Data report

Seismicity in Iceland 2003

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Abstract — *In 2003 the SIL seismic monitoring network consisted of 41 seismic stations. The total number of earthquakes located by the SIL system in 2003 was about 10400, which is the lowest number in the last 10 years. However the number of earthquakes of magnitude greater than 1.5 was similar to 2002. Eight felt earthquakes were reported in 2003. The largest earthquake in 2003 occurred about 7 km southwest of Kleifarvatn on the Reykjanes Peninsula on August 23 at 02:00. It had a magnitude $M_{lw} = 5$ and was felt in many parts of SW–Iceland. The aftershock activity was most intense the first two days after the main shock and culminated about a week later. Seismicity beneath the Mýrdalsjökull glacier was high and as in 2002 was continuous throughout the year under the western part. From mid year 2003 the seismic activity has increased at Grímsvötn volcano in the Vatnajökull ice cap. Some earthquake swarms occurred on the northern part of the Reykjanes Ridge with earthquakes greater than 4. Several earthquake swarms with earthquakes of magnitude about 3 were recorded in the Tjörnes Fracture Zone. Aftershock activity still continues on the main faults from June 2000 in the South Iceland Seismic Zone.*

INTRODUCTION

The SIL seismic system is a network of 3-component digital seismic stations and a data processing system (Jakobsdóttir *et al.*, 2002). At the end of the year 2003 the network consisted of 41 SIL seismic stations. One new SIL seismic station, Krókóttuvötn, was installed north of Mývatn in the middle of the year. Two stations were discontinued in January 2003, Skammadalshóll, south of Mýrdalsjökull, and Grindavík, on the Reykjanes Peninsula.

A total of 10400 earthquakes were located by the SIL seismic system in 2003 compared with about 14000 in 2001 and 2002 (Figures 1 and 2). The number of earthquakes greater than or equal to 1.5 is similar for the years 2003 and 2002.

The magnitude scale used here is our local moment magnitude scale M_{lw} (Slunga *et al.*, 1984). It is scaled in a manner resembling the Richter local magnitude scale M_l.

Here we focus mainly on the seismic activity on the Reykjanes Peninsula and beneath Mýrdalsjökull and Vatnajökull, which had high seismic activity in 2003. Following is a short description of the seismicity in other areas during 2003.

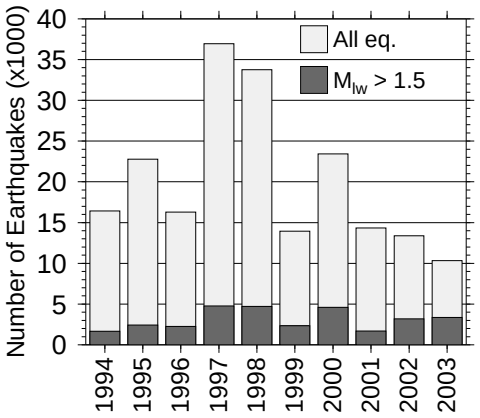

Figure 1. Annual number of earthquakes from 1994 to 2003. *– Árlegur fjöldi jarðskjálfta fyrir árin 1994 til 2003.*

