Vegetation Reconstruction by Plant Macrofossils for the ca. 1200-year-old Altaussee Mire (Styria, Austria)

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presented by
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1. Abstract

A sediment core of 100 cm length was extracted from a small mire west of Altaussee, Styria, Austria, and examined for its macrofossil content. According to radiocarbon dating, the base of the mire can be considered around 1200 years old. Under the mire a sediment layer of approximately 30–50cm of minerogenic particles points to a flood or mudslide event which brought along a lot of minerogenic and organic debris and rubble ahead of the mire formation around AD 800. Macrofossils from coniferous trees in the lower half of the sediment core are not very numerous and macrofossils from deciduous trees are non-existent, so it is highly unlikely that the area was densely forested. Macrofossil finds of *Coenococcum geophilum,* a fungal species in soils, which can handle water stress very well, suggest poor soil conditions or erosional features during this time (ca. AD 880–1150). Simultaneously, larval cases from caddisflies indicate some standing water. A transitioning zone follows in the middle layers of the sediment core, where brown mosses (Amblystegiaceae) dominated and moisture levels were still high (ca. AD 1275–1400). As moss macrofossil numbers decline rapidly in the upper half of the core (ca. AD 1540), a change in moisture levels can be inferred and anthropogenic influence becomes more evident. Especially in the settlement areas, residents did a lot of drainage work to improve soil conditions and gain better land for agricultural purposes. Cerealia and flaxseed (*Linum*) macrofossils finds also attest this agricultural impact, and the furrows from historical ploughing can still be seen today on aerial photos of the site.

2. Introduction and Approach

Altaussee is a municipality situated in the Austrian state of Styria. It belongs to the Ausseer Becken ("basin") which is part of the Salzkammergut region ("salt domain"). Altaussee is especially known today as a climatic spa and many people come here to enjoy the good air and tranquillity amidst the magnificent alpine region. The idyllic lake and its adjacent landscapes are natural protected sites as they provide habitats for a multitude of animals and plants.

Only little is known regarding the earliest human settlements in the Ausseer region. Somewhat more is known about the Bronze Age and the subsequent Roman Era as several archaeological discoveries stem from these periods, followed by the Bavarians in the early Middle Ages (Lamer 1998). The first references to salt mining in the area also date back to the Middle Ages (Lamer 1998). In parallel with the poorly documented prehistoric and ancient times, previous research on vegetation development in the region and whether it was influenced by human presence is limited.

In this Bachelor thesis macrofossils from a sediment stratigraphy extracted from a mire near Lake Altaussee will be examined and described. Different macrofossil deposits can give indications of environmental and vegetation changes. Was there possibly a time when the site was submerged for a longer period? How do the macroremains reflect on agriculture and lifestyle of past human populations? How do the macrofossil assemblages compare to the present vegetation? This study intends to provide some initial insights into the environmental developments of the area.

3. Study Site

3.1. Overview

The study site is a small, unprotected mire (Figs. 1 & 2), which is about 200 m walking distance west from the shoreline of Lake Altaussee at an altitude of 712 m and at the GPS coordinates 47,635050 N and 13,765015 E.

At first glance, the respective area looks like a common meadow. On closer inspection, the remnants of a moor can be seen (Fig. 3). The farmers in order to drain the moor and obtain agricultural land and/or a high yielding pasture implemented channels.

This situation is mirrored in the vegetation survey, which was done on the same day as the core extraction (June 1, 2022).

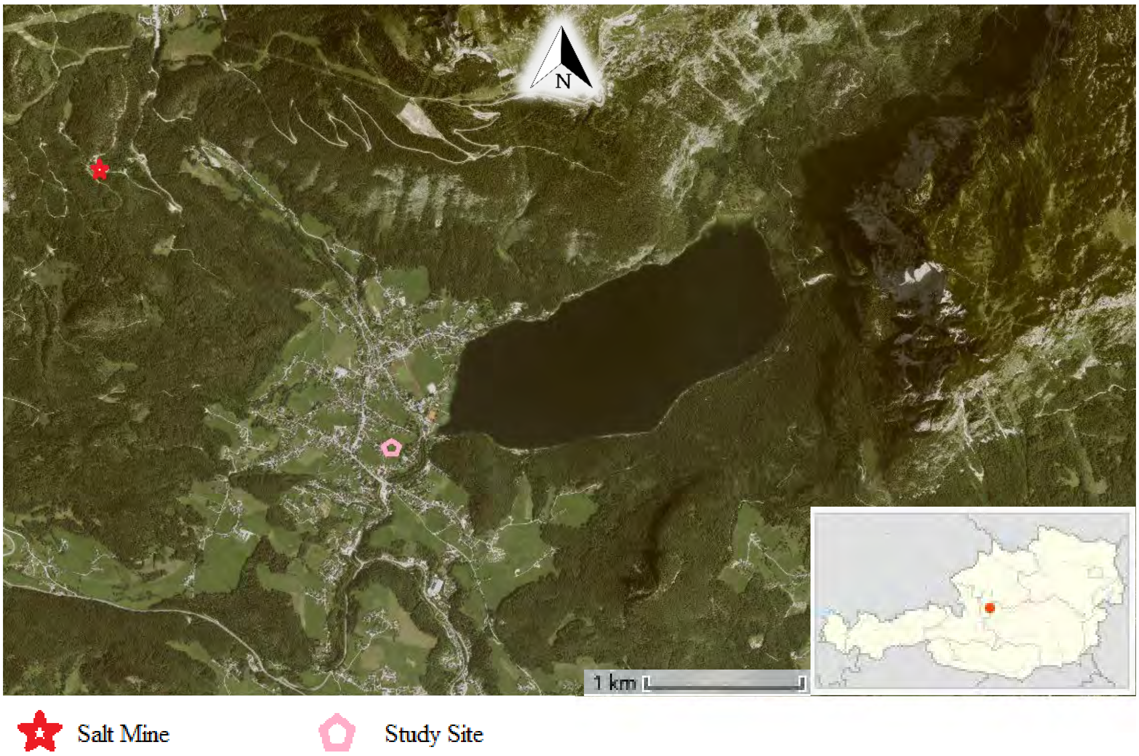

Fig. 01: Satellite photo showing the location of the mire study site west of Lake Altaussee (Styria, Austria). The site is situated in the settlement area of the Altaussee municipality embedded between spectacular mountain landscapes (Altered from: Scribble Maps 2022).

Fig. 02: The mire study site west of Lake Altaussee (Styria, Austria) in a close-up satellite image. The study site area differs from the rest of the meadows around due to different drainage management (Altered from: Scribble Maps 2022).

Species preferring a humid location like *Dactylorhiza maculata* were found as well as species that are common for meadows like *Trifolium pratense* (Fig. 4). There were also species growing that indicate pasturing and trampling, like *Plantago lanceolata*. Table 1 below contains the plant species found at the drill site and the immediate vicinity. As the survey was done only on the day of the core extraction, it should be mentioned that the list cannot be considered an exhaustive.

Tab. 1: Plant species found at the study site in Altaussee (Styria, Austria) in 2022.

Species	Family	Growth habit	Life-cycle	Common name
Alchemilla vulgaris	Rosaceae	herb	perennial	lady's mantle
Amblystegiaceae (brown mosses)	Amblystegiaceae	cryptogam	perennial	brown mosses
Anthoxantum odoratum	Poaceae	herb	perennial	sweet vernal grass
Briza media	Poaceae	herb	perennial	quaking grass
Carex hirta (cf.)	Cyperaceae	herb	perennial	hairy sedge
Crepis biennis	Asteraceae	herb	perennial	rough hawksbeard
Dactylorhiza maculata	Orchidaceae	herb	perennial	heath spotted-orchid
Equisetum arvense	Equisetaceae	herb	perennial	common horsetail
Eriophorum angustifolium	Cyperaceae	herb	perennial	common cottonsedge
Filipendula ulmaria	Rosaceae	herb	perennial	meadowsweet
Galium album	Rubiaceae	herb	annual	white bedstraw
Lotus corniculatus	Fabaceae	herb	perennial	bird's-foot trefoil
Potentilla erecta	Rosaceae	herb	perennial	erect cinquefoil
Lychnis flos-cuculi	Caryophyllaceae	herb	perennial	ragged-robin
Phragmites vulgaris	Poaceae	herb	perennial	common reed
Plantago lanceolata	Plantaginaceae	herb	perennial	narrowleaf plantain
Polygala vulgaris	Polygalaceae	herb	perennial	common milkwort
Rubus idaeus	Rosaceae	shrub	perennial	red raspberry
Rumex acetosa	Polygonaceae	herb	perennial	sorrel
Trifolium pratense	Fabaceae	herb	perennial	red clover

3.2. Geology

Altaussee is situated in the Northern Limestone Alps at the northern edge of a region called the Ausseer Becken, a slightly sloping terrain between 700 and 1000 meters in elevation that was formed during the last glacial age (Götzinger 1935). The surrounding mountains and valley landscapes represent Mesozoic formations. A large part of the mountainous area around Altaussee belong to the Dachstein Formation (Dachsteinkalk; Fig. 5) which is characterized by lack of water and vegetation and therefore is called Totes Gebirge ("Dead Mountain Range") (Frischmuth 1946). Another large part of the area is made up of Plassenkalk, also a limestone formation (Fig. 5).

Fig. 03: Photo of the mire study side west of Lake Altaussee (Styria, Austria), view in northwesterly direction. Photo taken on June 1st 2022. © Victoria Wenger.

Fig. 04: Photo of the exact sediment coring spot at the study site west of Lake Altaussee (Styria, Austria). After drilling, a PVC pipe was put into the drill hole to mark the spot. Photo © Victoria Wenger.

Of major importance for the region's productivity is the area around the mountain Loser, where specific layers of rocks called Allgäuschichten provide a suitable basis for grasslands, which are vital for alpine farming and livestock breeding (Möbus 1997; Scholz 2016).

South of Lake Altaussee, Mesozoic dolomite formations occur as well as Pleistocene moraines (Fig. 5). Most housing and roads are built on these moraines, interspersed with intermediary mires (Frischmuth 1946). The location where the sediment sample was taken is situated in an alluvial fan, which belongs to the current Holocene epoch (Amt der Steiermärkischen Landesregierung 2022a).

