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The paleolake Stifter Hollow and signs of the last stage of Quaternary glaciation in the Plešné Lake cirque

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Abstract
During the last glacial period, the highest parts of the Bohemian Forest were subjected to a local mountain glaciation. The Last Glacial Maximum extent of the small glaciers is roughly known, but less attention has been paid to the last phase of their activity. Here, we present the existence of depositional landforms that were likely associated with the last advance and final retreat of a glacier in the cirque of Plešné Lake. Based on a high-resolution digital elevation model and a field survey, two discrete debris accumulations were identified at elevations of 1140 and 1190 m a.s.l. The lower accumulation dams Stifter Hollow, a small paleolake with a surface area of 0.1 ha. Coring at this former lake found a maximum thickness of lake and peat deposits of 3.5 m. Radiocarbon dating of the retrieved sediments revealed a minimum age of sedimentation onset of ~12 300 calibrated years BP, which represents the minimum age of the latest retreat of the glacier in this part of the cirque. We believe that further investigations of these landforms have great potential to provide important contributions to knowledge of the deglaciation in Central European low mountains between the Fennoscandian Ice Sheet and glaciated Alps.

Key words: last deglaciation, Younger Dryas, Late Quaternary, lake sediments, Šumava, Bohemian Massif

Introduction

The Bohemian Forest (also known as the Bavarian Forest, Bayerischer Wald, Böhmerwald, or Šumava Mts.) is a low mountain ("Mittelgebirge") range on the border region of the Czech Republic, Germany, and Austria (elevation of the highest peak, Großer Arber, is 1 456 m a.s.l.). The glacial origin of the cirques in the Bohemian Forest was first proposed by Partsch (1882) and Bayberger (1886). These two pioneers and later authors (e.g., Rathsburg 1928, Priehäusser 1930, Kunský 1933, Ergenzinger 1967, Hauner 1980) also dealt with questions of the maximum extent of the Pleistocene glaciation. Some assumed the presence of a large ice cap during the last glacial cycle (= Vistulian, Weichselian, or Würm) covering the highest parts of the mountains (e.g., Bayberger 1886, Priehäusser 1930), while others suggested only the existence of isolated cirque glaciers and small valley glaciers with tongues up to a few kilometers long (e.g., Rathsburg 1928, Hauner 1980). The greatest attention was paid to eight glacial cirques in which lakes are currently located. According to research performed in the last three decades, including the surface exposure dating of moraines, only cirque or short valley glaciers were present during the Last Glacial Maximum

(LGM), which belongs to the marine isotope stage (MIS) 2, i.e., 29–14.7 cal. kyr. BP (the unit expresses age in calibrated kiloyears before 1st January 1950) (Pfaffl 1997, Raab & Völkel 2003, Reuther 2007, Vočadlová & Křížek 2009, Mentlík et al. 2013, Vočadlová et al. 2015). In addition, Hauner et al. (2019) drew attention to the existence of older glacial deposits of Riss (MIS 6) age which were related to the erosive activity of Kleiner Arbersee, Großer Arbersee, Gruftbach, Kleiner Regen Südlicher Rachel, Reschwasser, and Plechý paleoglaciers.

The longest MIS 2 glaciers in the Bavarian part of the mountains were located in the Kleiner Arbersee valley (~2.6 km; Raab & Völkel 2003) and Großer Arbersee valley (~2.9 km; Hauner et al. 2019). The longest glacier in the Czech part of the mountains (~2.1 km) was located in the Prášilské Lake valley (Mentlík et al. 2010). The LGM local equilibrium line altitudes (ELAs) were likely placed between 925 and 1 160 m a.s.l. (Raab & Völkel 2003, Vočadlová & Křížek 2009, Mentlík et al. 2010, Mentlík et al. 2013). From three to five moraines documenting at least two glacial stages were reported in the valleys of Černé Lake, Čertovo Lake, Kleiner Arbersee, Laka Lake, and Prášilské Lake (Raab & Völkel 2003, Vočadlová & Křížek 2009, Mentlík et al. 2013, Vočadlová et al. 2015). According to Hauner et al. (2019), the largest glaciers in the region had a two-phase advance during the LGM followed by a regression phase evidenced by 2–5 recessing moraines. The regression phase was interrupted by a massive advance, corresponding to the Gschnitz stadial (= Heinrich event 1, see Ivy-Ochs et al. 2006) in the Alps, at which point massive moraines with lobe-like basins were formed (Reuther 2007, Hauner et al. 2019). Some of these basins were likely transformed to lake basins during another glacier regression at ~14 700 cal. yr. BP (Hauner et al. 2019, Vondrák et al. 2019). However, the youngest phases of glacier readvance in the Bohemian Forest could occur even later, during the last three millennia of the Last Glacial period (Mentlík et al. 2013, Hauner et al. 2019).

In the Plešné Lake valley, two moraine sequences corresponding to two stages of glacial retreat were proposed by Votýpka (1979, 1981). However, the latter locality is one of the least studied from a paleoglaciological perspective. The aim of this study is to document the most likely youngest glacial landforms in the Plešné Lake cirque and assess their paleoenvironmental significance.