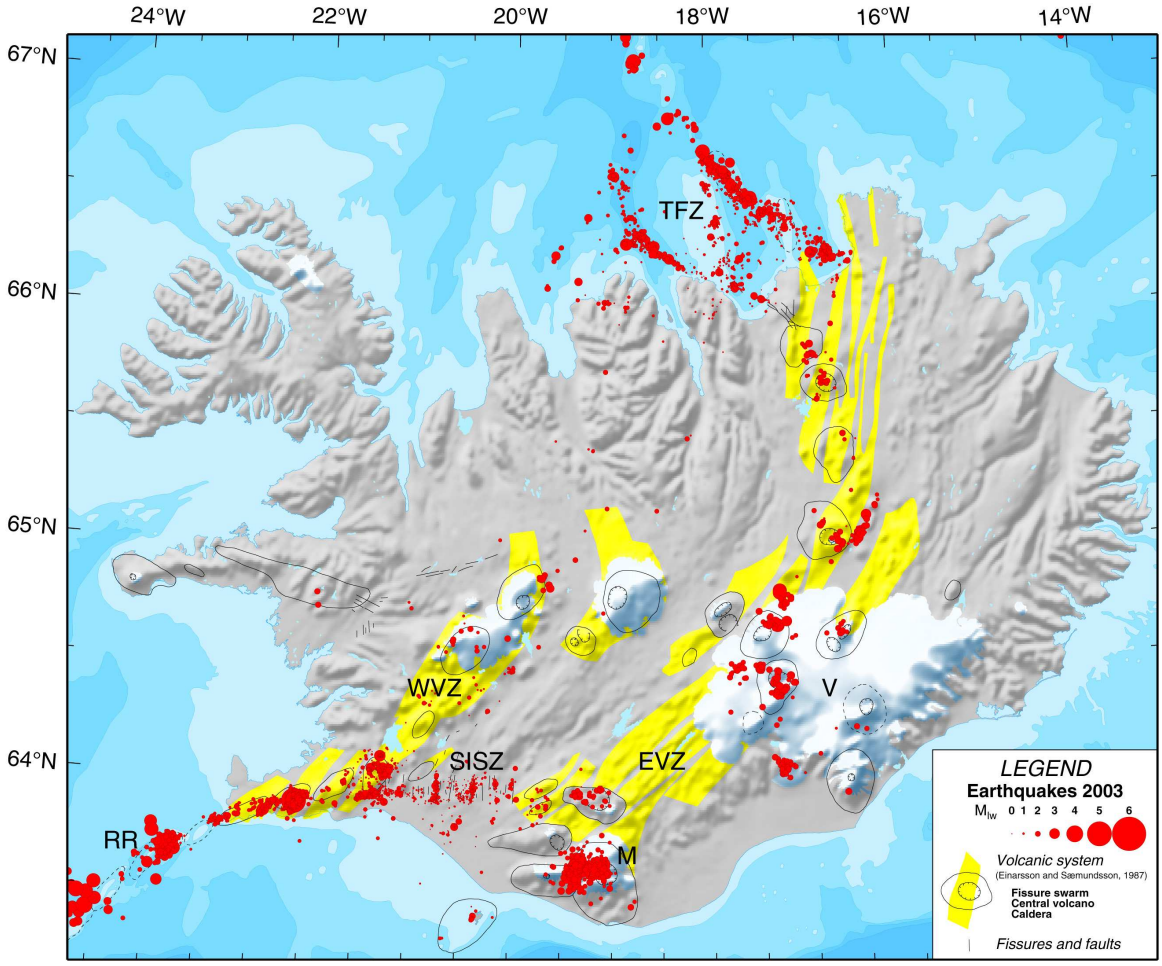

Figure 2. Earthquake epicenters (red dots) recorded in the year 2003 by the SIL seismic system. The main tectonic features of Iceland are shown. RR denotes the Reykjanes Ridge, SISZ the South Iceland Seismic Zone, EVZ the Eastern Volcanic Zone, WVZ the Western Volcanic Zone, TFZ the Tjörnes Fracture Zone, V the Vatnajökull Ice Cap and M the Mýrdalsjökull glacier – *Kort sem sýnir jarðskjálfta (rauðir punktar) sem staðsettir voru með SIL kerfinu árið 2003.*

The seismic activity in the South Iceland seismic zone (SISZ) was mainly concentrated on the faults of the June 2000 main shocks. The number of these aftershocks is decreasing and most of them cluster close to the origin of the main shocks.

The Tjörnes Fracture Zone had several earthquake swarms. Earthquake swarm activity occurred north and east of Grímsey in June, August and October. The biggest earthquake in these swarms, with magnitude $M_{lw} = 3.7$, occurred 18 km north of Grímsey on October 15. There was also swarm activity in the mouth of Eyjafjörður and in Öxarfjörður.

Increased earthquake activity has been on the northern part of Reykjanes Ridge since 2000. At the end of April, swarm activity was recorded close to Geirfuglasker with an earthquake of magnitude 4. An earthquake of magnitude 4 was also recorded about 15 km SW of Eldeyjarboði in a swarm at the end of the year. An earthquake $M_b = 5$ (NEIC) was recorded on 62.9 degrees north, on the Reykjanes Ridge on July 19.

An earthquake of magnitude $M_{lw} = 3.2$ occurred beneath Nesjavellir in the Hengill area on March 11. It was felt in Reykjavik and Selfoss. Some small earthquakes at about 16 km depth were recorded by Heimaey in the Westmann Islands in August and November.

