

THE TRIGLAV GLACIER

Matej Gabrovec
Borut Peršolja

The Triglav Glacier is located in the Julian Alps at the altitude of 2,445 meters. The last hundred years of its half a millennium history has been marked by a retreating trend. The situation of the last four hundred years can be reconstructed by studying older moraines whose age has been established according to the overgrowth of the blue-green algae *Chroococcus lithophilus* Erceg (Šifrer 1963), by studying old paintings and photographs, and on the basis of individual mentions, particularly in the mountaineering literature. Fieldwork findings match the preserved descriptive and photographic mate-

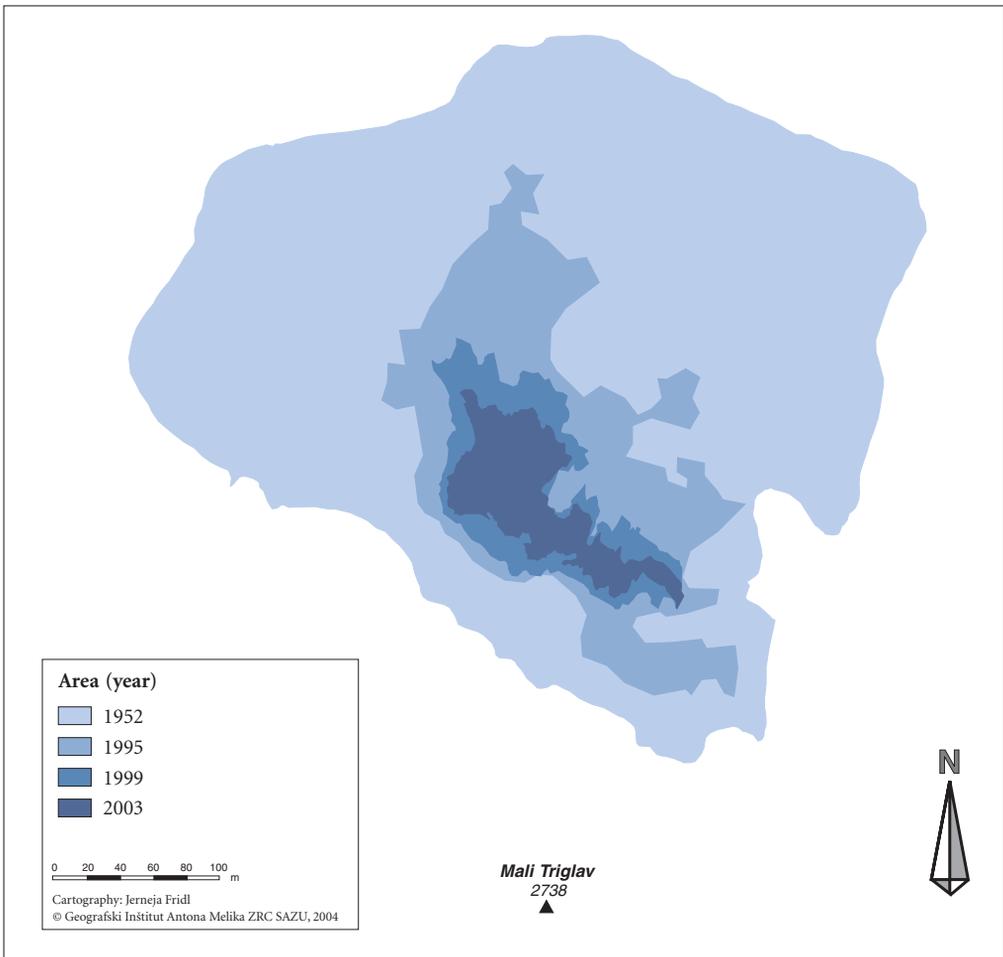


Figure 1: The size of the Triglav Glacier in 1952, 1995, 1999 and 2003.

rials very well. In the last fifty years, the Triglav Glacier has been the subject of constant observations and research (since 1946) and this work ranks among the oldest uninterrupted scientific studies in Slovenia.

Table 1: Survey of the surface area changes of the Triglav Glacier.

Year	Surface area in hectares	Altitude of the upper edge	Altitude of the lower edge
1900	32	2600	2280
1952	12.5	2565	2390
1995	3.0	2545	2415
1999	1.1	2510	2440
2003	0.7	2495	2445

Data on the surface area of the Triglav Glacier – including the oldest in the course of more than fifty years of uninterrupted monitoring and measuring – has been acquired in various ways. At first, annual measurements included measuring the distance from the ice to measurement points placed by the researchers on the margin of the glacier. Periodically, classical geodetic measurements were made with a theodolite, the first in 1952, and later in 1995 and 1999.

In 1999, we took the first aerial photos using a photogrammetric camera in the usual stereo technique. The shooting was successful, and the data enabled the high quality processing and presentation of a three-dimensional model of the glacier. We therefore repeated the aerial photography in 2001 and 2003, and on the basis of helicopter shots, 1:1,000-scale digital topographical plans of the Triglav Glacier and a digital model of heights were elaborated for all shootings.

We first used the ground penetrating radar on the Triglav Glacier in 1999 (Verbič, Gabrovec 2002). On two cross-sections, we acquired data on the formation of the slope or basin where the glacier is situated. In 2000, we again took georadar measurements on 14 cross-sections and upgraded the data on the sub-glacier surface. The three-dimensional data on the surface of the glacier, together with the data on its thickness, enabled us to calculate its volume in individual years. If the surface of the glacier shrank to one twentieth of its original size in half a century, its volume shrank to less than one hundredth of the original volume.