Study site

The Plešné Lake cirque (48.775000N, 13.861667E), located just below the summit of Plechý / Plöckenstein (1 378 m a.s.l.), is the most significant glacial landform of the Plechý-Třístoličník Massif in the eastern Bohemian Forest. The granitic bedrock of the cirque (coarse-grained two-mica granite of the Plechý / Plöckenstein type) is a unique feature within the mountain range (Votýpka 1975, René & Hájek 2011, Breiter 2016, Procházka et al. 2020) providing specific environmental conditions in this location (Kaňa & Kopáček 2006, Kopáček et al. 2018). A similar bedrock geology (dominating granite of Eisgarn type and / or Weinsberg type) can be found in only two other cirques in the mountain range – Hirschbach II (= Wiesriegelkar) and Großer Schwarzbach (= Bärenriegelkar) (Křížek et al. 2012). The summit planation surface of the highest part of the Plechý-Třístoličík Massif was remodeled by periglacial and glacial processes in the Quaternary. Due to the uniform plutonic rocks, the initial phase of cirque formation was affected mainly by the orientation of the local tectonic faults, while the effect of selective weathering was rather less important (Votýpka 1975, 1979, 1981). The final shaping of the cirque was determined by local glacial processes.

The current cirque is located just to the east of the summit planation surface (>1 350 m a.s.l.), which probably served as a source area of snow being redistributed by wind towards the leeward cirque (Jeník 1961, Steffanová & Mentlík 2007). The highly-overdeepened cirque height is 274 m, width 760 m and length 1008 m, giving a surface area of 60.9 ha and volume of 104.9×10^6 m^3 (Křížek et al. 2012). According to Votýpka (1979, 1981), the cirque height is even higher (316 m) when the elevation of the bedrock level hidden under the Plešné Lake is estimated. The cirque as a whole is oriented mainly to the northeast, but some parts of the ragged headwall slopes are also facing east and south (Fig. 1). Votýpka (1979, 1981) described the two phases of glaciation of the Plešné Lake cirque, both occurring during the last glacial period. The older phase is evidenced by the frontal moraine situated NE of Plešné Lake, and the younger phase was responsible for creating the natural dam of the lake. The spatial extent of the entire moraine complex was also shown by Krause & Margold (2019) (Fig. 1A). The estimates of Votýpka (1979, 1981) about the age of the moraines corresponds with surface-exposure LGM ages obtained from other moraines in the Bohemian Forest, showing comparable dimensions and other morphological features (Reuther et al. 2011, Mentlík et al. 2013, Hauner et al. 2019). However, an older age of the cirque and possible pre-Eemian (>130 ka) phases of the local glaciation are speculated by some authors based on cirque dimensions (Steffanová & Mentlík 2007) or the presence of a moraine with estimated Riss age at 925 m a.s.l. (Haimerl 2007, Hauner et al. 2019).

In 2004, the unmanaged Norway spruce forest in the Plešné Lake cirque was infested by the European spruce bark beetle (*Ips typographus* L.) and 88–99% of mature trees had died by 2011 (Kopáček et al. 2015). Due to the forest dieback, local landforms are currently more prominent than in the past. In the northern part of the cirque headwall at an altitude of 1 130 m a.s.l., there is a small concave depression with a plateau (48.776550N, 13.861000E; see Fig. 1B) under a relatively high cliff (~180 m height difference). This cirque-like

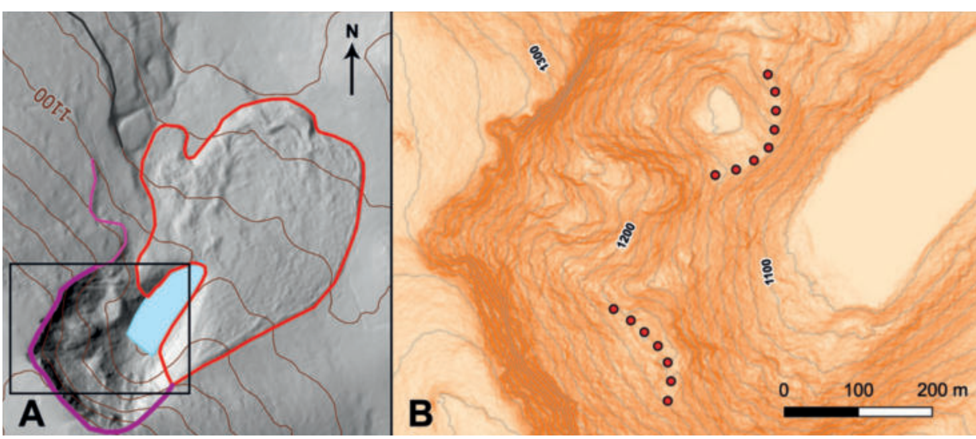

Fig. 1. A) The well-developed moraine complex (bounded by the red line) in the Plešné Lake cirque described by Krause & Margold (2019). The blue area shows Plešné Lake. B) A detailed LiDAR DEM-derived slope image of the upper part of the cirque (area indicated by the black rectangle in part A) with the two newly described distinct debris accumulations indicated by red dots. The contour interval is 10 m. The northern accumulation (probable moraine) in the upper part of the figure dams the basin of the Stifter Hollow paleolake.

landform is well visible from the nearby Adalbert Stifter Monument viewpoint that is situated on the edge of the cliff (Fig. 2). The plateau at the bottom of the depression has long been considered a possibly infilled lake (Kopáček J. – pers. comm.). It is covered by peat bog vegetation (mainly mosses) with several recently dead Norway spruce individuals (*Picea abies* (L.) H. Karst.) and two very shallow (up to 20 cm of water depth) periodical pools. The first coring in this location was carried out in 2014 by Petr Kuneš, Jennifer L. Clear, and Miroslav Svoboda, who confirmed the presence of lake sediments and named the locality Stifter Hollow (in Czech "Stifterova díra") (Vondrák et al. 2015, Vondrák 2019).