REYKJANES PENINSULA

The Reykjanes Peninsula is a continuation of the oblique spreading ridge, Reykjanes Ridge, and connects it to the South Iceland Seismic Zone (SISZ) and the Western Volcanic Zone (WVZ).

On August 23, 2003 at 02:00 an $M_{lw} = 5$ earthquake occurred west of Kleifarvatn on the Reykjanes Peninsula at about 4 km depth (Vogfjörð, 2004); (Figure 3). The earthquake was felt in many parts of SW–Iceland. More than 1200 aftershocks followed on the same day and the day after of which 10 were greater than 3 in magnitude. The aftershock activity culminated about a week later. The epicenters of the aftershocks aligned on a NS-line containing the main shock and also on an ENE-line from the main shock into Kleifarvatn. The optimum fault plane solution for the main event and the aftershocks indicate that the fault plane is a N–S right–lateral strike slip fault. This seismic activity on the Reykjanes Peninsula is the greatest since June 2000 when 3 earthquakes of magnitude greater than 5 were triggered on the Reykjanes Peninsula by the main shock in SISZ on June 17, 2000 (Vogfjörð, 2003).

An earthquake swarm was recorded in Bláfjöll in early April with the biggest earthquake of magnitude 2.2. A small earthquake swarm took place at Fagradalsfjall in October.

MÝRDALSJÖKULL

The Katla volcano is located under Mýrdalsjökull. It has shown signs of unrest since 1999 when a jökulhlaup emerged from the southern part of the glacier and a new cauldron was formed and other cauldrons showed changes in size (Guðmundsson et al., 2000; Vogfjörð 2002). GPS measurements in Austmannsbunga, at the northeastern rim of the Katla caldera, have also shown uplift and outward displacements from the year 2002 (Sturkell *et al.*, 2003a). The seismicity under Mýrdalsjökull is mainly concentrated in two areas, within the Katla caldera and to the west of the caldera where the seismicity is usually seasonal with nearly all earthquakes occurring in the second half of the year (Einarsson and Brandsdóttir, 2000). In 2002 the pattern of seismicity in the western part of Mýrdalsjökull changed from seasonal to continuous seismic activity throughout the year (Þorbjarnardóttir *et al.*, 2003). The majority of earthquakes located under Mýrdalsjökull in 2003 originated under the western part, where the seismic activity had the same continuous pattern as in 2002. The seismicity within the caldera was mainly under its northern part (Figure 4). On September 22, an earthquake swarm occurred beneath the northeastern rim of the caldera, close to Austmannsbunga. The biggest earthquake in that swarm had a magnitude $M_{lw} = 3.9$.

VATNAJÖKULL

The Vatnajökull ice cap includes several volcanic systems. The most active is the Grímsvötn volcano, which erupted last in 1998, and has since been inflating (Sturkell *et al.*, 2003b). From mid year 2003 the seismicity at Grímsvötn increased (Figure 5). Most of the earthquakes have their origin close to the southern rim of the Grímsvötn caldera.

In the beginning of July 2003 a small earthquake swarm occurred beneath Bárðarbunga. Some earthquakes were recorded on Loki ridge, the ridge striking eastward from Hamarinn, and also some in Kverkfjöll. Icequakes were recorded in Skeiðarárjökull in relation to jökulhlaups from Grænalón or rainfall (Roberts *et al.*, 2005).

