10 The Karst System Siebenhengste-Hohgant-Schrattenfluh

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Abstract

The karst region Siebenhengste-Hohgant-Schrattenfluh is located in west-central Switzerland, north of Lake Thun. Although it is not well known outside the karst and caving community, it is one of the important karstic sites of the world. Surface landscape is impressive, with vast karren fields with distinct micromorphologies, stark contrast of sandstone and limestone pavements and the impressive view on the high Bernese Alps. The underground landscape is rich as well, with more than 340 km of cave passages developed below three adjacent massifs. Caves evolved in response to valley deepening processes, which could be dated by cave sediments. Soft tourism (hiking, walking) developed in the last two decades, and protected zones have multiplied in recent years.

Keywords

Karst landscape • Cave system • Speleogenesis • Dating methods

10.1 Introduction

The karstic area of Siebenhengste-Hohgant-Schrattenfluh lies in the Prealps of western central Switzerland, north of Lake Thun and Interlaken (47°N, 8°E; Fig. 10.1). It extends from the spring area at Lake Thun, at 558 m a.s.l., up to the summits of Hohgant, at 2197 m a.s.l. When looking at the area from a plane or with Google Earth, it is not typically karstic at first sight, since only the karren fields of Siebenhengste and Schrattenfluh are bare. However, below the green landscape, covered by non-carbonate rocks, the limestone is also karstified. The area is of prime interest because of the vast and spectacular karren fields of Siebenhengste and Schrattenfluh, and of the many different microkarren forms of Innerbergli (Hohgant). The underground cave network is one of the largest in the world. The Réseau Siebenhengste-Hohgant has a length of 160 km, ranging over a vertical extent of 1340 m, and altogether, the area up to Schrattenfluh comprises more than 340 km of cave passages.

The paper presents a short overview of the karren fields and karren forms that are found in the area, and gives hints for further research in that domain. The cave network morphology and sediments contain archives of useful information about the past landforms and climate conditions. Cave morphology makes possible to infer speleogenetical phases, and sediments provide dates to establish the timing of landscape-forming processes of this region. Such information is generally lost outside of caves because of glacial and/or river erosion as well as vegetation overgrowth.

10.2 Geographical, Geological and Hydrogeological Setting

10.2.1 Geography and Climate

The mountain range belongs to the frontal alpine range (Helvetic Prealps), forming the first alpine rocks facing the Swiss Plateau. Most of the area belongs to the southeast-dipping limb of an anticline. Its northwestern limit is formed by high cliffs (Fig. 10.2). Elevations of the summits located along the cliffs range between 1950 and 2197 m a.s.l. Denuded karren fields occur above 1700 m a.s.l., in the area where limestone is exposed. Below, sandstone mainly crops out; therefore, the area is mainly covered by forest, meadows and swamps. The climate is humid and temperate, dominated by western winds. The average annual temperature is about 2 °C at 1700 m a.s.l., and annual precipitation ranges between 1500 and 2000 mm.

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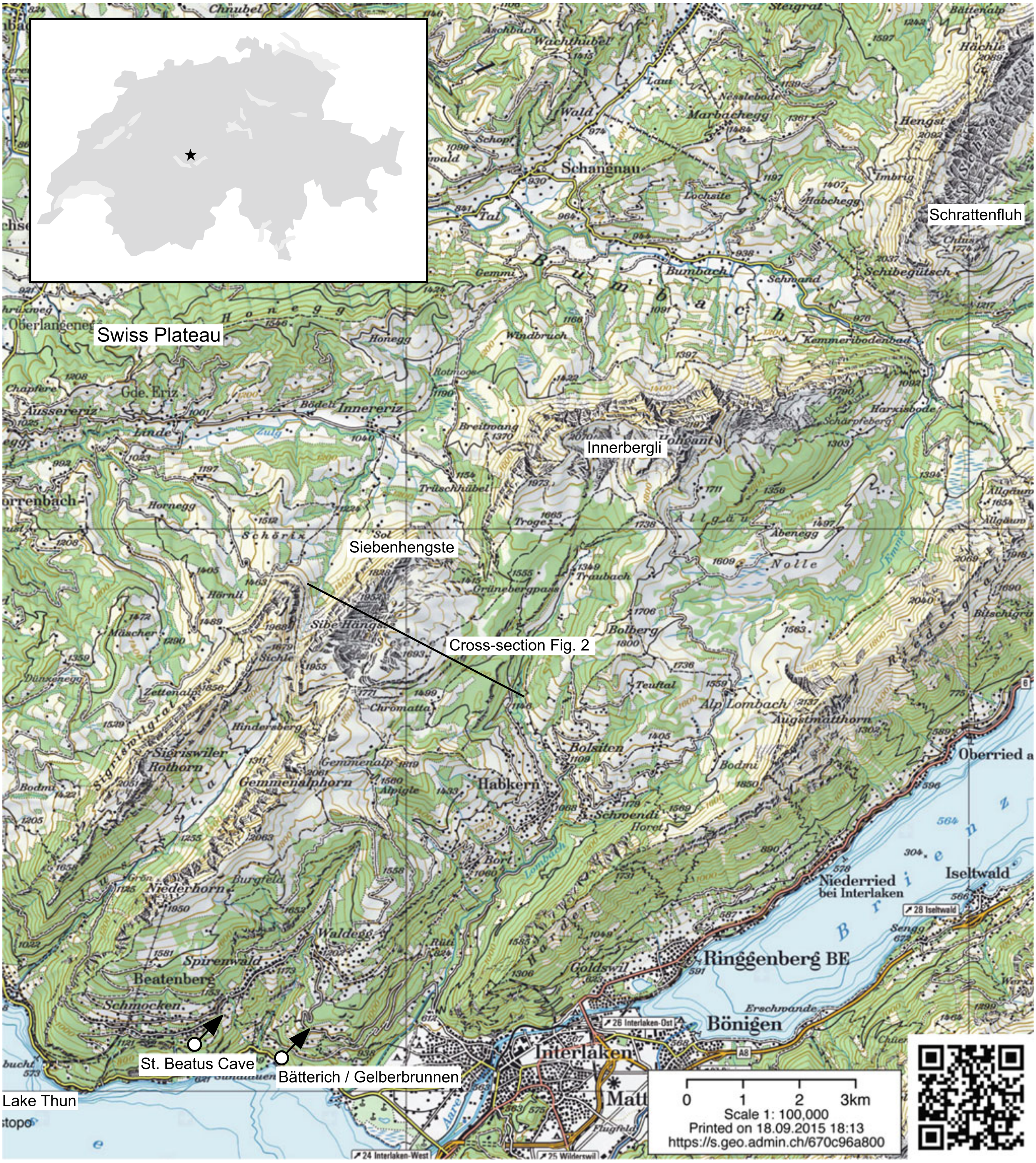

