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Measurements of Distance and Tilt Changes in Fissures of Northern Iceland

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Abstract. In an active tectonic fissure about 50 km north of Krafla in N-Iceland, relative movements of the fissure walls were recorded for about one month in the summer of 1976, during an inflation period of Krafla. Distance changes of the walls, measured by two-component extensometers, show a widening tendency of about 5 µm per day; this is superimposed by sudden widenings of up to 0.05 mm and temperature effects with diurnal peroid. Tilt measurements of the fissure walls confirm these results, especially the sudden effects and the diurnal ones, and show, moreover, a northward tilting of the whole region perhaps caused by mass transport at depth and/or in response to the inflation of the Krafla magma chamber.

Key words: Extensometer measurement – Tilt measurement – Fissure movements

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1. Introduction

In the rift zones of Iceland the tectonic fissures can be considered a visible expression of crustal deformation. The deformation has been studied by geodetic measurements by several authors (Gerke et al., 1978; Möller and Ritter, 1980; Tryggvason, 1980; Spickernagel, 1980; Torge and Kanngiesser, 1980; Johnson et al., 1980). Details of the movements cannot be detected by classical geodetic measurements, because in most cases there is a time interval of one or more years between two measurements, and the distances between control points are large and cross more then one fissure. Therefore, if we are interested in the character of fissure movements, we have to apply continous measuring techniques as they are used in rock mechanics and engineering surveying. We have chosen to use extensometers and tiltmeters.

North Iceland is currently experiencing a rifting episode with the center of activity in the Krafla caldera (Björnsson et al., 1977; 1979). A magma chamber below the caldera seems to be continuously inflated by inflow from depth; occasionally it is deflated suddenly by magma excaping into opening fissures of the Krafla fissure swarm.

Besides monitoring the movements in the immediate vicinity of Krafla (Tryggvason, 1980), it seems desirable to monitor the fissure movements at greater distance. We have chosen a fissure in the Kelduhverfi area some 50 km to the north (Fig. 1). We report here measurements taken during the first documented inflation phase of Krafla, beginning early 1976 and ending on September 29, 1976. The observations ended before the deflation and thus can give only a limited insight into the behaviour of the fissures. New observations have therefore been made in 1978, the analysis of which has, however, not yet been completed.

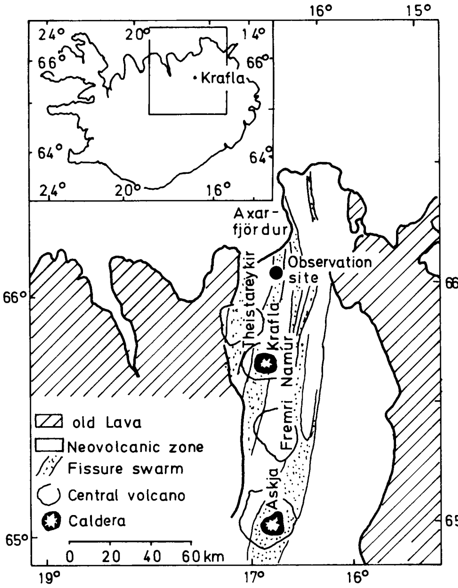

Fig. 1. Location map of fissure investigated

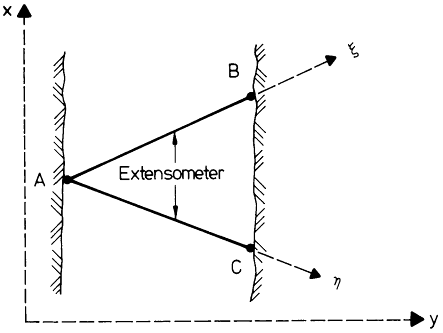

Fig. 2. Two-component extensometer; principle

2. The Two-Component Extensometer Measurements

The first investigations of this kind were carried out by Gerke and Pelzer (1972). In order to record movements along and across

