

## Seismicity in Iceland 2002

Bergþóra S. Þorbjarnardóttir and Gunnar B. Guðmundsson

*Department of Geophysics, Icelandic Meteorological Office, Bústaðavegur 9, 150 Reykjavík, Iceland;  
 begga@vedur.is, gg@vedur.is*

**Abstract** — Nearly 14,000 earthquakes were located by the SIL seismic system in 2002, on a network of 42 stations. The largest earthquake episode took place within the Tjörnes Fracture Zone, between the islands of Grímsey and Kolbeinsey. This swarm was initiated by a magnitude 5.5 ( $m_b$ ) earthquake. Seismic activity beneath the Mýrdalsjökull glacier was greater than usual and prevailed throughout the year. Seismicity beneath Vatnajökull was also considerable in 2002 with several jökulhlaups accompanied by icequakes, earthquakes and seismic tremor, an earthquake swarm by the Esjufjöll mountains and a magnitude 4.3 ( $m_b$ ) earthquake plus aftershocks beneath the Bárðarbunga central volcano. A significant number of events was located along the June 2000 South Iceland Seismic Zone faults.

### INTRODUCTION

The SIL seismic system comprises a network of three-component digital seismic stations and a data processing system (Jakobsdóttir *et al.*, 2002). From 1990 to 2001 42 stations were installed along the active seismic zones and rift zones in Iceland. No station was added to the network in 2002, but considerable work was put into improving the quality of the system.

The SIL system records microearthquakes down to magnitudes less than zero using a locally derived magnitude scale. As earthquakes exceeding magnitude 4 tend to be underestimated by the local scale, body-wave magnitudes ( $m_b$ ) calculated by the National Earthquake Information Center (NEIC) are used instead.

Seismicity within the Tjörnes Fracture Zone (TFZ), beneath the Mýrdalsjökull glacier and the western Vatnajökull ice cap is emphasized here (Figure 1). The earthquake activity in these areas was above average in 2002. The faults of the June 2000 South Iceland Seismic Zone (SISZ) earthquakes were still fairly active in 2002 but this aftershock activity is decreasing gradually.

Reports from the public were received concerning

14 earthquakes felt during the year. A list of these earthquakes is in Table 1.

### SEISMICITY WITHIN THE TJÖRNES FRACTURE ZONE

Most earthquake swarms in 2002 occurred along the Tjörnes Fracture Zone, offshore northern Iceland (Figure 1). The largest earthquake episode started with a magnitude 5.5 earthquake ( $m_b$ , NEIC) on September 16. It was located 53 km NNV of the island Grímsey, in the northernmost part of the zone (Figure 2), and was felt widely along the northern coast. NEIC calculated the focal planes as either striking N35°E and dipping 73° to the southeast or a near vertical plane striking N125°E. Over 300 aftershocks were recorded, the largest with magnitude 4.3 ( $m_b$ ) on September 17. The aftershocks were distributed along a 15 km long zone, extending SSE from the main-shock hypocenter (Figure 2). This is the largest swarm that has been recorded in this area since 1994 when the SIL seismic network was extended to north Iceland. Simultaneously and following this swarm came two other swarms, about 15 km NNV of Grímsey and 5 km east of the island, with a total of over 200 earth-