Fig. 10.1 Map of the Helvetic Prealps between Lake Thun and Schrattenfluh (swisstopo)

10.2.2 Geology

Karst features are developed predominantly within the Schrattenkalk Formation (Barremian to Aptian, Cretaceous, Urgonian facies), which is 150–340 m thick (Fig. 10.2). It is underlain by the Drusberg marls (Lower Barremian). These marls are 30 to 50 m thick. Most of the underground rivers are located at the bottom of the limestone, and follow the dip on top of the impervious Drusberg marls, often along main faults (Jeannin 1989). The Hohgant Formation (Eocene),

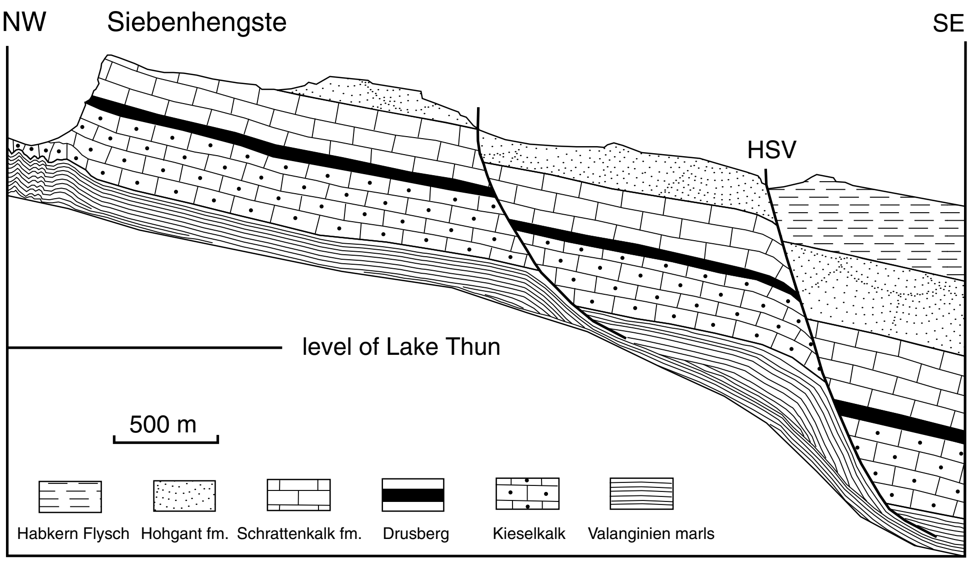

Fig. 10.2 Geological cross-section across the Siebenhengste. The monocline and the normal faults are easily visible. HSV is the Hohgant-Sundlauenen fault. The geology is as follows: Habkern Flysch, of mixed lithology (limestone, sandstone, marl) and age (Cretaceous to Oligocene); Hohgant formation, of mixed lithology (sandstones to subordinate pure limestone), of Eocene age; Schrattenkalk formation, pure limestone of Middle Cretaceous age; Drusberg marls, Lower Cretaceous, Kieselkalk formation, siliceous limestone, Lower Cretaceous, Valanginien marls, Lower Cretaceous

which is locally more than 200 m thick, overlies the Schrattenkalk Formation (Fig. 10.2). The Hohgant Formation is not a singular uniform sandstone body, but comprises rock sequences deposited in several cycles starting with limy sandstone and ending with purely quartzitic sandstone (Breitschmid 1976). Locally, bioherms of pure lithothamnia limestone are found. Therefore, parts of the Hohgant formation may be well karstified and contain caves. In most of the region, faults enable surface waters to eventually flow through the sandstones down into the Urgonian limestones. The Hohgant Formation is covered by Globigerina marls, upon which thick flysch deposits of the Pennine Nappes are overthrusted. Both marls and flysch are impervious.

