The Aletsch Region with the Majestic Grosser Aletschgletscher

14

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Abstract

The Aletsch region is situated in the UNESCO World Heritage Swiss Alps Jungfrau-Aletsch and must be reckoned with right to the classic and splendid high-mountain regions in the world. The region stretches from the rocky steppes with a Mediterranean character to the glaciers. It is a perfect example of the mountain and glacier's formation. The basement of the region was formed by orogenic processes in the last approximately 500 million years. During the Ice Ages, the glaciers gave the shape of the contemporary landscape with characteristic forms, for example *roches moutonnées* and moraine deposits. Permafrost, frost weathering and rock mass movements are well presented and designed the landscape too. This rich diversity of glacial landscapes is a perfect example of the actual climatic change and geomorphological processes in high-mountain regions. The famous *Grosser Aletschgletscher*—the largest and longest glacier of the Alps—with the three world-famous peaks of Eiger, Mönch and Jungfrau in the catchment lies in the core of the World Heritage site. Its history is well documented over the last 3500 years. The once famous *Märjelensee*, an ice-dammed lake at the edge of the Grosser Aletschgletscher, has shrunk as the glacier is retreating dramatically since the end of the Little Ice Age around 1860.

Keywords

Bernese Alps • Aar massif • High-mountain geomorphology • Glaciers • Holocene glacier fluctuations • Glacial lake

14.1 Introduction

The Aletsch region (about 7°53'– 8°8'E/46°19'– 46°24'N) is enclosed in the water tower of Europe. It extends between Naters (678 m a.s.l.) and Fiesch (1049 m a.s.l.) in the Rhone River valley to the highest peaks, the Mittaghorn (3982 m a.s.l.), the Mönch (4107 m a.s.l.) and the Jungfrau (4158 m) in the north, where the Aletsch region is well developed with the Jungfrau Railway, built between 1896 and 1912 (Fig. 14.1). Up to 1,000,000 tourists drive up with this train every summer to the icy, splendid Jungfraujoch. From the south, the Aletsch region is well accessible via Blatten near Naters, Riederalp, Bettmeralp or Fiesch. Since 2001, the Aletsch region forms with the famous *Grosser Aletschgletscher* the heart of the UNESCO World Heritage Swiss Alps Jungfrau-Aletsch which covers 824 km^2 and contains a large part of the Bernese Alps.

A large part of the Aletsch region is located in the rain shadow of the Bernese Alps and the Pennine Alps. For this reason, in a relatively short distance, the annual rainfall rises from 737 mm in Brig in the south (697 m a.s.l.) to 3600 mm in the Jungfrau–Mittaghorn region in the north (3892–4158 m a.s.l.). The mean annual temperature is lowered along the same elevation profile from 8.5°C to –7.2°C. On the southern slopes this Alpine scenery is gradually transformed, via different altitudinal vegetation and climatic zones, from a sub-Mediterranean rocky steppe into a glacierised zone with arctic character. Only a narrow strip along the southern edge is a settlement and farming region. Further to the north, most of the Aletsch region is covered by glaciers. Due to the relatively dry conditions, the southern slopes of the Aletsch region need to be irrigated. Therefore miles of irrigation channels—called *Suonen*—had to be built along some steep slopes.

The following chapter contains a brief overview of the geological conditions in the Aletsch region, and the most important geological and geomorphological processes that have shaped actually the landscape are discussed in

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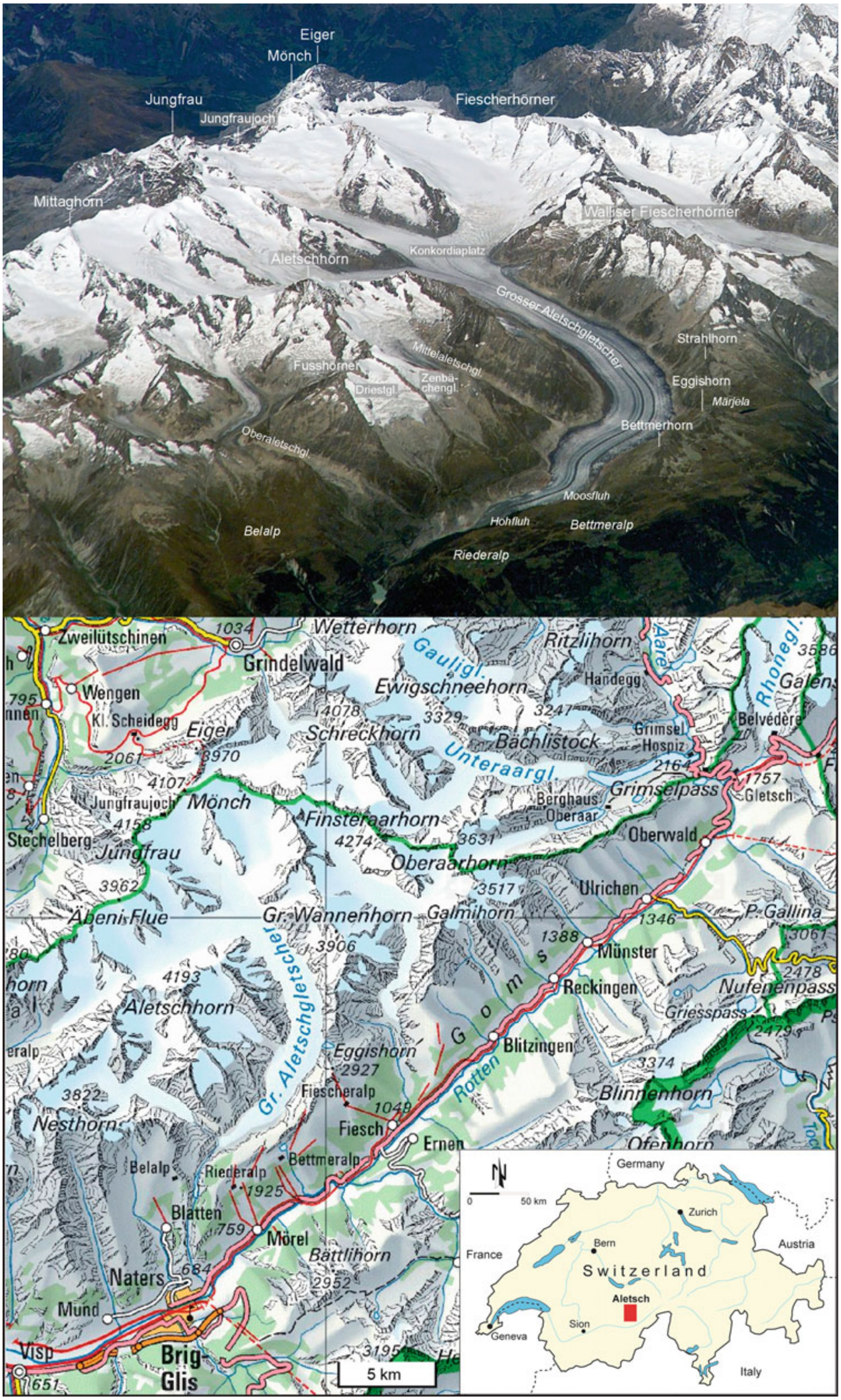

Fig. 14.1 The Aletsch region shown from space. The Grosser Aletschgletscher is clearly marked by dark medial moraines extending along the glacier's length parallel to the valley axis (photo: NASA, ISS013-E-77377, 5 September 2006; map: swisstopo)

Sect. 14.3. The major part of this contribution (Sects. 14.4–14.6) encompasses the Grosser Aletschgletscher as well as the Märjelensee (Sect. 14.7), once a piece of arctic jewellery in the Alps.

