The avalanche at Flateyri, Iceland October 26th 1995 and the avalanche history.

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ABSTRACT. An avalanche struck the village Flateyri on 26.10.1995 killing 20 people. There was also an enormous property damage. The avalanche went further than previously known for avalanches from Skollahvilft. The weather conditions are discussed using weather maps, data from nearby weather stations, and descriptions by the inhabitants. An attempt is made to evaluate the volume of deposits from the avalanche as well as the mass. Furthermore some speculations are made on the snow depth in the starting zone and there is a short discussion about the return period of avalanches from Skollahvilft. The revised avalanche history of Flateyri is also discussed.

INTRODUCTION

An avalanche cycle occurred in the Westfjords and NW-Iceland during 23.-26.10.1995 in which there was enormous damage and loss of life stock. On 26.10.1995, at 4 a.m. an avalanche fell from Skollahvilft, Flateyri, killing 20 people. Prior to this there had hardly been any fatalities in Flateyri due to avalanches.

During roughly a two-year period prior to this there had been 2 fatal avalanche accidents in the close surroundings of Ísafjörður. All of these exceeded the existing hazard zones.

In this article a short description of the surroundings is given with a glimpse of the avalanche history to begin with, to better understand the relevant locations in the description of the weather, the avalanche at Flateyri and the avalanche cycle.

SURROUNDINGS OF FLATEYRI

Flateyri is located in Önundarfjörður in the Westfjords, i.e. in the NW-peninsula (figure 1), and the population is about 400. The direction of the fjord is NW-SE and Flateyri is on the northern side. The mountain above, Eyrarfjall, reaches a height of 660 m a.s.l. at the rim of Skollahvilft.

Skollahvilft is the name of an extensive bowl reaching from a height of approximately 300 m up to 660 m. Below is a gully that narrows down to 180 m a.s.l. and is embraced by belts of cliffs on both sides. The village has expanded during the past decades towards the mountainside.

During previous years the main threat to the village was Innra Bæjargil, since avalanches from there hit a few houses and came close several times.

Skollahvilft and Innra Bæjargil both face SW and accumulate snow in northerly wind. The snow accumulation area is quite extensive, since there is a plateau above the gullies. When the wind blows from N-NE the transport of snow from the plateau can be enormous, as was the case before the avalanche in October.

Figure 1 shows the locations of the weather stations mentioned in the section about the weather. Ísafjörður is the largest town in the area, with about 3500 inhabitants. A snow observer has been working there for a long time, previously for the community, but now fulltime for the IMO. One of his duties is to measure the precipitation every day. An automatic weather station is, at the height of 753 m on Þverfjall, between Ísafjörður and Flateyri. At the other stations mentioned in the article the measurements are done mainly manually.

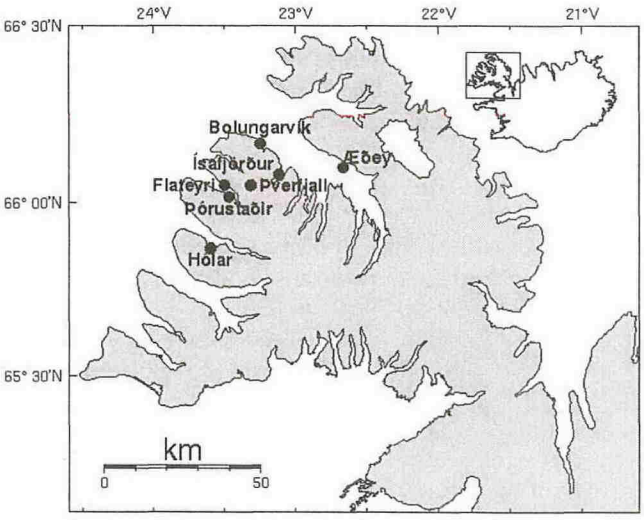

Figure 1. Vestfirðir, the Westfjords, Flateyri and the weather stations (Gunnar Guðmundsson)

THE AVALANCHE HISTORY OF SKOLLAHVILFT

Figure 2 shows the run-out zone of the avalanche as well as some the places in the village mentioned in the article.