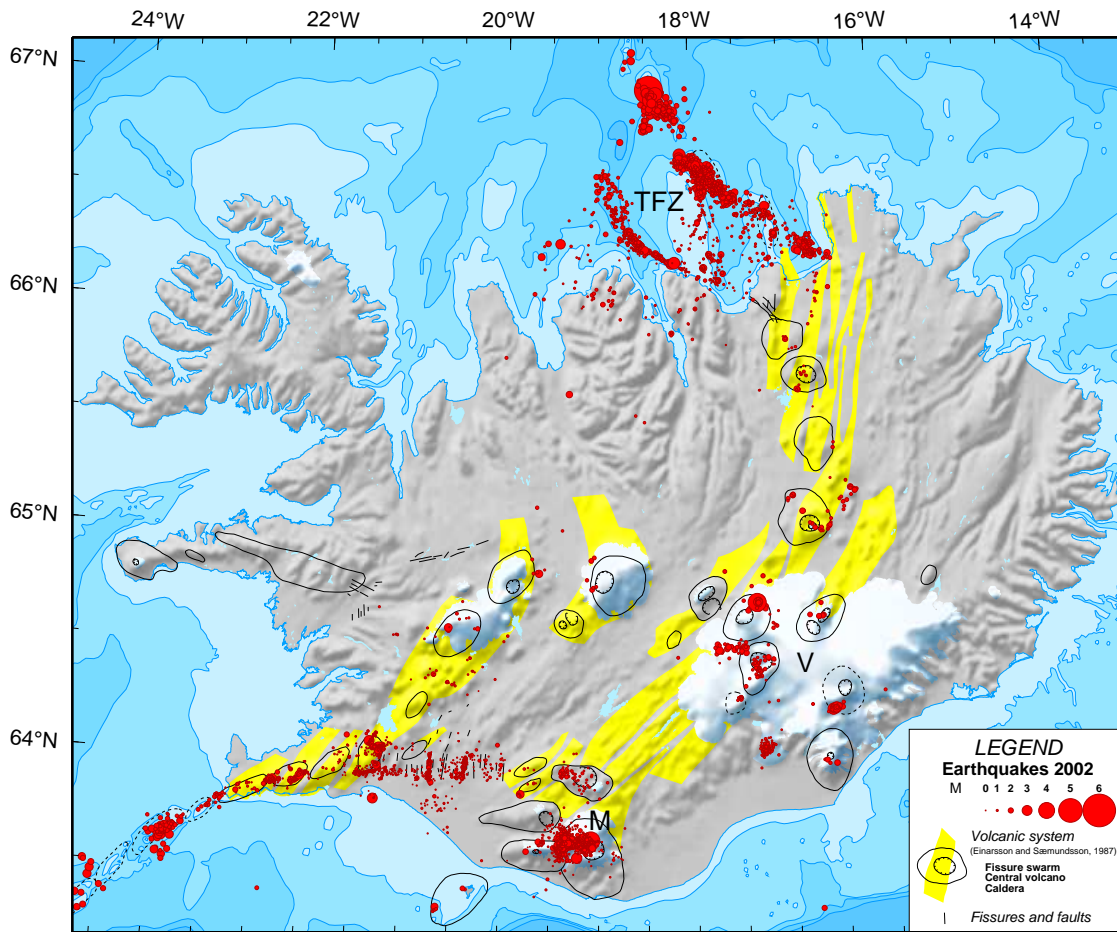


Figure 1. Earthquake epicenters (red dots) recorded during 2002 by the SIL seismic system plotted on a tectonic map of Iceland. TFZ denotes the Tjörnes Fracture Zone, V the Vatnajökull ice sheet and M the Mýrdalsjökull glacier. – *Kort sem sýnir eldstöðvakerfi og brotabelti landsins ásamt jarðskjálftum (rauðir punktar) sem staðsettir voru með SIL kerfinu árið 2002. Lítil virkni var í N og V-gosbeltunum, á Hengilssvæðinu og á Reykjanesskaganum, talsverð virkni á Reykjaneshryggnum en mest í Tjörnesbrotabeltinu (TFZ).*

quakes. Several earthquakes were also recorded about 20 km south of the mainshock.

### MÝRDALSJÖKULL

Seismic activity beneath the western part of the Mýrdalsjökull glacier (Goðabunga) has changed over the last semesters. Seasonal seismicity preferentially occurring during the autumn months (Einarsson and Brandsdóttir, 2000) has now been prolonged (Figure

3). Seismicity during the first months of 2002 was of similar intensity as during the last months of 2001. Though a decrease in the number of earthquakes was observed during the spring and summer months, the seismicity prevailed throughout the year. GPS measurements show steady uplift and horizontal displacement beneath the Katla caldera from 1999, which suggests inflow of magma into the volcano (Sturkell *et al.*, 2003).