14.2 The Rock Basement of the Aletsch Region—Tectonic and Geological Overview

The Aletsch region passes from north to south across the Aar Massif, which in terms of geology is part of the European basement (Fig. 14.2). With a length of 115 km and a width of 35 km it is the largest Central Massif beside the Gotthard Massif eastwards and the Aiguilles Rouges/Arpille Massif and Mont Blanc Massif westwards. In the Mesozoic, the Aar Massif was the Helvetic and Ultrahelvetic depositional environment in the Tethys Sea that spread in the east of the supercontinent Pangea. More than half of the Aar Massif consists of gneiss and granite and owes its origin to two main orogeneses. The high-grade metamorphic gneisses and amphibolithes of the crystalline basement (*Altkristallin*) originated during the Caledonian orogeny about 450 million years ago. It occupies approximately 50 % of the Aar Massif. In the Carboniferous, about 300 million years ago, during the Variscan orogeny a tremendous amount of granitic magma invaded forming the Central Aare Granite (Labhart 2007). With a surface area of 550 km^2, the Central Aare Granite is the largest contiguous granite complex of the Swiss Alps. The contact with the crystalline basement (*Altkristallin*) is razor sharp and can be observed at various points in the Aletsch region (Fig. 14.3). During the Alpine orogeny at the beginning of the Tertiary when the African plate pushed against the European plate, the *Altkristallin* was raised and compressed. The sediments deposited on the northern edge of the Tethys were moved, slanted or folded. On the northern edge of the Aletsch region, a narrow band of the Mesozoic sedimentary cover (Autochtonous) is well visible and builds most of Wetterhorn and Eiger. Locally, for example at Jungfrau, it is embedded in the crystalline basement forming wedges (see Zumbühl et al., this volume). The north and south of the Central Aare Granite, enclosing the pre-Variscan crystalline basement, are referred to as northern and southern Gneiss Zone (Labhart 2007).

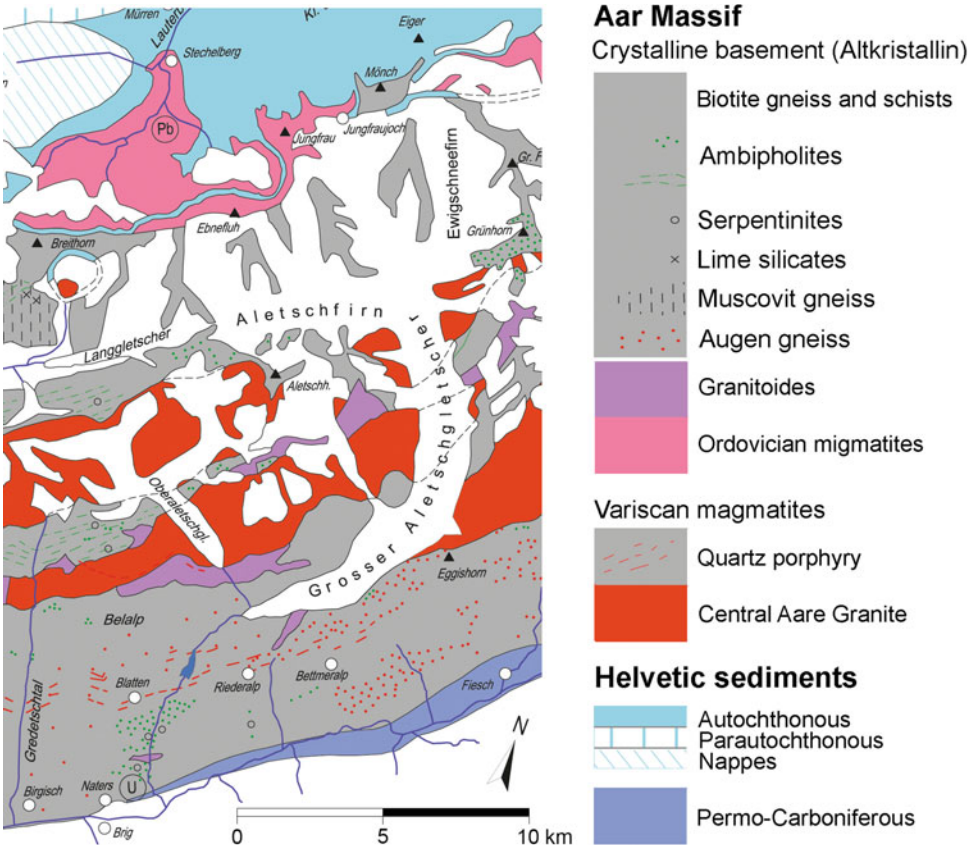

Fig. 14.2 Geological-tectonic map of the Aletsch region (modified after Labhart 2007)

