

Volcanogenic hazards and risks to road systems

Preliminary assessments at Snæfellsjökull

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The Leverhulme Trust

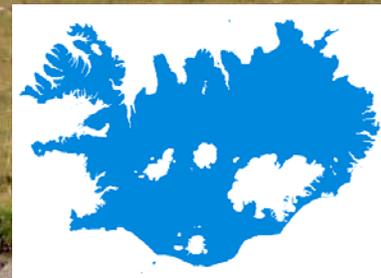


Vegagerðin-supported projects

2005 – 2007: **Holocene jökulhlaups from Snæfellsjökull**
KTS

2007 – 2008: **Quantifying volcanic hazards and risk for road systems – case study at Snæfellsjökull volcano.**

KTS, FS, Amy Clifton, Guðrún Larsen, Hreggviður Norðdahl, Rósa Ólafsdóttir (all at Jarðvísindastofnun Háskolans), Haukur Jóhannesson (ÍSOR)



Assessing hazard

Hazard:

A threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period.

NOT TO BE CONFUSED WITH Volcanic activity.

- **Collect a record of past eruptions**
- **Determine the frequency of past eruptions**
- **Define “time period” of reference**
- **Identify volcanic processes which may occur.**
- **Determine the probability that an area will be affected by any volcanic event.**

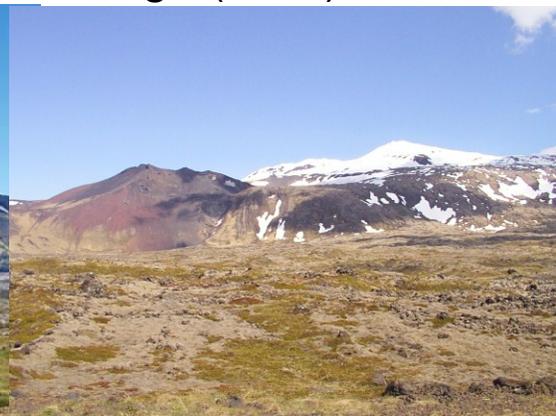
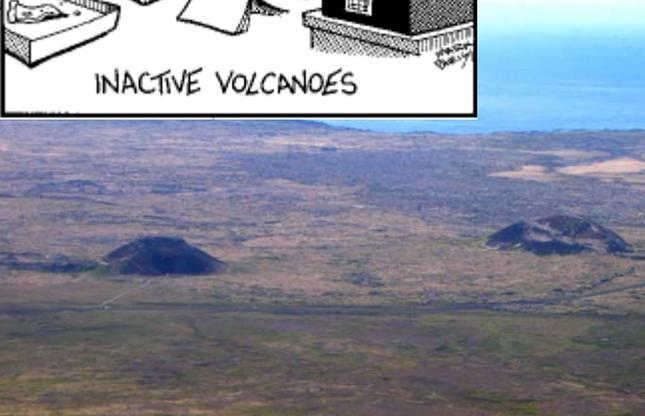
Past activity of Snæfellsjökull



Snæfellsjökull – somewhat older than 700,000 years.

Pleistocene – period of major glaciations - glacial palagonite formations (moberg: subglacial eruptions) and interglacial lavas.

Holocene, last c.10,000 years: over 25 eruptions have occurred from the central volcano producing lava, tephra and jökulhlaup or lahar events. Three major plinian eruptions - the most recent being c.1855 radiocarbon years ago (Sn-1).



Past activity of Snæfellsjökull

Major Holocene eruptions:

Sn-1: 1855 ± 25

Sn-2: 3960 ± 100

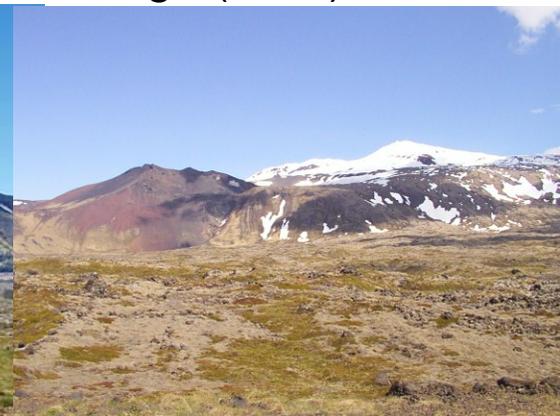
Sn-3: c.7000 - 9000

Ages in radiocarbon years B.P.
(Steinthórsson 1967,
Jóhannesson et al. 1981,
Larsen et al. 2002)

Snæfellsjökull – somewhat older than 700,000 years.

