THIRTY YEARS OF BOREHOLE STRAINMETER MEASUREMENTS IN ICELAND

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Abstract

Over short intervals, borehole strainmeters can resolve strain changes as small as 0.0001 mm km^{-1} (i.e. 1×10^{-10}), making them ideal for measuring crustal deformation over periods ranging from minutes to months. Positioned at depths of ~200 m below the Earth's surface, borehole strainmeters are sheltered from environmental disturbances and are thus able to record minuscule levels of strain in the surrounding rock. As field-deployable sensors, the frequency response and dynamic range of borehole strainmeters is unsurpassed.

In 1979, in collaboration with the Icelandic Meteorological Office (IMO), the Department of Terrestrial Magnetism at the Carnegie Institution of Washington (CIW) installed eight Sacks-Evertson dilatometers in south-west Iceland (Table 1). Funding for the purchase and installation of these instruments was provided by CIW, with operational responsibility given to IMO. At each site, a volumetric strainmeter was grouted into place in a bedrock borehole at depths ranging 58–401 m (Table 1). To minimise the start-up cost of the network, disused boreholes were chosen to host the instruments; however, owing to varying borehole diameters, CIW had to make each strainmeter to individual specifications. Remarkably, the functionality of the network is good: six of the eight original sites are active today (Table 1).

Until September 1986, continuous readings from the network were saved as analogue tracings on paper drums at each station. Subsequently, measurements were telemetered via radio to IMO in Reykjavík, where the data were stored on magnetic reels. Since June 1991, data have been archived at IMO on hard-disk drives and compact discs. The conversion to digital telemetry afforded a continuous, 20-bit data-stream from the strainmeter network.

In the present configuration, analogue measurements from each strainmeter are over-sampled continuously at a rate of 109 Hz. Data from each strainmeter are transmitted via radio frequency at a baud-rate of 4,800 to a central repeater on a mountain range on the outskirts of Reykjavík; here, the digital signal is filtered at 50 Hz and then multiplexed into a single stream. From the repeater station, the data are beamed directly to IMO at a baud-rate of 19,200. The signal is then de-multiplexed and time synchronisation is provided by a GPS clock. The raw, 50 Hz data are held at IMO for 30 hours in a 1.1 GB ring-buffer, from which 1 Hz samples are archived from a single binary file. These data are stored in compressed ASCII format as hourly files in a directory for the current day. The same directory also contains auxiliary measurements of battery voltage at each location and, at some sites, precise measurements of borehole temperature. To date, over 45 GB of 1 Hz data have been collected.

The network was established to register crustal deformation before and during strong earthquakes in south-west Iceland, but it is also possible to observe strain changes during eruptions of Mount Hekla. Positioned ~15 km from the volcano's summit, BUR is the closest strainmeter to Hekla. Strain pulses registered at BUR tens of minutes before the 1991 and 2000 eruptions of Hekla enabled public warnings to be issued before each eruption began. Four Hekla eruptions have occurred since 1970 – each separated by a repose interval of ~10 years. With the increasing likelihood of another Hekla eruption, and the strainmeter network entering its thirtieth year of operation, the goal of this presentation is to document the present state of the network, and to outline how its measurement capabilities can be improved.

Station	*Latitude*	*Longitude*	*Depth*	*Active?*
BUR	*64.11 N*	*19.80 W*	*181 m*	*Yes*
GEL	*64.32 N*	*19.29 W*	*233 m*	*Yes*
HEL	*63.84 N*	*20.40 W*	*393 m*	*Yes*
JAD	*64.30 N*	*20.15 W*	*58 m*	*No*
RIF	*63.96 N*	*21.27 W*	*292 m*	*No*
SAU	*63.99 N*	*20.43 W*	*180 m*	*Yes*
SKA	*64.21 N*	*20.53 W*	*125 m*	*Yes*
STO	*63.75 N*	*20.21 W*	*401 m*	*Yes*

Table 1: Active strainmeters in the Icelandic network: September 2009. Although SAU and SKA are listed as active, both stations are considered unserviceable. Geographic co-ordinates are in decimal degrees relative to the WGS 84 ellipsoid. Depth measurements are referenced to the top of the borehole casing.