Precision Levelling in Surtsey

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INTRODUCTION

In late June 1967 a levelling profile was established across the lava of Surtsey. This profile consisted of 42 bench marks and was about 2060 meters long. This profile has been levelled five times, in June 1967, August 1967, June 1968, July 1969 and June 1970. In June 1968 the profile was surveyed to determine the location of each bench mark (Tryggvason 1970). During each levelling an attempt has been made to determine the sea level elevation. The repeated levellings of the Surtsey profile show that the lava of Surtsey has been subsiding continuously between 1967 and 1970. The rate of subsidence has been decreasing continuously during the same period. The maximum subsidence has been observed near the center of the island where the rate was more than one millimeter per day in 1967 (Tryggvason 1968).

RATE OF DEFORMATION OF THE SURTSEY LAVA

The repeated levellings in Surtsey allow determination of the vertical component of ground deformation between any two levellings.

The levellings provide the elevation differences between any pair of bench marks (Figure 1). The vertical component of ground deformation between two levellings is the change in the measured elevation difference.

During one levelling at time t_1 the elevation of bench mark A is H_{A1} and that of bench mark B is H_{B1}. At another levelling at time t_2 the elevation of these same bench marks are H_{A2} and H_{B2}. The difference in elevation of these two bench marks are:

$$DH_{AB1} = H_{B1} - H_{A1}$$

and

$$DH_{AB2} = H_{B2} - H_{A2}$$

The vertical component of deformation between bench marks A and B during the time interval t_1 to t_2 is:

$$V_{AB12} = DH_{AB2} - DH_{AB1}$$

and the rate of deformation is:

$$R_{AB12} = \frac{V_{AB12} =}{t_2 - t_1}$$

The vertical component of deformation, as defined above can be a ground tilt or a more complicated deformation. If the horizontal distance between the two bench marks is short, the observed deformation can be interpreted as one component of ground tilt. However, the deformation observed in Surtsey (Figure 2) varies rapidly along the profile, so a linear tilt cannot be expected between any two bench marks.

Figure 2 shows the deformation between bench mark 601 on the east coast of Surtsey and each of the other bench marks of the Surtsey. All the bench marks have subsided relative to 601 and the rate of subsidence has decreased by a factor of approximately two each year. Thus the subsidence of bench mark 625 relative to 601 was 32.2 cm during the first year between June 1967 and June 1968, 17.0 cm during the second year and 7.7 cm during the third year. If the deformation between two bench marks a short distance

