# A short, incomplete history of analog seismographs in Iceland

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## Early decades

The first seismograph in Iceland was set up by German scientists in 1909 in Reykjavík. It was located in the old building of the Nautical School (Stýrimannaskólinn) at Öldugata 23, that still stands. This location was presumably chosen because of the precise time keeping. A visible time mark was given every day from this location for the benefit of navigation of ships in the Reykjavík harbour.


*Öldugata 23, the location of the first seismograph in Iceland in 1909.*

The seismograph was a Mainka seismograph that measured the horizontal N-S component of the ground movement. Another seismograph of the same type was added in 1913. It measured the E-W component. The operation of these instruments did not go very smoothly. It was frequently interrupted and finally stopped in 1914 because of the First World War (Tryggvason, 1951).
These seismographs were mechanical, i.e. no electronics. The amplification was achieved by connecting rods between the horizontal pendulum and the recording pen. The recording was by a fine needle on smoked paper taped on a rotating drum. The soot on the paper was then fixed in a bath of shellack. The amplification was low, only 100.

The operation of the Mainka seismographs was resumed in Reykjavík in 1925 and 1927, soon after the Icelandic Meteorological Office was founded, at the initiative of Þorkell Þorkelsson, its first director. The operation was continuous until 1952, when improved instruments were installed.

A set of three short-period Sprengnether seismograps was set up in Reykjavík in 1951-1952. These had a much higher amplification than the old instrumens, but was seriously limited by the high level of microseisms, i.e. continuous tremor originating in the Atlantic Ocean, with a high spectral peak near 6 sec. period. These instruments had an electromagnetic sensor and recorded with a light beam on photographic paper. The old Mainka instruments were then moved to Akureyri and Vík í Mýrdal, thus forming the first network in Iceland. Some of the largest earthquakes could then be located instrumentally, even though the accuracy was not good.

New stations were set up at Kirkjubæjarklaustur in 1958 and Eyvindará near Egilsstaðir in 1967, consisting of one vertical electromagnetic Willmore sensor. A similar sensor was added to the station in Reykjavík in 1966.

A large step was taken in 1964 when a state-of-the-art seismic station was established in Akureyri, in the basement of the police station. It was a part of the World Wide Standardized Seismograph Network (WWSSN) that was established and run by the US Geological Survey. The network consisted of more than 120 stations that were distributed throughout the Earth, each one with three long-period sensors and three short-period sensors. The main purpose of the network was to monitor nuclear explosions, but it also provided the first reliable maps of global seismicity, forming one of the backbones of the Theory of Plate Tectonics. The data from this network were copied and distributed to several data centers, one which was at the Lamont-Doherty Earth Observatory in New York. Data from the Akureyri station were used in numerous studies of world seismicity and the internal structure of the Earth.

Data from the stations listed so far were analysed at the Icelandic Meteorological Office (Veðurstofa Íslands). A Seismological Bulletin was issued every year since 1926, listing earthquake epicenters and magnitudes, and other pertinent information.

**Electronic revolution**

A major advance in seismometry took place in the sixties, mainly due to the invention of the transistor and other electronic components. Measurements using electronic components became reliable and electronic circuits could be designed that did not require connection to the electric mains and could be run outside under field conditions. The eruptions in Surtsey 1963-1967 sparked new interest in earthquake monitoring. A seismograph was operated for a while on Heimaey (Pálmason, 1966) and a grant was obtained to buy and build a seismic system to operate on Surtsey, consisting of a 7-track tape recorder, sensors and amplifiers (Sigurgeirsson and Stefánsson, 1967; Einarsson, 1974).

The Surtsey eruptions also coincided with the advent of the Plate Tectonics Theory and attracted the interest of the international geoscience community to Iceland. A group from the Lamont-Doherty Earth Observatory came to Iceland in 1967 and brought several portable seismographs with them. The idea was to trace the plate boundary through Iceland by locating microearthquakes that were thought to occurr more or less continuously along the boundary.

This did not really work, but instead it was discovered that geothermal areas do behave in this way (Ward et al. 1969; Ward and Björnsson, 1971).