An important normal fault, stretching from Lake Thun to Schrattenfluh (the Hohgant-Sundlauenen Fault HSV), disrupts the continuity of the southeastward dipping monocline of the Siebenhengste range (Fig. 10.2). The offset of the fault is 200–1000 m, depending on the location. Several subparallel normal faults are also present. The normal faults in the Siebenhengste region mainly developed during the Lower Cretaceous to the Eocene.

10.2.3 Hydrogeology

The hydrogeology of the area is somehow complicated, because surface rivers (flowing on flysch and sandstone) and underground karst rivers are interwoven. Much of the region is drained by underground karst systems emerging at two main locations: the St. Beatus spring and the Bätterich/Gelberbrunnen springs.

The St. Beatus spring with a discharge ranging between 10 l/s and 2–3 m^3/s (average 72 l/s) has a catchment area of about 10.5 km^2 that lies in the southeast part of the region (Häuselmann et al. 2004). The Bätterich/Gelberbrunnen spring catchment extends at least 21 km to the northeast, reaching the Schrattenfluh massif, as proven by a tracing experiment (Fig. 10.3). As the main spring (Bätterich) lies below Lake Thun, the discharge of the system is very difficult to measure. It probably exceeds 20 m^3/s during floods. The catchment area of the Bätterich/Gelberbrunnen system is around 32 km^2 and is largely covered by sandstone where surface flow may occur locally. Recharge rates are therefore difficult to assess.

10.3 Landforms and Landscapes

10.3.1 General Overview of the Landscape

The karst area of Siebenhengste-Hohgant-Schrattenfluh is not the largest in size of Switzerland. However, the moderate altitude (less frost weathering compared to high-alpine karren fields), the very pure limestone and the gently sloping monocline are the reasons why beautiful karren fields formed. The photographs of Schrattenfluh (Fig. 10.4) show the vastness and the desert-like appearance of the landscape. The Siebenhengste, albeit smaller, occurs in the same

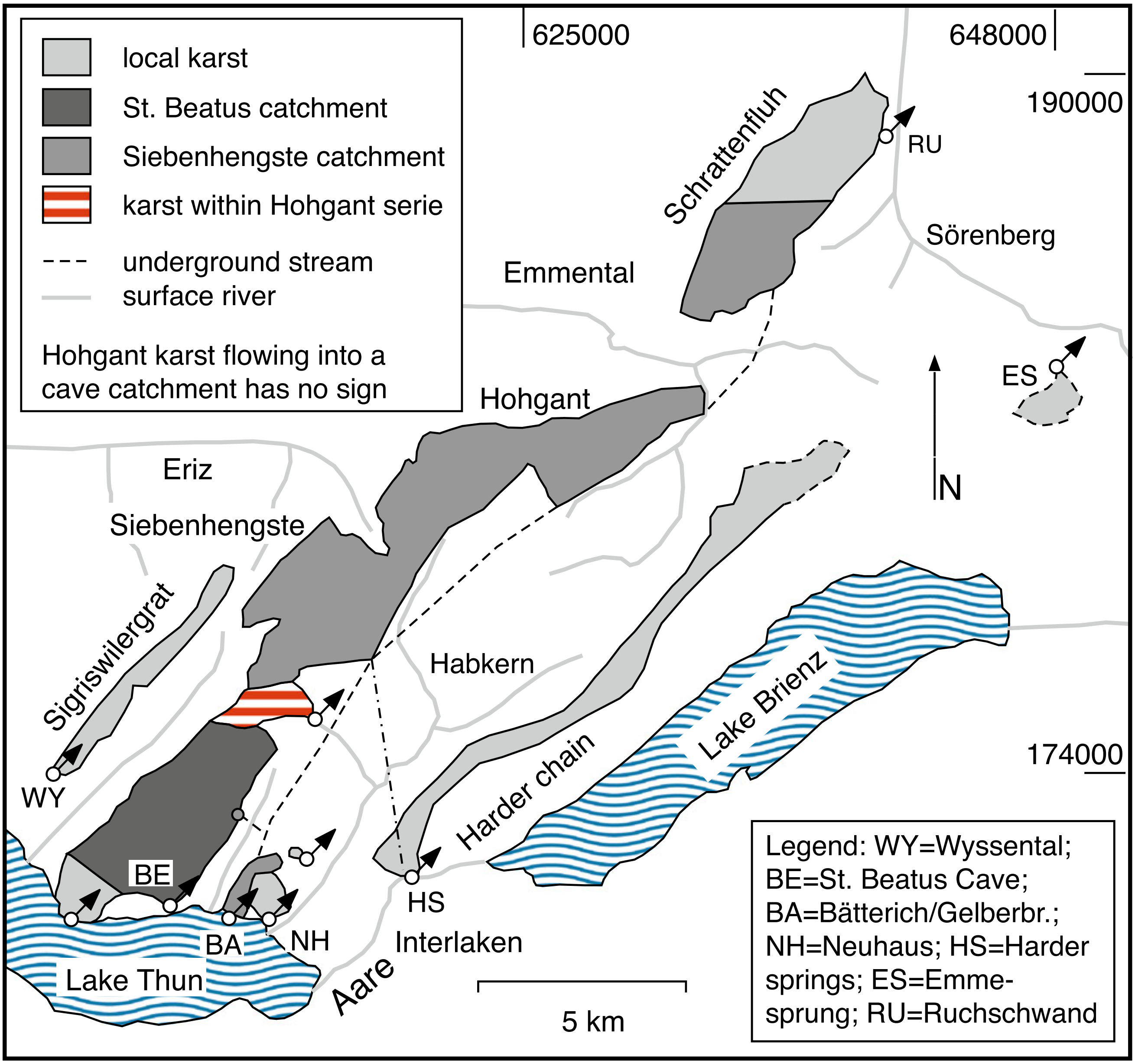

Fig. 10.3 Catchment areas of the wider region. The most important catchment is the one of Siebenhengste-Hohgant-Schrattenfluh, followed by the one of Beatus Cave. All other catchment areas are much less known. The link of Harder Springs to the Siebenhengste catchment was proved in a 1959 dye tracing experiment that never could be repeated