Flateyri lies on a small reef into to ocean from the northern part of Önundarfjörður. The reef is quite flat up towards the houses that stand closest to the mountain at an elevation of less than 10 m. Those houses were built after 1970 and there were not any buildings farther uphill than where the church stands now, until after 1930.

The avalanches that went down to the uninhabited area have usually not been noticed or recorded when there was not any damage or accident.

Some of the gaps in the avalanche history have been filled after the accident in October 1995. People are concerned and willing to give interviews to inform about the old avalanches remembered. It was not customary to collect such information in the past, except when there was an accident or some severe damage. People are shocked. This was the third avalanche in 2 years that left dead victims behind in a small area. One fell in Súðavík in Jan. 1995, killing 14 people. Another one fell in Seljalandsdalur, the skiing area for Ísafjörður, down to Tugnudalur, damaging summer cottages and killed one person, just after Easter 1994. It could have been a bigger disaster just some few days earlier, when many people stayed at the cottages. All of these avalanches went further than expected on the risk maps.

An effort has been made to collect all available information by interviewing the local people of Flateyri and going through literature. The reviewed avalanche history will be published in 1998.

At present the avalanche history of Flateyri includes 23 recordings about avalanches from Skollahvilft. Information about 7 previously unknown old avalanches from Skollahvilft has been obtained from interviews and recorded since the accident and 4 more avalanches have been extended, i.e. they went further than previously recorded.

The avalanche in October 1995 has the longest run-out distance of all of the known ones, 4 more went down to the museum (figure 2) or further, and 7 more down below the graveyard.

Some of the inhabitants said that avalanches fell down to the road which is above the lagoon, every year. These are not included here.

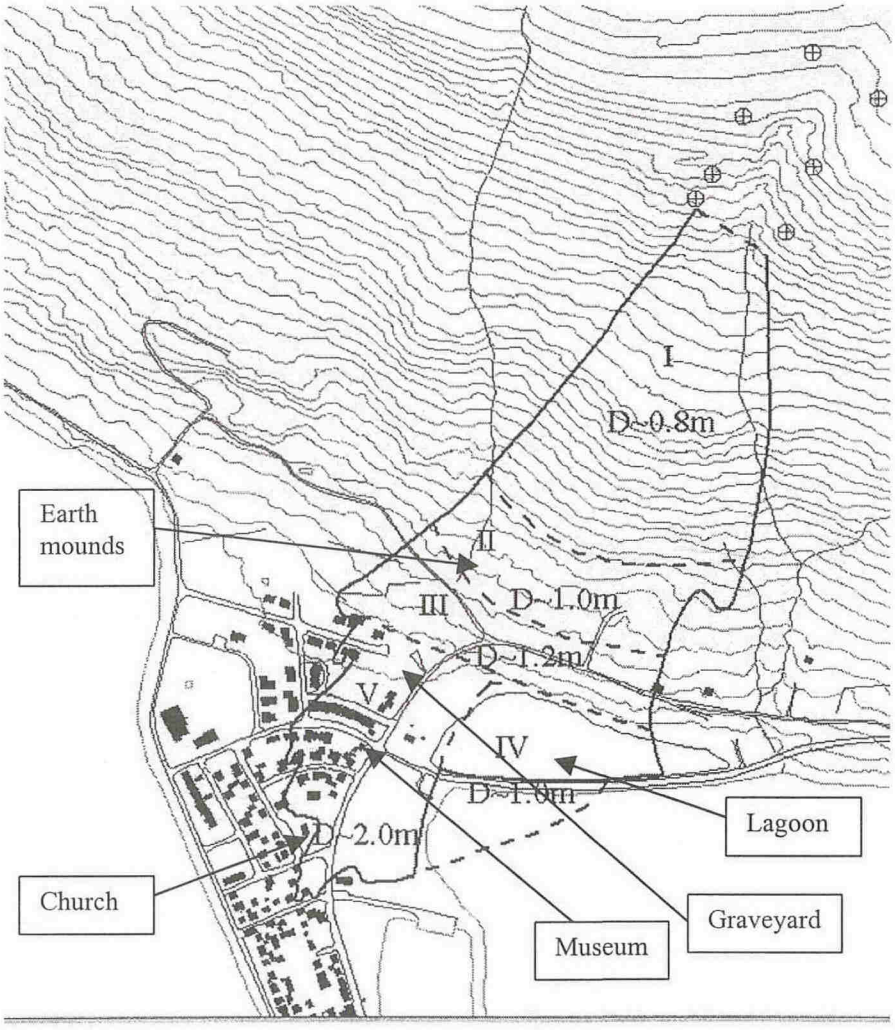

Figure 2. The avalanche and the zones of "equal" depth, ⊕ show places of signs on ground