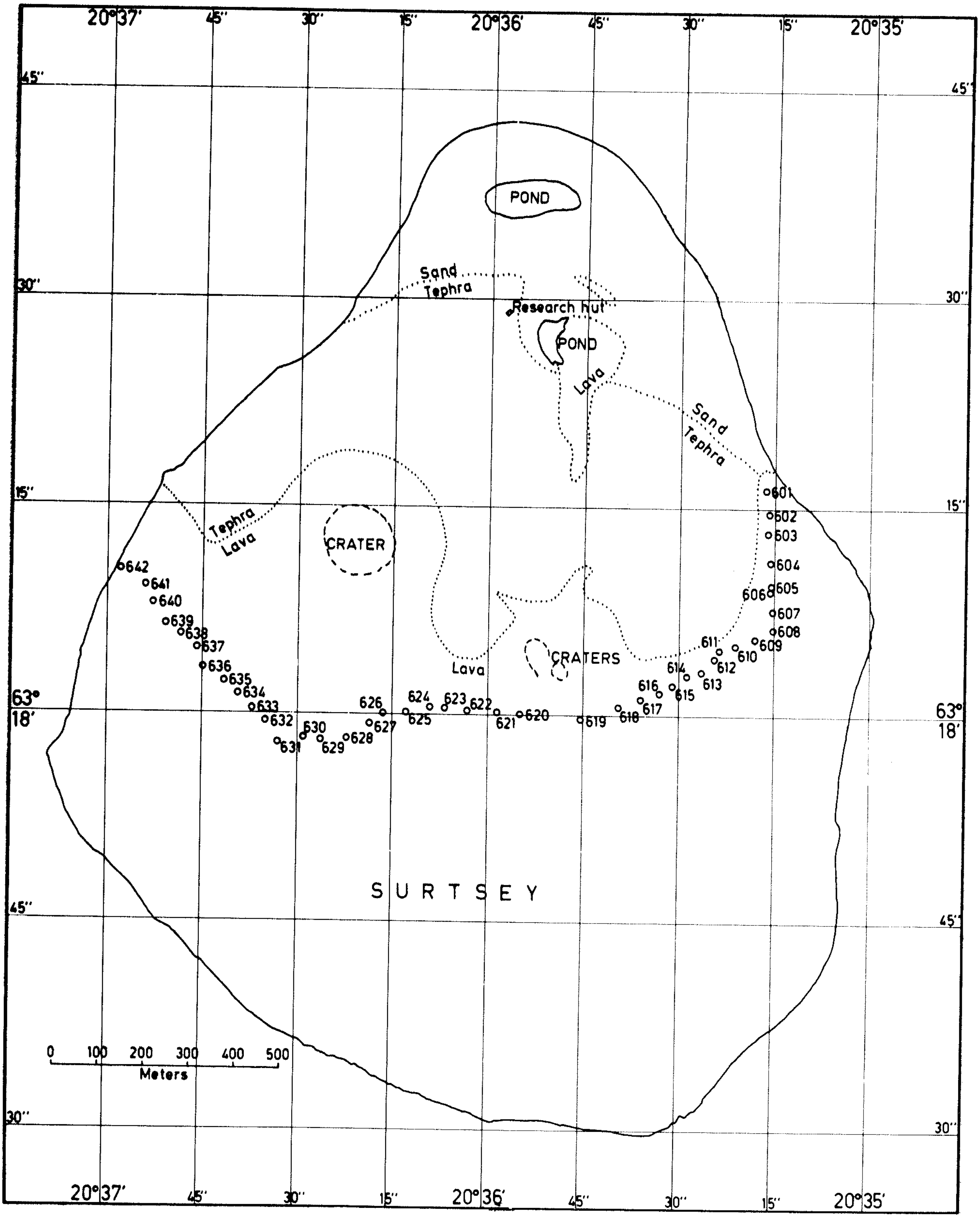

Fig. 1. Map of Surtsey showing location of the levelling profile.

