A natural Calorimeter at Grímsvötn; an Indicator of geothermal and volcanic Activity

HELGI BJÖRNSSON
Science Institute, University of Iceland,
Dunhagi 3, 107 Reykjavík, Iceland

ABSTRACT

The heat output of the subglacial geothermal area at Grímsvötn is estimated from the total volume of water in jökulhlaups which originate from the caldera. The volume melted by the subglacial heat source is estimated by subtracting the glacier surface ablation from the total water volume. Variations in heat output are presented for the last 125 years. An average or base heat flux of 4000–5000 MW, derived by this method, is in agreement with a former estimate of the average heat flux, which was obtained by a mass balance study on the glacier. This heat flux has been explained by the heat extraction of water penetrating into hot rock boundaries of magma. A decline has been observed in this base flux over the last 80 years, which may be due to lack of recharge to the magma body. In the same period a comparable increase has been observed in the heat output of another thermal area 10 km northwest of Grímsvötn. Four peaks in the heat flux at Grímsvötn rise by a factor of 2 to 3 above the base flux. We suggest that at least two of them are caused by intrusion of magma at the base of the glacier.

The total inflow of magma into the Grímsvötn area is estimated to be about 50×10^6 m^3yr^{-1} of which 3% has been extruded on the ice cap surface, 10% transported to the glacier bed and 87% have been solidified in the upper crust. This inflow of magma equals the average annual rate at which magma has been erupted to the surface of Iceland. The heat energy removed by volcanic eruptions is an order of magnitude less than the heat removed by hydrothermal convection.

INTRODUCTION

At Grímsvötn in Vatnajökull nature offers a unique calorimeter for estimating the heat flow from a geothermal area. (Fig. 1). The ice cap covers the thermal area and almost no heat escapes into the atmosphere. Hence, the volume of ice melted at the glacier bed is a measure of the heat released by thermal activity within the area. A long-term mass balance model for the drainage basin has given an estimate for the average heat flux at Grímsvötn of 5000 MW (*Björnsson* 1974). The heat flow can be estimated by an alternative approach. First we estimate the volume of meltwater which drains down to Skeidarársandur in jökulhlaups from Grímsvötn (Fig. 1), second the volume melted at the thermal area is separated from the total volume of the jökulhlaups by subtracting the surface ablation. This approach does not only give an average value for the heat flux, but also hints at fluctuations in the heat output.

OBSERVATIONS

Since 1934 all jökulhlaups from Grímsvötn have been observed by scientists who have estimated their volumes. All the way back to 1850 estimates of volumes exist. They have been inferred from detailed descriptions of the floods by inhabitants in the flood area, and based on comparisons with measured floods after 1954 (*Thorarinsson* 1974, *Rist* 1955, 1976, *Stefánsson* 1983). A conservative estimate of the water volume is given in Fig. 2a. For calculating the volume melted by the subglacial heat source, glacier surface ablation of 0.15 km^3yr^{-1} was subtracted from the total volume of the jökulhlaups. This value for the ablation is based on observations on Vatnajökull for the last 30 years (*Björnsson* 1974) and may be a rather high value for the whole period considered. Fig. 2b shows the computed rate of melting by the subglacial heat source and the heat flux required to melt ice at that rate. In this estimate we have assumed that each jökulhlaup drains out the volume of water melted since the last jökulhlaup. This implies that the lake is assumed to drop down to the same level in each jökulhlaup. Exceptions from this rule may introduce false fluctuations. If the lake level fell less than normal in one jökulhlaup, the rate of melting since the last flood would be underestimated, but