

Plate 3.8 Holocene Glacial Fluctuations

Introduction

At the end of the last Ice Age, approximately 11 000 to 11 500 years ago, mean annual temperatures rose considerably within a few decades. This marked the beginning of the Holocene age. During this era the mean summer temperatures varied very little over the long-term, approximately $\pm 1^{\circ}\text{C}$ compared to the present. The movement of the glaciers, which had melted way back into the Alpine valleys at the beginning of the post-glacial age, was thus limited to a small area called the forefield, which in many cases is easily identified today, owing to its meagre vegetation. The forefield is found between the terminal moraine that marks the glaciers' greatest extent (e.g. as in 1850/60) and the glaciers' current limit. Within the post-glacial periods of warmer and cooler conditions there have been series of fluctuations from maximum to minimum extensions, some glaciers shrinking to even less than their current state. The last noticeable warm period is called the Mediaeval Climatic Optimum, from around the end of the 8th century to about 1300, and the last marked cold period is called the Little Ice Age (around 1300 to 1850/60) [2]. Since glaciers are good indications of climatic change, their fluctuations indirectly reflect the natural variations in climatic conditions since the last Ice Age.

Methods

Glacial fluctuations in the Holocene can be reconstructed using various methods of differing precision and covering different periods back into the past:

- Glaciological methods (over the past 120 years) mainly provide direct data (measurements) concerning the volume, surface area and fluctuations in length (cf. map 3.7).
- Historical methods (past 500 to 700 years) involve the study of historical material such as written accounts, visual records, maps and relief models. These are only available in any adequate quantity for those glaciers which drew the attention of travellers, scientists and artists through their reputation and scenic attraction. Most of the written accounts that can be used date from the 16th century onwards. Paintings and drawings date from as early as the beginning of the 17th century, but became far more abundant with the emerging popularity of Switzerland as a tourist destination in the 18th century. Photographs are available from as early as 1849.
- Archeological methods (past 700 to 800 years) can be used where land has been cultivated in the vicinity of glaciers and where traces of ancient human activity can be correlated with the development of the glacier, such as foundations and beams from old buildings, for example, or remains of abandoned irrigation channels, particularly in the Valais [1].
- Glaciomorphological methods (entire Holocene) are used in the forefield where soils and trees may be discovered that were covered or uprooted when the glacier advanced. The age of organic fossil remains can be determined using radiocarbon dating. The growth rings of fossil trees can also be examined (dendrochronology) and the trees can be dated to the nearest year in some cases [1,2,3].

The Aletsch glaciers

The Grosse Aletsch glacier is the largest glacier in the Alps. Since it reached a maximum length in 1856, the tongue of this glacier has receded by 3.37 km, representing around 24 m per year. Until the 1870s it was fed by the left-hand tongue of the Oberaletsch glacier. At its last maximum, the right-hand tongue, which has completely disappeared today, extended almost as far as the buildings at «Üssers Aletschi» (cf. map).

Using all the methods mentioned above, it has been possible to reconstruct the changes in length of the glacier tongue over the past 3500 years [1,2]. The main method used was the dating of fossilised trees found within the forefield, some of them actually still where they had grown. By this

means evidence was obtained not only of ten glacial growth phases, some quite marked, but also of periods when the glacier was similar to today or smaller, for example in the Bronze and Iron Ages, during Roman times and in the early Middle Ages. The most recent segment of the curve, from the 12th century on, has made use of archeological evidence and historical visual and written sources. The «Oberriederi» should be mentioned in this connection. This is a system of three irrigation channels which were used from the 12th century until around 1580, most probably with an interruption in the second half of the 14th century, to take water from the Grosse Aletsch glacier to Oberried. This was possible because of the small extent of the Grosse Aletsch glacier at the time. Precise dendrochronological dating shows, however, that the glacier advanced at the beginning of the Little Ice Age, around 1300, and reached a maximum shortly after 1369. The growth period which began in 1580 and reached a peak around 1678 finally put the Oberriederi irrigation system out of service.