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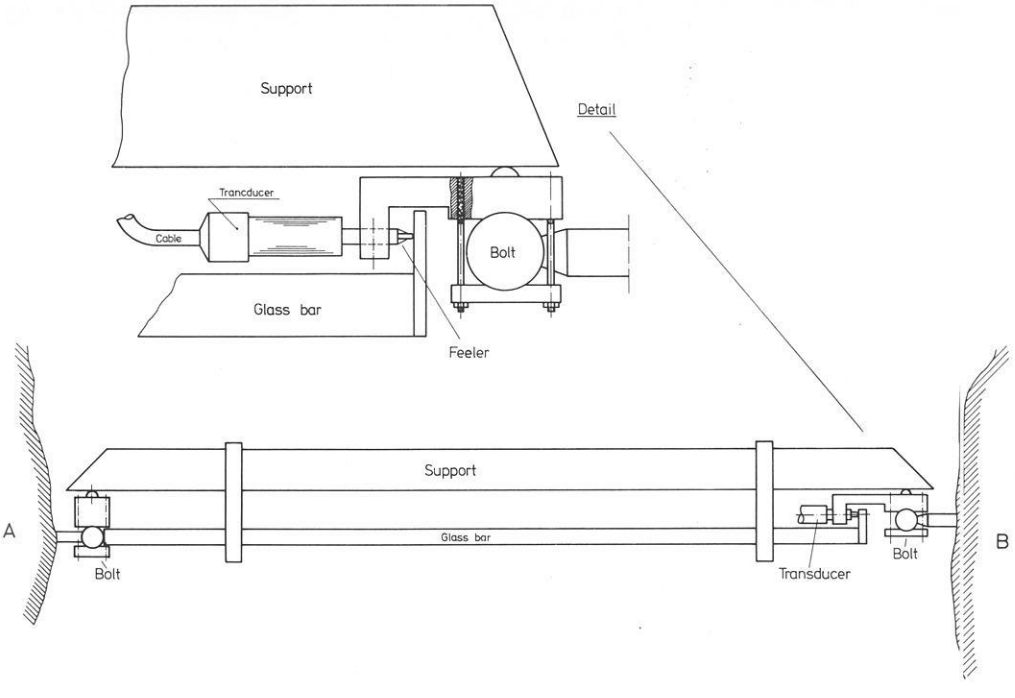

Fig. 3. Details of extensometer

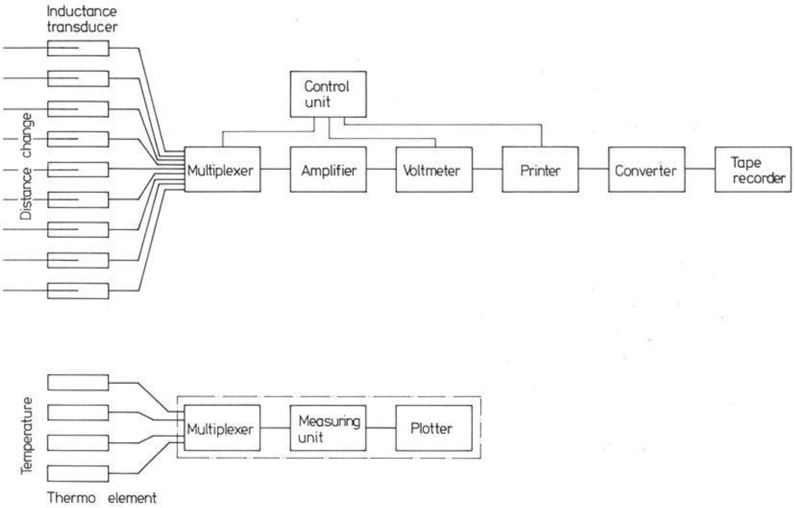

Fig. 4. Measuring and recording device

a fissure a two-component extensometer was developed (Fig. 2) and installed in five fissures in the Gjásticki area. Fissure movements in the ξ- and η-direction could be recorded by mechanical recording devices with a resolution of about 0.2 mm, and transformation of the recorded movements into an arbitrary x,y-coordinate system could be done off-line without difficulties. But, unfortunately, no movements greater than a few tenths of a millimeter occurred within the recording period of about two years (1967–1969). Therefore, in a second attempt, a new higher-resolution two-component extensometer was developed at Geodätisches Institut, Universität Hannover; it is described in detail below.

