. 19-20), mollusks, amphibians, and aquatic insects (Koroiva & Pepinelli, 2019, p. 13)). Around it, a network of ecosystems was formed, creating the clashing ground for the survival of many species.

Taxon	Depth in meters	Reference
Sparganium cf. emersum	0.5 m	Chase & Knight, 2006; Chaichana et al., 2011
Ranunculus Sect. Batrachium sp.	1m	Mihu-Pintilie, 2018
Goenlandia densa	1m	Guo & Cook,1990; Boedeltje et al., 2005; Nichols & Shaw, 1986
Potamogeton alpinus	1.5 m	Guo & Cook,1990; Boedeltje et al., 2005; Nichols & Shaw, 1986
Zannichellia palustris	2 m	Van Vierssen, 1982; Posluszny & Sattler,1976)
Stuckenia pectinata	3.5 m	Ganie et al., 2016; Case & Madsen, 2004
Potamogeton crispus	4 m	Guo & Cook,1990; Boedeltje et al., 2005; Nichols & Shaw, 1986
Myriophyllum spicatum	5 m	Chase & Knight, 2006; Chaichana et al., 2011
Characeae	14 m	Larkin et al.,2018

Figure 5.4 Table contains the identified aquatic plants and the depth where they can be found in a lacustrine environment. Created by MF Catalinoiu

.

5.1.4 Reconstructing the Lake Margins and the Surrounding Damp Grounds Zone

The lake margins' surroundings are not a unitary environment, comprising environmental subzones transitioning from a mainly aquatic environment to a primarily terrestrial one. These subzones are the macrophyte plant zone, composed of partially submerged plants placed close to the margins in shallow waters and the waterside environmental area. To reconstruct the lake margins and the surrounding damp grounds containing the plants belonging to the `Waterside & Damp ground, ``Woodland and shade tolerant` and ` Unclassified` categories with additional data from Bigga et al. (2015). The additional data comprises *Salix, Phragmites australis,* and *Thypa* sp.

The identified plants from the `Waterside & Damp ground ` category represent two environmental areas:

- The macrophyte plant environmental zone is formed by the plants that are partially submerged with roots in the water and represented by *Hippuris vulgaris, Schoenoplectus lacustris, Sparganium erectum, and Eleocharis palustris,* representing 66.23% of the total number of seed belonging to plants from lake margins and damp ground environmental zone. To this list, *Phragmites australis* and *Typha* sp were added from Bigga et al. (2015)
- The waterside vegetation environmental zone, formed by the plant associated with moist soils prone to flooding of the lake margins, is represented by *Ranunculus Sceleratus;* although not a classic riparian but associated with damp grounds*, Rumex maritimus, Persicaria cf. hydropiper, Bidens sp., Alnus glutionosa*. Together, they represent 33.77% of the total number of seeds. The additional data to this list is *Salix* sp. from Bigga (2018).

Since it is difficult to assign a specific habitat for the `Unclassified` category since the seeds were not identified at the species level, the woodland, shade-tolerant *Rubus fruticosus*, and the plants from the 'Unclassified' category will be positioned in a transitional area between the waterside environmental zone and the upland terrestrial zone.

5.1.4.1 Reconstructing the Macrophyte Plant Environmental Zone on the Lake Margins

The zone of shallow, still, or slowly flowing waters near the margins the habitat for macrophyte plants, which can exhibit varying parts above and below the water's surface, depending on the species and environmental conditions. Some have aerial portions like leaves, stems, and flowers above the waterline, while others are entirely submerged. These plants absorb nutrients from the water, helping to control eutrophication and storing carbon in their biomass and sediment. The seeds from the data set that will be used to reconstruct this environmental area belong to the `Waterside & Damp ground` category: *Hippuris vulgaris, Schoenoplectus lacustris, Sparganium erectum,* and *Eleocharis palustris*.

The presence of these species establishes that we are talking about slowly moving eutrophic waters with significant nutrient content (Misson et al., 2016, p. 211; Jain et al., 2005, p. 1019; Cianfaglione et al., 2017, p. 2317). Their presence was fundamental for the equilibrium of the environment. They could absorb nutrients, release oxygen, control the algae bloom, and create habitats and feeding grounds for many insects, birds, fish, and other aquatic organisms. However, the presence of their seeds in large numbers does not indicate that a particular species is more represented than the other because they all rely on propagating through rhizomes. As specific plant species lack in this context, which species predominated in numbers cannot be determined. The environment is constantly changing, influenced by water levels, temperature variations, and chemical composition. Simultaneously, it is intricately connected to other habitats crucial for the survival of these species. The subset of identified plants here does not offer a comprehensive view of the middle Pleistocene environment at Schöningen 12 II-4c. This limitation is attributed to material loss during sediment processing in the rescue excavation. A more extensive species count was achieved at Schöningen 13 II-4, where a more comprehensive analysis of pollen and botanical macrofossils was applied (Bigga et al., 2015, p. 93).

The absence can be further examined by juxtaposing the plant list with a contemporary lakeside environment. The specific region selected for observation lies along the shores of the Vliet in the Netherlands (Fig 5.5). For an archaeologist, studying a present-day environment can be invaluable when reconstructing one from the distant past. In my analysis, a notable absence became evident – the absence of common plants typically found in the wetlands adjacent to water bodies across various climatic zones, such as the common reed or *Phragmites australis* and cat tail of genus *Typha* (Fig 5.13) (Scheffer, 1998). However, these plants are present in samples from Schöningen 13II-4 (Bigga, 2018, p.89). Their presence is essential for the lake lacustrine environment since it absorbs excess nutrients from eutrophic waters. Reduce the quantity of phosphate and nitrate in the water, offering at the same time shelter and food for birds and small mammals (Grace, Wetzel,1981, p. 465; Grace, Wetzel,1998, p. 138; Marks et al.,1994, p. 290).

Figure 5.5 Example of Thypa and Phragmites australis environment on the lake margins on the Vliet The Netherlands, image taken on the 13th of July 2023 by MF Catalinoiu

5.1.4.2 Reconstructing the Lacustrine/ Waterside Environment Zone

The waterside environment represents the transition from aquatic to terrestrial zones. It is neither wet enough to be considered an aquatic ecosystem nor dry enough to be terrestrial with specific ecological tolerances (Gregory et al., 1991, pp. 541-544; Swanson et al., 1982, pp. 269-274).

Lacustrine plants exhibit some general characteristics:

- Hydrophilic adaptations, meaning that are plants adapted to water-saturated soils and frequent floodings
- Tolerance to water level changes due to seasonality, adapted to having the roots in the water but also dry during the low rain season
- The deep root system that ensures the stabilization of the river/lake banks and access to water during the dry periods and erosion control
- Nutrient filtering improves water quality by reducing sedimentation and nutrient run-off.
- Drought resistance, adapted to survive during the dry periods
- Dynamic growth changes their growth rate in response to either changes in the water levels or temperatures.

Rumex maritimus, Persicaria cf. hydropiper, Ranunculus sceleratus, Bidens sp., and Alnus glutinosa are the plants attached to the waterside environment. *Rubus fruticosus, Chenopodium sp., Viola sp.,* and *Carex sp.* are added to this list because, although not exclusively, waterside plants are versatile and can adapt to different environments. Although the sample contains a limited number of seeds belonging to these plants, it does not necessarily indicate that they are not representative of the environment. Instead, their presence may reflect the taphonomy since their deposition approximately 300 ka ago. It's important to consider that seeds tend to remain close to the plants that produced them, especially in the context of slowly moving water.

- The presence of these plant species suggests a diverse and dynamic aquatic environment with a range of water conditions, including wetlands *Ranunculus sceleratus* (Van der

Toorn, 1980, p. 390)., brackish waters, and lacustrine areas *Alnus glutinosa*, *Rumex maritimus* (Deptuła et al.,2020, p. 9), *Bidens* sp. (Ballard,1986, p. 1455).

- These plants play essential roles in stabilizing soil, fixing the nitrogen in the soil *Alnus glutinosa* (Van Smeerdijk,1989, p. 489)., preventing erosion, and providing habitats for various organisms, highlighting their ecological significance (Zuo et al., 2014, p. 35).
- Adaptations include hydrophytic features and tolerance to varying water levels *Alnus glutinosa, Ranunculus sceleratus*. Indicate the resilience of these plants in responding to environmental changes (Gill,1975, p. 86).
- The varied reproductive strategies contribute to their ability to colonize new territories (McVean,1955, p. 61) and sustain populations in different ecological niches, such as *Persicaria hydropiper*, *Bidens sp., Rubus fruticosus* (Caplan & Yeakley, 2013), (Fig 5.6).

Figure 5.6 Example of a dense thicket of Rubus fruticosus competing for space and light with Rumex and other species of plants on the lake margins in Vlietland, The Netherlands, picture taken by MF Catalinoiu, 13 July 2023

Viola sp., *Chenopodium* sp., and *Carex* sp. fall within the unclassified category, sharing a remarkable versatility in colonizing disturbed areas. These plants exhibit adaptability across diverse ecosystems, ranging from woodlands and meadows to uplands (Noble et al., 1979, p. 1004). Their capacity to thrive extends to various soil types, encompassing waterlogged and well-drained conditions, additionally, they display resilience in adapting to climates spanning from arid to temperate regions (Naczi et al.,1998, p. 439).

The dataset was supplemented by incorporating additional plant species identified through palynological studies at Schöningen 13 II 4, specifically those in waterside zones. These species include *Salix* sp. (willow), *Betula* sp. (birch), *Juniperus communis* (juniper), and *Sambucus nigra* (elderberry) (Bigga, 2018, p.56). Although not exclusive to waterside, *Salix and Sambucus* are commonly found in lacustrine zones and are notably absent from my dataset. They thrive in moist soils, and their adaptability to various environments makes them successful colonizers. *Betula sp.* can be found in lacustrine zones, adapted to persistent wet conditions on the riverbanks and wetland areas. It is a pioneer and highly competitive tree that appears after environmental disturbances.

5.1.4.3 The Vegetation Layers of the Lacustrine/Waterside Zone

A waterside zone comprises distinct ecological layers or strata determined by the proximity to the water body and environmental conditions (Fig. 5.7). These layers are not always sharply defined, and transitional areas or overlaps between them can exist. Elements like soil composition, moisture content, and specific plant species present in the waterside zone influence the composition of each layer. All these layers contribute to the ecological diversity and functionality of the lacustrine ecosystem.

- **Emergent layer**: Macrophyte plants like *Hippuris vulgaris, Schoenoplectus lacustris,* and *Typha sp*. oxygenate and filter water, providing refuge for wildlife (Kelsey & West, 1998, p. 257). It may have been a hiding place for hominins during ambush hunting (Haws, 2012, p. 280).

- **Herbaceous and ground cover layer**: Stabilizes soil, aids nutrient cycling, and provides habitat for small animals and includes *Rumex maritimus, Persicaria cf. hydropiper,* and *Viola sp.*
- **Shrub layer**: Comprises woody vegetation in shaded areas near the lake margins, promoting biodiversity and serving as a buffer. Species include *Rubus fruticosus, Sambucus nigra*
- **Tree layer**: *Alnus glutinosa*, *Betula sp., and Salix sp* form a canopy, providing nesting sites and shelter. They stabilize soil, filter pollutants, and contribute to nutrient cycling (Lyon & Gross, 2005, p. 268).

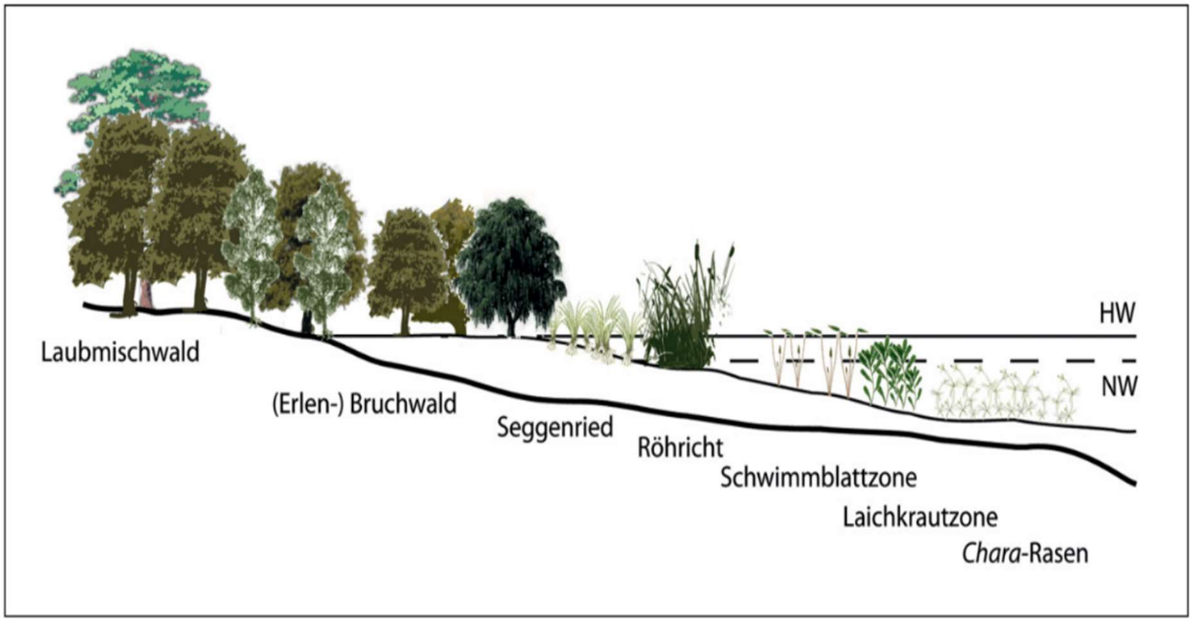


Figure 5.7 The layer reconstruction of the lacustrine zone starts with the aquatic area and finishes with the upland terrestrial zone. Graphic by Gerlinde Bigga. Modified from Bigga 2018, Fig. 3, page 66

Many bird species nest in the trees, using the canopy for shelter, while predatory birds, such as owls and hawks, hunt for prey in the tree canopy. Some animals are adapted to a tree-dwelling lifestyle and may spend most of their lives in the canopy or use tree cavities as their home (Dobkin et al.,1995, p. 694). Insects, such as beetles, butterflies, and ants, utilize trees for shelter, feeding, and mating. Bees and butterflies visit tree flowers for nectar and play a crucial role in pollination. Birds and mammals in the tree layer can aid in the dispersal of seeds, contributing to forest regeneration.

5.1.5 Reconstruction of the Upland Terrestrial Zone

If the waterside and aquatic zones are considered local environmental zones, the transition to the terrestrial zone would advance the environmental reconstruction to a regional level. A terrestrial zone follows the lacustrine zone, moving further away from the water body, and is often called the "upland" or "terrestrial" zone. This zone typically has distinct characteristics compared to the lacustrine area, including differences in soil types, vegetation, and ecological processes (Shugart,1998, pp. 45-58):

- well-drained soils compared to the waterlogged found in the lacustrine zone, with less moisture due to the distance from the water body
- soil types can vary according to the geology and topography, from sandy soils to loams and clayey soils
- vegetation transition that marks the transition from the lacustrine zone to the terrestrial area, with a wide diversity of plants adapted to the soil type and climate
- dryer microclimate compared to the cooler and more humid microclimate of the lacustrine zone
- Forested areas can be present in terrestrial zones with a canopy of trees adapted to well-drain soils

The distance between the lacustrine zone and the terrestrial zone on a lake's margins can vary, influenced by numerous factors (Ilhardt et al., 2000, pp. 9-14):

- Lake size and shoreline slope: a small lake with a gentle slope may favor an extended lacustrine zone, while a smaller lake with a more significant slope favors a more abrupt transition to a terrestrial zone
- Dense vegetation in the lacustrine zone favors a gradual transition between the two zones, while in poor vegetation, the transition is abrupt.

- Erosion and Sedimentation: while erosion may extend the lacustrine zone further inland, the sedimentation can narrow it.

Incorporating regional data into my dataset involves integrating pollen analysis data sourced from the Schöningen 13 II-4 sublayer c in the Urban & Bigga (2015), p.65, study (Fig 5.9), which includes information on *Pinus sylvestri* (pine tree) and *Larix* sp. (larch tree). Additionally, was integrated data from wood fragment analysis conducted on Schöningen 12 II-4 as presented in Bigga (2018) study (Figure 5.8). The wood fragments used for identifying these trees were taken from within the lake sediment. This suggesting that the primary means of transportation was water, likely from the runoff from nearby Elm Hill or the lake drainage basin. This dataset encompasses *Abies alba (European silver fir), Fraxinus excelsior (Ash), Picea sp., and Acer* sp. (Maple). The most notable inclusion in this category is *Picea sp (Spruce)*, identified as the wood used by the Middle Pleistocene hominins to craft the famous spears discovered at Schöningen 13 II-4 (Schoch et al.,2015, pp. 220-223).

Figure 5.8 Schöningen 12 II-4 platform 4 to 6, the position of the identified wood fragments and the type of tree it represents. Taken from Bigga (2018),fig. 21, page 56

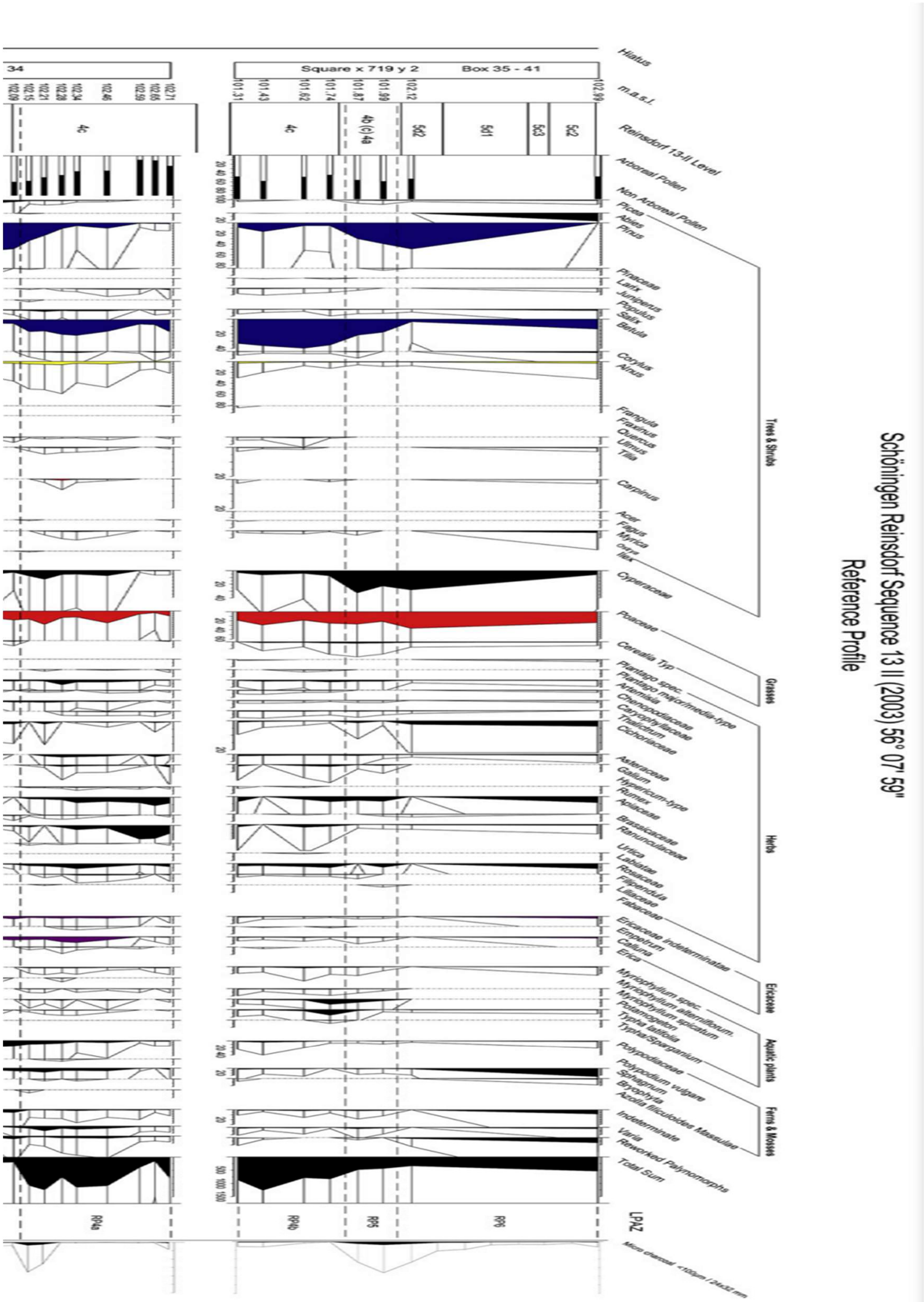


Figure 5.9 Pollen diagram of reference profile Schöningen 13 II (2003), layer 4, sublayer c, b, a, and layer 5. Where LPAZ - Local Pollen Assemblage Zones; RP-Reference Profile. Modified from Urban & Bigga (2015), fig 7, page 65

- The diverse soil preferences of these trees indicate the versatility of the terrestrial zone. *Pinus sylvestry* and *Larix* sp can adapt to various soils, from well-drained to poor. *Abies alba* grows on well-drained (Dobrowolska et al., 2017, p. 329), often acidic or neutral soils, while *Pis.cea* prefers well-drained soils with a neutral to acidic pH. *Acer* is adaptable to different soil types, from neutral to slightly acidic, while *Fraxinus* prefers calcareous soil.

