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Multi-methodological reconstruction of the lake level at Morgarten in the context of the history of the Swiss Confederation

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Abstract
In AD 1315, the Habsburgs fought against the Swiss Confederation at Morgarten. Since historical records are very limited, the battle has been the subject of very controversial discussions. Its location and outcome seem likely to have been influenced by the landscape and the size of the Aegeri lake, but only sparse and contradictory information are available. Numerical, semi-quantitative and relative dating techniques were applied to reconstruct the lake's dimensions and the landscape. Results obtained from radiocarbon dating of mires (last sedimentation phase of the lake), geomorphic mapping, geoelectrics, soil maps (surface age indication) and archaeological findings were pieced together and gave an astonishingly good consensus. In the Lateglacial, the lake level was higher (750–760 m a.s.l.): because of a catastrophic event, it decreased by 25 m. About 5500 BP, the lake level was at 732 m a.s.l., and since the Roman period, it has varied between 724 and 727 m a.s.l. At the time of the battle the lake was at 726 m – that is, about 2 m higher than today. Together with the cooler climate, the greater extension of the fens and larger lake, the valley floor was wet and unpleasant. If a Habsburg army had to cross this region, they would likely have preferred to walk on a more accessible trail along the footslopes (where they probably were attacked). Precise landscape reconstruction provides new input for historical research. Details about the exact location of the battle, however, remain unclear, and the myth of the battle at Morgarten persists.

Keywords
archaeology, dating, lake level, landscape reconstruction, Morgarten, soils

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Introduction

The hamlet 'Morgarten' in the Aegeri valley plays an important role in the foundation history and identity formation of Switzerland. In the year AD 1315 (15th of November), the Habsburgs led by Duke Leopold 1 and his army were defeated by the Swiss confederation force. In the commemorative culture, the hamlet 'Morgarten' is a symbol of a successful fight, in a metaphorical sense, of David against the apparently superior Goliath. Morgarten is considered to be a first significant test for the Swiss Federation founded in AD 1291. This perception of history is typical for the 19th and part of the 20th century. As a consequence, Morgarten is a component of the collective memory of Switzerland. Morgarten is close to the border of the cantons of Schwyz and Zug – a reason why these two cantons tried to claim about 100 years ago the battle for their own territory. The battle itself has, however, been more and more controversially discussed (Hess, 2008; Morosoli et al., 2003; Wiget, 1997). Its site can be derived from chronicles more or less plausibly, but its precise location is not known (Morosoli et al., 2003). Most historians suggest that the battle was fought in canton Schwyz. In this case, the battle could not have taken place exactly at Morgarten (the hamlet that gave the name to this battle), but about 1–2 km further to the south near the localities 'Schafstetten' and 'Tschupplen' (see Figure 1). A minority, however, believe that the battle was fought entirely within the territory of canton Zug (and thus exactly at the hamlet Morgarten). The number of combatants is also a matter of speculation. The chronicles usually glorified this event and grossly exaggerated the numbers of warriors involved. The battle of Morgarten was first mentioned in a few sentences (e.g. AD 1316 by the abbot Peter von Zittau or in the chronicles of 1340–1344 by the abbot Johannes von Viktring). The Minorite Johannes von Winterthur mentioned in his report (1340–1348) that the Habsburg army had 20,000 warriors – a completely exaggerated number. Currently, the general opinion oscillates between two extremes: a large battle with c. 2000 deaths (and 3000–5000 Habsburgs involved) and a little brawl with only a few casualties (Wiget, 1997). It nonetheless seems certain that an event took place near Morgarten. A consequence of this 'battle' was that the Swiss cantons renewed and strengthened their alliance (reported in the so-called 'Morgartenbrief', 9th of December AD 1315). The key question is where exactly did this battle happen and how many warriors were involved (or were killed).

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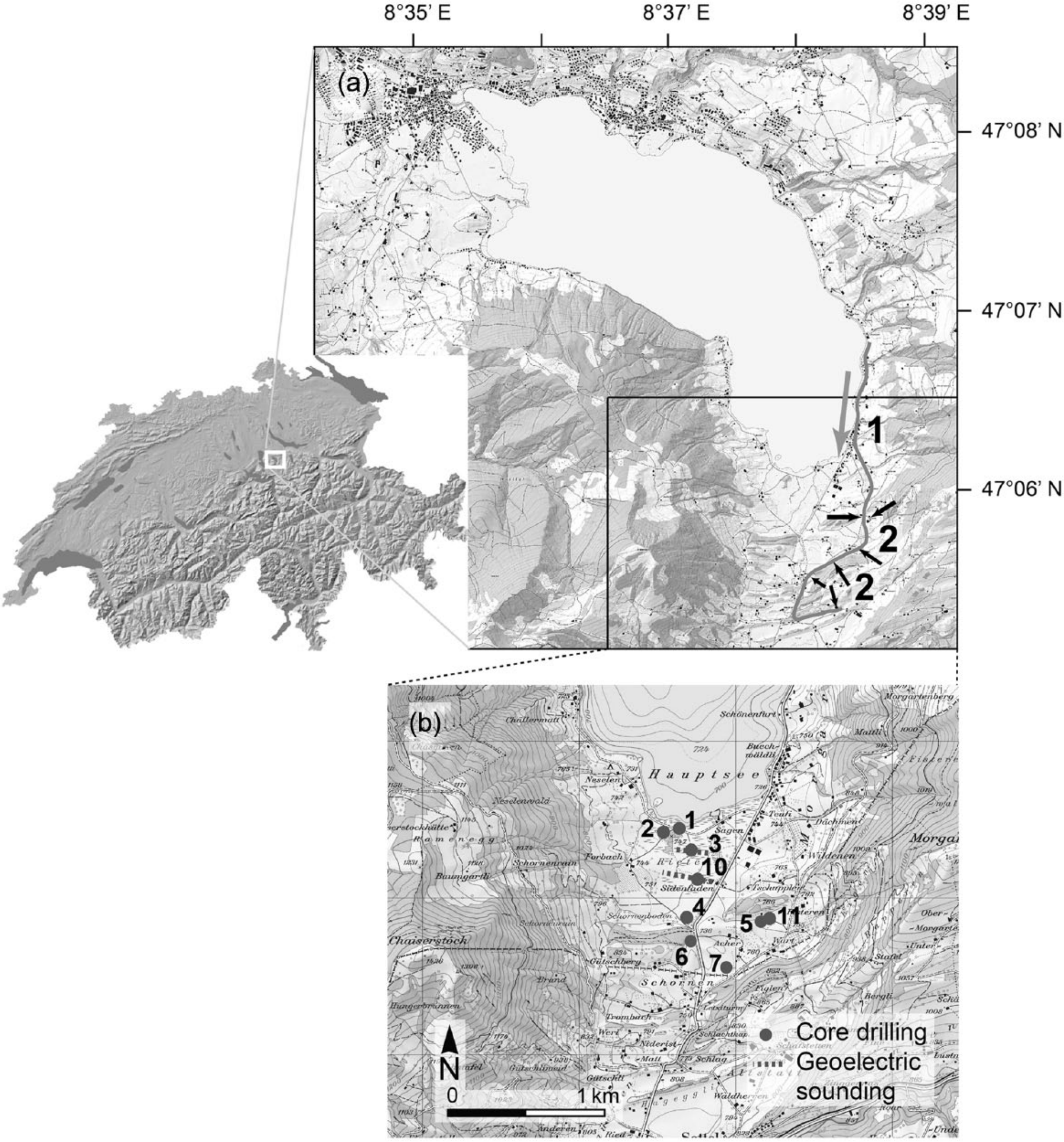

Figure 1. (a) Investigation area with the Aegeri lake in the centre. The battle at Morgarten either took place near Morgarten (1) or (more likely) between the localities 'Schafstetten' and 'Tschupplen' (2). The grey line and arrow indicates the advance of the Habsburgs and the black arrows the attack of the Swiss force. (b) Overview of the drilling sites together with the geoelectric measurement transects. Reproduced by permission of swisstopo (BA15043).

The Habsburg troops had to follow the small and partially steep shoreline along the Ägerisee. Their path in travelling from Morgarten to Sattel was thus decisively determined by the size of the lake. Also, the outcome of the following battle (or maybe it was rather a brawl?) seemed to be decidedly influenced by the lake's size and shape, which has been very controversially discussed (Hürlimann, 1911; Sidler, 1910; see also Morosoli, 2003; Morosoli et al., 2003), but still has not clearly been established. Paintings show (although the painters were not eyewitnesses) that the Swiss attacked the adversarial warriors with stones (14th and 15th centuries) and (in later paintings) even boulders (that were pushed from steep slopes) and tree trunks in an ambush. Many who tried to escape drowned in a nearby lake (e.g. chronicles of Benedict Tschachtlan, 1493). The famous mural painting of Ferdinand Wagner (1847–1927) in the town hall of Schwyz shaped the view of this battle for generations.

But, where steep slopes are found today, there is no lake, and where the present-day Lake Aegeri is situated, there are not any really steep slopes. Consequently, the question arises, 'Was the landscape and particularly the Lake Aegeri different to the present-day conditions'? Therefore, it is hypothesised that the Lake Aegeri was larger at the time of the battle at Morgarten.