Material and methods

The spatial extent of the main moraine complex beneath Plešné Lake, including the terminal moraine, has already been published by Krause & Margold (2019), therefore we focused on the uppermost part of the cirque, i.e., the headwalls. For identification of potential glacial landforms in the Plešné Lake cirque, we used a digital elevation model (DEM) created by Light Detection and Ranging (LiDAR) technology obtained from the Czech Office for Surveying, Mapping and Cadastre (ČÚZK 2016, Digital terrain model of the Czech Republic of the 5th generation, https://geoportal.cuzk.cz). The raster DEM with a spatial resolution of 2 m and vertical random error of approximately 30 cm was employed to generate the following derived raster and vector layers using ArcMap 10 software (Environmental Systems Research Institute 2010, http://www.esri.com): shaded relief, slope gradient, aspect, combined plan and

Fig. 2. Stifter Hollow paleolake (blue dots) and the surrounding arc-shaped distinct debris accumulation (the ridge of the probable moraine is indicated by red dots) seen from the Adalbert Stifter Monument viewpoint. Photo: D. Vondrák.

slope curvature, and contours with 2 m vertical interval. We further used these layers for the visual recognition of particular landforms, and delineation of their natural limitations (Smith & Clark 2005, Chandler et al. 2018). Additionally, to evaluate shaded sections of the cirque as potential sites of longer ice preservation, we calculated a global radiation raster showing the total annual amount of incoming solar radiation in WH/m^2 (Chueca & Julián 2004).

Selected localities in the cirque were subsequently visited in October 2020. During the same field survey, a sediment coring was performed at the Stifter Hollow paleolake using a Russian peat corer of 0.05×0.5 m chamber. The greatest sediment thickness was found near the eastern edge of the infilled part of the lake basin (48.776601N, 13.861132E) where a 338 cm long core (SH20) was recovered. The shape of the infilled part basin was investigated using a transect of nine cores collected with the corer. This was done in irregular steps (from 1 to 8 m) as the surface of Stifter Hollow was covered by fallen Norway spruce trunks after a local bark-beetle outbreak (Kopáček et al. 2015). The SH20 core mentioned above had the maximum sediment thickness within the transect.

Two sediment samples, 270–271 cm and 337–338 cm, were radiocarbon (^{14}C) dated (Beta Analytic Inc., Miami, USA) using accelerator mass spectrometry (AMS). Both ^{14}C dates were calibrated using the IntCal20 ^{14}C calibration curve for the Northern Hemisphere atmospheric samples (Reimer et al. 2020) in the OxCal online software (Bronk Ramsey C., 2021, University of Oxford, version 4.4, https://c14.arch.ox.ac.uk/oxcal.html). The selection of the two sediment samples was done based on a visual description of lithological units within the core and the variation in the strontium to rubidium ratio (Sr/Rb). Sr and Rb contents (%) in the studied sediment were measured by means of X-ray fluorescence (XRF) spectroscopy at the depth interval that likely represents former in-lake sedimentation. For XRF core scanning we had developed an innovative technique recently described by Kletetschka et al. (2018), where a handheld XRF analyzer (Delta, Olympus, USA) was coupled with a programmable moving core holder and autonomously run by a computer. In this way, we performed XRF analyses along the flat upper surface of every 50 cm long part of core SH20 with 2 mm steps, using the so-called “Geochem” mode and 2.5 mm collimated beams – the first beam up to 11 keV for lighter elements (5 minute exposure) and the second beam up to 50 keV for heavier elements (5 minute exposure). The Sr/Rb ratio was used as a proxy for terrigenous input from the paleolake catchment (Xu et al. 2010).

Results and discussion

During our field survey, we observed two convex arc-shaped ridges with dimensions larger than 100×30 m, composed of non-sorted coarse material with boulders (diameter up to ~2 m) that were not reported in previous studies describing the geology and geomorphology of the cirque (Fig. 2, Fig. 3). However, we had already assumed their existence on the basis of LiDAR DEM data, as two distinct arc-shaped ridges (Fig. 1B) were considered distinct debris accumulations (DDA, *sensu* Whalley 2009).

The northern arc-shaped DDA at an elevation of ~1 140 m a.s.l. delimits the small overdeepened cirque-like depression of 200×300 m dimensions, which could be considered a second-order cirque *sensu* Delmas et al. (2015). The north-facing steep slopes (some sections >50° and over 150 m high) of the depression follow a structural W-E ridge developed in the ragged cirque headwall below the Adalbert Stifter Monument viewpoint.