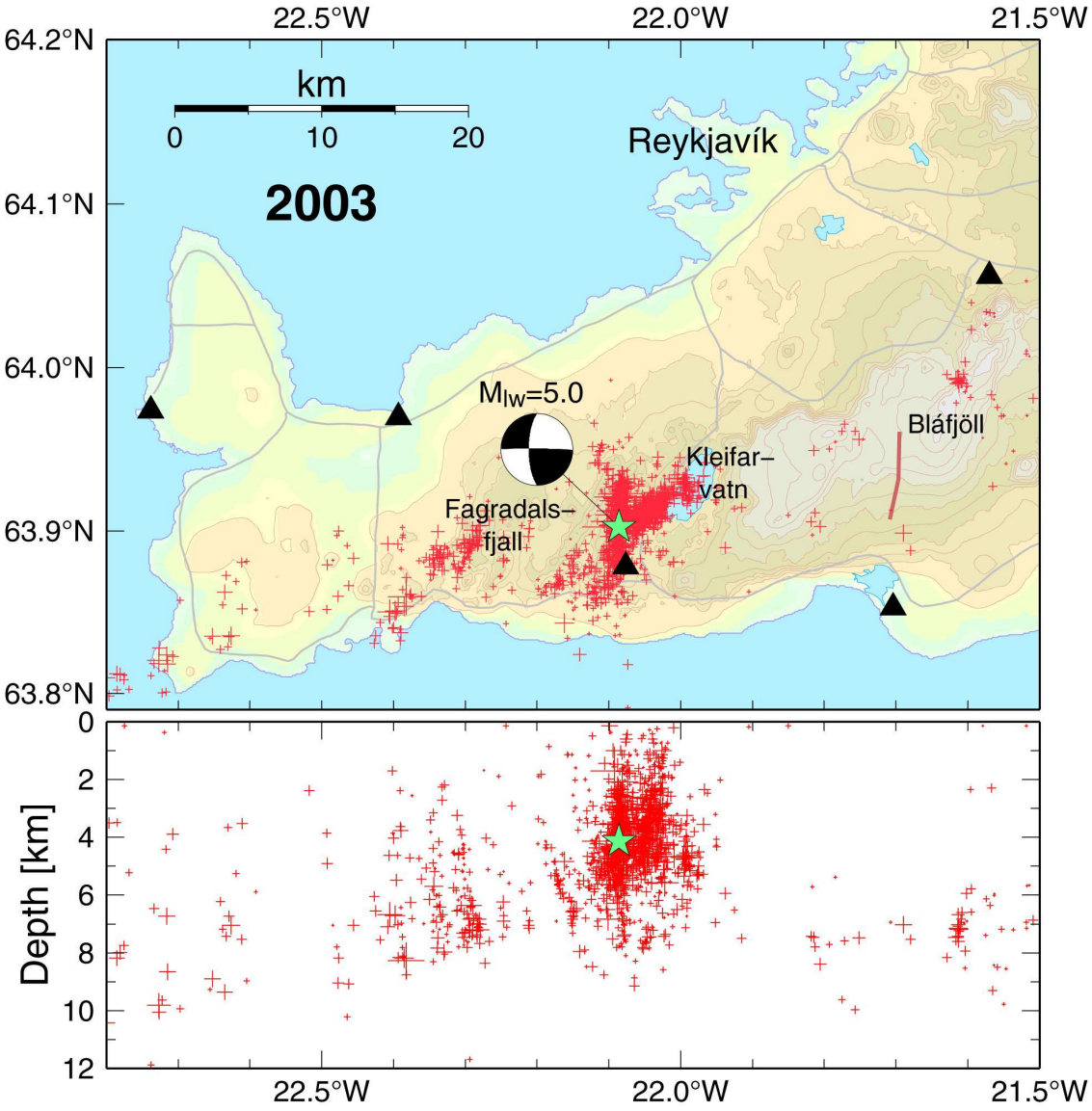

Figure 3. The map shows earthquake epicenters (red crosses) and an E–W cross section of the earthquake depth distribution on the Reykjanes Peninsula in 2003. The green star denotes the location of the $M_{lw} = 5$ mainshock on August 23. The mainshock's focal mechanism is also shown. – *Kort sem sýnir jarðskjálfta (rauðir krossar) á Reykjanesskaganum árið 2003 ásamt dýptarþversniði af jarðskjálftunum. Staðsetning stærsta skjálftans, 5 stig, er sýnd með grænni stjörnu. Brotlausn skjálftans og eftirskjálftar endurspegla færslur á nær lóðréttu NS hægrihandar sniðgengi.*