The basic concept of the extensometer is given in Fig. 2. Changes in distance are measured between a fix point A at one wall of a fissure and fix points B and C at the other wall. Figure 3 shows one component of the measuring device, installed between A and B, for example. The distance between the fixed points, realized by the faces of spherical steel bolts, is bridged by a glass bar which is supported at its BESSEL-points. Because of the small thermal expansion coefficient of the special glass ($10^{-8}K^{-1}$) the length of the bar may be considered invariable. Changes in distance between A and B will result in movements of the feeler of an inductance transducer, where they will be transformed into electric signals.

By a screened cable the transducer is connected via a multiplexer with a central measuring unit (Fig. 4). An automatic control unit allows common recording of the data of eight transducers or four two-component extensometers.

In 1976 the extensometer was installed in Iceland for the first time. In this year new fissuring and opening of existing fissures occurred in the Kelduhverfi area in N-Iceland, related to the volcanic activity near Krafla (Björnsson et al., 1977; 1979). At the time the behaviour of the Krafla caldera and of the fissure swarm was not yet understood in as much detail as it is today. Therefore, one of the active fissures in the area (Fig. 1), i.e., one which

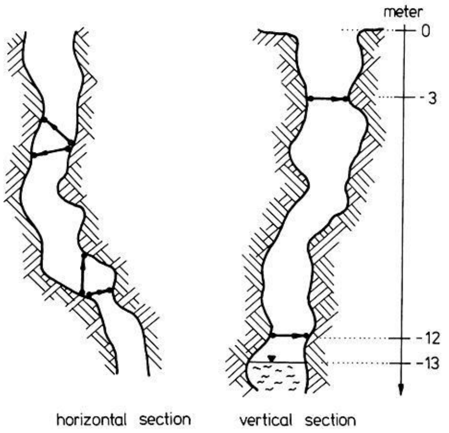

Fig. 5. Installation of two-component extensometers in the fissure

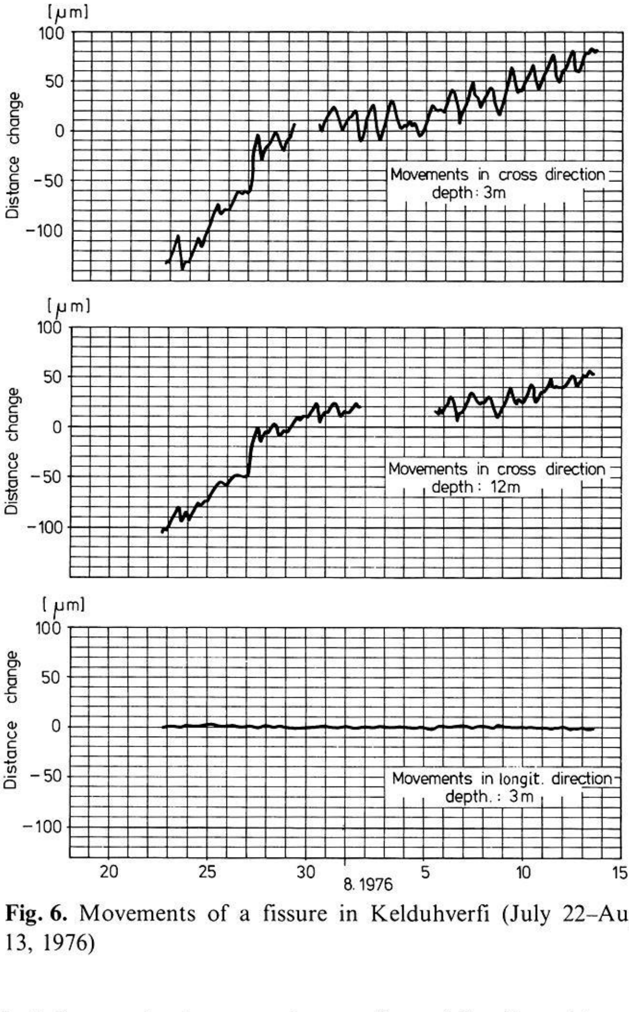

Fig. 6. Movements of a fissure in Kelduhverfi (July 22–August 13, 1976)

had shown extension, was chosen rather arbitrarily and two sets of extensometers were installed in it. Each set consisted of four two-component extensometers arranged as shown in Fig. 5. The extensometers were working for more than three weeks (July 22–August 13); the sampling rate was one per 15 min.