WEATHER

The weather forecast

At the Icelandic Meteorological Office (IMO) the weather forecast indicated a series of lows as the main influence on weather during a period in late October 1995. After the first series of lows during 21.-23.10.1995 the first avalanche struck a factory in Ísafjörður, Steiniðjan. Then a series of lows with more snowstorms in the NW was expected.

Evacuation

Following the avalanche-zone map, valid at the time, local authorities in Flateyri evacuated the avalanche endangered areas on the evening of the 24th.

Weather maps and analysis

Einar Sveinbjörnsson wrote an article shortly after the accident about the weather conditions (1995). Roughly translated: *The catastrophic weather last week was caused by very unfavorable circumstances in the atmosphere, so early in the autumn, that the late summer air masses were still dominating Britain and N-Europe, while at the same time the king of winter was governing off the E-Greenland shore.*

Weather maps follow on figures 3 and 4. They show the analysis on 25.10.95 at 00, and on 26.10.95 at 03.

From 21.10.1995 until the avalanche fell from Skollahvilft, there were lows in the vicinity or moving across the country.

During the first days the lows came from the SW or W, causing snow in the Westfjords. After that the lows approached from the S and SE (figures 3 and 4). A high over Greenland kept their speed down so their influence in Iceland lasted longer. The pressure gradient was high between Greenland and Iceland and across Iceland as well.

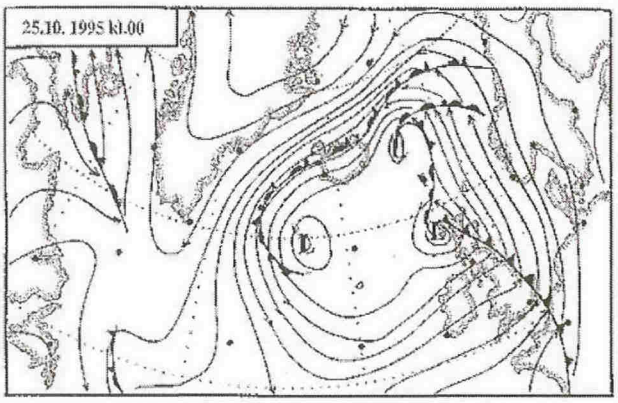

Figure 3. Weather analysis 25.10.95 00:00 (Trausti Jónsson)

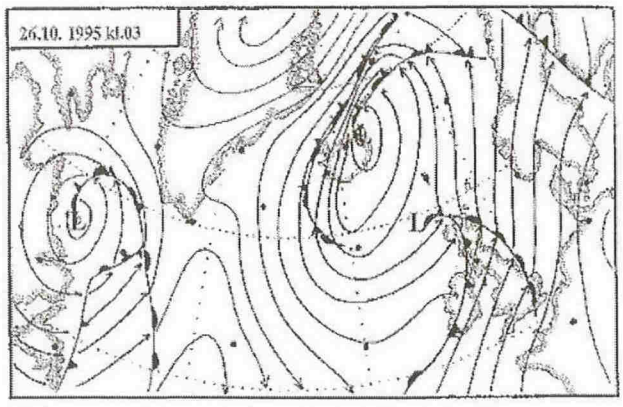

Figure 4. Weather analysis 26.10.95 03:00 (Trausti Jónsson)

On the 25th at 00 (figure 3) a low was south of Iceland with a frontal area across the northern part of the country. The wind was enormous during the night of 24th to 25th the mean 10 min. wind speed at Þverfjall was up to 48 m/sec, i.e. 170 km/h or 93 knots. There was heavy precipitation in most of the country, mostly falling as snow, but as rain or sleet in the SE and E. The low that was just north of Scotland in figure 3 moved NNW and was slowed down NE of Iceland (figure 4). The two fronts shown in figure 4 provided heavy precipitation in the N and NW for a while, but the wind at Þverfjall was not quite as strong as the night before, only 26 m/s, i.e. 93 km/h or 50 knots.

