Notable Events

The 30th August 2012, Mw 6.7 Jan Mayen Earthquake

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Excerpt from the
Summary of the Bulletin of the International Seismological Centre:

Sørensen, M. B., The 30th August 2012, Mw 6.7 Jan Mayen Earthquake, *Summ. Bull. Internatl. Seismol. Cent.*, July - December 2012, *49*(7–12), pp. 33–40, Thatcham, United Kingdom, 2016, doi:10.5281/zenodo.999222.

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6.1 The 30th August 2012, M_W 6.7 Jan Mayen Earthquake

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6.1.1 Introduction

On 30th August 2012, a magnitude (M_W) 6.7 earthquake occurred along the Jan Mayen Fracture Zone (JMFZ), a major transform structure off-setting the Kolbeinsey and Mohns ridges in the North Atlantic Ocean (see Figure 6.1 for the locations of all tectonic structures referred to herein). This was the third $M \geq 6.0$ event to occur along the JMFZ in the last decade and followed intense clusters of foreshock activity during the months prior to the event.

The Jan Mayen region is characterized by the geodynamic processes associated with the interaction between the JMFZ and the slowly spreading Kolbeinsey and Mohns ridges. South of the JMFZ, the Jan Mayen Island is a volcanic island located at the northern part of the Jan Mayen Ridge, a continental fragment torn off eastern Greenland as spreading shifted from the Aegir Ridge to the Kolbeinsey Ridge during the Oligocene (Talwani and Eldholm, 1977). The Island itself is much younger and of volcanic origin. Jan Mayen hosts an active volcano, the Beerenberg volcano, which last erupted in 1985. To the north of the Island is the Jan Mayen Platform, which is characterized by normal faults striking NE, parallel to the spreading axis of the Mohns Ridge.

The Jan Mayen region has a high level of seismicity, mainly associated with the JMFZ, but also with the spreading ridges. Rodriguez-Pérez and Ottemöller (2014) presented 13 events of tectonic origin that had occurred since 1951 within the magnitude range $5.8 \leq M \leq 7.0$. The authors illustrated that almost the entire JMFZ had ruptured at least once during this time period. Most recently, two $M \geq 6.0$ earthquakes occurred along the JMFZ in April 2004 ($M = 6.3$) and January 2011 ($M = 6.1$). The locations of these events are shown, alongside the 2012 event in Figure 6.1. Slip distributions for five $M_W \geq 5.8$ events in the JMFZ, including the three most recent events, are presented by Rodriguez-Pérez and Ottemöller (2014). They found that the events had relatively simple slip distributions with the exception of the 2012 event which had two main asperities and a more complex source time function.

Earthquakes in the Jan Mayen region are monitored by the Norwegian National Seismic Network (NNSN) which operates two stations with vertical short-period seismometers and one broadband station on the

Island. In addition, there is an IMS station that is operated by NORSAR. Data from the NNSN serve as the basis for the work presented herein.

This article presents an overview of the August 2012 event and its source characteristics, as derived by Rodriguez-Pérez and Ottemöller (2014). The fore- and aftershock activity which has been recorded in connection with the event is then presented and compared to recent event sequences recorded in connection with other large earthquakes in the Jan Mayen region.