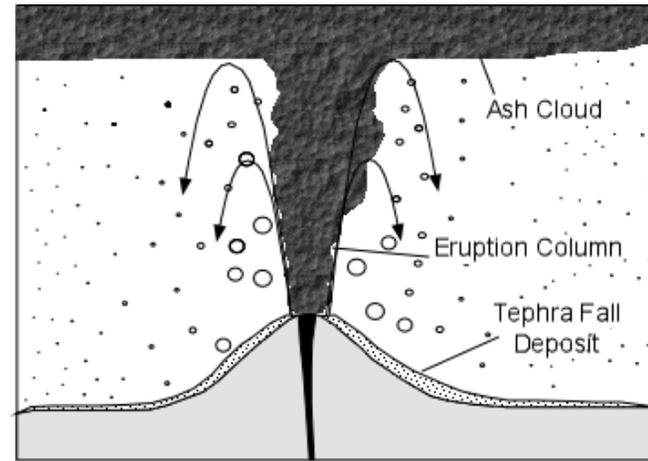
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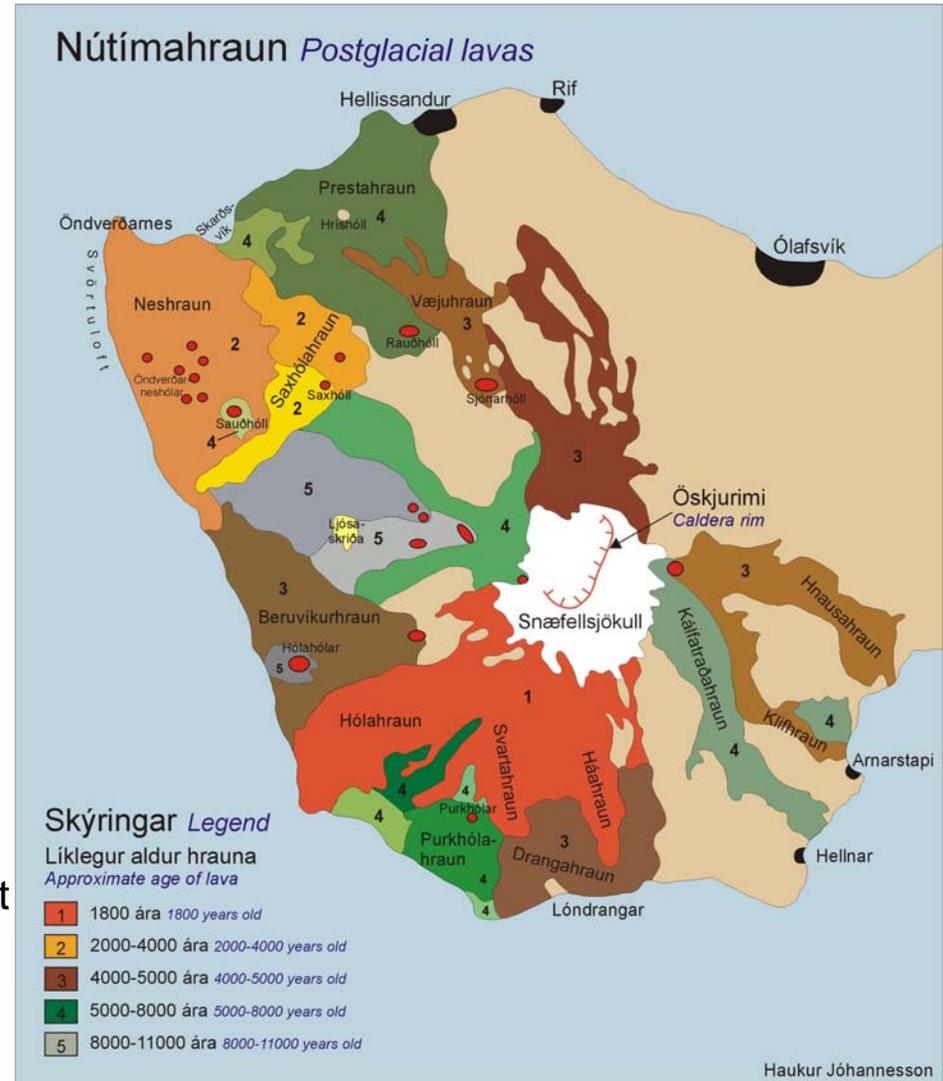
Tephra fall