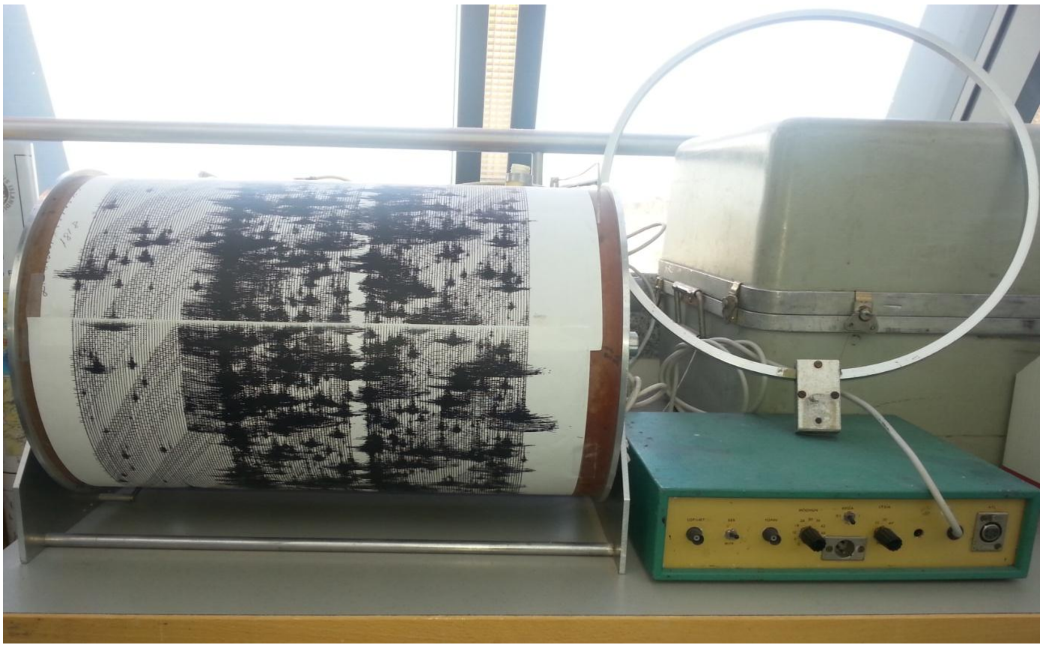
The results of the microearthquake studies led to a major project to monitor the seismicity of the Reykjanes Peninsula, that was showing very high activity at this time (Björnsson et al., in press 2018). The instrumentation from Surtsey was modified and augmented to establish six semi-permanent station on the peninsula. In addition a large field project was launched in the summers of 1971 and 1972 (Klein et al., 1973, 1977).

Three of the portable instruments, that the Lamont-group brought, were set upp in South Iceland and „forgotten" over the winter time in 1971 and 1972. This was done to test how well these prototype instruments would perform under difficult circumstances and in the care of non-technical people. The best locations were at Skammadalshóll near Katla volcano and Laugarvatn, in the secondary school. These instruments recorded, among other things, the beginning of the eruption in Heimaey in January 1973 (Björnsson and Einarsson, 1974).

**Landsnet**

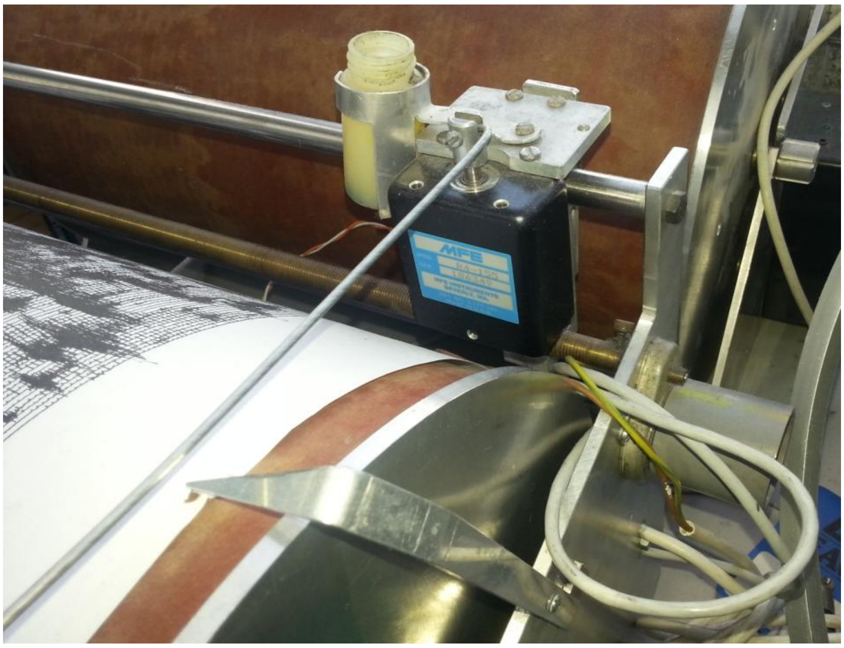
The positive experience of operating sensitive seismographs at farms and installations throughout the country led to the idea to design and build similar instruments and form a network to cover the active parts of the country. Small grants were obtained from the NATO science program for a three-year project for this purpose. The design was based on the prototype instruments from Lamont, but the electronics parts were designed by Marteinn Sverrisson at the Science Institute, University of Iceland. The hardware was made by Karl Benjamínsson in the machine shop of the institute. The work was directed by Sveinbjörn Björnsson and Páll Einarsson (Einarsson and Björnsson, 1987) .