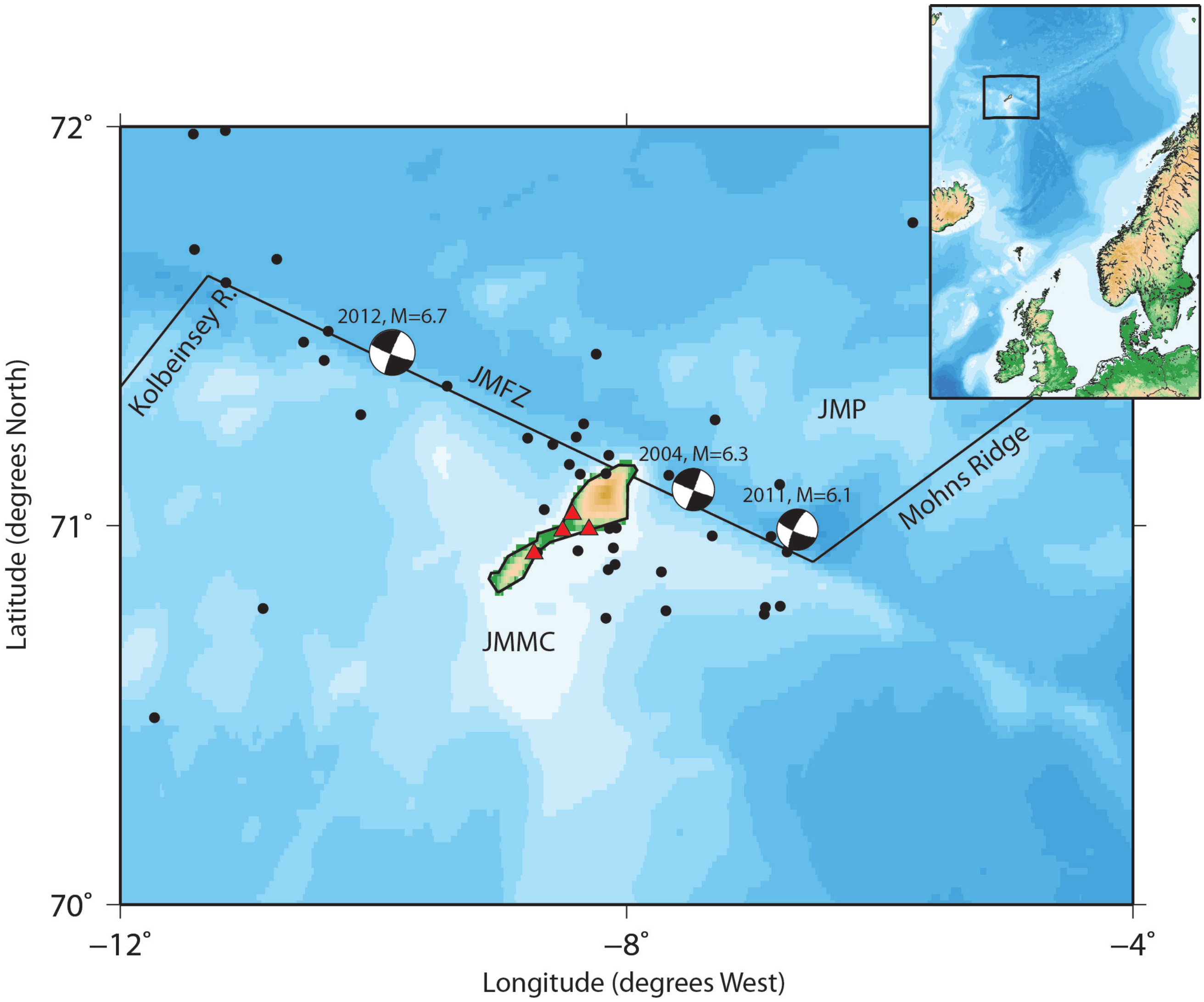

Figure 6.1: The Jan Mayen region in the North Atlantic Ocean. $M \geq 5.0$ earthquakes since 1900, as recorded by the NNSN, are marked as black dots. Focal mechanisms are shown for the three recent $M \geq 6.0$ earthquakes. The locations of seismic stations on Jan Mayen are marked as red triangles. The approximate location of the plate boundary is indicated by the black line. JMFZ: Jan Mayen Fracture Zone, JMMC: Jan Mayen Microcontinent, JMP: Jan Mayen Platform.

6.1.2 The 30th August 2012 Earthquake

The 30th August 2012 earthquake had a moment magnitude (M_W) of 6.7 and ruptured with an almost pure left-lateral strike-slip focal mechanism (Figure 6.1). The event is located in the northern part of the JMFZ, in an area devoid of any large earthquakes since the occurrence of a $M = 7.0$ event in 1951.

Rodriguez-Pérez and Ottemöller (2014) performed a slip inversion and studied the source parameters of this event. They found that the 2012 event ruptured a 42 x 20 km fault plane. The slip distribution was complex, exhibiting two main asperities with up to 1.6 m slip (Figure 6.2). The average static stress drop was determined to be 2.59 MPa with a static stress drop of 4.23 MPa on the asperities covering *ca.* 21% of the fault plane.