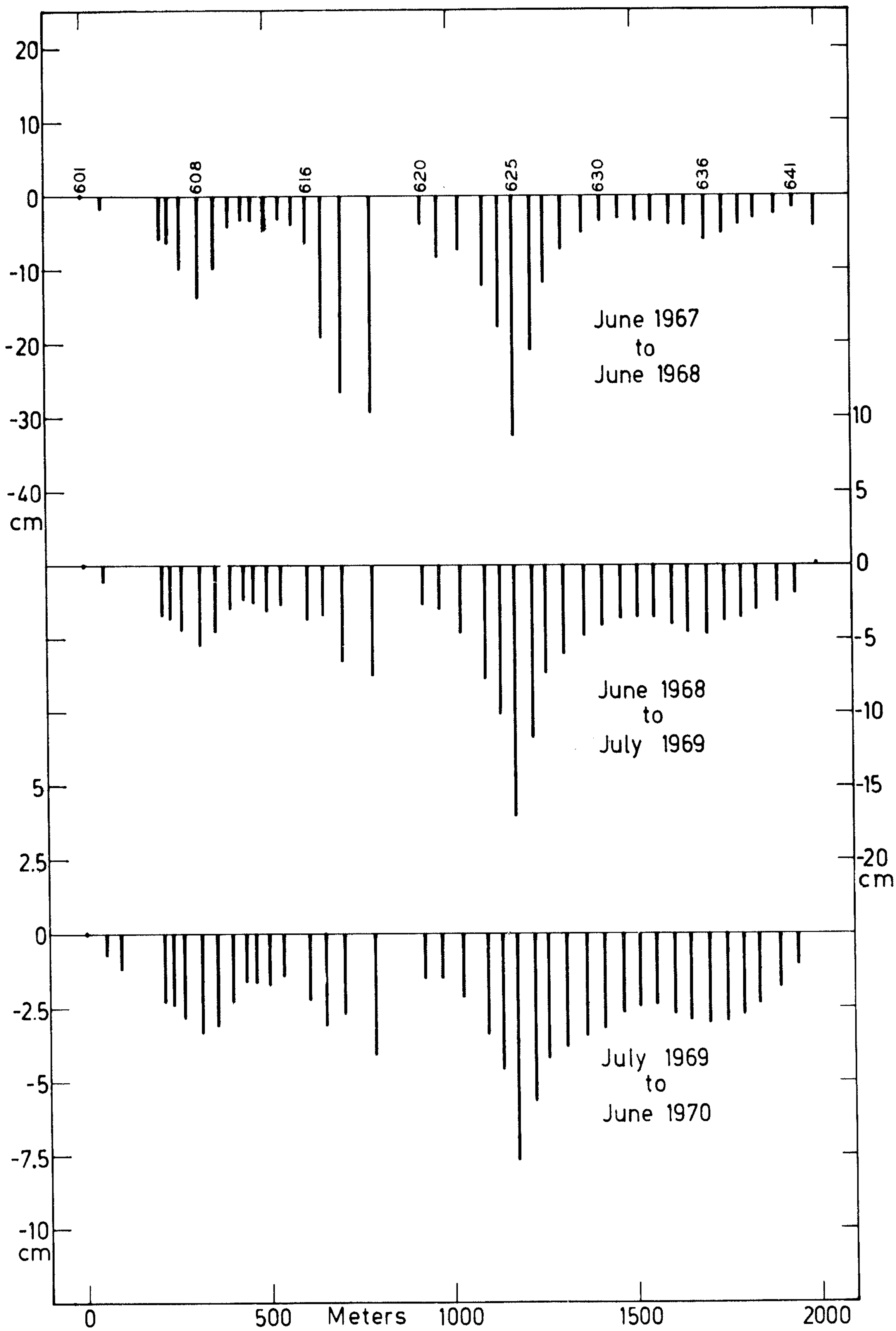

Fig. 2. Annual rate of subsidence of the Surtsey bench marks relative to 601 on the east shore of the island. The vertical scale is changed by a factor of two each year to show more clearly that the subsidence rate is slowing down by a factor of approximately two every year.