Particularly at the beginning of the 20th century, the discussions about the landscape and the extension of the former Lake Aegeri were very intense – also because of the fact that both the cantons Schwyz and Zug aimed to claim this heroic battle for themselves. Sidler (1910) made geomorphic investigations in this area and concluded that the lake level was approximately 6 or 7 m higher in AD 1315 than today. He furthermore conjectured that

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small lakes or pools existed in small side valleys. Because of these circumstances, the troops had to follow a narrow track along the footslopes of the surrounding mountains where the battle finally took place ('Tschupplen' and 'Schafstetten' – both localities in canton Schwyz). Hürlimann (1911), however, vehemently contradicted his opponent. He noted that Sidler (1910) considered only the south-eastern part of the lake. Hürlimann (1911) assumed, without being very precise, that part of the farming land (north-western and south-eastern part of the Aegeri lake) and some buildings (western part, downstream) would have been under water with a higher lake level of about 6 m. According to Hürlimann (1911), the lake had similar dimensions to the present and the battle took place at Morgarten (canton Zug). Furthermore, it is known that the lake dimension was distinctly greater (Hantke, 1967; Morosoli et al., 2003) at the end of the Last Glacial Maximum (LGM). Because of the fact that extensive areas of fens are present (that might be because of former higher lake levels) at the southern end of the Lake Aegeri, the hypothesis of Sidler could be plausible but really hard facts (e.g. dating of geomorphic features) are absent. A systematic investigation, using modern techniques, has not been undertaken until now. Our aim was, therefore, to delineate landscape evolution and particularly the lake level in the year AD 1315 as precisely as possible. As shown by other investigations (e.g. Morellón et al., 2011; Pérez-Sanz et al., 2013), a multi-methodological and/or a multi-proxy approach is necessary to obtain a robust control on age constraints that enables a reliable reconstruction of the landscape and lake levels. Using such a general approach, we aimed to trace back landscape evolution for the period after the LGM – focussing particularly on the medieval period around AD 1300. This finally should contribute to the 'demystification' of the battle at Morgarten.

Study area

Lake Aegeri is adjacent to the northern front of the Swiss Alps and is located in the canton Zug (Figure 1). The catchment has an area of 48 km^2, and the present-day lake level is at 724 m a.s.l. The only outlet is the river 'Lorze'. The Aegeri valley lies between unfolded and dislocated and erected molasse. Conglomerates are an important component of this molasse. Marl and sandstone layers are found between the conglomerate deposits (Möbus, 1997). The conglomerates resist weathering much better than the marl or sandstone layers. This gives rise to a ridge-shaped landscape having salient conglomerates. More clay-rich material has accumulated in the depressions between the conglomerate ridges, leading to less-permeable soils and thus to the formation of fens (Furrer, 2003). Finally, above Tertiary Molasse lies Quaternary till. The lake itself contains 0.357 km^3 of water. After glacier melt at the end of the last ice age, the lake was dammed by lateral and end moraines and had a level of about 750–760 m a.s.l. that was considerably higher than today (Furrer, 2003).

Materials and methods

Multi-methodological approach

To trace back landscape evolution, more reliable results are obtained using a multi-methodological approach that allows for an extended interpretation, mutual control and a more accurate estimate of possible error sources. We consequently used a broad spectrum of methods to elucidate the timing of changes of the landscape in general and the lake level in particular. To obtain a comprehensive view of landscape changes in the Aegeri valley, the following procedure was applied (Egli et al., 2015):

- Geomorphic mapping;
- Investigation of mires next to and close to the Aegeri lake:
  - chemical and physical characterisation of the sediments and layers
  - dating of sediments and layers

- Geoelectric soundings to explore the type of sediments and subsurface
- Analysis of existing and detailed soil maps
- Evaluation of existing archaeological data and foundation explorations

Geomorphic mapping

A geologic map also including geomorphic objects such as moraines and other Quaternary features exists (Hantke, 1967) at a scale of 1:25,000. Based on this map and on previous descriptions of Sidler (1910), the southern part of the Aegeri valley (adjacent to the lake) was chosen for further investigation. A particular focus was placed on relict shore terraces. These terraces were spatially referenced using GPS and drawn on topographic basic maps (Landeskarte LK25, Geländemodell SwissALTI3D, Orthophoto SWISSIMAGE). The terraces were clearly identifiable in the field because their edges have steep slopes. Furthermore, a digital elevation model derived from high-resolution LIDAR data (0.5 m resolution, canton Zug) clearly shows these landscape features. In addition, alluvial cones, rock debris and geologic ridges were mapped.

Mire and sediment sampling strategy

Core drilling was performed south of the Aegeri lake because the most important and largest fens around the lake are to be found in this location (Figure 1). These fens are, furthermore, close to the presumed AD 1315 battlefield at Morgarten. The detailed investigation of these mires and sediments should help to obtain information about the sedimentation environment and the age when mires started to develop (after the lake was infilled with sediments). With this, dating of lake levels should be possible and conclusions about landscape evolution are enabled.

We sampled peat and sediments at several sites close to the Aegeri lake and in adjacent small valleys (Figure 1; Table 1). The investigation of the mire and sediments in adjacent small valleys should provide an answer to the question as to whether former small side-lakes or pools have existed. Sites 1, 2, 3, 4 and 10 were on mires directly related to the Aegeri lake, whereas site 6 (and 6b) is behind a molasse conglomerate-rim and sites 7, 5 and 11 in a side valley or on a former terrace. Sites 5, 6, 7 and 11 have a 13 to 25 m higher elevation than the lake.

Core sampling was performed using a Humax rotating drill and a Russian side-opening sampler (Macaulay). As far as possible, the Humax drilling device was used because this technique allows sampling of volume-based material (enabling the determination of the bulk density). Under very wet sediment conditions, the Macaulay device had to be used. To optimally determine the sampling points, probing was done using the Pürckhauer auger (having a small diameter and a length of about 1.2 m). In the field, this instrument helped to estimate the thickness of the peat layer (the peat thickness was rather low; see below) within the fens and to explore the ideal sites.

Chemical analyses

The samples were oven-dried (70°C) and sieved to <2 mm (fine earth). Soil, sediment and peat pH (0.01 M $CaCl_2$) was determined for the fine earth samples using a soil:solution ratio of 1:2.5.

Total C and N contents of the soil were measured using a C/H/N analyser (Elementar Vario EL). Carbonates were determined by dissolution with HCl. Organic C was calculated as the difference between total C and inorganic C values.

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Table 1. Characteristics of the investigation sites (core drilling and geoelectric measurements).

Site	Swiss coordinates	Altitude (m a.s.l.)	Land use, vegetation	Investigation depth (cm)	Method
1	690597/217476	725	Protected fen	0–121	Core drilling (Humax)
2	690510/217406	732	Protected fen	0–59	Core drilling (Humax)
				0–139	Core drilling (Macaulay)
3	690717/217307	727	Protected fen	0–371	Core drilling (Humax)
				0–2500	Geoelectric sounding
4	690678/216839	737	Protected fen	0–285	Core drilling (Humax)
				280–347	Core drilling (Macaulay)
5	691145/216860	750	Drained fen, pasture	0–415	Core drilling (Humax)
6	690714/216714	738	Protected fen	0–269	Core drilling (Humax)
6b	690714/216714	738	Protected fen	0–350	Core drilling (Macaulay)
7	690924/216546	741	Drained fen, pasture	0–392	Core drilling (Humax)
10	690764/217110	731	Protected fen	0–350	Core drilling (Macaulay)
				0–3000	Geoelectric sounding
11	691182/216871	750	Drained fen, hay production	0–220	Core drilling (Humax)

Radiocarbon dating

Organic samples (organic residues such as peat and read particles) and in one case a bulk sample (sediment and peat) were cleaned using an acid-alkali-acid (AAA) treatment. The samples were then heated under vacuum in quartz tubes with CuO (oxygen source) to remove any absorbed CO_2 in the CuO. The tubes were evacuated, sealed and heated in the oven at 900°C to obtain CO_2. The CO_2 of the combusted sample was mixed with H_2 (1:2.5) and catalytically reduced over iron powder at 535°C to elemental carbon (graphite). After reduction, the mixture was pressed into a target and carbon ratios were measured by Accelerator Mass Spectrometry (AMS) using the tandem accelerator of the Laboratory of Ion Beam Physics at the Swiss Federal Institute of Technology Zurich (ETHZ).

The calendar ages were obtained using the OxCal 4.2 calibration program (Bronk Ramsey, 2001, 2009) based on the IntCal 13 calibration curve (Reimer et al., 2013). Calibrated ages are given in the 1σ range (minimum and maximum value for each).

Electrical resistivity tomography

The purpose of electrical resistivity tomography (ERT) is to determine the resistivity distribution of the subsurface. Potential difference patterns provide information on the geometry of subsurface heterogeneities and their electrical properties. The wide range of resistivity values for most materials is basically a function of their varying water content. Resistivity is calculated by measuring the current flowing between two electrodes having a known potential difference inserted into the ground. ERT surveys give an image of the subsurface resistivity distribution. Knowing the resistivity values of different material types, conversion of the resistivity tomogram into an image of different materials making up the subsurface can be made (Kneisel, 2006).

The 2D ERT surveys were carried out using a GeoTom instrument (Geolog, Augsburg) along two transects using different electrode spacings. The first ERT profile was located at site 10 using a profile length of 150 m and an electrode spacing of 1.50 m. The second measurement was performed closer to the lake at site 3, using a profile length of 100 m and an electrode spacing of 1 m. Both measurements were carried out using the Wenner configuration.