6.1.3 Fore- and Aftershock Activity in Connection with the 30th August 2012 Event

The 30th August 2012 earthquake was preceded by two clusters of strong foreshock activity. Figure 6.3 presents a histogram of the daily number of earthquakes in 2012 in the region covered by the map in Figure 6.1, based on data from the NNSN. On average, 2.5 earthquakes were recorded daily during this period. Three distinct clusters of increased activity are observed on 11th-13th June, 13th-16th July, and following the main shock on 30th August. If the three clusters of enhanced activity are excluded from the average calculation, the daily average drops to 1.4 events. During the June cluster, 44 earthquakes were recorded within a three day period. These events were in the magnitude range 1.5 $\leq M_L \leq$ 2.9 and could not be associated with any specific main shock. The July cluster consisted of 82 events that occurred within a four day period (44 events occurred on 14th July) in the magnitude range 1.1 $\leq M_L$ $\leq$ 3.9. There was no distinct main shock associated to this cluster. Following the second cluster, the seismicity level was slightly above average, but it dropped shortly before the occurrence of the main shock.

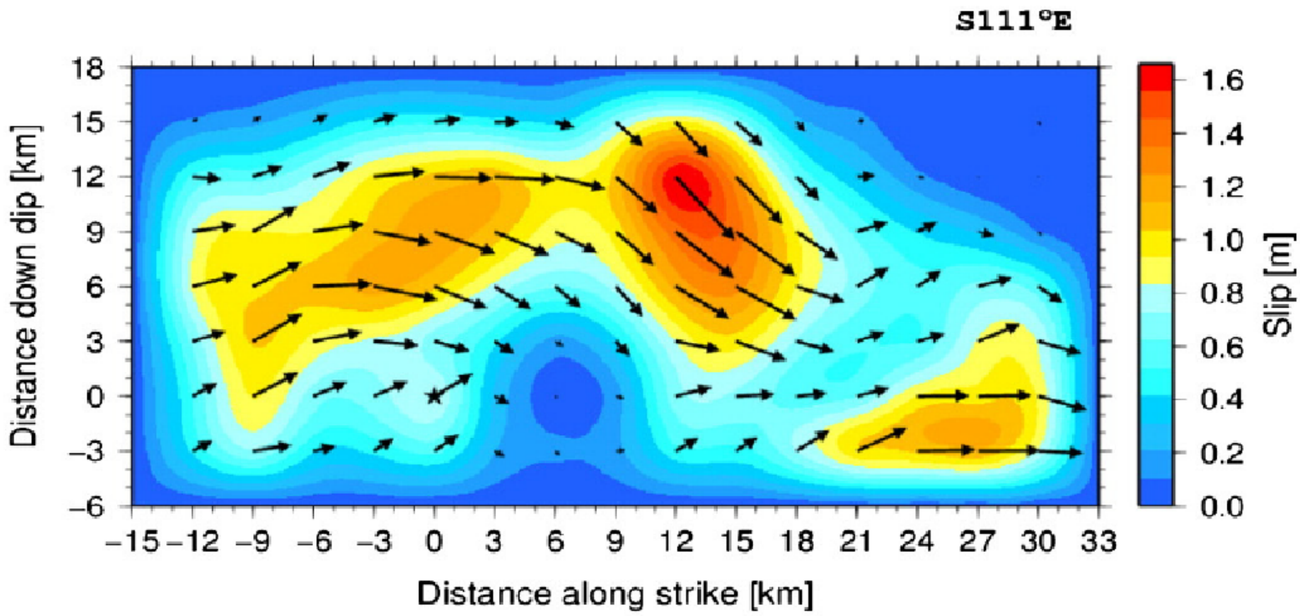

Figure 6.2: *Slip distribution for the 30th August 2012 earthquake inferred from teleseismic recordings. From Rodriguez-Pérez and Ottemöller (2014).*

To study the two clusters of events preceding the main shock in more detail, event locations are shown in Figures 6.4a and 6.4b for the months of June and July, respectively. Events occurring in the two clusters are marked as red. The vast majority of these cluster events are located in the epicentral area of the 30th August M_W = 6.7 earthquake and can thus be considered as foreshocks. Figure 6.4c shows the seismicity recorded during the first month after the 30th August event. There is strong aftershock

