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Seismic Monitoring in Þeistareykir, Krafla and Námafjall

November 2016 to March 2017

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Title:	Seismic Monitoring in Þeistareykir, Krafla and Námafjall. November 2016 to March 2017.		
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Abstract:

In Þeistareykir, Krafla and Námafjall geothermal areas and their surroundings, 2894 earthquakes were recorded by the local seismic network between November 1st 2016 and March 31st 2017. The vast majority of these events (2561) were located in and round the Krafla geothermal field. In Þeistareykir and Námafjall 140 and 136 earthquakes were located. While in Krafla more earthquakes are shallow (few events deeper than 3 km) and expands over a wider area, seismic activity both in Þeistareykir and in Námafjall is limited to narrow chimneys reaching 6 to 7 km down into the crust.

In Þeistareykir, a relatively large number of bigger earthquakes (magnitude > 1.0) has been recorded while small events are lacking. The number of big events indicates a stronger crust than in Krafla and Námafjall while the lack of small events could be an expression of the same phenomena or an artefact caused by the small number of seismic stations in the area, making detection and localization of small earthquakes challenging.

Keywords:

Seismicity, earthquakes, brittle-ductile boundary, magnitude, ÍSOR, Landsvirkjun

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1 Introduction

This report covers the seismic activity in the geothermal areas of Þeistareykir, Krafla and Námafjall from November 1st 2016 until March 31st 2017. During this period a total of 2894 earthquakes were recorded by the local network consisting of 17 seismic stations operated by ÍSOR for Landsvirkjun. Additionally, data of the regional SIL network operated by the Iceland Meteorological Office was available for earthquake localization. For a detailed description of the network, see Blanck et al. (2016).

2 Recorded earthquakes

Of the 2894 earthquakes that were recorded by the local network the vast majority or 2561 events are located in Krafla geothermal area. In Þeistareykir 140 earthquakes could be located and in Námafjall 136. The remaining 57 events lie outside the three fields as they were defined for the analysis in this report (black boxes in figure 1) and form three small clusters. The first of these small clusters is elongated, N-S oriented and lies north of Krafla and southeast of Þeistareykir in 4 to 6 km depth (Ágústsson, 2016). Another cluster lies west of the main Krafla geothermal field and most likely related or a derivate of it. The third small cluster lies in between Krafla and Námafjall geothermal field and appears in the surface projection as it could be connecting the two geothermal fields but the N-S section reveals that the activity here is located at greater depth and probably in no direct relation to either of the two fields (Ágústsson and Guðnason, 2016; Blanck et al., 2016).