Figure 2: The Triglav Glacier, 1975 (photography Milan Orožen Adamič).



Figure 3: The Triglav Glacier, 2003 (photography Matej Gabrovec).

Table 2: Survey of volume and thickness changes of the Triglav Glacier.

Year	Volume in m ³	Greatest depth in m	Average depth in m
1952	1,700,000	45	18
1992	130,000	20	6
1999	35,000	10	3

In 1976, we began taking pictures of the glacier regularly, about once in a month, from two permanent positions in the vicinity of the Triglavski dom Lodge on Mount Kredarica (2,515 m). More than four thousand pictures allow us to monitor the condition of the glacier during the year and to make comparisons between individual years. At the end of the 1990's, the methodology of photogrammetric processing was applied to the photographs and an elaboration of a plane model of the surface of the glacier in different periods was done (Triglav, Kosmatin Fras, Gvozdanovič 2000).

In its present condition, the Triglav Glacier no longer deserves its name. All the typical characteristics of a glacier are changing or even disappearing. With the reduction of the thickness and surface area of the glacier, the structure of the ice has changed. For the formation of glacier ice with a volume density of 870–910 kg/m³, the decisive factors are a sufficient quantity of snow precipitation, the duration and manner of transformation, and the weight from the top on lower-lying layers. Bluish-green glacier ice is practically gone, replaced by thicker and darker water ice that only needs a continuous weight to complete its transformation.

Visible proof of the movement of the glacier are glacier fissures, which occur due to the differences in the velocity of different parts of the glacier. These are clearly visible in old photographs from the beginning of the 20th century, as well as in scenes from the first Slovene movie, *V kraljestvu Zlatoroga/In*

the Kingdom of the Goldenhorn, made in 1931. It is obvious that in the last few years, the glacier has no longer moved since the last glacier fissure was observed in October 2001. Gravitational movement (consecutive as well as regelation movement) has stopped due to the physical entrapment of the glacier in a shallow bowl (Peršolja 2003), which we were able to identify on the subglacier surface using georadar measurements.

In the second half of the 1980's, the glacier divided into many smaller parts. The disintegration of the glacier was followed by the covering of individual parts by rubble (Gabrovec 1998). This means that the Triglav Glacier will probably not thaw entirely since the rubble deposits will protect it and convert it into fossilized or trapped ice (Peršolja 2003).

The annual changing of the glacier is the consequence of a complicated combination of the effects of various climatic factors in the warm and cold halves of the year, its thawing and growing periods. Changes over a longer period are also the result of global climate changes. Cooling during the transition from the Middle Ages to the Modern Age (Little Ice Age) caused the occurrence of the Triglav Glacier. The rapid shrinking of the glacier in the last decade is undoubtedly connected to the rising temperature in this period. The data from the meteorological station on Mount Kredarica (2,514 m) in the immediate vicinity of the glacier is clear proof of this (Nadbath 1999). On the other hand, abundant snow precipitation in 2001 (Vrhovec, Velkavrh 2001) temporarily stopped the shrinking of the glacier, and a similar event happened in the 1970's (Šifrer 1987).

- Gabrovec, M. 1998: The Triglav Glacier between 1986 and 1998 (Triglavski ledenik med letoma 1986 in 1998). *Acta Geographica (Geografski zbornik)*, 38: 89–110. Ljubljana.
- Nadbath, M. 1999: The Triglav Glacier and Climate Variations (Triglavski ledenik in spremembe podnebja). *Ujma* 13: 24–29. Ljubljana.
- Peršolja, B. 2003: The Skuta glacier gained leadership (Prvenstvo prevzema ledenik pod Skuto). *Scientia (Znanost)*, 13. 10. 2003. Ljubljana.
- Šifrer, M. 1963: New findings about the glaciation of Triglav. The Triglav Glacier during the last 8 years (Nova geomorfološka dognanja na Triglavu. Triglavski ledenik v letih 1954–1962). *Acta Geographica (Geografski zbornik)*, 8: 157–210. Ljubljana.
- Šifrer, M. 1987: The Triglav Glacier in the years 1974–1985 (Triglavski ledenik v letih 1974–1985). *Acta Geographica (Geografski zbornik)*, 26: 97–137. Ljubljana.
- Triglav, T., Kosmatin Fras, M., Gvozdanovič, T. 2000: Monitoring of Glaciers Surface with Photogrammetry, Case Study on Triglav Glacier (Spremljanje površja ledenikov s fotogrametrijo, študija na primeru Triglavskega ledenika). *Acta Geographica (Geografski zbornik)*, 40: 7–30. Ljubljana.
- Verbič, T., Gabrovec, M. 2002: The ground-penetrating-radar measurements of the Triglav Glacier (Georadarske meritve na Triglavskem ledeniku). *Geographical Bulletin (Geografski vestnik)*, 74-1: 25–42. Ljubljana.
- Vrhovec, T., Velkavrh, A. 2001: Maximum snow depth on Kredarica (Največja debelina snežne odeje na Kredarici). *Geographical Bulletin (Geografski vestnik)*, 73-2: 25–32. Ljubljana.