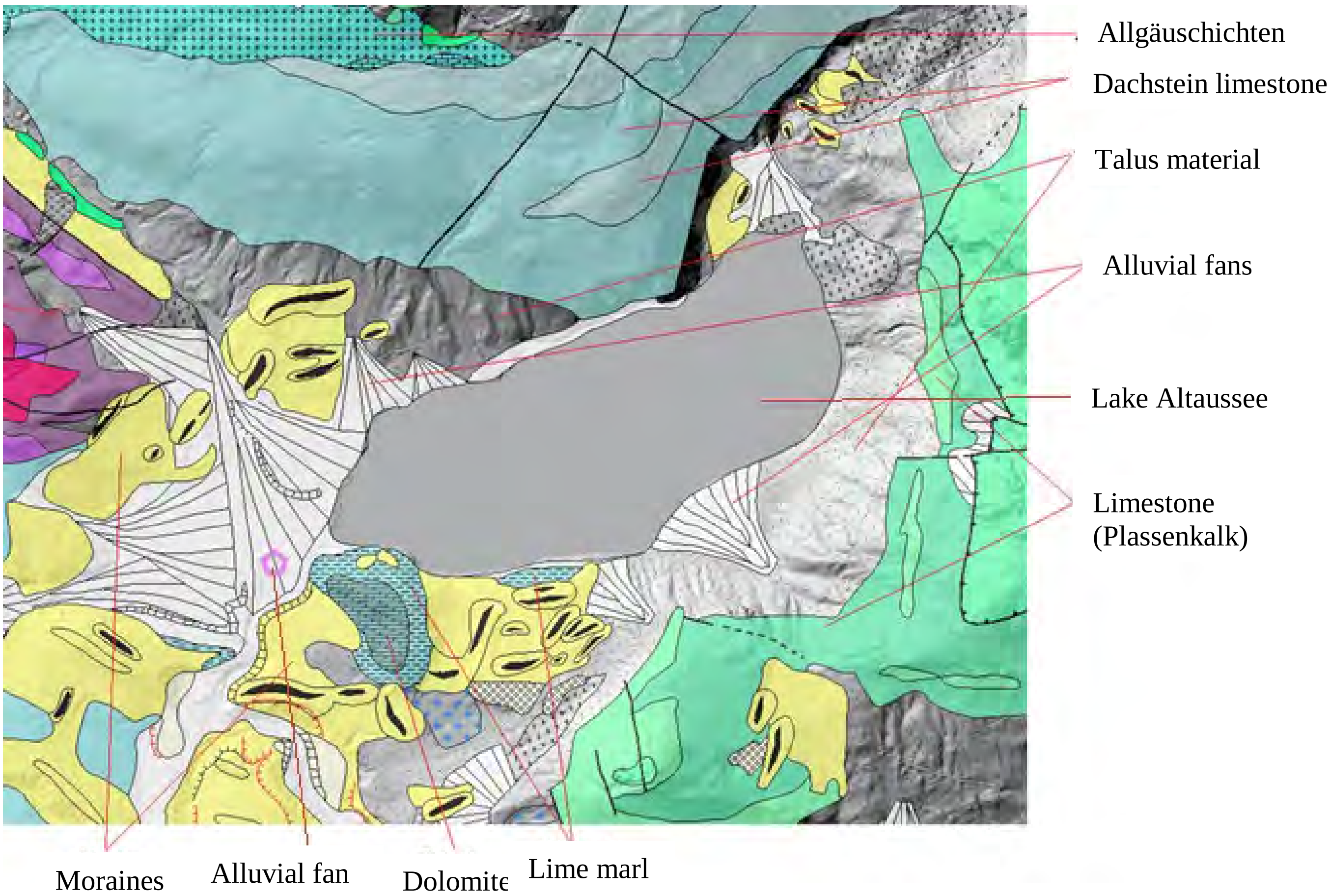

Fig. 05: Geological map of the region around Lake Altaussee (Styria, Austria). Study site marked with ⬠. (Altered from: Amt der Steiermärkischen Landesregierung 2022a).

3.3. Climate

Altaussee has a moderate bracing climate, which means the climate is suitable for recreation, especially in the winter months (Amt der Steiermärkischen Landesregierung 2022b). Due to its basin location at the northern edge of the Alps, rain-laden clouds brought by north-westerly and westerly winds accumulate and usually bring a lot of precipitation in the summer and winter months, making the region one of Austria's most snowy areas (Prettenthaler et al. 2010).

As can be seen in the climate diagram for the Ausseer Becken below (Fig. 06), precipitation maxima are reached during the summer months from June to August. The average annual precipitation is 1532 mm and the average annual temperature 7,3 °C.

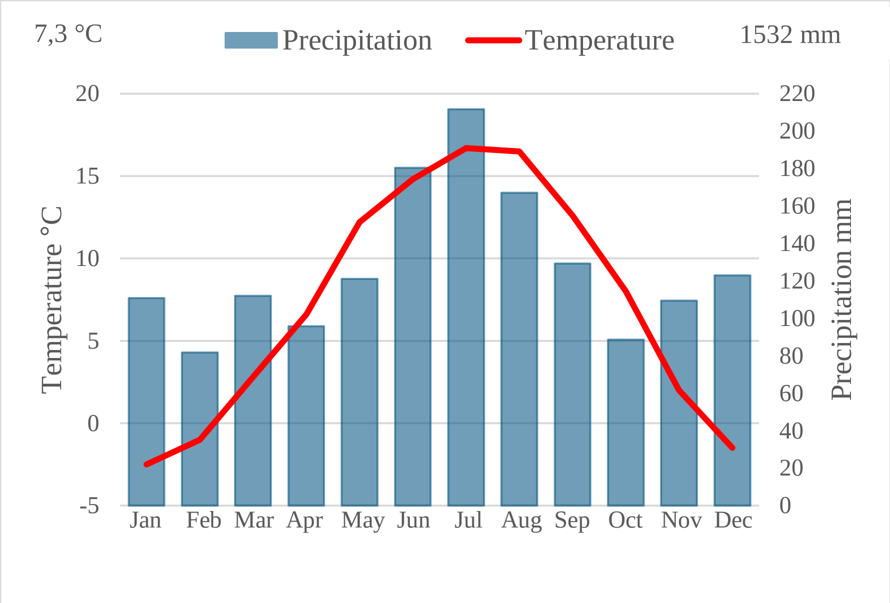

Fig. 06: The mean monthly temperature and precipitation for the Ausseer Becken (Styria, Austria) (Data taken from ZAMG 2022).

3.4. Extant Vegetation

The region around Lake Altaussee belongs to the western part of the Northern Alps (Bundesforschungszentrum für Wald 2022). In montane altitudes from 400 to 800 m beech forests (*Fagus sylvatica*) grow mixed with firs (*Abies alba*), maple (*Acer pseudoplatanus*) and ash trees (*Fraxinus excelsior*). Spruce (*Picea abies*)–fir–beech communities dominate the next higher altitude levels from 800 to 1450 m. Anthropogenic interventions are frequent as segregation to mere spruce–fir, and spruce–beech forest occur, or respectively, spruce or beech pure stands. Depending on location and soil conditions, other tree communities and pure stands can be observed. In subalpine altitudes from 1450 to 1650 m spruce grows frequently mixed with larch (*Larix decidua*) (Kilian et al. 1994). Pure stands of spruce trees also dominate because of a substantial need for firewood to produce salt from salt mines in past centuries. High amounts of wood were also needed for the tunnels and the piping of the salt mines (Frischmuth 1946, Lamer 1998).

Precipitous rocks, forests, and lush meadows characterize the Altausseer landscape. In addition to the tree species mentioned above, the stone pine (*Pinus cembra*) can also be found at sunny subalpine and alpine hillside locations. Down in the valley, beech and maple trees are frequent among the deciduous trees. Rowan (*Sorbus aucuparia*) and elderberry (*Sambucus nigra*) are common as well. Grassland vegetation can differ significantly depending on location and soil properties. Noteworthy is the rich flowering of daffodils (*Narcissus poeticus*) at Pentecost around Lake Altaussee, which usually grow in abundance and prosperously in the humid meadows of the morainic lands (Frischmuth 1946).

3.5. History of Human Presence

Regarding the earliest human settlement of the Ausseer region there is only very scarce evidence. The Salzofenhöhle (“salt furnace cave”) in the Dead Mountains, a cave explored since 1924, where a large number of animal bones, mainly of bears, were found with some stone tools as well as a fireplace (Mirsch 2013), plays an important role. Remains of other Stone Age settlements have not yet been discovered in the Ausseer region as well as in the entire Styrian Salzkammergut. However, a stone axe was found on the Pötschenhöhe and a stone hammer at a location that can no longer be determined (Lamer 1998). Both objects are said to be about 8000 years old, i.e. from the Mesolithic period (Lamer 1998).

Somewhat more numerous are the finds that can be assigned to the Bronze Age, i.e. to the period from about 2200 to about 800 BC. Among others, a bronze dagger and a bronze sword originate from the area of today's municipality of Altaussee (Mirsch 2013). From the so-called Hallstatt period, among other things, a spiral brooch was preserved (Mirsch 2013).

Three so-called Roman stones in the Styrian Salzkammergut date back to the Roman period, which began with the shifting of the northern border of the Roman Empire to the Danube in 16/15 BC. For the 5th to 8th centuries AD (Medieval period) there are no archaeological finds so far (Mirsch 2013). An impressive relic of the Bavarian immigration from the late 8th century onward is a burial ground discovered in Bad Mitterndorf in 1873. From then on, it is highly likely that the settlements in the region were permanent (Lamer 1998). The first written record of salt mining in Altaussee dates to AD 1094 but the actual start of salt mining might have been much earlier as evidenced by archaeological finds in the nearby municipality of Hallstatt (Friedel 1985). For the Ausseer region salt mining is still important today.

4. Materials & Methods

4.1. Field work

On June 1st 2022, three sediment cores were extracted with a 5.0 cm wide and 50 cm long stainless-steel Russian peat borer (invented by Belokopytov & Beresnevich in 1955; Burt & Thompson 2020) under the management of Professor Jean Nicolas Haas, with the help of Marcel-Luciano Ortler, Clemens Schmalfuß, Lisa-Maria Weber, and myself. Two cores (ALTMO22-1 and ALTMO22-2; the abbreviation ALTMO meaning ALTaussee MOor) were not investigated further as the desired depth (minerogenic layer in ca. 100 cm depth) was not reached. However, at the third attempt the desired depth of 100 cm was reached and we successfully extracted the sediment core ALTMO22-3 (Figs 7 & 8). The sediment sample actually consists of two core parts, the first one from 0 to 50 cm and the second one from 50 to 100 cm. Both core samples were separately put into 50 cm PVC pipe halves (cut length-wise) and wrapped tightly with plastic film in order to avert microbial activity and drying out. Aluminium foil was then used to lightproof the packaging. The sediment cores were retained in a cold storage room at 4 degrees Celsius at the Department of Botany at the University of Innsbruck.

Fig. 07: Photo showing the uppermost core part (0–50 cm) from the mire stratigraphy of our study site west of Lake Altaussee (Styria, Austria). Photo taken directly at the study site before packaging. Photo © Victoria Wenger.

Fig. 08: Photo showing the second core part (50–100 cm) from the mire stratigraphy of our study site west of Lake Altaussee (Styria, Austria). Photo taken directly at the study site before packaging. Photo © Victoria Wenger.

4.2. Sampling for Palaeoecological Analyses

Sampling for macrofossil analyses and radiocarbon dating took place at the Department of Botany of the University of Innsbruck. Ahead, the sediment core was photographed in order to protocol sedimentological conditions and layers. Afterwards, sediment slices of 1 cm thickness were extracted from the core every 10 cm starting at a core depth of 97 cm (Figs. 9 & 10). This means that a sample of 1 cm was e.g. taken from 96.5 cm to 97.5 cm. Correspondingly samples were also collected at the core depths of 87, 77, 67, 57, 47, 37, 27, 17 and 7 cm (Tab. 2). A standard folding rule was used to determine the depths and the samples were cut by knife and carefully removed from the pipe. The outer smear layer resulting from turning the peat borer in the sediment was then removed to avoid contamination and from every sample, also 1 cubic centimetre was removed for palynological analysis. These latter samples were put into small plastic bags and were stored in the freezer at the Department of Botany for later examination, as palynological analysis would go beyond the scope of this bachelor thesis. The remaining samples for macrofossil analysis (Tab. 2) were also put into transparent, self-sealing plastic bags of which the tare weights were determined earlier and therefore the samples could subsequently be weighed in the laboratory.

Fig. 09: Photo of the uppermost core part (0–50 cm) from the mire stratigraphy of our study site west of Lake Altaussee (Styria, Austria) taken after sample collection at the Department of Botany. Gaps were filled with labelled Styrofoam pieces. Photo © Victoria Wenger.

Fig. 10: Photo of the second core part (50–100 cm) from the mire stratigraphy of our study site west of Lake Altaussee (Styria, Austria) taken after sample collection at the Department of Botany. Gaps were filled with labelled Styrofoam pieces. Photo © Victoria Wenger.