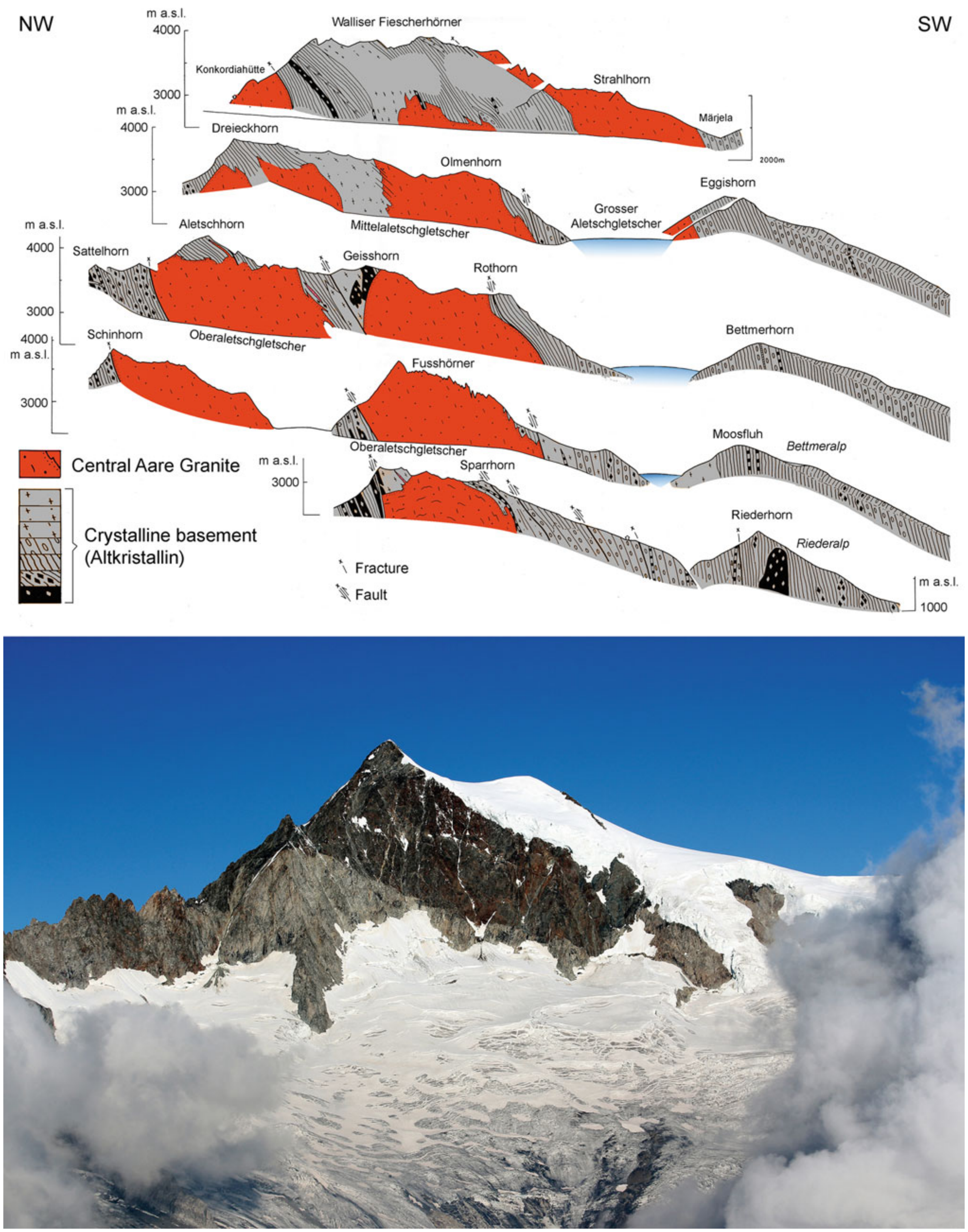

Fig. 14.3 Geological profiles and Aletschhorn (4193 m a.s.l.), the highest peak in the Aletsch region, view from Eggishorn. The dark and older crystalline basement (*Altkristallin*) lies above the younger Central Aare Granite (profile after Steck 1983; photo H. Holzhauser 2011)

14.3 The Ravages of Time Gnaws on the Rock Basement—Geomorphological Processes and Landforms

Within the last approximately 500 million years, geological processes formed the basement of the Aletsch region. The Ice Age glaciers gave it the present appearance, with characteristic surface forms. In the last 11,700 years, during the Holocene, the glaciers eroded and accumulated comparatively only in a small region and created the Little Ice Age moraine ramparts that are clearly visible in many places and limit the proglacial area. Geomorphological activities are observed today too, and increasingly due to the current global warming. They result in a complex interplay of different processes (glacial erosion and accumulation, frost weathering, gravitational movements, release of rocks due to shrinkage of glaciers and permafrost).

14.3.1 Faults and Rock Mass Movements

Various large and small fracture systems and faults that are considered mainly in the context of large-scale uplift and subsidence during the waning Alpine orogeny are visible within the Aletsch region (Fig. 14.4a; Steck 1968). The schists of the crystalline basement in the Aletsch region generally have a NW-SE strike and are slanted. Flexural toppling tilts the steeply to vertically stratified rock as a result of gravity (uphill-facing scarps, *Hakenwurf*, Fig. 14.4b).

Since the retreat of the Grosser Aletschgletscher after the Ice Age and also after the maximum Little Ice Age extent around 1860, the ice was lost as an abutment. Because of the geological and terrain conditions found at the slopes adjacent to the tongue of the Grosser Aletschgletscher, the steep slopes became unstable, and a number of slumps in the lateral moraines as well as rock mass movements (*Sackungen*, slope saggings) developed and are currently active. In addition, the rock once covered by the glacier is shattered by frost weathering what accelerated this process. A small sagging took place between 1966 and 1975 at the tongue of the Grosser Aletschgetscher near Tälli (Fig. 14.4c). First, smaller rock falls occurred and finally, the entire rock body dropped rapidly and was riddled with cracks and crevasses (Kasser et al. 1982). Since at least the 1970s, on the right side of the valley below Driest, a displacement of an unstable slope mass of about 450,000 m^2 moved downhill up to 20 cm/year (Kääb et al. 2000). By movement, unweathered bedrock was exposed as a bright stripe of about 250 m (Fig. 14.4c). A larger and still active slope movement formed after the melt back of the Grosser Aletschgletscher at the end of the last Ice Age at Moosfluh. The region is about 1.5 km wide and extends down to the maximum moraine rampart of 1860 from the Grosser Aletschgletscher. Between 1990 and 2008, horizontal movement of the rock mass in direction to the glacier amounted from 4 to 30 cm/year (Strozzi et al. 2010).

The instability on the right flank of the Moosfluh became active in autumn 2015. In 2016 and 2017, a strong acceleration of the landslide has been observed involving an estimated volume of 2.5 km^3. There were numerous cracks and rockfalls on some steep slopes. The rock movements were in the range of several centimetres and decimetres per day. In 2016, 2.5 million cubic metres of rock broke away in a single event (Kos et al. 2016).

14.3.2 Glacial Erosion and Glacial Deposits

Impressive is the environment shaped by the glacier. During the last Ice Age (called Würm in the Alps) the Grosser Aletschgletscher confluenced with the Rhonegletscher and only the highest peaks of the surrounding mountains projected above the ice. The maximum height of the Ice Age glaciation is clearly visible at the upper limit of the vertically sloping rock wall at Geissgrat, Zenbächenhorn and Rothorn, for example (Fig. 14.4d). The trimline is just below these vertical rock walls. Also the gently rounded ridge from Hohbalm below Bettmerhorn to Moosfluh and Riederfurka (Fig. 14.4e) and the depression of Märjela (see Sect. 14.7) are due to the landscape-shaping force of the ice. Numerous *roches moutonnées* were formed there by the glacier, at some place even crowds of *roches moutonnées* (*Rundhöckerflur*; Fig. 14.4f) occur.

Around 12,300 years ago, the Grosser Aletschgletscher advanced for the last time during the Lateglacial (Egesen advance during the Younger Dryas). Its tongue ended in Naters near Brig (Fig. 14.1). A moraine rampart from this former glacial extent is well preserved on the left slope of the Aletsch valley which stretches with interruptions below the Eggis- and Bettmerhorn to Riederfurka (*Moränenweg*, Fig. 14.4g). On the opposite side of the valley traces of this glacial extent can be seen at Alp Driest where the Driestgletscher confluenced with the Grosser Aletschgletscher (Fig. 14.4d).