The distances in the ξ,η-directions (Fig. 2) were transformed into an orthogonal x,y-system parallel and perpendicular, respectively, to the fissure direction and plotted as functions of time. Typical plots are shown in Fig. 6, the other plots are very similar in character.

The recording period fell into the first inflation period of Krafla from December 1975/January 1976 to September 29, 1976. The question was wether or not the fissure continued to widen during the inflation period, after it had widened by up to several decimeters, easily detectable, in the beginning.

The result during the period of observation was a widening of the fissure, recorded by the upper and lower extensometers; the amount of widening is of the order of 0.2 mm. In detail we can separate three effects:

(a) a more or less uniform widening tendency of about 5 μm per day,

(b) sudden changes in distance of up 0.05 mm, for example on June 27 and, less significant, on June 23,

(c) periodic distance changes with an amplitude of about 10 μm and a frequency of one cycle per day; they are interpreted as temperature effects (see temperature plot in Fig. 7).

In contrast to this, no significant movements in the longitudinal direction of the fissure were observed (see Fig. 6, bottom).

3. Measurements of Tilt Changes

Tilt measurements were carried out between July 28 and August 15 near the extensometer station No. I. Two Hughes bubble tiltmeters TM 3 (nos. 34 and 35) were used. Each of them measures tilts in two orthogonal directions. The linear range of the instruments is about 49 μrad the resolution is better than $\pm 4.8 \cdot 10^{-3}$ μrad. The construction principles and further details are described by Harrison (1976a). The tiltmeters were installed on both sidewalls of the fissure, about 13 m below the earth's surface (Fig. 8). A special suspension was constructed which permits a strain- and stress-free installation of the instruments. In addition, each tiltmeter was protected against mechanical and meteorological influences by a stainless-steel coverage and a wooden box, which was filled with styrofoam. The orientation of the orthogonal tilt axes is shown in Fig. 8 for both instruments. The signals were recorded by two-channel analog recorders, which were installed in a tent. In addition, temperature and air pressure were measured at different sites (Fig. 8). During the recording period, short interruptions occurred caused by technical failures.

The analog records of the tilt measurements were digitized with a sampling rate of 1 per 5 min. The meteorological data were sampled only once per hour. Gaps in the record were interpolated with smoothing cubic spline functions. The digitized tilt changes are plotted in Fig. 9.

We can see in the beginning a small tilt in the direction of the tiltmeters which conforms to an inclination of the western fissure wall to the west and of the eastern fissure wall to the east. From August 7–11 large, mostly reversible, tilt changes occurred. In this period a strong south storm disturbed the measurements. During the last days of observations, small periodical tilt changes were observed without any obvious drift direction.

The data analysis was performed with the usual statistical methods, such as the computation of regression models, cross-correlation functions, Fourier and power spectra, to find the mean drift terms, correlations with meteorological effects, tilts, and significant frequencies.

The cross-correlation functions between the tiltmeter records and the meterological time series show no significant dependency of the tilts on temperature changes. Only the temperature measured near the tiltmeters rendered correlation coefficients between +0.5 and +0.6.

