Ground deformation at Katla: Results of precision levellings 1967–1995

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Abstract — *The volcano Katla in South Iceland is known to have erupted about twice each century in historic time. The last large eruption occurred in 1918 but a minor eruption probably occurred in 1955. Three optical levelling tilt stations were constructed in 1967 in the vicinity of Katla, to detect and observe any ground deformation which might precede the next Katla eruption. Two of these stations were located near the east edge of the Mýrdalsjökull glacier, and one near the south edge, all at a distance of 10 km or more from the volcanic vent which erupted in 1918. These stations were levelled once each year from 1967 to 1973. No observations were made from 1973 to 1986, when the levellings were resumed. The results of these repeated levellings at the optical levelling tilt stations near Katla are that ground tilt caused by annual variation of the glacier load is observed at the stations near the east edge of the glacier. Ground tilt related to the volcano Katla has not been observed, although uplift towards west or north-west at a rate of 0.1 μrad per year at the station Kötlukriki is vaguely suggested.*

INTRODUCTION

The volcano Katla is covered by the glacier Mýrdalsjökull in South Iceland. During eruptions of Katla, voluminous floods (jökulhlaup) of melt water flow over the Mýrdalssandur plain towards the south coast of Iceland. Eruptions have occurred twice each century during the last several hundred years with the last eruption in 1918, and earlier eruptions in 1860, 1823, 1755, 1721, 1660, 1625, and 1580 (Thoroddsen, 1925). Prior to 1580, eruption frequency was probably similar, but historic records are incomplete. A flash flood on June 25, 1955 was considered to be caused by a small sub-glacial eruption which did not melt its way to the glacier surface (Tryggvason, 1960).

In addition to the jökulhlaup which inundate most of the Mýrdalssandur plain, each Katla eruption causes serious, sometimes disastrous, ash fall in the areas surrounding the volcano. The floods, which arrive at about the same time as visible eruption, flow over the main route of land transport and travel in the area. The floods begin very suddenly, causing danger to those on the road across Mýrdalssandur, especially if eruption begins during weather of limited visibility.

Description of earlier eruptions of Katla mention rather strong earthquakes a few hours before the visible eruption, but otherwise, no signs of the coming eruption are known. However, it is considered as certain that some underground processes precede the eruptions, probably lasting for months or years. If some observations or measurements can be designed to detect these assumed premonitory processes, prediction of coming eruptions could be feasible. The most probable subsurface process to precede eruptions of Katla is pressure increase in a magma chamber beneth the volcano.

If pressure increases in some volume within an elastic solid, the surface of this solid will be displaced in direction away from this volume. For a source, small relative to its depth, the flat surface of this elastic solid will be uplifted according to the Mogi equation (Mogi, 1958), which says that the surface particles