Weather data from nearby stations

The following graphs show the temperature and wind measured on Þverfjall as well as measured precipitation at the weather stations on the lowland.

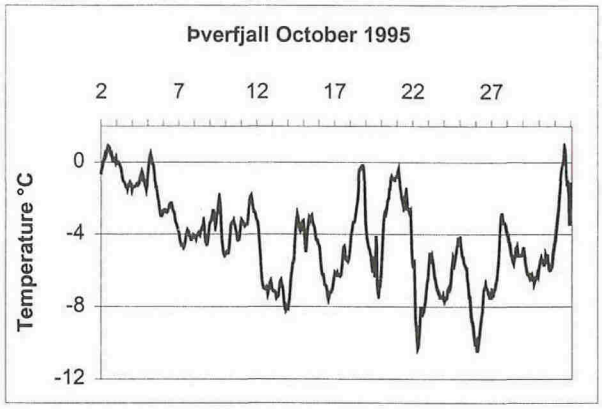

Figure 5. Temperature in October at Þverfjall, at the height of 753 m

During the 18th the temperature was highest at Þverfjall, or –0.2° to –0.8°C from 14:00 to 22:00. It has possibly been thawing a short while in Skollahvilft that day, building the layer seen later underlying the slab where it set off in the starting zone.

The temperature on the weather stations, except Þverfjall, went down to –4°C on the 22nd and around zero from 23.-24.10.1995. The next day it fell below zero and down to –4°C the 26th.

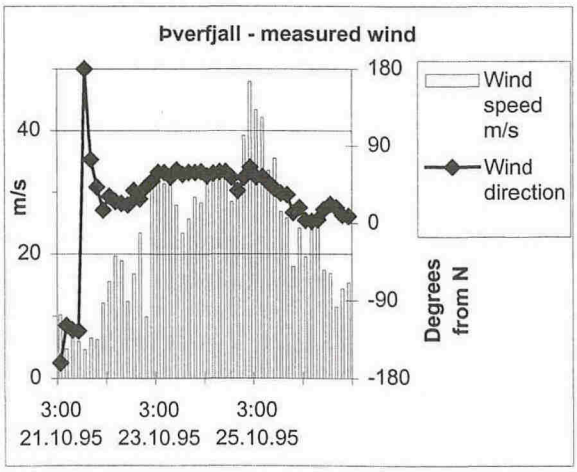

Figure 6. Wind at Þverfjall

Figure 6 shows the wind at Þverfjall. During most of this period the wind was blowing from NE and finally from N at the time of the accident.

According to Harald Norem (1994) the amount of snow transported is proportional to the third power of the wind force.

According to these, doubling the wind speed will result in eight times more transport of blowing snow.

The strong wind along with the lows and their fronts added to the transport of snow settling at the lee sides of mountains. With the wind blowing from the NE and then from the N, the bowl of Skollahvilft was filled from the most sensitive directions. Finally the snow slab ruptured and rushed down, gathering a lot of snow in Skollahvilft and on the way down the mountain side

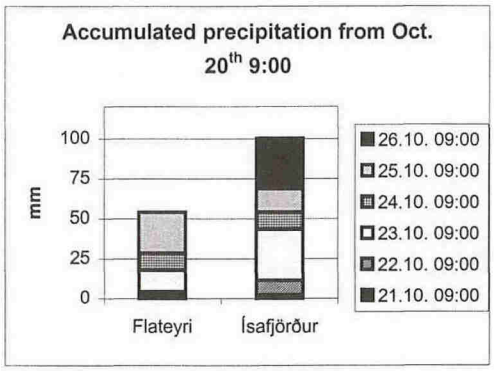

Figure 7. Accumulated precipitation the days before the avalanche

Figure 7 shows the accumulated measured precipitation at Flateyri and Ísafjörður during the period of snowstorms, measured 21.-26.10.1995 in Ísafjörður but only to the 25th in Flateyri, since the avalanche took the precipitation gauge.