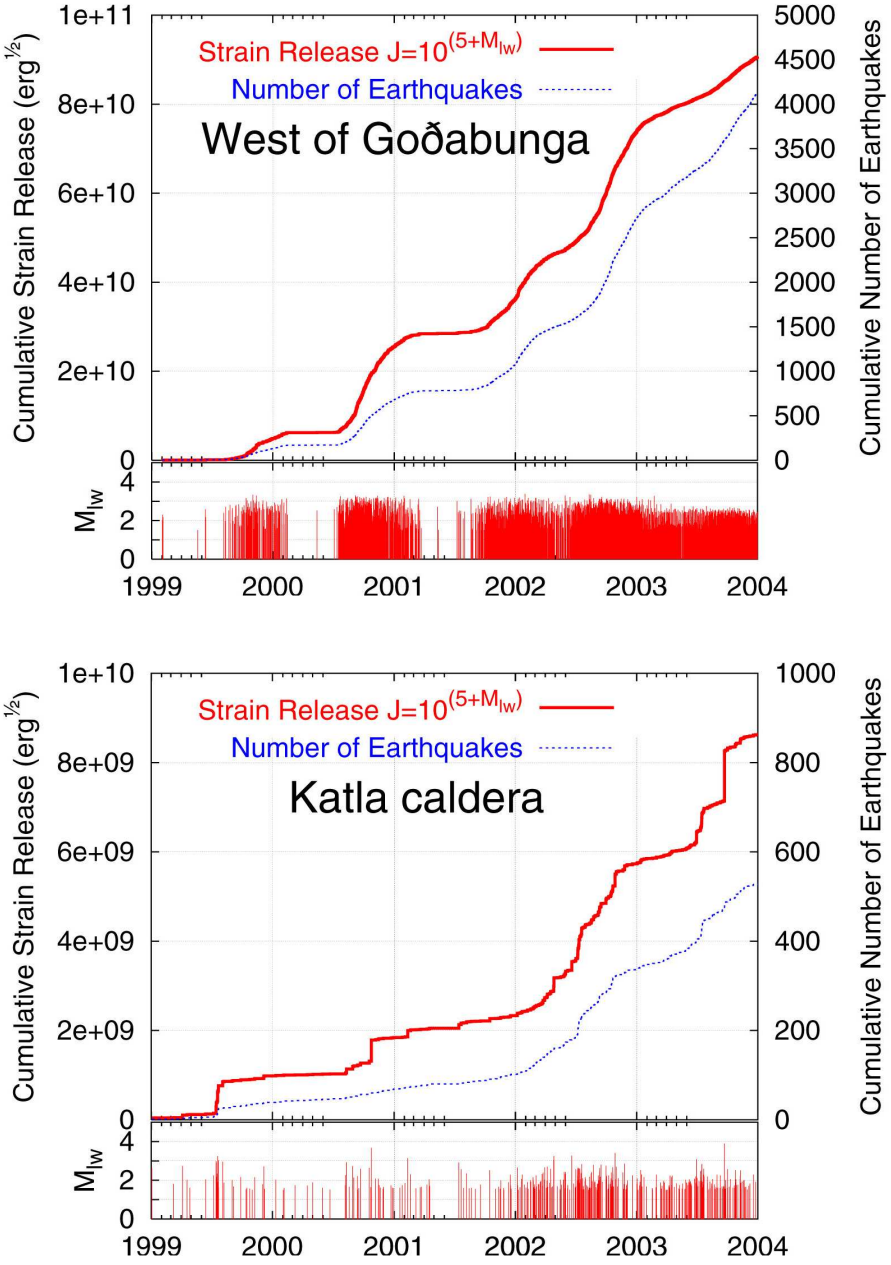

Figure 4. Cumulative strain release (in $\mathrm{erg}^{1/2}$) and cumulative number of earthquakes in the two active areas beneath Mýrdalsjökull, west of Goðabunga and within the Katla caldera. Magnitude vs. time 1999–2003 is plotted beneath each graph. – *Línuritin sýna uppsafnaða streitu og uppsafnaðan fjölda jarðskjálfta frá 1999 til 2003 í vestanverðum Mýrdalsjökli og í Kötluöskjunni, og stærð sem fall af tíma.*