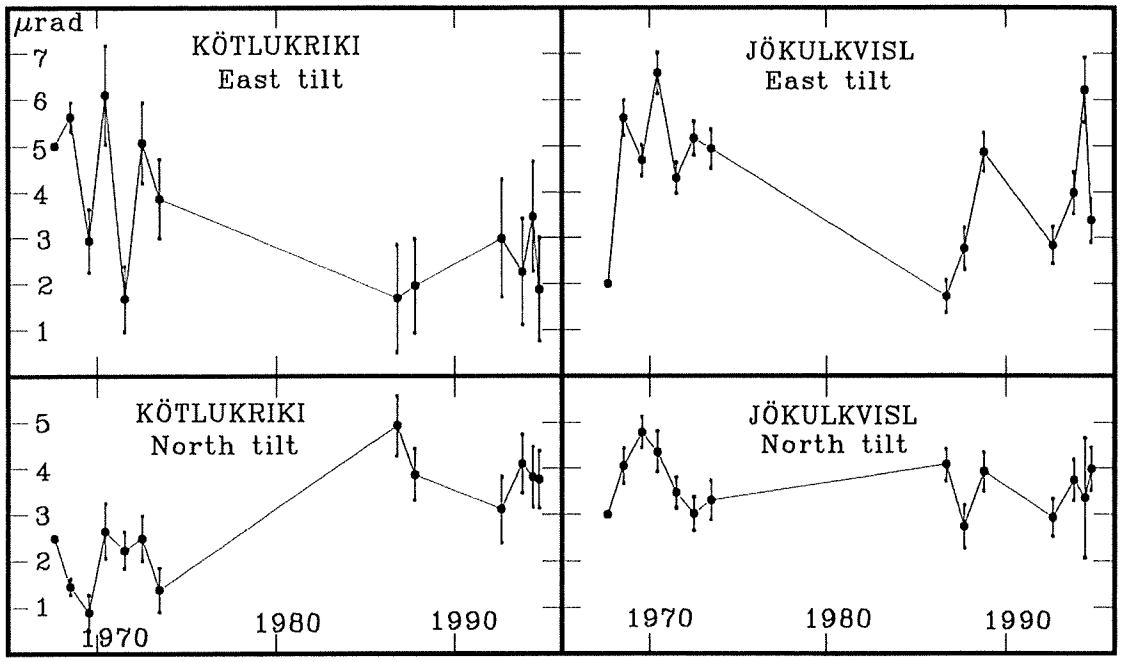

Figure 3. Observed ground tilt at two optical levelling tilt stations, Kötlukriki and Jökulkvísl, near the eastern extremities of the glacier Mýrdalsjökull. Error bars show one standard error of tilt computed for the period from first observation to each succeeding observation. Horizontal scale is time from beginning of the year 1965 to end of the year 1995. Vertical scale is either east- or north-component of ground tilt in microradians, positive if uplift is towards east or north. – *Mældar hallabreytingar við austurjaðar Mýrdalsjökuls, í Kötlukrika og við Jökulkvísl. Fyrsta mæling var gerð árið 1967. Lóðrétti ásinn sýnir hallabreytingu til austurs (efri hlutinn) og norðurs (neðri hlutinn) á árunum 1967-1995.*

field is about 15 cm, and that the thickness of the elastic lithosphere is 5 to 10 km.

Suggested tilt up towards west or north-west at the station Kötlukriki between 1967-1973 and 1986-1995 (Figure 3) is possibly the result of less average glacier load during the latter period.

CONCLUSIONS

Observations of ground tilt at the edge of the Mýrdalsjökull glacier from 1967 to 1995 suggest that annual variations in the glacier load causes measurable ground tilt. There is no clear evidence that subsurface magma movement at Katla has caused any ground deformation during this period. There is a vague indication of secular tilt, up towards west or north-west, at the station Kötlukriki, and observations at the station Jökulkvísl do not contradict such secular tilt. The suggested tilt rate is 0.1 μrad per year at Kötlukriki, and less at Jökulkvísl. This tilt rate is too small to be observed with confidence and can be caused by less average glacier load during the observations of 1986-1994 than during the observations of 1967-1973.

Considering the rate of secular tilt of 0.1 μrad per year at Kötlukriki to be real, and assuming that this tilt is caused by increase of pressure in a magma chamber at 5 km depth below Katla, then a ground uplift of about 0.6 mm per year is suggested. To cause this much uplift, about one million cubic meters of magma

