Observation of Creep Rate of Snow on Mountain Slopes, Teshio District, Hokkaido*

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Abstract

The creep rates of snow covers on mountain slopes were measured to determine the stress distribution in the snow cover in Teshio District, Hokkaido. Measurements were made on the snow cover of the north and south slopes of a ridge running from east to west on which the Avalanche Research Station of the Institute of Low Temperature Science was established in 1965. Although both slopes have approximately the same angle of uniform inclination, about 35°, with no trees, they greatly differ in avalanche hazard wise. Every year many avalanches occur on the south slope, but none are seen on the north slope.

In total four sites for observation were selected, *i.e.*, the upper part and middle part on the south and north slopes of the ridge respectively, to measure the creep of snow cover on the slope. At each site, a vertical cut plane was made in the snow cover by an electrically heated wire laid in parallel with the contour line of the slope. An iron bar marker was placed on the ground beforehand as the base line to measure the amount of creep of snow cover.

An observation snow wall was made perpendicularly to the cut plane every two weeks at each site. The stratification of snow layers and distribution of snow density, temperature, hardness, shape of snow particle, particle size and free water content were also measured on the snow wall.

I. Introduction

Every winter heavy snowfalls cover the northern half of Japan where 22 million people live. Economic losses caused by snow damages particularly by avalanches have increased with industrial development. Thus, Snow Damage Section of the Institute of Low Temperature Science was established in 1963 to study the physical characteristics of snow covers and the dynamics of avalanches.

Avalanche hazard districts in Japan lie between 36° and 46° latitude. The southern part of this district has warm weather; the temperature is nearly 0°C even in mid-winter. The snow cover is generally very deep and wet throughout the winter. Most of the avalanches are of the surface or ground type of wet snow. The northern part, on the other hand, has cold weather in winter with rather light weight dry snow. The temperature gradient in the snow cover changes the snow particles into depth hoar which makes the snow cover weak mechanically. Avalanches are of the ground or surface type of dry snow in winter and of wet snow in early spring.

Now, in the Teshio District, many avalanches occur on mountain slopes every winter. For instance in January, 1961, an iron bridge under the jurisdiction of the Japanese National Railways was destroyed by an avalanche near the Avalanche Research Station.

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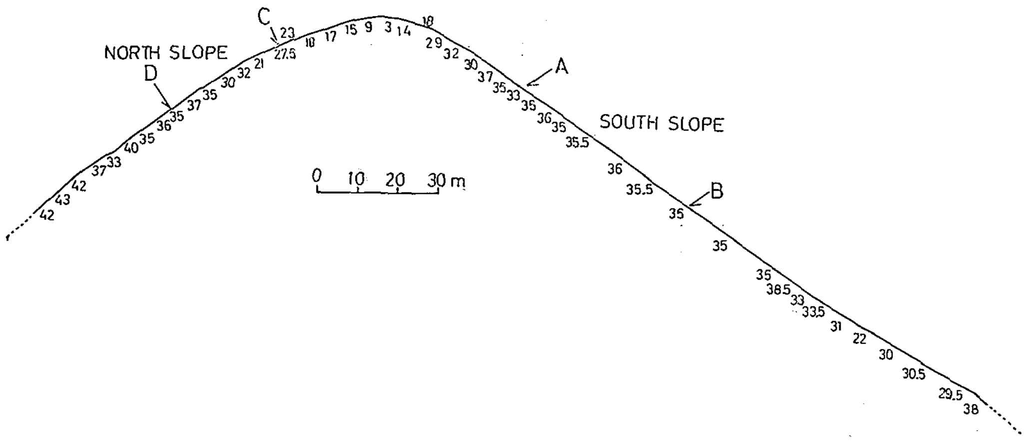

Fig. 1. Profile of experiment slopes.