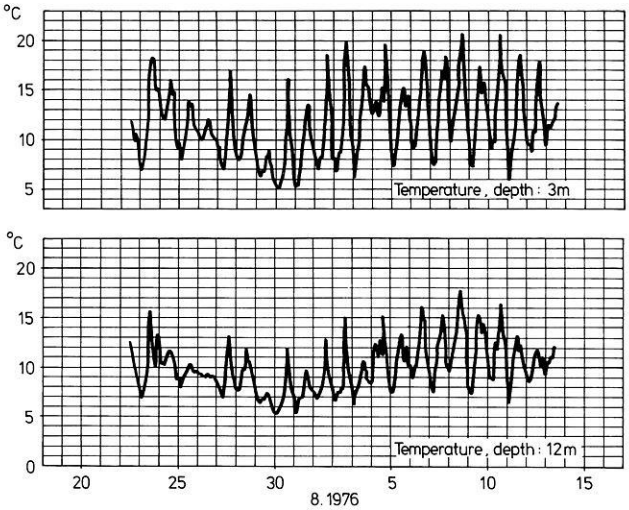

Fig. 7. Air temperature in the fissure

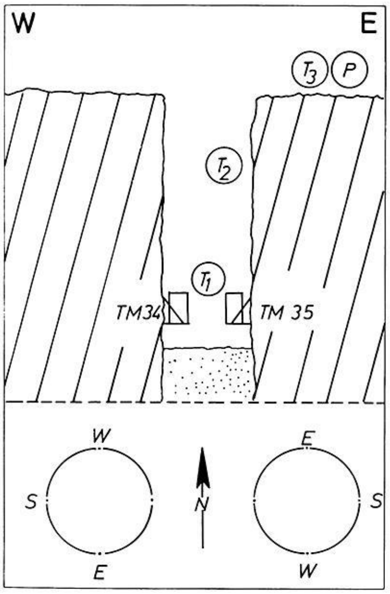

Fig. 8. Installation of tiltmeters *(TM 34, TM 35)* thermometers (T_1, T_2, T_3) and barometer *(P)*; on the bottom the geographical orientation of the instrumental tiltaxis are shown

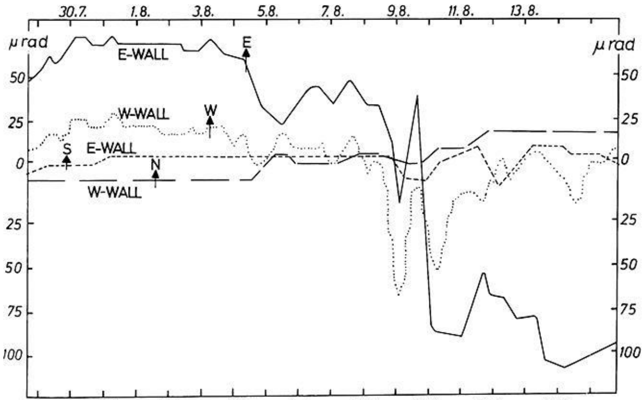

Fig. 9. Plot of the observed tilt changes in μrad; geographical coordinates.

Table 1. Mean tilt rates in μrad/h as obtained by regression analysis

Instrument	Component	Tilt rate (μrad/h)	Tilt to:
TM 35 (east wall)	N-S E-W	−0.591 −0.004	West North
TM 34 (west wall)	N-S E-W	−0.106 +0.089	East North

The cross-correlation functions between tilts and temperature generally change slowly. The maxima are marked weakly with a lag of nearly one day. The results of the regression analysis of the tilt observations with time are presented in Table 1.

The *mean tilt rates* or drift rates (μrad/h) during the observation period emphasize different inclinations of the fissure walls. The tilting of the eastern wall was about five times greater than the tilting of the western wall. In total, the western fissure wall tilted to east about 148.2 μrad, the eastern wall to west about 30.1 μrad. Parallel to the fissure walls, in the north-south direction, a small inclination of the fissure walls is evident. The tilt of both fissure walls to the north amounts to about 2.4 μrad. The difference between the short-term tilting of the fissure walls away from each other (see above) and the average tilting toward each other is rather striking and has not yet been explained.

The regression coefficients of tilts with temperature and air pressure are only significant for the temperature T_1 measured near the tiltmeters. These temperature changes can explain 29% (TM 3 No. 34) and 41% (TM 3 No. 35) of the observed tilts.

The Fourier- and power spectra of the tilt observations demonstrate daily periods with amplitudes of 7.3 μrad. These oscillations coincide with the daily temperature changes. Furthermore oscillations of 5 and 3 h period are found, which however, have no correlation with the temperature changes.

4. Discussion and Conclusions

The small correlation between temperature and the aperiodic tilt changes demonstrates that the observed tilt is not purely caused by instrumental thermal drift. Only part of the tilts can be explained with such effects. The diurnal tilt and widening periods are correlated well with the daily temperature wave, thus we assume that we have observed some thermally induced motion of the fissure walls.