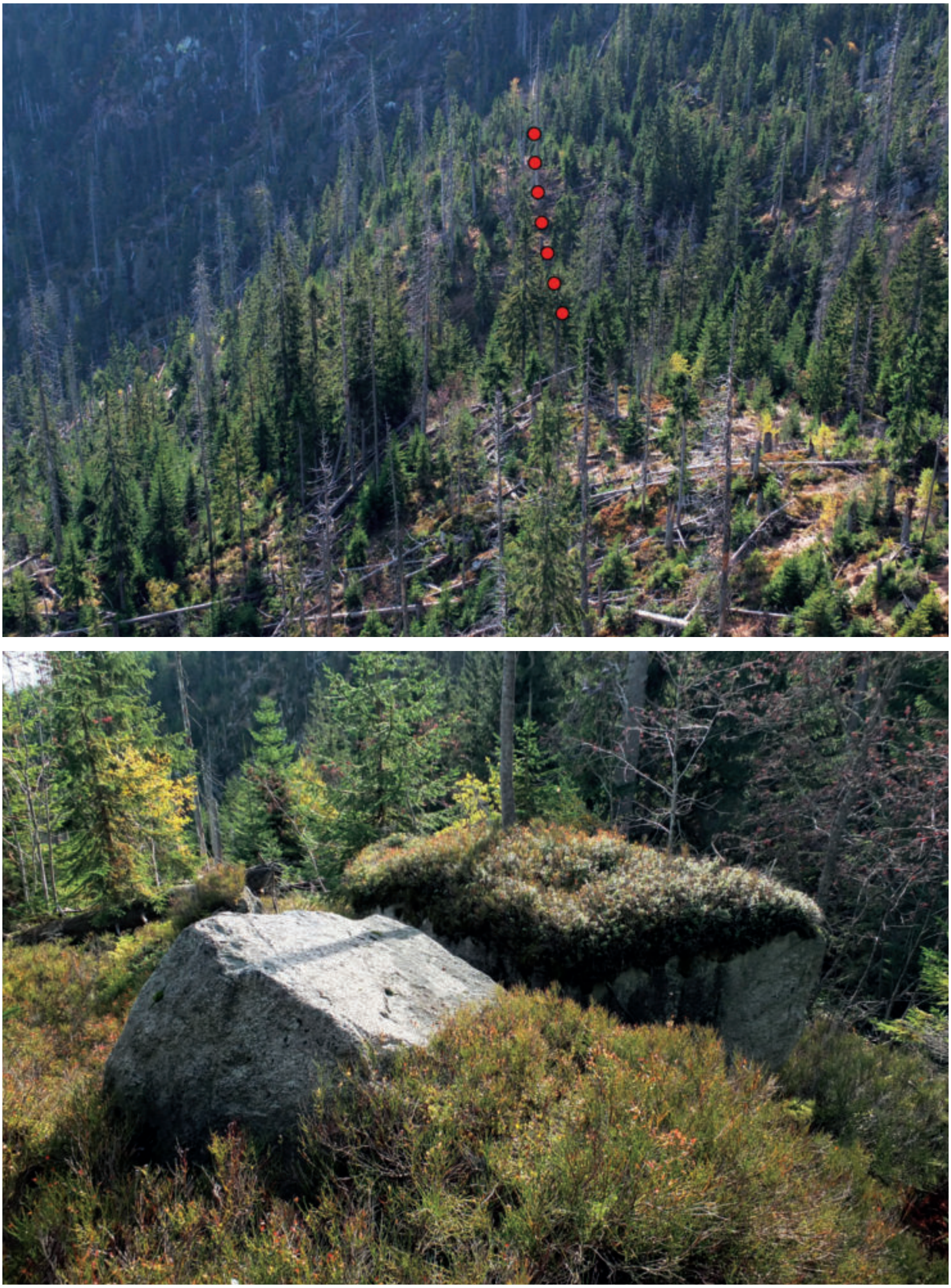

Fig. 3. The southern distinct debris accumulation located under the central part of the Plešné Lake headwall – a lateral view from the Adalbert Stifter Monument viewpoint with a ridge indicated by red dots (top) and granite boulders (~2 m in diameter) at the highest part of the ridge (bottom). Photos: D. Vondrák.

The southern DDA developed in the north-east-facing slope of the central part of the cirque at an elevation of ~1 190 m a.s.l. is smaller, damming only a minor depression in the slope. It is situated below a very steep (>60° and over 150 m high) north-east to north facing section of the cirque headwall. Above both of these DDAs, the slopes indicate very low insolation values, with minimum values of computed annual solar radiation below 3×10^5 WH/m^2, which is almost five-times less than the maximum values within the cirque (Fig. 4). The shaded leeward position of slopes and elevation of both sites could have enabled a longer preservation of glacial ice. In both cases, the dimensions of the above-positioned cirque sections seem to be sufficient for initiation and preservation of erosive glacial lenses (Cook & Swift 2012, Barr & Spagnolo 2015). This is especially notable in the case of the northern DDA, bordering a small separate slightly overdeepened second-order cirque infilled by the paleolake, which excludes any other interpretation of this DDA than a glacial moraine (e.g., pronival rampart or rockfall accumulation; see Shakesby 1997, Whalley 2009, Hedding & Sumner 2013).