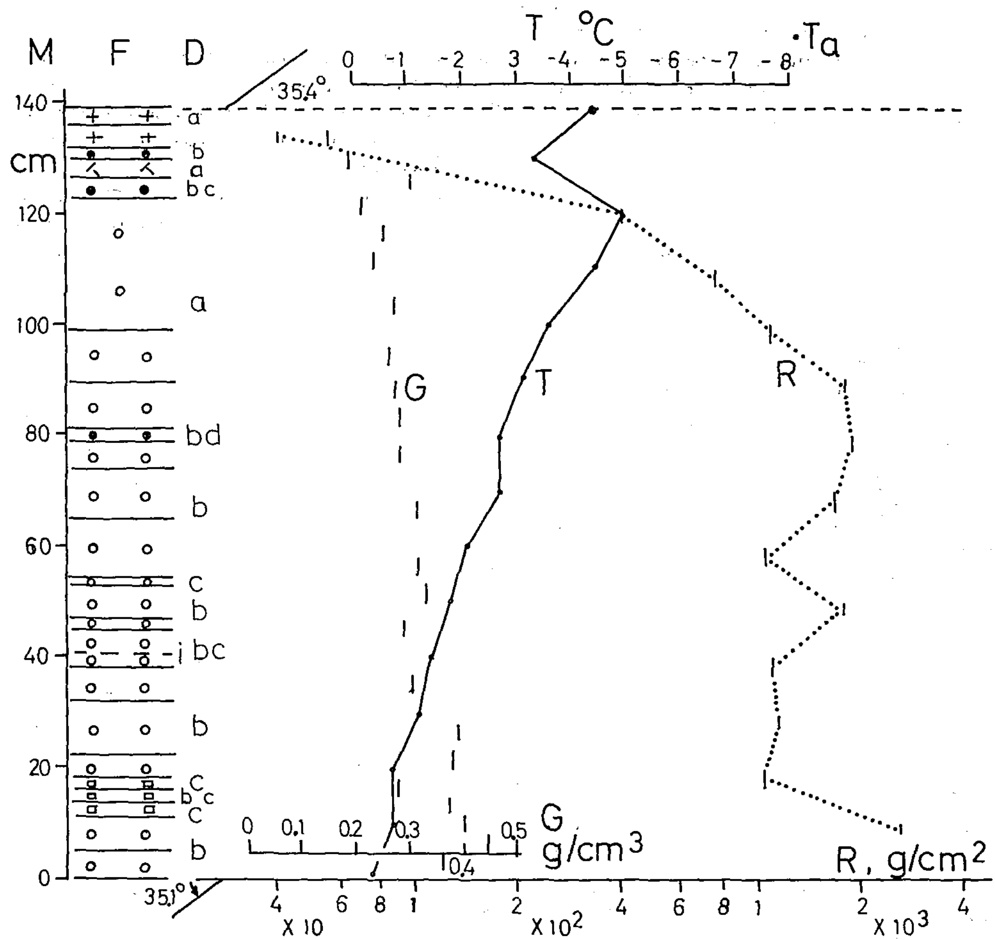

Fig. 2. Physical characteristics of snow at site B, February 23, 1966

II. Physical Characteristics of Snow Covers

The physical characteristics and the creep rates of the snow cover were measured on the south and north slopes of the ridge on which the Avalanche Research Station was established in 1965. The profile of the slopes is illustrated in Fig. 1. The numerals and the arrows with the letters A, B, C and D in the figure show the angles of inclination and the observation sites on the slopes respectively.

At each observation site a snow pit was made and the stratification of snow layers, distribution of snow density, temperature, hardness, shape of the snow particle, particle size and free water content were measured every two weeks. The air temperature, wind direction, wind velocity and solar radiation were recorded automatically in the Station throughout the winter.

Examples of the physical characteristics of the snow cover at site B and D on 23rd and 24th of February of the winter of 1965–1966 are illustrated in Figs. 2 and 3 in