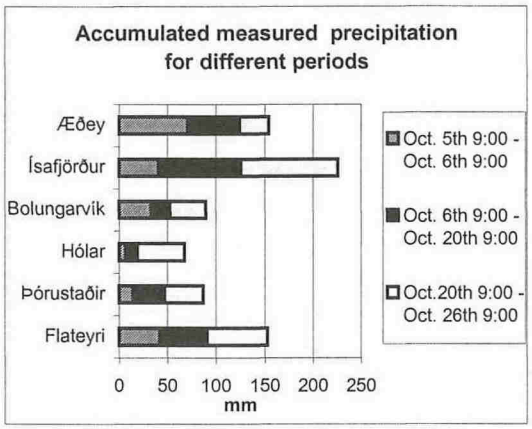

Figure 8. Accumulated precipitation around Flateyri

Figure 8 shows accumulated precipitation for different periods in all of these stations. The first part shows the precipitation for 24 hrs., i.e. from 05.-06.10.1995. It was over 40 mm both in Flateyri and Ísafjörður. The temperature was just going below zero on Þverfjall, so the precipitation has been falling partly as snow in the mountains that day.

The precipitation from 05.-20.10.1995 indicates, that there must have been some snow accumulation in the high mountains. The wind on Þverfjall during this period was mostly from northerly directions.

As before the precipitation for Flateyri is only until 25.10.1995.

The total amount could indicate the accumulated precipitation or snow during the cold period of the month in the high mountains.

According to E. J. Fröland et al. (1996) measured precipitation can be very inexact in strong winds and cold weather. The wind during this period indicates that probably all of these values are to low.

The inhabitants of Flateyri said they had never seen so intensive snowfall as during the night of 25th to 26th.

The morning after the avalanche, big trucks could not get around in the village because of snow, which is very unusual.

THE AVALANCHE AT FLATEYRI

The avalanche struck the village just before 4 a.m. when people were asleep. Some of them woke up by a sound and then a kind of explosion.

Figure 9. The 1st floor of a house floated with the avalanche

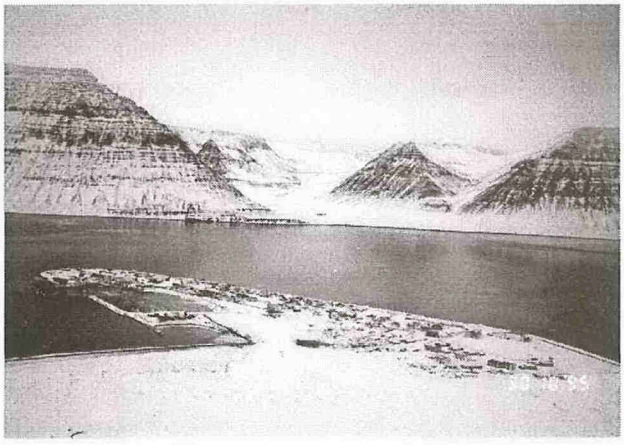

Figure 10. Flateyri seen from Skollahvilft on the 30.10.1995

One family slept on the 1st floor, which was swept off from the ground floor, and floated on top of the avalanche (figure 9). The ground floor was completely destroyed, but the family was safe.

The run-out distance of the avalanche was greater than known in the history of avalanches in Flateyri. The run-out

area was defined below the gully as is drawn in figure 2. A picture taken a few days after the avalanche (figure 10) shows an oversight over Flateyri from the cliffs to the W of the gully at the top of the run-out zone. The avalanche hit 30 houses and additionally touched 3. A total of 45 people were in the 30 houses, of which 25 were rescued, 5 of them injured, but 20 were killed. 16 houses were completely damaged, 7 were severely damaged, and 7 had minor damages.

The avalanche was thrown over the gully high up on both sides, and the x-markings on figure 2 show where marks were found on the ground in the spring of 1996.

There were three crowns or fractures seen in the starting zone 2 days after the avalanche fell. The main one was in the middle of Skollahvilft, approximately 90 m wide, on the average 2.5 m high but up to 3.7 m The main crown was at the height of approximately 630 m. At that location the depth of the snow that the slab glided on was 1.6 m, i.e. a total of 5.3 m snow depth in the direction of the crown which was 63°. At the bottom of the crown there was a 1-2cm thick hard layer, where the slab had broken originally. Probably it was formed 18.-19.10.1995, when the temperature went up towards zero at Þverfjall, since the height of the crown in Skollahvilft was just 120 m below it, which means approximately 0.5-1.0°C temperature difference.