14.3.3 Frost Weathering

Frost weathering is one of the most important processes of physical weathering in the high mountains and is strongly dependent on the nature of the rocks (lithology) and the weak zones (such as fractures, foliation surfaces). This ultimately determines the size and shape of weathering products. In the Aletsch region with schist-dominated


a
b
Sparrhorn
Driest
Tälli
M
M
c
Geissgrat
Zenbächenhorn
Rothorn
K
d
Moosfluh
e
f
Bettmerhorn
Eggishorn
g
Eggishorn
h

◀ **Fig. 14.4** Examples of geological and geomorphological landforms: **a** Faults at Belalp (arrows); **b** flexural toppling ("Hakenwurf", Moosfluh above Riederalp) in the crystalline basement; **c** slumps and rock mass movements (M) below Tälli and Driest. The black arrow indicates unweathered bedrock; **d** White arrows: Lateglacial moraine ramparts (Egesen advance, Younger Dryas, around 12,300 before present) from the Driestgletscher and former confluence with the Grosser Aletschgletscher (K). The dark arrow indicates the Little Ice Age moraine rampart. Dashed lines: Upper limit of glaciation during the Last Glacial Maximum (Würm); **e** Glacier shaped ridge between Bettmerhorn and Moosfluh; **f** Clusters of *roches moutonnées* at the Üssers Aletschji; **g** Lateglacial moraine rampart (arrows) from the Grosser Aletschgletscher (Egesen); **h** Frost weathering on Eggishorn (photos H. Holzhauser 2011)

Fig. 14.5 The Rock glacier "Grosses Gufer" (G) situated between Eggis- and Bettmerhorn (photo H. Holzhauser 2011)

crystalline basement it is well expressed. For example, the summit and the southern slope of Eggishorn referred to by the historian Mark Lutz in his book of 1827 disparaged as a "terrible heap of rubble" consists of pieces of laminated gneiss of the *Altkristallin* (Fig. 14.4h). The lower part of the northern face of Eggishorn, however, is composed of compact Central Aare Granite and mainly shows forms due to glacial processes.

14.3.4 Rock Glaciers

Rock glaciers are important indicators of permafrost in the high mountains and are located near the lower limit of discontinuous permafrost. Between Bettmer- and Eggishorn numerous rock glaciers have developed, some of which are still active. The largest rock glacier in the area is the *Grosses Gufer* (Fig. 14.5). It begins below Elselicka at 2600 m a.s.l. where the steep rock walls provide the material due to frost weathering over a distance of about 600 m. The volume was estimated at around 3 million m^3 in 1962 (Messerli and Zurbuchen 1968). The *Grosses Gufer* flows from there against the Grosser Aletschgletscher and its steep front ends today on the moraine rampart of 1860 about 2360 m a.s.l., where the trail leads to Märjela. The Lateglacial moraine rampart of the Younger Dryas (approximately. 12,300 years ago) was overran by this rock glacier long time ago. Initial studies in the 1960s showed that in 1950–1962 the rock glacier moved with the speed of 8–16 cm/year at the top and around 16–33 cm/year in the middle part. The highest flow velocities were measured in the front part, amounting to 58–75 cm/year (Messerli and Zurbuchen 1968). New measurements showed flow velocities of 30–100 cm/year since 2007/08 (Strozzi et al 2009; PERMOS 2013). In midsummer, crossing the *Grosses Gufer* allows hearing subterranean streams and in some places the melt water escapes from the rock glacier with icy cold temperatures of around 1°C. This water was captured in the sixteenth century (probably even earlier) and led in the irrigation channel "Riederfurka" to the pastures on Riederalp and Oberried (Holzhauser 1984).

14.4 The Famous Grosser Aletschgletscher—an Icy Superlative in the Alps

In his book *The glaciers of the Alps*, published in 1860, the Irish physicist and mountaineer John Tyndall (1820–1893) wrote: *"The Aletsch is the grandest glacier in the Alps: over it we now stood, while the bounding mountains poured vast feeders into the noble stream"*. For the geologist Edouard Desor (1811–1882), longtime friend and companion of Louis Agassiz (1870–1873), the Grosser Aletschgletscher was *"[…] the largest and most beautiful of the Swiss glaciers"* (Fig. 14.6a–c). The Grosser Aletschgletscher is a typical valley glacier. With a length of 20.7 km from Jungfraujoch and a surface of about 79 km^2, the Grosser Aletschgletscher is the largest and the longest glacier in the Alps. Its volume is estimated to be about 13.4 km^3. (Dr. A Bauder, Institute of Glaciology VAW-ETH Zurich, personal communication 2015). The accumulation area is bordered to the north by famous mountains such as Jungfrau (4158 m a.s.l.) and Mönch (4099 m a.s.l.). It includes the firn basins Grosser Aletschfirn, Jungfraufirn, Ewigschneefäld and Grüneggfirn (from west to east), which confluence at *Konkordiaplatz* (Fig. 14.7). They form large medial moraines such as the Kranzberg and Trugberg moraines. Their swinged shape and dark colour give the characteristic appearance to the Grosser Aletschgletscher. On Konkordiaplatz, where the glacier bed is considerably overdeepend, ice thickness is about 800–900 m as measured by a hot water drilling in the years 1990 and 1991 (Aellen and Herren 1994; Hock et al. 1999; Farinotti et al. 2009; Jouvet et al. 2011). The bedrock was not reached, as a mix of ice-rock debris made further drilling impossible. The lowest point is limited only to a very small area. At the outlet of Konkordiaplatz the ice is 550–600 m and near Märjela about 400–500 m thick. In a sweeping arc, the Grosser Aletschgletscher flows from Konkordiaplatz in southeast direction and its tongue ends deep into the coniferous forest amid abraded and fractured rocks at about 1620 m a.s.l. (Figure 14.7).

Below Konkordiaplatz the greatest flow velocities of ice were measured on the glacier surface at around 180–200 m/year and in the Aletschwald area the ice flows only about 60–80 m/year down the valley (Aellen and Röthlisberger 1981; Jouvet et al. 2011). In the ablation area the Grosser Aletschgletscher is steadily losing ice through melting. At the height of the Aletschwald the annual ice loss is comprised between 9.8 and 12.7 m (summer and winter ablation; measurements by Pro Natura Center Aletsch). This ice loss is not quite compensated by continued flow of ice from the accumulation area. Currently, the surface in the lower part of the glacier tongue is reduced by 2.25–3.75 m/year. The annual changes in thickness at Konkordiaplatz amount around 1 m/year since 1990 (Bauder et al. 2007).