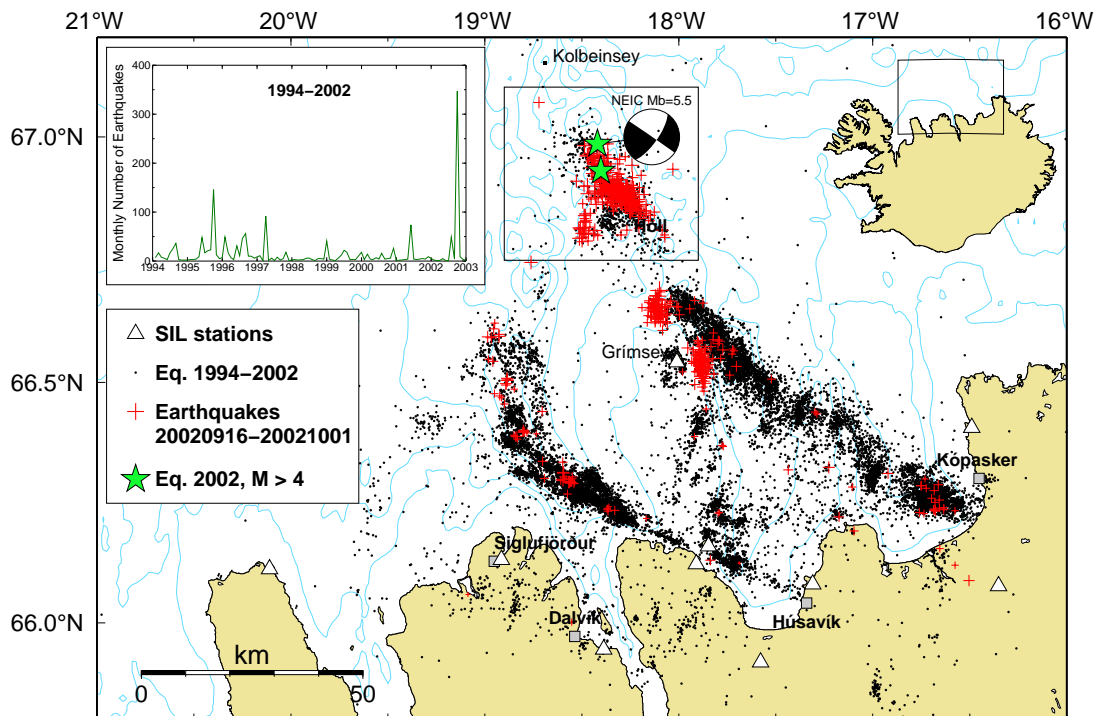


Figure 2. Earthquake epicenters within the Tjörnes Fracture Zone during 2002. Red crosses denote earthquakes from September 16 to October 1. Green stars denote  $m_b > 4$  earthquakes. Also shown is the NEIC fault plane solution for the mainshock and the monthly number of earthquakes during 1994–2002 within this region. – Kortið sýnir staðsetningar jarðskjálfta í Tjörnesbrotabeltinu 2002. Rauðir krossar eru skjálftar frá 16. september til 1. október. Grænar stjörnur tákna  $m_b > 4$  skjálftana. Brotlausn aðalskjálftans er einnig sýnd. Línuritíð sýnir fjölda jarðskjálfta á mánuði frá 1994 til 2002 á svæðinu.

The largest Mýrdalsjökull earthquake recorded by the SIL system, 4.3 ( $m_b$ ), occurred on April 27, 2002 at the northeastern rim of the Mýrdalsjökull (Katla) caldera.