Soils

Soils are an additional tool for exploring landscape evolution. A detailed soil map of the entire investigation area was available (at a scale of 1:25,000; Amt für Umweltschutz des Kantons Zug, 1998). Soil cartography and classification was performed according to the FAL system (Brunner et al., 1997) and translated to WRB-system (IUSS Working Group WRB, 2014). Soil maps provide information about soil types and orders, hydrologic conditions, chemical and physical characteristics and so on. The longer a surface is exposed to weathering, the more developed are the soils. We gave a particular focus to Dystric Cambisols having a soil thickness relevant for plant growth (= soil volume − skeleton volume − groundwater volume; the result is related to depth instead of volume) of 50–70 and 70–100 cm (according to the Swiss soil mapping system). Soil thickness is considered as the sum of the A and B horizon. Dystric Cambisols represent the most advanced soil development state in this region. These soils have a maximum age of about 18,000 years because soil development could only start after the melting of glaciers after the LGM. Dystric Cambisols are characterised by a relatively low pH and they are completely free of carbonates. The question is now, 'What could be the minimum age for such soils'? How much time is needed to develop an acid soil having a thickness of 50–70 or 70–100 cm? Using the soil map, the occurrence of Dystric Cambisol can be visualised. Knowing the locality and altitude of the Dystric Cambisols that are close to the lake (and subsequently have a higher altitude than the lake), minimum ages can be calculated since when the lake must have reached a lower level (soils do not form under water).

In temperate climates having a considerable amount of annual precipitation, dissolution and leaching of carbonates are enhanced (Blume et al., 2010). The parent material of the investigation area contains approximately 20–30% carbonates (Amt für Umweltschutz des Kantons Zug, 1998 and own measurements). Carbonate has to be leached completely from the parent material before a Dystric Cambisol can start to develop.

To obtain an estimate for reaching such a soil evolutional state, the time elapsed to leach all the carbonates to a depth of 50–70 and 70–100 cm was calculated. Egli and Fitze (2001) and Egli et al. (2008) showed that water draining from calcareous soils from Sub-Arctic to temperate areas is usually close to equilibrium with calcite and dolomite. Thus, the annual amount of rainfall (and subsequently the percolation rate through the soil) and temperature are the most important driving factors in carbonate leaching. Egli and Fitze. (2001) showed that carbonate dissolution in this region (groundwater, soils at the neighbouring Rossberg mountain) is in equilibrium with pCO_2 and varies between a $\log pCO_2$ of −2.2 to −2.6. In addition, a small contribution to acidity is also derived from NO_x, NH_x and SO_x depositions that were set to 0.02, 0.04 and 0.02 mol m^{-2} yr^{-2}, respectively (pre-industrial values; cf. Schöpp et al., 2003). The reaction constants were adjusted for +7°C (mean annual temperature close to the Aegeri lake). In addition to this, dilatation effects (volumetric changes) during pedogenesis because of carbonate leaching have to be taken into account. The parent material has a given bulk density ρ_p and

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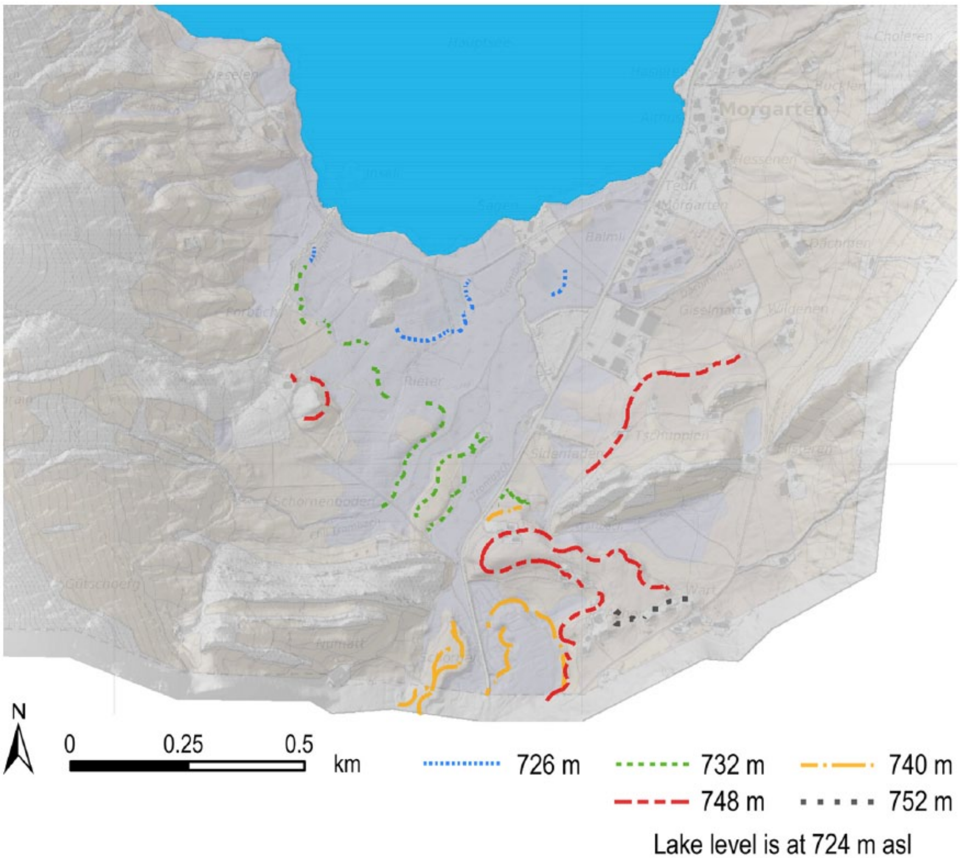

Figure 2. Mapped remnants of former lake terraces at the southern end of the Aegeri lake. Reproduced by permission of swisstopo (BA15043).

carbonate content C_p. The developing soil has a bulk density of ρ_w and a carbonate content of 0% (Dystric Cambisol). The soil is built up from the residual, non-calcareous material. Per unit volume, the residual, non-calcareous material for the parent material (R_p) and soil (R_w) is

$$R_p = \left(100\% - C_{p,\mathrm{CaCO_3}}(\%)\right) \cdot \rho_p \quad (1)$$

$$R_w = \left(100\% - C_{w,\mathrm{CaCO_3}}(\%)\right) \cdot \rho_w \quad (2)$$

Because of the substantial loss of carbonates, the compaction can be estimated using Eq. 3:

$$F = \frac{R_w}{R_p} \quad (3)$$

with R_w and R_p as the concentration of the residual material in the soil and parent material, respectively. The amount of carbonate (M=mass) that has to be leached to form a profile of a given thickness Δz is:

$$M_{\mathrm{CaCO_3}} = F\left(C_{\mathrm{CaCO_3}} \rho_p \Delta z\right) \quad (4)$$

Relating this mass per unit area to the mass flux per unit area and time $m_{\mathrm{CaCO_3}}$, then the time (t) necessary to form the soil can be calculated

$$t = \left(\frac{M_{\mathrm{CaCO_3}}}{m_{\mathrm{CaCO_3}}}\right) \quad (5)$$

Such an approach enables the delineation of the maximum extension of the lake for the last few centuries up to millennia if the spatial extension of Dystric Cambisols close to the lake is known. Although this method is based on several assumptions (e.g. homogeneity of the parent material), it enables at least a semi-quantitative dating of surfaces.

Archaeological findings

A search for historical buildings and archaeological findings was performed at the Agency for cultural heritage and archaeology of the canton Zug. Of special interest were objects and findings around the Aegeri lake from the prehistoric and early historic periods. In addition to this, an evaluation of documented excavations for constructions was performed. In this case, everything covering time periods before or shortly after AD 1315 was considered. Relevant information such as geographic position (coordinates), altitude, type of object and dating technique were registered.

Spatial analyses

A geographic information system (GIS) was used for evaluating and displaying spatial data from the study area. All spatial data used were processed in Environmental Systems Research Institute (ESRI) ArcCatalog and ArcMap software, v10.2.2 with ArcInfo license. Basic datasets included a soil map (1:25,000), a digital elevation model (LIDAR, 0.5 m resolution), the digital elevation model SwissALTI3D, Orthofotos SWISSIMAGE and the Swiss topographic maps LK25.

Results

Geomorphic mapping

Several terrace systems could be distinguished at 726, 732, 740, 748 and 752 m a.s.l. (Figure 2). All these terraces can be interpreted as relicts of former shorelines of higher lake levels. As a