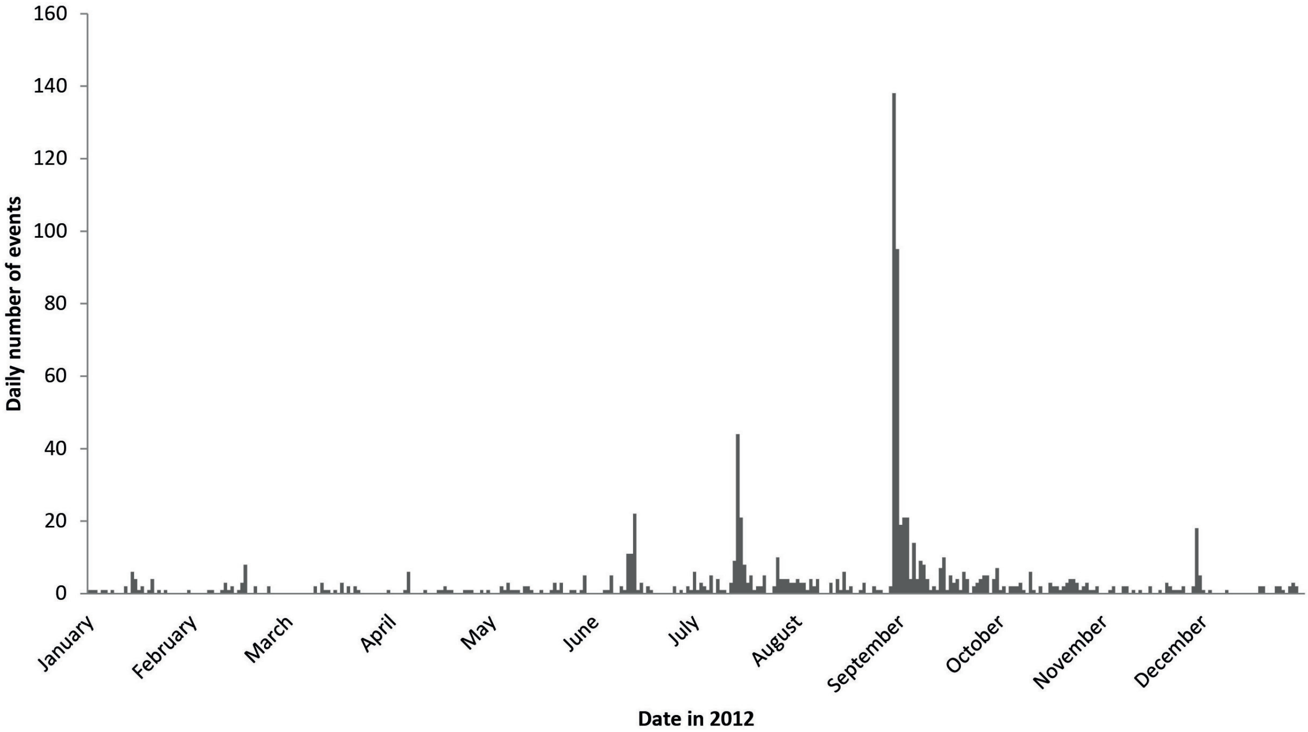

Figure 6.3: *Histogram showing the daily number of earthquakes in the Jan Mayen region, as recorded by the NNSN, in 2012.*

activity in the epicentral area, and the aftershock distribution indicates that the rupture propagated mainly from the epicenter, towards the SE. This is in agreement with the results of Rodriguez-Pérez and Ottemöller (2014). In addition to the aftershock activity near the rupturing fault plane, an increased level of seismicity is observed along the JMFZ and in the Jan Mayen Microcontinent .

Especially noteworthy are two clusters of events located NW and SE of the Jan Mayen Island, between -9 $^\circ$ and -8 $^\circ$ longitude, respectively (highlighted by the red squares in Figure 6.4c). Due to the station configuration on the Island however, these events are associated with relatively large location uncertainties. The event locations are highly sensitive to the S-arrival time and a slight change in the phase reading can lead to the event location jumping from one cluster to the other. It is thus not certain whether these events represent one or two clusters. There is, however, a strong indication that the events are not located in the JMFZ, but in the continental fragment.

It is not clear if and how these cluster events are linked to the 30$^{\text{th}}$ August earthquake, but some insight can be gained by studying the temporal evolution of seismicity in the region during the months June-September 2012. Figure 6.5 shows, in addition to the spatial seismicity distribution (top left), the temporal seismicity distribution as a function of both latitude (top right) and longitude (bottom left). The clusters of seismicity in June and July are clearly seen in these plots of temporal seismicity distribution. The aftershock activity following the 30$^{\text{th}}$ August event is also evident, and it is interesting to observe that the clusters of strong activity in the Jan Mayen Microcontinent are activated immediately after the occurrence of the main shock. This strongly supports a direct link between the main shock and these events, though we do not currently have a detailed explanation for their occurrence. Future Coulomb stress transfer modeling may give us further insight into this problem.