During the Holocene maximum glacial extents, for the last time around 1860, the Oberaletsch- and the Mittelaletschgletscher confluenced with the Grosser Aletschgletscher. The Oberaletschgletscher, the second largest glacier in the Aletsch region with an area of 17.4 km^2 and a length of 9.1 km, was divided by a massive rock plateau in two glacier tongues. The left tongue pushed through the Oberaletsch gorge, filled it with ice and flowed together at the Tälli with the Grosser Aletschgletscher. The right glacier tongue was wider and flatter and went close to the huts of Üssers Aletschji (Fig. 14.6c). Sharp-edged moraine ramparts testify to this last maximal glacial extension in the mid-nineteenth century. A few years later, the left glacier tongue was separated from the Grosser Aletschgletscher and has retreated about 1.5 km since then. The right glacier tongue melted completely away.

On the eastern flank of Aletschhorn (4193 m a.s.l.), the highest peak of the Aletsch region, the Mittelaletschgletscher with an area of 6.8 km^2 and a length of 5.3 km emanates. It hung up until the early 1970s together with the Grosser Aletschgletscher (Fig. 14.6a).

Above the Grosser Aletschgletscher, between Fusshorn and Zenbächenhorn two other glaciers occur, the Driestgletscher with area of 2.02 km^2 and a length of 2.08 km and the Zenbächengletscher with an area of 0.85 km^2 and a length of 1.2 km (Fig. 14.6b). They end up in a broad front and are not very thick. Since the last glacial extension around 1860, they have lost about half of their areas. Both the Driest- and the Zenbächengletscher show moraine ramparts of the Little Ice Age maximum extent. They still wear little vegetation in contrast to the upstream Lateglacial moraine ramparts which are completely overgrown (Fig. 14.4d).

14.5 Research Activities on the Grosser Aletschgletscher

First measurements of ablation were taken by Arnold Escher von der Linth in 1841 when he visited the Märjelensee. Later, in 1869, Charles Grad measured also the ablation and

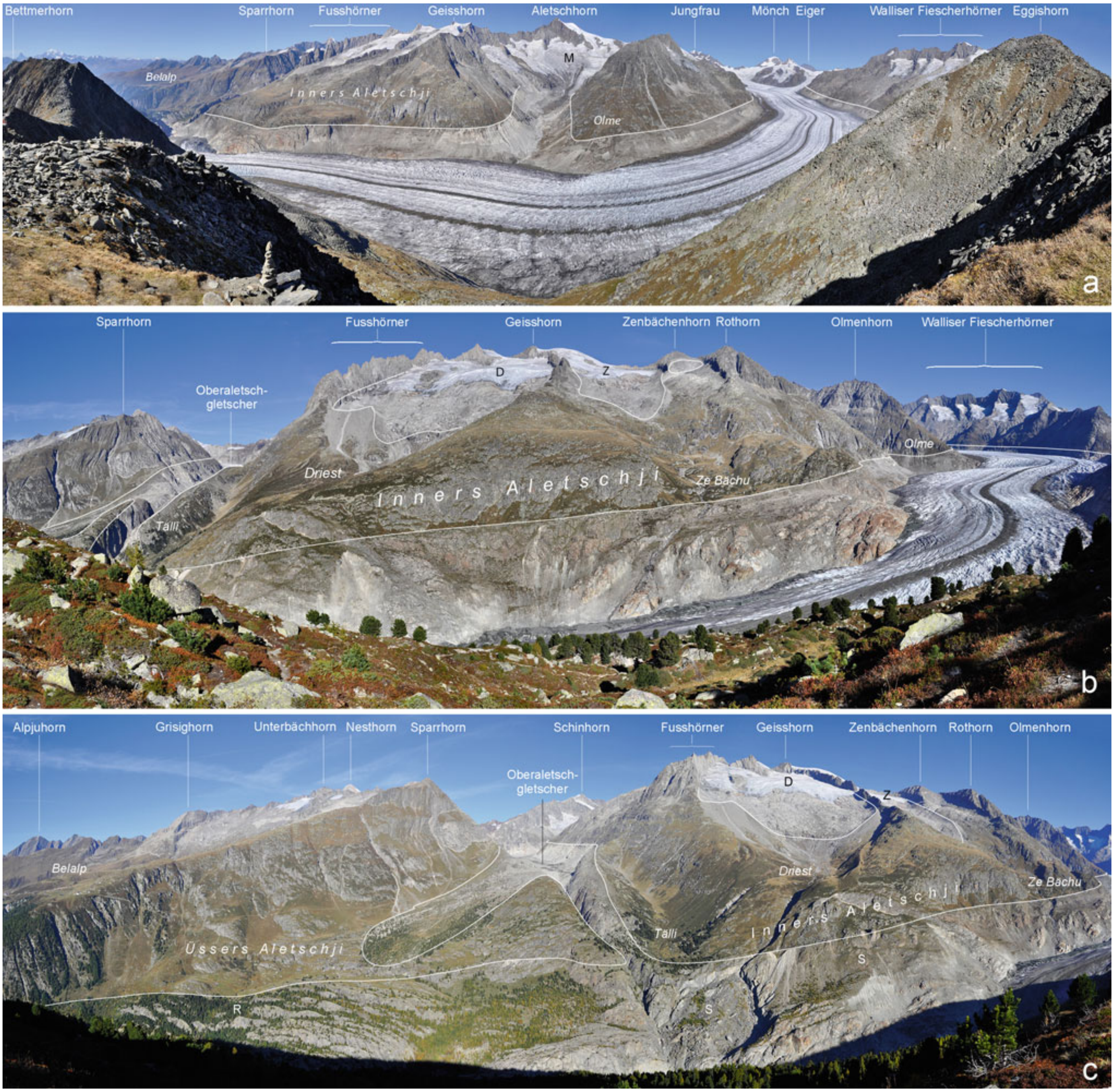

Fig. 14.6 Panoramic views on the Grosser Aletschgletscher with **a** the Mittelaletschgletscher (M); **b** the Driestgletscher (D) and the Zenbächengletscher (Z); **c** the Oberaletschgletscher, the Driestgletscher (D) and the Zenbächengletscher (Z); R clusters of *roches moutonnées* in the Üssers Aletschji, S rock mass movements. The solid white lines indicate the last Little Ice Age Maximum around 1860 (photos H. Holzhauser 2011)

for the first time took measurements of the velocity rate. First measurements in the firn region were carried out in 1918; first depth and velocity measurements in 1937 (Holzhauser 2009).