4.3. Sample Preparation

Before sieving, the volume of each sample was determined via water displacement by putting the sample into a measurement cylinder with distilled water. An overview of the samples from the mire stratigraphy of Lake Altaussee (Styria, Austria) is shown in Table 02 and Figure 11. The samples were then sieved using different mesh sizes.

Table 02: Overview for the sediment sample extracted from the mire stratigraphy of Lake Altaussee (Styria, Austria).

Sample	Depth	Net weight	Volume	Density
ALTMO22-3	7 cm	6,67 g	6 cm^3	1,112 g/cm^3
ALTMO22-3	17 cm	9,63 g	9 cm^3	1,070 g/cm^3
ALTMO22-3	27 cm	6,70 g	7 cm^3	0,957 g/cm^3
ALTMO22-3	37 cm	8,37 g	7 cm^3	1,196 g/cm^3
ALTMO22-3	47 cm	8,34 g	7 cm^3	1,191 g/cm^3
ALTMO22-3	57 cm	8,34 g	8 cm^3	1,043 g/cm^3
ALTMO22-3	67 cm	9,25 g	8 cm^3	1,156 g/cm^3
ALTMO22-3	77 cm	8,63 g	8 cm^3	1,079 g/cm^3
ALTMO22-3	87 cm	9,15 g	8 cm^3	1,144 g/cm^3
ALTMO22-3	97 cm	13,86 g	7 cm^3	1,980 g/ cm^3

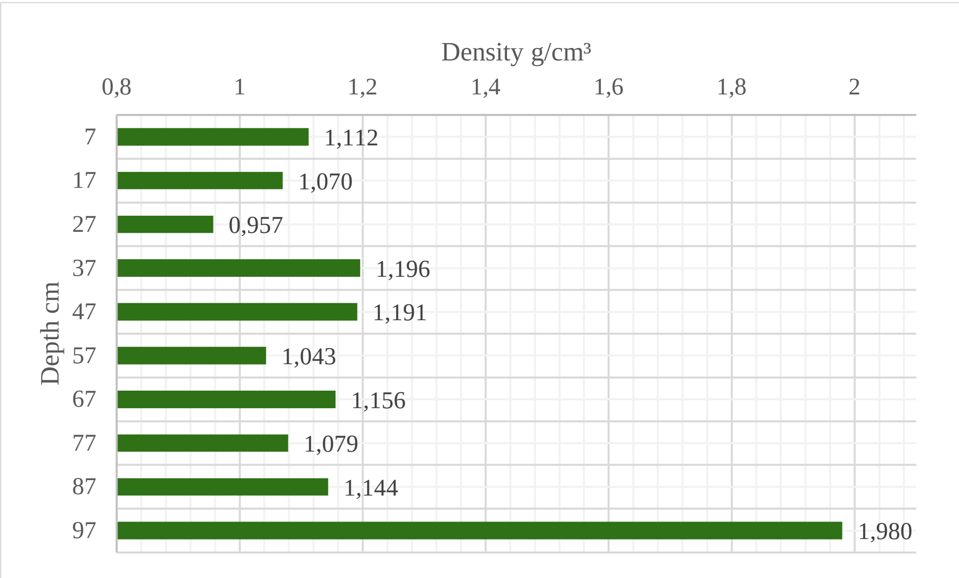

Fig. 11: Soil density and depth relationship for the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria). Soil density mostly varies between 1,0 and 1,2 g/cm^3. Overall trend is an increase of density with depth. The highest density occurs in the lowest sample at 97 cm depth.

The sieves were put over each other according to size beginning with the biggest mesh size on top: 1000 µm, 500 µm, 250 µm and 125 µm. The sediment samples were then carefully washed with a gentle jet of distilled water to loosen the soil structure. After a certain amount of time the macrofossils were separated from the sediment and afterwards they could be cautiously washed into small closable plastic cups. These macrofossil remains were also kept in cold storage until further examination. This way for each sample four fractions of macrofossils were obtained.

4.4. Macrofossil Analyses

In the current study the sieve sizes of 1000 and 500 µm were analysed. The smaller sample sizes are kept in cold storage for possible future analysis as looking at all four sieve sizes would go beyond the scope of this Bachelor thesis. Each sample was put into a petri dish and closely examined under a binocular microscope. Macrofossils were carefully retrieved with special tweezers and separated into small plastic containers. Similar remains were collected in the same containers. Plant and animal macroremains were looked at in detail with an Olympus SZ60 stereo microscope which is capable to magnify up to 63x. Seeds were identified using the determination literature and the seed atlas by Jacomet et al. (1989) and Cappers et al. (2012), and/or then compared to the reference collection at the Department of Botany. Some macrofossils which occurred in high numbers like indeterminable plant remains, roots or minerogenic particles were not exactly counted, but the amount on 1 cm^2 of the petri dish was counted and then extrapolated to the overall petri dish surface area of 63,62 cm^2. The raw data of macrofossil findings can be seen in table A1 (Appendix), and the normalized (10 ml) macrofossil findings can be found in table A2 (Appendix). The number of macrofossils, which were extrapolated, can be seen in table A3 (Appendix).

Due to the different sediment layers and the resultant differences in volume of the samples, the counted macrofossil findings were normalized to a determined unit quantity of 10 ml via the software Tilia for result presentation.

Furthermore, some macroremains were photographed with a Leica DMC4500 microscope camera and scale bars were added according to magnification levels. Selected macrofossil photos can be found in figures A1, A2 and A3 in the appendix

4.5. Radiocarbon Dating

A piece of pine bark (Pinaceae, 4.2 mg in dry weight) from a depth of 87 cm was selected for radiocarbon dating in order to determine the age of the mire (Tab 03). The sample was transferred into a new glass container that was weighed beforehand, and left to dry for a couple of days in the laboratory. After drying, the container including the sample was weighed again, and the tare weight was subtracted. The sample was then sent to the University of Bern in Switzerland, where Dr. Sönke Szidat and his team performed radiocarbon dating at the LARA facility of the University of Bern. The resulting radiocarbon age was then converted into calendar ages according to atmospheric data and calibration (Wacker 2010, Reimer et al. 2020).

Tab. 03: Radiocarbon dating performed at the University of Bern (Switzerland) on a plant macrofossil from the mire stratigraphy of Lake Altaussee (Styria, Austria).

Lab Code	Sample label	Age_uncal (y BP)	±1s (y)	Fin. C cont. (µgC)	$\delta^{13}C$ (‰)	Material	measurement
BE-19605.1.1	1_Haas_08_22: ALTMO-87cm	1143	21	801	-23,3	Pinaceae bark	graphite

5. Results

5.1. Radiocarbon Dating

Dr. Szidat used the software SwissCal 1.0. (Wacker 2010) for calibration and the atmospheric data from Reimer et al. (2020) to measure ^{14}C concentration. A mean radiocarbon date of AD cal. 882 ± 106 was determined for the mire (at a depth of 87 cm), with a most probable date of AD 926 ± 52 (84.76% probability, 2 sigma range) (Fig. 12).

With the radiocarbon age determined, the number of years per centimetre accumulation were calculated (13.1 years per cm) and the age for each depth was extrapolated (Tab 04).

5.2. Macrofossil Analysis

5.2.1. Local Macrofossil Assemblage Zones

Macrofossil data were integrated into the software Tilia (Version 3.0.2) and statistical diagrams created and edited for further analysis. A cluster analysis was done using the CONISS method ("Constrained incremental sum of squares") by which local macrofossil assemblage zones (LMAZ) could be distinguished. These assemblage zones differ in terms of macrofossil findings.

Four LMAZ could be identified by this cluster analysis (Fig. 13):

Depth cm	Age AD
97	751 ± 106
87	882 ± 106
77	1013 ± 106
67	1144 ± 106
57	1275 ± 106
47	1406 ± 106
37	1537 ± 106
27	1668 ± 106
17	1799 ± 106
7	1930 ± 106

Tab. 04: Sample depths and their corresponding ages for the mire stratigraphy of Lake Altaussee (Styria, Austria).

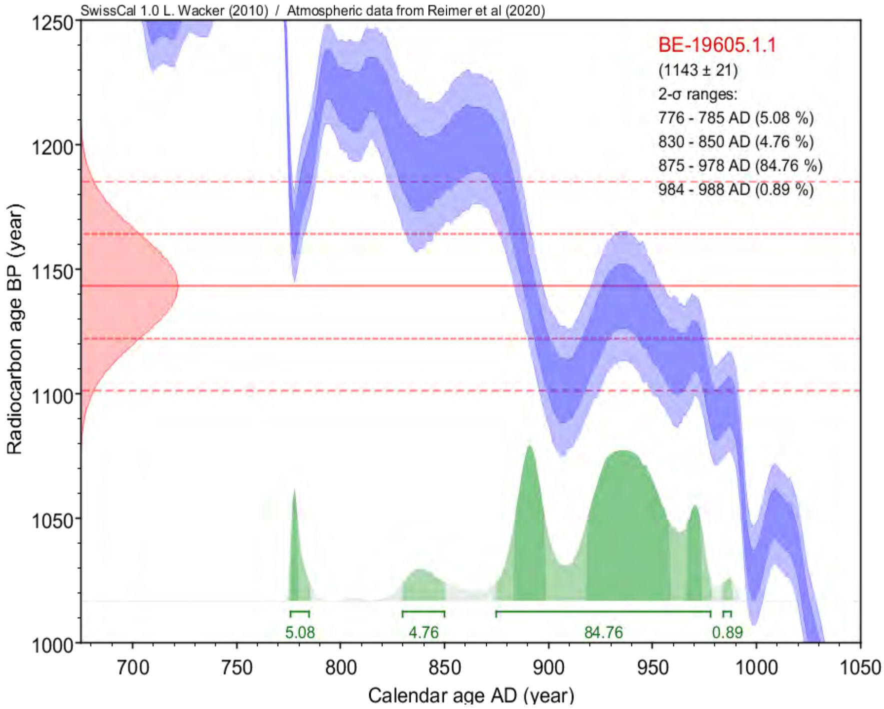

Fig. 12: Calibration of the radiocarbon measurement at 87 cm depth from the mire stratigraphy of Lake Altaussee (Styria, Austria). The y-axis shows the uncalibrated radiocarbon age expressed in years BP (before present), and the x-axis shows calendar years (derived from the calibration after Wacker (2010) and Reimer et al. (2020)). Blue curves show the radiocarbon measurements from the atmospheric data, the red curve on the left indicates the radiocarbon concentration of the sample. The green curves show probable calibration ranges for the sample. There is a probability of 84.76 % that the sample dates from AD 926 ± 52.

LMAZ 1: ca. AD 700–800

This zone at a depth of 100 to 92 cm is characterized by massive amounts of minerogenic particles and only a small number of indeterminable vegetative remains (Fig. 13). Charcoal finds are highest at this depth and wood remains (Substantia lignosa, SL) were found as well. With respect to animal remains, pieces of bivalve shells were found. Furthermore, the fungal species *Coenococcum geophilum* was detected.

LMAZ 2: ca. AD 800–1065

The second zone encompasses a larger area at a depth of approximately 92 to 62 cm (Fig. 13). Looking at the Tilia diagram (Fig. 13), it is noticeable that LMAZ 2 is one of two zones in which most macrofossils from trees are found. Findings include *Picea abies* and *Pinus* needles as well as *Pinus* seeds. The highest amount of Substantia lignosa (SL) was recorded for this zone and charcoal finds occur in considerable amounts. Concerning herbs, more specifically graminoids, Poaceae and Cyperaceae remains were found. Other interesting discoveries from this zone include a seed and a charred seed pod from *Linum catharticum* (ca. AD 985). Furthermore, one *Silene* cf. *vulgaris* seed and one Ranunculaceae seed that was not determined further were found in the upper layers of this zone. Regarding cryptogams, numerous remnants of the moss family Amblystegiaceae appear for the first time and large amounts of indeterminable root material emerge in LMAZ 2. Similar to LMAZ 1, *Coenococcum geophilum* can be found throughout the entire zone. In terms of zoological findings, Coloeptera remains and Lumbricidae eggs emerge for the first time. Coprolites, fossilized faeces, were found quite numerous in this zone. Compared to the first zone, minerogenic particles are very scarce.