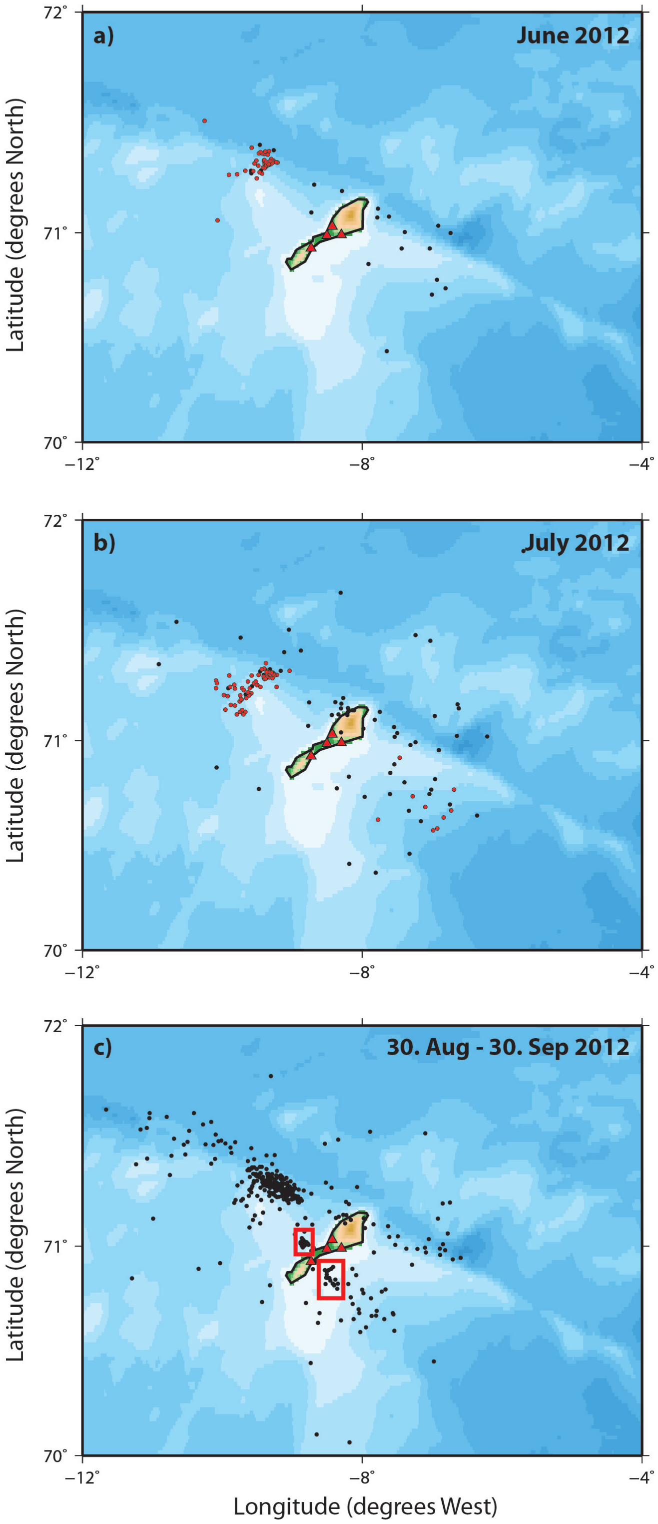

Figure 6.4: *Seismicity (dots) recorded by the NNSN during (a) June 2012, (b) July 2012, and (c) the period 30th August – 30th September 2012. (a,b) Cluster events in June and July are marked as red. (c) The aftershock clusters in the Jan Mayen Microcontinent are marked with red squares. The seismic stations on Jan Mayen are marked as red triangles.*

