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If the eternal ice melts, mighty summits will teeter

The Alps are mighty and magnificent. Or are they mighty and terrifying because they are beginning to crumble and tumble down into the valleys below? This question has been raised by the dramatic events of summer 2017 in the Swiss mountains. This has highlighted the impact rising temperatures are having on the Alps.

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There was no indication that anything out of the ordinary would happen in the Grisons mountains on 23 August 2017. It was a bright summer's day. But then at 9.30 a.m., three million cubic metres of rock came loose on the 3,369-metre-high Piz Cengalo. The mass of rock crashed into the valley below and fragmented. The impact pulverised a 10 to 15-metre-thick glacial sheet lying in the rockfall's path. The rubble combined with the loose rock saturated with melt water at the bottom of the mountain. Shortly afterwards a torrent of mud and debris rolled down the mountain, heavy and powerful enough to push huge lumps of rock down into the valley too. "Rolled down" is not really an accurate description. The mudslide travelled at up to 40 kilometres an hour towards the village of Bondo five kilometres away and collided with part of it.

The incident claimed the lives of eight hikers whose bodies have still not been found. As Piz Cengalo is under observation due to previous rockfalls and a warning system has been installed high above the village, nobody in Bondo itself was hurt. The warning system raised the alarm, giving them time to reach safety from the mudslides and falling debris.

Just a week later, another large section of rock came away from Piz Cengalo during a night-time storm. Another mudslide hurtled down into the valley. There was a third landslide on 15 September. Several hundred thousand cubic metres of rock crashed down the mountainside for over two hours. The "Bondarini", as the residents of Bondo are known, are aware that another one and a half million cubic metres of rock are moving on Piz Cengalo.

Moosfluh provides a wonderful view of the Aletsch glacier. However, the glacier is no longer a safe place for hiking as it is melting away.

First the mountain, then the glacier...

A change of location – the Trift glacier on the 4,000-metre-high Weissmies normally moves down the valley at a rate of around 15 centimetres a day. The Bondo landslide was still making the headlines when the movement of the Trift glacier's permanently monitored ice sheets began gathering pace. The speed of movement increased to two and then four metres a day. That is a staggering rate for glaciers. Experts and authorities raised the alarm on 9 September and requested 220 residents of Saas Grund to leave their homes. The evacuation was completed by 6 p.m. and the hiking area was cordoned off. These steps did not come a moment too soon. In the early hours of the morning on the following day, the tip of the glacier under observation broke into pieces, slid over the steep rock face and fragmented into ice granulate upon impact. Nobody was hurt.

...and finally an entire mountainside

Another change of location – Moosfluh at an altitude of 2,234 metres, close to Bettmeralp, provides wonderful panoramic views of the Aletsch glacier. However, the mountain slope abutting the glacier is no longer a safe place for hiking. Warning signs prohibit access by mountain climbers because "people can disappear into the large holes, such as glacial crevasses, on the hiking route", warns the safety officer responsible for the area. His warning does not appear exaggerated. Around 160 million cubic metres of rock are moving here. It is the largest movement of rock in Switzerland and is very rapid at times. Whereas the Moosfluh moved by a few millimetres a year on average in previous millennia, this suddenly increased to 30 metres in 2016. Such astonishing rates have not been recorded anywhere else in the Alps. Deep fissures and metre-wide crevices in the terrain in places suggest that a far larger mass could plunge into the valley here than in the Bondo landslide.

Cengalo, the Trift glacier and Moosfluh – these three locations raise the question as to whether significant climate change lies behind the extensive degeneration and whether, as a consequence, the Alps will no longer be seen as mighty and magnificent but instead as a mighty and terrifying place to visit.

Geologist Hugo Raetzo warns: "Temperatures in the Alps have risen at twice the rate of the global average since the late 19th century."

"We are experiencing rising temperatures"

Geologist Hugo Raetzo from the Hazard Prevention Division of the Federal Office for the Environment points out the obvious first of all: "We are experiencing rising temperatures in the high mountain regions." Temperatures in the Alps have risen at twice the rate of the global average since the late 19th century. The increase in temperature has also become more acute in the mountains in recent decades. This rise in temperature is obviously impacting on the glaciers and the permanently frozen and therefore stabilising substrate, known as permafrost, explains Raetzo. In addition to the general warming, which is causing the permafrost to thaw, the very hot summers of recent times are also a factor, indicates the natural scientist. Hot summers could become the "trigger point" for rockfalls. Rockfalls and landslides were more frequent in the summers of 2003 and 2015 when higher than average temperatures were recorded.

