HÖSKULDSVATN: CAUSE OF UNUSUALLY HIGH LAKE LEVEL IN 1991

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ABSTRACT

Lake Höskuldsvatn is located about 10 km southeast of Húsavík, North Iceland, at an elevation of 262 m. This lake has no surface outflow, and the lake level varies and is controlled by precipitation, evaporation and possibly by variations in the subterraneous path of flow from the lake. During the summer of 1991, the lake level was higher than previously observed and the cause of this anomalous lake level was of considerable concern. An investigation of the lake behavior indicates that the primary cause of the high lake level in 1991 was heavy precipitation during the preceding years, but ground deformation of the recent Krafla volcanic episode may have reduced the permeability and the hydraulic gradient of the ground water drainage from the lake.

INTRODUCTION

The lake Höskuldsvatn lies about 10 km southeast of Húsavík, north Iceland, in a tectonic depression controlled by the Húsavík fault, a NW–SE trending right lateral fault, a branch of the Tjörnes transform fault zone. Its elevation is 262 metres according to official maps and it has no surface outlet. The topography gives the catchment area of the lake about 30 km^2 (Figure 1), but because of high permeability of the Pleistocene and Holocene volcanic formations of the area, rain water seeps into the ground, and the effective catchment area is partly determined by the groundwater flow. The lake elevation is controlled by precipitation of the catchment area, evaporation and permeability of the geologic environment. This elevation varies considerably, but it has not been measured systematically.

It is known, however, that the lake level is higher in the spring than later during the summer, and the old road along the south shore of the lake has frequently been under water in early summer, while the winter snow was melting, but a bypass road was used under those circumstances. The lake level did not subside as usually during the summer of 1991, and was very high throughout the summer. In late July, the old road bypass became flooded, and a new track had to be laid to make the road passable. This had to be repeated later in the summer of 1991 because of further increase of the lake elevation. This high stand of the lake has never been observed since the road was opened almost 60 years ago, indicating some unusual circumstances in the hydrology of the area. However, on October 28, the lake level had subsided about 34 cm since August (Svavar Jónsson, pers. comm.)

There have been some speculations about the cause of this increased lake elevation, and several possibilities have been suggested. A frequently mentioned possibility is an increase in the precipitation. Another is increased melting of perennial snow fields in the mountains. The lake bottom may have become less permeable because of sediment influx, and even the regional permeability may possibly have decreased because of tectonic processes that have compressed the subsurface drainage channels.

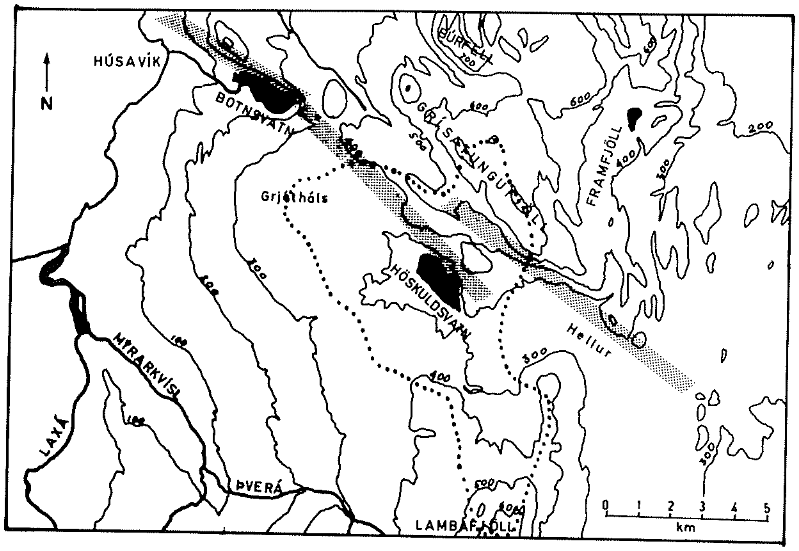

Figure 1. Map of Höskuldsvatn and the surrounding area. The Húsavík fault traces are shaded and the Höskuldsvatn catchment area is encircled by a dotted line. Contour interval is 100 m (redrawn from Landmælingar Íslands, 1980). *– Kort af nágrenni Höskuldsvatns. Misgengissprungan um Húsavík er skyggð og vatnasvæði Höskuldsvatns er merkt með punktalínu.*

PRECIPITATION

Meteorological observations have been made in the vicinity of lake Höskuldsvatn for more than 60 years, including measurements of the precipitation. However, it should be emphasized that measurements of precipitation during the winter are very inaccurate, because it falls mostly as snow, usually in moderate to strong wind. No simple devices to measure snowfall in strong wind do exist, and the measured precipitation is probably smaller, possibly much smaller, than the actual precipitation. This uncertainty of the measured amount is present mainly if the precipitation falls as snow, while during the summer, when the precipitation falls as rain, the measurements are more reliable.