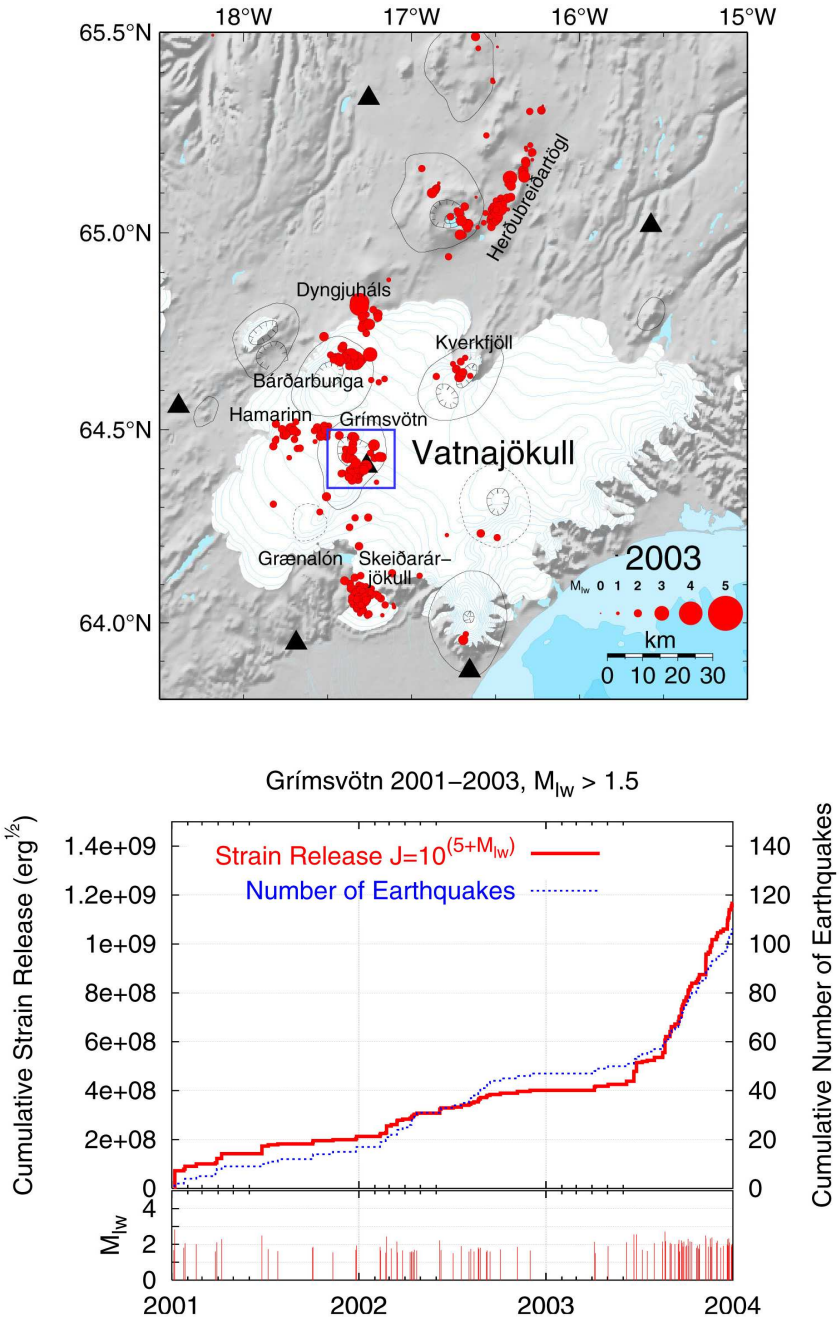

Figure 5. A map of earthquake epicenters (red dots) beneath and north of Vatnajökull (top). The graph shows cumulative strain release and cumulative number of earthquakes within the Grímsvötn central volcano from 2001 to 2003 and a magnitude vs. time plot. – *Kort sem sýnir upptök jarðskjálfta (rauðir punktar) á Vatnajökulssvæðinu. Línurit sýnir uppsafnaða streitu og uppsafnaðan fjölda jarðskjálfta í Grímsvötnum ásamt stærð sem fall af tíma frá 2001 til 2003.*

Table 1. Earthquakes felt in 2003. – *Jarðskjálftar sem menn fundu á árinu 2003.*