- The combination of *Picea Abies* adaptability to various temperature and precipitation levels (Carlisle & Brown,1968, p. 270), *Larix* sp. ability to withstand harsh winters in northern regions (Schmidt,1995, pp. 6-8), and *Abies alba's* preference for chilly summers and harsh winters in montane areas suggest a diverse climate within the upland terrestrial zone. *Picea* thrives in temperate climates (Liu & Hytteborn,1991, p. 392), and both *Acer sp.* and *Fraxinus excelsior* trees are found in temperate regions, showcasing adaptability to distinct seasons.

The collective inclination towards well-drained soils, colder climates, and consistent year-round rainfall among these trees signifies a terrestrial environment conducive to robust tree growth. Additionally, the prevalence of calcareous soils, particularly favored by the *Fraxinus* tree, introduces a distinctive soil characteristic to the broader environmental profile. This, coupled with the affinity of *Carex* sp. for calcareous soils, may suggest the existence of tree clusters within an open grassland on the limestone Elm Hill. Also, The landscape may exhibit zones with different combinations of coniferous and broad-leaf trees, indicating the ecological diversity within this terrestrial environmental zone.

One of the most remarkable aspects of this environment is its role as a haven for diverse wildlife. These forests' dense canopy and underbrush provide vital habitat and shelter for many animals, birds, and insects. These forests become a sanctuary for animals, offering secure breeding grounds, hiding places, and foraging opportunities.

5.1.6 The Reconstruction of the Lacustrine Paleoenvironment. Adding together all the Reconstructed Environmental Zones

This chapter integrates the reconstructed environmental zones—the Aquatic zone, Lacustrine/Waterside zone, and Upland terrestrial zone—to form a complete reconstruction of the lacustrine paleoenvironment corresponding to sublayer II 4c from Schöningen during the Middle Pleistocene's Reinsdorf interglacial. The objective is to comprehensively depict the local and regional environment, addressing the first research question and its sub-questions that guide this investigation.

What is the detailed reconstruction of the lacustrine paleoenvironment at the Reinsdorf interglacial site Schöningen 12, corresponding to sublayer II4c? How can we characterize the paleolake's water chemistry, depth, and speed during this specific timeframe?

The aquatic environment described in the data collected from the identified macrofossil from the sediment taken from Schöningen 12 II-4 sublayer `c` is characterized by several key features. Calcareous mud indicates high alkalinity and pH levels in the water, further supported by specific plant species like *Potamogetonaceae, Characeae, and Myriophyllum*. These conditions suggest that the environment had high-nutrient water, resulting in elevated alkalinity and pH values. Typically, such conditions limit the growth of aquatic plants, except for those adapted to thrive in eutrophic environments.

The slow-moving waters in this environment had a maximum depth of approximately 2 to 4 meters (Bigga et al., 2015) and were likely close to the shore. The presence of calcareous mud in the lake sediment was likely due to rivulet channels flowing into the lake, possibly from nearby limestone formations like Elm Hill. This suggests that the area experienced high erosion due to a lack of vegetation, possibly indicating a cooler climate.

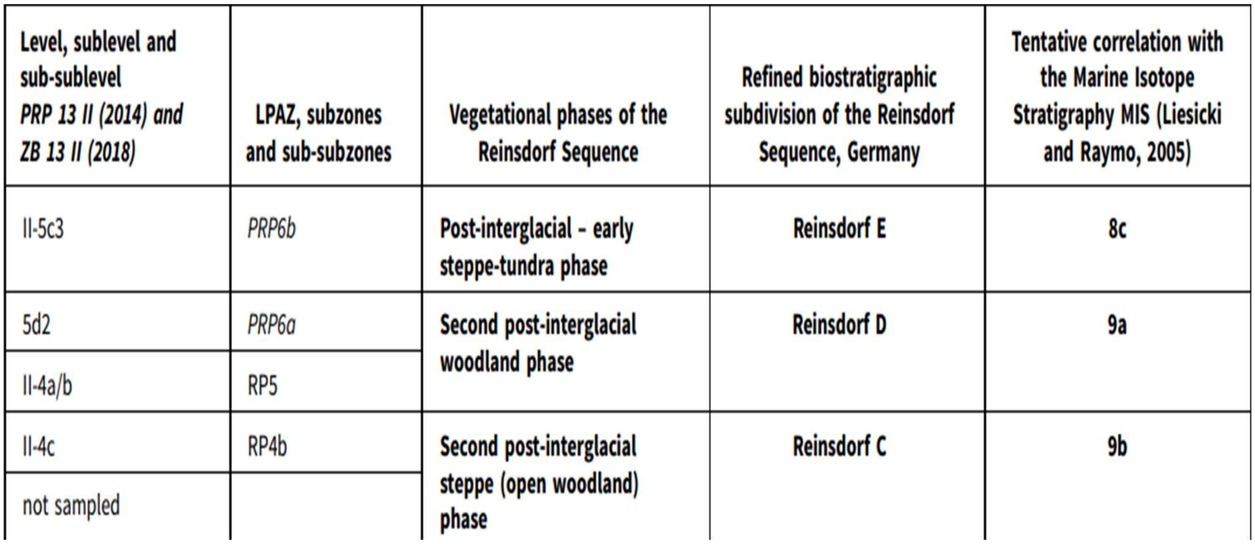
Groenlandia densa and *Potamogeton alpinus*, which prefer cooler and clear waters, suggest that these plants may have been growing in the rivulets that fed into the lake. The moving waters likely carried their seeds and deposited them in the lake sediment.

The presence of *Hippuris vulgaris, Schoenoplectus lacutris, Ranunculus sceleratus, Thypa, and Phragmites* suggests that the lake margins have the characteristics of wetlands or shallow-water zones.

Palynological data from sublevel II-4c suggests an open landscape with cooler, drier conditions with evidence of increased lakeshore turbulence and active stream, fluvial fans formed from seasonal river activity. The lake had higher aquatic productivity and high oxygen conditions, possibly due to increased inflow activity or wind action (Urban et al., 2023, p. 170). The loss of woodland led to rising lake levels and frequent flooding, transforming into a grass-dominated landscape. Also, the presence of the *Ostracoda* is an indicator of cooler, slightly brackish waters (Quante et al., 2022, p. 716).

The aquatic zone reconstruction can be accurate because the sample is taken within the lake. Therefore, the aquatic and macrophyte plants are better represented than those from waterside or terrestrial zones since the macrofossils are not traveling too far from the source.

Within the waterside zone, there is a notable abundance of *Carex* sp. seeds compared to other plant species that typically inhabit this environment. This prevalence suggests the presence of open areas within the lacustrine zone, supporting the notion of a steppe woodland phase (Fig 5.10) (Urban et al., 2023, p. 158). Despite these open spaces within the lacustrine zone, there were numerous areas with thickets made of *Rubus* and *Sambucus*, a natural magnet for birds, mammals, hominins, and pollinators, alternating areas with clusters of *Alnus* and *Salix* on the margins. Creating a vivid mental picture based on this data is challenging. Even with advanced software for reconstructing environments (Fig 5.11), generating a complete representation of the paleoenvironment is difficult. Nevertheless, the aim is to get as close to understanding this paleoenvironment as possible.



Level, sublevel and sub-sublevel *PRP 13 II (2014) and ZB 13 II (2018)*	LPAZ, subzones and sub-subzones	Vegetational phases of the Reinsdorf Sequence	Refined biostratigraphic subdivision of the Reinsdorf Sequence, Germany	Tentative correlation with the Marine Isotope Stratigraphy MIS (Liesicki and Raymo, 2005)
II-5c3	*PRP6b*	**Post-interglacial - early steppe-tundra phase**	**Reinsdorf E**	**8c**
5d2	*PRP6a*	**Second post-interglacial woodland phase**	**Reinsdorf D**	**9a**
II-4a/b	RP5			
II-4c	RP4b	**Second post-interglacial steppe (open woodland) phase**	**Reinsdorf C**	**9b**
not sampled				

Figure 5.10 Local pollen assemblage zones, subzones, vegetational phases, and biostratigraphy of the Reinsdorf Sequence and tentative correlation with the Marine Isotope Stratigraphy (MIS). Modified from Urban et al. (2023), table 1, p. 160.

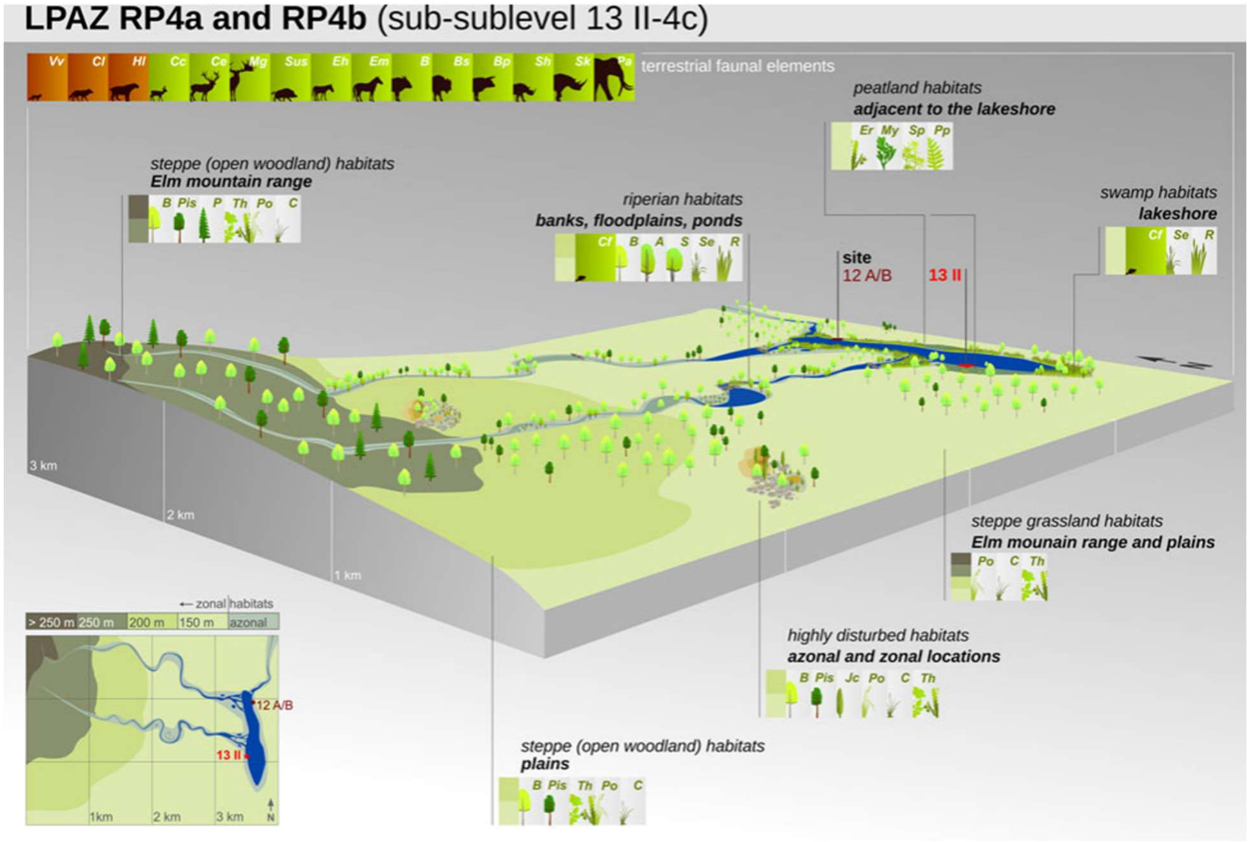


Figure 5.11 Simulation of landscape reconstruction at Schöningen, corresponding to sublayer II 4 c. It contains flora identified from pollen assemblages LPAZ RP4a and 4b. Taken from Urban et al. (2023), fig 19, page 170.

Figure 5.12 The symbols used to represent flora and fauna in the simulation for reconstructing the environment Schöningen after pollen assemblage. Taken from Urban et al. (2023), fig. 11, p. 161.

The added data from wooden fragments from Bigga (2018) and pollen assemblage from Urban & Bigga (2015) add new shades to the reconstruction. Therefore, the LPAZ RP4a (102.120 – 102.710 m a.s.l) pollen sample taken from the lower part of sublayer `c` indicates:

- Very low amounts of *Pinus* (pines), indicating that pine trees were not a dominant component of the vegetation in this specific zone, implying that the environment was less supportive of pine growth
- High values of NAP (non-arboreal pollen). Indicates as predominant a variety of shrubs, herbs, and possibly aquatic plants

- Increasing amounts of *Betula* (birches) towards the zone's top suggest a changing vegetation composition. It could indicate a transition from one type of vegetation to another caused by a shift in climacteric conditions, increased moisture, and lake surface (Urban et al., 2023, p. 154).
- The presence of *Alnus* (alders) and *Myrica* (bayberry)indicates a mix of woody shrubs in a highly nutrient environment, and it can be associated with high precipitation levels in temperate or colder climates.
- Indications of acid-raised bog environments with *Sphagnum* moss can indicate high precipitation, cooler temperatures, and a higher lake level that ensures moisture and increases the bog-dominated area (Clymo & Hayward, 1982, p. 231).
- The dominance of *Ranunculaceae* pollen indicates the presence of possible extended aquatic habitats within this zone (Mihu-Pintilie, 2018, p. 210).
- The occurrence of *Apiaceae* with Oenanthe aquatica suggests a terrestrial influence, pointing towards a coexistence of terrestrial and aquatic vegetation in this environment. The mention of *Oenanthe aquatica* might relate to its affinity to moderate to cooler temperatures (Hroudová et al.,1992).
- The inflow of material outside the ecological zone during the lower part of sublevel II-4c. The mention of material inflow suggests that the water transported materials outside the immediate ecosystem into this zone. This could be due to factors like water flow or sediment deposition, indicating some level of environmental dynamism, most likely increasing erosion on the uplands due to the formation of open spaces.

The LPAZ RP4b (101.310 – 101.805 m a.s.l) pollen sample from the upper part of sublayer `c` captures a shift in the climate that is indicated in:

- A substantial increase in *Betula (birch)* pollen (up to 40%) can indicate a severe disturbance in the area favoring Betula growth. These changes could have been caused by the shifts in temperature and precipitation patterns. Substantial environmental disruptions, such as fires that eliminate potential competitors or the expansion of a wetter environment, can also influence Betula's presence. The increase in light availability is due to the disappearance of taller trees, which can help the proliferation of light-loving Betula (Urban et al., 2023, p. 155).

- Decreasing amounts of *Ericaceae* (erica) and *Ranunculaceae* (buttercup) suggest that the environmental conditions in the area have changed. It could be due to shifts in temperature and moisture levels. For instance, a gradual drying of the region or a change towards more alkaline soils could have made the habitat less favorable for these taxa (Stevens et al., 2004, p. 154).
- *Typha latifolia* (cattail) and *Potamogetonaceae* (pondweed) could indicate that the lake may have become shallower over time, possibly due to sedimentation, a drop in water levels, or changes in nutrient input. Such changes could be driven by alterations in precipitation patterns, temperature, or geologic factors affecting the lake's hydrology (Sümegi et al., 2009, pp. 277-282).
- *Juniperus and Salix* are present in low quantities, and these taxa are often associated with specific ecological niches, such as drier or lacustrine areas. Their scarcity could suggest that other plant species were more competitive or better adapted to the prevailing conditions (Merkt & Müller,1999, p. 51)
- Occasional findings of *Larix* (Larch)pollen and minimal *Picea* (spruce) pollen. These conifers are in the vicinity but not significant as a component of the forest. *Larix* is often found in cold, boreal regions, while *Picea* prefers cooler and moister conditions. These sporadic findings might indicate that these conifers were marginal or rare components of the local vegetation during the Middle Pleistocene. It could be due to microclimatic conditions that allowed them to persist in isolated pockets (Mamet et al.,2019, p. 31)
- An increase in *Poaceae* (grass) pollen by about 20% shows a significant shift towards grass-dominated vegetation. Grasses are well-adapted to open, sunny environments and are often associated with disturbance-prone ecosystems. This increase could be due to increased fire activity, possibly driven by changing climatic conditions, or the expansion of grasslands due to grazing pressure from herbivores. It might also suggest transitioning from a more closed forested

landscape to a more open one (Andrieu-Ponel et al., 2010, p. 316)This paleoenvironment is not empty but is populated with numerous mammals identified (Fig 5.12) from the bone assemblages (Kolfschoten, 2014; Urban et al.,2023, p. 161). These are *Vulpes vulpes* (Fox), *Canis lupus* (Wolf), *Homotherium latidens* (Saber-toothed tiger), *Capreolus capreouls* (Roe deer), *Cervus elaphus* (Red deer), *Megaloceros giganteus* (Giant deer), *Sus scrofa*(Wild boar),*Equus hydruntinus*(European wild ass), *Equus mosbachensis* (Wild horse), *Bos/Bison spp.*(Bovide), *Bison priscus* (Steppe bison),*Bos primigenius* (Aurochsen), *Stephanorhinus kirchbergensis* (Merck`s rhinoceros), *Stephanorhinus hemitoechus* (Steppe rhinoceros), *Palaeoloxodon antiquus* (Straight-tusked elephant). Including large grazers in this list confirms the steppe phase implied by the botanical evidence. Given the substantial presence of large game animals, it was almost inevitable that hominins would also inhabit the area. The discovery of the wooden spears, butchery location with bones displaying cut marks, and flint debris at Schöningen 13 II 4 further supports the notion of hominin presence in this region (Conrad et al., 2015; Böhner et al., 2015, p. 213). This aquatic domain serves as a magnet, drawing in predators in search of prey, herbivores seeking nourishment from the waterside vegetation, waterfowl feasting on aquatic plants, and scavengers dealing with the remains of those that have met their demise. These interactions form intricate connections, weaving a complex network that shapes the ecological dynamics across the entire landscape.

5.2 Hominin Behaviour during the Reinsdorf Interglacial at Schöningen 12 II, Corresponding to Sublayer 4 c

Following the paleo-landscape reconstruction in the preceding chapter, which addressed the initial research question, the focus is now on investigating hominin behaviour within this ancient ecosystem from the perspective of plant use. The focus now centers on the important role of plant utilization in their daily lives. This exploration is essential in understanding how the environment influenced hominin behaviour, thus addressing our second research question:

What insights can we derive from vegetation reconstruction about potential plant use, hominin behaviour, and exploitation strategies at the middle Pleistocene site Schöningen 12 II during Reinsdorf interglacial corresponding to sublayer 4c?

Hominins occupied a unique ecological niche, being on the line between predators, foragers, and sometimes even prey for other top predators sharing the lake margins. Their survival strategies evolved over generations in response to the complexities of this lakeside environment. Schöningen is renowned for discovering wooden spears, establishing hominins as skilled hunters rather than mere scavengers (Speth, 1989, pp. 320-330). While extensive research has focused on hunting, the study of plant use has been somewhat overlooked. This is because proving it is challenging, and any artifacts made from plants or wood have long since vanished due to natural processes.

Wooden tools from the Middle Pleistocene are less common in archaeological records than abundant stone tools. A notable find is the Clacton Spear, which dates back around 400,000 years. It is recognized as one of the oldest wooden implements due to exceptional preservation in waterlogged conditions. Subsequent discoveries like the Schöningen Spears emphasize the occasional yet significant use of wood for tools during this period, showcasing the adaptability and ingenuity of ancient hominins in utilizing diverse materials.

In the pages ahead, the relationships between hominins and the plant world will be explored. In the upcoming pages, exploring the relationships between hominins and the plant world will draw insights from studies with modern hunter-gatherer societies, providing informed assumptions about their plant-related activities. The crafting of spears from *Picea* wood underlines the importance of plants.

But plants were not being just used to make tools/weapons. Recent discoveries are showing the use of wood for the earlies wooden structure 476 ka years ago in Zambia (Barham et al.,2023, p. 107), underlining the fact that every year we discover something new about hominins' abilities, proving that they were not as simpletons as we thought they were. But the plant use goes beyond their use for tools and structures; hominins used plants for their diet or medicinal purposes, indicating their knowledge of plants as natural food sources and remedies for treating injuries and illnesses. The ability to control fire, a significant development, relied on access to plant materials, indicating that plants were meeting their various survival needs.

Whether as sources of food, medicine, fire, or tools, plants played multiple roles. This exploration focuses on the connection between early hominins and the natural world, even when direct evidence has vanished. It illustrates their deep knowledge of the surrounding environment and their underestimated cognitive ability.