The published precipitation data for stations in the vicinity of Höskuldsvatn reach back to 1929 at Húsavík, the nearest station, and back to 1936 to 1938 at the stations Grímsstaðir, Sandur, and Reykjahlíð (Veðurstofa Íslands, 1924–1990). The station at Húsavík has an almost continuous record, while the other stations have less continuous observations, and no annual precipitation is given for several years. However, the station at Húsavík has been moved several times within the community. This makes any comparison between precipitation of different periods very uncertain, as the measured precipitation, especially if it falls as snow, depends very much on the location of the meter, relative to houses and other features of the surroundings.

Table 1. Average annual precipitation in mm for each decade as measured at meteorological stations near Höskuldsvatn (From Veðurstofa Íslands, Veðráttan 1924–1990) — *Meðalársúrkoma í mm á veðurathugunarstöðvum í kringum Höskuldsvatn.*

Years	Húsavík	Reykjahlíð	Sandur	Mánárbakki
1931–1940	545			
1941–1950	472	402	455	
1951–1960	615	405	526	
1961–1970	782	412	548	544
1971–1980	799	414	602	539
1981–1990	888	473	574	610

Table 1 indicates steadily increasing precipitation during the last 5 decades at Húsavík and some increase is indicated at other stations in the area. If the catchment area of lake Höskuldsvatn has experienced similar increase in precipitation as observed at Húsavík, then the rise in Höskuldsvatn lake level may be entirely caused by the precipitation. It may be noted that the observed precipitation at Húsavík during the year of 1990, the last year of published data, exceeded 1200 mm, the highest annual value ever observed during the 62 years of precipitation observations at Húsavík.

SNOW MELTING

The mountains Grísatungufjöll lie partly within the catchment area of lake Höskuldsvatn. These mountains are known for heavy snowfall. In early summer, their snow cover exceeds that of mountains of similar elevation farther inland, as Lambafjöll and Gæsafjöll. Several small snow patches do not melt during the summer, but no glaciers have developed. There is probably minor accumulation of snow and ice during periods of unusually cool summers, as occurred frequently between 1960 and 1990, but this accumulation is assumed to be insignificant relative to the annual precipitation. The summer of 1991 was slightly warmer than the average, causing some of the accumulated snow patches of previous years to melt. However, this is certainly of no significance with respect to the total amount of water flowing towards lake Höskuldsvatn.

The meltwater during spring and early summer is generally transported by surface flow, while later in the summer, rain water enters the ground without forming surface streams. This is a characteristic of the part of Iceland covered by Pleistocene to Recent volcanics, where the ground is very permeable, but a thin layer of ice or frozen soil prevents the water from seeping down during spring and early summer. However, this has no effect on the total amount of water in the area, although the direction of surface flow may be different from the groundwater flow. It is quite possible, that a fraction of the rain water that seeps into the ground within the 30 km^2 catchment area of lake Höskuldsvatn as defined by the topography will not flow towards the lake, but take a subsurface path leading elsewhere. Similarly, rain water falling outside the catchment area of a lake may take a subsurface path towards the lake.

SEDIMENT TRANSPORT

It has been suggested that the bottom of lake Höskuldsvatn has become less permeable in recent years, causing less water to seep out of the lake. This effect is caused by sediments brought into the lake by meltwater streams during spring and early summer. It is certainly not known whether more sediment has been brought into the lake in recent years than earlier. Most of the catchment area of lake Höskuldsvatn has been subject to wind erosion in the past, removing most of the topsoil. Only limited wind erosion has been occurring in recent years.

Erosion by meltwater certainly exists, bringing some sediments into the lake. There is, to the best of my knowledge, no evidence for more rapid stream erosion in recent years than earlier. Increase in the number of grazing sheep in the area during the last four decades may have damaged the limited vegetation, resulting in gradually increasing erosion. However, this is a pure speculation, based on very limited information.