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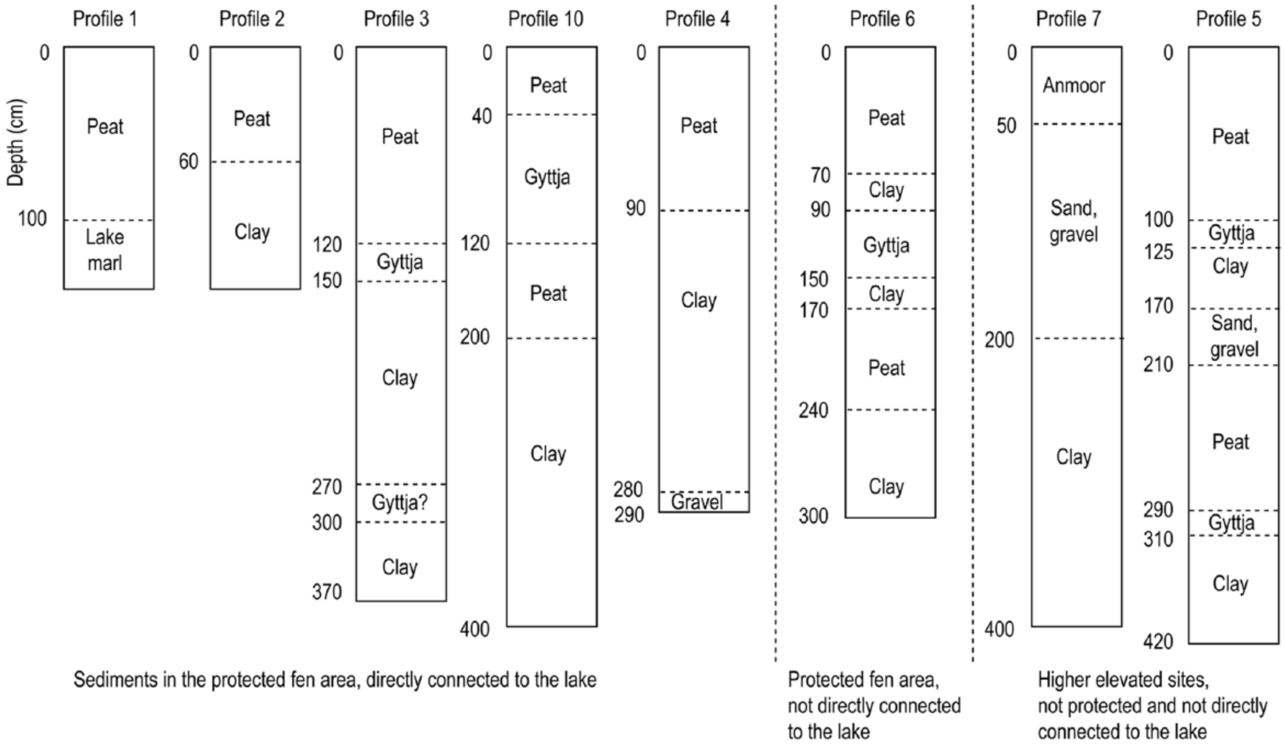

Figure 3. Description of the sediment profiles.

basic principle, terraces at higher levels and increasing distance to the present-day lake are coupled to older lake levels. Whether these terraces really follow a chronological sequence (hypothesis: that is, a constant lowering of the Aegeri lake) cannot be answered based solely on their relative position. Technically speaking, it is not certain whether there were or were not lake level fluctuations, that is, later increases that submerged older terraces.

The northern part of the terrace at 748 m a.s.l. appears in the map of Hantke (1967) as moraine. However, this seems to be unlikely because remnants of the terrace can be followed at exactly the same altitude over long distances (Figure 2). Considering the distinct end moraines at the northern end of the Aegeri valley, that can be attributed to the Schlieren stadial (23,450–24,010 cal. BP; Hantke, 1967; Ivy-Ochs et al., 2008), a first traceable lake level is estimated to have occurred at about 750–760 m a.s.l. after glacier melting. In the postglacial phase, the Aegeri lake had its largest extension: later, lake levels were at an altitude of 740 m a.s.l. and lower.

Mire cores

At all drilling sites, the fen is not particularly thick. At most sites, the peat layer is limited to a thickness of c. 1 m (Figure 3). The profiles 1, 2, 3, 4 and 10 are within the same fen complex. At the edges of this fen, the mire is strongly affected by human impact (agriculture) and degradation and humification of the peat layer is obvious. In such areas, Gleysols rather than Histols are now developing. Below the peat or gyttja layer, clays (glacigenic and/or lacustrine clays) are found. Whether the clays are of glacigenic or only lacustrine origin is not fully clear. The varved structure of the clays however would rather indicate lacustrine clays (part of it probably was washed out from glacigenic sediments and deposited in the former lake). At profile site 1, well-expressed lake marl was found.

Site 6, at 738 m a.s.l., is characterised by alternating layers of peat and clay. At a depth of 150 cm and deeper, charcoal particles were detected and lower than 300 cm some gravelly stones were also intercalated with the clay. The peat and organic gyttja point to the presence of a former small lake or pool. The sites 7 and 5 (11) are at higher elevations (741 and 750 m a.s.l., respectively). Site 7 is strongly and site 5 (11) less strongly drained. Both sites are now used as pasture and/or for hay production. As a consequence, the former fen is strongly degraded and the top layer at site 7 is now only an anmoor (Zanella et al., 2011). Because of periodic water saturation, the humus consists of an organo-mineral horizon Aa with a dark colour having a high organic content. A histic horizon was absent. Below the anmoor (site 7), a gravel deposit was found that overlaid a clay layer. Profile 5 also has quite a complex structure. Peat and clay layers alternate together with a sandy-to-gravelly layer (Figure 3). In most cases, the pH value of the sediments was between 6 and 7.5 (Figure 4). When a higher amount of organic material (peat) was present, values below 6 were registered. At sites 2, 6 and 7, several layers are carbonate-free, and when a high organic matter (OM) content was present (Figure 4), the pH values even dropped below 5.0. Site 3 also had almost no carbonate and rather low pH values. This site is characterised by peat and a well-expressed gyttja layer. The other profiles mostly consisted of sediments having a carbonate content in the range of 20–50%. In the case of profile 1, a distinct peat layer to a depth of 1 m was found: at this point, a bright white layer of varved lake marl appeared, containing many snail shells, and the carbonate content rose to about 90%.

When peat or gyttja was present, organic carbon concentrations of more than 30% were measured (Figure 4). Profiles 5, 6 or even 10 showed strongly varying OM concentrations. Within the first two 2–3 m of the profile, no or only a small amount of carbonates was measured. At a depth of 250 cm, carbonates strongly increased. The repeated layers of peat–gyttja–peat indicate that a small lake or pool (having a variable size) most likely existed at these sites. Profile 5 shows to a great depth very high OM contents. Similarly to site 10, the two peat and the gyttja layers (between about 40 and 120 cm) indicate that a pool temporarily existed here.

Because of agricultural use, profile 7 seems to be more and more similar to a soil profile having not over-high C values in the top horizon together with a typical decrease of OM with depth

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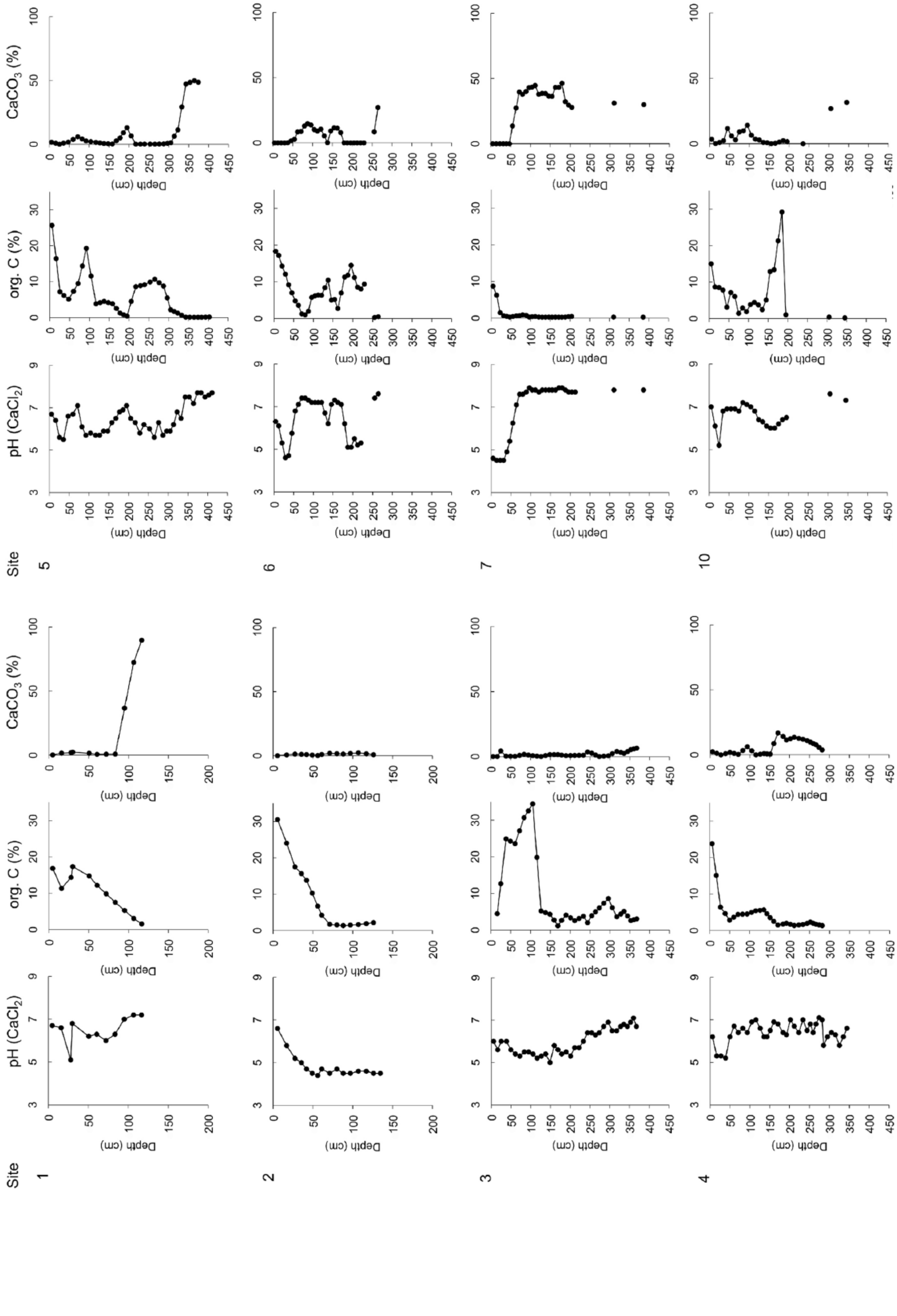

Figure 4. Chemical properties of the sediments as a function of depth and sites.