Comprehensive and systematic glaciological studies started when the High Alpine Research Station Jungfraujoch was established in 1931. Studies were originally limited to Jungfraufirn and Ewigschneefäld and were extended in the 1950s also to the tongue of the Grosser Aletschgletscher. Since 1922, the mass balance change has been detected first using hydrological and from the 1950s—glaciological method (Aellen and Funk 1990). Recently, radar measurements have been carried out by the Institute of Glaciology of ETH Zurich (Dr. A. Bauder, Versuchsanstalt für Wasserbau,

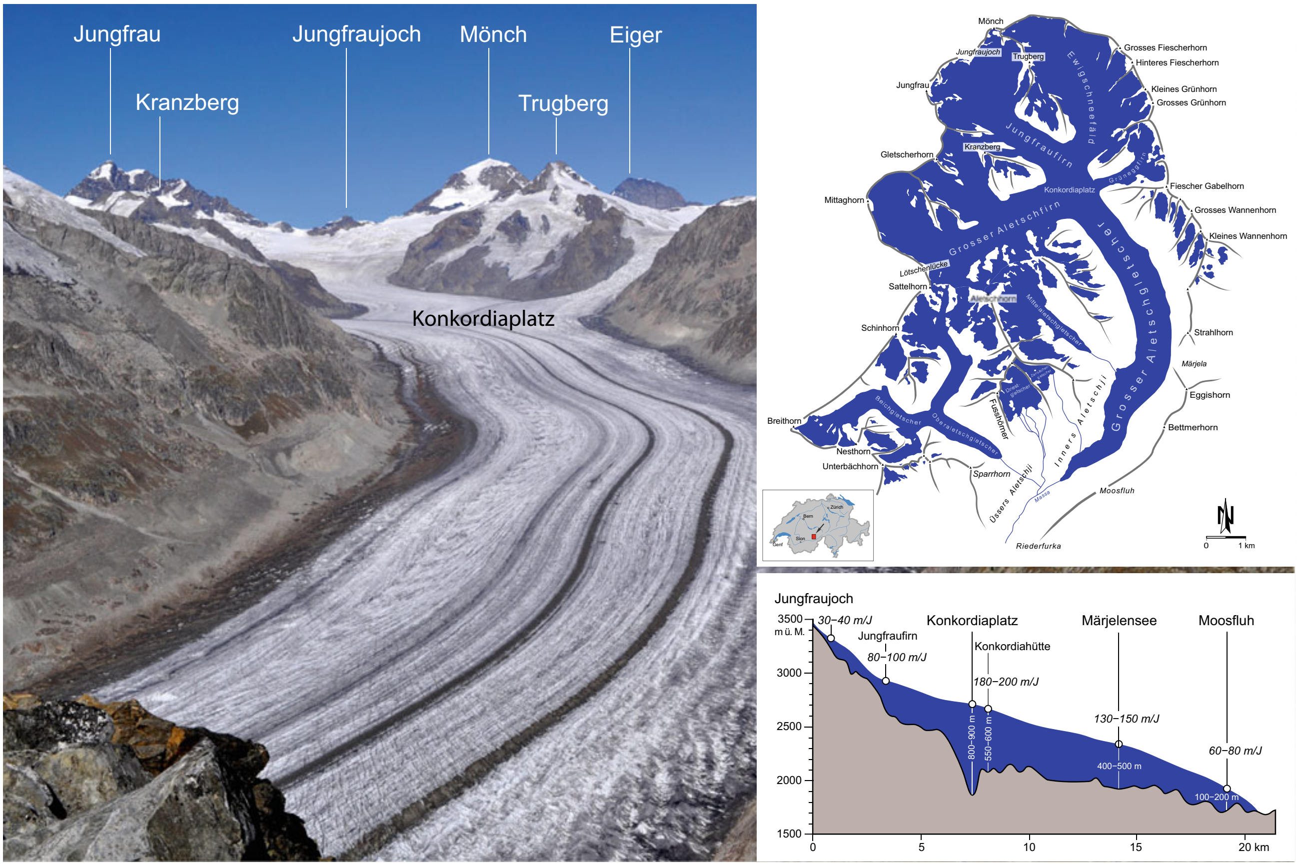

Fig. 14.7 View from Eggishorn to the Konkordiaplatz. The dark medial Kranzberg- and Trugberg moraines are clearly visible. The map shows the glaciated area and the longitudinal profile shows the overdeepening at the Konkordiaplatz as well as the thickness and flow velocities (in metres per year) of the ice (map GLAMOS.CH; profile after Jouvet et al. 2011 and Bauder A. VAW/ETHZ; photo H. Holzhauser 2011)

Hydrologie und Glaziologie (VAW), ETH Zürich, personal communication 2015). As a contribution to the "International Geophysical Year 1956" a map of the Grosser Aletschgletscher in the scale of 1:10,000 was created in 1957 by the Swiss Federal Office of Topography and VAW-ETHZ. This cartography in five map sheets published between 1960 and 1964 can be seen as a highlight of glaciological research on the Grosser Aletschgletscher (Kasser 1961).

14.6 Fluctuations of the Grosser Aletschgletscher Since 3500 BC

The tongue of the Grosser Aletschgletscher has, in the past, reached deep into the pine forest, sometimes coming very close to inhabited regions. During recent maxima of the Little Ice Age, mountain huts have been destroyed, an irrigation channel has been made unusable and pine forest and arable land have been covered. Using various methods to reconstruct Holocene glacial fluctuations—glaciological, historical, archaeological and glaciomorphological ones (Zumbühl and Holzhauser 1988, 2007), it was possible to reconstruct changes in length of the glacier tongue of the Grosser Aletschgletscher over the past 3500 years (Fig. 14.8, Holzhauser 1984, 2009; Holzhauser et al. 2005). The most recent segment of the curve presented in Fig. 14.8, from the twelfth century AD onwards, is based on dendrochronological and archaeological evidence as well as visual and written historical sources. The period from the twelfth century AD backwards is reconstructed only by means of dendrochronologically dated fossil wood found within the proglacial area, some of them actually still in situ.

From the late Bronze Age to the Middle Ages, evidence from dendrochronologically dated trees is obtained not only of growth phases of glaciers, some quite marked, but also of