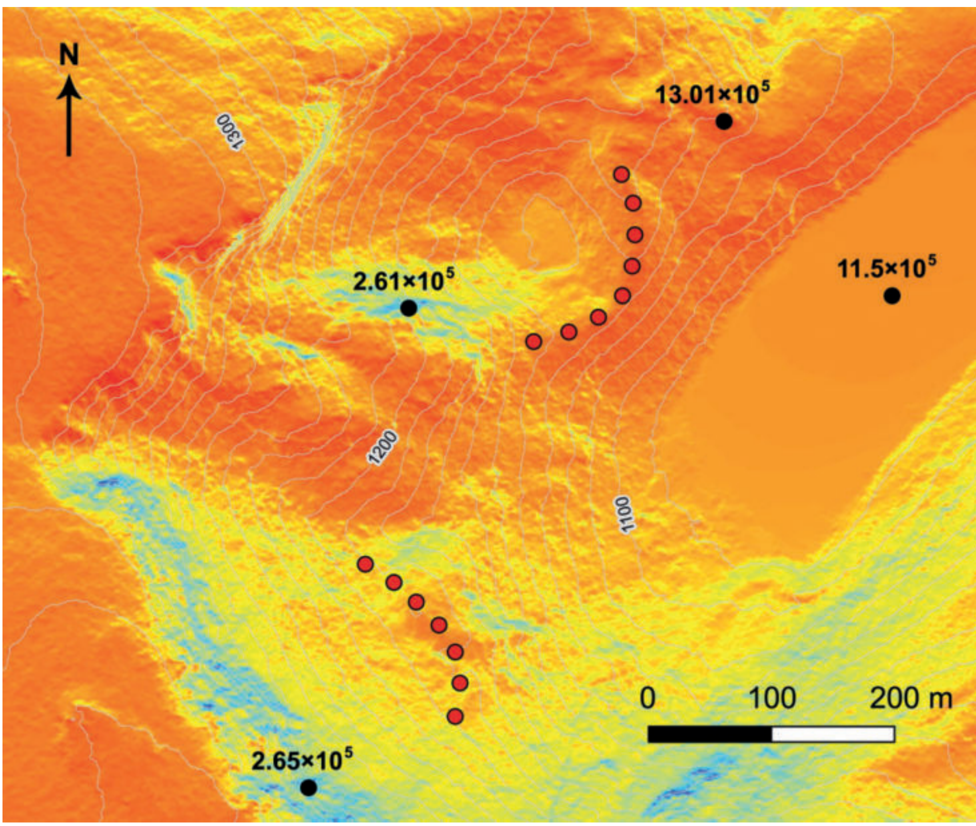

Fig. 4. LiDAR DEM-derived annual solar radiation image of the upper part of the Plešné Lake cirque showing insolation as an important factor for the preservation of potential small ice bodies during the last phase of glaciation. The values of annual solar radiation next to the black dots are printed in WH/m^2. Note significant differences between minimum (blue) and maximum (red) values. The two newly described distinct debris accumulations (northern and southern) are indicated by red dots. The contour interval is 10 m. The northern accumulation in the upper part of the figure dams the basin of the Stifter Hollow paleolake.

Thus, these DDAs are most likely associated with the youngest phase of the local glaciation. Similar landforms identified as moraines in similar topographic positions have been described from other mountain ranges in Central Europe. One example is the uppermost moraine of the Wielki Śnieżny Kocioł cirque in the Krkonoše / Karkonosze Mts., which has been assigned to the Younger Dryas glacial fluctuation by the results of ^{10}Be surface exposure dating (Engel et al. 2014). Another example of a similar moraine assigned to the youngest phase of the last glacial period has been documented in the uppermost part of the Zastler Loch cirque in the southern part of the Black Forest / Schwarzwald Mts. (Hofmann et al. 2020). Further examples of very young glacial deposits were reported from the uppermost parts of large glacier cirques in the Bavarian part of the Bohemian Forest by Hauner et al. (2019). These landforms are located at similar altitudes as the DDAs described in this study: at 1 236 m a.s.l. in the Südlicher Rachel (= Alter See) cirque, at 1 195, 1 205 and 1 225 m a.s.l. in the Kleiner Arbersee (= Westlicher Seebach) cirque, at 1 120, 1 130 and 1 160 m a.s.l. in the Großer Arbersee cirque, at 1 200 m a.s.l. in the Schwellbach cirque, at 1 235 m a.s.l. in the Großer Schwarzbach cirque, and at 1 200 m a.s.l. in the Kleiner Schwarzbach cirque.