TECTONIC PROCESSES

The meteorological conditions in Iceland are characterized by low temperatures and high humidity. This means that evaporation is not very significant in the hydrological cycle and any lake with no surface outlet must have a subsurface drainage. In the case of Höskuldsvatn, this subsurface drainage must carry significant amount of water, at least 1 m^3/s on the average. This estimate is based on the catchment area which is about 30 km^2 and precipitation in excess of evaporation which is estimated to be more than 1000 mm per year.

If the subsurface drainage is confined to shallow conduits, then the surface topography will indicate the hydraulic gradient and hence the path of this drainage. Maps show that the saddle point to the east or southeast of the lake exceeds 280 m elevation, but not 300 m. Another saddle point to the southwest exceeds 300 m, but not 320 m. A third saddle point to the northwest, on the Húsavík fault, exceeds 360 m elevation.

Drainage to the east would carry the water through Holocene lavas into the Þeistareykir fissure swarm, and towards north, east of the Tjörnes mountains. Great fresh water springs are found at sea level in this area.

Drainage to the southwest would carry the water through Pleistocene lava and glacial moraines towards Reykjahverfi, where it would supposedly create rather large springs. No such springs are found in the most probable area, which excludes this path for the subsurface drainage of lake Höskuldsvatn.

Drainage to the northwest, along the Húsavík fault, would carry the water towards the lake Botnsvatn, where water flows from several rather large springs. However, the location of the springs does not favor drainage from the Höskuldsvatn area towards lake Botnsvatn.

This leads to the conclusion that the probable path of the subsurface drainage of lake Höskuldsvatn is towards east, through Holocene lavas and the Þeistareykir fissure swarm, towards Lón in Kelduhverfi. This path lies in an area where considerable ground deformation did occur during the period of the Krafla fires, 1975—1984, although limited observations exist in this area.

The flanks of the Krafla fissure swarm are known to have been compressed in E–W direction simultaneously with the widening of the fissures (Tryggvason, 1984). This compression occurred in the area east of lake Höskuldsvatn and may have changed the flow characteristics of the aquifers. Another characteristic of the ground deformation is the uplift of the flanks of the fissure swarm. This caused tilt up in easterly direction in the area of lake Höskuldsvatn, as measurements of 1976 and 1980 show when related to earlier measurements (Tryggvason, 1981). The ground tilt from 1972 to 1980 near lake Höskuldsvatn was about 12 microradians, up towards northeast. In the Þeistareykir fissure swarm, this tilt was about 15 microradians up towards east, and at a location due east of Höskuldsvatn and 7 km west of the central axis of the Krafla fissure swarm, a tilt of 75 microradians was observed from 1972 to 1980. This tilt represents uplift of the region through which the subsurface drainage occurs, relative to lake Höskuldsvatn.

Thus, both horizontal compression and ground tilt is likely to restrict somewhat subsurface drainage from lake Höskuldsvatn towards east.

Measurements of one short line of precision leveling in October 1991 indicate that the ground tilt in this area has continued after 1980, which is not surprising in light of the continued volcanic activity in 1980 through 1984.

It cannot be estimated at this time how much effect these tectonic processes have had on the subsurface drainage of lake Höskuldsvatn. They may be insignificant.

MEASUREMENTS 1991

In the fall of 1991 the elevated surface of lake Höskuldsvatn caused some concern among the local population. A farmer found fissures in the ground in an area 12 to 15 km south of lake Höskuldsvatn, which he judged as recent. These fissures were found in soil. Their direction was irregular and the width was frequently about 5 cm.

An expedition was arranged on October 21 to investigate these fissures. At that time, some snow had covered the ground, making search for small fissures difficult. However, some irregular fissures were found at a location 3.5 km southeast of the farm Heiðarbót at about 350 m elevation. These fissures were in thick soil, clearly caused by frost action, and thus not related to any tectonic processes, nor to the unusually high water level of lake Höskuldsvatn. It has not been verified if the fissures found beneath the snow cover were the same as seen by the farmer in snow free ground one week earlier, but his description indicates the same type of fissures.

It was decided to relevel a line of precision leveling, immediately southeast of the south end of lake Höskuldsvatn, to determine if any significant ground deformation had occurred since last leveling of this profile in July 1980. This leveling was conducted on October 22–23 under less than ideal conditions. The ground was frozen and partly covered by snow at the beginning of this leveling, but the weather was warm, causing snow and frozen ground to thaw. However, an acceptable result was obtained by covering the line three or four times.