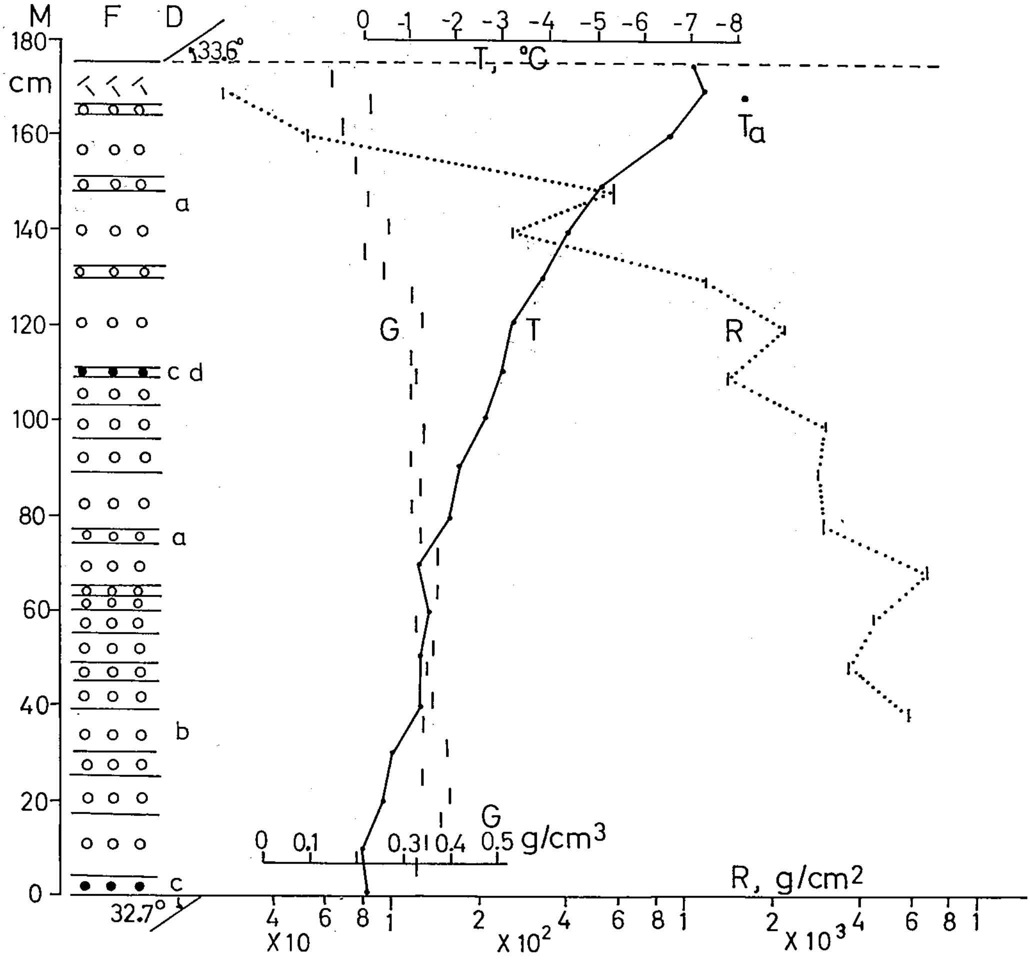

Fig. 3. Physical characteristics of snow at site D, February 24, 1966

which the International Classification* of snow was used. The letter symbols M, F, D, R, T and T_a are the depth of the snow cover perpendicular to the ground, grain shape, grain size, snow hardness, snow temperature and air temperature respectively. The snow hardness was measured by Kinosita's hardness guage. The grain size D is expressed in the figures by the letter symbols a, b, c, d and e which are defined in the International Classification as follows; $a<0.5$ mm, $0.5 \leq b<1.0$ mm, $1.0 \leq c<2.0$ mm, $2.0 \leq d<4.0$ mm, and $e \geq 4.0$ mm.

Some modified graphic symbols of the snow particle shape of the International Classification were used in Figs. 2 and 3. The square represents depth hoar crystals of solid type which has the shape of hexagonal thick plate or hexagonal short prism reported in this book by Akitaya (1966). The International Classification defines the square symbol to be snow grains with flat facets which show a distinct sparkling effect in

Fig. 4. Snow profile at site B, February 23, 1966

* Commission of Snow and Ice of the International Association of Hydrology (1951, 1954).

bright sunlight. The depth hoar crystals of solid type has the same characteristic features as those above defined.

The solid circle in the International Classification represents snow of rounded grain, namely, the grains of compact snow and granular snow. In this paper the solid circle is used only for the granular snow transformed by wet metamorphosis and the white circle is newly introduced to represent grains of the compact snow metamorphosed through the dry process.