5.2.1 Exploring the Plant Tool Crafting

The prevalence of stone tools in archaeological sites worldwide has shaped the narrative of the early tools employed by hominins. However, we must acknowledge that the label `Stone Age `might not entirely capture the true nature of the era's tool production. While stone tools are abundant and well-preserved, tools crafted from plant materials, like those found in waterlogged conditions, such as Schöningen spears, might have preceded them. It is reasonable to infer that the initial tools of hominins were made from plants, indicating a phase that could be better characterized as the Plant/Wood Age.

The scarcity of well-preserved plant tools has led to an emphasis on stone tools in archaeological discourse. Yet, the discovery of tools like the Schöningen spears challenges the traditional Stone Age narrative, offering a glimpse into the early preferences of hominins for wood in tool creation. This preference underscores their adeptness in understanding wood properties and highlights their capacity for informed decision-making and skill in utilizing environmental resources.

As we explore the transition from mere scavengers to proficient hunters, the enigma lies in deciphering the cognitive leap that accompanied the development of tools and hunting strategies. The evidence of meat consumption, marked by distinctive cut marks on bone fragments and the presence of flint scrapers, suggests a level of hunting sophistication (Vaquero, 2008, p. 3178). However, the distinction between accessing and processing animal carcasses and the ability to secure these resources is subtle yet pivotal. This transition, intricately tied to cognitive enhancement (Wynn, 2002, p. 402), poses a fascinating puzzle that has captivated archaeologists and anthropologists alike, marking a significant juncture in the evolutionary journey of hominins.

The narrative takes an interesting turn with the discovery of the Schöningen Spears in the 1990s. Unearthed in a specific hunting context, these ten spears were surrounded by animal bones exhibiting clear-cut marks at a designated butchery site. The bones, primarily from processing *Equus mosbachensis* (Wild horse), established the intended purpose for which these spears were crafted (Thieme, 1997, p. 809; Thieme, 2005, p. 125). This discovery challenged the previous notion that hominins were primarily scavengers. Even earlier findings, such as partial thrusting spears (420- 379 ka old) made of yew (Taxus baccata) at Clacton-on-Sea, were initially interpreted as digging sticks until reconsidered in light of the Schöningen spears (Allington-Jones, 2015, p. 274)

The bone assemblage from Schöningen also included other significant big mammals at that time, such as *Homotherium latidens* (Saber-toothed tiger*), Capreolus capreouls* (Roe deer*), Cervus elaphus (*Red deer*), Megaloceros giganteus (*Giant deer*), Sus scrofa(*Wild boar*), Equus hydruntinus(*European wild ass*), Bos/Bison spp. (*Bovide*), Bison priscus (*Steppe bison*),Bos primigenius (*Aurochsen*), Stephanorhinus kirchbergensis (*Merck`s rhinoceros*), Stephanorhinus hemitoechus (*Steppe rhinoceros *), Palaeoloxodon antiquus* (Straight-tusked elephant) (Kolfschoten, 2014; Urban et al., 2023, p. 161).

Large game species at the butchery site in Schöningen indicate that this location was not the result of a single hunting event but rather a site where repeated hunting events occurred (Schoch et al., 2015,p. 224). This observation aligns with the idea that the design of spears was specifically crafted to be effective in hunting large game. It underlines the remarkable adaptability of hominids in tailoring their tool-making practices to align with their hunting strategies, showcasing a sophisticated understanding of their tools and the targeted prey.

Numerous papers addressed hunting during the Middle Pleistocene, emphasizing its crucial role in shaping human behaviour, social structures, and survival strategies. Although existing research has predominantly concentrated on the lithic aspects of tool production, the importance of plant materials in shaping efficient hunting tools has frequently been overlooked. This paper explores the deliberate wood selection for spears, considering the physical properties, availability, and ecological implications. Exploring the plant-centric dimension of hunting tools enhances our understanding of how hominids interacted with and exploited their natural surroundings.

From the ten spears discovered at Schöningen 13 II 4, nine were made of Picea sp. wood, and one was made of *Pinus sylvestri* (Fig 5.13). The palaeobotanical data indicates the presence in the regional upland terrestrial zone of *Abies alba, Pinus sylvestris, Picea sp., Acer sp., Larix sp., and Fraxinus excelsior,* and in the local lacustrine zone featured *Alnus glutinosa, Betula sp., Salix sp.,* and *Juniperus communis*. Considering the wood availability, the choice of wood is pretty specific since the spears were made from older trees, from a 60 to 31-year-old *Picea* (Fig 5.15) (Schoch et al., 2015, p 222). The compressed rings, indicative of slow growth, likely resulted from a colder climate, showcasing a very dense hardwood. This suggests a well-thought-out decision made with a good understanding of the properties of the wood.

Another essential thing to mention is that these trees were not found in the vicinity but further upland, being part of the terrestrial environment zone. Their selection of wood suggests thorough consideration of what the alternatives were. They went for dens and hardwood but in the same lightweight and elastic that could easily be thrown, dense and hard enough to pierce the skin of a large animal (Milks, 2022 p. 9). Thus eliminating the other choices that were either too soft (*Salix, Juniperus*) or too difficult to work with (*Betula, Alnus, Fraxinus*).

From all the trees on the upland terrestrial environmental zone at Schöningen (Fig 5.16), *Fraxinus excelsior* is a hardwood, generally denser and harder than softwoods. In theory, it would be a better choice than *Pinus* and *Picea*. While hardwoods like *Fraxinus* are robust and resistant to wear, they can be more brittle than softwoods (Roszyk et al., 2020, p. 2). This increased brittleness may make them more prone to breakage, especially under specific stresses. *Pinus* and *Picea's* higher elasticity and fibrous structure make them well-suited for throwing (Milks, 2022, p.9). The flexibility allows the wood to absorb the impact shock, reducing the likelihood of breakage, and it is generally lighter than *Fraxinus*. For throwing spears, a balance between weight and strength is crucial. The moderate density of the *Pinus* and *Picea* provides an advantageous compromise (Schoch et al., 2015, p. 222-223). Hardwoods like *Fraxinus* can be denser, resulting in heavier tools. This added weight might be a disadvantage in throwing spears, where a balance between weight and aerodynamics is crucial. Hardwoods can be more challenging to work with due to their density. Crafting tools from hardwoods may require more effort and specialized techniques. As a hardwood with moderate density and hardness, *Acer* may offer some durability but could be less suitable for throwing spears due to its increased density.

From the trees on the lakeside environmental zone (Fig 5.16), *Betula*, another hardwood with good strength but less density, might lack the necessary durability for high-impact hunting activities. As softwoods with lower density and hardness, *Juniperus* and *Alnus* may compromise durability and strength, making them less suitable for robust hunting tools. *Salix*, as a softwood with low density and hardness, might lack the necessary strength for spear-making (Milks, 2022, pp. 10-11).

Therefore, the choice of *Pinus* and *Picea* over *Fraxinus, Acer, Betula, Juniperus, Alnus, and Salix* could be influenced by a balance between flexibility and durability. As softwoods, *Pinus* and *Picea* offer flexibility and sufficient durability for spear-making. Softwoods are generally easier to work with than hardwoods, which may have played a role in the selection process. The specific wood types available in the local environment could also have influenced the choices made by hominins at Schöningen.

Based on their knowledge of the wood properties, it is safe to assume that spears were not the only tools they made out of wood, only the ones that survived due to the water-logged environment in which they survived at Schöningen. The technique in manufacturing these spears marks a thorough thinking about what the final product should do. The flint scrapers cleaned the bark and carved the spear to make it more aerodynamic. The spear tip was meticulously carved from the thicker end of the branch, a deliberate choice to ensure its density for effective penetration through the skin (Schoch et al.,2015, p.220).

The crafting of a spear involves a series of mental processes and actions that could be put in a chaine operatoire of thinking through a spear-making process.

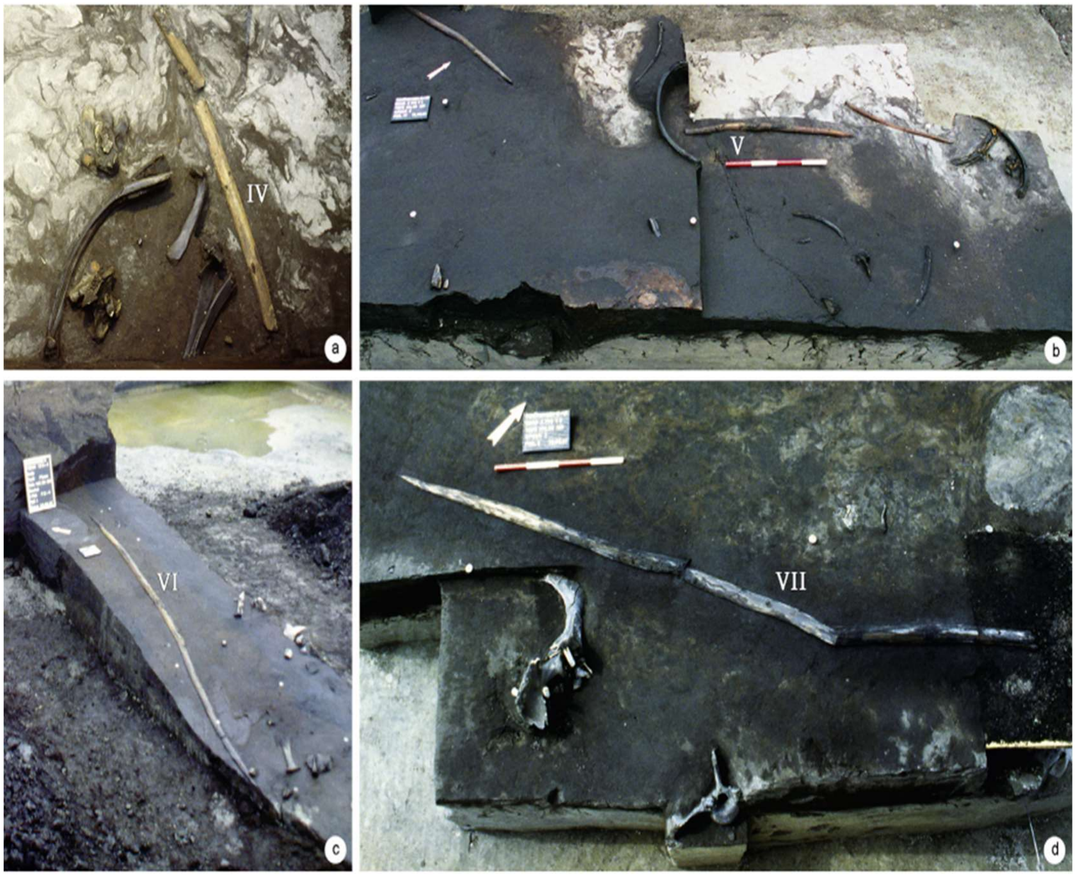


Figure 5.13.Schöningen 13 II-4. a) Part of spear IV, b) spear V, c) spear/lance VI, and d) spear VII. Photo: P. Pfarr. (Lower Saxony State Service for Cultural Heritage), taken from Schoch et al. (2015), fig.6, p 221.

Each phase reflects a thoughtful and strategic approach to crafting effective hunting tools, from identifying the need to cultural transmission.

This skillful approach emphasizes the Schöningen hominins' cognitive abilities, highlighting that Middle Pleistocene hominins were anything but simple-minded creatures. The crafting of a spear involves a series of mental processes and actions that could be put in a *chaine operatoire* of thinking through a spear-making process (Fig 5.14). Each phase reflects a thoughtful and strategic approach to crafting effective hunting tools, from identifying the need to cultural transmission.

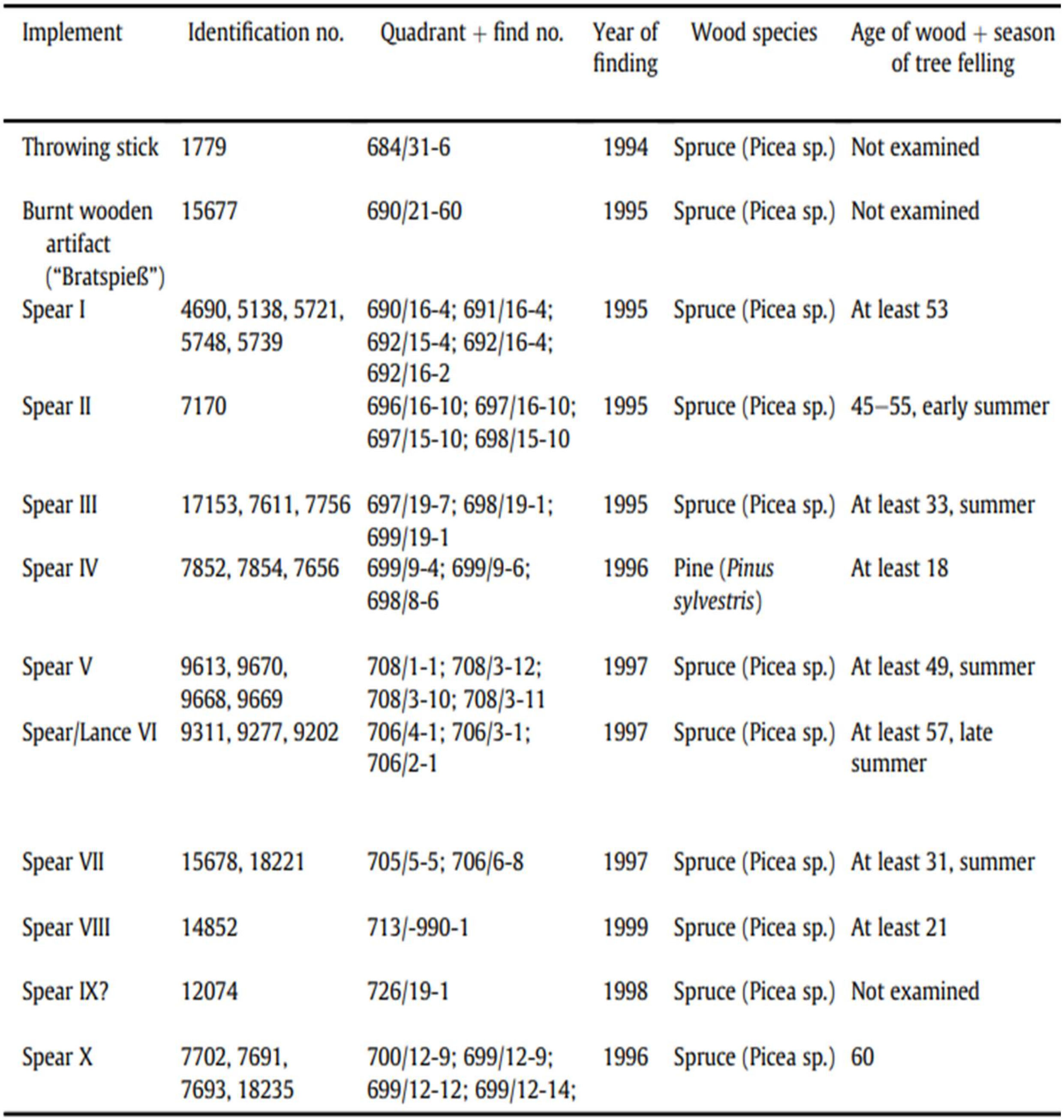
Actions	Cognitive process	Description
Phase I - Identifying the Need	**Trigger**	Recognize the need, hunger, and the need to hunt to satisfy hunger.
Phase II - Material Selection	**Decision-Making** **Consideration**	Choose suitable materials based on knowledge of local resources. Assess wood types, available stones, or bone for spear components.
Phase III - Conceptualization	**Purpose Definition** **Visualization**	Clearly define the purpose of the spear (e.g., hunting large game). Mentally conceptualize the spear's design, considering length, weight, and tip shape.

Phase IV - Tool Preparation	**Tool Selection** **Tool Crafting**	Choose appropriate tools (scrapers, hand axes) based on their effectiveness. Create or modify tools as necessary, envisioning their application in crafting.
Phase V - Hunting Strategy Formulation	**Game Assessment** **Plan of Action**	Consider the targeted prey's behaviour, size, and habitat. Devise the hunting strategy for which the spear needs to be crafted.
Phase VI - Material Processing	**Wood Shaping**	Visualize the spear considering the length and ergonomic grip, ensuring the right balance between sharpness and durability according to the hunting strategy.
Phase VII - Refinement and Optimization	**Quality Assessment** **Adjustments**	Evaluate the spear's balance, weight, and overall effectiveness Make mental adjustments for optimization, refining the design if necessary.
Phase VIII - Learning Process and Cultural Integration	**Post-Huning Learning Process**. **Cultural Integration**	Asses the spear's performance based on the wood of choice and crafting technique. Use the knowledge gained for future spear crafting and adjusting techniques for improvement.

Phase IX - Cultural Transmission	**Demonstrative Learning**	Learning by observing and imitating experienced individuals within the cultural group, facilitating skill acquisition
	Cultural Transmission	An evolutionary trait that uniquely benefits by promoting shared knowledge, adaptability, and the preservation of effective techniques across generations, securing the survival of future generations.

Figure 5.14 Table containing the possible cognitive chaine operatoire for crafting a spear at Schöningen during Reinsdorf interglacial following Haidle (2009), How to think a simple spear. Created by MF Catalinoiu

Hunting is a multi-faceted endeavor beyond throwing a spear to kill an animal. It is a comprehensive process that involves planning, strategy development, and the ability to anticipate animal behaviour. Specifically, in big game hunting, effective communication within hunting groups is essential to coordinate movements and actions. These collective actions offer a glimpse into a hominin society sufficiently organized to engage in big game hunting with a high degree of communication and cooperation. The cultural transmission of spear-crafting knowledge at Schöningen represents an evolutionary trait fostering shared knowledge, adaptability, and the preservation of effective techniques. This trait ensures the survival and thriving of hominins in their challenging Middle Pleistocene environment. The intergenerational transfer of skills and strategies underscores hominins' adaptive nature, enabling them to thrive in the complex conditions of the time.



Implement	Identification no.	Quadrant + find no.	Year of finding	Wood species	Age of wood + season of tree felling
Throwing stick	1779	684/31-6	1994	Spruce (Picea sp.)	Not examined
Burnt wooden artifact ("Bratspieß")	15677	690/21-60	1995	Spruce (Picea sp.)	Not examined
Spear I	4690, 5138, 5721, 5748, 5739	690/16-4; 691/16-4; 692/15-4; 692/16-4; 692/16-2	1995	Spruce (Picea sp.)	At least 53
Spear II	7170	696/16-10; 697/16-10; 697/15-10; 698/15-10	1995	Spruce (Picea sp.)	45–55, early summer
Spear III	17153, 7611, 7756	697/19-7; 698/19-1; 699/19-1	1995	Spruce (Picea sp.)	At least 33, summer
Spear IV	7852, 7854, 7656	699/9-4; 699/9-6; 698/8-6	1996	Pine (*Pinus sylvestris*)	At least 18
Spear V	9613, 9670, 9668, 9669	708/1-1; 708/3-12; 708/3-10; 708/3-11	1997	Spruce (Picea sp.)	At least 49, summer
Spear/Lance VI	9311, 9277, 9202	706/4-1; 706/3-1; 706/2-1	1997	Spruce (Picea sp.)	At least 57, late summer
Spear VII	15678, 18221	705/5-5; 706/6-8	1997	Spruce (Picea sp.)	At least 31, summer
Spear VIII	14852	713/-990-1	1999	Spruce (Picea sp.)	At least 21
Spear IX?	12074	726/19-1	1998	Spruce (Picea sp.)	Not examined
Spear X	7702, 7691, 7693, 18235	700/12-9; 699/12-9; 699/12-12; 699/12-14;	1996	Spruce (Picea sp.)	60

Figure 5.15 Schöningen 13 II-4: Information on the wooden artifacts containing wood species, age, and the season when it might have been cut, modified from Schoch et al.(2015), table 1, p. 216.

	Density (g/cm3)	Modulus Rupture MoR (MPa)	Modulus Elasticity MoE (GPa)	Compressive Strength Comp (MPa)	Data source
Abies alba	0.35	66	8.28	26.9	Milks, 2022
Juniperus communis	0.52	61.66	8.75	43.75	Milks, 2022; Hänninen et al., 2012
Larix sp	0.47	90	11.8	52	Milks, 2022
Picea sp	0.37	63	9.7	35.5	Milks, 2022
Pinus sylvestri	0.42	83.3	10.1	41.5	Milks, 2022
Acer sp.	O.54	53.8	9.79	40.1	Milks 2022
Alnus glutinosa	0.44	75.9	9	42.2	Milks, 2022
Betula sp	0.53	114	13.9	51.4	Milks, 2022

Fraxinus excelsior	0.66	106.6	12.31	79.9	Roszyk et al., 2020
Salix sp.	0.28	56.2	7.76	26.9	Milks,2022

Figure 5.16 Table containing the available types of wood and their properties (density, elasticity MoE, resistance to breakage MoR, resistance to compression Comp) at Schöningen during Reinsdorf interglacial corresponding to sublayer II4c. Modified from Milks (2022) table 2, p. 14

While refocusing on the central question of hominin behaviour from a plant-centered perspective, a different story emerges in the lakeside environment of Schöningen during the Reinsdorf interglacial, particularly within sublayer II 4c. This narrative uncovers a connection between hominins and their natural surroundings, where their survival and sustenance are closely linked. The lake's presence is the key to enabling all of this. It serves as the rendezvous point for hunters and prey, whether hominins, other mammals, or even the tiniest insects. Animals of all sizes congregate here to satisfy their hunger and thirst.