LMAZ 3: ca. AD 1065–1900

The third and largest zone (in terms of sediment depth) stretches from 62 to 8 cm and also contains tree macrofossils (Fig. 13). *Abies alba* and *Larix decidua* needles were found at 67 cm depth. SL remains and charcoal finds also occur but in lower amounts than in the previous zone. This zone encompasses also high amounts of herb and root remains. In terms of herbs, Poaceae as well as Cyperaceae remains occur. Bicarpellate Cyperaceae fruit remains dominate in the lower layers while tricarpellate Cyperaceae fruit remains start to emerge in the centre and dominate in the upper layers of this zone. Seeds of *Eleocharis palustris*, *Silene* cf. *vulgaris*, *Linum catharticum*, *Potentilla* spec. and *Fragaria vesca* were found in different quantities. Like in zone 2, charred macrofossils from crop plants were found, including Cerealia seeds (ca. AD 1275–1400) and a *Linum usitatissimum* seed pod (ca. AD 1535). Amblystegiaceae remnants appear in very high numbers in the deeper layers of the zone, but amounts decrease considerably going upward. Root material occurs in high amounts throughout the zone albeit going upward the numbers decline. *Coenococcum geophilum* remains were found as well and zoological findings include Coleoptera and insect remains especially in the lower part, Lumbricidae eggs and Trichoptera larval cases in the central and upper parts of the zone. Noticeable are also the Gastropoda shell findings at the boundary to zone 4. Almost no minerogenic particles were found

LMAZ 4: since ca. AD 1900

The fourth and last zone comprises the most recent peat layer in which only a very few findings can be reported. *Potentilla* spec. seeds appear as well as tricarpellate Cyperaceae fruits. Low quantity of root material found in the samples differs from the other zones. Concerning faunal remains, relatively large amounts of Gastropoda shells occur in this zone but otherwise only one insect egg was found. Minerogenic particle numbers increase compared to LMAZ 3.

5.2.2. Macrofossils from Trees

Taking a closer look at the macrofossils of trees (Fig. 14) it is apparent that only remains of coniferous trees were found. The majority of coniferous macroremains can be attributed to the lower core part and occur mainly in the depth from 87 to 57 cm (ca. AD 880–1280). In this depth range, findings include needles (Fig. A1) of *Abies alba*, *Larix decidua* and *Picea abies* as well as Pinaceae periderm fragments and seeds. *Larix decidua* and Pinaceae remains outnumber the other coniferous tree finds. One needle of *Abies alba* (Fig. A1 Photo 2) was found at a depth of 57 cm (ca. AD 1280) and one needle of *Picea abies* (Fig. A1 Photo 5) at 67 cm (ca. AD 1140) while *Larix decidua* needles were found at both of these depths. *Pinus* spec. needles and one Pinus seed were found at 77 cm (ca. AD 1010) and another undetermined Pinaceae seed at 67 cm. Pinaceae periderm macroremains occur at depths of 87 cm, more numerous at 57 cm and strikingly at 17 cm (ca. AD 1800), a find that deviates from the other fossil findings regarding depth.

Wood (SL) and charcoal remains (Fig. A1 Photo 6) occur more numerous at depths from 97 to 57 cm (ca. AD 750–1280) which corresponds with the tree macrofossil finds. However, it should be noted that most charcoal finds were made in the deepest samples at a depth of 97 cm (ca. AD 750). Charcoal fragments remain quite numerous in the depths of 77, 67 and 57 cm (ca. AD 1010–1280). Charcoal macrofossils also occur at depths of 47 to 27 cm (ca. AD 1410–1670) but numbers decrease with lower depth. A detailed diagram of all charcoal finds, including charred seeds and other charred plant remains can be found below.

5.2.3. Herbaceous Plant Macrofossils including Cryptogams

Regarding herbs, several interesting macrofossils were found in various depths (Fig. 15). Seeds of *Linum catharticum* (Fig. A2 Photo 5) occur at depths of 67 cm (ca. AD 1140) and 17 cm (ca. AD 1800). Another possible *Linum* seed was found in the most recent layer at 7 cm (since ca. AD 1900). Furthermore, charred seed pods of potentially *Linum catharticum* at 67 cm and *Linum usitassimum* at 37 cm (ca. AD 1540) were detected. Two Cerealia seeds, both charred, were found at depths of 57 and 47 cm (ca. AD 1280–1410). One *Silene* cf. *vulgaris* seed was found in the samples from 67 cm while several more occurred at a depth of 37 cm. One Ranunculaceae seed (Fig. A2 Photo 6) which could not be determined further was found at 67 cm.

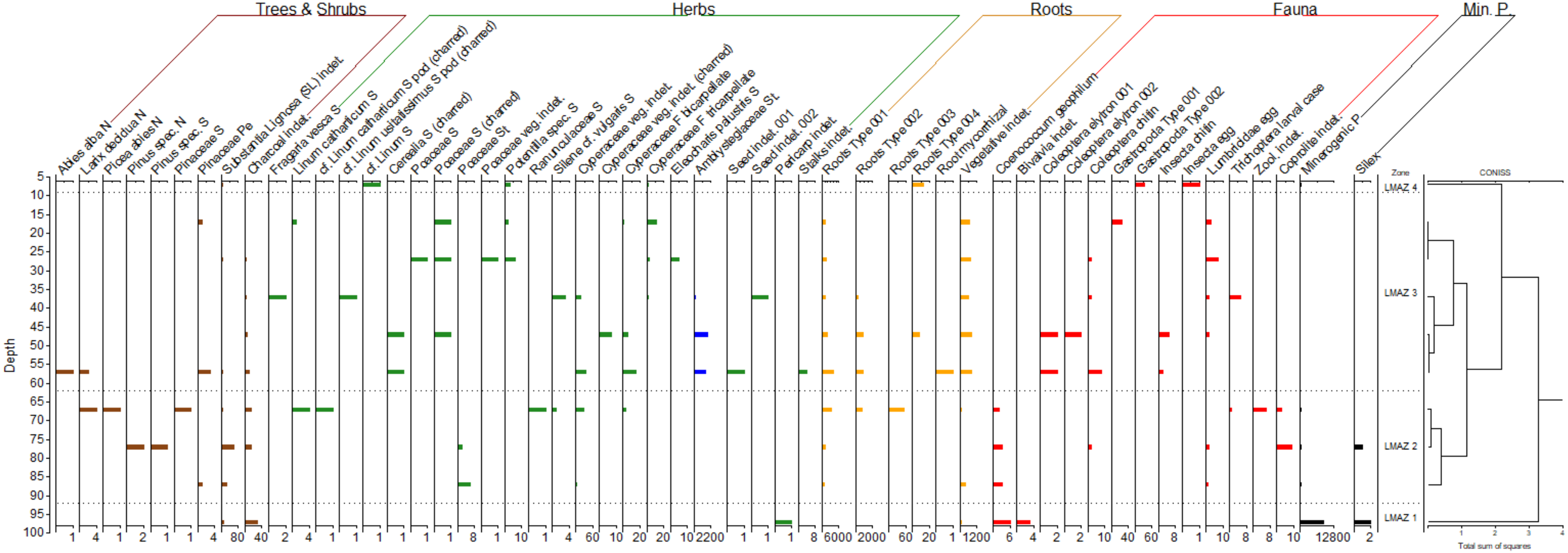

Fig. 13: Tilia diagram showing all macrofossils found in the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria), normalized to 10ml. The x-axis shows the number of finds of each taxon or macrofossil, the y-axis shows the core depth at which they were found. Tree macrofossils are shown in brown, herbaceous plant fossils in green, cryptogams in blue, roots and indeterminable plant remains in yellow, fauna including fungi in red and minerogenic particles in black.

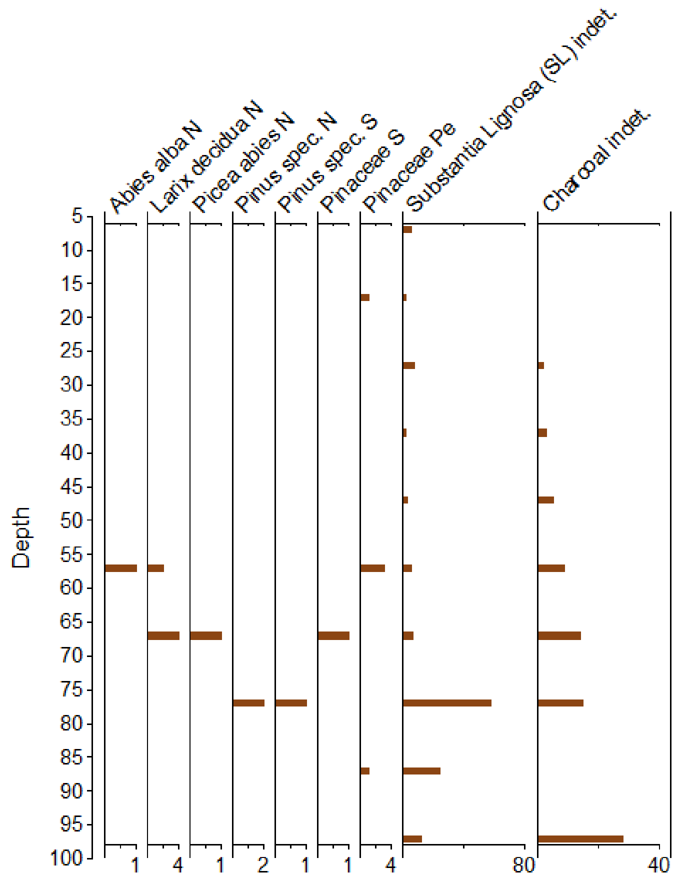

Fig. 14: Diagram showing macrofossil finds from trees for the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria), normalized to 10 ml. SL and charcoal fragments were included in this group.

Two *Fragaria vesca* seeds were found at a depth of 37 cm (ca. AD 1540) and two undetermined seeds were found, one at 57 cm (ca. AD 1280) and the other at 37 cm. *Potentilla* cf. *erecta* (Fig. A1 Photo 1) seeds appear somewhat more numerously for the first time at a depth of 27 cm (ca. AD 1670) and were also found in the samples from 17 and 7 cm (ca. AD 1800–1900 onwards). An undetermined piece of pericarp was found at 97 cm depth (ca. AD 750).

Scarce remains of cryptogams, more precisely brown mosses (Amblystegiaceae), were detected in the sample from 87 cm depth (ca. AD 880) but numbers of Amblystegiaceae macrofossils explode at a depth of 57 to 47 cm (ca. 1280–1410). Further upward at a depth from 37 to 17 cm (ca. AD 1540–1800) stems were found as well but numbers decline drastically (Fig. 16).