This leveling indicated a ground tilt of 10.8 microradians up towards an azimuth of 115 degrees, or 25 degrees south of east since 12 July 1980. This compares with observed tilt of 10.6 microradians, up towards an azimuth of 64 degrees, or 26 degrees north of east, between 30 June 1976 and 12 July 1980.

Thus the up-slope tilt vector points towards the region where greatest tectonic and volcanic activity occurred during the two periods respectively. During the period June 1976 to July 1980, greatest widening of fissures took place in the central to northern part of the active part of the Krafla fissure swarm, with the greatest rifting events of January, July, and November, 1978 and May 1979, occurring mainly between Hrútafjöll and the Kelduhverfi lowland, while the activity of July 1980 through 1984 was concentrated south of Hrútafjöll.

There is every reason to assume that the observed tilt between levelings of July 1980 and October 1991 did occur during the period 1980 through 1984, while there was still high rate of volcanic and tectonic activity in the Krafla region.

CONCLUSION

The increased elevation of the Höskuldsvatn lake level is primarily caused by increased precipitation during the last decades. The tectonic processes in connection with the recent volcanic activity of the Krafla region may have contributed to the high lake level by restricting the subterraneous water channels, and by changing the tilt of these channels. The hypothesis that influx of sediment into lake Höskuldsvatn may have contributed to this high lake level is not supported by any known evidence. Fresh ground fissures west of Lambafjöll are surface features, not related to the high water level of lake Höskuldsvatn.

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ÁGRIP

HÖSKULDSVATN: ÓVENJUHÁ VATNSSTAÐA 1991

Sumarið 1991 var vatnsstaða Höskuldsvatns svo há að gamli vegurinn yfir Reykjaheiði varð ófær af þess sökum. Vitað er að hátt er í vatninu á vorin, þegar snjó er að leysa þar í nágrenninu, en vatnsstaðan lækkar jafnan er líður á sumarið og gamli vegurinn frá Húsavík til Kelduhverfis hefir ekki orðið ófær snemma sumars vegna hæðar Höskuldsvatns eftir að hann var opnaður fyrr en 1991, enda þótt oft hafi þurft að aka utan vegar á melunum við vatnið þegar hátt var í því. Há staða Höskuldsvatns sumarið 1991 vakti athygli vegna þess að vatnið hækkaði í júlí og ágúst, þegar venjan er að lækki í vatninu, og auk þess var vatnsstaðan hærri en nokkru sinni fyrr að því er kunnugir töldu.

Höskuldsvatn er afrennslislaust á yfirborði, en vegna mikillar úrkomu og lítillar uppgufunar hlýtur allmikið vatn að renna neðanjarðar frá vatninu. Sennilega liggur leið vatnsins um hraunin til austurs sunnan Sæluhúsmúla og síðan til norðurs í Lón í Kelduhverfi.

Ástæða þess hve hátt var í Höskuldsvatni sumarið 1991 er að líkindum óvenjumikil úrkoma, en úrkomumælingar á Húsavík benda til meiri úrkomu á síðustu árum en fyrr, sér í lagi á árinu 1990 þegar mældist rúmlega 1200 mm ársúrkoma, sem er meira en tvöföld meðalúrkoma 1931–1960. Þessar úrkomumælingar þarf þó að taka með gát vegna þess að aðstæður við mælingarnar hafa breyst og mælingastaður hefir verið fluttur nokkrum sinnum, en aðstæður á mælistað ráða miklu um hve mikil úrkoma mælist, einkum ef um snjókomu er að ræða.

Hreyfing jarðskorpunnar í nýliðnum Kröflueldum hefir valdið nokkru landrisi austan Höskuldsvatns, miðað við landið við vatnið. Þetta hefir áhrif á neðanjarðar rennsli til austurs frá vatninu, og hefir sennilega valdið einhverri vatnshækkun síðan 1975, umfram áhrif af aukinni úrkomu.

Mýrdalsjökull, horft til vesturs. Í forgrunni er norðurhluti Mýrdalssands og Kötlujökull (Höfðabrekkujökull). Sunnan hans er Háabunga en Kötlukollar norðan. Nyrðri farvegur jökulhlaupsins 1918 sést greinilega í Krika, norðan Kötlujökulsins. Fjær sést til Eyjafjallajökuls. Ljósm. Oddur Sigurðsson, 10. nóvember 1976.
Mýrdalsjökull, viewed from the east towards Eyjafjallajökull, across the outlet glacier, Kötlujökull. Photo. Oddur Sigurðsson, November 10, 1976.