setting. In Siebenhengste, *Schichttreppenkarst* and *Schichtrippenkarst* (following Bögli 1964) prove the passage of ancient glaciers (Fig. 10.5a). Both forms result from the glacial scraping off of single limestone beds along bedding planes. If the remaining beds are towards the mountain top, the morphology looks like steps, so it is called Schichttreppenkarst; if the remaining beds are towards the mountain base, they are called Schichtrippenkarst. *Spitzkarren* (Fig. 10.5b), on the other hand, could only develop in areas, which were not covered by the main glaciers of the last glaciation; otherwise, they would have been destroyed by the glacier. Therefore, the summit area of Siebenhengste with Spitzkarren was a nunatak during the Last Glacial Maximum (LGM; Schlüchter 2009).

The karren fields are bordered by Hohgant sandstones. The more or less impervious character of these rocks, together with a significant part of low-solubility material, enhancing soil generation, explains why most of the sandstone areas are grassy, swampy, and in lower areas, forested (Fig. 10.6). Much of the waters collected in the sandstone area eventually disappears underground (Fig. 10.7) and joins the main karst body. Especially in the border between

Fig. 10.4 Schrattenfluh karren field. **a** The northern part of the Schrattenfluh is more rugged and partially overgrown by vegetation; **b** The middle part of the karren field is homogenous. With respect to the Siebenhengste, it is more steeply inclined (photos R. Wenger)

limestone and sandstone, many brooks emerge from the sandstone and disappear underground when reaching the limestone. In Innerbergli karren field, ancient ponors (visible as shafts) are prominently seen along a line from the present stream course towards the karren field (Fig. 10.8). This shows that the karren field in limestone was gradually exposed, and not uncovered at once by a glacier scraping off the sandstone cover. This does not exclude (partial) erosion from a glacier per se; the general topography of the karren field and adjacent areas reveal the presence of typical glacial forms such as *roches moutonnées* (Fig. 10.9) and glacio-karstic forms such as *Schichttreppenkarst*. Most of these forms are probably related to the geomorphic action of local glaciers.

Fig. 10.5 **a** *Schichtrippenkarst* in the sense of Bögli (1964) is proof of an ancient glaciation; **b** *Spitzkarren* on the summit of Siebenhengste. Such acicular structures could not have survived the last glaciation. The largest Spitzkarren reach almost one metre in height (photos Association française de karstologie)

10.3.2 Influence of Glaciations

Franz Knuchel tried, already back in the 1960s, to quantify surface corrosion at the Siebenhengste karren field (Fig. 10.10). Taking into account corroded limestone, present-day precipitation and corrosion rates, he concluded that the last glaciation terminated 14,500 years ago—a value that was confirmed by Quaternary scientists only much later (Schlüchter and Kelly 2000). Unfortunately, Knuchel never published these results.

Fig. 10.6 Area covered with sandstone (wet, partially swampy, vegetated and forested) No traces of karstification are seen on the first sight, but the brook in the picture disappears underground 30 m further (photo P. Häuselmann)

Fig. 10.7 A ponor within the sandstone area where a river disappears underground. It will only reappear at an elevation 1000 m lower, at Lake Thun (photo D. Sanz)

Knuchel, as well as a Belgian caver, André Minet (1970), found granite pebbles in the SW of Siebenhengste, near Wagenmoos, at an altitude of 1700 m a.s.l. Since it is assumed that the Aare glacier during LGM did not rise above 1400 m a.s.l. in this region (Schlüchter 2009), these pebbles are supposed to come from previous glaciations, as also proven by findings in caves by Jeannin (1991). A detailed analysis of these (and other) pebbles by Gnägi and Schlüchter (2012) showed not only that they really are of glacial origin, but that they have their source area in the southern side of the Upper Valais area! Thus, these pebbles travelled across one of the present-day deep troughs, crossed the second most important alpine ridge, crossed again the present-day Lake Thun area, and finally were deposited in the Siebenhengste! Dating of such pebbles with cosmogenic nuclides, found in A201 cave (Siebenhengste), revealed an age of 1.87 $\pm$ 0.21 Ma (Häuselmann et al. 2007). This gives the minimum age of deposition in the area. The first glaciations seem therefore to present S-N ice-flow directions, which are completely disconnected from the present-day valleys direction with a W-WNW trend. These old pebbles were conserved on Siebenhengste because of the presence of efficient traps in the karst system, and to a lower degree of mechanical erosion at the surface than in non-karstic massifs.