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Table 2. Description, radiocarbon and calibrated ages of the dated samples (calibrated using OxCal 4.2; Bronk Ramsey, 2009; Reimer et al., 2013).

Sample code	ETH number	Core	Depth (cm)	Material	^{14}C age BP (uncal)	±1σ	$\delta^{13}C$	±SD $\delta^{13}C$	Calibrated age	Calendar years	Reporting
									cal. BP	cal. AD/BC	
									1σ	1σ	
UZ 6159	ETH-50238	1	0–10	Peat	−300	25	−23.8	1.1	modern	1956–1957	cal. AD
UZ 6160	ETH-50239	1	89–101	Peat	225	25	−23.6	1.1	302–152	1648–1798	cal. AD
UZ 6161	ETH-50240	2	11–23	Peat	−1750	25	−26.2	1.1	modern	1981–1983	cal. AD
UZ 6162	ETH-50241	2	53–59	Peat	−4460	25	−21.0	1.1	modern	1964–1965	cal. AD
UZ 6157	ETH-50236	3	21–33	Peat	−275	25	−21.9	1.1	modern	1956	cal. AD
UZ 6158	ETH-50237	3	111–121	Peat	375	25	−26.5	1.1	496–334	1455–1617	cal. AD
UZ 6170	ETH-50993	3	311–324	Reed	5361	28	−19.4	1.1	6267–6029	4318–4080	cal. BC
UZ 6155	ETH-50234	4	12–21	Peat	−1380	25	−24.3	1.1	modern	1986–1988	cal. AD
UZ 6156	ETH-50235	4	218–228	Peat	−635	25	−22.3	1.1	modern	2001–2003	cal. AD
UZ 6171	ETH-50994	4	270–278	Peat	−493	24	−16.0	1.1	modern	2005–2007	cal. AD
UZ 6172	ETH-50995	5	223–234	Peat	−525	24	−15.0	1.1	modern	2004–2006	cal. AD
UZ 6173	ETH-50996	5	292–301	Sediment and peat	1918	26	−19.5	1.1	1890–1827	60–124	cal. AD
UZ 6204	ETH-56606	6	41–50	Peat	−741	31	−30.8	1.0	modern	1998–2000	cal. AD
UZ 6199	ETH-56601	6	125–133	Peat	169	31	−23.4	1.0	283–0	1668–1950	cal. AD
UZ 6201	ETH-56603	6	233–241	Peat	595	32	−31.3	1.0	640–549	1310–1401	cal. AD
UZ 6202	ETH-56604	6	241–250	Peat	380	32	−30.8	1.0	500–333	1450–1618	cal. AD
UZ 6206	ETH-56608	6b	40–47	Peat	−1110	30	−24.9	1.0	modern	1990–1992	cal. AD
UZ 6209	ETH-56611	6b	120–130	Peat	262	31	−31.2	1.0	422–157	1529–1794	cal. AD
UZ 6205	ETH-56607	7	50–59	Reed	3476	35	−32.7	1.0	3827–3696	1878–1747	cal. BC
UZ 6208	ETH-56610	10	170–180	Peat	3809	36	−37.6	1.0	4247–4100	2298–2151	cal. BC
UZ 6200	ETH-56602	10	200–210	Peat particle	4013	35	−27.3	1.0	4521–4435	2572–2486	cal. BC
UZ 6203	ETH-56605	10	210–220	Peat particle	4247	36	−28.8	1.0	4858–4729	2909–2789	cal. BC
UZ 6207	ETH-56609	10	220–230	Peat particle	4590	35	−24.8	1.0	5444–5092	3495–3143	cal. BC

and a corresponding increase in pH and carbonates. The top 50 cm of this profile are strongly disturbed (because of management practices such as draining). The black colour of these first 50 cm however still indicates that a mire must have been present.

Radiocarbon dating

A total of 23 sediment samples were dated (Table 2). In most cases, peat material was used. The ages varied between modern and a maximum of 6267–6029 cal. BP. In general, ages were youngest in the top layers and increased with depth. In most cases, the top layers not surprisingly showed a modern age. Relatively close to the lake (profile 1), a mire started to develop around 1648–1798 cal. AD (Table 2). The shallow peat at profile 2 had only modern ages. Profile 3 has a relatively thick peat layer over a shallow gyttja layer followed by lacustrine clays. This peat seems to have grown since 1455–1617 cal. AD (with a probability of 53% the age of the peat base is between 1455–1513 cal. AD). At a depth of 311–324 cm, a reed remnant was found in the lacustrine sediments. This reed gave a very old age (6267–6029 cal. BP) and we have to assume that it was washed into the former lake and deposited with the clays. Consequently, it does not have any relation to the formation of the peat at this site. The next closer site 10 at an elevation of 731 m a.s.l. has a formation phase. Peat material at a depth of 170–230 cm showed old ages in the range of 4100–5444 cal. BP (Table 2). The upper layers were not dated but it has to be assumed that their ages would decrease towards a modern age. Profile 4 is at the upper end of the (protected) fen area where there is now a small creek inlet. This is reflected in the peat material that has modern ages throughout the profile (Table 2). These results cannot be easily explained. Here, we assume that repeated disturbances (deposition of young material) have occurred. Profile 6 (738 m a.s.l.), situated in a flat valley area, shows that repeated formation of peat has taken place and that also a small lake seemed to exist. The base of the peat yielded a maximum age of 640–549 cal. BP (Table 2), although a minor age inversion along the profile could be measured. This peat started to form shortly after the battle at Morgarten. That the first 50 cm of profile 7 has a degraded and partially humified peat points to an anthropogenic influence. Not far below the surface, a reed remnant was already found having quite a high age. This site is situated at a higher elevation (741 m a.s.l.). As a consequence of its topographic position, higher ages are expected here. Unfortunately, only one ^{14}C dating is available. At the highest elevated site (750 m a.s.l.), a complex stratigraphy was observed. Already at a depth of 223–234 cm, modern ages were measured. This young age may be because of translocated, younger aged particles or because of a distinct accumulation (because of an erosion event) of material on top of an already existing peat. At a depth of 292–301 cm, the peat had an age of 1890–1827 cal. BP (Table 2).

ERT

Two transects, one at site 10 and another one at site 3, were measured to explore the sediment layers in more detail. Both tomograms (Figure 5) did not exhibit high contrasts in resistivity values and showed basically very low resistivity values between 25 and 100 Ωm, typical for water-saturated and/or clay-rich sediments. Nonetheless, the tomograms clearly show the most important sediment structures. The chosen measurement geometry allowed sufficient depth penetration to resolve the uppermost ~ 25 m of the subsurface in reasonable detail. At site 10 (RTB 10), a layer having a resistivity of 25–50 Ωm (blue colours) was measured to a depth of about 3–5 m. Such low values indicate clay-rich sediments and/or saturated conditions. Below, a spatially very heterogeneous layer having a resistivity

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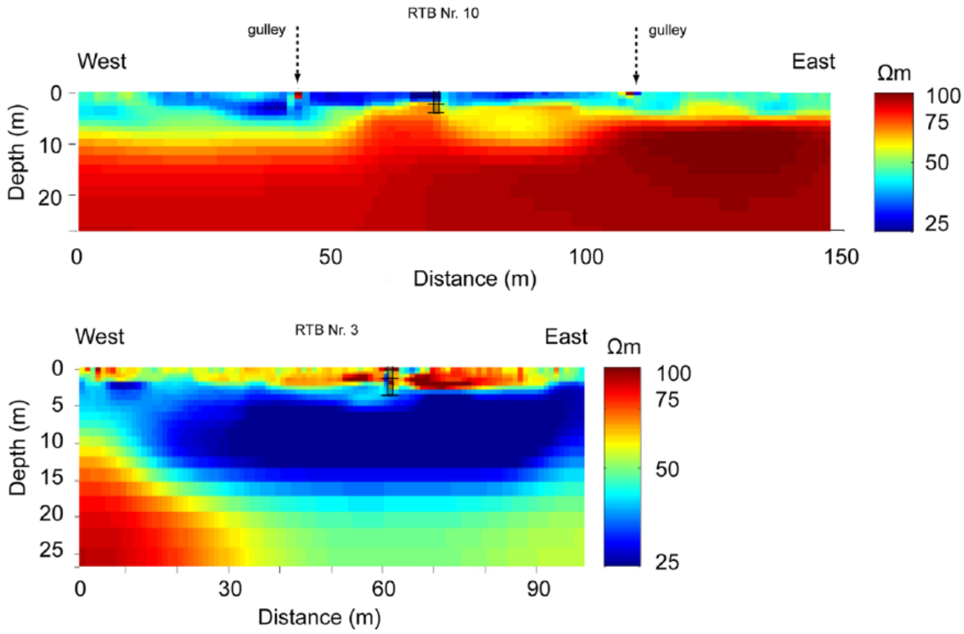

Figure 5. Tomograms (electrical resistivity of the subsurface given in Ωm) of site 10 (above) and 3 (below). Electrode spacing at site 10 was 1.5 m and at site 3, 1 m.

of 50–70 Ωm (yellow colours) appears between about 5 and 10 m depth. The third and lowermost layer exhibits a resistivity in the range of 70–100 Ωm (red colours). The low resistivity values can be interpreted as the main (ground)water layer. The layers below, however, also seem to be water saturated (but with lower water content). The shape of the different layers seems to indicate two erosion incisions (close to gulley 1 and 2, Figure 5) caused by small creeks or gullies that partially were infilled over time. At site 3, a large part of the subsurface has very low resistivity values of about 25 Ωm (blue colour). This layer has a thickness of about 18–20 m and a basin-shaped form, which may indicate a former lake bed at 10–15 m below the current ground level that was recently infilled. The higher resistivities of 70–100 Ωm (red colours) at >15 m depth in the western part of the profile are probably related to the subsurface continuation of the nearby conglomerate ridge *Heroltzbüel* (see, for example, Figure 1). However, as the sensitivity of the ERT method in the lower edges of the tomograms is very low, the anomaly may only hint at a structure having higher resistivity, but no detailed conclusions can be derived from either the shape or the resistivity values in this zone.