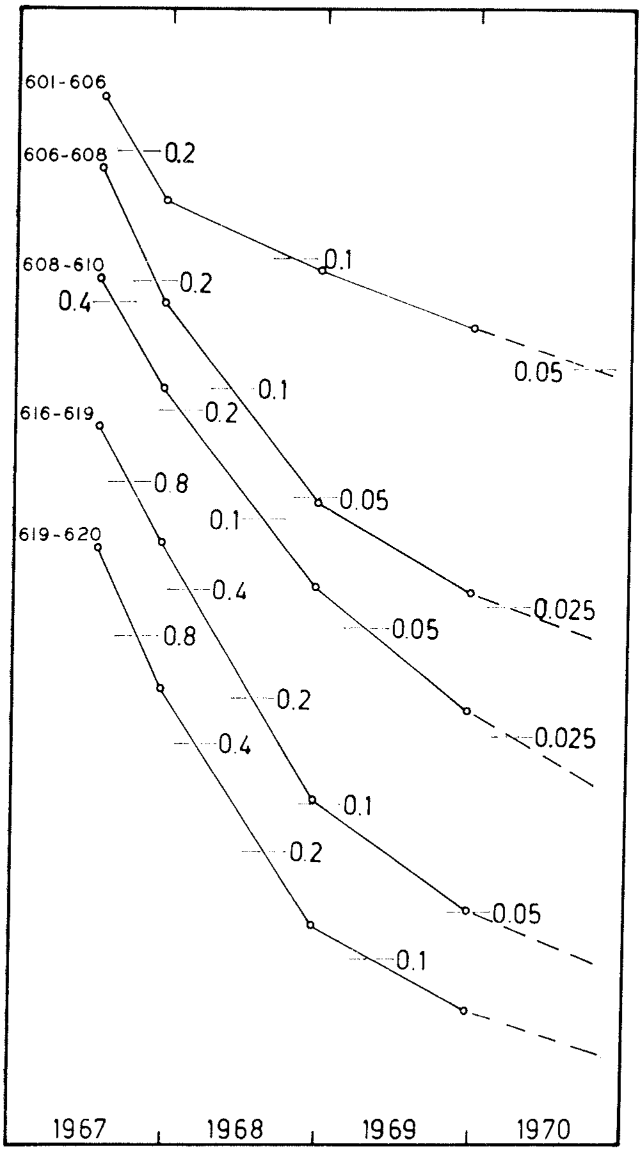

Fig. 3. Rate of deformation as a function of time for selected bench mark intervals on the eastern half of the levelling profile. The rate is given in millimeters per day with separate scale for each curve.

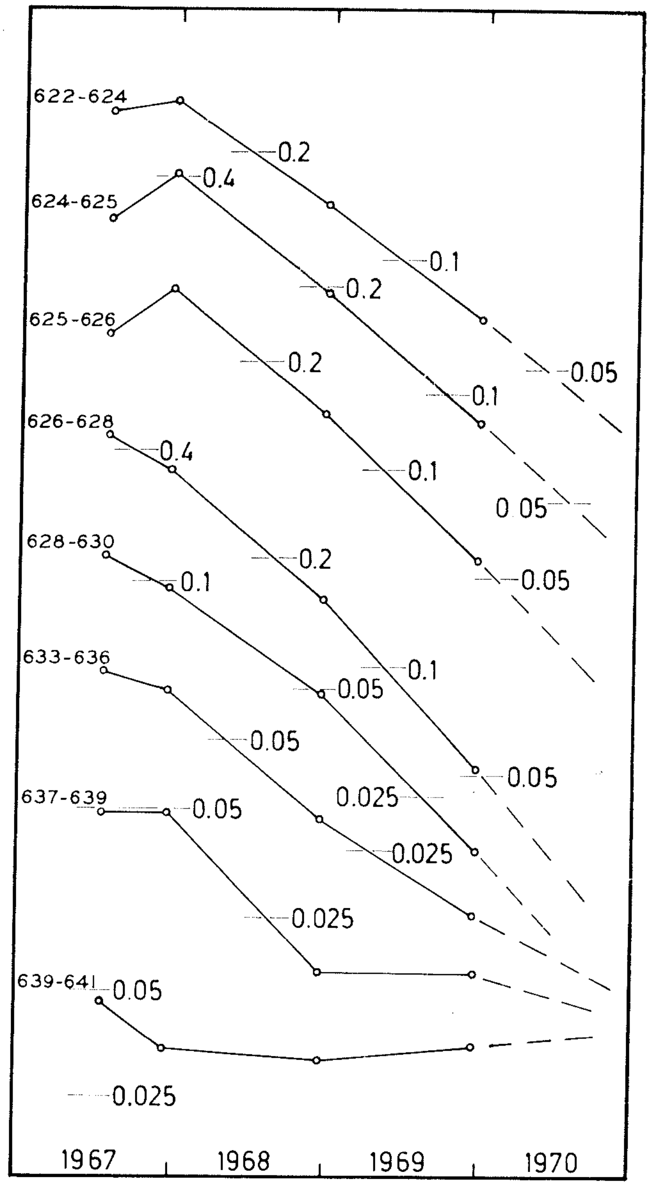

Fig. 4. Rate of deformation as a function of time for selected bench mark intervals on the western half of Surtsey. The convex shape of the curves is strikingly different from the same type of curves in Fig. 3 for the eastern half of the island.

apart is studied, it is evident that the rate of decrease in the deformation is different for different parts of the profile. On the eastern part of the profile (between bench barks 601 and 620) the deformation rate decreased more rapidly during the first part of the observation period than later (Figure 3) so curves showing the logarithm of the deformation rate versus time are concave, while on large portion of the western half of the profile this pattern is differnt so the same type of curves are convex (Figure 4). Near the west coast of Surtsey between bench marks 639 and 641 the deformation rate has been nearly constant during the 3 years of observation.

This rather irregular trend in the rate of deformation of the Surtsey lava surface makes it difficult to predict with any accuracy how much deformation will take place during the coming years or when this deformation will come to an end. However, the rapidly decreasing rate of deformation indicates that the total subsidence after the 1970 levelling, relative to bench mark 601, will not exceed 10 centimeters for any point on the levelling profile.

