

G E O P H Y S I C S

Earth Tremors from the Surtsey Eruption 1963-1965

A Preliminary Survey

by

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Four seismological stations were in operation in Iceland when the Surtsey eruption began. They are listed below, together with their coordinates and distance from Surtsey.

Station	Lat. N	Long W	Distance from Surtsey
Akureyri	65°40'	18°06'	291 km
Kirkjubæjarklaustur	63 47	18 03	137 "
Reykjavík	64 08	21 54	117 "
Vík í Mýrdal	63 25	19 01	80 "

The seismograph at Akureyri was a Mainka instrument, with a magnification of about 100, measuring N-S ground motion. No tremors were observed there from Surtsey due to distance and low magnification of the instrument.

The seismograph at Kirkjubæjarklaustur is a vertical Willmore instrument. The maximum magnification used was about 10000, for a ground period of 0.1 to 0.7 seconds.

At Reykjavik three seismographs were operated, one Sprengnether E-W, and two vertical component seismographs. One of them was a Sprengnether short period seismograph. The third seismograph was a Willmore, which was connected to a galvanometer of 1.4 sec. period. Since this galvanometer is not designed for use with the seismograph, the magnification was unknown, but was estimated to be about 1300 for a ground period of 0.3 to 1.5 sec. Some rearrangements were made during the eruption, the most important one on December 12, 1963, when a N-S component Sprengnether was connected. After that only one vertical component was used at any one time, either Sprengnether or Willmore depending on

circumstances. All the Sprengnether seismographs were operated with a magnification of 400 or 1000.

At Vík a Mainka N-S seismograph was in operation, magnification 40 was used.

The present survey is based mainly on seismograms from Reykjavik, since they were most readily available for evaluation, but seismograms from Vík and Kirkjubæjarklaustur were used in several cases.

Microseisms are quite strong in Iceland, and their intensity shows a strong correlation with wind and swell. In relatively quiet weather their period is 1-5 seconds and the ground amplitude is 1 to 5 μ . In strong weather with heavy seas the period is 6 to 7 sec. and the amplitude is 20-30 μ or more. Changes in average amplitude take place rather slowly, over several hours. The ground waves which originated at Surtsey and will be described later, had to be distinguished from the usual microseisms. In stormy weather this proved to be very difficult.

From November 1st to 20th hardly any unusual activity could be observed on the seismograms at Reykjavik. The only exception occurred on November 12th, from 1400 to 2400*, when very weak waves with a period of 0.8 to 1.2 sec. were intermittently observed, which is much shorter than normal for microseism at that time. Otherwise the seismograms were quite usual. All earthquakes could be traced to other sources, and the microseisms were normal for the season.

At Kirkjubæjarklaustur several very weak earthquakes were registered on the 6th to 8th November, some of which were from an origin at a distance of 140 kilometers, approximately the same as to the eruption later on. From 1100 on the 12th to 0130 on the 13th weak tremors with a period of 0.2 to 0.4 period was observed, and again between 1100 and 1600, with a maximum between 1300 and

* All times are given in GMT.

1400. Similar tremors were also observed on the 14th from about 0500, but their amplitude was much smaller than before, and diminished gradually and disappeared in the afternoon. Small and very rapid tremors with a period of 0.1 sec. were observed on the 13th between 0600 and 1300, but they may have been caused by ice drift on a river near the seismograph or other local sources.

Shortly after midnight on November 21st other kind of tremors made their appearance, and were much in evidence for months to come. These waves were quite regular, their period was usually 2.0 sec., but sometimes it dropped to 1.5 sec. especially when the waves were weak. These waves often lasted for hours, but their increase and decrease took place in only a few minutes, and was much more rapid than for regular microseisms. This characteristic and the regular period distinguished these waves from the usual microseisms. Changes in their intensity sometimes coincided with marked changes in the eruption (on December 1st for example), and when a seismograph was operated in the Westman Islands they were observed there also, but with a larger amplitude. It is therefore considered almost certain that these waves originated in the vicinity of Surtsey. At Kirkjubæjarklaustur these waves were also observed, but wave components with a period of 0.7 - 1.5 sec. were also in evidence. The seismograph had its maximum sensitivity near this range.