10.3.3 Micromorphology of Karren Fields

Although all karren fields in the area present beautiful examples of karren forms, the Innerbergli karren field is distinctive, because almost all morphologies (with the exception of *Spitzkarren*) are found within a short distance (Bitterli and Häuselmann 2010). As in most parts of the other karren fields, all the micromorphologies present in Innerbergli had been chiselled out since the last glaciation. Only larger karst features, such as shaft entrances, could be conserved after the erosion related to local glaciers. Research on dissolution around letters/numbers painted by cavers 30 to 40 years ago evidenced a corrosion rate of 0.014 mm/a, which is in good agreement with other sites worldwide (Häuselmann 2008).

As in many alpine karren fields, *rillen-* and *rinnenkarren* are well developed in the region (Fig. 10.11), especially in Innerbergli. *Mäanderkarren*, *hohlkarren*, grikes, *flachkarren*, and *trittkarren* are also present. So far, the Innerbergli karren field was only researched by Franz Knuchel, trying to decipher the influence of karstification since the last glaciation, but due to the well-developed forms, the clear geomorphologic context, the easy access and the good knowledge on climate conditions, future research projects on karren genesis are in discussion.

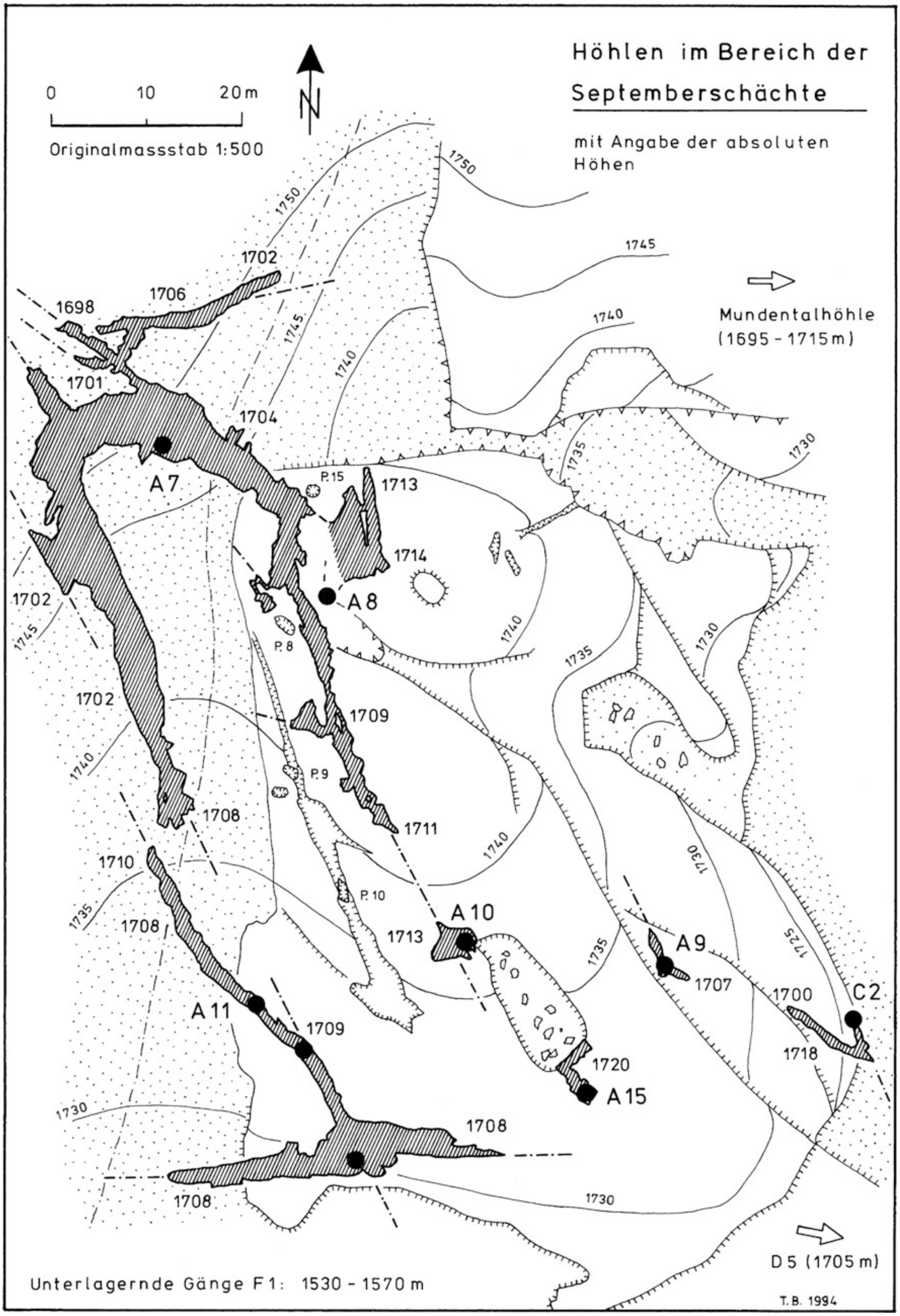

Fig. 10.8 Plot of the entrances of Septemberschächte in Innerbergli. The shafts A7, A8, P9, P10, A10 and A15 are thought to be progressively older ponors proving a backweathering of the sandstone covering the karren field. Dotted areas: limestone overgrown with vegetation; white: limestone at the surface; grey: underground passages