The design critera were that the instrument had to be inexpensive, yet robust and easily serviceable by the local people. It had to be sesitive in the frequency band 3-30 Hz for the detection of local earthquakes, yet insensitive in the band of microseisms (0.1-0.2 Hz) from the swell of the North Atlantic Ocean, that seriously limits the sensitivity of island seismographs. The sensor was a geophone of 3 Hz natural frequency. The amplifier had a HP filter selection (at 0.1 or 1 Hz) that could be adjusted according to the level of microseisms activity, also LP filter adjustable between 15 and 30 Hz. The electronics was arranged on five boards that could be individually replaced in case of failure, i.e. power board, pre-amplifier, amplifier, power amplifier, and time signal receiver. Radio time was put directly on the seismographic trace, thus avoiding using a clock and cumbersome clock corrections. Recording was by pen and ink on paper attached to a rotating drum. Usually the paper sheet was changed once per day. This allowed a time resolution of 90 mm per minute, one line per 10 minutes on a sheet that is 90 cm long. During days of very high activity the interval between lines was increased to avoid tangling of the lines. Then the sheet had to be changed more often.

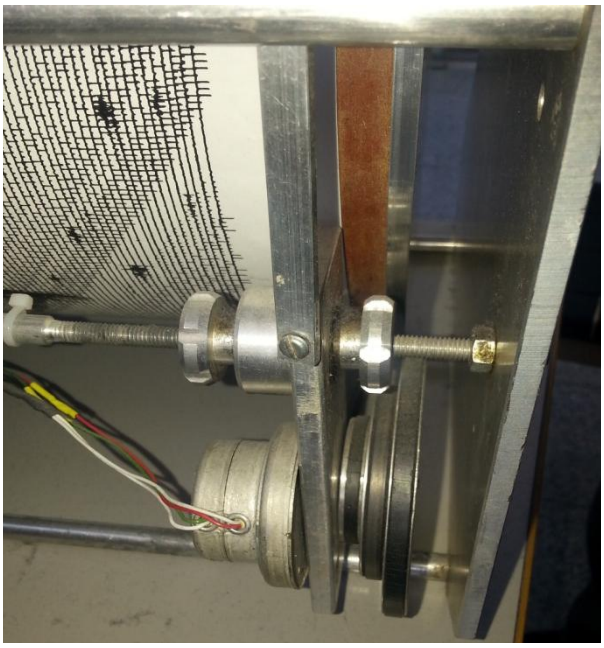


*The seismograph of Landsnet. Drum recorder with a sheet showing a local recording of an earthquake swarm in the Hengill area, electronics box, and a loop antenna for the reception of the time signal. The grey box was used for the field version of the seismograph.*


*The front of the electronics box: Input for the time signal antenna, seconds filter, tone input for FM modulated signals from a signal receiver, amplifier 0-60 dB, HP-filter, input for geophone signal, LP-filter, 220 VAC power cord, 12 VDC power input.*



*The pen-motor and translation-motor assemblages of the Landsnet seismograph. The pen was made at the SI from a drawing pen tip attached to  a syringe pipe. A special recording ink was used, available in different colors, black, red, green and blue.*



*The rotation-motor assemblage of the Lansnet seismograph. It offered three different speeds of rotation. The most used time resolution was 90 mm per minute.*

The seismograph could be modified for a telemetered version. The power amplifier card was then simply exchanged for a tone modulator and the tone fed into a hand-held radio link. The tone on the receiving end was then de-modulated and amplified in a similar box and fed into the pen-motor of the recorder. The telemetering system required a line-of-sight and often a repeater station to carry the signal over large distances. This was used for seismic stations on the Reykjanes Peninsula and in the Hengill area near Reykjavík. During the Krafla episode in 1975-1984 several stations were also telemetered to a central recording station in Reynihlíð. A network of telemetered stations was installed in Central Iceland in 1985, funded by Landsvirkjun (the National Power Company), for the monitoring of the active volcanoes around their main power stations. The signals were telemetered over repeater stations on Búrfell and Skarðsmýrarfjall to Reykjavík, where they were recorded on paper at the Science Institute.