5.2.2. Exploring the Potential of Plant Nutrition

The question of the dietary use of plants has been a longstanding debate in the tapestry of human evolution. The image of hominins as primarily meat-eaters is being reshaped by mounting evidence of their engagement with plant-based foods. Botanical macrofossils, often overshadowed by their more conspicuous animal counterparts, are emerging as critical pieces in the dietary puzzle, indicating the substantial role that plant consumption played in the lives of Middle Pleistocene hominins.

Supporting this notion, archaeological finds reinforce the idea of plants being integral to the Middle Pleistocene hominin diet. While the presence of animal bones displaying cutmarks or charring is an indicator of meat consumption, such evidence abounds in the archaeological record. In contrast, discerning the presence of plants in the hominin diet demands a distinct approach. This entails sediment analysis to identify phytoliths, scrutiny of dental calculus for starches (Henry et al., 2011, p. 490), and thoroughly examining botanical macrofossils to deduce their potential use as food resources. Yet, teeth provide more than calculus as evidence for a plant-based diet; assessing enamel thickness and studying wear patterns on teeth can offer valuable insights into the types of foods that early humans might have consumed. This becomes especially significant when investigating archaeological sites where human fossils are often scarce or absent.

Moreover, teeth offer more than calculus as proof of plant consumption. Assessing enamel thickness and deciphering the wear patterns on teeth can signal the types of foods hominins might have consumed. Therefore, previous studies examining tooth size, wear patterns, and enamel thickness have provided evidence of a diverse diet, including nuts, seeds, fruits, tough fibrous plants, and meat (Pontzer et al., 2011; Lucas et al., 2008).

For instance, *Paranthropus robustus*, a hominin species from around 2 million years ago, displayed thick enamel on their teeth, indicating a diet rich in fibrous plant material (Sponheimer et al., 2006, p. 980). Additionally, studies of dental wear patterns on the teeth of *Neanderthals* (Bocherens et al., 2016) and *H. erectus* reveal distinct enamel pitting and chipping patterns consistent with the abrasive nature of plant-based diets (Pontzer et al, 2011, p. 686). Sima de los Huesos (430kay to 600kay) from Spain, where 1600 hominin bones were found belonging to species like *H heidelbergensis* and *early Neanderthals*, is an illustrative example. Analysis of dental remains from this site uncovered microwear patterns consistent with the mastication of tough plant material. This bolsters the notion that Middle Pleistocene hominins actively processed and consumed plants, showcasing their adaptability in obtaining essential nutrients from the plant kingdom.

While dental calculus primarily contains mineralized deposits formed from saliva and food particles adhering to teeth, it can capture starch grains and other micro-remains like plant particles and microfossils. Starch grains, microscopic granules of plant starch, are a good indicator of plant consumption. They become trapped in dental calculus when individuals consume starchy plant foods. Researchers extract and analyze these starch grains to identify the types of plants consumed (Copeland & Hardy, 2018, p. 3). Starch grains can also be found on the surfaces of archaeological artifacts like grinding stones or tools used for processing plants, offering specific information about the plant species incorporated into the diet (Henry, Brooks & Piperno, 2014, p. 45). For example, at the El Sidrón cave in Spain, Neanderthal dental calculus contained traces of plant starch granules, including legumes and grasses (Radini et al., 2016, p. 291). This emphasizes the use of plants in their diet and challenges the simplistic view of Neanderthals as primarily carnivorous. The study of dental calculus from Qesem Cave in Israel revealed microfossils of plant tissue starch grains, indicating the ingestion of diverse plant species (Kovárník & Beneš, 2018, p. 89).

Phytoliths, microscopic silica particles formed within plant cells, are another crucial indicator of hominin plant use. Phytoliths can be found within sediments and soils, often preserved in layers reflecting the environmental conditions of the time (Neumann et al., 2017, p. 2). At the Gesher Benot Ya'aqov site in Israel, excavations revealed numerous plant macrofossils dating back nearly 780,000 years, including seeds and fruits. This diverse plant repertoire suggests that early humans were not just opportunistic carnivores but actively incorporated a significant amount of plant material into their diets (Melamed et al., 2016, p. 14677).

Furthermore, examining archaeological sites in different regions provides a rich tapestry of evidence for plant consumption. For instance, the Tabun Cave in Israel, dating back approximately 400 ka, yielded seeds and plant phytoliths, indicating the incorporation of plants into the diet, potentially by *Homo erectus* (Albert Cristóbal,1999, pp. 5-6). Stone tools and evidence of animal hunting also suggest a diverse diet. Similarly, the Amud Cave in Israel, from around 500 ka to 250 ka, contains phytoliths, seeds, and plant fibers, pointing to plant use as a food source by early hominins (Madella et al.,2002, p. 705). The presence of plant materials complements the evidence of meat consumption from animal bones.

In conclusion, the tapestry of evidence supporting the role of plant consumption in the Middle Pleistocene hominin diet is rich and diverse. It draws from meticulous analyses of dental remains, dental calculus examination, and botanical macrofossils and phytoliths at various archaeological sites. This collective evidence underscores the adaptability and resourcefulness of early humans in utilizing plant resources, adding depth to our understanding of their dietary choices and the complex interplay between hominins and the plant kingdom during this period.

With the established argument regarding including plant consumption in the hominin diet, the next step is to transition to the Schöningen site and analyze the possible edible plant species in my dataset. This analysis will be followed by adding the potential edible plant species identified in the studies conducted by Bigga (2018) and by Bigga et .(2015).

Before delving into the discussion of potential edible plants present at Schöningen sublayer II 4c, it's crucial to acknowledge the dual nature of plants. As captivating as they are, plants can also pose significant risks. While we observe them being consumed by herbivores, birds, and insects, and their mere appearance might instill a sense of safety, it's essential to recognize that plants, like everything in our environment, contain chemical compounds ranging from deadly to harmful or beneficial. Humanity has undergone extensive trial-and-error processes to navigate this complex world of plants and distinguish between friends and foes, gradually accumulating plant knowledge over generations. Therefore, we could evaluate the possibility of a plant not only by sight and smell but by using the sense of taste. All these senses combined could decipher the potential deadliness in a plant.

The tongue is responsible for our sense of taste. It has taste buds that detect different flavors (Fig 5.17). Taste buds are small sensory organs on the tongue and some parts of the oral cavity. They contain specialized cells that respond to various chemical compounds in our food, allowing us to perceive different tastes. The tongue is divided into different regions, each sensitive to tastes such as sweet, sour, salty, bitter, and umami (Thomas et al.,2022, pp. 251-255).

The distribution of taste sensitivity on the tongue is quite specific:

- The tip and front part of the tongue are highly attuned to sweet tastes. Taste buds in this area are responsive to sugars and sweet substances. These sweet substances, primarily carbohydrates, are recognized as beneficial for various bodily functions, including brain activity, energy levels, and metabolic processes.

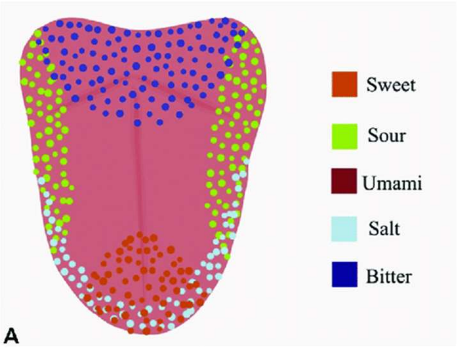


Figure 5.17 Taste areas: sweet, bitter, sour, salt, umami. Taken from Thomas et al.(2022), fig 3 , page 254.

- Moving to the sides of the tongue, we find sensitivity to both sweet and salty tastes. Taste buds on the sides can identify sugars and salts in our food. The detection of salt taste helps identify sodium. It is essential for maintaining electrolyte and fluid balance, regulating blood pressure, ensuring pH stability in the body, and supporting proper nerve and muscle function.
- The back part of the tongue specializes in detecting bitter tastes. Taste buds here are acutely responsive to bitter compounds, often associated with potentially harmful or toxic substances in food. The ability to recognize bitterness serves as an important warning signal.
- In the central region of the tongue, taste sensitivity is less specialized, and one can perceive a broader range of flavors, including sour and umami. Sour taste buds respond to acidic substances, specifically vitamin C, serving as a defense mechanism to assess the safety of foods. They help determine if a fruit is safe to consume and hasn't yet spoiled, preventing potential ingestion of fungal or bacterial contamination or fermented products with an alcohol content that could induce nausea and vomiting. Additionally, umami taste buds are sensitive to savory and meaty flavors, aiding in identifying protein presence in the food.

The moment when we acquired the ability to taste different flavors it could be pinpointed with precision through molecular clock dating method. This method is used in evolutionary biology to estimate the timing of evolutionary events based on changes in DNA or protein sequences over time (Dos Reis et al., 2016, p. 71). We can date when these sensory traits, such as taste perception, were developed in our ancestral lineages. The exciting prospect lies in our imminent discovery of when we gained the ability to discern the diverse tastes of sour, sweet, salty, bitter, or umami. This revelation will finally settle the long-debated question about the varied diet of hominins. We can construct a comprehensive chronology of our dietary preferences and habits by establishing a timeline for when these taste abilities emerged.

From the total number of plants identified at Schöningen that incorporate the dataset and those cataloged in Bigga2018 and 2015 studies, the most promising plants for consumption were selected without necessitating cooking. These chosen plants possess qualities that make them appealing, including vibrant colors, attractive fruits and flowers, and a pleasing taste profile that encompasses fruits, shoots, and leaves (Fig 5.18).

Foraged edible plant parts exhibit distinct seasonality. Spring emerges as a crucial period, especially after the rigors of winter, when hominins must enhance their diet with an influx of vital vitamins and carbohydrates. During this season, the focus often shifts to young shoots, buds, leaves, and inner bark (Zackrisson et al.,2000, pp. 100-101). One significant reason for this preference is that plants are amassing reserves of nutritious sap to fuel new growth in shoots, stems, leaves, and buds. Young shoots tend to be less tangy because they contain fewer tannins. This dynamic changes as the plant or tree becomes clothed in leaves, marking the commencement of a new cycle. During the early spring, the inner bark of pine and spruce trees, known as cambium, transforms. It accumulates water, sugars, and vital nutrients such as vitamin C (Blanche et al.,1992). As buds and flowers appear, the plant's energy and nutritive sap become dedicated to its development. When the flowers start to fade, the plant directs its entire reservoir of energy and nutrients toward the maturation of fruits and seeds. Consequently, the leaves and other plant parts begin to wither during this phase. Seeds and fruits, in essence, represent the culmination of nutritional enrichment.

Botanical name and common name	**Part used for consumption**	**Foraging season**	**Source**	**Reference**
Abies alba/ Siver fir	inner bark	Spring	Bigga, 2018	Jman Rdezic, 2006
Acer sp./ Maple	Young shoots, sap	Spring	Bigga, 2018	Lans et al., 2007
Betula sp./ Birch	inner bark, sap, leaves, flowers	Spring	Schöningen 12 II 4c dataset	Angier, 2008
Bidens sp./ Spanish needles	Raw young leaves and flowers	Summer	Schöningen 12 II 4c dataset	Liang et al., 2020
Carex sp. / Sedges	Some species have edible roots and seeds.	Spring to Summer	Schöningen 12 II 4c dataset	Thomasson, 1983
Chenopodium sp./ Goosefoot	Young shoots and leaves contain vitamin C; seeds are consumed raw or cooked.	Spring to Summer	Schöningen 12 II 4c dataset	Guil, Rodríguez-Garcí & Torija,1997
Corylus avellana/ Hazelnut	seeds	Late Summer	Bigga et al., 2015	Pardo-De-Santayana et al., 2005
Fraxinus excelsior/ European Ash	Seeds and young shoots, raw	Spring to late Summer	Bigga, 2018	Montó et al., 2014;
Hippuris vulgaris/ Mare`s tail	Young shoots that taste like asparagus and young leaves, eaten raw	Spring to Summer	Schöningen 12 II 4c dataset	Ager &Ager, 1980
Myriophyllum spicatum/ Watermilfoil	Roots are sweet and crunchy, eaten raw	Spring	Schöningen 12 II 4c dataset	Moerman, 1988
Persicaria cf. hydropiper/ Water pepper	peppery spiciness used raw	Spring to Summer	Schöningen 12 II 4c dataset	Ibadullayeva et al, 2021; Shiraliyeva et al., 2021

Picea sp. / Spruce	Inner bark, seeds, shoots	Spring	Bigga et al., 2015	Svanberg, 2012
Pinus Sylvestri/ Pine tree	Inner bark, shoots, pollen	Spring	Bigga et al., 2015	Zackrisson et al, 2000
Phragmites australis/ Common reed	Leaves, shoots, stems, seeds, and roots contain starch and sugars.	Spring, Summer	Bigga et al., 2015	Zhang et al., 2016
Potamogeton alpinus/ Alpine pondweed	Root raw or cooked, nutty flavor	Spring	Schöningen 12 II 4c dataset	Moerman, 1988;
Potamogeton crispus/ Curly pondweed	Young leaves and roots, cooked or raw	Spring	Schöningen 12 II 4c dataset	Moerman, 1988;
Ranunculus sceleratus/ Celery leaved buttercup.	Poisonous	No foraging	Schöningen 12 II 4c dataset	Ozturk et al.,2008
Rubus fruticosus/ Blackberry	Fruits contain vitamins C and K and minerals.	Late Summer to Early Autumn	Schöningen 12 II 4c dataset	Meng et al., 2022
Rumex maritimus/ Golden dock	Young leaves eaten raw or cooked, contain oxalates	Spring	Schöningen 12 II 4c dataset	Oztuk et al.,2008; Shiraliyeva et al., 2021
Salix sp./ Willow tree	Young leaves, inner bark	Spring	Bigga et al., 2015	Matyjaszczyk & Schumann, 2018
Sambucus nigra/ Elderberry	Flowers fruits after thermic processing	Late Summer	Bigga et al., 2015	Sidor & Gramza-Michałowska, 2015
*Schoenoplectus lacustris/*Common club-rush	Root raw or cooked, buds on the rhizomes crisp and sweet are eaten raw, young shoots raw or cooked, seeds, stems raw or cooked, pollen raw or cooked.	Spring to Summer	Schöningen 12 II 4c dataset	Jain et al., 2011

*Sparganium erectum / B*ur-reed	Tubers and stems, raw or cooked	Spring to Summer	Schöningen 12 II 4c dataset	Aranguren et al., 2011
Stuckenia pectinata/ Sago pondweed	Highly nutritious tubers, leaves, and seeds	Spring to Summer	Schöningen 12 II 4c dataset	Downard et al.,2017
Typha/ Common cattail	Leaves, stem, flowers, root	Spring, Summer	Bigga et al., 2015	Gott, 1999
Viola sp./ Violet	Leaves and flowers raw	Spring	Schöningen 12 II 4c dataset	Jman Rdezic, 2006

Figure 5.18 Table containing the edible plants identified at Schoninger during Reinsdorf interglacial corresponding to sublayer II4c. It includes the scientific and common names, edible parts, and foraging season to which the study belongs and references. Created by MF Catalinoiu

.

The question arises: Why would humans turn to plant consumption in the spring when they typically manage during the autumn and winter when plants are scarce? Hominins were omnivores (Sponheimer et al., 2006, p. 980) as all the studies on teeth morphologies indicate, and it is safe to assume that they were supplementing their diet with plants in the seasons when edible plants were more abundant. One significant reason is the body's need for essential vitamins, which often remain unmet with a winter diet primarily focused on protein. Vitamin C stands out among these vitamins, as it prevents diseases like scurvy associated with its deficiency (Durzan, 2009, p. 2). The heavy consumption of meat also leads to gout, a type of arthritis that occurs when there is a buildup of uric acid in the body, leading to the formation of sharp, needle-like crystals in and around the joints (Roddy & Doherty, 2010). These crystals can cause severe pain, inflammation, and other symptoms. Another reason would be that their active lifestyle necessitates the carbohydrates that an additional plant consumption might bring (Hardy et al., 2022, pp. 5-10) following the colder climate in North Europe at that time (Ponzer & Wood, 2021). Hence, it could be reasonably inferred that their diet comprised a balanced blend of plant and protein sources, particularly during seasons when plant resources were readily available.

But there is another reason they might have chosen to add plants to their daily diet, which will result from the `rabbit starvation syndrome` or protein poisoning (Hardy & Moncel, 2011, p. 1). Protein poisoning, commonly referred to as rabbit starvation or mal de caribou, occurs when individuals consume excessive amounts of lean protein without sufficient intake of fats and carbohydrates. Historical observations of this condition are notable among certain Native American populations and Arctic explorers who heavily relied on lean game meats for sustenance (Gadsby & Steele, 2004, pp. 48-55). It can also manifest in spring when animals shed their winter fat layer. When protein intake exceeds the body's metabolic capacity, various issues may arise. Optimal energy production depends on a balanced intake of macronutrients, and an overabundance of protein without adequate fats and carbohydrates can lead to high energy expenditure for lean protein digestion, resulting in ketosis, dehydration, electrolyte imbalance, and gastrointestinal problems (Noli & Avery, 1988, pp. 396-397). Prolonged persistence of these issues could potentially lead to fatal consequences.

The lake margins at Schöningen were a treasure trove of foraging opportunities, even with this partial list of available plants. They provided diverse edible resources for early hominins, including starchy tubers, crisp, sweet, nutty shoots, and tender young leaves. These resources were sourced from aquatic and macrophyte plants like *Hippuris vulgaris, Myriophyllum, Potamogeton, Schoenoplectus, Sparganium*, *and Stuckenia*. While these plants are known for their natural water-filtering properties, gathering them from eutrophic waters can introduce potential health risks. Eutrophic waters, characterized by high concentrations of phosphates, nitrates, and other toxins often brought about by algal blooms, pose a concern when ingesting parts of these plants. The accumulation of these contaminants in the plants can lead to health issues upon consumption (Melaram et al., 2022, pp. 1-3).

The lake margins were a continuous attraction for hominins throughout the year due to the wide variety of edible parts offered by plants like *Phragmites, Typha*, and *Schoenoplectus*. Early spring enticed foragers with the roots of these plants, followed by shoots in spring stems, flowers, and pollen in early summer. The seasonal progression culminated in late summer and early autumn when the seeds of these plants became ripe for the picking.

Spring graced the lake margins with beautiful flowers such as *Bidens* and *Viola*, adding a delightful touch to the hominins' diet. Additionally, the pepperiness of *Persicaria* contributed a unique flavor to their meals during spring, while the rich, fragrant blossoms of *Sambucus* enhanced their experience in the summer. The season extended into late summer with the temptation of delicious blackberries and elderberries, offering a satisfying conclusion to their foraging endeavors. As autumn arrives, the season of nuts begins, marked by the delectable offerings of Corylus.

While plant resources may have a limited availability, this can be advantageous. It ensures a more diverse diet and prevents the accumulation of specific chemical compounds in the body. Plants like *Rumex* and *Chenopodium* species contain oxalates, and it is advisable to consume them in shorter durations to avoid potential health risks associated with extended consumption. In Romania, plants like *Rumex* (known as Stevia) and *Chenopodium* rubrum (referred to as Loboda) have a traditional place in the diet, primarily during the spring months of March and April. During this season, the leaves of these plants remain crisp and are rich in essential nutrients such as vitamins C, E, and K, as well as calcium, potassium, magnesium, and zinc. We turned to these plant sources to compensate for the deficiency of essential vitamins during the winter. As we do today, reliable fresh fruits and vegetables are available year-round, but this was not always feasible back then. These plants are commonly consumed raw in salads and cooked like spinach. Cooking them is a practical step as it helps to reduce the oxalate content.

The environmental reconstruction and the list of plants identified at Schöningen, whether through pollen analysis or macrofossil examination, provide only a partial glimpse of the likely environment. As a result, the range of plant-based food options might have been even more diverse than currently understood. Although incomplete, the list of plants at Schöningen Lake margins exemplifies the varied and nutritious resources available to hominins throughout the year, showcasing their resourcefulness in adapting their diet to the changing seasons, showing that the hominins in the past were likely acutely attuned to these intricacies of plant and tree life cycles. This awareness informed their foraging strategies, which adapted following the changing seasons. While it may be challenging to offer definitive proof of these practices, insights gleaned from ethnoarchaeological studies of contemporary hunter-gatherer societies suggest that a deep understanding of the evolving dynamics within the life cycles of plants and trees backed up their strategies. This understanding highlights, once again, their advanced cognitive abilities, raising questions about our current knowledge of the hominins at Schöningen.