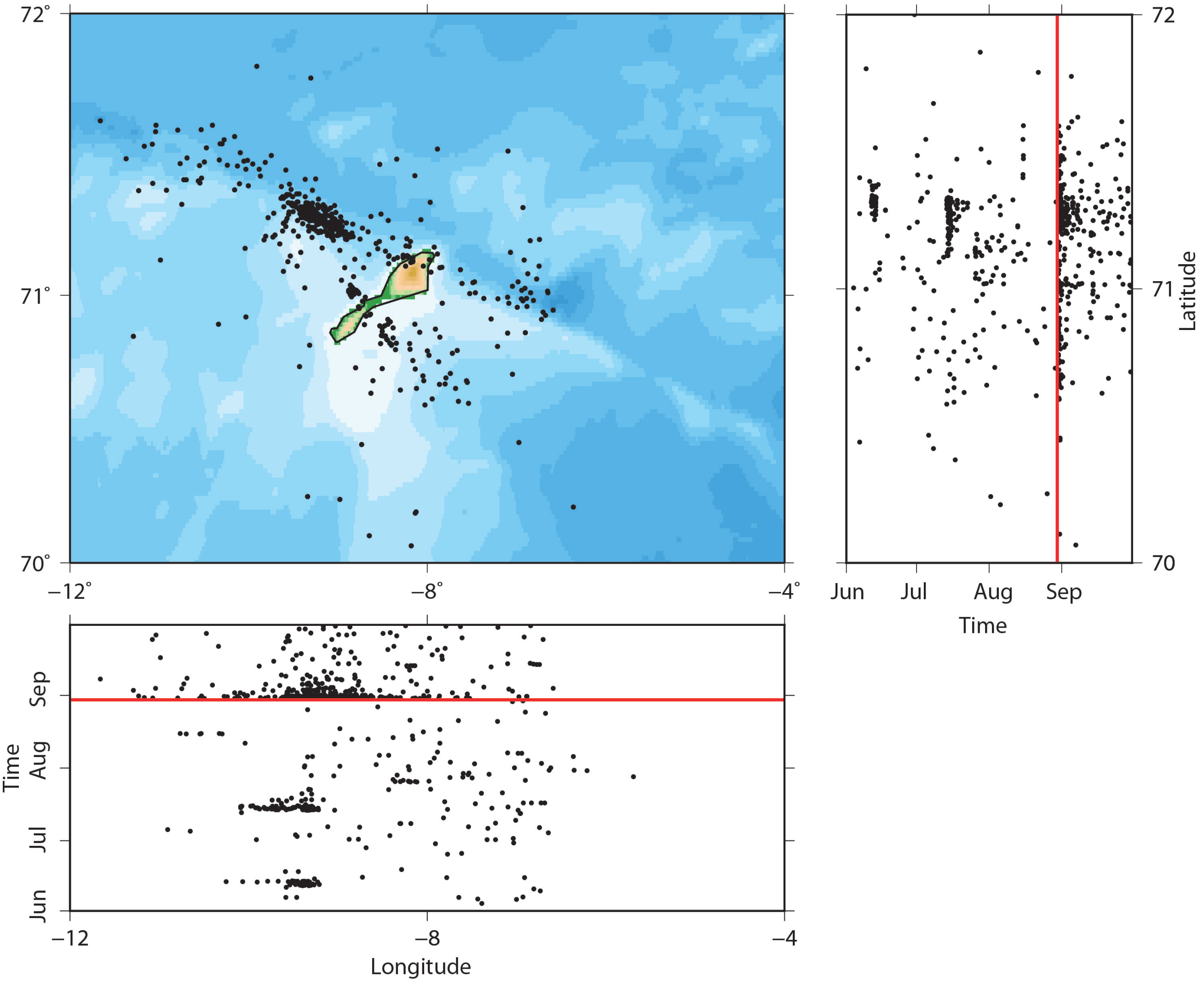

Figure 6.5: *Spatial (top left) and temporal (top right and bottom left) seismicity distributions in the Jan Mayen region during the months June-September 2012. The origin time of the 30th August event is indicated by the red lines in the temporal seismicity distribution plots.*

Similar plots to the one presented in Figure 6.5 have been prepared for the 2004 and 2011 $M \geq 6.0$ earthquakes to see if they were preceded by similar clusters of foreshock activity or if they triggered aftershocks in the Jan Mayen Microcontinent (Figure 6.6). Figure 6.6a shows a cluster of activity in June 2003 in the epicentral area of the 2004 earthquake. This sequence contained 60 events that occurred within a three day period, starting with a $M_W = 4.1$ event on 19th June. Figure 6.6b shows no clear foreshock clusters prior to the 2011 event, though increased seismicity levels were observed in a larger area containing the epicentral area in late February and early September 2010. Neither the 2004 event nor the 2011 event triggered noteworthy activity in the Jan Mayen Microcontinent. There was, however, significant activity in the Jan Mayen Platform, to the north of the JMFZ, in connection with both of these events.