Origin date	Origin time	Latitude	Longitude	Depth km	M_{lw}	Felt at location
2003-03-11	17:27:45.1	64.109	-21.265	7.1	3.2	Selfoss, Mosfellsbær
2003-04-06	21:05:02.9	63.947	-21.321	7.5	3.2	Hveragerði, Þorlákshöfn
2003-05-15	17:34:33.9	63.860	-22.382	8.3	3.3	Grindavík
2003-05-16	06:44:05.6	63.853	-22.385	8.2	2.2	Grindavík
2003-05-26	17:50:42.9	65.638	-16.878	5.0	1.9	Reykjahlíð
2003-08-23	02:00:11.8	63.902	-22.086	4.1	5.0	SW-Iceland
2003-09-13	13:39:29.8	63.934	-21.405	5.0	2.3	Ölfus
2003-11-19	23:06:04.7	63.953	-21.074	4.7	2.4	Selfoss

On October 3 and 18, two earthquakes of magnitude 3.2 and 3.4 occurred near Dyngjuháls close to the northwestern edge of Vatnajökull ice cap. An earthquake swarm lasting from November 3–22 took place in Herðubreiðartögl in the Askja fissure swarm. The biggest earthquakes in that swarm had magnitudes close to 3.

Acknowledgements

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ÁGRIP

Jarðskjálftavirkni á Íslandi árið 2003

Í lok árs 2003 var 41 jarðskjálftastöð í SIL jarðskjálftamælanetinu. Ein ný SIL stöð, Krókóttuvötn norðan við Hlíðarfjall í Mývatnssveit, bættist við SIL netið um mitt ár. Tvær jarðskjálftastöðvar voru lagðar niður í byrjun árs, Skammadalshóll í Mýrdal og Grindavík á Reykjanesskaga. Um 10.400 skjálftar mældust undir og við landið á árinu. Stærsti skjálftinn varð aðfaranótt 23. ágúst kl. 02:00 og mældist staðbundin vægisstærð hans $M_{lw} = 5$. Upptök hans voru á um 4 km dýpi vestan við Kleifarvatn á Reykjanesskaga. Brotlausn skjálftans og eftirskjálftar benda til þess að brotaplan hans hafi verið á næstum lóðréttu NS hægrihandar sniðgengi. Skjálftinn fannst víða um SV–land allt austur til Víkur í Mýrdal. Skjálftahrinan var öflugust fyrstu tvo sólarhringana en síðan dró verulega úr henni og henni var lokið fyrir mánaðamótin. Á árinu urðu nokkrar skjálftahrinur nyrst á Reykjaneshryggnum. Stærst var hrina við Geirfuglasker í lok apríl með skjálfta yfir 4 stig. Í lok ársins varð hrina sunnar á Reykjaneshryggnum eða um 15 km suðvestan við Eldeyjarboða. Stærsti skjálftinn þar mældist um 4 stig. Undir vestanverðum Mýrdalsjökli, vestan við Goðabungu, var viðvarandi skjálftavirkni allt árið eins og verið hef-

ur frá miðju ári 2001. Undir Kötluöskjunni var virkni mest við Austmannsbungu. Frá miðju ári 2003 hefur skjálftavirkni undir Grímsvötnum farið vaxandi. GPS mælingar sýna aukinn kvikuþrýsting undir Kötlu og Grímsvötnum. Í Skeiðarárjökli mældust nokkrar ísskjálftahrinur sem tengdust jökulhlaupum eða mikilli úrkomu. Í október mældust 2 skjálftar yfir 3 að stærð með upptök undir Dyngjuhálsi við norðvestanverðan Vatnajökul. Í nóvember var skjálftahrina við Herðubreiðartögl, austan við Öskju. Stærstu skjálftarnir í þeirri hrinu mældust um 3 stig. Úti fyrir Norðurlandi var skjálftavirkni mest úti fyrir mynni Eyjafjarðar á Húsavíkur-Flateyjarsprungunni og einnig á Grímseyjar-Öxarfjarðar beltinu, bæði austan Grímseyjar og inn í Öxarfirði. Stærstu skjálftarnir á þessum svæðum voru rúmlega 3 að stærð. Á Suðurlandi var ennþá áframhald á eftirskjálftavirkni á Holta- og Hestvatnssprungunum frá stóru skjálftunum árið 2000 en virknin þar minnkar þó stöðugt. Undir Nesjavöllum við Hengil mældist þann 11. mars skjálfti að stærð 3 sem fannst á höfuðborgarsvæðinu og Suðurlandi. Tvær litlar skjálftahrinur mældust undir Heimaey í Vestmannaeyjum í ágúst og nóvember en slíkar hrinur eru mjög óvanalegar þar.

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