The waves just described were first observed on November 21st, as stated before, but their amplitude increased considerably on December 1st at 1407-1411. They were very much in evidence on Dec. 2nd and 3rd, and again on 7th to 8th, but diminished after that. Still they were observed every day from time to time until the end of the year, but were very weak after Dec. 22nd, with a period of close to 1 sec. They increased again on Dec. 30th, but disappeared on January 4th 1964 for the time being.

The first earthquake, which definitely had an origin near Surtsey, occurred at 1219 Dec. 17th 1963 (magnitude 3.8) and another much weaker just before 2300. On the 23rd at 2306 there was again a small quake, followed by several still smaller quakes

on 24th. Still another small quake was at 2010 on January 3rd, followed by a stronger one at 1052 on the 4th. From January 7th to 10th fifteen earthquakes were observed at Reykjavik and several more at Kirkjubæjarklaustur. Four of these earthquakes were felt at Westman Islands, on the 7th at 2210 and 2231, 8th at 0133 and 9th at 1633. The three first felt earthquakes had a magnitude of 4.2, the last one 4.6.

On January 11th the long waves were observed again and had a maximum intensity on the 13th and 15th, but were obscured by microseisms on the 19th. Two rather small earthquakes were observed at Reykjavik on January 23rd at 1106 and 1421. These two and three more were observed at Kirkjubæjarklaustur.

The long waves appeared again at Reykjavik on the 24th in the afternoon, and were very strong the following day between 1109 and 1157 (amplitude 10μ). They were very pronounced the next six days, but disappeared on the 31st about 0230 and were not observed again with certainty until February 12th. The maxima of these waves in the period from January 20th to March 31st 1964 is given in Table I. The amplitude is given on those days when microseisms were not pronounced. The long waves almost disappeared from the Reykjavik observations on 28th to 29th of March, but very weak tremors were observed on 17th to 24th of April and in the evening of July 9th. The long waves were not observed again until next summer.

An earthquake from Surtsey was observed at Reykjavik at 1752 on January 31st 1964, and the following day eleven quakes were observed, at 0004, 0203, 0257, 0729, 0743, 0857, 1140, 1452, 1554, 1555 and 1658, but twice as many were observed at Kirkjubæjarklaustur. The earthquakes at 0257, 0729, 0857 and 1452 were the strongest ones, with a magnitude of 3.2 to 4.5. Some of these quakes were felt at Westman Islands.

Two small earthquakes were registered at Kirkjubæjarklaustur at 1047 and 1156 on March 9th, and also at 1015 on July 14th, 1964.

After that no tremors or earthquakes originating at Surtsey until May 1965 were observed.

On May 8th 1965 at 1041 a small earthquake or tremor with a probable origin at Surtsey was observed in Reykjavik. This tremor was followed by many others the next twelve days. They are listed below, and magnitude is assigned to the largest ones. The times of the earthquakes and tremors are as follows: On the 9th at 1601 (small), 10th at 0251 (magnitude 4.2) and 0315, 11th at 0033 and 0759 (both small), 13th at 0102 (very small, followed by very weak tremors the same day and the next), 14th at 1718 (magnitude 4.2) and 2140 (weak tremor), 15th at 0703 and 1718 (magnitude of both 3.7), 16th at 0711 and 0810 (both small), same day at 1320 (magnitude 4.0), 17th at 2357 (small), 18th at 0115 (very weak tremor). On the 19th six earthquakes were registered, the largest at 1415 (magnitude 4.2). The others, which were much smaller were registered at 1513, 1536, 1611, 1655 and 2038. Weak indefinite tremors were also registered at 1433 and 1453. An earthquake at 1501 on the 20th (magnitude 3.8) concluded this series. No tremors or earthquakes originating near Surtsey were observed during the next month.