Fig. 10.9 View to a sort of a "*roche moutonnée*" in Innerbergli karren field. Although not very typical, the position and shape of the limestone hump tells that it was remodelled by a glacier (photo C. Prenez)

10.3.4 Tourism Impacts

The karren fields, although spectacular, are not necessarily of major interest for an average tourist. Furthermore, the area was spared from the big ski development, experienced by the destinations south of Interlaken (Grindelwald, Lauterbrunnen)—the village of Habkern has only one single ski lift. In recent years, tourism promoters discovered that the region is suitable for cross-country skiing and hiking, and they deliberately decided to develop soft tourism. However, the area comprises many wetlands in the flysch- and sandstone-covered areas. Therefore, in parallel to growing tourism, vast areas of wetlands and many forested areas were set aside for either undisturbed development or wildlife

Fig. 10.10 Franz Knuchel measuring corrosion activity on the Siebenhengste karren field. He was a precursor of the present-day scientists working in the area (photo taken by unknown person)

refuge. This protection of the landscape has already led to restrictions for accessing some caves.

10.3.5 The Underground Landscape

The word "landscape" refers to the visible features of an area. Nevertheless, caves are part of the territory, which can be visited, described and interpreted by humans in a similar way to landscapes at the surface. The underground landscape of Siebenhengste is mainly characterised by two types of cave passages: meanders (high and narrow canyons) and tube passages (cave passage with an elliptical cross-section). The size of canyons typically ranges between 0.4 and 4 m in width and between 2 and 40 m in height. The size of tubes is rarely larger than 5–7 m in diameter. The minimal size of cave passages is mainly given by the size a person can penetrate (about 0.5 m). Sometimes both profiles are combined, forming a key-hole cross-section (tube entrenched by a canyon). Along the contact with Drusberg marls, the entrenchment of the marls, which are mechanically less stable than limestones, often formed larger "square" passages ("*Kastenprofil*") and sometimes even rooms. Their size typically ranges between 5 and 50 m in width and/or height. Another typical feature are shafts (vertical passages) with diameters ranging between 1 and 50 m and depths between 5 and 180 m in the Siebenhengste region. All these types of cave passages can be more or less filled with sediments, decorated with speleothems, and can be traversed by flowing water or being fossil since millions of years, leading to a large variety of underground landscapes.

The cave region between Lake Thun and Schrattenfluh encloses four main massifs: Niederhorn, Siebenhengste, Hohgant and Schrattenfluh. With 160 km, the longest cave system is the Réseau Siebenhengste-Hohgant, which combines the two central massifs and reaches down to the level of Lake Thun, with 1340 m total height difference. Figure 10.12 displays all the caves of the area between Niederhorn and Hohgant, summing up a total length of 340 km. Caves of the Schrattenfluh massif are less extended, summing up about 30 km, but further discoveries may change the picture.

Such a vast cave system was not carved out of the rock in a single event. The morphological analysis of cave passages gives us hints to discover the genetic phases. If the water can circulate freely in the rock (i.e. without geological constraints, such as folds or faults), it flows vertically downwards until reaching the water table or the bottom of the aquifer (the top of the Drusberg marls in the Siebenhengste region). In this latter situation, water then follows the top of the marls down-dip until it reaches the water table. Then, it flows more or less horizontally towards the spring along the most karstifiable way, which is often a bedding plane. The elevation of the spring is generally close to the valley bottom (Häuselmann et al. 2003), and the spring itself defines the height of the water table inside the karstified massif. Therefore, elevations of ancient karst water tables (thus of ancient valley bottoms) are seen in the morphology of cave passages. A careful interpretation of the "underground landscape" thus directly tells us about the evolution of the landscape above ground (Häuselmann et al. 2002). In Siebenhengste cave system, 14 speleogenetic phases were identified so far. During the first, oldest and uppermost five phases the system had their spring in Eriz Valley (Fig. 10.13). At that time the Aare Valley did obviously not exist, as also proved by the exotic pebbles found by Gnägi and Schlüchter (2012) (see above). In the following nine phases underground flows were directed towards the area of present Lake Thun in the Aare Valley.

Such a complete information is no more available at the surface due to glacial erosion. However, caves enclose even more information: they contain speleothems and other sediments which can be dated. The most common dating methods are U/Th on speleothems (range up to 500 ka), and concentrations of cosmogenic nuclides on quartz (range up to 5 Ma). Both techniques were applied in the Siebenhengste area, providing ages of the respective phases, i.e. of the valley incision rate, as well as on the presence or absence of glaciers at a given time (Häuselmann et al. 2007, 2008). Such a complete reconstruction makes the Siebenhengste massif to be a renowned example among karst scientists and geomorphologists.