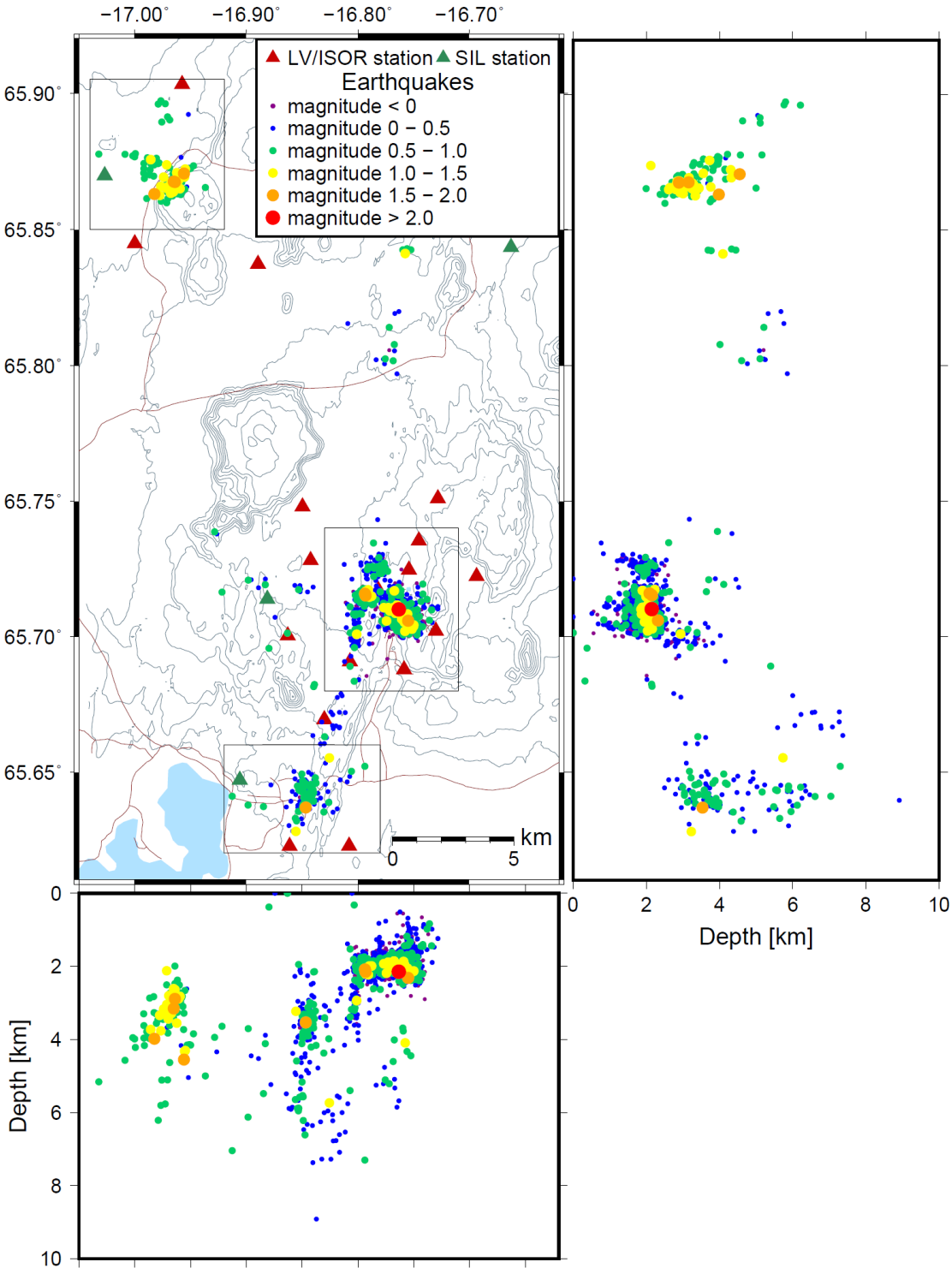

Figure 1. *Spatial distribution of earthquakes in Þeistareykir (box in the northwest), Krafla (central) and Námafjall (south) geothermal area in surface projection and E-W and N-S sections.*

2.1 Krafla

Krafla geothermal field shows a similar earthquake distribution as seen in the last annual report (Blanck et al., 2016). Earthquakes inside the geothermally active area are very shallow (1.5 to 2.5 km depth) (figure 2). A small sub cluster in the southwest of the main production area has been located in greater depth (up to 4 km depth), clearly marking the southeast edge of the shallow heat source. The ratio of small events is relatively high with the few bigger events being located at the lower edge of the active depth range (figure 1).

The brittle ductile boundary, which is per definition the depth above which 95 % of earthquakes have occurred, is in about 2.3 km depth (figure 2).