Soils

The main soil units and types are given in Figure 6 (Amt für Umweltschutz des Kantons Zug, 1998). Because of glacigenic fine-grained sediment deposits and the high amount of precipitation, a significant part of the region has relatively wet soils and areas having mires. Close to the lake, the existence of fens is because of lake aggradation. The most developed and weathered soils are Dystric Cambisols. If a soil is not too strongly influenced by water, then the soil development sequence is as follows: Skeletic Leptosol or Calcaric Regosol → Eutric Cambisol → Dystric Cambisol. Figure 6 shows the most developed soils (Dystric Cambisols) separately that are furthermore classified into soils having a thickness relevant for plant growth of 50–70 and 70–100 cm (according to the Swiss classification; Brunner et al., 1997).

Taking a closer look at the spatial distribution of Dystric Cambisols in the surrounding of the lake, those having a thickness of 70–100 cm (older soils) are found only above an altitude of 732 m a.s.l. and those having a thickness of 50–70 cm (younger soils) above an altitude of 726 m a.s.l. (Figure 6). The question is now, 'What is the shortest time that is needed to form such soils'? Using a mean annual precipitation of 1600 mm per year for the area of interest (BAFU, 2007), an estimated surface runoff of 50–100 mm and a maximum evapotranspiration of 600–650 mm then a percolation rate in the order of 850–950 mm per year is obtained. When the hydrologic data are combined with the carbonate dissolution reactions, the rate of carbonate leaching from soils can be calculated. In addition, volumetric changes have to be taken into account (Eq. 3). The parent material has a carbonate content of approximately 20–30%. This gives the starting point. Based on this, the minimum time required to form a Dystric Cambisol having a thickness of 50–70 cm is in the range of about 1000–2500 years (taking the minimum and maximum values of the above-mentioned parameters). For a Dystric Cambisol having a thickness of 70–100 cm, the time required for a complete carbonate leaching is in the range of 1900–3700 years.

This means that the lake level must have been at a maximum level of 726 m a.s.l. for the last 1000–2500 years and at a maximum level of 732 m a.s.l. before this period until a maximum of 3700 years ago.

Archaeology

Most archaeological sites are found close to Ober and Unterägeri. A more detailed description of the discovered items is given in Table 3. Considering the location and distance to the lake, then the following three sites are particularly relevant for the reconstruction of the former lake level.

River timbering (Roman period; dated 82–221 cal. BP). During excavations for a building pit (in the year 1994), a wooden construction (stakes; Norway spruce) close to the river 'Lorze' was found (ADA-nr. 514, Table 3). The remaining top edge of this construction was at 723.8 m a.s.l. The deepest level of the building pit was at 723.04 m a.s.l. It can be assumed that the stakes extend another metre into the subsurface. Along the stakes, which are built in a palisade-like form, some alluvial sediments were found. Because of the age of this palisade, the wooden stakes can be attributed to the Roman period. This construction thus appears

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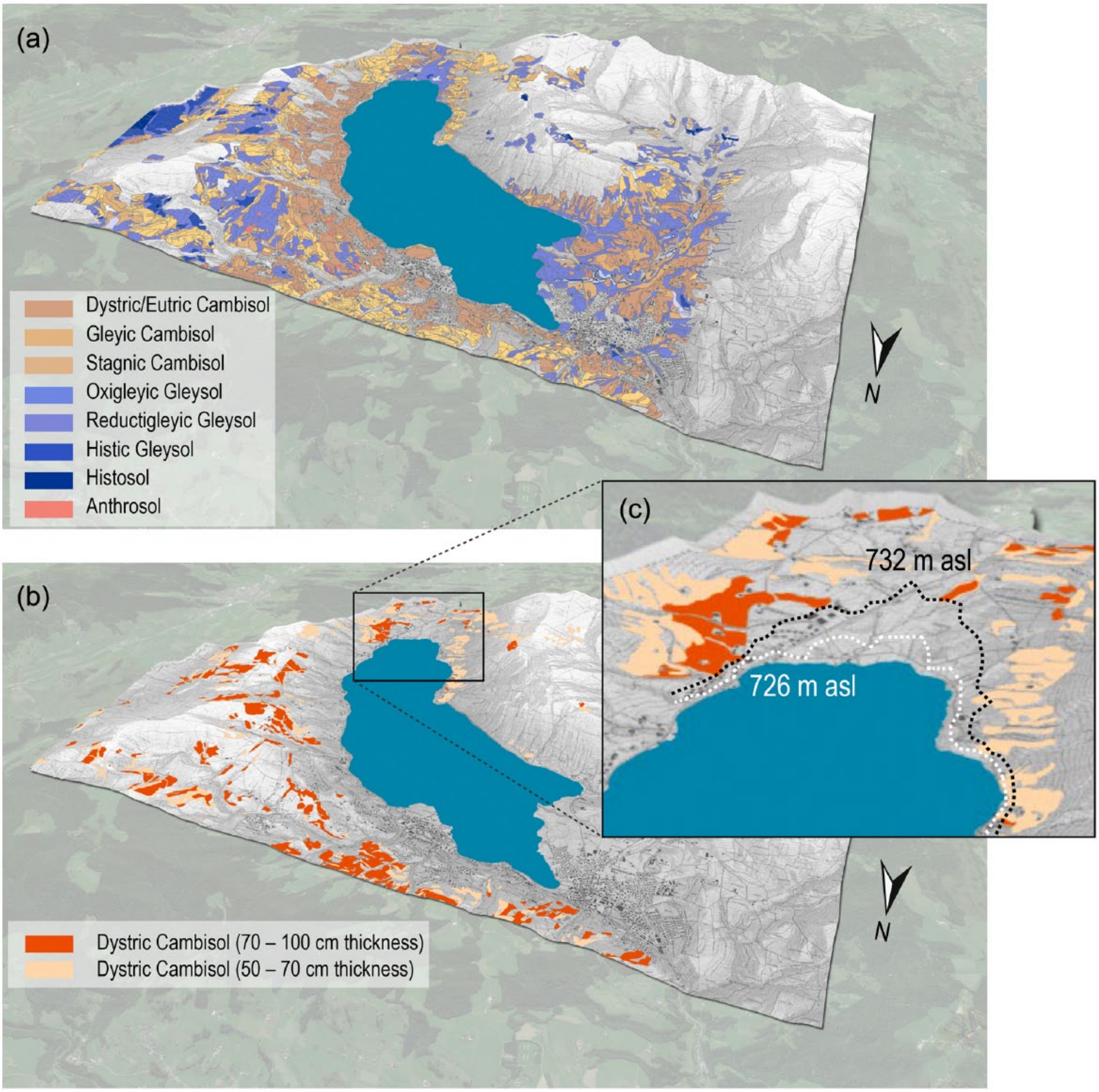

Figure 6. (a) Soil map (with the major soil units; above) of the whole investigation area and (b) distribution of Dystric Cambisols having a thickness of 50–70 and 70–100 cm. (c) Shorelines of higher lake levels delineated from the spatial distribution of Dystric Cambisols having a thickness of 50–70 cm (present above an altitude of 726 m a.s.l.) and 70–100 cm (present above an altitude of 732 m a.s.l.). The soil maps (GIS) were adjusted to the Google Earth elevation model for a three-dimensional visualisation. Reproduced by permission of swisstopo (BA15043).

to have been intended to stabilise and line the outlet river 'Lorze' and suggests that the lake level must have been at least 724 m a.s.l. or even higher; otherwise, this construction would have been located above the level of the lake, which makes little sense. Furthermore, this construction also indicates that the lake level was not higher than 726 m a.s.l. because the stabilisation and lining of the river Lorze would then have been submerged and the construction would have been useless.

Early medieval graves. During the new construction of a hotel (Gasthof zum Seefeld) in Unterägeri in 1908, two human skeletons were found side by side in the boggy soil (newspaper report in the 'Zugernachrichten' ZN Nr. 62, 28 May 1908; Table 3). Close to the haunch of one of the skeletons, an iron belt-buckle was identified. The orientation of the skeleton – from west (head) to east (feet) – was also striking. Although the finds appear to have been mislaid in the meantime (Bollinger and Hochuli, 1996), they were dated to the late Antiquity or early Middle Age. The location of the grave gave an indication: the Merovingians (beginning of the 5th century until mid-8th century) entombed deceased persons outside their settlements (Marti, 2000). The deceased were buried close to churches. A further indication for the early Middle Age (AD 500–1050) is the iron belt-buckle similar to those that can be found as a piece of grave furniture over the whole of Switzerland during this period. In addition, the orientation west–east of the deceased persons in the grave is typical for the Merovingian period (Graenert, 2005). Consequently, the lake level was at that time certainly not higher than 725 m a.s.l. (probably slightly lower – most likely at about 724 m a.s.l.).

