Ten years of thermal evolution of the Gjálp edifice: 1996 - 2006; Implications for jökulhlaup hazard

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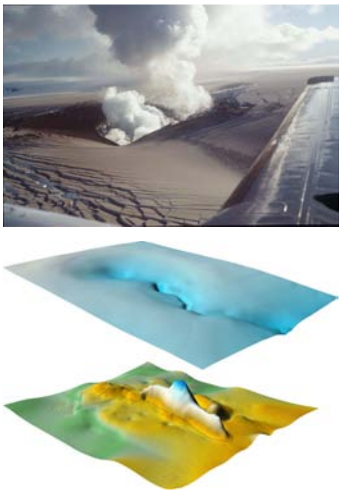

Fig 1.:
top down:
Photograph of the Gjálp eruption site and a 3D model of the Gjálp edifice, view from SW.
(based on Gudmundsson et. al. 2002)

Introduction:

The Gjálp eruption (Figs. 1,2) in 1996 formed a 6 km long and 500 m high subglacial hyaloclastite ridge. During the eruption a large depression was formed in the surface of the Vatnajökull ice cap as ice melted and the meltwater drained away from the eruption site. Ice flow measurements and surface depression mapping have been done annually since the eruption, allowing inflow of ice and volume changes of the depression to be monitored. Taking into account the surface mass balance, these data can be used to estimate heat output from the subglacial ridge. The results (Figs. 3,4) indicate several months of very fast ice melting after the eruption, followed by a 4 - 5 years period with major geothermal activity in the ridge, while in the last 4 years the ridge appears to be much cooler.
If this behaviour is characteristic for a cooling volcano of this type, it implies that considerable jökulhlaups may happen in the first several months after an eruption but little jökulhlaup hazard persists when a few years have passed.

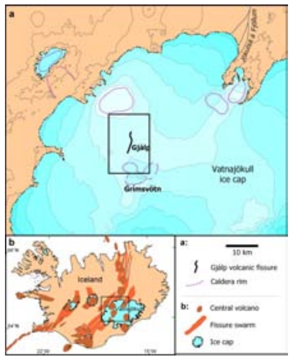

Fig 2.:
Location map.

To estimate the heat output of Gjálp (Fig. 4) the principle of 'conservation of mass' was applied to the system. The ice flow rates into the system were estimated from the measured surface velocities. Combining these results with the surface depression volume changes (Fig. 3) and surface mass balance data it is possible to estimate the melting rates at Gjálp edifice.

The heat output after 1998 was averaged over two four-year periods 1998 - 2001 and 2002 - 2005 respectively. The average power for 1998 - 2001 was 880 ± 140 MW but in the period 2002 - 2005 the power was 30 ± 140 MW.

The preliminary conclusion is therefore that no significant melting occurred at the base at Gjálp after 2001. However, a small ice cauldron with steep walls exists at the site of the subaerial crater of Gjálp, suggesting that some heat remains at the site of the main crater of 1996.

The inflow rates from the north into the Gjálp area were constrained with a numerical, Full Stokes ice flow model. A method for estimating the basal heat flux by simulating the glacier surface evolution was developed and successfully tested on the eastern side of Grímsvötn caldera (Fig. 5). This method will be applied in the near future to the Gjálp data and will help to constrain and improve the heat output record.

Ridges of similar size and shape to that of Gjálp are prominent features of the volcanic zones in Iceland. An important constituent of these ridges is consolidated hyaloclastite, formed by alteration of the volcanic glass into palagonite. The rate at which this alteration takes place for ridges formed in short-lived subglacial eruptions is unknown. However, apparently in most cases they have acquired considerable consolidation before glacial erosion could remove the initially unconsolidated hyaloclastite pile. In the oceanic island of Surtsey, formed in 1963-1967, the rate of alteration was temperature dependent and took a few years. It is possible that the 5-6 years of geothermal activity at Gjálp was sufficiently long for consolidation but this remains speculative until examined by drilling.

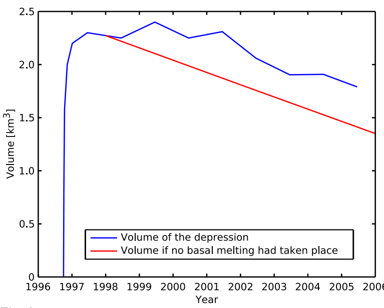

Fig. 3:
Volume evolution of the surface depression above the Gjálp hyaloclastite ridge.

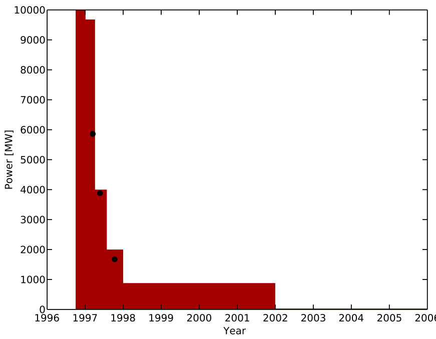

Fig. 4:
Heat output of Gjálp estimated from surface depression changes plotted in red. The black dots are combined InSAR and GPS results from S. Gudmundsson et. al., (2002)

2-D flow model study in Grímsvötn: 1998 - 2004

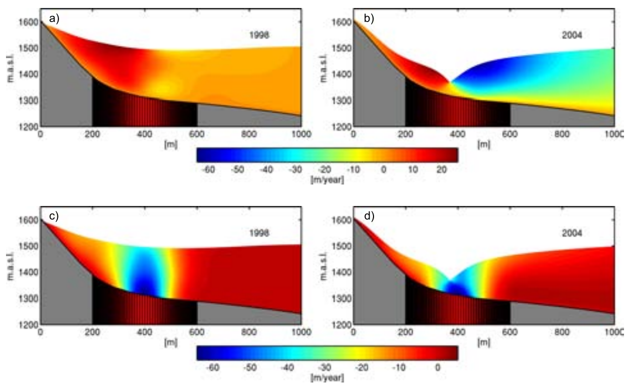

Fig. 5:
The numerical method for estimating the heat flux at the base of a glacier by simulating the glacier surface evolution was tested on the eastern side of the Grímsvötn caldera.

This method resolves the horizontal (a)/(c) and vertical (b)/(d) components of the flow field through time. At the Grímsvötn caldera a 6 years period was simulated including a surface mass balance measured for this area of Vatnajökull. By matching the simulated surface evolution with the measured data, it is possible to infer the heat flux at the base of the glacier.

In the test case of Grímsvötn, a heat flux of 280 W m^{-2} was estimated assuming a constant heat flux over the 6 years period. A sensitivity study of the model parameters proved the method to be very useful if sufficient field data is provided. (Jarosch and Gudmundsson, 2006)

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