### VATNAJÖKULL

A group of central volcanoes underlies the Vatnajökull ice cap. Geothermal areas within these volcanoes melt the glacier at the bedrock. The accumulation of meltwater, reaching a critical level, results in a jökulhlaup (Björnsson, 2002). Jökulhlaups from Grímsvötn into the river Skeiðará (Skeiðarárhlaups) occurred in March, April, and May 2002 (Matthew

Roberts, 2003). Seismic tremor and icequakes were recorded in Skeiðarárjökull in relation to these jökulhlaups. Five jökulhlaups from Grænalón into the river Súla (Súluhlaups) occurred during the second half of the year (Roberts, 2003). Icequakes in Skeiðarárjökull were also recorded during the Súluhlaups (Figure 4).

Both Skaftá cauldrons (Skaftárkatlar) drained into the river Skaftá during the year. A jökulhlaup from the eastern cauldron occurred in July and the western cauldron in September. Seismic tremor was recorded by the nearest SIL stations during these jökulhlaups. Earthquakes in the vicinity of the Skaftá cauldrons were also recorded.

Table 1: Earthquakes felt in 2002

time	latitude	longitude	* $M_{lw}$	** $M_l$	$m_b$
20020129 070730.219	65.63940	-16.86470	1.96	1.96	
20020201 204055.996	64.05502	-21.22188	3.50	3.15	
20020221 013934.909	63.83001	-21.26507	3.15	2.98	
20020301 020515.799	63.97683	-21.23606	2.75	2.57	
20020406 223622.541	64.08354	-21.31849	3.43	3.02	
20020410 174507.895	66.47377	-17.58992	2.83	2.98	
20020427 072145.438	63.65787	-19.07634	3.25	3.28	4.3
20020524 003949.290	63.98468	-16.59221	2.33	2.08	
20020916 184824.850	66.97527	-18.43660	5.25	4.96	5.5
20020916 185050.991	66.88854	-18.43155	3.02	3.33	
20020917 124004.889	66.93153	-18.40207	3.38	3.99	4.3
20021021 030908.033	64.22314	-16.61146	3.21	3.20	
20021115 222748.407	66.21027	-18.17465	2.95	3.33	