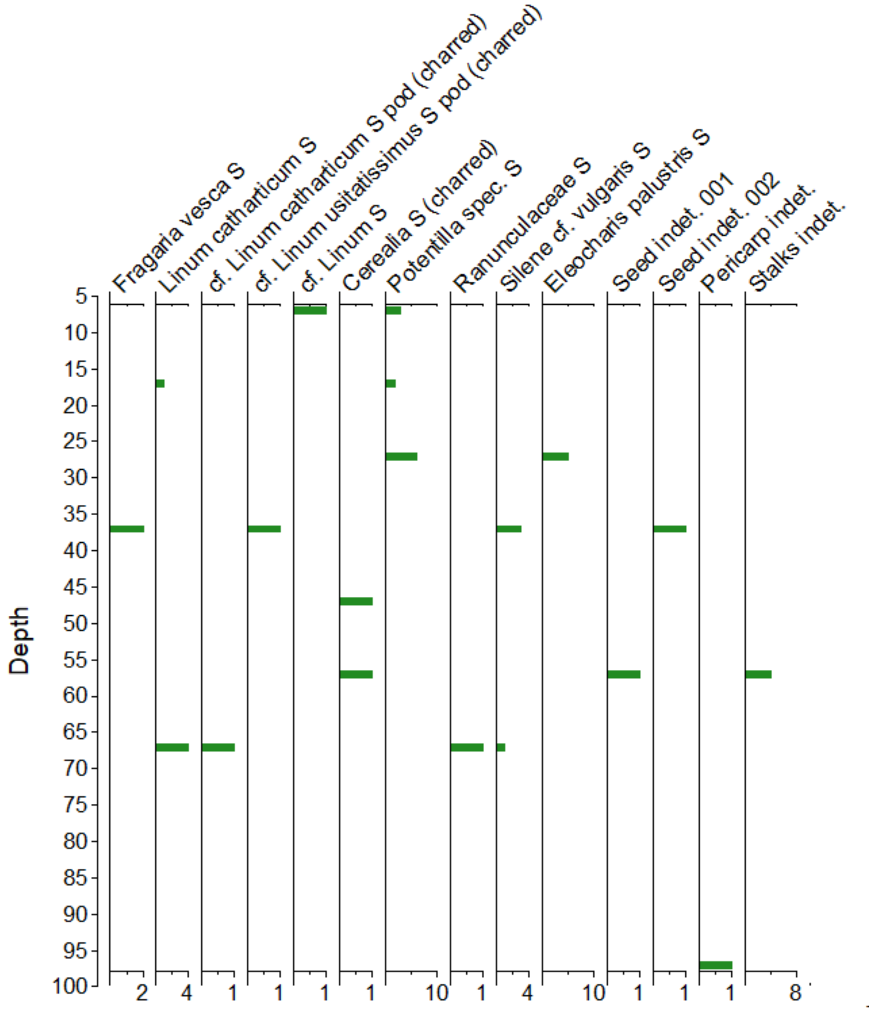

Fig. 15: Diagram showing herbaceous plant macrofossils for the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria), normalized to 10 ml.

Concerning graminoids and sedges, most frequent macrofossil finds belong to the Cyperaceae family (Fig. 16). Vegetative remains were found at depths of 87, 67, 57, 47 (charred) and 37 cm (ca. AD 880–1540). Bicarpellate Cyperaceae fruit remains dominate from 67 to 47 cm (ca. AD 1140–1410) while tricarpellate fruits appear quite frequently from 37 to 7 cm (ca. AD 1540–1900). A considerable number of Eleocharis palustris seeds were found at a depth of 27 cm (ca. AD 1800). Poaceae macrofossils appear in almost every depth, albeit to a much lesser amount than the Cyperaceae macrofossils. Stems and other vegetative remains of Poaceae were found at depths of 87, 77 and 27 cm. Seeds, mostly charred, were found at 47, 27 and 17 cm (ca. AD 1410–1800).

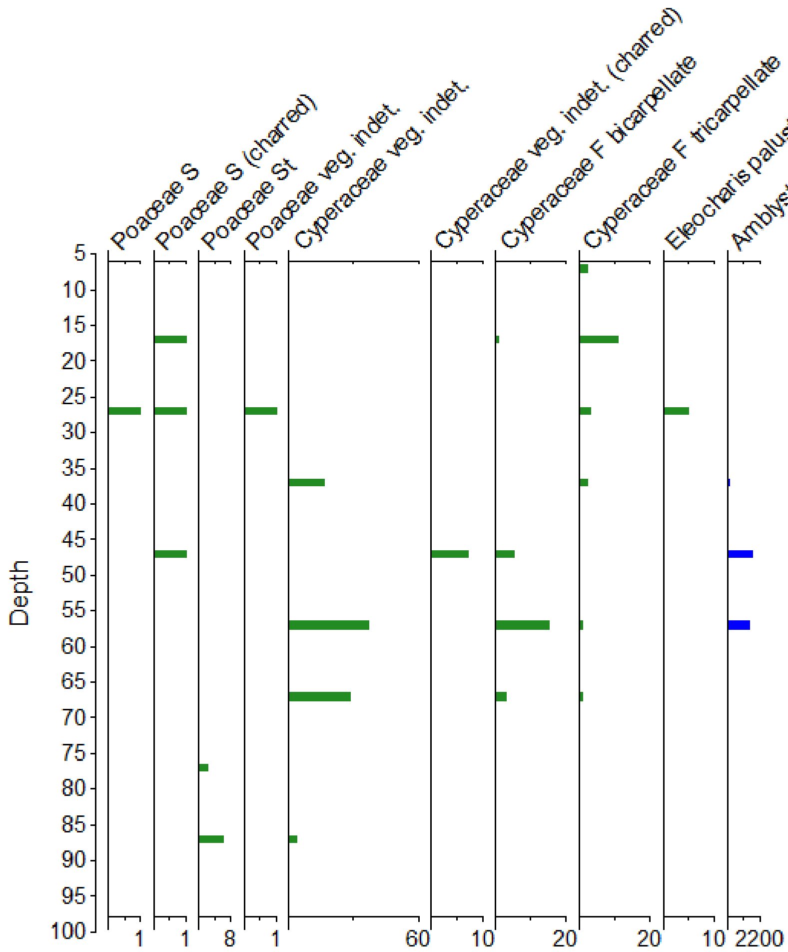

Fig. 16: Diagram showing grass and moss macrofossils for the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria), normalized to 10 ml.

5.2.4. Charcoal and Charred Macrofossils

As mentioned above, most charcoal fragments were found in the deepest samples at a depth of 97 cm (ca. AD 750) (Fig. 17). Findings remain quite numerous in the depths of 77, 67 and 57 cm (ca. AD 1010–1280). Charcoal macrofossils also occur at depths of 47 to 27 cm (ca. AD 1410–1670) but numbers decrease in lower depths.

Other charred macrofossils were found in every sample starting at a depth of 67 cm and going upward to 17 cm (ca. AD 1140–1800). Only at a depth of 87 cm (ca. AD 880) and in the most recent layer at 7 cm (since ca. AD 1900) no charred material could be discovered.

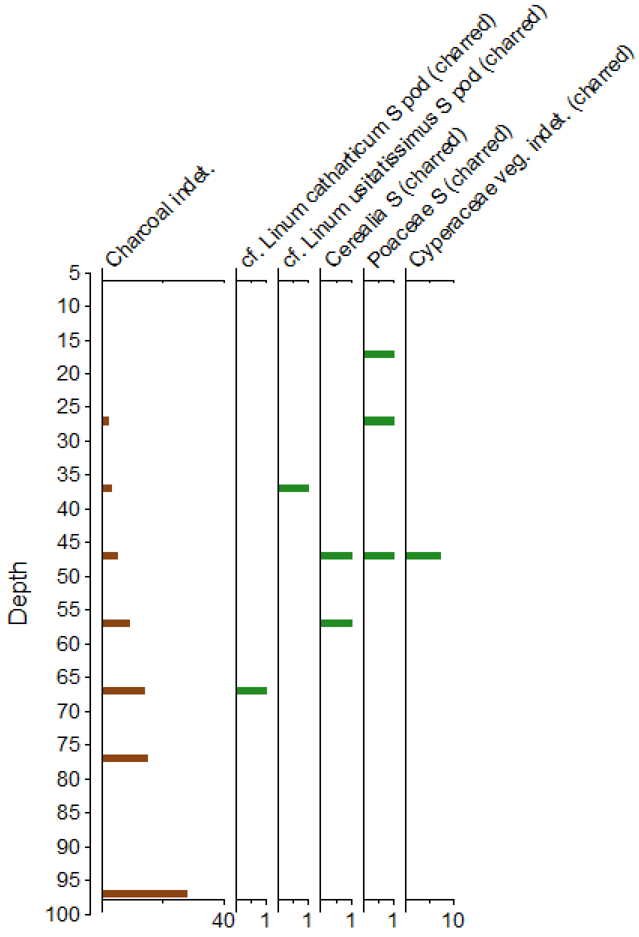

Fig. 17: Diagram showing charcoal and other charred macrofossils for the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria), normalized to 10 ml.

5.2.5. Faunal Macrofossils and Fungal remains

In the area of macrofossils from animals, Bivalvia shell pieces were found at the lowest depth of 97 cm (ca. AD 750) (Fig. 18). High amounts of shell remains from two types of Gastropoda occurred in the two top samples at 17 and 7 cm (ca. AD 1800 onwards). Coleoptera chitin and elytra were found especially at medium depths of 47 and 57 cm (ca. AD 1280–1410), but also occur in other depths. Chitin of other insects was found only in medium depths of the sediment core. A single insect egg was found at 7 cm depth. Eggs of Lumbricidae were detected throughout the core but get more numerous in the upper part. Signs of caddisflies (Trichoptera) were found at depths of 67 (ca. AD 1140) and in higher numbers at 37 cm (ca. AD 1540). Coprolites and other undetermined zoological remains were found only at depths of 77 and 67 cm (ca. AD 1010–1140). The fungal species *Coenococcum geophilum* was found continuously in the lower part of the sediment core to a depth of 67 cm (ca. AD 1140).

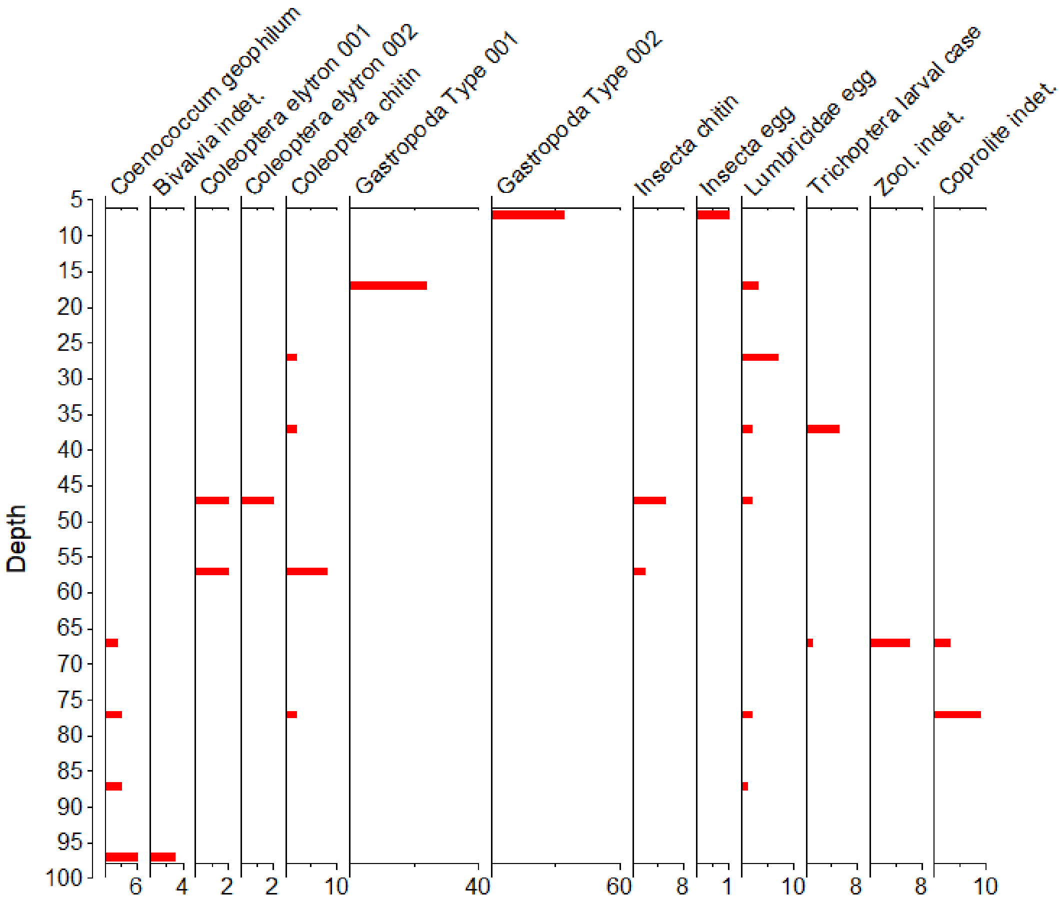

Fig. 18: Diagram showing zoological macrofossils for the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria), normalized to 10ml. Remains of Fungi (*Coenococcum geophilum*) were also included in this figure.