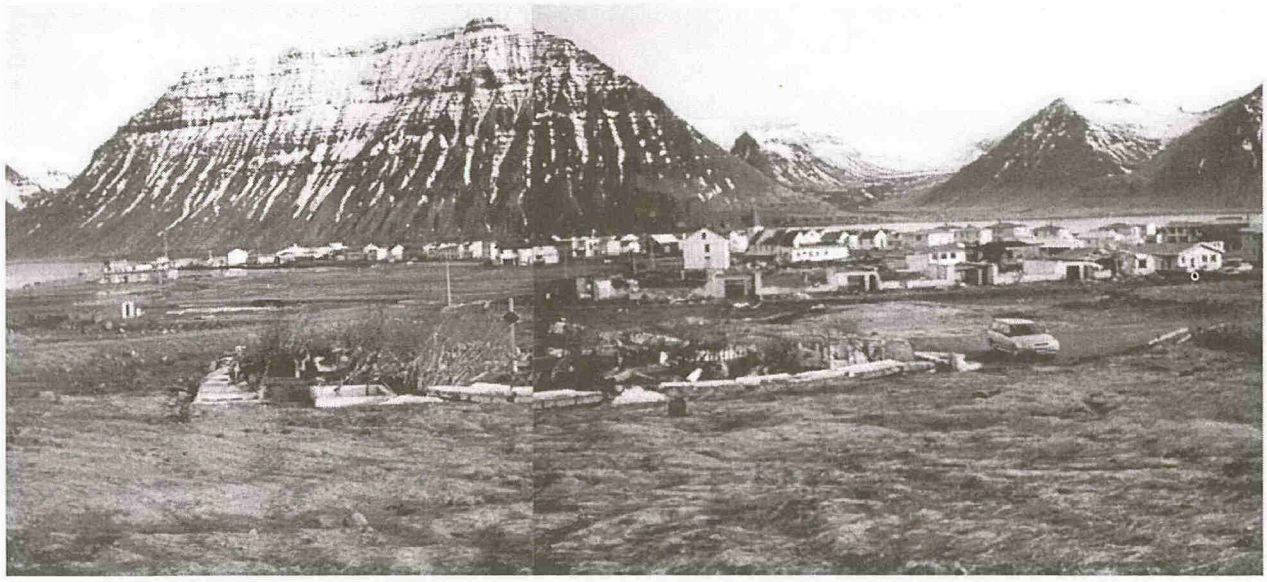

Figure 11. Flateyri in the spring of 1996

Figure 11 shows the graveyard and some of the ruins after the avalanche. The church can be seen farther down the "eyri", to the right of the center of the picture.

General information

The slope of the snow surface below the fracture was 48°. The slope of the bedrock there is about 40°. The density of the snow in the fracture was measured 2 days after the avalanche fell, and was 360 kg/m³. It is rather high, but consistent with the density Oddur Pétursson, the snow observer in Ísafjörður measured in the fracture zone after the avalanche at Seljalandsdalur-Tungudalur. It is also consistent with a measurement at an experimental site in a starting zone area above Siglufjörður, which lies in the north of Iceland. At that location the density was measured approximately
400 kg/m³ for new snow, according to Tómas Jóhannesson (unpublished data). In all of these cases the snow was accumulated in wind. This high density of the snow pack of relatively new snow and its cohesion explains perhaps why the snow slab did not break before building up to such a thick layer.

The average slope of Skollahvilft is approximately 30°, from the height of 180 m to 630 m, but 32° from the height of 300 m. The slope below the gully down to the village is 13°, but the slope from the village up to the crown is approximately 22°. The slope of 10° is a little bit above the location of the earth mounds, which form a kind of a belt located in zone II on figure 2.

The total length of the avalanche was 1850 m, the maximum width 450 m and the slope from the end of the avalanche to the main crown was 19° (the α-angle).