Chapel St Vit (Haselmatt). The chapel St Vit is mentioned in surviving documents for the first time in the year 1492 or 1493 during its re-consecration (Eggenberger et al., 2008; Table 3). The chapel is mentioned as 'reaedificata' (meaning 'rebuilt'). The

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Table 3. Archaeological sites close to the Aegeri lake.

ID (ADA ZG[a])	Description	Date	Site	Swiss coordinates (East/Nord)	Altitude (m a.s.l.)	Source
1131	Clay pit 'Merz' with timber piles and stone axes (Neolithic)	c. 3400–2400 BC	Unterägeri	687540/220512	728	ADA ZG, Huber et al. (2009)
1134 and 829	Early medieval graves (Hotel Seefeld)	c. AD 500–1050	Unterägeri	687365/221080; 686965/221605	725.5	ADA ZG
304	Wooden piles in the lake (^{14}C dated)	1320–1630 cal. AD	Oberägeri	689550/220750	724	ADA ZG
514	Wooden construction (^{14}C dated)	82–221 cal. BP	Unterägeri	686800/221350	724	ADA ZG
193	Chapel St Vit	AD 1492/1493	Oberägeri	691413/218491	727	Eggenberger et al. (2008)
50	Parish church St Peter and Paul	AD 1319	Oberägeri	689189/221079	735	Eggenberger et al. (2008)
	Presbytery (close to the parish church Oberägeri)	AD 1611	Oberägeri	689157/221065	735	Morosoli (2003)
	House 'Zurlauben'	AD 1574	Oberägeri	689101/221157	735	Morosoli (2003)

[a]Agency for cultural heritage and archaeology of the canton Zug.

chapel is affiliated to the Parish church St Peter and Paul in Oberägeri. In total, 6 building phases are known for this chapel. Only some minor wall fragments of the oldest (undated) phase (prior to the reaedificata phase) are preserved. One has to assume that all building phases took place at exactly the same place. The chapel is situated at 727 m a.s.l.

All in all, the investigation of the archives leads to reasonably well-datable objects and constrains the maximum lake level.

Discussion

Geoarchaeological evidences

The mapped terraces could be considered as relicts of former shorelines (Håkanson and Jansson, 1983). During the Lateglacial, the Aegeri lake had a greater extension and a higher level (at about 750–760 m a.s.l.) and was dammed by moraines. These moraines broke and led to a lake outburst in the Lateglacial (Ammann, 1993). As a consequence of this catastrophic event, the lake level abruptly dropped by about 25 m to a level that probably was quite close to the present-day situation. Because of this lake outburst, the valley subjacent to Aegeri lake was cleared and a wide alluvial cone formed at Baar (about 8 km distance from the Aegeri lake; Ammann, 1993).

The shore region of a lake can be a very dynamic zone where different types of sediments can be deposited. During the last lake sedimentation phase, an increased amount of organic material is usually deposited and a moor starts to form. Typical for moors that have formed in a sedimentation zone is the succession of peat and lake sediment layers such as gyttja or lake marl (Cohen, 2003). In general, the fen south of the Aegeri lake has a rather shallow thickness. A distinct part of this fen seems to have started to grow after the battle at Morgarten. With a mean annual growth rate of about 0.5–1.5 mm (Succow and Jeschke, 1986), a thickness of 35–105 cm would be the result, which finally fits well with the measured values. Together with the radiocarbon dating, the fen at sites 1–3 seemed to develop after AD 1315. Lake marl at site 1 and gyttja at site 3 indicated the presence of a former lake. It consequently seems likely that the lake level was slightly higher than today: until the 15th century, the lake level appears to have been 726–727 m a.s.l. Geoelectric measurements revealed a basin-shaped form of the subsurface at site 3 that can be interpreted as a former lake bed in 10–15 m depth to the current ground level.

Peat usually develops continuously and has a gradual structure. The deepest layers have the oldest age and the highest the youngest age. It is commonly known that also age inversion because of bioturbation, translocation of organic particles, frost heave and so on may occur (Trettin et al., 1982). Such a minor age inversion was also found at site 6. We can, nonetheless, assume that the sedimentation of a small lake or pool together with the peat formation started after AD 1315.

A sedimentation phase is indicated for 3500–2150 cal. BC at site 10 (731 m a.s.l.) in 170–230 cm depth. Assuming a peat formation rate of about 0.5 mm per year, then the thickness of 60 cm nicely fits to a maximum duration of 1300 years. It seems that the lake level was in that period (about 5450–4100 cal. BP) at an altitude of c. 730–732 m a.s.l. Lake sedimentation seemed to be enhanced by the creeks (cf. geoelectric measurements at site 10). Geoelectric measurements indicate a subsurface structure that may point to the former existence of a small pool at ~ 5–7 m depth in the western part of the longitudinal profile (Figure 5).

The stratigraphy of the sites 6 and 5 (11) indicate that in side valleys, some small pools or lakes seemed to exist. At site 6, the hypothesised small lake most likely started being infilled 640–549 cal. BP, while at site 5, a mud-flow probably covered a former fen. This gave rise to a repeated structure of peat over varved clays that is interrupted by a gravel layer. These two sites (5 and 6) would confirm Sidler's hypothesis (Sidler, 1910) that small lakes or pools have existed in side valleys.

Using the archaeological and pedological evidences, additional time constraints and indications about the former extensions of the lake could be derived. As shown by other investigations (e.g. Auriemma and Solinas, 2009), archaeological remains can be used as a lake level change marker. In our case, the river timbering close to Unterägeri reveals that the lake level must have been 724 to maximum 726 m a.s.l. during the Roman period. The early Middle Age graves (in Unterägeri) are a clear indication that the lake level must have been not higher than 724 or 725 m a.s.l. during the period AD 500–1050. It would appear that the lake level was slightly higher in the following periods. A further indication is given by the chapel St Vit (located at 727 m a.s.l.) that was first mentioned in 1492/1493 (but appears to have existed prior to that date). Because of the increasing industrialisation in the 19th century, the riverbed of the Lorze (the lake outlet) was lowered with the consequence that the lake level also decreased by 1 m (from 725 to 724 m a.s.l.; Morosoli, 2003).

Applying the concept of Egli and Fitze (2001) and Egli et al. (2008), the minimum time required for the decalcification of soils and subsequently the minimum time to form a Dystric Cambisol was calculated. Based on these estimations and the spatial distribution of the most developed soils (Dystric Cambisols), additional

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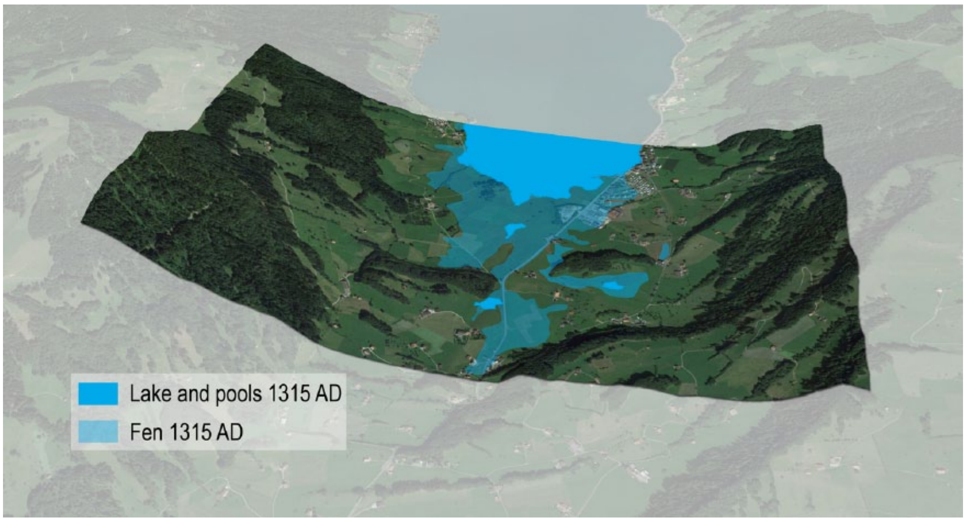

Figure 7. Modelled extension of the Aegeri lake, small pools and fens near Morgarten at the time of the battle (AD 1315). The former extension of the fens was derived from field observations and the soil map (drained mires and now partially Histic Gleysols, and still existing Histosols, mires). For visualisation, the digitised lake level was adjusted to the Google Earth elevation model. Reproduced by permission of swisstopo (BA15043).

hints about the maximum extent of the former lake could be derived. During the last c. 2000 years, the lake level was not higher than 726 m a.s.l. and earlier until about 3000 years, not higher than 732 m a.s.l.

Using this information, a quite clear model of lake level variations and landscape can be developed.

Landscape model

Lateglacial. After the LGM, the Reusss-/Muota-glacier system still covered the Aegeri valley that became ice-free approximately 18 kyr BP (Wehrli, 2005; Wehrli et al., 2007; Figure). A lake was formed having its surface at about 750–760 m a.s.l. (Ammann, 1993; Figure 8). Corresponding shoreline terraces are found at 748, 752 and 760 m a.s.l. The lake level seemed to be variable already at that time. In the Lateglacial, the damming moraines broke and a lake outburst was the consequence. Within a very short time, the lake level decreased dramatically (Ammann, 1993). A likely cause could have been large earthquakes that occurred in central and northern Switzerland between about 11,500 and 13,800 BP (Strasser et al., 2006, 2013). These earthquakes were strong enough to trigger multiple mass movements in the Lakes Zurich and Lucerne (Strasser et al., 2006). Strasser et al. (2008) demonstrated that a major outburst of the Lake Zurich was triggered by primary earthquake shaking or by secondary effects, such as overtopping by landslide-generated waves.