5.2.3. Exploring the Potential of Medicinal Plant Use

Demonstrating self-treatment behaviours through archaeological discoveries presents a unique set of challenges, even more so than tracing plant diets. This is mainly due to the interpretive nature of the evidence. Even if we uncover pollen and macrofossils of medicinal plants at specific archaeological sites, these findings remain subject to interpretation. Skeptics might argue that the wind carried in these remains or was merely a part of the grasses that early hominins used for bedding (Solecki, 1975, p. 880). The intricate balance between scientific evidence and interpretation underscores the complexity of unearthing hominins' self-treatment practices mainly because it is still unclear whether it is a result of Lamarckian inheritance (Burkhardt, 2013, p. 796) when the treats are transmitted genetically, meaning that their knowledge regarding the self-treatment is a result of genetically transmitted information. Or whether these behaviours are predominantly adaptive responses to immediate environmental challenges and health concerns. Self-treatment behaviours are typically learned or instinctual responses specific to individuals' conditions within a single generation, which are transmitted through learning to the next generation (Neco et al., 2019, p. 377). As learning behaviour, self-treatment behaviours are linked to cognitive abilities such as problem-solving, memory, social learning, decision-making, tool use, and general intelligence. The self-treatment demonstrates their capacity to adapt to challenges and utilize their cognitive abilities to learn how to address health-related issues effectively.

An argument favoring self-treatment behaviour is that it's not exclusive to humans but extends to animals, birds, and insects. For example, chimpanzees consume *Aspila* spp. and *Lipia plicata* leaves to address stomach issues. Marquis apes ingest *Veronica amigdalina* for treating intestinal worm infestations and estrogen intake. Arboreal primates consume clay to neutralize plant toxins and regulate stomach pH. Baboons eat *Balanites aegyptica* to prevent trematode worm infestations (Glander, 1994, pp. 277-278). Amazonian parrots consume clay to counteract toxins ingested from the plants they eat to aid in digestion (Brightsmith et al., 2018, p. 113). Bees forage resin to combat fungal infections in their hives (Simone-Finstrom & Spivak, 2012, p.1), while Monarch butterflies utilize milkweed to combat parasites (Shurkin, 2014, p. 17340). Elephants turn to *Entada schefferi* for pain management, while wild dogs, bears, and jackals consume *Carey arborea* and *Dalbergia latifolia* to combat intestinal worms and parasites (Huffman, 2003, p. 372). Sheep also exhibit self-treatment behaviour by grazing specific plants, consuming soil as needed, or rubbing against plants as an insect repellent (Villalba et al., 2006, p. 1137). Archaeology identified the presence of plants through two main sources: within the sediment layers of notable open-air sites like Gesher Benot Ya'aqov, dating back to approximately 780,000 years (Goren-Inbar, 2020, p. 2456), Kebara Cave, which is around 60,000 years old (Lev et al., 2005, p. 476), and within the dental calculus of ancient individuals, as seen in the case of Qesem Cave, with an age of approximately 420,000 years (Hardy, 2016, p. 129), and El Sidron, where evidence of plants like yarrow and chamomile have been identified (Hardy et al., 2013, p. 873).

Botanical name and common name	**Parts used**	**Medicinal uses**	**Data source**	**Reference**
Abies alba/ Common Silver Fir	Inner bark, needles, resin, shoots	Skin problems, expectorant, antimicrobial	Bigga 2018	Papp et al., 2022
Acer sp. / Maple	Sap, inner bark, seeds, leaves	Sap for sore eyes, bark infusion for blindness, cough, blood purifier, and skin ailments	Bigga 2018	Unger et al.,2014; Moerman, 1988
Alnus glutinosa / Ash tree	Leaves, inner bark, sap	Leaves are used for treating bleeding wounds, and the bark contains salicin used for cholera, stomach cramps, anemia, colds, and laxatives, and it regulates menstruation. Sap for skin problems, ulcers, and sores	Schöningen 12 II 4c dataset	Heinsen, 1972; Uchytil, 1989; Moerman, 1988; Goodrich et al., 1980.

Phragmites australis/ Common Reed	Shoots, seeds,	Arthritis, bronchitis, cholera, cough, diabetes, diarrhea, fever, gout, jaundice, leukemia, nausea, rheumatism, sores, stomach pains, typhoid fever, rhinitis, bacterial meningitis, and seeds as an aphrodisiac	Bigga et al., 2015	Kiviat & Hamilton, 2001
*Betula sp./*Birch	Raw or boiled leaves, inner bark, leaves,	Skin disease, kidney problems, rheumatic pains, asthma, cold, stomach illnesses, arthritis	Bigga et al., 2015	Rastogi et al., 2015
Bidens sp./ Spanish needles	Leaves, and flowers, raw	Treat sore eyes, swollen glands, toothaches, juice for burns, conjunctivitis, ulcers, fever, rubella, scarlatina, and diuretics.	Schöningen 12 II 4c dataset	Zuleta et al., 1995; Kokwaro, 1976
Carex sp. / Sedges	Roots, seeds, raw, boiled	Treats bronchitis, abdominal and stomach disorders, liver problems, arthritis, rheumatism, skin problems	Schöningen 12 II 4c dataset	Noori et al., 2015
*Chenopodium sp./*Goosefoot	Young leaves, seeds, raw or boiled	Antimicrobial and worm infestation, anti-inflammatory, cough, pulmonary obstruction, abdominal pain	Schöningen 12 II 4c dataset	Yadav et al., 2007
Corylus avellana/ Hazelnut	Leaves, flowers, inner bark, catkins, nuts	Stimulates blood circulation and bile secretion and fights liver problems, astringent, and fever. Induces wound healing and sweating.	Bigga et al., 2015	Rosa, 2022
Fraxinus excelsior/ White Ash tree	Leaves, seeds, inner bark	Leaves as tonic for after childbirth, seeds aphrodisiac, diuretic, emetic, and fever. Bark for lice, snakebite, itching, sores, antiaging, anticancer, antihypertensive	Bigga 2018	Middleton et al., 2005; Moerman, 1988
*Hippuris vulgaris/M*are`s tail	Raw leaves as juice	Wound healing	Schöningen 12 II 4c dataset	Grieve & Herbal, 1984
Myriophyllum spicatum/ Watermilfoil	Roots, raw or boiled	Sore throat, cough, fever, stomach problems	Schöningen 12 II 4c dataset	Moerman, 1988
Persicaria cf. hydropiper/ Water pepper	Leaves, raw	Astringent for wounds and skin problems. Anti-inflammatory, diuretic, stimulant effect, carminative remedy for toothache, gout, rheumatism, hemorrhoids	Schöningen 12 II 4c dataset	Grieve, 1984; Foster & Duke, 1990; Shiraliyeva et al., 2021

*Picea sp. / S*pruce	Inner bark, shoots, seeds, cones, resin	Treats lung problems, wounds, and sores. Inner bark and shoots treat throat problems, coughs, colds, rheumatism, stomach pains, constipation, gonorrhea, and snow blindness. Cones for rheumatic pains. Resin is an antiseptic used for skin problems and diarrhea.	Bigga 2018	Moerman, 1988; Svanberg et al., 2012
*Pinus Sylvestri/ P*ine tree,	Needle, inner bark, resin, raw and boiled	Treats coughs, colds, allergies, urinary and sinus infections, skin infections, arthritis, headaches and a good source of vitamin C	Bigga et al., 2015	Moerman, 1988; Svanberg et al., 2012
*Rubus fruticosus/ B*lackberry	Fruits, leaves, young shoots, raw or boiled	Treats cough, colitis, anemia, dysentery, diarrhea, cancer, skin problems, ulcers, sore throat, hemorrhoids, fluid retention, gout, bleeding, heart disease	Schöningen 12 II 4c dataset	Krauze-Baranowska, 2014; Verma et al., 2014; Zia-Ul-Haq et al., 2014
*Rumex maritimus/G*olden dock	Young leaves, roots, seeds, raw or boiled	Leaves raw for burns and ringworm, seeds as aphrodisiac, roots for skin disease	Schöningen 12 II 4c dataset	Khaliq et al., 2023; Shiraliyeva et al., 2021
Salix sp./ Willow tree	Inner bark	Contains acetylsalicylic acid(aspirin), and treats pains, inflammation, and fever	Bigga et al., 2015	Tawfeek et al.,2021
Sambucus nigra/ Elderberry	Flowers, fruits, raw or boiled	It treats conjunctivitis, constipation, diabetes, diarrhea, headaches, rheumatism, skin problems, flu, colds, coughs, infections, heals burns, and improves complexion.	Bigga et al., 2015	Ulbrich et al., 2014; Wichtl & Bisset, 1994
Schoenoplectus lacustris/ Common club-rush	Roots	Astringent and diuretic, treats cancer	Schöningen 12 II 4c dataset	Chopra & Nayar, 1956; Duke & Ayensu, 1985
Sparganium erectum / Bur-reed	Leaves, root	Chest and abdominal pains, chills	Schöningen 12 II 4c dataset	Moerman, 1988
Typha/ Common Cattail	Flowers, stems, pollen, leaves,	Flowers stop wound bleeding and heal burns. Stem diuretic and astringent. Leaves are analgesic, diuretic, and antioxidant. Pollen is		Sezik et al., 2022

		stringent, desiccant, and soothing for uterine bleeding in postpartum and abscesses. Roots are anti-inflammatory, antioxidant, and diuretic.	Bigga et al.,2015	
Viola sp./ Violet	Flowers, leaves, raw or boiled	Treatment for cough, headache, migraines, epilepsy, insomnia, respiratory problems, pain, fever, infection, inflammation, and bronchitis.	Schöningen 12 II 4c dataset	Mahboubi & Kashani, 2018

Figure 5.19 Table containing the possible medicinal plant from the list of edible plants and their medical effects. Created by MF Catalinoiu

These discoveries not only imply that plants were a part of the dietary practices of these ancient populations but also raise the possibility of medicinal applications, given the presence of plants known for their medicinal properties.

Considering that self-treatment behaviour is observed not only in primates but also in various other animals. Since plants were already a part of the diet of hominins and hominins displayed cognitive abilities, it's reasonable to infer that they were familiar with the medicinal properties of these plants (Fig 5.19). This suggests that hominins likely used these plants for medicinal purposes regularly.

Due to their lifestyle and environment, the hominins might have suffered from various open wounds, fractures, and muscle sprains induced by hunting, wild animal encounters, environmental hazards, and fighting. Skin affections are caused by worms, fungi, and bacteria due to their contact with infested waters, the environment, and insect bites. Stomach, liver, and intestinal diseases are caused by ingesting contaminated meat, plants, and water. Anemia and vitamin deficiencies are caused by their diet, especially during the late Autumn and Winter seasons. Problems with childbearing and birth and postpartum. As well as diseases caused by nutrition or genetically transmitted alignments that could affect heart, blood pressure, and blood circulation (fig 5.20).

But what would have been the implications of this behaviour for the Hominins of the Middle Pleistocene at Schöningen corresponding to sublayer II 4c?

These behavioural implications could have affected on:

- **Evolutionary Significance:** The ability of early hominins to engage in self-treatment using medicinal plants could have carried evolutionary implications (Spikins et al.,2019, p. 98). Those who could effectively use these plants for healing and relief from injuries and illnesses may have experienced lower mortality rates, improved survival, and greater reproductive success. This could have led to the selection and persistence of this valuable trait over generations.

  Group Dynamics and Communication: The knowledge of medicinal plant use was not instinctual but learned and culturally transmitted among Middle Pleistocene hominins at Schöningen. This cultural transmission contributed to a shared knowledge base within their group. This raises questions about their communication methods. Did they rely solely on imitation or communicate beyond body language? If so, it suggests that Modern *Homo sapiens* might not be the sole possessors of effective communication. This further underlines the need to explore the cognitive capabilities of Schöningen hominins.

Type of Injuries	Possible medicinal plant used	Reference
Lacerations, open wounds, abrasions, puncture wounds caused by hunting, accidents, fighting, wild animals, and environmental hazards.	*Alunus*- leaves *Abies, Pinus, Picea- re*sin, needles shoots, bark *Acer, Betula, Chenopodium, Hippuris, Persicaria, Carex* – leaves *Rumex*- root *Sambucus* – flowers *Typha* – flowers and pollen	Papp et al, 2022; Moerman, 1988; Heinsen, 1972; Rostogi et al., 2015; Noori et al., 2015; Yadav et al., 2007; Grive & Herbal, 1984; Grieve, 1984; Foster & Duke, 1990; Khadiq et al.,2023; Ulbrich et al., 2014; Wichtl & Bisset, 1994; Sezik et al, 2022; Shiraliyeva et al., 2021
Burns from managing fire	*Rumex*- young leaves *Sambucus*- flowers *Bidens*- flowers and leaves *Typha*- flowers	Zuleta et al., 1995; Khadiq et al.,2023; Ulbrich et al., 2014; Wichtl & Bisset, 1994; Sezik et al, 2022; Shiraliyeva et al., 2021
Skin affections are caused by worm, fungal, and bacterial agents caused by highly infested waters, insect bites, scratches, and contact with rotten meat, plants, or other hominins.	*Alnus*- leaves *Abies, Pinus, Picea*- resin, poultice from needles, shoots, bark *Acer*- sap *Betula, Chenopodium, Persicaria, Carex* – leaves	Moerman, 1988; Heinsen, 1972; Papp et al., 2022; Rostogi et al., 2015; Noori et al., 2015; Yadav et al., 2007; Grieve, 1984; Foster & Duke, 1990; Krauze-

	Rumex- root *Sambucus* – flowers *Rubus* – leaves, young shoots	Baranowska, 2014; Verna et al, 2014; Ulbrich et al., 2014; Wichtl & Bisset, 1994; Khadiq et al.,2023; Svanberg et al.,2012.
Insect bites	*Fraxinus* – leaves *Typha*- pollen	Moerman, 1988; Middelton et al., 2005
Snake bites	*Fraxinus*- leaves, inner bark	Moerman, 1988; Middelton et al., 2005
Intestinal/ stomachal/ liver problems caused by ingestion of infested meat, plants, water	*Alnus, Betula* – inner bark *Bidens, Rubus* – leaves, young shoots *Picea*- shoots, inner bark *Corylus – shoots,* leaves *Phragmites* - shoots	Moerman, 1988; Heinsen, 1972; Kiviat & Hamilton, 2001; Rosa, 2022; Rostogi et al., 2015; Zuleta et al., 1995; Krauze-Baranowska, 2014; Verna et al., 2014; Svanberg et al., 2012.
Eye affection, blindness, soreness,	*Acer*- sap and inner bark *Bidens*- leaves and flowers *Picea*- inner bark	Moerman, 1988; Zuleta et al., 1995; Svanberg et al., 2012.
Respiratory tract problems	*Abies*- shoots, needles, inner bark *Acer*- inner bark *Phragmites*- shoots *Carex*- leaves, root *Chenopodium* – seeds *Picea*- shoots, inner bark *Pinus*- shoots, inner bark *Viola*- flowers and leaves	Papp et al., 2022; Moerman, 1988; Yadav et al., 2007; Kiviat & Hamilton, 2001; Noori et al., 2015; Svanberg et al., 2012; Mahboubi & Kashani, 2018.
Kidney, rheumatic, and arthritis problems	*Betula*- leaves and inner bark *Carex*- roots and leaves *Picea*- shoots, inner bark *Pinus* - shoots inner bark *Phragmites*- shoots *Rubus*- leaves, young shoots *Sambucus*- flowers, fruits	Kiviat & Hamilton, 2001; Noori et al., 2015; Rostogi et al., 2015; Krauze-Baranowska, 2014; Verna et al., 2014, Moerman, 1988; Svanberg et al., 2012; Ulbrich et al., 2014; Wichtl & Bisset, 1994.
Bone fractures and muscle sprains	*Corylus*- inner bark, leaves *Fraxinus*- inner bark, leaves *Alnus* – inner bark leaves *Pinus, Picea, Abies*- inner bark, shoots *Acer* – inner bark, leaves	Rosa, 2022; Moerman, 1988; Heinsen, 1972; Papp et al.,2022; Middleton et al., 2005; Svanberg et al., 2012.
Toothaches	*Salix* – inner bark *Persicaria*- flowers and leaves *Bidens*- flowers and leaves	Zuleta et al., 2015; Grieve, 1984; Foster & Duke, 1990; Tawfeek et al., 2021; Shiraliyeva et al., 2021
Childbearing and post-partum affection	*Fraxinus*- leaves, inner bark *Typha* - pollen	Moerman, 1988; Middleton et al., 2005; Sezic et al., 2022.

Pain and inflammation	*Salix- inner bark* *Alnus*- inner bark	Moerman, 1988; Tawfeek et al., 2021.
Anemia and vitamin deficiencies	*Rubus*- fruits, young shoots, leaves *Picea, Pinus* – shoots, inner bark *Sambucus*- flowers, fruits *Chenopodium, Rumex*- young leaves	Yadav et al., 2007; Krauze-Baranowska, 2014; Verna et al., 2014; Moerman, 1988; Ulbrich et al., 2014; Wichtl & Bisset, 1994; Svanberg et al., 2012.
Heart and blood-related illnesses	*Acer* – bark *Sparganium* - shoots	Moerman, 1988

Figure 5.20 The table contains possible injuries and diseases that could have affected the hominins at Schöningen 12 II4c and possible natural remedies that could have been used. Created by MF Catalinoiu

- **Adaptive Behaviour**: Self-treatment behaviours represented adaptive responses to immediate environmental challenges and health concerns. In the dynamic environment of Schöningen, where open wounds, fractures, infections, and other health issues were potential threats, hominins likely used their cognitive abilities to adapt and acquire strategies for effectively avoiding these challenges.
- **Influence on Tool crafting**: The knowledge of using plants for medicinal purposes may have influenced tool-making practices. It's possible that specific tools were crafted to facilitate plant processing, illustrating the intricate relationship between cognitive abilities, environmental adaptation, and the creation of implements designed to utilize medicinal plants' benefits.
- **Conflict Resolution and Social Interactions**: The presence of self-treatment behaviour s could have had a significant impact on conflict resolution and social dynamics within hominin groups. The ability to treat injuries and illnesses may have fostered cooperation, group cohesion, and reduced conflicts, ultimately contributing to the group's overall well-being.

In terms of cognitive abilities, the implications of self-treatment behaviour could be understood through the following:

- **Recognition of Health Issues:** Self-treatment behaviour implies that early hominins had the cognitive ability to recognize health issues within their communities. This recognition likely involved understanding what constituted a deviation from normal health or physical well-being. This cognitive skill suggests a level of observation and pattern recognition (Henke, 2010, pp. 523-526)

- **Identification of Medicinal Plants:** Early hominins needed to identify and distinguish various plant species, recognizing which ones had medicinal properties. This required knowledge of local flora, the ability to differentiate between plant types, and an understanding of the specific healing properties of certain plants. This action implies accessing the memory encoding, categorization, and long-term memory section of the brain (Kuhl et al., 2012, p. 467-468)
- **Selective Plant Gathering:** Once the appropriate medicinal plants were identified, early hominins had to selectively gather and prepare them. This involved recognizing the correct plant parts to use, understanding the timing of harvesting for maximum efficacy, and possibly knowing how to process or prepare these plants for medicinal use. These activities showcase cognitive planning and problem-solving abilities, accessing the long memory encoding long-term memory areas of the brain (Versace et al.,2009, pp. 522-524).
- **Adaptive Thinking:** Self-treatment behaviour reflects the ability of early hominins to think adaptively and make informed decisions about their well-being. They need to assess the severity of health issues, consider available remedies, and choose the most appropriate course of action. Adaptive thinking hints at problem-solving and decision-making skills (Rellihan, 2012, p. 248-262).
- **Long-Term Learning:** The use of medicinal plants implies that early hominins engaged in long-term learning and accumulated knowledge over generations. They likely learned from successful and unsuccessful treatment attempts, adapting their practices and passing down refined knowledge. This long-term learning demonstrates their cognitive capacity for cumulative culture (Squire, 2004, p. 171-173).
- **Transmission of Knowledge:** The ability to use and pass down knowledge about medicinal plants and their applications is a cognitive implication of self-treatment behaviour. This transmission of knowledge across generations suggests effective communication,

opening a long debate regarding their language and possible means of communication (Planer, 2017, p. 219-220).

The implications of self-treatment behaviour for the Hominins of the Middle Pleistocene at Schöningen, Sublayer II 4c, are multifaceted. These behaviours contributed to the survival and fitness of these early humans and had cultural, cognitive, and even social significance. From a cognitive point of view, remembering which plant is suitable for what purpose involves memory encoding, categorization, pattern recognition, language and communication, long-term memory, cumulative learning, adaptation, and social learning. These cognitive processes collectively contribute to preserving and applying this knowledge in early hominin groups.