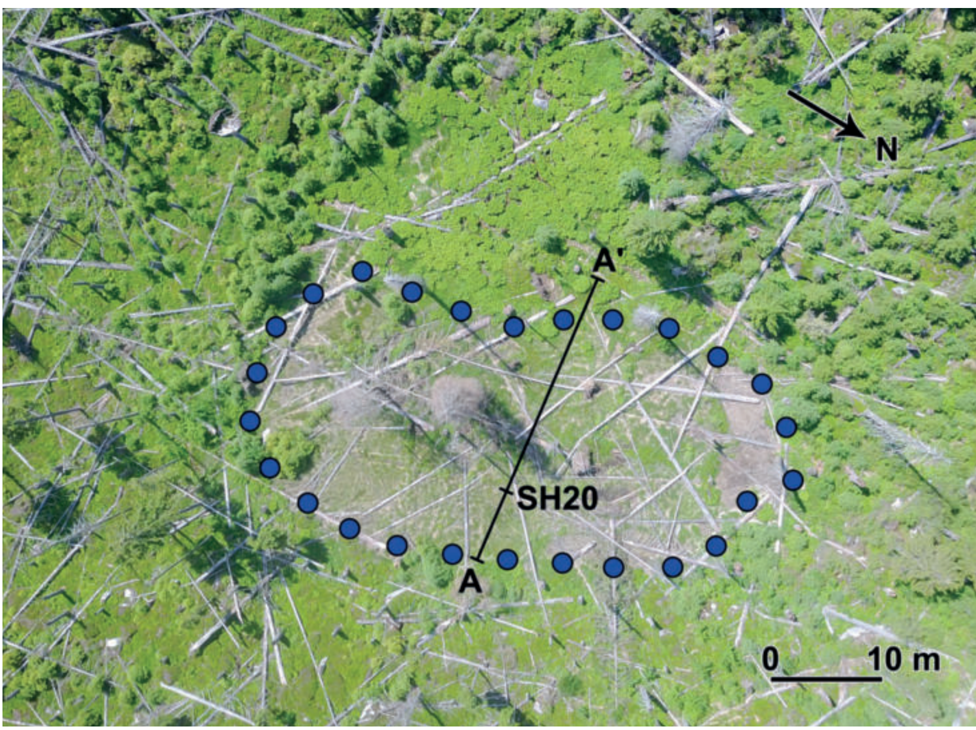

Fig. 5. Probable extent of lake sediments in the Stifter Hollow basin (blue dots). The black abscissa shows the position of the stratigraphical cross-section of the paleolake basin (see Fig. 6) together with the location of the maximum sediment thickness coring site (core SH20). The southwestern edge of the lake is adjacent to a talus fan (see the light green vegetation cover without trees in the upper part of the figure). Grey-brown patches without vegetation in northern part of the basin represent periodic pools during a dry period. Aerial photo: G. Kletetschka.

The northern DDA serves as a natural dam of the Stifter Hollow paleolake. Here, we present a reconstruction of the shape of the infilled part of the Stifter Hollow basin, a lithological description of these sediments, and ^{14}C dating of the oldest sedimentation unit representing clastic sediments in the basal part of the core SH20.

Stifter Hollow is 50 m long and 20 m wide paleolake with surface area of ~0.1 ha (Fig. 5). It is the smallest and the highest known (1 130 m a.s.l.) former glacial lake in the Bohemian Forest (Vondrák et al. 2019, Vondrák 2019). We performed sediment coring that revealed a maximum thickness of Late Quaternary deposits (350 cm) in the northeastern part of the basin. It cannot be ruled out that the actual thickness of the deposits in the center of the lake is greater than we show in Fig. 6, as the coring could not be performed there due to the fallen spruce trunks. In the southwestern part of the basin, the deposits gradually turn into sandy material from a nearby talus fan (see Fig. 5, Fig. 6).

A general lithostratigraphy description of the studied core (SH20) is shown in Fig. 7. We divided the sedimentary record into three main zones corresponding to major changes in the paleolake history. Within these zones, particular lithological units were differentiated. The first zone (338–271 cm) represented clastic sedimentation in the earliest period of the lake evolution. Its lower unit (338–281 cm) was dominated by light grey silty medium sand followed by a unit of grey sandy coarse silt with an organic admixture (281–271 cm). This lithological characterization corresponds well with the low Sr/Rb ratio values (0.069–0.274, average 0.138), which document a high portion of terrigenous detritus in the sediment (Xu et al. 2010). The second zone (271–158 cm) was characterized by organic sedimentation in the lake environment. The lower unit of this zone (271–264 cm), with brownish silty sediment, was rather a transition from clastic to predominantly organic sedimentation, with Sr/Rb values still low (0.103–0.221, average 0.149). At the depth of 264 cm, the Sr/Rb ratio began to rise sharply, and the color of the sediment changed to dark brown. We consider this middle unit of the second zone (264–190 cm) to be a classic lake gyttja sediment (i.e., mud-like, homogeneous, non-plastic sediment with high organic content, also referred