III. Creep Rate of Snow and Principal Axis of Stress

The creep profile of the snow cover was obtained at four sites A, B, C and D in Fig. 1. In late autumn an iron bar of 4 m length was fixed to the ground of each site along the contour line, and at the both ends of the bar bamboo poles were put vertically in the ground as the markers of the site. In winter snow pits were made at the bamboo poles and the snow cover was cut vertically by an electrically heated wire along the vertical plane determined by two plumb lines at the both ends of the iron bar. This artificial plane crevice had a width of about 1 mm at first and changed its shape and width according to the creep movement of snow layers throughout the winter season.

Figure 4 shows the snow profile at site B on 23 rd February, 1966. The pit wall was coloured by ink to make the snow stratification visible. There can be seen two

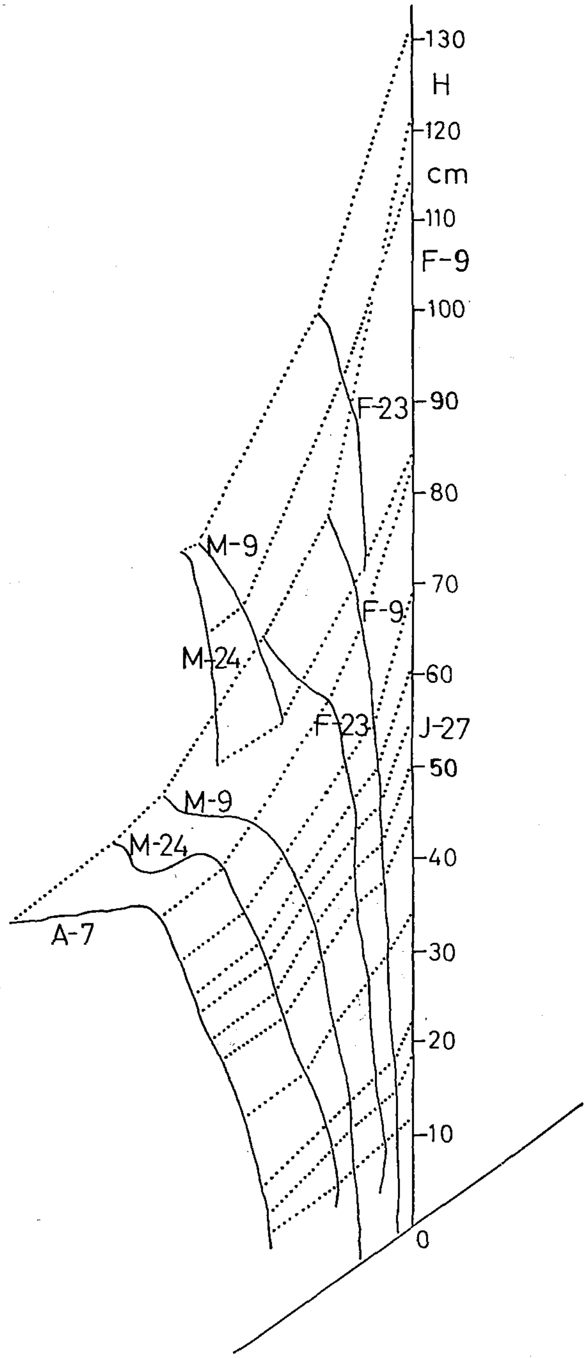

Fig. 5. Creep movements of two artificial crevices in the snow cover, at site B, from January 27 to April 7, 1966. The displacements of the intersections of crevices and boundaries of snow layers give the displacement vectors shown by the dotted line on the figure