Discrepancies between the generally accepted model of cave genesis, the Four State Model of Ford and Ewers (1978), and observations in Siebenhengste caves and in

Fig. 10.11 **a** *Rinnenkarren* on a steep fault line in Innerbergli; **b** *Rillenkarren* "mountains" are very typical of many alpine karren fields, but in Innerbergli they are very spectacular (photos C. Prenez)

other alpine cave systems, led to the formulation of another speleogenetic model. This new model postulates that horizontality (or undulation) of the cave is related to uniform (or contrasting) recharge (Gabrovsek et al. 2014). This shows the possibility that the geometry of the cave system gives hints to paleoclimatic conditions: constant rain would give rather horizontal passages, contrasting climate would yield undulating passages. In any case, paleoclimatic research is

Fig. 10.11 (continued)

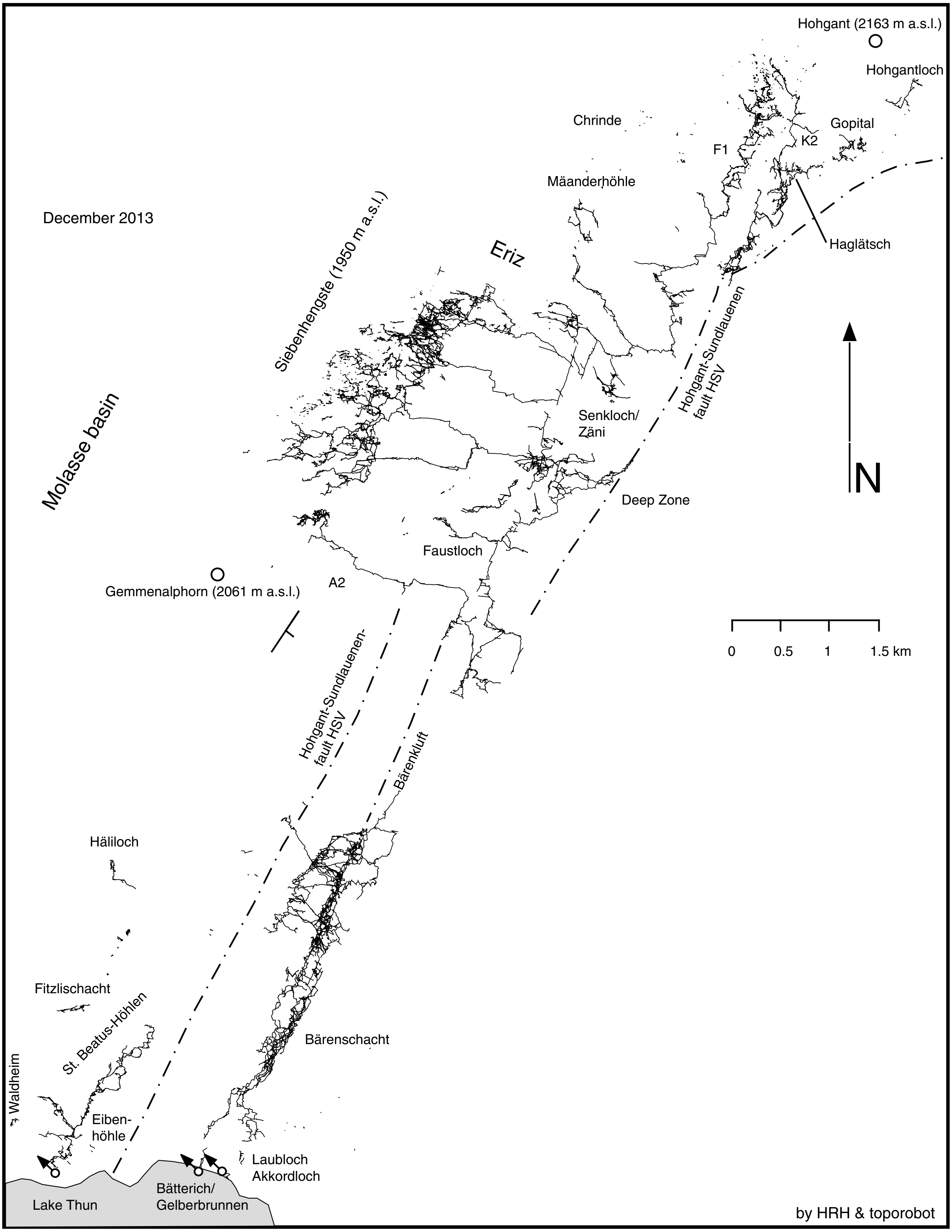

Fig. 10.12 Overview of the caves between Lake Thun and Hohgant. The density of caves is impressive