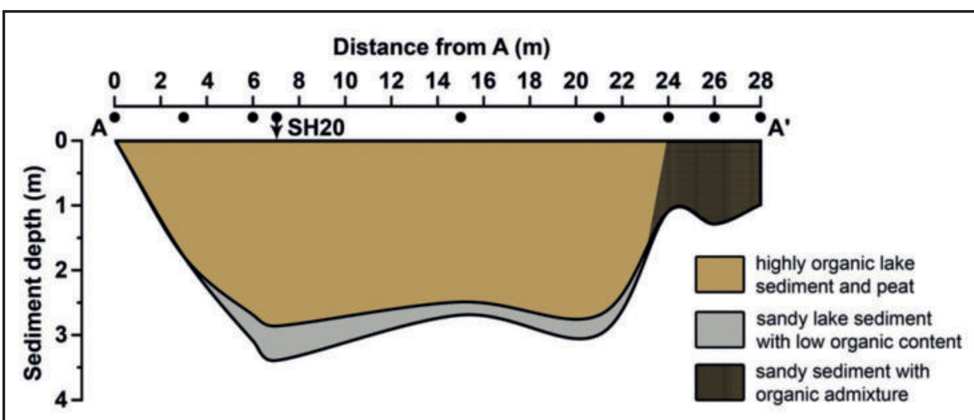

Fig. 6. Stratigraphical cross-section of the sediments deposited in the Stifter Hollow paleolake basin. The black dots show the positions of bore holes within the cross-section and the black arrow shows the position of the core SH20. The sandy lake sediment with low organic content represents the lithostratigraphycal Zone 1, and the highly organic lake sediment and peat represent Zones 2 and 3 (for details see Fig. 7).

to as *Limus detrituosus*). Between 190 cm and 158 cm, the sediment was even darker and contained an increased amount of plant macroremains and peaty layers. In the same depth interval (190–158 cm), the Sr/Rb ratio reached the highest values within the measured part of the core (0.204–1.500, average 0.733), documenting a higher fraction of biogenic deposits and more intensive chemical weathering in the lake catchment (Xu et al. 2010). This upper unit of the second zone likely represents a final stage of the lake evolution, when the water body was gradually transformed to an ombrotrophic peat bog. The third zone (158–0 cm) consisted of a lower peaty unit which was replaced by a dark soil with abundant wood fragments at the depth of ~95 cm. The uppermost 5 cm of the core were filled with undecomposed dead and living plants of *Sphagnum* L. If we take into account that several spruces grew on the surface of the infilled lake until recently (Fig. 4), the changes around the depth of 95 cm can be interpreted as a shift from a wet peat bog environment to a waterlogged spruce forest. This last phase of terrestrialization in Stifter Hollow is more pronounced than in the sedimentary records of two other infilled lakes located in the Czech part of the Bohemian Forest – Stará Jímka and Malé Černé Lake (Vočadlová et al. 2015, Vondrák et al. 2019).

Two sediment samples representing the older edge of the lower unit of Zone 2 (270–271 cm) and the base of the core SH20 (337–338 cm), respectively, were ^{14}C dated (Table 1, Fig. 7). The ^{14}C date of the younger sample, 11 402–11 813 cal. yr. BP (2σ),

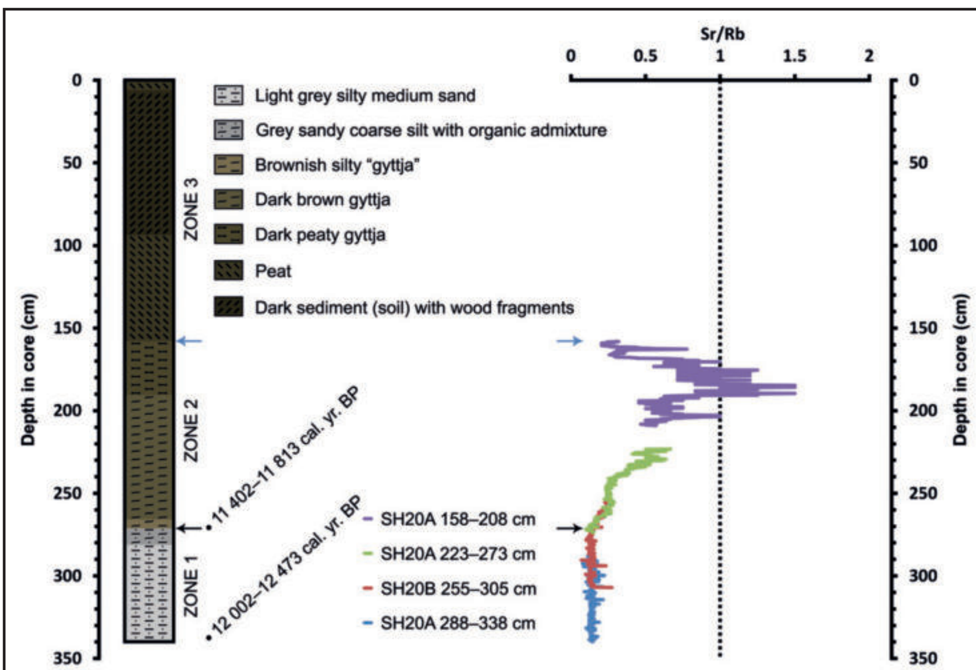

Fig. 7. Simplified lithostratigraphy of the core SH20 along with the strontium to rubidium ratio (Sr/Rb) measured on four 50 cm long core drives using XRF spectroscopy. Black arrows show the Younger Dryas-Holocene transition (Zone 1 / Zone 2), and blue arrows show the estimated end of the lacustrine sedimentation (Zone 2 / Zone 3). Black dots show two calibrated ^{14}C dates.

Table 1. List of radiocarbon ages for the core SH20. Dates were calibrated using the IntCal20 calibration curve (Reimer et al. 2020) in the online application OxCal version 4.4.