The interpretation of the aperiodic drift, however, depends on the chosen model and is hampered by the shortness of the measurement period. The simplest assumption is that we have observed the motion of individual disjuncted blocks. Each extensometer and tiltmeter was fixed to such a separate block. The results of the two tiltmeters point to this model, since we have measured tilt rates rather different in magnitude; moreover, the widening of the fissure is accompanied by a mutual tilting of the fissure walls toward each other.

Not in favour of this model is the observation that the direction of the *drift* of the extensometers and tiltmeters is similar. We can deduce then that the motion is caused by one physical phenomen such as the volcanic activity in the Krafla caldera as described by Björnsson et al. (1979).

As shown in Fig. 1 the fissure is located near the northern end of the Krafla fissure swarm. The measurements were carried out during the inflation phase between January and September 1976 of Krafla, where none or only weak seismic activity in the fissure swarm was observed (Björnsson et al., 1979). In good agreement with Björnsson et al. (1979), in the fissure outside the Krafla caldera the small widening is accompanied by mutual tilting of the fissure walls.

However, it is not possible to give absolute values for the translation (widening) and rotation (tilting) of the fissure walls. Tilt-strain coupling (Harrison, 1976b) acting on the extensometers and tiltmeters prevents an exact separation. Similar to the widening, the tilting of the fissure to the north seems to be correlated with the inflation phase of the Krafla caldera. Direction and magnitude of the tilting coincide with the predictions by the inflation-deflation model of the Mogi-type (Björnsson et al., 1979). However, we cannot yet be sure of observing regional tilting of the Earth's crust. The analysis of extensometer and tilt measurements in the earth-tide range has shown, that aperiodic drift is mostly a local effect, caused by environmental disturbances of the measuring site. The measurements presented therefore have to be understood as a first investigation, to give a qualitative impression of the kind and magnitude of fissure motions. The interpretation of the results can only be definitive, if the observation will be continued for several inflation-deflation phases of the Krafla caldera. Therefore the extensometer measurements were continued in 1978, but results cannot yet be presented here.

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References

Björnsson, A., Johnson, G.V., Sigurdsson, S., Thorbergsson, G., Tryggvason, E.: Rifting of the plate boundary in North Iceland 1975–1978. J. Geophys. Res. **84**, 3029–3038, 1979

Björnsson, A., Saemundsson, K., Einarsson, P., Tryggvason, E., Grönvald, K.: Current rifting episode in North Iceland. Nature **266**, 318–323, 1977

Gerke, K., Möller, D., Ritter, B.: Geodätische Lagemessungen zur Bestimmung horizontaler Krustenbewegungen in Nordost-Island. In: Festschrift für W. Höpcke, Wiss. Arbeiten d. Lehrst. f. Geodäsie, Photogrammetrie und Kartographie an der TU Hannover, Nr. 83, Hannover 1978

Gerke, K., Pelzer, H.: Island: Triangulation, Deformationsvierecke, Registrierungen. Deutsche Forschungsgemeinschaft, Forschungsbericht Unternehmen Erdmantel, Wiesbaden 1972

Harrison, J.C. Tilt observations in the oorman Mine near Boulder, Colorado. J. Geophys. Res. **81**, 329–336, 1976a

Harrison, J.C.: Gravity and topographic effects in tilt and strain measurements. J. Geophys. Res. **81**, 319–329, 1976b

Johnsen, G.V., Björnsson, A., Sigurdsson, S. Gravity and elevation changes caused by magma movement beneath the Krafla caldera, Northeast Iceland. J. Geophys. **47**, 132–140, 1980

Möller, D., Ritter, B. Geodetic measurements and horizontal crustal movements in the rift zone of NE-Iceland. J. Geophys. **47**, 110–119, 1980

Sigurdsson, O. Surface deformation of the Krafla fissure swarm in two Rifting events. J. Geophys. **47**, 154–159, 1980

Spickernagel, H. Results of height measurements in the northern Iceland 1965/1977. J. Geophys. **47**, 120–124, 1980

Torge, W., Kanngieser, E.: Gravity and height variations during the present rifting episode in Northern Iceland. J. Geophys. **47**, 125–131, 1980

Tryggvason, E. Subsidence events in the Krafla area, North Iceland 1975–1979. J. Geophys. **47**, 141–153, 1980

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