Regular waves, similar to those observed first on Nov. 21st 1963, again made their appearance on July 3rd in the forenoon, after an absence of over a year. Their period was now 1.2 to 2.3 sec., 1.2 being most frequent. They were observed daily (except July 5th) until August 11th, but with varying intensity and frequency. On August 12th to 14th the waves seem to diminish and almost disappear. But strong microseisms on these days may partly obscure them.

Late on the 14th the waves increased again and were visible until 11th of September, although they were disturbed by microseisms on August 23rd and 24th. The period in August was 1.3 to 2.0 sec. The waves had maximum amplitudes on August 31st and September 9th, and had then a period of 1.2 sec. September 12th

to 15th microseisms were intense, and no waves from the eruption could be distinguished. They were however observed again September 16th to 18th (period 1.2 sec.). September 19th to October 1st they were very weak or entirely absent, but microseisms were strong during the first days of this interval. October 2nd to 7th the eruption waves were observed again, this time with a period of 1.0-1.2 sec., but after that they were hardly visible at all to the end of the month, but microseisms were strong, especially on 12th to 20th and 26th to 27th.

Earthquakes began again in the Surtsey area on October 28th. The seismographs at Reykjavik registered the first quake at 1155 (magnitude 3.5). Earthquakes from Surtsey had not been registered since May 20th. The next earthquake was observed at 1055 on Nov. 4th, it was somewhat weaker than the previous one. The third one was at 1934 on the same day (magnitude 3.9), and a quake on Nov. 5th at 0152 may also have originated in the Surtsey area. Further earthquakes from Surtsey were the following (magnitude is given in parenthesis when determined): November 9th at 0227 (3.4), 13th at 0107 (4.2), 17th at 1048 (4.4), 1143 (4.4) and 1546 (4.2), 21st at 1027 (4.2), 22nd at 0003 (4.6), 23rd at 1125 (3.5), 24th at 1119 (3.6) 1139 and 1623 (both small). On November 27th at 0007 a small earthquake was observed which may have originated near Surtsey.

Tremors and regular waves were observed every now and then in November, especially on the 1st, 2nd, 5th, 6th, 8th, 9th, 12th, 21st, 23rd and 24th.

No earthquakes are known to have originated at Surtsey in December 1965, but tremors were observed on the 4th, 6th, 12th, 22nd and 27th.

On February 24th to 27th the ground wave activity often seemed to be at maximum near the high tide. Spring tide was at maximum on these days. The examples are so few, however, that it is difficult to decide if the coincidence is significant or dependent on chance alone.

Table I. Times and Amplitude of Ground Waves from the Surtsey Eruption, January 20th to March 21st, 1964. Observed at Reykjavik.

The amplitude given is the N-S ground motion in μ .
The magnification of the seismograph used was 750 at $T_g = 2.0$ seconds.

Date	GMT	Amplitude
20/1	2111-2123	
24/1	1630-1640	
"	1839-1930	5
25/1	1109-1157	10
27/1	2203-2244	
28/1	0152-0333	
"	0701-0727	13
"	1511-1541	
"	2011-2018	12
29/1	0005-0050	
"	0513-1200	
30/1	1403-1407	
"	1844-2015	
16/2	2232-2241	
17/2	0532-0545	
21/2	2111-2123	
24/2	1630-1640	
"	1839-1930	4.5
26/2	1709-1716 *	
"	1722-1744	5
27/2	0429-0433	
1/3	0926-1004	
2/3	2032-2050	5
4/3	1857-1900	
"	2000-2234	
8/3	1123-1130	
9/3	0621-0641	
"	0849-0912	8
11/3	0049-0055	
"	0540-0607	3
12/3	0147-0149	3
"	0347-0407	
18/3	1855-1902	
"	2105-2131	5
21/3	0637-0736	

* Short regular waves, $T_g = 1.0$ sec.