Sample depth (cm)	Laboratory number	Material dated	Method	Radiocarbon age (^{14}C years BP)	Calibrated 2σ range (cal. yr. BP)
270–271	Beta-583548	bulk	AMS	10 080±30	11 402–11 447 (8.6%) 11 469–11 585 (21.7%) 11 596–11 813 (65.1%)
337–338	Beta-583549	bulk	AMS	10 370±40	12 002–12 473 (95.4%)

represents the age of the onset of the highly organic in-lake sedimentation, and coincides well with the Younger Dryas-Holocene transition at 11 650±99 cal. yr. BP that was defined based on the NGRIP ice core global stratotype (Walker et al. 2009). Such a rapid change in organic matter input, which is related to the start of the Early Holocene warming and subsequent shifts in vegetation cover, is also known from other Bohemian Forest lakes (Vondrák et al. 2019, Moravcová et al. 2021). The base sample had a 2σ age of 12 002–12 473 cal. yr. BP. If we consider that the sampling device has a 13 cm long tip in front of the coring chamber (i.e., the actual thickness of fine sediments at the coring site is ~350 cm), the minimum age of the sedimentary record is even slightly higher (~12 300 cal. yr. BP). Therefore, the water body appeared at least during the middle of the Younger Dryas cooling (Walker et al. 2009). Stifter Hollow seems to be one of the younger lakes in the Bohemian Forest, as a lower age of base sediment (10 762–11 187 cal. yr. BP, IntCal20) has only been reported for Prášilské Lake (Vondrák et al. 2019). In contrast, sedimentary records of Kleiner Arber Lake, Malé Černé Lake, Plešné Lake, Rachel Lake, and Stará Jímka reach ages of ≥14 500 cal. yr. BP (Raab & Völkel 2003, Kletetschka et al. 2019, Vondrák et al. 2019). However, little attention has been paid so far to the origins of Bohemian Forest lakes and paleolakes, and some of them may be of similar age to Stifter Hollow.

The minimum age of in-lake sedimentation in Stifter Hollow, ~12 300 cal. yr. BP, can also be interpreted as the minimum age of the northern DDA (moraine). In general, data on the age of Bohemian Forest moraines are still scarce. Reuther (2007) and Reuther et al. (2011) published in situ-produced ^{10}Be surface exposure ages of sixteen moraine boulders and three bedrock outcrops in the Kleiner Arber Lake valley. Another set of eleven ^{10}Be exposure ages data from moraine boulders of Prášilské Lake and Laka Lake valleys was published by Mentlík et al. (2013). The authors compared their results with ages from the Kleiner Arber Lake valley (Reuther 2007) in order to build a regional ^{10}Be chronology. According to their results, the main phases of the Würm glaciation occurred before 19.5±2.1 ka, and two phases of lesser extent occurred around 16 ka and 14 ka. They also stated that the last indicated phase may correlate with the Older Dryas cooling (= Aegelsee oscillation, see Lotter et al. 1992, Ammann et al. 2013). However, the youngest exposure ages presented in their study are 13.1±1.5 for Prášilské Lake valley and 14.1±1.3 ka for Laka Lake valley. Considering the analytical uncertainties of these ages reported as a 1σ error range, it is possible that the moraines were formed earlier, before the Termination 1a warming (i.e., the onset of the Bølling biozone and the Late Glacial interstadial) at ~14 700 cal. yr. BP (Lotter et al. 2012), or later, after the Younger Dryas cooling onset at ~12 800 cal. yr. BP (Ammann et al. 2013, Kletetschka et al. 2018). Such an interpretation would be more consistent with published data from the Eastern Alps (Reuther 2007), the Krkonoše Mts. (Engel et al. 2014), and the Tatra Mts. (Engel et al. 2015, 2017, Makos et al. 2018), where Younger Dryas moraines are well developed but Older Dryas moraines are indistinct or missing. The reasons for this seem to be clear – the Older Dryas cooling lasted only ~140 years, whereas the Younger Dryas cooling lasted ~1 200 years (Ammann et al. 2013). A future investigation of glacial landforms in the Bohemian Forest, including sedimentological analyses and ^{10}Be/^{26}Al or luminescence dating of additional moraine complexes together with ^{14}C dating of lake sediments, might provide further insights into the regional glaciation history. This is exceptionally important for further palaeoclimatological reconstructions on a European scale (see e.g., Barr & Spagnolo 2015, Rea et al. 2020).

Conclusions

Here, we report findings of two arc-shaped distinct debris accumulations in the uppermost section of the Plešné Lake cirque, eastern Bohemian Forest, Czechia, that have not been described in previous publications focused on local glaciation during the last ice age. One of these accumulations (probable moraine) borders a single second-order cirque and dams a small paleolake – Stifter Hollow. The lake and peat deposits from this site can be used as a valuable natural archive as they cover the younger half of the Younger Dryas cooling and entire Holocene period (i.e., last ~12 300 years of "postglacial" history). Moreover, the two accumulations are key landforms for future research into deglaciation of the Bohemian Forest, because they likely represent unique evidence for the last stage of glacier readvance in this mountain region. Therefore, the Plešné Lake cirque deserves attention as a valuable paleoenvironmental site.

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