Calculations and speculations

The run-out zone was divided by the depth of the deposits into 5 regions (I-V in figure 2) and the volume calculated. The density of the deposits was measured 28.10.1995 and was 420 kg/m³. The snow depth on the run-out area before the avalanche fell was estimated in order to get the part originating from Skollahvilft. There were two possibilities considered, one with an equal depth of snow of 0.75 m, according to the snow on the roads when they were cleaned for the rescue teams, the other 0.75 m in the town , and increasing in the zones uphill, with a maximum of 1.3 m in the highest one. The density of the snow was estimated 250 kg/m³.

To try to estimate the snow depth in Skollahvilft before the avalanche fell, or rather thickness of the slab, the mass was recalculated for a density of 360 kg/m³. The horizontal area for Skollahvilft was roughly estimated from a map.

The average width was estimated to be 300 m and the length from 630 m height to 300 m height was 530 m. The area was then ca. 160.000 m². Possibly the staring zone included ca. 70% of Skollahvilft.

Table 1. Results of calculations

Description	Result	Thickness in Skollahvilft
Total area of deposits	350.000 m²	
Total volume	405.000 m³	
Total mass	170.000 tn	
Mass from Skollahvilft if the snow was 0.75 m in the area.	105.000 tn	2.6 m
Mass from Skollahvilft if the snow was 0.75 - 1.3 m in the area.	80.000 tn	2.0 m

The total depth of snow in the direction of the crown including its height was 5.3 m and its slope 63° as mentioned previously. The slope of the land surface at the location of the main crown is 40°. If the total snow depth is recalculated to be vertical, as measured usually, it would have been 6.7 m at the crown, so the results in the table are possibly rather too low than too high.

In the attempt to evaluate the volume and mass of the avalanche, as well as the thickness of the mass that rushed down from Skollahvilft, the conclusions from the calculations are quite inaccurate, since much of the data is based on estimation.

THE RETURN PERIOD

Tómas Jóhannesson (1998) calculated the return period of avalanches from Skollahvilft. An avalanche with a similar run-out distance as the one in October 1995 is estimated to have a return period of approximately 150 years.

THE AVALANCHE CYCLE

The avalanche cycle lasted 23.-26.10.1995. The first known avalanche fell at 3 a.m. and broke windows and a door at Steiniðjan in Ísafjörður and cut off a power line.

In the Westfjords there were a total of 28 avalanches recorded, of which at least 13 fell during the 23rd and the others on the 25th and the 26th. There were 19 recordings of avalanches from the 24th to the 26th from the northwestern part of Iceland, some including many avalanches in one recording.

An avalanche fell in Skutulsfjörður on the 25th at 14, and went through a new garbage plant, Funi. Luckily the two men at work were in the only room that was almost unaffected by the avalanche. In Súgandafjörður, between Flateyri and Skutulsfjöður, there was a large avalanche, which set off an ocean wave that destroyed a swimming pool and sunk a boat on the other side of the fjord.

In the NW horses were killed, trees damaged and properties on farms destroyed.

THE PROTECTIONS

After the avalanche from Skollahvilft the law has been changed. Now IMO is responsible for watching over the conditions for avalanche danger and deciding evacuation in cooperation with the local civil guard in each avalanche village or town. Evacuation maps have been made for every avalanche town and there are one or two snow observers in these towns working as employees of the IMO. They are in touch with an employee at the avlanche section at the IMO during the winter season and together they evaluate the avalanche danger.

Protection measures are being built above Flateyri. There is a V-shaped deflecting wall above the village that has been designed by VST and NGI (1996). Plans have been made for protections in the other towns as well.

The avalanche danger can never be completely eliminated. Adding to our knowledge about the avalanche history, as well as understanding better the nature that is behind this threat, is vital for the future protections against avalanche danger.

ACKNOWLEDGEMENTS

This article is primarily based on a more detailed report written in Icelandic about the avalanche at Flateyri and the avalanche cycle (Svanbjörg Helga Haraldsdóttir, 1998a). Trausti Jónsson at the IMO provided the weather maps and gave advice and he, Kristín Vogfjörð and Kristján Jónasson advised about the language. Gunnar Guðmundsson made a map with locations for this article.

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