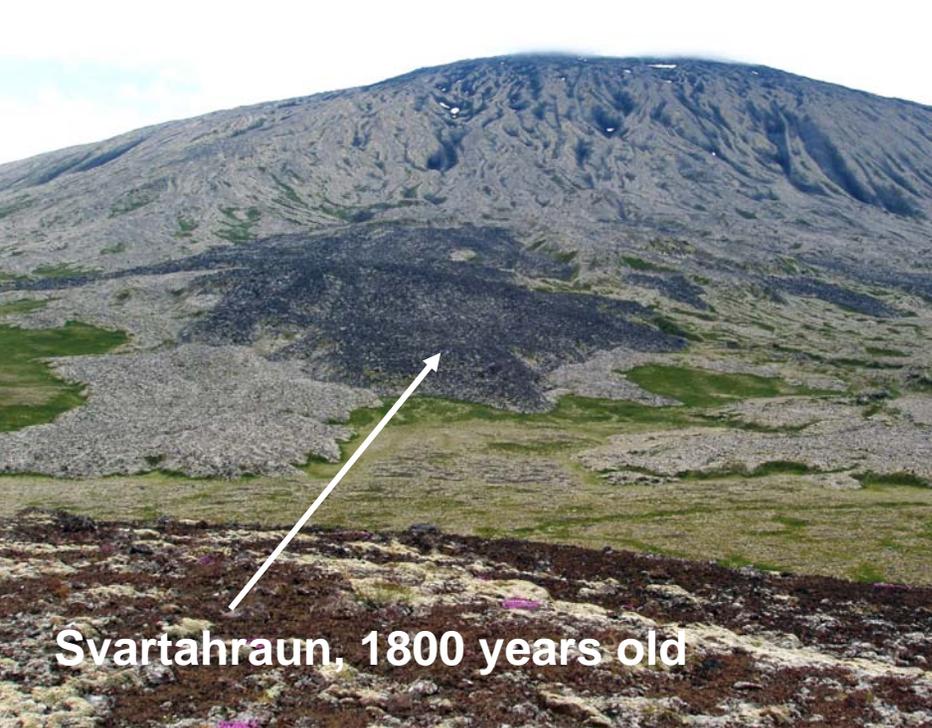
- **Tephra** has been produced from the central volcano and also from local small craters and fissures on the margins of the volcano and on low land surrounding Snæfellsjökull.
- Haukur Jóhannesson et al (1981) identified past tephra isopachs with axes orientated to the northeast of the volcano. Thickness of tephra deposition reduces with distance from the volcano (>5m thick at <3km, **20cm thick at 5-10km (e.g. in Ólafsvík)**, 5-10cm thick at 15km, 1-2.5cm thick at 45km).
- Snæfellsjökull central volcano airfall tephra has been deposited to the west and south of the volcano, although dramatically thinner than to the northeast (less than 10 cm).
- Central caldera tephra is predominantly **pale, vesicular pumice** of very low density, capable of floating on water.
- Local craters, for example Saxhóll, produce dark, more **dense basaltic tephra and scoria**.



Lava flows - postglacial

- Lava flows are distributed **radiating** in virtually every direction from the volcano. Higher topography to the northeast limits the spread of lava flows in that area.
- The most recent central caldera eruption ($S_n=1$) sent lava flows to the **south and south-west**.
- Young flows are also found on the low plains around the volcano, associated with local craters and a shield-type feature to the northwest.
- Pre-Holocene flows are found to the **north and east**.
- Lower-flank craters produced basaltic lava flows and upper-flank craters intermediate-to-silicic material.
- Flows from the main caldera and flank fissures are thick, with steep flow fronts, indicating viscous, slower flow. **Aa lava** (apalhraun)
- Flows on the lower land are thinner, most probably reflecting more runny lava with higher flow rates. **Pahoehoe lava**. (helluhraun)





Svartahraun, 1800 years old



23 m

Kálfatraðahraun, 5000-8000 years old.