A relict terrace at 740 m a.s.l. could not be fully integrated: it could indicate a lake level before the outburst or point to an increase of the level after the outburst.

A next phase is documented by the start of peat formation at site 10 (731 m a.s.l.) that is close to the terrace at 732 m a.s.l. A lake level at 732 m a.s.l. about 5500 BP seems therefore to be plausible (Figure 7). This would also comply with the spatial distribution of Dystric Cambisols (having a soil thickness of 70–100 cm) that needed at least 1900–3700 years to form. The age of the terrace at 741 m a.s.l. could not be clearly dated. The age obtained from a reed particle (3827–3696 cal. BC; site 7) seems to be too young for this terrace. An increase of the lake level again to 741 around 3.8 kyr ago seems to be a quite speculative. Further investigation would be necessary here.

Late Antiquity or early Middle Age. A small lake or pool seems to have existed at site 5 and started to be infilled from 60–124 cal. AD. According to the archaeological findings (river timbering, 82–221 cal. AD; Roman period), the level of the Aegeri lake seemed to be at c. 724 up to a maximum of 726 m a.s.l. This is supported by the spatial distribution of the Dystric Cambisols having a thickness of 50–70 cm and needing 1000–2500 years to form. In addition, the early medieval graves (c. AD 500–1050) determine a maximum lake level around 724 or 725 m a.s.l.

Around AD 1300. Radiocarbon dating of the mire south to the Aegeri lake showed that a sedimentation phase started in the 15th century. Before this, the lake level was at 726 or 727 (absolute maximum) m a.s.l. There are not many archaeological findings in the time period between the early Middle Age and the 15th century. The missing contracts (agriculture) for the valley floor close to the lake (near the locality Rieter, ADA ZG; see also Sidler, 1910) gives rise to the hypothesis that no activities seemed to have taken place because the area was submerged or, because of the very wet conditions, too difficult to be managed. The lake shore terrace found at 726 m a.s.l. speaks for a longer stability of the lake level at this altitude.

Also for this period, we obtain some additional information from soil development: Dystric Cambisols (having a thickness of 50–70 cm and needing a formation period of at least 1000 years) are found close to the lake at an altitude of 726 m a.s.l. and higher. Furthermore, the reconstruction of the chapel St Vit (situated at 727 m a.s.l.) in the year 1492/1493 is a further important marker point.

At the time of the battle at Morgarten, the lake level was consequently at 726 m a.s.l. – temporarily maybe even at 727 m a.s.l. during very wet periods (Figures 7 and 8). In addition, in side or adjacent valleys, small lakes or pools seem to have existed at that time. Noteworthy are also the climatic conditions at that time. The battle at Morgarten falls into the first cold phase of the 'Little Ice Age' (which lasted until about AD 1850; Büntgen and Hellmann, 2014). A distinct cold phase controlled Europe from about AD 1300–1400 (Pages 2k Consortium, 2013). As a consequence of the cooler climate, larger fens and also some additional temporary small pools have to be expected in the region of interest.

'Modern' age. The small lake close to site 6 disappeared during the 15th to the 17th century. Also, the Aegeri lake seemed to shrink slightly and reached a surface level of about 725 m a.s.l. In 1857, the lake level was decreased artificially for energy purposes needed because of increasing industrialisation (Morosoli, 2003).

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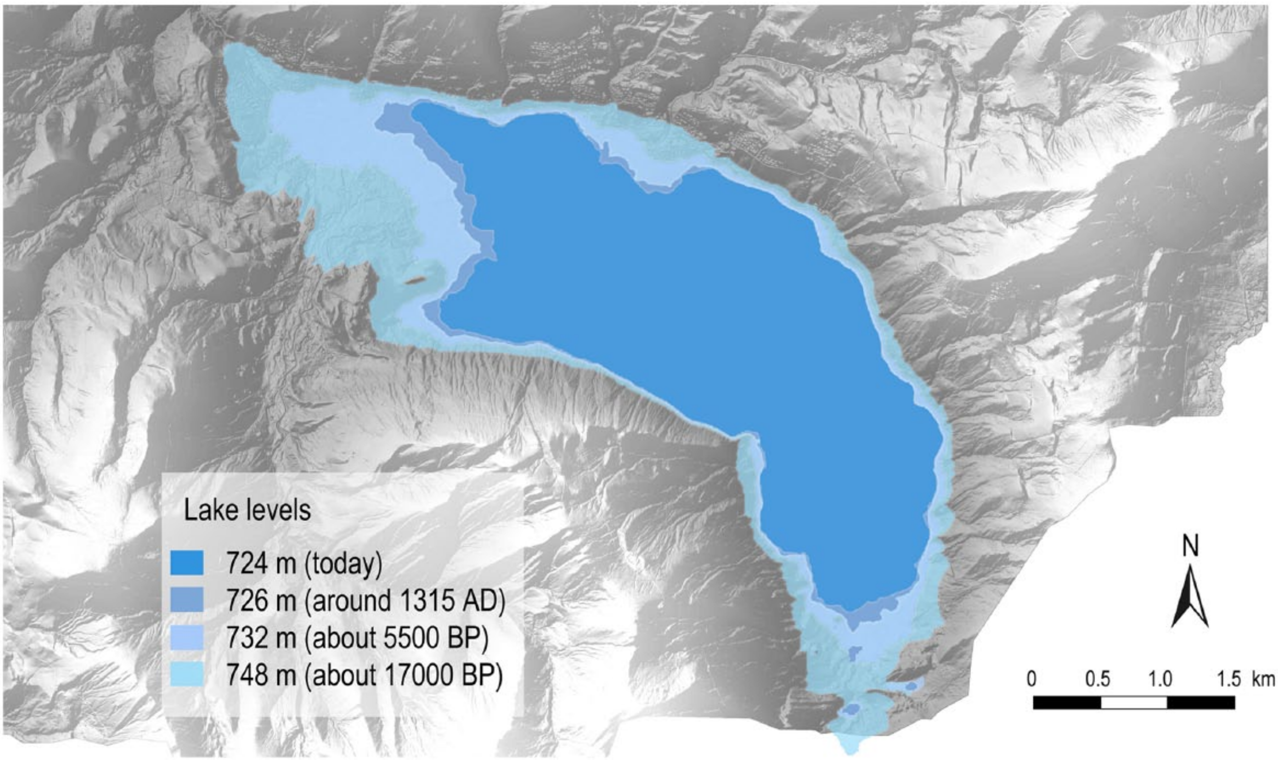

Figure 8. Modelled spatial extension of the Aegeri lake since the Lateglacial. The lake surface was digitised (using the LIDAR-based digital elevation model) based field evidences (terraces; ^{14}C dating) and, at the north-western end, adjusted to the damming moraines (for the oldest level). Reproduced by permission of swisstopo (BA15043).

This lake level decrease is indeed noted in the Dufour maps before and after the year 1857.

Conclusion

The chosen multi-methodological (using numerical, semi-quantitative and relative dating techniques) approach shed light on the landscape evolution of the Aegeri valley and in particular on the lake level at the time of the battle at Morgarten. The results obtained from peat bog dating, geomorphic mapping, geoelectric measurements, soil map evaluation and archaeological findings were pieced together like a puzzle. The spatial distribution of the most developed soils to delineate the timing of lake level position, dating of the start of mire formation (as an indication of complete lake sedimentation) and archaeological findings give astonishingly congruent results.

During its whole history, the lake surface showed several quite distinct changes (with a dramatic variation in the Lateglacial; probably because of an earthquake and a subsequent rupture of the moraine-dam). Even during the Holocene, the lake surface varied considerably (with a higher lake level of about 8 m c. 5500 BP). The trigger mechanisms of the lake level fluctuations during the Holocene are not really known. The effluent river 'Lorze' (and subsequently also the lake Aegeri) was probably dammed several times by material deposited by a side-influent (Hüri river) that joins the Lorze (at about 100–200 m distance to the lake). At the time of the battle at Morgarten, the lake level was most likely 2 up to a maximum of 3 m higher than today, that is, at an altitude of about 726 up to 727 m a.s.l. We therefore refute Sidler's (1910) hypothesis that the lake level was about 6 m higher than today. The vehement opponent of Padre Sidler, Dr Hürlimann, seems to be right in this respect: the extension of the lake was not distinctly greater. Padre Sidler was, however, not wrong in all points. In the surroundings of the Aegeri lake, the existence of several small lakes or pools was manifested. These pools probably did not have as large an extension as Sidler (1910) reckoned. In addition, the area covered by fens must have been larger than at present. Together with the cooler climate, the greater extension of the fens and slightly larger lake, the valley floor and side valleys were simply wet and unpleasant (Figure 8). If a Habsburg army had to cross this region in the year 1315, they certainly would have preferred to take a route that was not completely wet and marshy. In theory, it would have been possible to walk or ride across the valley floor – but with great difficulty. It therefore seems to be quite logical that the army would have preferred a dry and more accessible route along the footslopes. However, with our investigation, we are not able to determine the exact location of the battle (also during the drilling campaigns we did not find any relicts of this battle). As mentioned, paintings show how the Habsburgs were attacked by the Swiss at the foot of steep slopes and that several warriors drowned in a nearby lake. Unfortunately, really steep slopes are lacking along the shoreline of the Aegeri lake. Some small lakes or pools seem to have existed close to the steep slopes. But it is questionable whether warriors really drowned there. As a consequence, room for speculation still exists and the myth of the Morgarten battle remains unresolved.

Nonetheless, precise landscape reconstruction provides a fundamental input for historical research and helps to check existing or establish new hypotheses.

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