Figure 5 shows a rough estimate of the subsidence rate relative to bench mark 601 along the Surtsey profile in the year 1973 assuming a continuation of the observed change in the subsidence rate during the three years, 1970 to 1973. This prediction indicates that the peak in subsidence rate between bench marks 616 and 620 has completely disappeared in 1973.

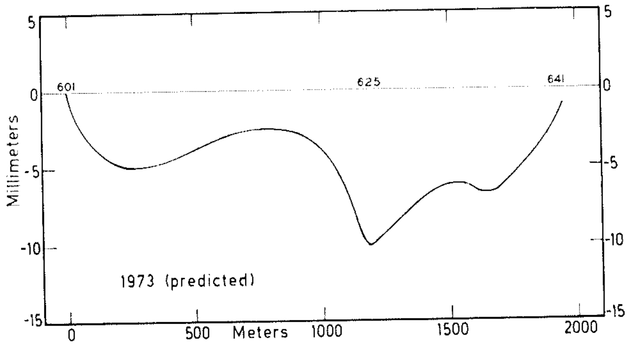

Fig. 5. Estimated annual rate of subsidence of the Surtsey profile in 1973 relative to bench mark 601. The horizontal scale is distance along the profile, the same as on Fg. 2.

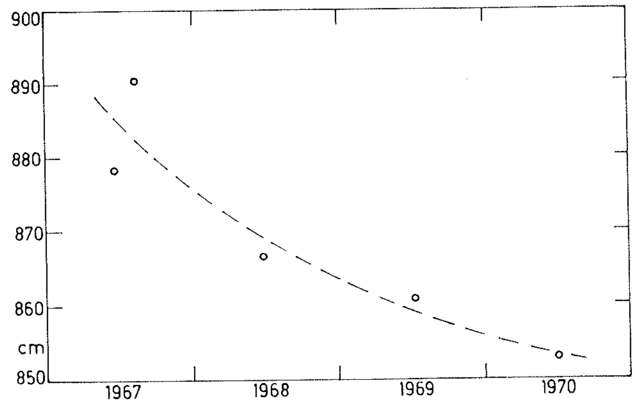

Fig. 6. Elevation of bench mark 601 above the surface of the pond "Dropi" or above ground water table at the pond site. The elevation given is very near the mean sea level elevation. The smooth curve is an estimate of the variation of elevation of 601 above mean sea level.

SUBSIDENCE OF SURTSEY

In 1967 and 1968 a lake (Dropi) existed on Surtsey north of the steep slopes of the principal craters. This lake had a very constant elevation during the days of the levelling work. In 1967 the elevation of this lake was compared with the elevation of a tidal pond near the north shore of Surtsey, and the surface elevation of the lake Dropi was found to be very close to mean sea level, probably about 10 centimeters above average sea level.

In 1969 and 1970 the lake Dropi had disappeared. However, the ground water table was close to the surface and small wells were dug to observe the water table.

Figure 6 shows the elevation of bench mark 601 above the surface of the lake Dropi (in 1967 and 1968) and above the ground water table at the site of the lake (in 1969 and 1970).

As the surface of the lake was very close to mean sea level in 1967, it is assumed that the water table in 1968 through 1970 at the site of the lake was also very near mean sea level. Therefore the elevation values on Figure 6 give the elevation of bench mark 601 above mean sea level, with an accuracy of approximately 10 centimeters.

It is clear from these measurements that bench mark 601 has been subsiding relative to mean sea level. The rate of subsidence is slowing down by a factor of approximately 2 each year. The rate of subsidence was probably 15 to 20 cm per year in 1967–68 but has slowed down to roughly 5 cm per year in 1969–70, resulting in a total subsidence of 30 to 40 centimeters between 1967 and 1970. In the discussion of the deformation of the lava surface on Surtsey, the subsidence of each bench mark relative to 601 was given. To obtain the absolute subsidence of each bench mark the subsidence of bench mark 601 has to be added to the relative subsidence.

ACKNOWLEDGEMENTS

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