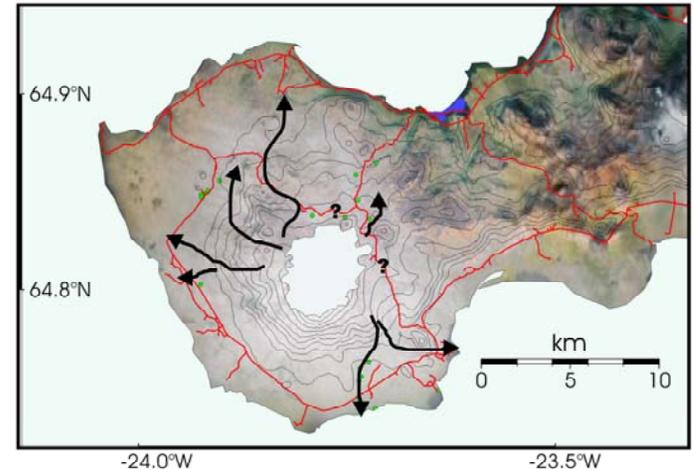


15 m

Háahraun, 1800 years old.

Floods / jökulhlaups / lahars

- Floods/lahars have flowed in most directions from Snæfellsjökull, mainly transporting pumice clasts.
- These floods were relatively small in comparison with historical Katla and Grímsvötn floods due to the smaller icecap and the numerous directions of flow.
- More extensive, larger-scale floods flowed to the north and east out of the main outlet glaciers draining the caldera.
- It is likely that some of water-transported pumice deposits on the southern and western slopes were emplaced by post-eruption rain-triggered lahars, remobilising the thick, unconsolidated airfall pumice deposits.

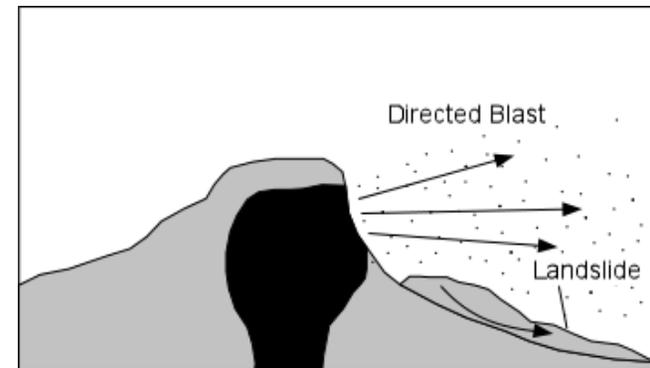
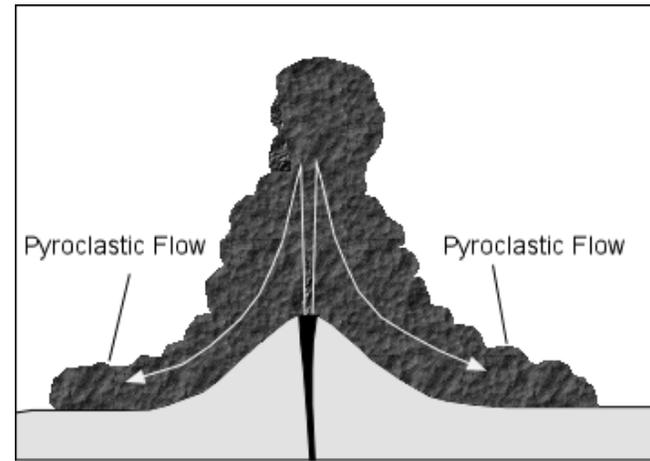


“Fluvially transported pumice deposits”



Pyroclastic flows, surges, wave effects and lateral blasts

- Pyroclastic flows, surges and wave (small-scale “tsunami”) effects may be likely events in a future eruption, based on the behaviour of other stratovolcanoes. No evidence of these has yet been identified in the geological record.
- It has been suggested that Snæfellsjökull may have experienced a lateral collapse/blast, like Mount St. Helens did in 1980, and may do again in the future. No evidence has yet been found for this (H. Jóhannesson, pers. comm., 2005).