Chapter 6. Conclusion

This study sought to explore the Middle Pleistocene site of Schöningen during the Reinsdorf interglacial, specifically sublayer 4c. The investigation centered on two main aspects: the reconstruction of the environment and hominin exploitation practices, discerned through a palaeobotanical dataset. Within this dynamic landscape, hominins strategically positioned themselves at the fringes of the lacustrine habitat. They hid amidst the *Rubus* thickets or concealed themselves amongst the *Phragmites* and *Typha,* waiting for the arrival of their prey. They use the marshy areas of the lake as a tactical terrain for capturing the big game, demonstrating their profound understanding of the environment.

The research objectives stemmed from the need to unravel the nuanced relationship between the environment and hominin behaviours. Understanding their adaptability to a constantly changing environment becomes important, as it offers essential perspectives on survival strategies and evolutionary dynamics, enhancing our comprehension of the intricacies shaping human evolution.

6.1 Answering the First Research Question

What is the detailed reconstruction of the lacustrine paleoenvironment at the Reinsdorf interglacial site Schöningen 12, corresponding to sublayer II4c? How can we characterize the paleolake's water chemistry, depth, and speed during this specific timeframe?

The aquatic environment at Schöningen 12 II-4 sublayer c, revealed through sediment macrofossils, unveils distinctive features. Calcareous mud indicates a chemically rich environment characterized by elevated alkalinity and pH levels in a nutrient-rich water body, fostering the precipitation of calcium carbonate. This conclusion is further supported by the ecosystem's coexistence of *Groenlandia densa, Characeae sp., Myriophyllum, and Potamogetonaceae*. Abundant *Zannichellia palustris* and *Stuckenia pectinata* suggest slow water movement and potential eutrophication. *Groenlandia densa*, *Potamogeton alpinus*, and

Crispus' preference for clear waters implies low turbidity and water velocity. Their ecological preferences for colder waters indicate the possible cooler environmental temperature conditions. The dominance of *Zannichellia, Stuckenia,* and other aquatic plant species adapted to various depths hints at shallow waters. *Ostracods, Potamogetonaceae, Zannichellia palustris, and Characeae sp* suggest slightly brackish conditions. Fluctuations in *Betula* pollen and the presence of *Typha* and *Potamogetonaceae* suggest potential variations in lake levels, sedimentation, or nutrient input.

Palynological data from the LPAZ RP4a and RP4b pollen samples from sublayer 4c indicate shifts in vegetation, reflecting changes in climate and disturbances in the vegetation with fluctuating lake levels. This shift in vegetation indicates changes in precipitation patterns that impact lake ecology, transforming the landscape into an open woodland setting. Where grasses and tree clusters are present. These changes coincide with fluctuating lake levels in sublayer 4c, followed by a continuous decrease in sublayer 4b. This decline aligns with the onset of colder conditions on layer 5 preceding the arrival of Saalian glaciation.

Identified large game animals and hominin presence, supported by bone assemblages, illustrate complex ecological dynamics. These findings contribute to understanding how climatic shifts influenced lake levels, water chemistry, and environmental interactions during the Middle Pleistocene at Schöningen 12 II-4.

6.2 Answering the Second Research Question

What insights can we derive from vegetation reconstruction about potential plant use, hominin behaviour, and exploitation strategies at the middle Pleistocene site Schöningen 12 II during Reinsdorf interglacial corresponding to sublayer 4c?

The palaeobotanical dataset unveils an open woodland landscape centered around a lake, with dynamic interactions between hominins, mammals, and vegetation. In this environment, hominins seek sustenance, utilizing the abundant resources reflected in the paleo data record. Their exploitation strategies include tool-making while employing locally available wood to craft spears for hunting big game. Additionally, these resourceful hominins supplement their diet with available plants. Furthermore, the accessible plants serve medicinal purposes in this complex dynamic between hominins and their environment.

6.2.1 Exploring the Plant Tool Crafting

The discovery of the Schöningen Spears challenges the prevailing notion of hominins primarily as scavengers. The bone assemblage, which includes remains of large game species, indicates multiple hunting events, underlining hominins' adaptability in crafting tools made for specific purposes, particularly hunting large mammals. To achieve this, hominins utilized spears crafted from the available wood.

The palaeobotanical dataset reveals a variety of trees positioned either along lake margins (*Alnus glutinosa, Betula sp., Salix sp.,* and *Juniperus communis*) or in the upland terrestrial zone (*Abies alba, Pinus sylvestris, Picea sp., Acer sp., Larix sp.,* and *Fraxinus excelsior*). The preference for *Pinus* and *Picea* over other woods signifies hominins' comprehensive understanding of the environment and plant/wood properties. This reflects their informed decision-making process, considering wood flexibility, durability, and suitability for crafting spears in big game hunting. Notably, the deliberate choice of slow-growing *Picea* trees and carving the spear tip from the thicker end of the branch illustrates their strategic decision to ensure spear density for effective penetration through animal skin. Furthermore, the fact that *Pinus* and *Picea* are not native to lake margins but are found further upland suggests a conscious decision-making process. Instead of opting for convenience by crafting a spear from nearby wood, hominins carefully selected wood, considering the chosen trees' ecology. This implies that they carried their tools with them, demonstrating a deliberate and considered approach.

The spear-making process involves cognitive steps, highlighting the skillful approach and cognitive abilities of Schöningen hominins. This intricate process reflects a thoughtful and strategic method in crafting effective hunting tools, pointing to the potential for cultural transmission and adaptability. These aspects carry implications for survival and evolution, emphasizing the versatility of hominins in their ability to adapt and thrive in different environments.

6.2.2 Exploring the Potential of Plant Nutrition

Examining dental remains, dental calculus, botanical macrofossils, and phytolith analysis across various archaeological sites highlights the adaptability and resourcefulness of Middle Pleistocene hominins in integrating plant consumption into their diets. This evidence enriches our understanding of their possible dietary preferences and the interplay between hominins and the environment.

The paleo data set emphasizes the presence of edible plants suitable for dietary supplementation. The lake margins, a prominent foraging ground, offer diverse edible resources throughout the year. Early spring presents opportunities for harvesting tree inner bark from *Alnus glutinosa, Pinus sylvestri, Picea, Betula,* and *Abies alba*. The starchy young shoots from *Myriophyllum spicatum, Potamogetonaceae, Pinus, Fraxinus, Picea, Chenopodium, Typha, and Phragmites* become accessible during this season. In Spring, leaves and flowers from *Betula, Persicaria hydropiper, Bidens, Viola, Chenopodium, Typha,* and *Phragmites* contribute to the foraging spectrum. Summer introduces flowers, leaves, nuts, and fruits such as *Sambucus nigra, Corylus avellana,* and *Rumex maritimus*. Late Summer and Autumn mark the availability of fruits from *Rubus fruticosus* and shoots from *Typha and Phragmites*.

The consistent reliance on lake margins for foraging implies that hominins strategically adapted their diets to the seasonal availability of edible resources in this specific environment, demonstrating their knowledge regarding plant properties. The focus on lake margins underlines the versatility of Middle Pleistocene hominins in obtaining essential sustenance from the surrounding environment.

6.2.3 Exploring the Potential of Medicinal Plant Use

Examining self-treatment behaviour s in Middle Pleistocene hominins at Schöningen, particularly in sublayer II 4c, reveals insights into their cognitive abilities, adaptive strategies, and potential evolutionary significance. Archaeological evidence, including dental remains and botanical macrofossils, provides a nuanced understanding of how early humans utilized plants for sustenance and medicinal purposes. The interpretive nature of this evidence adds complexity, with debates on whether identified medicinal plants were used for healing. Self-treatment behaviours observed in humans and non-human species highlight the cognitive abilities involved, encompassing problem-solving, memory, social learning, decision-making, and tool use.

The paleo data set includes identified plants that might have been used for medical purposes. Some of these medical issues are lacerations, open wounds, abrasions, burns, puncture wounds caused by hunting, accidents, fighting, wild animals, and environmental hazards, one could use resin, needles, leaves, and flowers from *Alnus, Abies, Pinus, Picea, Acer, Betula, Chenopodium, Hippuris, Persicaria, Carex, Rumex, Sambucus, Typha, Bidens*. For respiratory tract problems, shoots, inner bark, and leaves from *Abies, Acer, Carex, Chenopodium, Picea, Pinus, Viola* could be used. For anemia and vitamin deficiencies, fruits, shoots, leaves, or inner bark from *Rubus, Picea, Pinus, Sambucus, Chenopodium, Rumex* could be employed. Numerous plants exhibit versatility in treating various illnesses, highlighting their significant importance.

The importance of self-treatment behaviours for evolution lies in the potential survival benefits conferred on the hominin population. The ability to identify and use plants for medicinal purposes implies a form of healthcare management within the population, potentially contributing to increased chances of survival and reproduction. This, in turn, could have influenced the overall fitness and adaptability of the hominin population over successive generations.

From a cognitive perspective, early hominins at Schöningen demonstrated health issue recognition, identification of medicinal plants, adaptive thinking, and knowledge transmission. These processes contributed to preserving and applying medicinal plant knowledge across generations. In the Middle Pleistocene, hominins addressed diverse health issues with specific plants, showcasing adaptability. Self-treatment behaviours at Schöningen reflect holistic interaction with the environment, emphasizing a profound connection with plants for both sustenance and well-being. This enriches our understanding of early human evolution, highlighting the intricate relationship between cognition, environment, and plant resource utilization.

6.3 Contributions and Considerations

The holistic approach to this study enhances our understanding of Middle Pleistocene Schöningen hominins, focusing on sublayer II 4c. It provides a detailed environmental reconstruction in a specific time frame, revealing an open woodland landscape with dynamic hominin-mammal-vegetation interactions. The study uncovers exploitation strategies and challenging scavenger notions by highlighting adaptability, strategic spear crafting, and deliberate tool carrying. Dental remains and botanical analysis showcase hominins' adaptability in incorporating plants into their diets, emphasizing hominins' resourcefulness. The investigation into self-treatment behaviour s reveals cognitive processes such as health issue recognition and knowledge transmission. The identified medicinal plants contribute to understanding early human evolution, emphasizing the intricate relationship between cognition, environment, and plant resource utilization for sustenance and well-being.

While the environmental reconstruction and identified plants at Schöningen provide a partial glimpse of the past, the inherent limitations suggest a potentially even more diverse range of plant-based food options than currently understood. The interpretive nature of archaeological evidence, including dental remains and botanical macrofossils, introduces ambiguity. Skepticism may arise regarding whether identified medicinal plants were used for healing or had alternative purposes, emphasizing the challenge of definitively attributing specific behaviours to hominins.

While detailed, the lacustrine paleoenvironment's reconstruction may be subject to the limitations inherent in paleoenvironmental reconstructions due to taphonomy. Assumptions in interpreting sediment macrofossils and palynological data may impact the accuracy of conclusions regarding water chemistry, depth, and speed of the paleolake.

Furthermore, the study focuses on a specific site (Schöningen) and sublayer (II 4c) during the Reinsdorf interglacial, limiting the generalizability of findings to other periods or locations. The scope is confined to the available archaeological evidence, and additional discoveries in the future may provide further nuances to our understanding of Schöningen hominins' behaviour.

6.4 Future Research

Future investigations at Schöningen can uncover additional layers of complexity in the behaviour s and adaptations of early hominins. Future studies may concentrate on enhancing our comprehension of dietary practices considering seasonal variations and the utilization of plant resources. As well as explore the nutritional aspects of their diet and how it contributed to their overall health.

Examine the cognitive dimensions of medicinal plant utilization by exploring the cognitive processes involved in recognizing and utilizing plants for medicinal purposes, considering factors such as problem-solving, memory, and social learning. Analyze the environmental impact on hominin behaviour by exploring how ecological changes, including shifts in vegetation and climate, influenced hominin behaviour at Schöningen. Investigate correlations between paleoenvironmental factors and changes in hominin exploitation strategies, tool-making, and dietary choices. Comparative studies with other Middle Pleistocene sites to identify similarities or differences in behaviour, tool use, and plant utilization. This could provide a broader understanding of regional variations in hominin adaptation. Integrating a multidisciplinary approach can provide a more comprehensive understanding of the complex interactions between hominins and their environment.

These potential research directions contribute to scholarly endeavors and provide insights that transcend temporal boundaries, linking us to the intricate tapestry of human evolution.

6.5 Final Thoughts

Turning the lens specifically to the Schöningen site, the analysis of potential edible plant species presents a promising avenue of study. Acknowledging the dual nature of plants as both sustenance and potential hazards is vital. Early hominins navigated this complex botanical world through trial and error, relying on their senses, including taste, to distinguish between edible and harmful varieties.

Incorporating self-treatment behaviour into the narrative provides a glimpse into hominins' interactions with their environment. Their ability to use plants for sustenance and medicinal purposes speaks to their cognitive abilities and adaptability. In their challenging environment, early hominins not only sought food but also addressed health issues, making self-treatment behaviour a significant aspect of their story.

While archaeological evidence of self-treatment behaviour is challenging, insights from modern hunter-gatherer societies and ethnomedicine suggest that early hominins likely exhibited similar behaviours. Their knowledge of plants with medicinal properties passed down through generations represents a form of early ethnobotany. The cognitive process behind self-treatment behaviour, including identifying the need for treatment selection and applying suitable plant species, is remarkable. This self-treatment behaviour expresses early hominins' profound connection with the natural world, extending beyond survival to holistic well-being. They actively sought remedies within their environment, revealing a sophisticated approach to addressing injuries and illness

Abstract

This study employs paleo data from the Middle Pleistocene site Schöningen during the Reinsdorf interglacial, specifically corresponding to channel II sublayer 4c. The primary objectives are reconstructing the paleoenvironment and comprehending hominins' exploitation strategies within this context. The dataset analyzes paleolake chemistry and the climatic conditions leading to the deposition on channel II of sublayer 4c, facilitating local and regional environment reconstruction.

Examining plant availability in the dataset illustrates their use in tool-making, crafting spears, and potential utilization for dietary and medicinal purposes, emphasizing adaptability across seasons. Through a comprehensive examination of the palaeobotanical dataset, this research elucidates the nuanced relationship between hominins and their environment.

The study uses a mixed-method approach to preserve organic remains from a sediment sample from Schöningen 12 II sublayer 4c. The sediment, formed in a waterlogged setting, was collected from Schöningen 12, channel II, platform 4, sedimentary cycle 4, and layer c, sifted through a 500-micron mesh sieve during an on-site rescue excavation. The research design combines quantitative methods for sediment data and qualitative methods for literature review, referencing Duistermaat, L. (2020) "Heukels' flora van Nederland," and conducting an extensive literature review on hominin behaviour. The study recognizes biases, including data collection constraints, specific mesh size use, potential biases, and limited contemporaneous sites.

The results reveal dominant obligated aquatic and waterside species specific to the lacustrine environment. The palaeobotanical dataset shows hominins strategically positioned at lacustrine fringes, utilizing the environment for hunting and possible plant-based sustenance. The investigation answers research questions on lacustrine paleoenvironment reconstruction, revealing shifting lake levels, low water velocity, alkalinity, and brackish conditions.

The composition of aquatic plants suggests the sediment sample was collected from an area that was at a 2 to 4 meters depth, not far from the shore. An increase in *Carex* and *Betula* pollen in the pollen diagram indicates a disturbance leading to a change in vegetation. In this context, hominins hunted on the lake margins, as evidenced by the discovered spears in the animal bones context.

The spear crafting reflects deep knowledge, with hominins favoring *Picea* and *Pinus* over other available trees. This choice demonstrates their understanding of wood durability and flexibility, crafting spears from denser old *Picea* trees with tips carved on the thicker end. This behaviour underlines their adaptability in spear crafting and deliberate tool carrying.

The presence of edible plants and those with medicinal properties in the paleo data showcases the availability of dietary and medicinal plant use, emphasizing their seasonal presence. Dental wear and dental calculus indicate plant diet by the early hominins, while self-treatment behaviours reveal cognitive processes and potential survival benefits.

The hominins at Schöningen during the Reinsdorf interglacial corresponding to sublayer II 4c were hunters and plant users for sustenance and healing. These early humans were far from being mere instinct-driven beings. They demonstrated the capacity to recognize patterns, access long-term memory, and engage in enduring learning about their environment. In this context, plants served as a source of sustenance and potential healing and a continuous source of knowledge.

Bibliography

Ager, T. A., & Ager, L. P. (1980). Ethnobotany of the Eskimos of Nelson Island, Alaska. *Arctic Anthropology*, 26-48.

Albert Cristóbal, R. M. (1999). Study of ash layers through phytolith analyses from the Middle Paleolithic levels of Kebara and Tabun caves.

Allington-Jones, L. (2015). The Clacton spear: The last one hundred years. *Archaeological Journal*, *172*(2), 273-296. https://doi.org/10.1080/00665983.2015.1008839

Andrieu, V., Field, M. H., Ponel, P., Guiot, J., Guenet, P., de Beaulieu, J. L., ... & Morzadec-Kerfourn, M. T. (1997). Middle Pleistocene temperate deposits at Dingé, Ille-et-Vilaine, northwest France: pollen, plant and insect macrofossil analysis. *Journal of Quaternary Science: Published for the Quaternary Research Association*, *12*(4), 309-331.

Andrieu-Ponel, V., De Beaulieu, J. L., Belmecheri, S., Björck, S., Brewer, S., Brulhet, J., ... & Wohlfarth, B. (2010, February). Organisation et dynamique des écosystèmes pendant les glaciations récentes du Quaternaire dans les régions médio-européennes et méditerranéennes. In *Quaternaire Q7*.

Angier, B. (2008). Field guide to edible wild plants. Stackpole Books.

Antolín, F., Steiner, B. L., & Jacomet, S. (2017). The bigger, the better? On sample volume and the representativeness of archaeobotanical data in waterlogged deposits. *Journal of Archaeological Science: Reports*, *12*, 323-333.

Aranguren, B., Longo, L., Mariotti Lippi, M., & Revedin, A. (2007). Evidence of edible plant exploitation. *Pavlov, Excavations*, *2011*, 170-179.

Azaele, S., Muneepeerakul, R., Rinaldo, A., & Rodriguez-Iturbe, I. (2010). Inferring plant ecosystem organization from species occurrences. *Journal of theoretical biology*, *262*(2), 323-329.

Ballard, R. (1986). Bidens pilosa complex (Asteraceae) in North and Central America. *American Journal of Botany*, *73*(10), 1452-1465.

Barham, L., Duller, G. A. T., Candy, I., Scott, C., Cartwright, C. R., Peterson, J. R., ... & Nkombwe, P. (2023). Evidence for the earliest structural use of wood at least 476,000 years ago. *Nature*, 1-5.

Bayındır, N., & İkinci, N. (2020). The role of environmental variables on distribution of Potamogetonaceae species. *Wetlands*, *40*(1), 125-133.

Bigga, G., Schoch, W. H., & Urban, B. (2015). Paleoenvironment and possibilities of plant exploitation in the Middle Pleistocene of Schöningen (Germany). Insights from botanical macro-remains and pollen. *Journal of human evolution*, *89*, 92-104.

Bigga, G. (2018). Die Pflanzen von Schöningen. *Botanische Makroreste aus den mittelpleistozänen Ablagerungen und das Nutzungspotential einer interglazialen Paläoflora. Forschungen zur Urgeschichte aus dem Tagebau von Schöningen*, *3*.

Birks, H. J. B. (2019). Contributions of Quaternary botany to modern ecology and biogeography. *Plant Ecology & Diversity*, *12*(3-4), 189-385.

Birch, J. (2021). Toolmaking and the evolution of normative cognition. *Biology & Philosophy, 36*(1), 4.

Blanche, Lorio, P. L., Sommers, R. A., Hodges, J. D., & Nebeker, T. E. (1992). Seasonal cambial growth and development of loblolly pine: Xylem formation, inner bark chemistry, resin ducts, and resin flow. *Forest Ecology and Management*, *49*(1), 151–165. https://doi.org/10.1016/0378-1127(92)90167-8

Bocherens, H., Bonilla, M. D. Z., Daujeard, C., Fernandes, P., Raynal, J. P., & Moncel, M. H. (2016). Direct isotopic evidence for subsistence variability in Middle Pleistocene Neanderthals (Payre, southeastern France). *Quaternary Science Reviews*, *154*, 226-236.

Boedeltje, G. E. R., Smolders, A. J., & Roelofs, J. G. (2005). Combined effects of water column nitrate enrichment, sediment type and irradiance on growth and foliar nutrient concentrations of Potamogeton alpinus. *Freshwater Biology*, *50*(9), 1537-1547.

Boismier, W. A., Schreve, D. C., White, M. J., Robertson, D. A., Stuart, A. J., Etienne, S., ... & O'Connor, S. (2003). A Middle Palaeolithic site at Lynford Quarry, Mundford, Norfolk: Interim statement. In *Proceedings of the Prehistoric Society* (Vol. 69, pp. 315-324). Cambridge University Press.