5.2.6. Minerogenic Particles and Silices Analysis

Minerogenic Particles occurred in extremely high amounts at a depth of 97 cm (ca. AD 750) (Fig. 19). They also appeared in other samples, but massively reduced. Among the many minerogenic particles, also flint (Silex) particles (Fig. 20) were identified, and several samples were brought to PD Dr. Urs Leuzinger at the Amt für Archäologie in Thurgau (Switzerland) to achieve a more precise analysis.

Urs Leuzinger examined the material under the microscope and it was confirmed that the particles are composed of silicate rock. According to Dr. Leuzinger (Leuzinger 2022), the tiny pieces of Silex and the other minerogenic particles are probably silicate gravel from a natural moraine or scree sediment. Anthropogenic deposition cannot be established from these finds, but cannot be completely excluded, for example in the context of agricultural soil fragmentation by historically known sledges with fixed silices underneath.

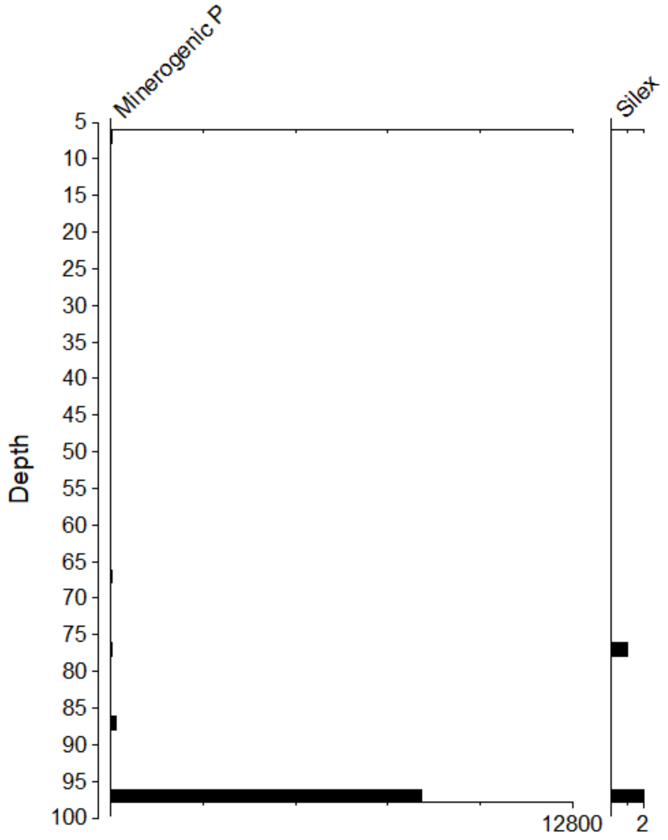

Fig. 19: Diagram showing minerogenic particles for the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria), normalized to 10ml.

Fig. 20: Example of a Silex particle found at the mire stratigraphy of Lake Altaussee (Styria, Austria).

5.2.7. Other Macrofossils

Finally, this group of other macrofossil remains contains findings that have not yet been discussed (Fig. 21). Several types of roots and undeterminable plant remains are included in this group. Root remains occur in relatively high amounts at almost every depth except at 97 and at 7 cm (ca. AD 750 and 1900). They reach a maximum at medium depth from 47 to 67 cm (ca. AD 1140–1410). One mycorrhizal root was found at 57 cm (ca. AD 1280). Like the roots, other plant remains appear quite frequently as well, but rather dominate in the upper half of the sediment core in depths from 57 to 17 cm (ca. AD 1280–1800).

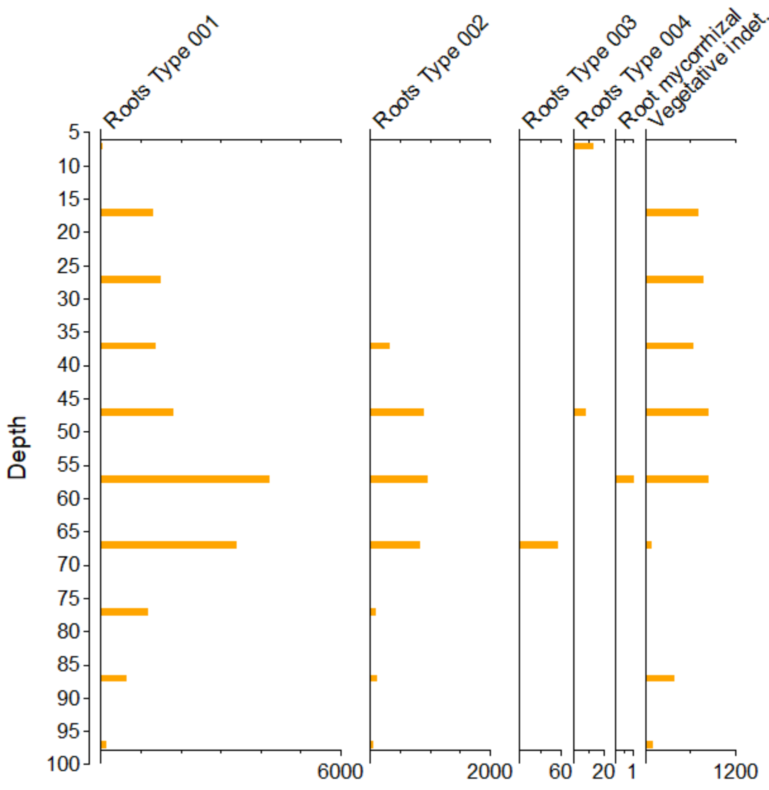

Fig. 21: Diagram showing other macrofossil finds for the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria), normalized to 10ml.

6. Discussion

The sample from the lowest depth at 97 cm (ca. AD 750) was characterized by massive amounts of minerogenic particles (> 6000 per 10 ml). This points to the underlying minerogenic sediment layer about 30–50 cm thick, and it also points to strong erosional processes ahead of the mire formation, which started around AD 800 according to the radiocarbon date of AD cal. 882 ± 106 in 87 cm depth, when extrapolating the age backwards to ca. 92 cm, the start of the peat growth. This compares extremely well with the age of a megaturbidite in the sediments of Lake Altaussee, which was dated to ca. AD 830 and may have been related to a huge earth quake event or catastrophic precipitation

(Rechenmacher et al. 2022), even if a hurricane event can’t be totally excluded. The minerogenic fen deposited below the studied peat bog might therefore also relate to such a huge environmental or climatic impact on the local landscape.

Other macrofossils in this lower sediment unit include charcoal fragments, *Coenococcum geophilum* sclerotia, plant roots and wood remains but all of them only in very small numbers. Vegetation possibly was meagre due to a presumed preceding fen deposition or fluvial activities and sediment movement related to the underlying minerogenic sediment deposition, given that below this layer more than 3 m of peat were found during the fieldwork, but not extruded. Such phenomena are also known from elsewhere (Zazula et al. 2006). Two pieces of bivalve shells were also found in this depth and considering the sparse number, it is unclear whether they occurred autochthonous. In this case they would point to a water habitat. However, it is more likely that at this time there may have been a flood or mudslide event which brought along a lot of minerogenic and organic debris and rubble.

Also to be discussed are the coniferous tree macrofossils which are mainly focused in LMAZ 2 and a few in the lower part of LMAZ 3. Whether these finds represent relicts of a forest vegetation is an open question as they occurred only in quite modest numbers. Furthermore, not a single macrofossil from deciduous trees could be detected. According to Frischmuth (1946) mixed forests with a high incidence of deciduous trees represent the natural forest vegetation in the valley. Macrofossils are heavy and compared to pollen are rarely transported far from their origin. However, there are exceptions and macrofossils can be displaced by heavy winter winds, streams or certain other events (Birks 2013). Flooding could be a relevant factor, as the study site is situated on an alluvial fan surrounded by moraines. Lands like these have a tendency for sediment movement and are highly susceptible to flooding, especially when there is a lot of precipitation (Santangelo et al. 2012). Thus, the macrofossils from conifers could stem from the near uplands. Furthermore, previous research from other regions in the Alps shows that climatic fluctuations and cooler phases during the Holocene caused rising lake levels (Haas et al. 1998). As we have already heard, the Ausseer landscape receives higher amounts of rainfall than other regions due to its basin location. Documented references that the region is prone to flooding are contained in the parish archives from Altaussee and Bad Aussee in which recurring flooding was recorded from about 1770 onwards (Frischmuth 1946). So it might be possible that plant remains were swept in by rivulet currents on the alluvial fan on which the mire formed ca. AD 800. Maybe the wood finds as well as the massive amounts of root material indicate that the area was once covered sparsely by trees, but as SL finds are not that numerous and absolutely no macrofossils of hardwood trees were found, this is mere speculation.

Perhaps a few trees managed to grow at the site in this time period (AD 880–1140), but soil properties were not favourable. Poor soil conditions could be indicated by the *Larix decidua* macrofossils as *Larix* has typical pioneer character and is able to grow on disturbed soils (Schulte et al. 2022). That soils were in poor conditions around this time could be confirmed by the macrofossils of *Coenococcum geophilum* found at depths of 97, 87, 77 and 67 cm, a fungal species typical for disturbed soils prone to erosional processes. The species is generally robust when it comes to environmental stress and is extraordinarily resilient to water stress (Coleman et al. 1989). Furthermore, larval cases from caddisflies indicate local standing water around 67 cm (ca AD 1140).

Charcoal fragments can indicate local or regional fires depending on the size of the fragments. This arrangement, however, is debatable as in various reference studies the range of sizes of either small or large particles differ considerably, as well as other factors like type and amount of vegetation, winds and deposition can play a major role (Cui et al. 2020). For this thesis, only sample sizes >500 µm were looked at, so charcoal particles could be considered large and therefore would indicate local fires. In the Holocene, anthropogenic fires started especially from the Iron Age onward (Reismann 2020). A special form of agriculture, the so-called “Brandwirtschaft” was essential for survival. Vegetation was burnt down and crops were cultivated for usually two years. Afterwards the original vegetation was allowed to grow back. Charred *Linum* and Cerealia macrofossils were found at depths 67 to 37 cm, which indicates that this special form of agriculture was performed between ca. AD 1140–1540.

Massive amounts of firewood were also needed to heat the brine from salt mines. This was also done in the valley (Lamer 1998). The first clue to salt mining in the area of Altaussee is recorded in a certificate from 1094 but it is still unknown if salt mining was already conducted during prehistoric times similarly to the neighbouring Hallstatt region (Friedel 1985). Naturally, these are only assumptions and additional research is necessary to better asses the origin of the charcoal fragments.