The Rhone glacier

In the mid-19th century the structure of the Rhone glacier was as follows: upper section – ice-fall – and lower section with imposing fan-shaped or flattened tongue (cf. photo). The forefield has at least seven terminal moraine systems, a feature which is rarely so clearly visible in other Alpine glaciers. The outer moraines A and B date from advances in the early Holocene or in the early Middle Ages. Moraine C was formed in the 14th century and indicates the maximum extent of the Rhone glacier during the Little Ice Age. Terminal moraine D was formed around 1600. From 1770 on the variations in length of the Rhone glacier can be reconstructed with reliable precision from visual records, some of which are extraordinarily accurate and of excellent artistic quality [6]. This period is characterised by three advances of varying importance within the «Gletschbode» (cf. map), as well as by extensive ablation since the end of the Little Ice Age. The greatest growth was seen between 1770 and 1781 (terminal moraines E and F), when the tongue of the glacier advanced by between 660 and 820 m, perhaps even 1100 m, the glacier thus possibly reaching a point beyond its maximum in the mid-19th century. Smaller advances (of around 420 m) were seen in 1810/1812 to 1818. At that time the tongue extended to within 80 to 180 m of the maximum length of 1856. The advance that started in 1831 ended in 1856, when the glacier attained its maximum for the 19th century (not in 1818 as Mercanton surmised). Today only the uppermost section of the glacier, which originally comprised three branches, still remains. As the photo shows, the glacier now ends above the section of bare rock, which means it has receded more than 2.1 km since the end of the Little Ice Age.

The Gorner glacier

During the maximum extension of the Gorner glacier the name «Bodengletscher» was given to the lowest section, which was easily visible from Zermatt and extended as far as «Schweigmatten» at the time. Since then the tongue has receded by an average of 19 m per year, making a total of 2600 m, and the Bodengletscher has completely disappeared (cf. photographs).

Thanks to high quality written and visual records, and in particular radiocarbon dating of fossil trees (dendrochronological analysis) from the forefield, it has been possible to reconstruct a complete and accurate picture of changes in the tongue of the Gorner glacier over the past 1400 years [2]. Following an advance in the 8th century, the Gorner glacier receded. During the subsequent Mediaeval Climatic Optimum and up until the beginning of the Little Ice Age around 1300, the end of the tongue apparently extended less far than in 1940. The glacier advanced again somewhat in the 12th century to a maximum length which was reached in 1186. Between 1327 and 1341 it advanced relatively slowly by only approximately 9 m per year. From 1341 until it reached its first maximum length within the Little Ice Age (1385) it began to move at a faster rate of around 20 m per year. The tongue thus advanced at an average of 17 m per year between 1327 and 1385, making a total of 1000 m over that period. After another period of retreat the Gorner glacier reached its second maximum length during the Little Ice Age, in 1669/70 (table 2).

Around 1791 the tongue was below the confluence of the Furggbach and the Gornera. This point marked the start of a long-term and more or less continuous phase of growth which lasted until 1859, when the glacier reached another maximum. During this period the tongue advanced on average 10 m per year destroying many houses and farm buildings as well as valuable farmland in the process (cf. map).

The Lower Grindelwald glacier

Owing to the fact that during the Little Ice Age the tongue of the Lower Grindelwald glacier often extended as far as the valley floor and was thus in close proximity to the village, it has been one of the best known and most visited glaciers in the whole of the Alps since the 18th century. Equally outstanding is the number of over 360 paintings, drawings and photographs up to 1900 and often also the quality of the historical written accounts and visual records of the glacier. Fossil soils and trees particularly found in the lateral moraines at Stieregg and Zäsenberg complete this evidence and enable the reconstruction of the glacier history over the past 3000 years. Owing to the mass of information sources covering the last 300 years a degree of precision can be achieved which is simply not possible in the case of most of the other Alpine glaciers [4,5].

It has been possible to identify a total of six marked growth periods for the Lower Grindelwald glacier between the end of the Bronze Age and the high Middle Ages [3]. The late Middle Age growth phase around 1338, which has been determined using dendrochronological investigations, falls within the Little Ice Age. In simplified terms the development of the glacier after 1560 can be summarised as follows:

- over a long period the glacier remained stable, extending as far as the Schopf rock terraces, around 1250 m further down than the present tongue (cf. illustrations dating from 1748/49, 1762, 1794 and 1808);
- there were at least six relatively short-term advances of between 400 and 600 m which led to the formation of a marked fan-shaped tongue («Schweif») which extended far down into the valley floor. Three maximum lengths were reached (in 1778/79, 1820/22 and 1855/56, cf. orthophoto) and during three periods the glacier was shorter, e.g. 1669 (cf. illustration);
- the long-term growth period which started around 1575 lasted until approximately 1600, the glacier increasing by about 1000 m to reach its maximum extension during the Little Ice Age;
- since the end of the Little Ice Age the Lower Grindelwald glacier has receded by about 2 km to its present limit well up in the gorge (cf. photographs from 1974 and 1998).

References

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