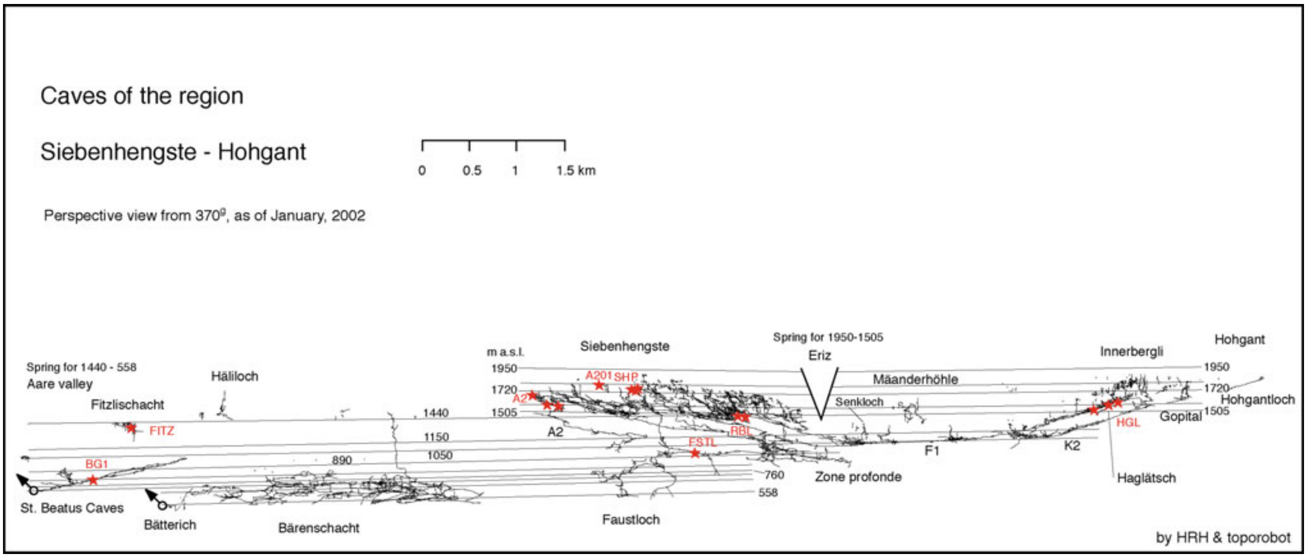

Fig. 10.13 Projection (370^{gr}) of the Siebenhengste caves. The lines represent speleogenetic phases related to ancient springs (and thus to paleovalley bottoms). Note that the altitude indicated is present-day altitude, not taking into account recent uplift of the Alps

going on (Luetscher et al. 2015), and still, there is a lot to be done with classical analysis of sediments and speleothems in order to investigate paleoclimatic conditions.

10.4 Conclusions

Karst areas are interesting regions for the study of landforms, landscape, landscape evolution and palaeoenvironments. The Siebenhengste region shows interesting karren forms, indicators of ancient glaciations, indicators of landscape evolution as well as palaeoclimate. Such a rich information about the last 2 to 5 millions of years of alpine history can almost only be found in karst regions because erosion removed most comparable indicators elsewhere. Caves are natural archives, which are not always easy to study and to decipher, but which often produce rewarding results.

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References

Bitterli T, Häuselmann P (2010) Die Höhlen des Innerberglis. Höhlenforschung im Gebiet Siebenhengste-Hohgant Nr. 8, Speleo Projects, Allschwil, 440 pp

Bögli A (1964) Le Schichttreppenkarst. Revue Belge de Géographie 88:63–81

Breitschmid A (1976) Geologie im Gebiet des Gemmenalphorns. Unpublished diploma thesis, University of Bern

Ford DC, Ewers RO (1978) The development of limestone cave systems in the dimensions of length and depth. Can J Earth Sci 15:1783–1798

Gabrovsek F, Häuselmann P, Audra P (2014) "Looping caves" versus "watertable caves": The role of base-level changes and recharge variations in cave development. Geomorphology 204:683–691

Gnägi C, Schlüchter C (2012) High-altitude erratics in the Bernese Alps (Switzerland). Swiss J Geosci 105(3):401–415

Häuselmann P, Jeannin PY, Monbaron M, Lauritzen SE (2002) Reconstruction of Alpine Cenozoic paleorelief through the analysis of caves at Siebenhengste (BE, Switzerland). Geodin Acta 15:261–276

Häuselmann P, Jeannin PY, Monbaron M (2003) Role of epiphreatic flow and soutirages in conduit morphogenesis: the Bärenschacht example (BE, Switzerland). Zeitschrift für Geomorphologie N.F. 47 (2):171–190

Häuselmann P, Bitterli T, Höchli B (2004) Die St. Beatushöhlen: Entstehung, Geschichte, Erforschung. Höhlenforschung im Gebiet Siebenhengste-Hohgant Nr. 7, Speleo Projects, Allschwil, 256 pp

Häuselmann P, Granger DE, Lauritzen SE, Jeannin PY (2007) Abrupt glacial valley incision at 0.8 Ma dated from cave deposits in Switzerland. Geology 35(2):143–146

Häuselmann P, Lauritzen SE, Jeannin PY, Monbaron M (2008) Glacier advances during the last 400 ka as evidenced in St. Beatus Cave (BE, Switzerland). Quatern Int 189:173–189

Häuselmann P (2008) Surface corrosion of an Alpine karren field: recent measures at Innerbergli (Siebenhengste, Switzerland). Int. Journal of Speleology 37(2):107–111

Jeannin PY (1989) Etude géologique de la région Burst-Sieben Hengste. Unpublished diploma thesis, University of Neuchâtel

Jeannin PY (1991) Mise en évidence d'importantes glaciations anciennes par l'étude des remplissages karstiques du Réseau des Siebenhengste (chaîne bordière helvétique). Eclogae Geol Helv 84 (1):207–221

Luetscher M, Boch R, Sodemann H, Spötl C, Cheng H, Edwards RL, Frisia S, Hof F, Müller W (2015) North Atlantic storm track changes during the Last Glacial Maximum recorded by Alpine speleothems. Nat Commun 6:6344. https://doi.org/10.1038/ncomms7344

Minet A (1970) Etude préliminaire de la région des Siebenhengste (Eriz, BE). In: Actes du 4e Congrès national de spéléologie, pp 35-47

Schlüchter C (compil) (2009) Die Schweiz während des letzteiszeitlichen Maximums (LGM), 1:500 000. GeoKarten 500. Bundesamt für Landestopografie swisstopo, Wabern

Schlüchter C, Kelly M (2000) Das Eiszeitalter in der Schweiz. Publikation des Geologisches Instituts der Universität Bern, Bern, 4 pp

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