A transition zone follows at a depth of 55 cm (ca. AD 1310) and transitioning between LMAZ 2 and 3 appears fluent. In the border region of the two zones, remains from coniferous trees as well as macrofossils of herbaceous plants were found. Mosses of the family Amblystegiaceae dominated the vegetation during this time (ca. AD 1280–1410) which indicates very high moisture levels. At these depth levels (57 and 47 cm), also the most Coleoptera findings were made. After doing some research and comparing elytra, the found beetle fossils might belong to the pill beetle family (Byrrhidae) which feed on moss. As moss macrofossil numbers decline rapidly from 37 cm (ca. AD 1540) upward a change in moisture levels can be inferred. Especially in the settlement areas on the moraines and the alluvial fan, residents did a lot of drainage work to improve soil conditions and gain better land for agricultural purposes (Frischmuth 1946). Thus, the change in moisture could be due to human activities. With the sharp decrease of moss vegetation there is also a change within Cyperaceae species from bicarpellate to tricarpellate fruit producing species, which might also be associated with hydrological changes or agricultural impact. Overall, it can be stated that sedges dominate over grasses.

Concerning the Cerealia grains and flaxseed (*Linum*) macrofossils, it is likely that they were cultivated at the study site as the furrows from ploughing can still be seen today (Fig. 2). Barley, oat and winter wheat are known to have been grown in the region (Frischmuth 1946). Flax was already grown thousands of years ago to spin and weave its fibers into linen. In more recent times, flax was cultivated, especially during times of war, also in the Altausee region (Frischmuth 1946).
A bit exotic seem the finds of *Silene cf. vulgaris* seeds, as the species prefers drier habitats. Perhaps this shows a transitioning to drier soils in the surrounding meadows. The two *Fragaria vesca* seeds that were found at 37 cm, too, seem quite extraordinary. Although they prefer humid habitats, the soil needs to be well drained. According to the age of the soil layer (ca. AD 1540), wild strawberries might have been gathered and cultivated in gardens nearby as earliest records of cultivation originate from the Middle Ages (Darrow 1966).

Based on the macrofossil analysis data and the resulting assemblage zones, the following succession of vegetation can be given: After a time with probably extensive sediment movements and only very limited plant growth, a change to a sparse tree cover could have occurred at the time period of approx. 90 cm and lasted to approx. 57 cm (ca. AD 840–1280). The macrofossils then document a progression into an entirely open habitat (including cereal and crop production) upward with very high moisture levels confirmed by the large amounts of Amblystegiaceae (ca. AD 1280–1410). Thereafter, moisture levels started sinking (at a certain point in time due to human intervention and agricultural activities) and the vegetation changed to herbaceous plants, predominated by sedges.

7. Conclusions and Outlook

Through the drilling at the mire in Altaussee and the examined macrofossils, a reconstruction of the vegetation and thus partly of the environmental conditions could take place. The different macrofossils also allow conclusions to be drawn about people's way of life at past times. Furthermore, it could be determined that probably some kind of major, catastrophic natural event contributed to enormous environmental changes and thus to the formation of the mire.

To find out how the conditions at the study site were before the formation of the mire, it will be necessary to drill through the layer of the minerogenic fen below 100 cm of mire depth. Afterwards, and if successful, a sediment core of the sediment layers beneath the here studied, 1200 years old mire deposits, could be extracted and then examined in palaeoecological terms, i.e. for plant and animal macrofossils, but also for its palynological (pollen, spores) content.

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8. Appendix

Table A1: Raw data of the macrofossil finds from the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria). Abbreviations: N = Needle, S = Seed, Pe= Periderm, F = Fruit, St = Stem, P = Particles.

	7 cm	17 cm	27 cm	37 cm	47 cm	57 cm	67 cm	77 cm	87 cm	97 cm
Abies alba N	0	0	0	0	0	1	0	0	0	0
Larix decidua N	0	0	0	0	0	2	4	0	0	0
Picea abies N	0	0	0	0	0	0	1	0	0	0
Pinus spec. N	0	0	0	0	0	0	0	2	0	0
Pinus spec. S	0	0	0	0	0	0	0	1	0	0
Pinaceae S	0	0	0	0	0	0	1	0	0	0
Pinaceae Pe	0	1	0	0	0	3	0	0	1	0
Substantia Lignosa (SL) indet.	5	1	7	1	2	5	6	57	24	12
Charcoal indet.	0	0	2	3	5	9	14	15	0	28
Fragaria vesca S	0	0	0	2	0	0	0	0	0	0
Linum catharticum S	0	1	0	0	0	0	4	0	0	0
cf. Linum catharticum S pod (charred)	0	0	0	0	0	0	1	0	0	0
cf. Linum usitatissimus S pod (charred)	0	0	0	1	0	0	0	0	0	0
cf. Linum S	1	0	0	0	0	0	0	0	0	0
Cerealia S (charred)	0	0	0	0	1	1	0	0	0	0
Poaceae S	0	0	1	0	0	0	0	0	0	0
Poaceae S (charred)	0	1	1	0	1	0	0	0	0	0
Poaceae St	0	0	0	0	0	0	0	2	6	0
Poaceae veg. indet.	0	0	1	0	0	0	0	0	0	0
Potentilla spec. S	3	2	6	0	0	0	0	0	0	0
Ranunculaceae S	0	0	0	0	0	0	1	0	0	0
Silene cf. vulgaris S	0	0	0	3	0	0	1	0	0	0
Cyperaceae veg. indet.	0	0	0	16	0	37	28	0	3	0
Cyperaceae veg. indet. (charred)	0	0	0	0	7	0	0	0	0	0
Cyperaceae F bicarpellate	0	1	0	0	5	15	3	0	0	0
Cyperaceae F tricarpellate	2	11	3	2	0	1	1	0	0	0
Eleocharis palustris S	0	0	5	0	0	0	0	0	0	0
Amblystegiaceae St.	0	13	21	127	1708	1526	0	0	1	0
Seed indet. 001	0	0	0	0	0	1	0	0	0	0
Seed indet. 002	0	0	0	1	0	0	0	0	0	0
Pericarp indet.	0	0	0	0	0	0	0	0	0	1
Stalks indet.	0	0	0	0	0	4	0	0	0	0
Roots Type 001	7	1272	1463	1336	1781	4197	3370	1171	633	116
Roots Type 002	0	0	0	318	891	954	815	85	92	32
Roots Type 003	0	0	0	0	0	0	54	0	0	0
Roots Type 004	13	0	0	0	8	0	0	0	0	0
Root mycorrhizal	0	0	0	0	0	1	0	0	0	0
Vegetative indet.	5	700	763	636	827	826	71	0	383	95
Coenococcum geophilum	0	0	0	0	0	0	2	3	3	6
Bivalvia indet.	0	0	0	0	0	0	0	0	0	3
Coleoptera elytron 001	0	0	0	0	2	2	0	0	0	0
Coleoptera elytron 002	0	0	0	0	2	0	0	0	0	0
Coleoptera chitin	0	0	2	2	0	8	0	2	0	0
Gastropoda Type 001	0	24	0	0	0	0	0	0	0	0
Gastropoda Type 002	34	0	0	0	0	0	0	0	0	0
Insecta chitin	0	0	0	0	5	2	0	0	0	0
Insecta egg	1	0	0	0	0	0	0	0	0	0
Lumbricidae egg	0	3	7	2	2	0	0	2	1	0
Trichoptera larval case	0	0	0	5	0	0	1	0	0	0
Zool. indet.	0	0	0	0	0	0	6	0	0	0
Coprolite indet.	0	0	0	0	0	0	3	9	0	0
Minerogenic P	36	3	0	0	1	3	33	23	149	8610
Silex	0	0	0	0	0	0	0	1	0	2

Table A2: Normalized data (10ml) of the macrofossil finds from the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria). Abbreviations: N = Needle, S = Seed, Pe= Periderm, F = Fruit, St = Stem, P = Particles.

	7 cm	17 cm	27 cm	37 cm	47 cm	57 cm	67 cm	77 cm	87 cm	97 cm
Abies alba N	0	0	0	0	0	1	0	0	0	0
Larix decidua N	0	0	0	0	0	2	4	0	0	0
Picea abies N	0	0	0	0	0	0	1	0	0	0
Pinus spec. N	0	0	0	0	0	0	0	2	0	0
Pinus spec. S	0	0	0	0	0	0	0	1	0	0
Pinaceae S	0	0	0	0	0	0	1	0	0	0
Pinaceae Pe	0	1	0	0	0	4	0	0	1	0
Substantia Lignosa (SL) indet.	7	1	10	1	2	6	6	66	26	9
Charcoal indet.	0	0	3	4	6	11	15	17	0	20
Fragaria vesca S	0	0	0	2	0	0	0	0	0	0
Linum catharticum S	0	1	0	0	0	0	4	0	0	0
cf. Linum catharticum S pod (charred)	0	0	0	0	0	0	1	0	0	0
cf. Linum usitatissimus S pod (charred)	0	0	0	1	0	0	0	0	0	0
cf. Linum S	1	0	0	0	0	0	0	0	0	0
Cerealia S (charred)	0	0	0	0	1	1	0	0	0	0
Poaceae S	0	0	1	0	0	0	0	0	0	0
Poaceae S (charred)	0	1	1	0	1	0	0	0	0	0
Poaceae St	0	0	0	0	0	0	0	2	7	0
Poaceae veg. indet.	0	0	1	0	0	0	0	0	0	0
Potentilla spec. S	4	2	9	0	0	0	0	0	0	0
Ranunculaceae S	0	0	0	0	0	0	1	0	0	0
Silene cf. vulgaris S	0	0	0	4	0	0	1	0	0	0
Cyperaceae veg. indet.	0	0	0	19	0	44	30	0	3	0
Cyperaceae veg. indet. (charred)	0	0	0	0	8	0	0	0	0	0
Cyperaceae F bicarpellate	0	1	0	0	6	18	3	0	0	0
Cyperaceae F tricarpellate	3	11	4	2	0	1	1	0	0	0
Eleocharis palustris S	0	0	7	0	0	0	0	0	0	0
Amblystegiaceae St.	0	13	31	152	2048	1830	0	0	1	0
Seed indet. 001	0	0	0	0	0	1	0	0	0	0
Seed indet. 002	0	0	0	1	0	0	0	0	0	0
Pericarp indet.	0	0	0	0	0	0	0	0	0	1
Stalks indet.	0	0	0	0	0	5	0	0	0	0
Roots Type 001	10	1321	2184	1596	2135	5032	3643	1357	692	84
Roots Type 002	0	0	0	380	1068	1144	881	98	101	23
Roots Type 003	0	0	0	0	0	0	58	0	0	0
Roots Type 004	19	0	0	0	10	0	0	0	0	0
Root mycorrhizal	0	0	0	0	0	1	0	0	0	0
Vegetative indet.	7	727	1139	760	992	990	77	0	419	69
Coenococcum geophilum	0	0	0	0	0	0	2	3	3	4
Bivalvia indet.	0	0	0	0	0	0	0	0	0	2
Coleoptera elytron 001	0	0	0	0	2	2	0	0	0	0
Coleoptera elytron 002	0	0	0	0	2	0	0	0	0	0
Coleoptera chitin	0	0	3	2	0	10	0	2	0	0
Gastropoda Type 001	0	25	0	0	0	0	0	0	0	0
Gastropoda Type 002	51	0	0	0	0	0	0	0	0	0
Insecta chitin	0	0	0	0	6	2	0	0	0	0
Insecta egg	1	0	0	0	0	0	0	0	0	0
Lumbricidae egg	0	3	10	2	2	0	0	2	1	0
Trichoptera larval case	0	0	0	6	0	0	1	0	0	0
Zool. indet.	0	0	0	0	0	0	6	0	0	0
Coprolite indet.	0	0	0	0	0	0	3	10	0	0
Minerogenic P	54	3	0	0	1	4	36	27	163	6212
Silex	0	0	0	0	0	0	0	1	0	1

Table A3: Table showing which macrofossils from the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria) were numerically extrapolated and at which depth. Abbreviations: St = Stem, P = Particles.