In a study focused on the 2004 earthquake, Sørensen *et al.* (2007) showed that the event triggered distinct clusters of aftershocks in the Jan Mayen Platform. Coulomb stress modeling showed that these events occurred in a region of increased stress due to the 2004 event, thus supporting the hypothesis that stress triggering may play an important role in controlling the aftershock distribution of large strike-slip earthquakes in the JMFZ.

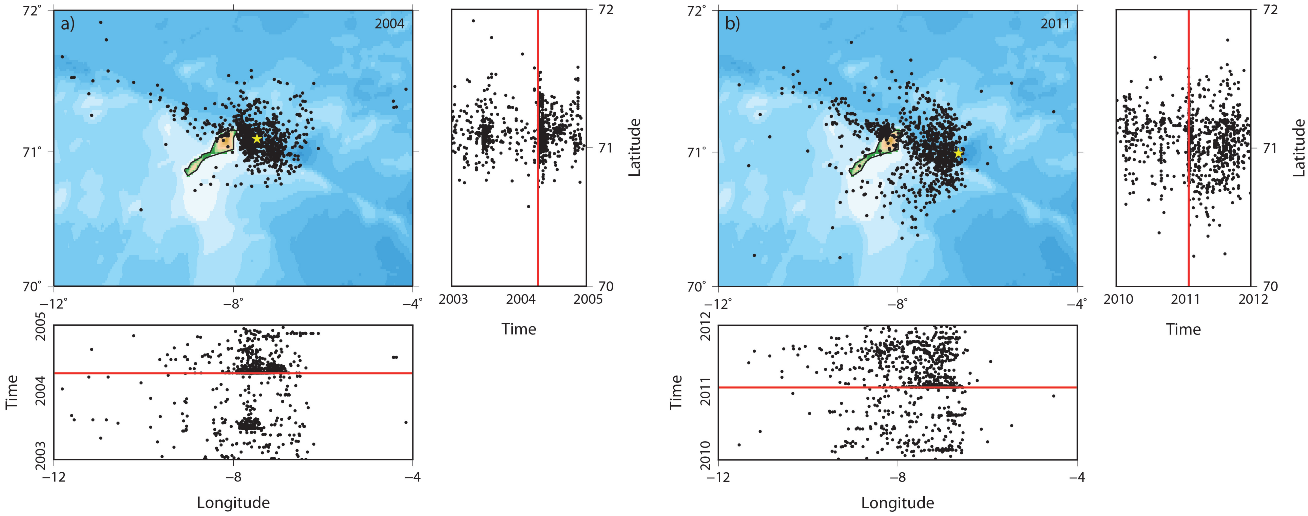

Figure 6.6: *As Figure 6.5 for earthquake sequences throughout (a) 2003-2004, and (b) 2010-2011. The epicentral locations of the 2004 and 2011 $M \geq 6.0$ earthquakes are shown as yellow stars in the spatial seismicity distribution plots.*

6.1.4 Summary

The 30th August 2012 Jan Mayen earthquake was the third $M \geq 6.0$ earthquake to occur along the JMFZ in the last decade. It ruptured a *ca.* 42 km-long segment of the northern part of the fracture zone that had not ruptured since 1951. The event was characterized by two intense clusters of foreshock activity in the epicentral region in June and July 2012. Following the event, aftershocks were observed mainly along the ruptured fault plane, but also along the entire fracture zone. Two clusters of aftershock activity in the Jan Mayen Microcontinent are also thought to be associated to this event. A comparison with two $M \geq 6.0$ events in 2004 and 2011 shows that the 2012 event is unique in terms of the clustered nature of both its foreshock activity and the aftershock activity in the Jan Mayen Microcontinent. A previous study of the 2004 $M \geq 6.0$ earthquake supports the hypothesis that these aftershocks are caused by Coulomb stress transfer in connection with the 30th August 2012 earthquake.

6.1.5 Acknowledgements

The data presented in this article was provided by the Norwegian National Seismic Network. Most of the data processing was done by Berit Marie Storheim. Many figures were plotted using the Generic Mapping Tools (Wessel *et al.*, 2013). I thank Lars Ottemöller for comments on the manuscript.

6.1.6 References

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