Brandes, C., Pollok, L., Schmidt, C., Wilde, V., & Winsemann, J. (2012). Basin modelling of a lignite-bearing salt rim syncline: insights into rim syncline evolution and salt diapirism in NW Germany. Basin Research, 24(6), 699–716. https://doi.org/10.1111/j.1365-2117.2012.00544.x

Brightsmith, D. J., Hobson, E. A., & Martinez, G. (2018). Food availability and breeding season as predictors of geophagy in Amazonian parrots. *Ibis*, *160*(1), 112-129.

Burkhardt Jr, R. W. (2013). Lamarck, evolution, and the inheritance of acquired characters. *Genetics*, *194*(4), 793-805.

Böhner, Serangeli, J., & Richter, P. (2015). The Spear Horizon: First spatial analysis of the Schöningen site 13 II-4. *Journal of Human Evolution*, *89*, 202–213. https://doi.org/10.1016/j.jhevol.2015.10.001

Caplan, J. S., & Yeakley, J. A. (2013). Functional morphology underlies performance differences among invasive and non-invasive ruderal Rubus species. *Oecologia*, *173*, 363-374.

Carlisle, A., & Brown, A. H. F. (1968). Pinus Sylvestris L. *Journal of Ecology*, *56*(1), 269-307.

Case, M. L., & Madsen, J. D. (2004). Factors limiting the growth of Stuckenia pectinata (sago pondweed) in Heron Lake, Minnesota. *Journal of Freshwater Ecology*, *19*(1), 17-23.

Cianfaglione, K., Papa, F., & Maggi, F. (2017). Volatile components of horsetail (Hippuris vulgaris L.) growing in central Italy. *Natural Product Research*, *31*(19), 2316-2320.

Chaichana, R., Leah, R., & Moss, B. (2011). Seasonal impact of waterfowl on communities of macrophytes in a shallow lake. *Aquatic Botany*, *95*(1), 39-44.

Chase, J. M., & Knight, T. M. (2006). Effects of eutrophication and snails on Eurasian watermilfoil (Myriophyllum spicatum) invasion. *Biological Invasions*, *8*, 1643-1649.

Chitnarin, A., Forel, M. B., & Tepnarong, P. (2023). Holocene ostracods (Crustacea) from a whale-fall excavation site from the Chao Phraya delta, Central Thailand. *European Journal of Taxonomy*, *856*, 120-151.

Chopra, R. N., & Nayar, S. L. (1956). *Glossary of Indian medicinal plants*. Council of Scientific and Industrial Research.

Clymo, R. S., & Hayward, P. M. (1982). The ecology of Sphagnum. In *Bryophyte ecology* (pp. 229-289). Dordrecht: Springer Netherlands.

Conard, N. J., Serangeli, J., Böhner, U., Starkovich, B. M., Miller, C. E., Urban, B., & Van Kolfschoten, T. (2015). Excavations at Schöningen and paradigm shifts in human evolution. *Journal of Human Evolution*, *89*, 1–17. https://doi.org/10.1016/j.jhevol.2015.10.003

Copeland, L., & Hardy, K. (2018). Archaeological starch. *Agronomy*, *8*(1), 4.

Daujeard, C., Vettese, D., Britton, K., Béarez, P., Boulbes, N., Crégut-Bonnoure, E., ... & Moncel, M. H. (2019). Neanderthal selective hunting of reindeer? The case study of Abri du Maras (south-eastern France). *Archaeological and Anthropological Sciences*, *11*, 985-1011.

Dennell, R. W., Martinón-Torres, M., & de Castro, J. M. B. (2011). Hominin variability, climatic instability and population demography in Middle Pleistocene Europe. *Quaternary Science Reviews*, *30*(11-12), 1511-1524.

Deptuła, M., Piernik, A., Nienartowicz, A., Hulisz, P., & Kamiński, D. (2020). Alnus glutinosa L. Gaertn. as a potential tree for brackish and saline habitats. *Global Ecology and Conservation*, *22*, e00977.

Dobkin, D. S., Rich, A. C., Pretare, J. A., & Pyle, W. H. (1995). Nest-site relationships among cavity-nesting birds of riparian and snow pocket aspen woodlands in the northwestern Great Basin. *The Condor*, *97*(3), 694-707.

Dobrowolska, D., Bončina, A., & Klumpp, R. (2017). Ecology and silviculture of silver fir (Abies alba Mill.): A review. *Journal of Forest Research*, *22*(6), 326-335.

Domínguez-Rodrigo, M., Egido, R. B., Egeland, C. P., Egeland, C. P., Domínguez-Rodrigo, M., & Barba, R. (2007). The hunting-versus-scavenging debate. *Deconstructing Olduvai: a taphonomic study of the bed I sites*, 11-22.

Dos Reis, M., Donoghue, P. C., & Yang, Z. (2016). Bayesian molecular clock dating of species divergences in the genomics era. *Nature Reviews Genetics*, *17*(2), 71-80.

Downard, R., Frank, M., Perkins, J., Kettenring, K., & Larese-Casanova, M. (2017). Wetland Plants of Great Salt Lake, A Guide to Identification, Communities, & Bird Habitat.

Drake, C. M. (1982). Seasonal dynamics of Chironomidae (Diptera) on the Bulrush Schoenoplectus lacustris in a chalk stream. *Freshwater Biology*, *12*(3), 225-240.

Duistermaat, L. (2020). *Heukels' flora van Nederland*

Duke, J. A., & Ayensu, E. S. (1985). Medicinal Plants of China. Reference Publications, Inc. ISBN 0-917256-20-4

Durzan, D. J. (2009). Arginine, scurvy, and Cartier's" tree of life." *Journal of Ethnobiology and Ethnomedicine*, *5*, 1-16.

Field, M. H., De Beaulieu, J. L., Guiot, J., & Ponel, P. (2000). Middle Pleistocene deposits at La Côte, Val-de-Lans, Isère department, France: plant macrofossil, palynological and fossil insect investigations. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *159*(1-2), 53-83.

Foster, S., & Duke, J. A. (1990). A field guide to medicinal plants: eastern and central North America. *The Peterson field guide series (USA)*.

Gadsby, P., & Steele, L. (2004). The inuit paradox. *Discover*, *25*(10), 48-55.

Ganie, A. H., Reshi, Z. A., & Wafai, B. A. (2016). Reproductive ecology of Potamogeton pectinatus L. (= Stuckenia pectinata (L.) Börner) in relation to its spread and abundance in freshwater ecosystems of the Kashmir Valley, India. *Tropical Ecology*, *57*(4), 787–803.

García-Moreno, A., Hutson, J. M., Villaluenga, A., Turner, E., & Gaudzinski-Windheuser, S. (2021). A detailed analysis of the spatial distribution of Schöningen 13II-4 'Spear Horizon' faunal remains. *Journal of Human Evolution*, *152*, 102947.

German Federal Institute for Risk Assessment (BfR), Unit of Food Toxicology, Germany, Matyjaszczyk, E., & Schumann, R. (2018). Risk assessment of white willow (Salix alba) in food. *EFSA Journal*, *16*, e16081.

Gijssel, K. V. (2006). *A continent-wide framework for local and regional stratigraphy* (Doctoral dissertation, Leiden University).

Gill, C. J. (1975). The Ecological Significance of Adventitious Rooting as a Response to Flooding in Woody Species, with Special Reference to Alnus glutinosa (L.) Gaertn. *Flora, 164*(1), 85-97.

Glander. K.E. (1994). Eating on the Wild Side: The Pharmacologic, Ecologic and Social Implications of Using Noncultigens. *Self-Medication, N. P*. 227.

Goodrich, J., C. Lawson & V.P. Lawson 1980. Kashaya Pomo Plants. Heyday Books, Berkeley, California. 171 pp

Goren-Inbar, N., Sharon, G., Melamed, Y., & Kislev, M. (2002). Nuts, nut cracking, and pitted stones at Gesher Benot Ya ʻaqov, Israel. *Proceedings of the National Academy of Sciences*, *99*(4), 2455-2460.

Gott, B. (1999). Cumbungi, Typha species: a staple Aboriginal food in southern Australia. Australian Aboriginal Studies, (1), 33-50.

Grace, J. B., & Wetzel, R. G. (1981). Habitat partitioning and competitive displacement in cattails (Typha): experimental field studies. The American Naturalist, 118(4), 463-474.

Grace, J. B., & Wetzel, R. G. (1998). Long-term dynamics of Typha populations. Aquatic Botany, 61(2), 137-146.

Gregory, S. V., Swanson, F. J., McKee, W. A., & Cummins, K. W. (1991). An ecosystem perspective of riparian zones. *BioScience*, *41*(8), 540-551.

Grieve, M., & Herbal, A. M. (1984). Penguin Books. London, UK, 199.

Guil, J. L., Rodríguez-Garcí, I., & Torija, E. (1997). Nutritional and toxic factors in selected wild edible plants. *Plant foods for human nutrition*, *51*, 99-107.

Guo, Y. H., & Cook, C. D. (1990). The floral biology of Groenlandia densa (L.) Fourreau (Potamogetonaceae). *Aquatic Botany*, *38*(2-3), 283-288.

Haidle, M. N. (2009). How to think a simple spear. *Cognitive archaeology and human evolution*, 57-73.

Hardy, B. L., & Moncel, M. H. (2011). Neanderthal use of fish, mammals, birds, starchy plants and wood 125-250,000 years ago. *PloS one*, *6*(8), e23768.

Hardy, K., Buckley, S., & Huffman, M. (2013). Neanderthal self-medication in context. *Antiquity*, *87*(337), 873-878.

Hardy, K., Radini, A., Buckley, S., Sarig, R., Copeland, L., Gopher, A., & Barkai, R. (2016). Dental calculus reveals potential respiratory irritants and ingestion of essential plant-based nutrients at Lower Palaeolithic Qesem Cave Israel. *Quaternary International*, *398*, 129-135.

Hardy, K., Bocherens, H., Miller, J. B., & Copeland, L. (2022). Reconstructing Neanderthal diet: the case for carbohydrates. *Journal of Human Evolution*, *162*, 103105.

Haws, J. (2012). Neanderthal use of coastal wetlands during the last glacial/interglacial cycle in Portuguese Estremadura. *Quaternary International*, *279*, 190.

Hänninen, T., Tukiainen, P., Svedström, K., Serimaa, R., Saranpää, P., Kontturi, E., ... & Vuorinen, T. (2012). Ultrastructural evaluation of compression wood-like properties of common juniper (Juniperus communis L.).

Heinsen, V. 1972. Mission San Antonio de Padua Herbs: Medicinal herbs of early days. Third edition. Lockwood, California.

Henke, K. (2010). A model for memory systems based on processing modes rather than consciousness. *Nature Reviews Neuroscience*, *11*(7), 523-532.

Henry, A. G., Brooks, A. S., & Piperno, D. R. (2011). Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq; Spy I and II, Belgium). *Proceedings of the National Academy of Sciences*, *108*(2), 486-491.

Henry, A. G., Brooks, A. S., & Piperno, D. R. (2014). Plant foods and the dietary ecology of Neanderthals and early modern humans. *Journal of human evolution*, *69*, 44-54.

Hérisson, D., Brenet, M., Cliquet, D., Moncel, M. H., Richter, J., Scott, B., ... & Van Peer, P. (2016). The emergence of the Middle Palaeolithic in north-western Europe and its southern fringes. *Quaternary International*, *411*, 233-283.

Hosch, S., & Zibulski, P. (2003). The influence of inconsistent wet-sieving procedures on the macroremain concentration in waterlogged sediments. *Journal of Archaeological Science*, *30*(7), 849-857.

Hroudová, Z., Zákravský, P., Hrouda, L., & Ostrý, I. (1992). Oenanthe aquatica (L.) Poir.: Seed reproduction, population structure, habitat conditions and distribution in Czechoslovakia. *Folia Geobotanica et Phytotaxonomica*, *27*, 301-335.

Huffman. (2003). Animal self-medication and ethno-medicine: exploration and exploitation of the medicinal properties of plants. *Proceedings of the Nutrition Society*, *62*(2), 371–381. https://doi.org/10.1079/PNS2003257

Ibadullayeva, S. C., Shiraliyeva, G. S., Gurbanova, L. Z., Askerova, A. A., Huseynova, A. E., Seyidova, L. M., & Qasimov, H. Z. (2021). Ethnopharmacological use of wild vegetable plants belonging to the Polygonaceae Juss. family spread in the Azerbaijan flora. *Biodiversity Journal*, *12*(3), 733-740.

Ilhardt, B. L., Verry, E. S., & Palik, B. J. (2000). Defining riparian areas. *Forestry and the riparian zone, Orono, Maine*, 7-14.

Jackson, Z. J., Quist, M. C., Downing, J. A., & Larscheid, J. G. (2010). Common carp (Cyprinus carpio), sport fishes, and water quality: ecological thresholds in agriculturally eutrophic lakes. *Lake and Reservoir Management*, *26*(1), 14-22.

Jain, A., Roshnibala, S., Rajshree, K., Sharma, H. N., Kanjilal, P. B., & Singh, H. B. (2005). Matting rush (Schoenoplectus lacustris (Linn.) Palla): Status, utility, threat, cultivation, and conservation options in Manipur. *Current Science*, 1018-1022.

Jain, A., Sundriyal, M., Roshnibala, S., Kotoky, R., Kanjilal, P. B., Singh, H. B., & Sundriyal, R. C. (2011). Dietary use and conservation concern of edible wetland plants at indo-burma hotspot: a case study from northeast India. *Journal of ethnobiology and ethnomedicine*, *7*(1), 1-17.

Jman Redzic, S. (2006). Wild edible plants and their traditional use in the human nutrition in Bosnia-Herzegovina. *Ecology of Food and Nutrition*, *45*(3), 189-232.

Julien, M. A., Hardy, B., Stahlschmidt, M. C., Urban, B., Serangeli, J., & Conard, N. J. (2015). Characterizing the Lower Paleolithic bone industry from Schöningen 12 II: A multi-proxy study. *Journal of Human Evolution*, *89*, 264-286.

Kelsey, K. A., & West, S. D. (1998). Riparian wildlife. *River Ecology and Management. Lessons from the Pacific Coastal Ecoregion*, 235-258.

Khaliq, T., Akhter, S., Sultan, P., & Hassan, Q. P. (2023). Critical review on Rumex dentatus L. a strong pharmacophore and the future medicine: Pharmacology, phytochemical analysis and traditional uses. *Heliyon*.

Kiviat, E., & Hamilton, E. (2001). Phragmites use by native North Americans. *Aquatic Botany*, *69*(2-4), 341-357.

Kokwaro J.O. (1976). Medicinal plants of East Africa. East Africa Literature Bureau. Kampala. Nairobi. Dar es Salaam.

Kolfschoten, T. (2014). The Palaeolithic locality Schöningen (Germany): a review of the mammalian record. *Quaternary International*, *326*, 469-480.

Koroiva, R., & Pepinelli, M. (2019). Distribution and habitats of aquatic insects. *Aquatic Insects: Behaviour and Ecology*, 11-33

Kuhl, B. A., Rissman, J., & Wagner, A. D. (2012). Multi-voxel patterns of visual category representation during episodic encoding are predictive of subsequent memory. *Neuropsychologia*, *50*(4), 458-469.

Koutsodendris, A., Müller, U. C., Pross, J., Brauer, A., Kotthoff, U., & Lotter, A. F. (2010). Vegetation dynamics and climate variability during the Holsteinian interglacial based on a pollen record from Dethlingen (northern Germany). *Quaternary Science Reviews*, *29*(23-24), 3298-3307.

Kovárník, J., & Beneš, J. (2018). Microscopic analysis of starch grains and its applications in the archaeology of the Stone Age. *Interdisciplinaria Archaeologica. Natural Sciences in Archaeology*, *9*(1), 83-93.

Krauze-Baranowska, M., Głód, D., Kula, M., Majdan, M., Hałasa, R., Matkowski, A., ... & Kawiak, A. (2014). Chemical composition and biological activity of Rubus idaeus shoots–a traditional herbal remedy of Eastern Europe. *BMC Complementary and Alternative Medicine*, *14*(1), 1-12.

Kunz, A., Urban, B., & Tsukamoto, S. (2017). Chronological investigations of Pleistocene interglacial, glacial and aeolian deposits from Schöningen (Germany) using post-IR IRSL dating and pollen analysis. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, 81-104

Lang, J., Böhner, U., Polom, U., Serangeli, J., & Winsemann, J. (2015). The Middle Pleistocene tunnel valley at Schöningen as a Paleolithic archive. Journal of Human Evolution, 89, 18-26.

Lans, C., Turner, N., Khan, T., Brauer, G., & Boepple, W. (2007). Ethnoveterinary medicines used for ruminants in British Columbia, Canada. *Journal of ethnobiology and ethnomedicine*, *3*(1), 1-22.

Larkin, D. J., Monfils, A. K., Boissezon, A., Sleith, R. S., Skawinski, P. M., Welling, C. H., ... & Karol, K. G. (2018). Biology, ecology, and management of starry stonewort (Nitellopsis obtusa; Characeae): A Red-listed Eurasian green alga invasive in North America. *Aquatic Botany*, *148*, 15-24.

Larson, T. E., Buswell, A. M., Ludwig, H. F., & Langelier, W. F. (1942). Calcium carbonate saturation index and alkalinity interpretations [with discussion]. *Journal (American Water Works Association)*, 1667-1684.

Lauer, T., & Weiss, M. (2018). Timing of the Saalian-and Elsterian glacial cycles and the implications for Middle–Pleistocene hominin presence in central Europe. *Scientific Reports*, *8*(1), 5111.

Lev, E., Kislev, M. E., & Bar-Yosef, O. (2005). Mousterian vegetal food in Kebara cave, Mt. Carmel. *Journal of Archaeological Science*, *32*(3), 475-484.

Liang, Y. C., Lin, C. J., Yang, C. Y., Chen, Y. H., Yang, M. T., Chou, F. S., ... & Chang, C. L. T. (2020). Toxicity study of Bidens pilosa in animals. *Journal of Traditional and Complementary Medicine*, *10*(2), 150-157.

Liu, Q., & Hytteborn, H. (1991). Gap structure, disturbance and regeneration in a primeval Picea abies forest. *Journal of Vegetation Science*, *2*(3), 391-402.

Lucas, P. W., Constantino, P. J., & Wood, B. A. (2008). Inferences regarding the diet of extinct hominins: structural and functional trends in dental and mandibular morphology within the hominin clade. *Journal of Anatomy*, *212*(4), 486-500.

Lyon, J., & Gross, N. M. (2005). Patterns of plant diversity and plant–environmental relationships across three riparian corridors. *Forest Ecology and Management*, *204*(2-3), 267-278.

Madella, M., Jones, M. K., Goldberg, P., Goren, Y., & Hovers, E. (2002). The exploitation of plant resources by Neanderthals in Amud Cave (Israel): the evidence from phytolith studies. *Journal of Archaeological Science*, *29*(7), 703-719.

Mahboubi, M., & Kashani, L. M. T. (2018). A Narrative study about the role of Viola odorata as traditional medicinal plant in management of respiratory problems. *Advances in Integrative Medicine*, *5*(3), 112-118.

Mamet, S. D., Brown, C. D., Trant, A. J., & Laroque, C. P. (2019). Shifting global Larix distributions: Northern expansion and southern retraction as species respond to changing climate. *Journal of Biogeography*, *46*(1), 30-44.

Mania, D., & Mania, U. (2005). The natural and socio-cultural environment of Homo erectus at Bilzingsleben, Germany. In *The hominid individual in context* (pp. 98-114). Routledge.

Marks, M., Lapin, B., & Randall, J. (1994). Phragmites australis (P. communis): threats, management and monitoring. *Natural Areas Journal*, *14*(4), 285-294.

McVean, D. N. (1955). Ecology of Alnus glutinosa (L.) Gaertn.: II. Seed distribution and germination. *The Journal of Ecology*, 61-71.

McNabb, J. (2005). Hominins and the Early-Middle Pleistocene transition: evolution, culture and climate in Africa and Europe. *Geological Society, London, Special Publications*, *247*(1), 287-304.

Melamed, Y., Kislev, M. E., Geffen, E., Lev-Yadun, S., & Goren-Inbar, N. (2016). The plant component of an Acheulian diet at Gesher Benot Ya ʻaqov, Israel. *Proceedings of the National Academy of Sciences*, *113*(51), 14674-14679.

Melaram, R., Newton, A. R., & Chafin, J. (2022). Microcystin contamination and toxicity: Implications for agriculture and public health. *Toxins*, *14*(5), 350.

Meng, Q., Manghwar, H., & Hu, W. (2022). Study on supergenus Rubus L.: Edible, medicinal, and phylogenetic characterization. *Plants*, *11*(9), 1211.

Merkt, J., & Müller, H. (1999). Varve chronology and palynology of the Lateglacial in Northwest Germany from lacustrine sediments of Hämelsee in Lower Saxony. *Quaternary International*, *61*(1), 41-59.