	17 cm	27 cm	37 cm	47 cm	57 cm	67 cm	77 cm	87 cm	97 cm
Amblystegiaceae St.				x	x				
Roots Type 001	x	x	x	x	x	x	x	x	
Roots Type 002			x	x	x	x	x		
Vegetative indet.	x	x	x	x	x			x	
Minerogenic P									x

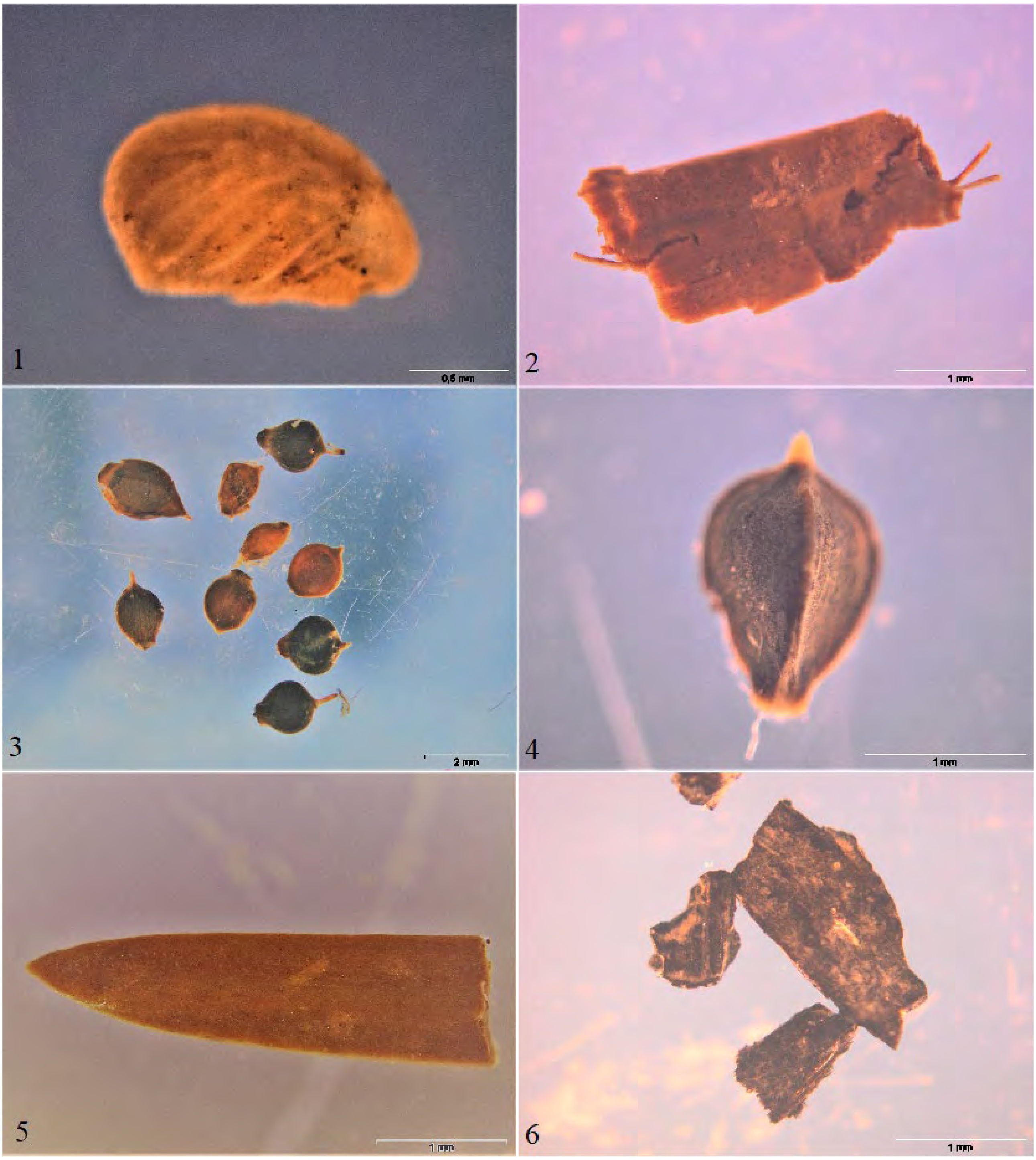

Fig. A1: Selected plant macrofossils found in the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria). 1: *Potentilla* cf. *erecta* seed; 2: *Abies alba* needle fragment; 3: *Carex* spec. fruit bicarpellate; 4: *Carex* spec. fruit tricarpellate; 5: *Picea abies* needle fragment; 6: Charcoal indet. fragments; Photos © Victoria Wenger.

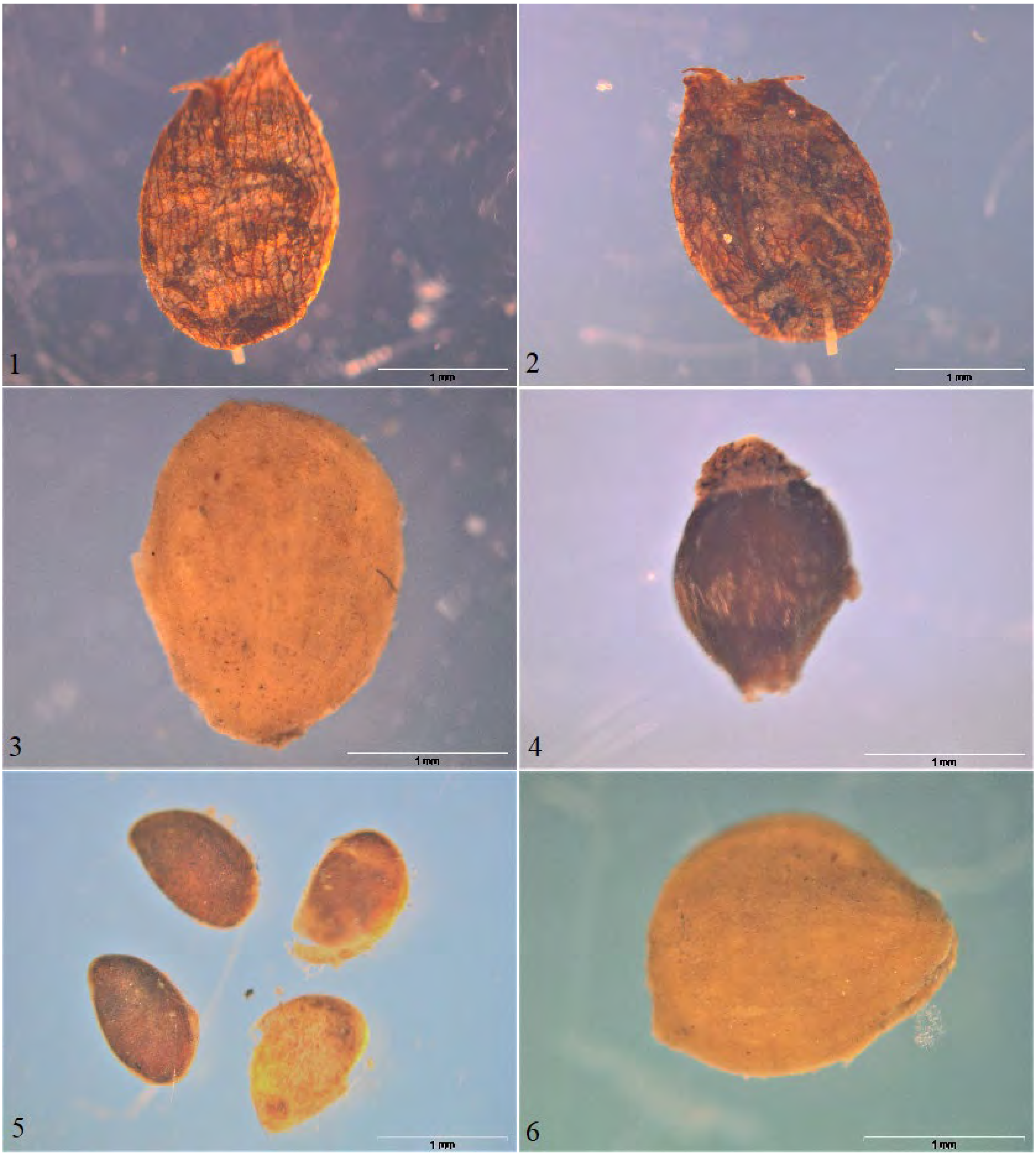

Fig. A2: Selected plant macrofossils found in the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria). 1 & 2: Seed indet. 001; 3: Seed indet. 002; 4: *Eleocharis palustris* seed; 5: *Linum catharticum* seeds; 6: Ranunculaceae seed; Photos © Victoria Wenger.

Fig. A3: Selected zoological macrofossils found in the sediment samples from the mire stratigraphy of Lake Altaussee (Styria, Austria). 1: Coleoptera elytra Type 001; 2: Coleoptera elytra Type 002; 3: Coleoptera chitin; 4: Bivalve fragments; 5: Gastropoda shells 001; 6: Gastropoda shells 002; Photos © Victoria Wenger.

Thurgau
Amt für Archäologie

Begutachtung von Silices aus Schlämmrückständen einer botanischen Kernbohrung vom Altausseer-See-Moor (A)

Am 5. September 2022 übergab mir a.o. Univ.-Prof. Dr. Jean Nicolas Haas vom Botanischen Institut der Universität Innsbruck insgesamt 5 Sedimentproben von Schlämmrückständen aus 7, 17, 37, 77 und 97 cm Tiefe (ALT MO22). Die ausgelesenen Steine stammen aus einer Kernbohrung in Moorablagerungen (vermutete Zeitstellung FMA und jünger) in der Nähe des Altausseer See in Österreich. Neben kleinen kantigen Steinchen liegen wenige Absplisse aus Silex *cf*. vor.

Rohmaterial
Eine makroskopische Analyse unter dem Binokular bestätigt, dass die ausgelesenen Steine aus silikatischem Material bestehten (cf. Hornstein, Radiolarit, Quarzit); es liegen keine Kalksteine ($CaCO_3$) vor, was ein stichprobenweiser Test mit 10%iger Salzsäure (HCl) bestätigte.

Typen
Die ausgelesenen winzigen Silexabsplisse sind scharfkantig. Bei den meisten liegt eine Ventral- und Dorsalfläche vor. Bei keinem Stein kann jedoch ein offensichtlicher anthropogener Artefaktcharakter nachgewiesen werden. Vielmehr handelt es sich bei sämtlichen Steinen wahrscheinlich um silikatischen Feinkies aus einem natürlichen Moränen-/Schottersediment. Bestossungen grösserer Steine können so auch auf natürliche Weise absplissartige Objekte erzeugt haben.

Resultat
Eine prähistorische Silexbearbeitung bzw. die Nutzung von Dreschschlitten mit Silexeinsätzen im Umfeld des Moors kann anhand der vorliegenden "Silices" nicht eindeutig belegt werden. Kein Objekt lässt sich zurzeit gesichert als Artefakt oder Abnutzungsrest bestimmen. Man müsste zuvor abklären, ob die vorliegenden Gesteinsvarietäten lokal vorkommen oder von einer weit entfernten Lagerstätte stammen.

Frauenfeld, 6. September 2022

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