Volcanogenic hazard at Snæfellsjökull

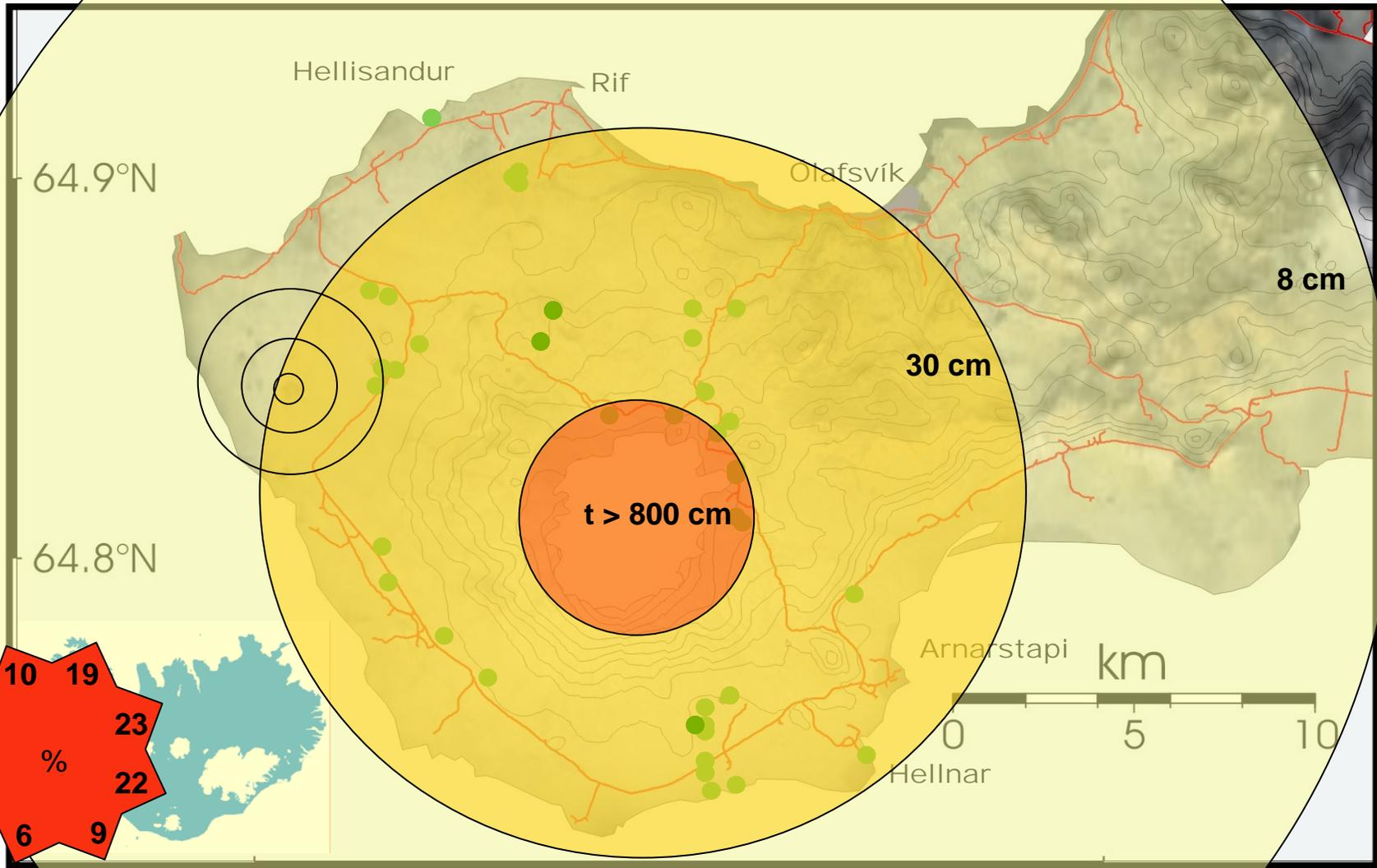
Two most likely scenarios:

- small crater eruption from the flanks or lowland or
- major central caldera eruption with limited or no ice cover.