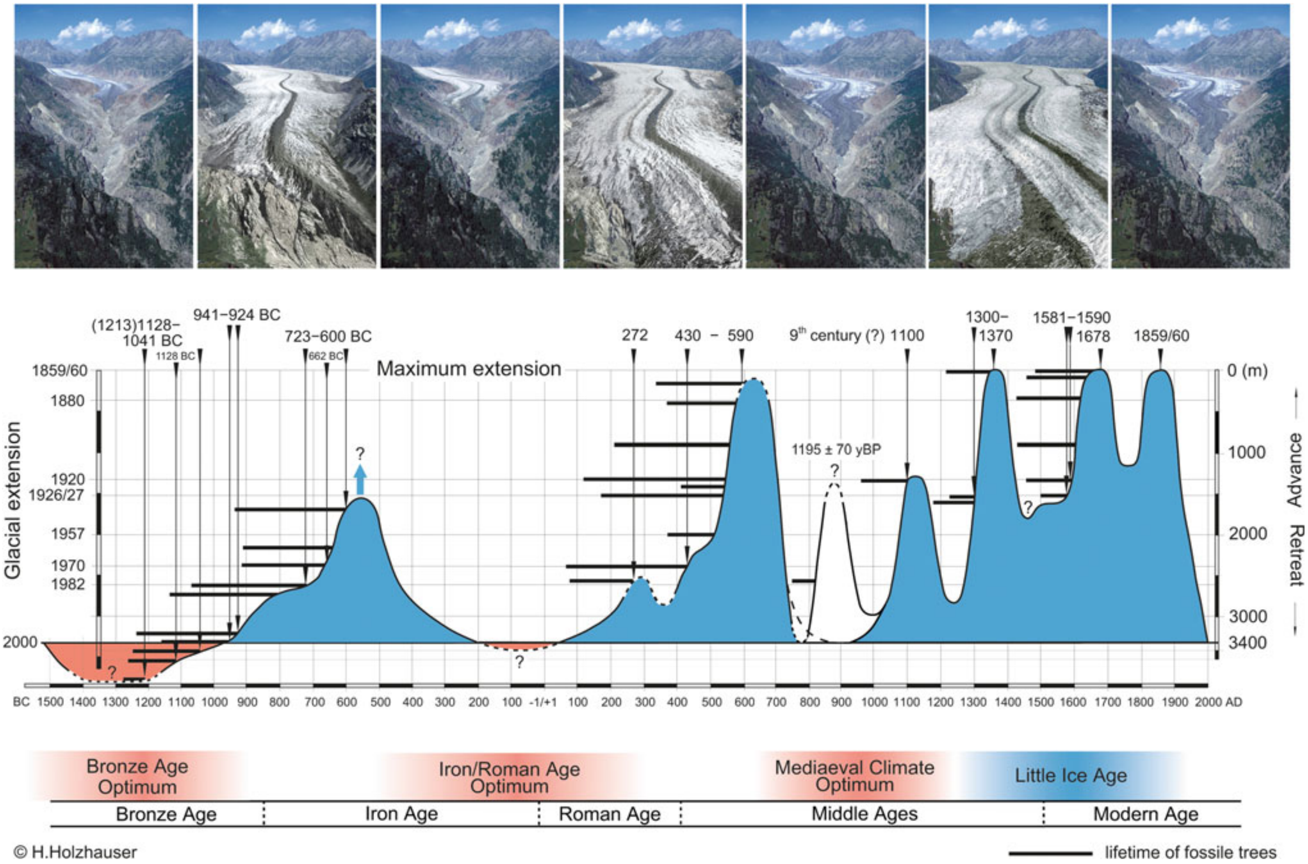

Fig. 14.8 Fluctuations of the Grosser Aletschgletscher over the last 3500 years. The above photographs show the supposed extent of the Grosser Aletschgletscher within seven periods: Bronze Age Optimum, Iron Age advance, Iron/Roman Age Optimum, early Mediaeval advance (Migration Period), Mediaeval Climate Optimum, around 1856 and in 2000 (photomontage H. Holzhauser. Original photograph from 1856: Frédéric Martens, Alpine Club London; photo H. J. Zumbühl)

periods when glacier size was similar to or smaller than today. During the late Bronze Age Optimum, the Grosser Aletschgletscher was from 1350 to 1250 BC about 900 to 1000 m shorter than it is today. During the Iron/Roman Age Optimum between 200 BC and AD 50 and in the early Middle Ages around AD 750, the glacier reached about today's extent or was even somewhat shorter than today. The Mediaeval Warm Period, from around AD 800 to the onset of the Little Ice Age around AD 1300 (Holzhauser et al. 2005), was interrupted by two weak advances in the ninth century (not certain) and around AD 1100. Precise dendrochronological dating shows a powerful advance around AD 1300. Three successive peaks characterize the Little Ice Age: a first maximum in the 1370s, a second between 1670 and 1680 and a third in 1859/60 (Fig. 14.9). Written documents indicate that in the fifteenth century the glacier was of a size similar to that of the 1930s. A very small advance around 1500 has been dated by both dendrochronology and archaeology (destruction of an irrigation channel).

The tongue length of the Grosser Aletschgletscher has been measured yearly since 1892, making the glacier behaviour in the following period extremely well documented. The glacier tongue is now approaching the previous minimum recorded length, as documented between 200 BC and AD 50. In this context, it must be borne in mind that the dynamics of the Grosser Aletschgletscher tongue not only constitute a smoothed but also a slightly delayed function of direct climate and mass balance forcing. In this case, the corresponding time lag is estimated at a few decades, which

Fig. 14.9 The Grosser Aletschgletscher viewed from Belalp around 1856 (left) and in 2018 (F. Martens, Alpine Club London; Archiv H. J. Zumbühl and H. Holzhauser). We can see the debris on the glacier tongue, produced by local rockfall due to the landslide at the Moosfluh

means that the glacier tongue would have to be hundreds of metres shorter than now in order to adjust to actual conditions. In view of the rapid warming during the past two decades, it is therefore highly probable that, in the near future, the previous minimum extent of late Bronze Age may be reached or even markedly exceeded.

14.7 The Märjelensee—Arctic Surroundings at the Foot of the Eggishorn

The Märjelensee on the edge of the Grosser Aletschgletscher was well known until the late twentieth century as one of the most beautiful and typical glacial lakes of the Alps. At its maximum extent known in 1878, the lake filled the depression of Märjela and was about 1.64 km long, 460 m wide and 78.5 m deep at its deepest point. With a surface area of 0.46 km^2 the lake contained at that time 10.7 million cubic metres of water (Lütschg 1915). The once deep blue lake with floating ice blocks together with the barren and rocky environment resembled an arctic landscape (Fig. 14.10). However, from that former "arctic jewel" is not much to see today. As a result of the profound and prolonged lowering of the surface of the Grosser Aletschgletscher the former ice barrier continuously lost thickness. Today in the spring and summertime only a small lake is formed at the edge of the ice (Fig. 14.11).

Centuries ago when the Grosser Aletschgletscher was even mightier than today the Märjelensee was a constant threat to the inhabitants in the valley below. It was infamous for his unpredictable and frequent water outburst floods. Through a fast opening basic crevasse in the icy barrier, the lake could empty suddenly (Lütschg 1915). The water masses were flowing then under the glacier as well as at the edge of the glacier and seriously damaged parts of the town of Naters as between 1813 and 1915. The Märjelensee would also flood parts of the Fieschertal, wreaking havoc on the village and the livestock. To prevent further flooding from the Märjelensee outbursts the cantonal engineer Ignaz Venetz designed in 1828 and 1829 two canals: a small canal that diverted the lateral inflows from Strahlhorn against the Fieschertal directly and a large canal that would lower the

Fig. 14.10 Historical views of the Märjelensee. **a** J. R. Bühlmann, 1835 (© Graphische Sammlung ETH Zürich); **b** H. Hogard, 1849 (the lake is empty due to a water outburst; Hogard and Dollfus-Ausset 1854; © H. Holzhauser); **c** around 1890 (postcard, private property); **d** around 1900 (postcard, private property); **e** around 1920 (postcard, private property); **f** in 1976 (photo © H. J. Zumbühl)

water level of the Märjelensee. The expected success was not achieved and the water flowing through the canals caused increased flooding in Fieschertal. Another attempt to lower the lake level and prevent lake outbursts was undertaken from 1889 to 1894, however, at a much deeper lake level. In direction to the Fieschertal a 583 m long gallery was built in the bedrock. This gallery was only flooded once, in 1896. During six weeks water flowed through the underground canal. Since then the water level of the Märjelensee has never reached the height of the gallery

Fig. 14.11 The Märjelensee in 2007 (photo H. Holzhauser)

again. In order to detect changes in the water level accurately, level constructions were installed in the years 1908 and 1909 (Lütschg 1915).