Middleton, P., Stewart, F., Al Qahtani, S., Egan, P., OROURKE, C., Abdulrahman, A., ... & DEY, S. S. (2005). Antioxidant, antibacterial activities and general toxicity of Alnus glutinosa, Fraxinus excelsior and Papaver rhoeas.

Mihu-Pintilie, A. (2018). Vegetation and Fauna. Environmental Bioindicators from the Lacustrine Water Body. *Natural Dam Lake Cuejdel in the Stânişoarei Mountains, Eastern Carpathians: A Limnogeographical Study*, 203-228.

Milks, A. (2022). Yew wood, would you? An exploration of the selection of wood for Pleistocene spears. *The missing woodland resources: Archaeobotanical studies of the use of plant raw materials*, 6-17.

Misson, G., Macor, A., Boscutti, F., & Casolo, V. (2016). Ecological characterisation of Hippuris vulgaris populations growing in spring water rivers. *Phyton (Horn)*, *56*(2), 209-224.

Moerman. D.1988. Native Americal Ethnobotany.Timber Press. Oregon. ISBN 0-881924539

Montó, F., Arce, C., Noguera, M. A., Ivorra, M. D., Flanagan, J., Roller, M., ... & D'Ocon, P. (2014). Action of an extract from the seeds of Fraxinus excelsior L. on metabolic disorders in hypertensive and obese animal models. *Food & function*, *5*(4), 786-796.

Morse, J. W., Arvidson, R. S., & Lüttge, A. (2007). Calcium carbonate formation and dissolution. *Chemical reviews*, *107*(2), 342-381.

Motuzaite Matuzeviciute, G., Mir-Makhamad, B., & Tabaldiev, K. (2021). The first comprehensive archaeobotanical analysis of prehistoric agriculture in Kyrgyzstan. *Vegetation History and Archaeobotany*, *30*, 743-758.

Naczi, R. F., Reznicek, A. A., & Ford, B. A. (1998). Morphological, geographical, and ecological differentiation in the Carex willdenowii complex (Cyperaceae). *American Journal of Botany*, *85*(3), 434-447.

Neco, L. C., Abelson, E. S., Brown, A., Natterson-Horowitz, B., & Blumstein, D. T. (2019). The evolution of self-medication behaviour in mammals. *Biological Journal of the Linnean Society*, *128*(2), 373-378.

Neumann, K., Chevalier, A., & Vrydaghs, L. (2017). Phytoliths in archaeology: recent advances. *Vegetation History and Archaeobotany*, *26*, 1-3.

Nichols, S.A, Shaw, B.H. 1986. Ecological life histories of the three aquatic nuisance plants, Myriophyllum spicatum, Potamogeton crispus and Elodea canadensis. Hydrobiologia. 131, 3 - 21.

Noble, J. C., Bell, A. D., & Harper, J. L. (1979). The population biology of plants with clonal growth: I. The morphology and structural demography of Carex arenaria. *The Journal of Ecology*, 983-1008.

Noli, D., & Avery, G. (1988). Protein poisoning and coastal subsistence. *Journal of Archaeological Science*, *15*(4), 395-401.

Noori, M., Jafari, M., & Zakeri, M. (2015). Root and aerial parts flavonoids of 3 Iranian Carex L.(Cyperaceae) species. *Int. J Plant Res*, *5*, 51-56.

Ozturk, M., Uysal, I., Guecel, S., Mert, T., Akcicek, E., & Celik, S. (2008). Ethnoecology of poisonous plants of Turkey and Northern Cyprus. *Pak. J. Bot*, *40*(4), 1359-1386.

Papp, N., Purger, D., Czigle, S., Czégényi, D., Stranczinger, S., Tóth, M., ... & Filep, R. (2022). The Importance of Pine Species in the Ethnomedicine of Transylvania (Romania). *Plants*, *11*(18), 2331.

Pardo-De-Santayana, M., Tardío, J., & Morales, R. (2005). The gathering and consumption of wild edible plants in the Campoo (Cantabria, Spain). *International Journal of Food Sciences and Nutrition*, *56*(7), 529-542

Parfitt, Simon & Ashton, Nick & Lewis, Simon & Abel, Richard & Coope, G & Field, Mike & Gale, Rowena & Hoare, Peter & Larkin, Nigel & Lewis, Mark & Karloukovski, Vassil & Maher, Barbara & Peglar, Sylvia & Preece, Richard & Whittaker, John & Stringer, Christopher. (2010). Early Pleistocene human occupation at the edge of the boreal zone in northwest Europe. Nature. 466. 229-33. 10.1038/nature09117.

Paterson, T. T. (1940, July). The Swanscombe skull: a defense. In *Proceedings of the Prehistoric Society* (Vol. 6, pp. 166-169). Cambridge University Press.

Peters, C., & van Kolfschoten, T. (2020). The site formation history of Schöningen 13II-4 (Germany): Testing different models of site formation by means of spatial analysis, spatial statistics and orientation analysis. *Journal of Archaeological Science*, *114*, 105067.

Planer, R. J. (2017). Talking about tools: did early Pleistocene hominins have a protolanguage? *Biological Theory*, *12*, 211-221.

Pontzer, H., Scott, J. R., Lordkipanidze, D., & Ungar, P. S. (2011). Dental microwear texture analysis and diet in the Dmanisi hominins. *Journal of human evolution*, *61*(6), 683-687.

Pontzer, H., & Wood, B. M. (2021). Effects of evolution, ecology, and economy on human diet: Insights from hunter-gatherers and other small-scale societies. *Annual review of nutrition*, *41*, 363-385.

Posluszny, U., & Sattler, R. (1976). Floral development of Zannichellia palustris. *Canadian Journal of Botany*, *54*(8), 651-662.

Quante, E., Pint, A., & Frenzel, P. (2022). Nonmarine Ostracoda as proxies in (geo-) archaeology—A review. *Geoarchaeology*, *37*(5), 711-732.

Radini, A., Buckley, S., Rosas, A., Estalrrich, A., De la Rasilla, M., & Hardy, K. (2016). Neanderthals, trees and dental calculus: new evidence from El Sidrón. *Antiquity*, *90*(350), 290-301.

Rastogi, S., Pandey, M. M., & Rawat, A. K. S. (2015). Medicinal plants of the genus Betula—Traditional uses and a phytochemical–pharmacological review. *Journal of ethnopharmacology*, *159*, 62-83.

Rellihan, M. (2012). Adaptationism and adaptive thinking in evolutionary psychology. *Philosophical Psychology*, *25*(2), 245-277.

Roberts, M. B., Bates, M. R., Bergman, C., Currant, A. P., Haynes, J. R., Macphail, R., ... & Whatley, R. C. (1986). Excavation of the Lower Palaeolithic site at Amey's Eartham pit, Boxgrove, West Sussex: a preliminary report. In *Proceedings of the Prehistoric Society* (Vol. 52, No. 1, pp. 215-245). Cambridge University Press

Roddy, E., & Doherty, M. (2010). Gout. Epidemiology of gout. *Arthritis research & therapy*, *12*, 1-11.

Rodríguez, J., Mateos, A., Hertler, C., & Palombo, M. R. (2016). Modeling human presence and environmental dynamics during the Mid-Pleistocene Revolution: New approaches and tools. *Quaternary International*, *393*, 19-23.

Rosa, A. (2022).Importance and role of common hazel (*Corylus avelana L.*)in folk medicine and Industry in Azerbaijan. *Бюллетень науки и практики*, *8*(11), 78-82.

Roszyk, E., Stachowska, E., Majka, J., Mania, P., & Broda, M. (2020). Moisture-Dependent Strength Properties of Thermally-Modified Fraxinus excelsior Wood in Compression. *Materials (Basel)*, 13(7), 1647. https://doi.org/10.3390/ma13071647

Scheffer, M. (1998). *Ecology of shallow lakes* (Vol. 1). London: Chapman & Hall

Schmidt, W. C. (1995). Around the world with Larix: an introduction. *Ecol. Manag. Larix For. Look Ahead*, 6-18.

Schoch, W. H., Bigga, G., Böhner, U., Richter, P., & Terberger, T. (2015). New insights on the wooden weapons from the Paleolithic site of Schöningen. *Journal of human evolution*, *89*, 214-225.

Schreve, Danielle. (2012). The Reinsdorf interglacial (Schöningen II) mammalian assemblage in its European context. The Chronological Setting of the Paleolithic Sites of Schöningen. 129-142.

Serangeli, J., & Conard, N. J. (2015). The behaviour al and cultural stratigraphic contexts of the lithic assemblages from Schöningen. *Journal of Human Evolution*, *89*, 287-297.

Serangeli, J., Böhner, U., Van Kolfschoten, T., & Conard, N. J. (2015). Overview and new results from large-scale excavations in Schöningen. *Journal of Human Evolution*, *89*, 27-45.

Serangeli, J., Rodríguez-Álvarez, B., Tucci, M., Verheijen, I., Bigga, G., Böhner, U., … Conard, N. J. (2018). The Project Schöningen from an ecological and cultural perspective. Quaternary Science Reviews, 198, 140–155. https://doi.org/10.1016/j.quascirev.2018.08.020

Sezik, E., Yeşİlada, E., Tabata, M., Honda, G., Takaishi, Y., Fujita, T., ... & Takeda, Y. (1997). Traditional medicine in Turkey VIII. Folk medicine in East Anatolia; Erzurum, Erzincan, Ağri, Kars, Iğdir Provinces. *Economic botany*, 195-211.

Shiraliyeva, G. S., Gurbanova, L. Z., Askerova, A. A., Huseynova, A. E., Seyidova, L. M., & Qasimov, H. Z. (2021). Ethnopharmacological use of wild vegetable plants belonging to the Polygonaceae Juss. family spread in the Azerbaijan flora. *Biodiversity Journal*, *12*(3), 733-740.

Shugart, H. H. (1998). *Terrestrial ecosystems in changing environments*. Cambridge University Press.

Shurkin. (2014). Animals that self-medicate. *Proceedings of the National Academy of Sciences - PNAS*, *111*(49), 17339–17341. https://doi.org/10.1073/pnas.1419966111

Sidor, A., & Gramza-Michałowska, A. (2015). Advanced research on the antioxidant and health benefit of elderberry (Sambucus nigra) in food–a review. *Journal of functional foods*, *18*, 941-958.

Sierralta, M., Frechen, M., & Urban, B. (2012). 230Th/U dating results from opencast mine Schöningen. *Die chronologische Einordnung der paläolithischen Fundstellen von Schöningen, Römisch-Germanisches Zentralmuseum, Mainz*, 143-154.

Simone-Finstrom, M. D., & Spivak, M. (2012). Increased resin collection after parasite challenge: a case of self-medication in honey bees?. *PloS one*, *7*(3), e34601.

Smart, R. M., & Barko, J. W. (1988). Effects of water chemistry on aquatic plants: interrelationships among biomass production, plant nutrition, and water chemistry.

Solecki, R. S. (1975). Shanidar IV, a Neanderthal flower burial in northern Iraq. *Science*, *190*(4217), 880-881.

Speth, J. D. (1989). Early hominid hunting and scavenging: the role of meat as an energy source. *Journal of Human Evolution*, *18*(4), 329–343. https://doi.org/10.1016/0047-2484(89)90035-3

Spicer, R. A. (1991). Plant taphonomic processes. *Taphonomy: releasing the data locked in the fossil record*, *9*, 71-113.

Spikins, P., Needham, A., Wright, B., Dytham, C., Gatta, M., & Hitchens, G. (2019). Living to fight another day: the ecological and evolutionary significance of Neanderthal healthcare. *Quaternary Science Reviews*, *217*, 98-118.

Sponheimer, Passey, B. H., de Ruiter, D. J., Guatelli-Steinberg, D., Cerling, T. E., & Lee-Thorp, J. A. (2006). Isotopic Evidence for Dietary Variability in the Early Hominin Paranthropus robustus. *Science (American Association for the Advancement of Science)*, *314*(5801), 980–982. https://doi.org/10.1126/science.1133827

Squire, L. R. (2004). Memory systems of the brain: a brief history and current perspective. *Neurobiology of learning and memory*, *82*(3), 171-177.

Stahlschmidt, M. C., Miller, C. E., Ligouis, B., Goldberg, P., Berna, F., Urban, B., & Conard, N. J. (2015). The depositional environments of Schöningen 13 II-4 and their archaeological implications. *Journal of Human Evolution*, *89*, 71-91.

Steudel-Numbers, K. L., & Wall-Scheffler, C. M. (2009). Optimal running speed and the evolution of hominin hunting strategies. *Journal of Human Evolution*, *56*(4), 355-360.

Stevens, P. F., Luteyn, J., Oliver, E. G. H., Bell, T. L., Brown, E. A., Crowden, R. K., ... & Weiller, C. M. (2004). Ericaceae. In *Flowering Plants· Dicotyledons: Celastrales, Oxalidales, Rosales, Cornales, Ericales* (pp. 145-194). Berlin, Heidelberg: Springer Berlin Heidelberg.

Svanberg, I. (2012). The use of wild plants as food in pre-industrial Sweden. *Acta Societatis Botanicorum Poloniae*, *81*(4).

Sümegi, P., Jakab, G., Majkut, P., Törőcsik, T., & Zatykó, C. (2009). Middle Age paleoecological and paleoclimatological reconstruction in the Carpathian Basin. *Ido;; járás QJ Hungarian Meteorol. Service*, *113*, 265-298.

Svanberg, I., Sõukand, R., Luczaj, L., Kalle, R., Zyryanova, O., Papp, N., ... & Kolosova, V. (2012). Uses of tree saps in northern and eastern parts of Europe. *Acta Societatis Botanicorum Poloniae*, *81*(4), 343-357.

Swanson, F. J., Gregory, S. V., Sedell, J. R., & Campbell, A. G. (1982). Land-water interactions: the riparian zone.

Tarling, D. H. (2010). Milankovitch cycles in climate change, geology and geophysics. In *Paper present at the 6th International Symposium on Geophysics, November* (pp. 11-12).

Tawfeek, N., Mahmoud, M. F., Hamdan, D. I., Sobeh, M., Farrag, N., Wink, M., & El-Shazly, A. M. (2021). Phytochemistry, pharmacology and medicinal uses of plants of the genus Salix: An updated review. *Frontiers in pharmacology*, *12*, 593856.

Thieme, H. (1997). Lower Paleolithic hunting spears from Germany. *Nature*, *385*(6619), 807-810.

Thieme, H. (2005). The lower Palaeolithic art of hunting: the case of Schöningen 13 II-4, lower Saxony, Germany. In *Hominid Individual in Context* (pp. 115-132). Routledge.

Thomas, D. C., Chablani, D., Parekh, S., Pichammal, R. C., Shanmugasundaram, K., & Pitchumani, P. K. (2022). Dysgeusia: A review in the context of COVID-19. *The Journal of the American Dental Association*, *153*(3), 251-264.

Thomasson, J. R. (1983). Carex graceii sp. n., Cyperocarpus eliasii sp. n., Cyperocarpus terrestris sp. n., and Cyperocarpus pulcherrima sp. n.(Cyperaceae) from the Miocene of Nebraska. *American Journal of Botany*, *70*(3), 435-449.

Tucci, M., Krahn, K. J., Richter, D., van Kolfschoten, T., Alvarez, B. R., Verheijen, I., ... & Urban, B. (2021). Evidence for the age and timing of environmental change associated with a Lower Palaeolithic site within the Middle Pleistocene Reinsdorf sequence of the Schöningen coal mine, Germany. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *569*, 110309.

Uchytil, R.J. (1989). Alnus rubra. In U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (2001, May). *Fire Effects Information System*. [Online]. Available: http://www.fs.fed.us/database/feis/. Retrieved September 22, 2023

Ulbricht, C., Basch, E., Cheung, L., Goldberg, H., Hammerness, P., Isaac, R., ... & Wortley, J. (2014). An evidence-based systematic review of elderberry and elderflower (Sambucus nigra) by the Natural Standard Research Collaboration. *Journal of dietary supplements*, *11*(1), 80-120.

Unger, L., Nicholson, A., Jewitt, E. M., Gerber, V., Hegeman, A., Sweetman, L., & Valberg, S. (2014). Hypoglycin A concentrations in seeds of Acer pseudoplatanus trees growing on atypical myopathy-affected and control pastures. *Journal of veterinary internal medicine* , *28*(4), 1289-1293.

Urban, B. (1992). Interglacial/Glacial Transitions Recorded from Middle and Young Pleistocene Sections of Eastern Lower Saxony/Germany. In: Kukla, G.J., Went, E. (eds) Start of a Glacial. NATO ASI Series, vol 3. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-76954-2_4

Urban, B., & Bigga, G. (2015). Environmental reconstruction and biostratigraphy of late Middle Pleistocene lakeshore deposits at Schöningen. *Journal of Human Evolution*, *89*, 57-70.

Urban, B., Kasper, T., Krahn, K., Van Kolfschoten, T., Rech, B., Holzheu, M., . . . Schwalb, A. (2023). Landscape dynamics and chronological refinement of the Middle Pleistocene Reinsdorf Sequence of Schöningen, NW Germany. *Quaternary Research, 114*, 148-177. doi:10.1017/qua.2022.65

Van Smeerdijk, D. G. (1989). Alder carr, growth and drowning in the IJsselmeer region, an aspect of the Dutch coastal development. *Acta botanica neerlandica*, *38*(4), 477-491.

Vaquero, M. (2008). The history of stones: behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic. *Journal of Archaeological Science*, *35*(12), 3178-3185.

Verma, R., Gangrade, T., Punasiya, R., & Ghulaxe, C. (2014). Rubus fruticosus (blackberry) use as an herbal medicine. *Pharmacognosy reviews*, *8*(16), 101.

Versace, R., Labeye, E., Badard, G., & Rose, M. (2009). The contents of long-term memory and the emergence of knowledge. *European journal of cognitive psychology*, *21*(4), 522-560.

Van der Toorn, J. 1980. On the ecology of Cotula coronopifolia L. and Ranunculus sceleratus L. Acta Botanica Neerlandia. 29 (5/6), 385 - 396.

Van Vierssen, W. (1982). The ecology of communities dominated by Zannichellia taxa in western Europe. II. Distribution, synecology and productivity aspects in relation to environmental factors. *Aquatic Botany*, *13*, 385-483.

Villalba, J. J., Provenza, F. D., & Shaw, R. (2006). Sheep self-medicate when challenged with illness-inducing foods. *Animal Behaviour*, *71*(5), 1131-1139. **ISSN:** 0003-3472 , 1095-8282

Wagner, G. A., Maul, L. C., Löscher, M., & Schreiber, H. D. (2011). Mauer–the type site of Homo heidelbergensis: palaeoenvironment and age. *Quaternary Science Reviews*, *30*(11-12), 1464-1473.

Wichtl, M., & Bisset, N. G. (1994). Herbal drugs and phytopharmaceuticals. Medpharm. *GmbH Scientific Publishers, Birkenwaldstrasse*, *44*, 650-652.

Wolfe, J. A. (1978). A paleobotanical interpretation of Tertiary climates in the Northern Hemisphere: Data from fossil plants make it possible to reconstruct Tertiary climatic changes, which may be correlated with changes in the inclination of the earth's rotational axis. *American scientist*, *66*(6), 694-703.

Wynn, T. (2002). Archaeology and cognitive evolution. *Behaviour al and Brain Sciences, 25*(3), 389-402. doi:10.1017/S0140525X02000079

Xu, K., Xu, X., Yang, Q. *et al.* (2023). Mechanistic Analysis and Bio-inspired Applications for a Bidirectional Stiffness of a Water Snail Operculum. *J Bionic Eng* **20**, 1930–1941 (2023). https://doi.org/10.1007/s42235-023-00384-4.

Yadav, N., Vasudeva, N., Singh, S., & Sharma, S. K. (2007). Medicinal properties of genus Chenopodium Linn.

Zackrisson, O., Östlund, L., Korhonen, O., & Bergman, I. (2000). The ancient use of Pinus sylvestris L.(Scots pine) inner bark by Sami people in northern Sweden, related to cultural and ecological factors. *Vegetation history and archaeobotany*, *9*, 99-109.

Zhang, S. C., Lin, S., Shen, A., Chen, H., Wang, F., & Huai, H. Y. (2016). Traditional knowledge on "Luchai"[Phragmites australis (Cav.) Trin. ex Steud. and Arundo donax L.] and their dynamics through urbanization in Yangzhou area, East China.

Zia-Ul-Haq, M., Riaz, M., De Feo, V., Jaafar, H. Z., & Moga, M. (2014). Rubus fruticosus L.: constituents, biological activities and health related uses. *Molecules*, *19*(8), 10998-1102

Zulueta, M. C. A., Tada, M., & Ragasa, C. Y. (1995). A diterpene from Bidens pilosa. *Phytochemistry*, *38*(6), 1449-1450.

Zuo, S., Wan, K., & Ma, S. (2014). Environmental restoration effects of Ranunculus sceleratus L. in a eutrophic sewage system. *Biochemical Systematics and Ecology*, *55*, 34-40.