The first seismographs of the new network were installed in the autumn of 1973 and summer of 1974 in South Iceland with emphasis on the Katla volcano. In the second phase of the project in 1974-1975 seismographs were installed in North Iceland. These stations showed increased activity around the Krafla volcano, that preceded the first dike injection event of Krafla tha began on December 20 1975. This led to increased monitoring activity in the Krafla area. Monitoring was also increased in other areas, including the Vatnajökull area and the South Iceland Seismic Zone. The final phase of the original project was then finished by installing stations around the central highland in 1977. Several stations were then added in the following years when opportunities arose, e.g., around Hengill in 1979. The stations are listed in the accompanying Station Table, their names, locations and operation times. The table will be updated as the scanning project progresses.

The sheets from the Landsnet stations were sent to the Science Institute where a preliminary analysis was carried out. The results were distributed by Skjálftabréf, a pamphlet containing approximate locations and other information. The first detailed epicentral maps of earthquakes based on the results appear in several papers in the eighties and nineties (e.g., Einarsson and Björnsson, 1987, Einarsson, 1991).

A new digital seismograph system became operational in South Iceland in late 1990, called the SIL-system. This system was expanded in the following years to cover the whole of Iceland. The operation of the old anolg network was then gradually phased out as the new, sophisticated network expanded. The last analog seismograph was taken out of service in 2010.

**The seismograms and time signal**

All the analog seismograms are written on drum recorders, i.e. a paper sheet was attached to a rotating drum and the recording element, pen, needle  or light beem, was moved sideways with respect to the drum, so that a continuous trace was written on the sheet. When the sheet was removed from the drum the trace formed lines, with time in each line progressing from left to right, like lines in a book. The time resolution of the recording was determined by the rotation speed of the drum, one, two, four or six rotations per hour, producing the same number of lines per hour on the final seismogram sheet.

A time signal was mixed with the seismic signal, a small excursion of the trace suprimposed on the movements of the ground. Thus any disturbance of the ground could be timed by measuring its distance from the neares time signal. On most seismographs a minute mark was considered sufficient, but on the Landsnet seismograph the second marks were used as well, in order to increase the timing accuracy. It was considered improtant to eliminate the need for clock corrections, so continuous radio time was used directly on the seismogram. The time signal from Rugby in England was used most of the time of operation. Another time signal was used during limited time period. It was a low-frequency navigation signal for submarines, called Omega, giving only minute marks.
The Rugby time signal was coded after June 1977, which came in very handy when reading the seismograms. The seconds marks came in two sizes, signifying 0 an 1 in a binary code. The date and time were indicated every minute of the seismogram. This made an easily readable pattern on the seismograms because each line was 10 minutes long, i.e. each hour contained six lines. If the time marks were properly aligned the last digit of the time would be the same in all vertical lines across the seismogram. Reading the rest of the code requires a bit of practice, but makes the life of the record reader a lot easier. So:

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0000 | or | 000 | or | 00 |
| 1 | 0001 | | 001 | | 01 |
| 2 | 0010 | | 010 | | 10 |
| 3 | 0011 | | 011 | | 11 |
| 4 | 0100 | | 100 | | |
| 5 | 0101 | | 101 | | |
| 6 | 0110 | | 110 | | |
| 7 | 0111 | | 111 | | |
| 8 | 1000 | | | | |
| 9 | 1001 | | | | |

Unnecessary zeros in the front are dropped.
Second marks number 17-24 tell the year, seconds no. 25-29 the month, no. 30-35 the day of the month, no. 36-38 the day of the week (Monday no. 1), no. 39-44 the hour (in England), no. 45-51 the minute beginning at the next minute mark.

The date and time Monday the 4th of July 1977 at 1635 would then appear:
011101110011100010000101011001100101
7 7 0 7 0 4 1 1 6 3 5

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