The Piz Cengalo is one of the mountains lying in the permafrost zone. Is it a typical example of a mountain that begins to disintegrate when it gets too hot in the mountains? Raetzo explains that it is not quite that simple. The correlations are often much more complex, and developments over millennia are a major factor. However, the Swiss Permafrost Monitoring Network reveals just how much the temperature has risen in the depths of the ground. The Corvatsch measurement station, for example, shows that the temperature at a depth of 10 metres is a degree higher today than it was 30 years ago. Temperatures are also rising at a depth of 20 metres, a level where seasonal fluctuations have had little effect in the past. Raetzo remarks: "It is certainly not the case that every mountain is disintegrating." But the geological structure increases the risk of landslide. This is illustrated by a simple example. If the substrate defrosts, a certain gradient is required before rock slides.

Fissures and crevices full of water

The Piz Cengalo is certainly steep. However, no definitive causal analysis of this specific case has yet been produced. The "Bondarini" are therefore left to speculate on the factors behind the Piz Cengalo landslide. Siffredo Negrini, a mountain guide, has tried to fathom out what happened. He has long avoided the mountain. He explains

Bondo residents survey the destruction caused by the avalanche of mud, debris and scree on 23 August.
Photos: Keystone

why: "Ice and snow melt quickly there, and water fills the fissures and crevices. It then freezes, cracking the rock." The recent incident aside, Raetzo points to a general lesson that must be learned on the Swiss mountains: "The permafrost is being warmed and the glaciers are receding – warm melt water, which is extremely prevalent in summer, is penetrating to great depths. This changes the situation and potentially also the stability of the terrain."

The abundance of melt water has also impacted on the Trift glacier. Raetzo explains that some of the melt water reaches the bottom of the glacier in hot summers, heating the very spot where the glacier is embedded into the rock – or at least should be. Experts unanimously agree that the glacial ice falls of 9 September were the result of high summer temperatures. Martin Funk, a glaciologist at the Federal Institute of Technology Zurich, comments: "Such an incident can only take place in summer." The climate is therefore having a direct impact on the glacier.

Most glaciers in the Alps are set to disappear by the end of the century, apart from a few at high altitude. Switzerland must therefore prepare itself for significant change. The first lesson for the lay person is that if the glaciers melt, their stabilising force is also lost. The entire tip of the Trift glacier broke off because there was nothing supporting it. The deeper sections of the glacier used to support the steep part of the Trift glacier, but they have now melted away.

The mountainside has no support

This process of change is accelerating as support structures disappear. Moosfluh provides a good example of this phenomenon. Here the Aletsch glacier is supported – or at least was – by the abutting mountainside. The Aletsch glacier has receded by around three kilometres in length since 1850 and 400 metres in height based on the tip today. Its dwindling dimensions mean the ice is no longer exerting pressure on the slopes. The original pressure of 35 bar "is no longer being applied", according to Raetzo, which clearly explains the movement of the Moosfluh.

Despite the principle that "melting glaciers mean the mountains lose a support structure", the consequences are not generally as dramatic as on the edge of the Aletsch glacier. Raetzo explains that the right "geological structure" also has to exist in the first place: Events far back in the Earth's history have probably caused "weakspots and clasts in the bedrock" on the mountain. The underground processes of fragmentation – which mean we are now seeing extremely dynamic geomechanical interaction – were therefore set in motion much earlier. Put simply, if the "eternal ice" is supporting a mountain that is already fragile, the melting of the glacier proves fatal.

After the dramatic events of summer 2017 in the mountains, one thing is clear – neither the landslide on the Piz Cengalo nor the break-up of the Trift glacier came as a complete surprise nor did they find Switzerland unprepared. Bondo constructed a protective wall several years ago to act as a collection basin for impending mudslides, which probably prevented the village from being destroyed. The Trift glacier has been under observation for years, along with the Bis glacier in Mattertal. At Moosfluh too the tiniest shift does not escape the attention of the experts because the mountain is being monitored. Radar systems, GPS, optical evaluation procedures and other measuring systems are deployed. It appears Switzerland is extremely well equipped in terms of technology for monitoring danger. Raetzo backs this up: "We have much accurate information on the movements in the areas under observation and are working at a high standard technically." National and cantonal environmental agencies and universities are collaborating on the trialling of GPS-based observation networks in pilot areas in Upper Valais. The GPS sensors deployed in unstable zones provide real-time data on movements. "The early warning systems we are working with are of a very high standard by international comparison," says Raetzo. But he warns against bullishness: "We'll never have control over nature despite all the technology at our disposal – not today nor in the future."

Federal Councillor Doris Leuthard underlined the message even more clearly in comments captured by TV cameras in Bondo: "We will continue to experience such incidents. Melting permafrost, mudslides and climate change are a reality, even if some people still refuse to believe it."