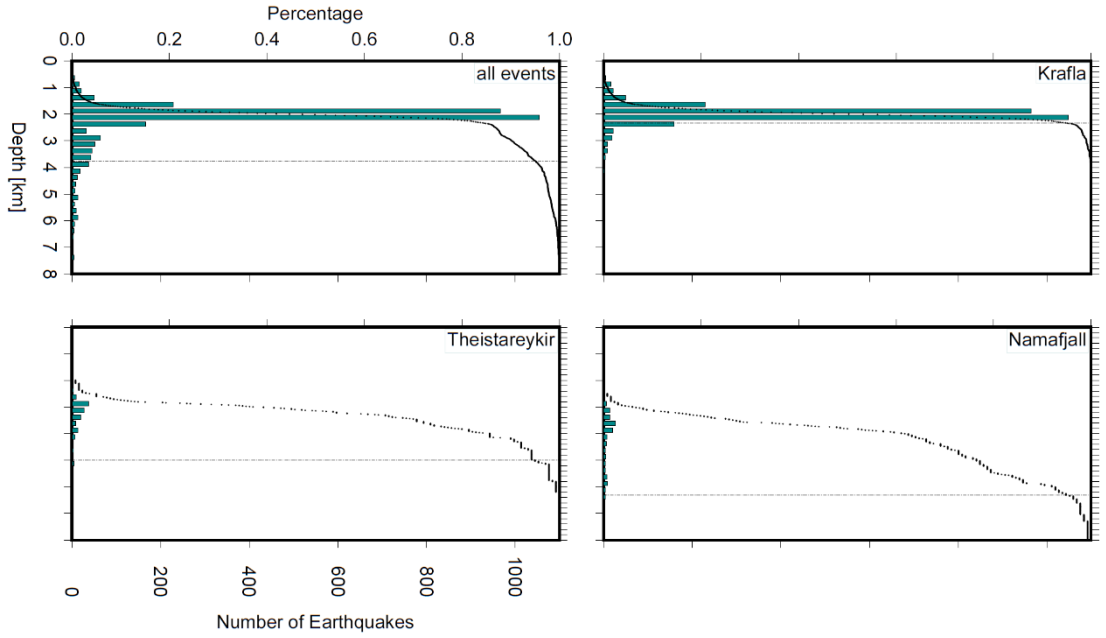

Figure 2. *Depth distribution of the events located in Krafla, Þeistareykir and Námafjall geothermal areas. The green bars indicated the absolute number of earthquakes recorded in each depth range, the dotted line the normalised cumulative number. The dashed line shows the depth above which 95 % of all events have been located, the so-called brittle-ductile boundary.*

2.2 Þeistareykir

In Þeistareykir, seismic activity is mostly limited to a vertical chimney from about 2 to 5 km depth directly underneath the geothermally active area. Additionally, there are a few events located slightly north of the main field at even greater depth (4 to 6 km). 95 % of the earthquakes have been located shallower than 5 km (figure 3).

Almost all events have a local magnitude of 0.5 and bigger. This could be a consequence of the limited sensitivity of the local seismic network that consists of only 4 seismic

stations in the near surroundings. At the same time we also see a relatively high number of bigger events here compared to Krafla and Námafjall (29 events with magnitude bigger then 1.0).

2.3 Námafjall

Seismic activity in Námafjall geothermal area is, similar to Þeistareykir, distributed over a larger depth range compared to Krafla. The shallowest events were located at about 2 km depth and the deepest ones in 7 km. One event has even been located in 9 km depth that is possibly due to a localization error. The brittle-ductile boundary, defined as the depth where 95% of earthquakes occur above, is in 6.3 km depth. Between 5 and 6 km depth there are fewer earthquakes than above and below that reflects the layering of the activity (Ágústsson and Guðnason, 2016).

Most events here have a local magnitude M_L between 0 and 1.0 and only 3 events have been measured of higher magnitude.

3 Magnitude distribution

The frequency-magnitude or Gutenberg-Richter relation (Gutenberg and Richter, 1956) describes the observation that small earthquakes are more common than bigger ones. On global scale, an earthquake of a certain magnitude is 10 times more likely to occur than an earthquake larger in magnitude by 1. Local deviations from this relationship can indicate variations from the average strength of the crust. For more detail on the Gutenberg-Richter relation and its implications, see Blanck et al. (2016).

In Krafla magnitudes from -0.58 to 2.08 have been measured (Figure 3), in Námafjall magnitudes lie between 0.04 and 1.72 and in Þeistareykir between 0.26 and 1.61.

The magnitude-frequency relation displayed for all events recorded in the area (see Figure 3) shows an even distribution of earthquakes in respect of magnitudes that can be approximated by a single straight line.