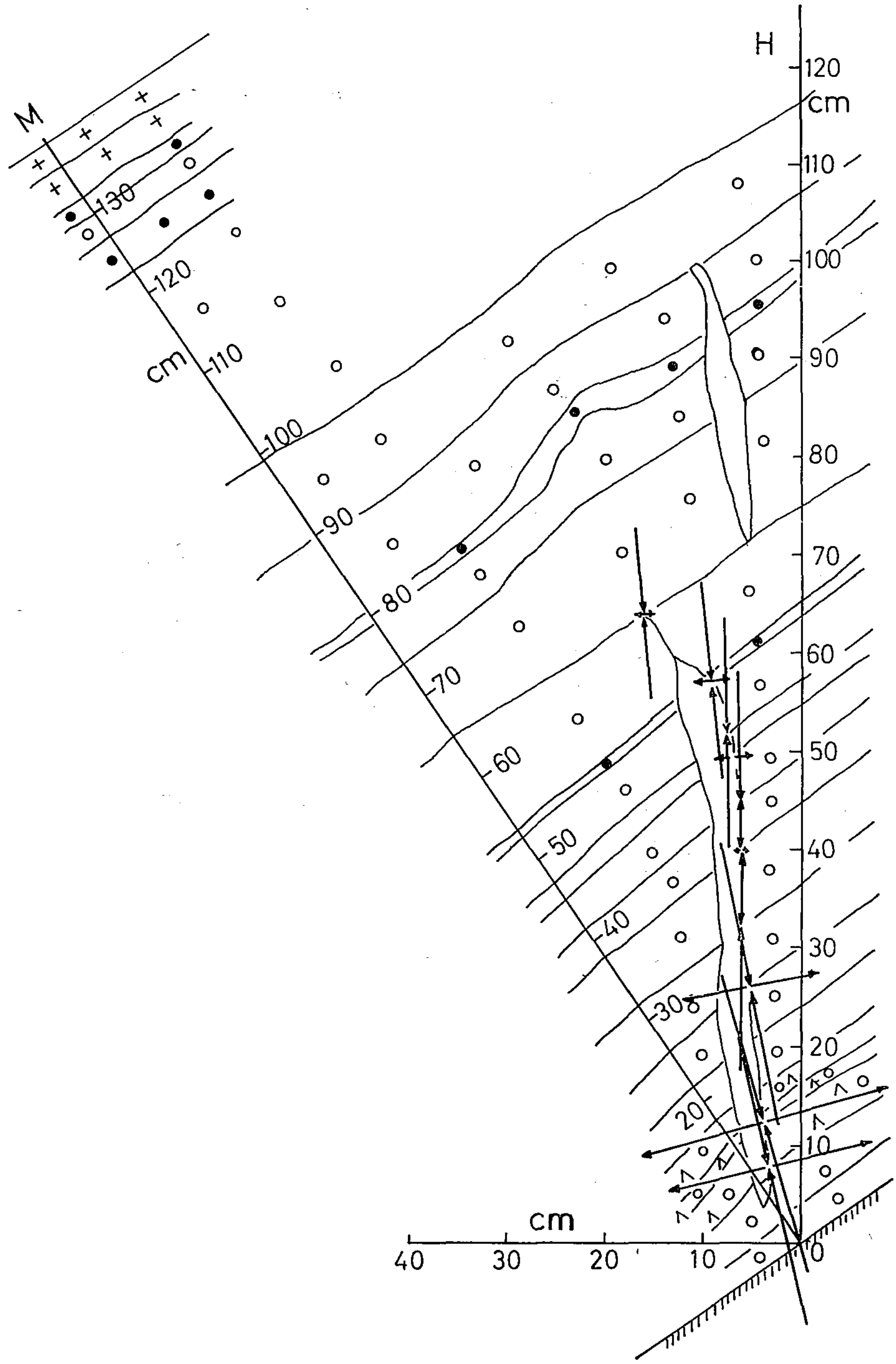

Fig. 6. Distribution of principal stresses at site B, February 23, 1966

crevices of which the lower one was cut on 27th January and the upper one was made on 9th February along the vertical plumb line of the photograph. The displacement of the crevice from the vertical plumb line just above the iron bar was measured every two weeks and the results at site B in the winter season of 1965–1966 are illustrated on Fig. 5. The solid lines represent the crevices and when it was open the uphill side surface of the crevice is indicated in the figure. The dotted lines in the figure show the displacement of the boundaries of snow layers.

Haefeli (1963) proposed a geometrical method to find out the directions of the principal stresses from the displacement vector of snow within the snow cover. And once these directions are determined the corresponding values can be easily be calculated if the creep deformation in the above lying snow takes place homogeneously. Figure 6 is one of the results of the stress distribution in the snow cover at site B on 23rd of February, 1966. Calculations were carried out under the assumption that the crevice was filled with uniform and continuous snow.

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