Volcanogenic hazard at Snæfellsjökull

- **Tephra:** to the northeast due to dominant wind directions, although this depends on local wind direction. Most far-reaching hazard.
- **Lava:** will flow along dominant channels and spread out over flatter surfaces. The locations depend most on the location of craters/fissures in terms. Holocene lavas are primarily located in the west and southern sectors and older lavas to the north and east. Therefore, south and west are more likely to experience lava flows.
- **Jökulhlaup/lahar:** the occurrence of jökulhlaups depends on the extent of the ice cap or snow cover at the time of the eruption. Due to the small ice cover now and patterns of snow accumulation, the highest jökulhlaup hazard is to the north, with smaller jökulhlaup hazard from ice or snow covered fissures/craters along the caldera rim to the south and west. Post-eruptive lahars caused by moving of sediments by heavy rain are most likely.
- **Related earthquakes:** Earthquake hazard associated with an eruption of pre/post-eruptive volcano deformation is likely. This could cause rockfalls and damage to roads.
- **Pyroclastic flow, wave effect and gases:** These are likely although since there is no known geological record of these their extent has yet to be assessed. Comparisons with similar volcanoes with similar scales of eruption can be used to assess hazard.



Tephrafall probabilities,
after Jónsson 1990.
Data 1958-1977

Tephra thickness data from Jóhannesson et al 1991 and Smith,
unpublished data 2005-2007. Fresh airfall thickness calculated based on
tephra deposits being 60% original thickness, after Þórarinnsson, S.

Assessing risk

Risk:

The probability of harmful consequences, or expected losses resulting from interactions between natural or human induced hazards and vulnerable conditions.

Risk = Hazards x Vulnerability (x Exposure)

NOT TO BE CONFUSED WITH **volcanic hazard**.

- Identify **hazards**
- Assess **vulnerability** (the conditions which increase the susceptibility of a community or structure to the impact of hazards)
- Assess **exposure** (physical aspects such as location)

Risk to road systems

– preliminary comments

- **Tephra-fall** poses the greatest and most widespread risk to road systems from an eruption of Snæfellsjökull or related craters in terms of widespread effect and cost of road clearance. The impact of tephra fall is most likely to affect a sector to the northeast of the volcano.
- **Jökulhlaups and lahars**, though small, may flow along drainages radiating from the volcano, particularly to the north. This could wash away small sections of road. Bridges to the north may require rebuilding. Town streets are predominantly out of high jökulhlaup/lahar risk zones. Arnarstapi to the southeast is the settlement closest to a potential flow path.
- **Lava flows** from the central cone or smaller craters may bury gravel roads. Metalled roads are largely out of high risk areas, apart from south of the volcano. The relatively low speed of lava flows should allow traffic diversions to be made in good time.
- **Pyroclastic flows** are common from stratovolcanoes and possible in the next major central caldera eruption. A pyroclastic flow would follow drainages and therefore may be most likely to the north. However, all drainages around the volcano would be at risk. This would bury or erode roads in its path and pose a serious risk to people and vehicle.



Summary



Outcomes by summer 2007:

Jökulhlaups and most probably lahars have occurred from Snæfellsjökull.

These were much smaller than those from Katla and Grímsvötn. They primarily carried pumice from the central caldera eruptions and from tephra fall deposits.

Outcomes by spring 2008:

Collection of available data on volcanic events from Snæfellsjökull

Determination of the size of flood events.

Hazard maps for each type of volcanic event.

Risk map for road system.

Takk fyrir:

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References

- Johannesson H, Flores R M, Jonsson J, 1981. A short account of the Holocene tephrochronology of the Snaefellsjokull central volcano, western Iceland. *Jokull*, 9: 23-30
- Jónsson, T. 1990. Hvert liggja gjóskugeirar? *Náttúru fræðingurinn*, v.60 (2), 103-105.
- Kjartansson G, 1968. Geological map of Iceland, sheet 2, west-central Iceland. Icelandic Museum Nat Hist, 1:250,000 geol map
- Larsen, G. et al. 2002. Correlation of late Holocene terrestrial and marine tephra markers, north Iceland. *Polar Research*, 21(2), 283-290.
- Steinthorsson S, 1967. Two new C-14 datings on tephra from Snaefellsjokull. *Naturufraedingurinn*, 37: 236-238 (in Icelandic with English abs)
- UN ISDR, international glossary of basic terms related to disaster risk reduction, 31/03/2004.