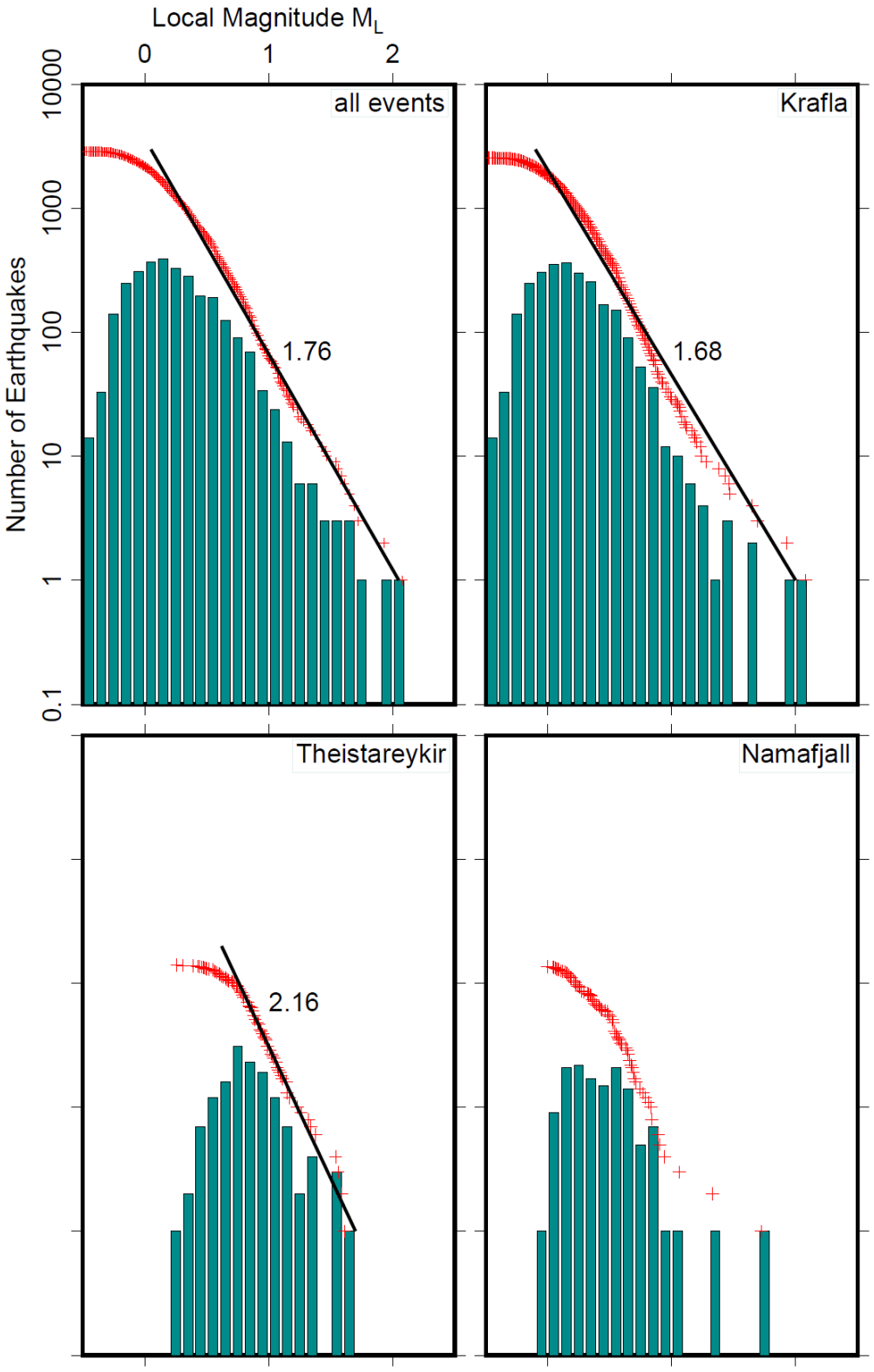

Figure 3. *Magnitude-frequency relation. In Krafla and Þeistareykir the magnitude frequency relation can be approximated with a single straight line. In Námafjall the distribution is more complex.*

The average slope of the line for all events together or so-called b-value is about 1.76. A b-value higher than 1 shows that there is a relatively high number of small earthquakes compared to bigger ones what is an indication of rather weak crust. Stress cannot be build up over longer periods of time to be released in few bigger events but is instead released early in many small earthquakes.

In Krafla and Þeistareykir, the distribution can be approximated rather well by a single straight line with b-values equal to 1.68 and 2.16, respectively, even though there appears to be a minor lack of mid-size events (around magnitude 1.0).

In Þeistareykir, there is a remarkable relatively high number of bigger earthquakes. As in Krafla, 29 events of magnitude bigger than 1.0 have been recorded. The presence of all these bigger events could indicate that the structure of the crust in Þeistareykir is sturdier in comparison to the other two areas, allowing stress to be build up to higher levels before being released.

In Námafjall, two lines would be needed to approximate the magnitude distribution. As previous analysis of this area has shown, the seismic activity shows different behaviour above and below 3.9 km depth (Ágústsson and Guðnason, 2016), indicating different physical properties in the two depth ranges.

4 Summary

In Þeistareykir, Krafla and Námafjall geothermal areas and their surroundings, 2894 earthquakes were located by the local seismic network, between November 1st 2016 and March 31st 2017. The vast majority of these events (2561) were located in and round the Krafla geothermal field. In Þeistareykir and Námafjall 140 and 136 earthquakes were located. While in Krafla more earthquakes are shallow (few events deeper than 3 km) and expands over a wider area, seismic activity both in Þeistareykir and in Námafjall is limited to narrow chimneys reaching 6 to 7 km down into the crust.

In Þeistareykir, a relatively larger number of bigger earthquakes (magnitude > 1.0) has been recorded while small events are lacking. The number of big events indicates a stronger crust while the lack of small events could be an expression of the same phenomena or an artefact caused by the small number of seismic stations in the area, making detection and localization of small earthquakes challenging. In Námafjall-that there are two depth ranges where seismic activity various significantly what is consistent with earlier studies.

5 References

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