\* Local magnitude based on seismic moment

\* Local magnitude

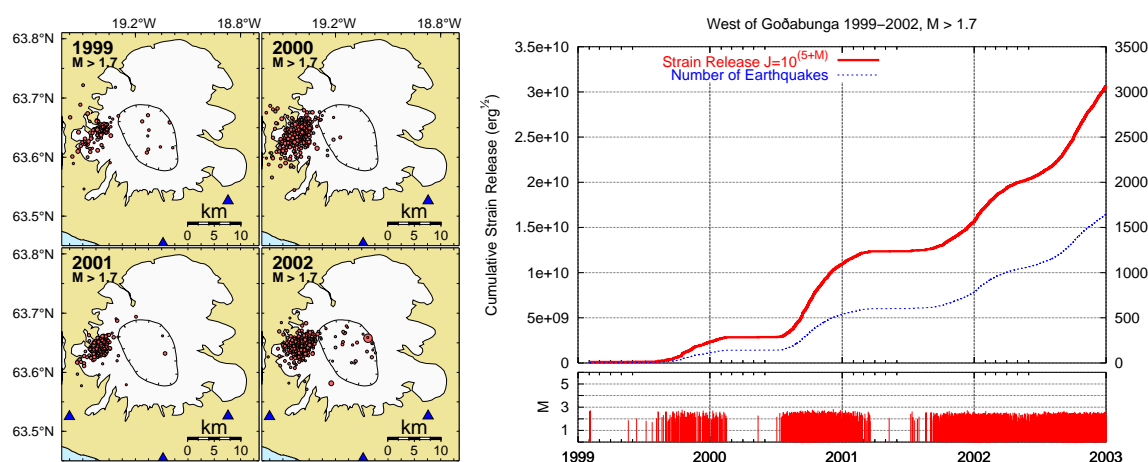


Figure 3. Epicenters ( $M_l > 1.7$ ) beneath the Mýrdalsjökull glacier and the cumulative number of  $M_l > 1.7$  earthquakes and strain release west of Goðabunga (western Mýrdalsjökull) from 1999 to 2002. This magnitude range represents a relevant comparison of the seismicity, since the detection level has been lowered during the last years. Triangles denote SIL seismic stations. Below, earthquake magnitude versus time for the same period. – Jarðskjálftakort ( $M_l > 1.7$ ) af Mýrdalsjökli árin 1999 til 2002. Þríhyrningar eru SIL stöðvar. Línuritinn til hægri sýna uppsafnaðan fjölda  $M_l > 1.7$  jarðskjálfta og streitu undir Goðabungu ásamt stærð skjálftanna yfir sama tímabil.