The increasing shrinking of the Grosser Aletschgletscher towards the end of the nineteenth century led to the decline in the level of the Märjelensee and a terrain threshold divided the lake into the larger and deeper lake at the edge of the glacier, the Gletschersee or Hintersee, and the shallower Vordersee, located further to the huts of the Märjelenalp (Fig. 14.12a). The Vordersee has increased since 1988 as part of the "Märjelen Project" by construction of an artificial dam and it now collects the spring water from the *Galtjinenquellen* (Galkina) below Strahlhorn (Fig. 14.12b). The water is passed from the barrier lake through the newly built, one kilometre long Tälligrat Tunnel into a reservoir. From this reservoir a pipeline leads water for irrigation to Lax and Martisberg, Goppisberg, Riederalp and Oberried. Another pipeline leads water into a reservoir on the Laxeralp where drinking water is treated. The drinking water is conducted from there to other reservoirs and is allocated to the aforementioned municipalities.

14.8 Conclusion

The Aletsch region located in the heart of the UNESCO World Heritage Swiss Alps Jungfrau-Aletsch is an eldorado not only for hikers and mountaineers, but also for glaciologists, geologists and geomorphologists. Because of its location—away from the former main tourist routes in the Rhone River valley—it was opened to tourism only late. Today, the well-accessible viewpoints at Jungfraujoch, Eggishorn and Belalp offer incomparably panoramic views onto the Pennine and Bernese Alps as well as onto the majestic Grosser Aletschgletscher, the most powerful glacier of the Alps. Its history could be completely reconstructed for the past 3500 years with the help of historical documents and analysis of fossil trees found in the glacier forefield. Once the Märjelensee, fed by glacial meltwater, was very famous because of its seemingly arctic character. This typical glacial lake was feared because of its irregular outburst floods. Today, only a small lake is formed sporadically since the surface of the Grosser Aletschgletscher has strongly decreased within the last 150 years.

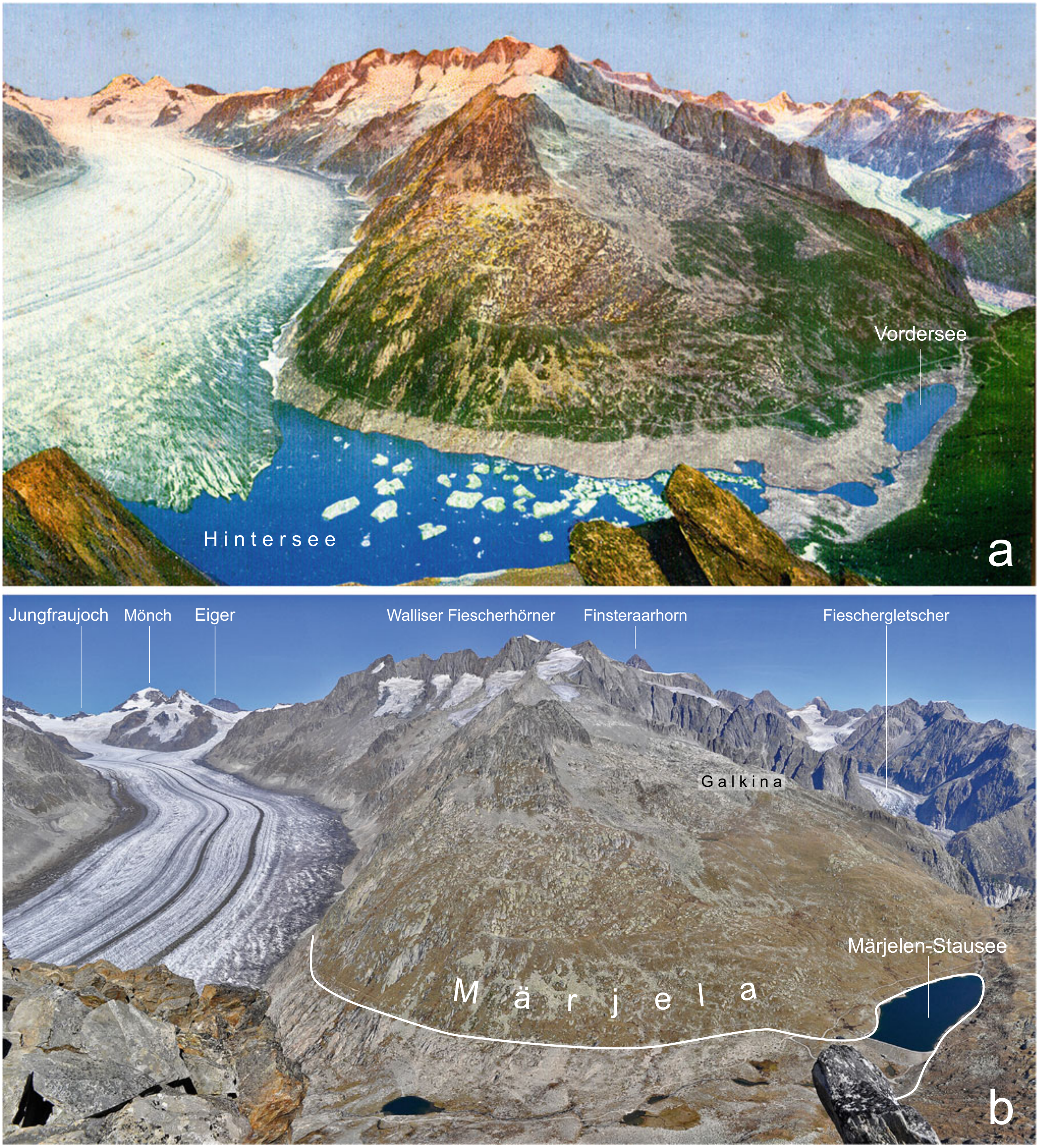

Fig. 14.12 Panoramic view over the Märjela. **a** Around 1900 with the Hinter- oder Gletschersee at the edge of the Grosser Aletschgletscher and the Vordersee (on the right); **b** In 2011. The Vordersee increased since 1988 as part of the "Märjelen Project" by an artificial dam. The white line indicates the lake level in 1878 (photo H. Holzhauser 2011)

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