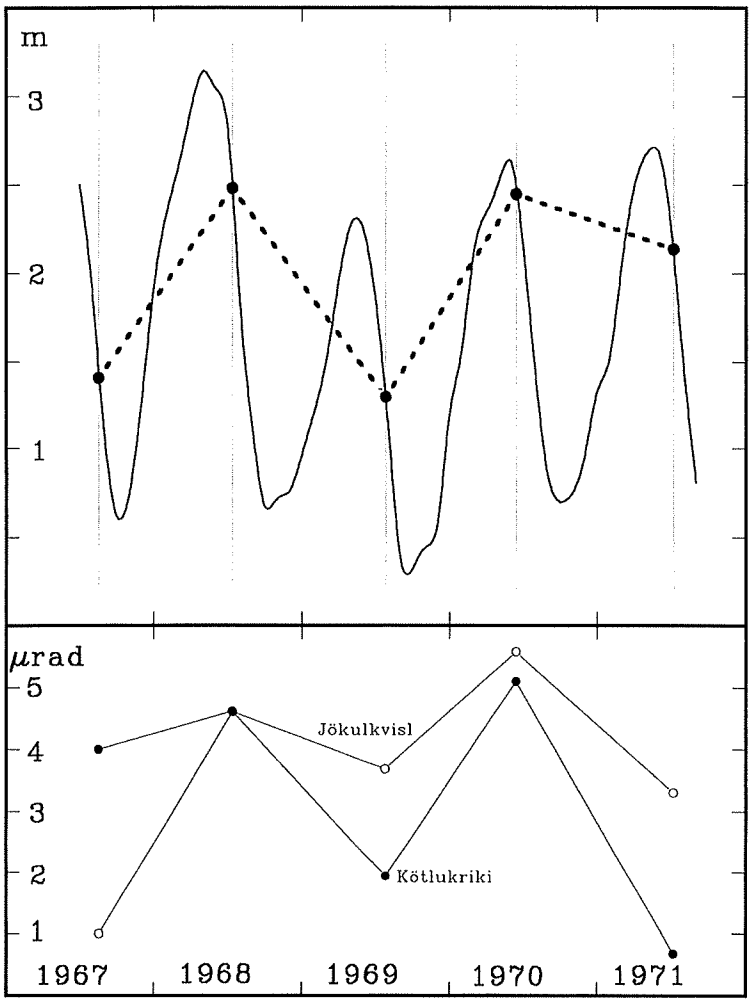

Figure 4. The top graph shows estimated variations in ice mass of the Mýrdalsjökull glacier (whole line), measured in meters of water equivalent over the entire surface of the glacier, and times of tilt observations at the stations Kötlukriki and Jökulkvísl (vertical dotted lines). Solid circles show the estimated ice mass at times of tilt observations. Bottom graph gives the observed variations of east component of ground tilt at the two tilt stations. Note the correlation between observed east component of tilt at either tilt station and the estimated mass of ice of the Mýrdalsjökull glacier (From Tryggvason, 1973). – *Efri hluti myndarinnar sýnir áætlaða breytingu á ísmagni Mýrdalsjökuls (heila línan), í jafngildi vatns á öllu yfirborði jökulsins. Fylltir hringir sýna áætlað ísmagn þegar hallamælingar voru gerðar við jökuljaðarinn. Neðri hluti myndarinnar sýnir breytingar á mældum halla til austurs í Kötlukrika og við Jökulkvísl. Nokkurt samræmi milli hallamælinga og áætlaðs ísmagns bendir til að breytingar jökulfargs valdi mældum hallabreytingum við jökuljaðarinn.*

need to be pumped into the magma chamber per year. At that rate, it would take 1000 years to accumulate one cubic kilometer of magma in the magma chamber, but that is roughly the volume of magma extruded in each of the large Katla eruptions. In conclusion, the tilt observations near Katla over a period of 30 years have failed to show any unrest of the volcano.

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ÁGRIP

HALLAMÆLINGAR VIÐ MÝRDALSJÖKUL TIL ÁKVÖRÐUNAR JARÐSKORPUHREYFINGA VIÐ KÖTLU

Sumarið 1967 voru sett niður 45 fastmerki á þremur stöðum við jaðar Mýrdalsjökuls, með það í huga að mæla jarðskorpuhreyfingar sem væntanlega eru undanfari Kötlugosa. Fastmerkin mynda þrjár stöðvar til hallamælinga, eina á Höfðabrekkuheiði, aðra í Kötlukrika og þá þriðju við Jökulkvísl. Í hverri stöð er 10 til 13 fastmerkjum raðað á tvær línur, sem skerast, og eru að jafnaði um 50 metrar milli merkja. Hallamælingar voru gerðar á þessum stöðvum einu sinni á ári frá 1967 til 1973, og aftur var hallamælt á árunum 1986 til 1994.

Niðurstöður þessara mælinga eru þær að mjög litlar jarðskorpuhreyfingar urðu milli mælinga, og ef marktæk hreyfing mældist, gekk hún oftast til baka á næsta ári. Hreyfingar frá fyrstu mælingu, árið 1967, til mælingar árið 1994, eru alls ekki marktækar, sem sýnir að eldfjallið Katla hefir ekki bólgnað svo mælanlegt sé með þeim aðferðum, sem notaðar hafa verið. Þó má segja að mælingarnar í Kötlukrika gefi smávegis vísbendingar um að land hafi risið til vesturs, í stefnu á Kötlu, en sú lyfting (halli lands) nemur ekki meira en 2-4 míkrógeislum á nær 30 árum, eða um 0.1 míkrógeisla á ári, sem gæti merkt að landlyfting við Kötlu nemi um 0.6 mm á ári að meðaltali. Slíkt landris gæti varað í árþúsundir án eldgoss.

Á Mýrdalsjökul safnast mikill snjór á hverjum vetri og svipað snjómagn bráðnar á hverju sumri. Vegna þessa er talsverður munur á þunga jökulsins eftir árstíðum, og einnig eftir því hve hlýtt eða úrkomusamt tíðarfarið er. Þegar hallamælingar við austurjaðar Mýrdalsjökuls eru bornar saman við áætlaðan þunga jökulsins kemur í ljós, að jarðskorpan undir jöklinum sígur á veturna, þegar jökulfargið eykst, en rís á sumrin, þegar jökullinn bráðnar. Þetta landsig og landris veldur mælanlegum hallabreytingum við jaðar jökulsins og má skýra allar mældar hallabreytingar við jaðar Mýrdalsjökul sem afleiðing mismunandi þyngdar jökulsins.