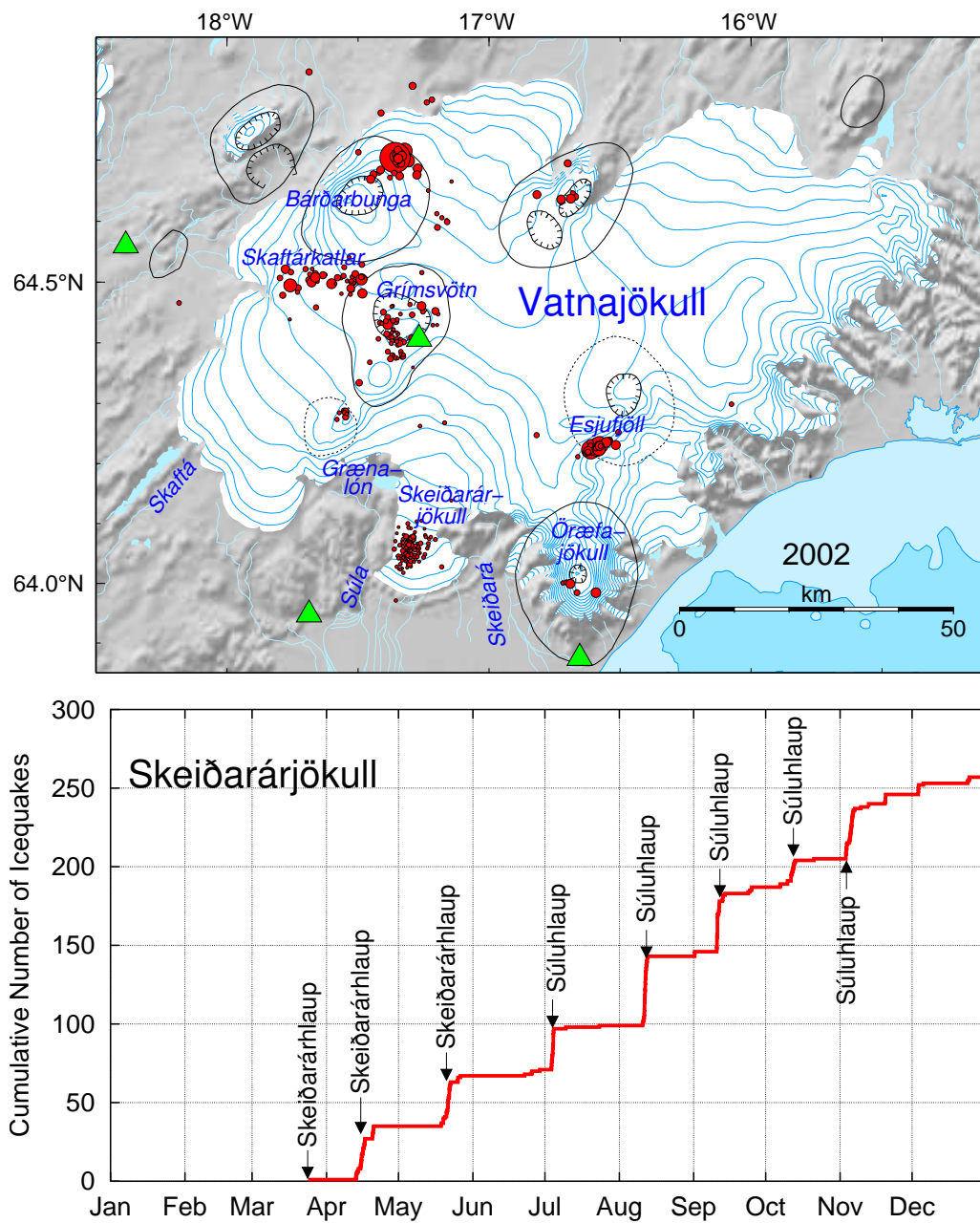


Figure 4. Map of the Vatnajökull ice cap with earthquakes and icequakes in 2002 along with the cumulative number of icequakes within the Skeiðarárjökull outlet glacier. Jökulhlaups in the rivers Skeiðará and Súlá are denoted. – Skjálftakort af Vatnajökli árið 2002. Línuritíð sýnir uppsafnaðan fjölda ísskjálfta í Skeiðarárjökli ásamt Skeiðarár- og Súluhlaupum.

Earthquake activity under Vatnajökull culminated in October, when a swarm occurred by the Esjufjöll mountains (Figure 4). About 90 earthquakes were located. Very few events have previously been located by the SIL system in this area. A total of 15 earthquakes, with magnitudes ranging from  $M_L$  0.9 to 2.2, were recorded in December 1996 and one in January 1997. Only 4 events have been located within this region since. The majority of earthquakes in the 2002 swarm had magnitudes between 1 and 2. Only a few earthquakes with magnitudes  $M_L < 1$  were located. The largest earthquakes reached magnitude 3.2. Earthquakes occurred simultaneously beneath Öraefajökull and Þórðarhyrna.

In November a magnitude 4.3 ( $m_b$ ) earthquake occurred on the northern flank of Bárðarbunga. Nearly 20 aftershocks were located.

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#### ÁGRIP

##### Jarðskjálftavirkni á Íslandi árið 2002

Tæplega 14.000 skjálftar mældust árið 2002 með SIL jarðskjálftamælaneti Veðurstofu Íslands. Flestar voru hrinurnar fyrir norðan land, í Tjörnesbrotabeltinu. Yfir 300 skjálftar mældust í hrinu sem hófst með skjálfta 5.5 stig ( $m_b$ , NEIC) um miðjan september, 53 km norður af Grímsey. Þetta er mesta virknin á þessu svæði síðan mælingar SIL kerfisins hófust fyrir norðan árið 1994. Samhliða þessari hrinu og í kjölfar hennar urðu tvær aðrar hrinur, um 15 km NNV og 5 km austur af Grímsey, með yfir 200 skjálfta samtals.

Einnig mældust skjálftar 20 km suður af aðalskjálftanum.

Haustvirkni undir Goðabungu 2001 hélt áfram af sama krafti fyrstu mánuði ársins 2002. Skjálftavirknin minnkaði lítillega á vor- og sumarmánuðum, en var þó viðvarandi allt árið.

Mikil virkni var á Vatnajökulssvæðinu á árinu. Jarðskjálftar og órói mældust samfara Skaftárhlaupum, bæði úr eystri og vestri Skaftárcötlum. Ísskjálftar mældust í Skeiðarárjökli samfara Skeiðarár- og Súluhlaupum. Mesta skjálftavirknin undir jöklinum 2002 var í hrinu við Esjufjöll í október, en þar mældust um 90 skjálftar. Lítil virkni hefur áður mælst við Esjufjöll með SIL kerfinu. Í nóvember varð skjálfti 4,3 stig ( $m_b$ ) norðan í Bárðarbungu. Nálægt 20 eftirskjálftar mældust.

Nokkur smáskjálftavirkni mælist enn á Hestvatns- og Holtasprungum, en fer minnkandi.

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