Aerial Observations and Thin Section Studies on Avalanches

(Avalanche Studies during 1962–1966 in Shiozawa)

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Abstract

In order to obtain more precise information about avalanches, as many detailed observations as possible should be made. However, as long as the collection of data depends on ground observers or has to be done on skis or in snow vehicles, it will be restricted by the variable weather in winter, the remoteness and steepness of the locations, etc. Helicopters have the advantage of rapid and unrestricted movement which is favourable and effective for making avalanche surveys and removes those difficulties mentioned above. These methods of aerial observation by helicopters as well as by survey airplanes, and sampling for studying the micrographical stratifications of the slide layers of surface layer avalanches have been tried out in practice during the three winter periods (1962–'65) and found very satisfactory. The three-year project for avalanche studies was made at the request of the National Research Center for Disaster Prevention of the Science and Technology Agency of the Japanese Government. This report is a brief record of the experiences of these observations which shows the possible developments of avalanche studies through these methods in the future.

I

Many photographs of various avalanche traces found in the mountainous region within a radius of 50 km from Shiozawa, central Japan, were taken from an observation helicopter stationed at the (Shiozawa) Snow Research Station during the observation period (Fig. 1). The region is the watershed of the river Tone, its altitude ranging

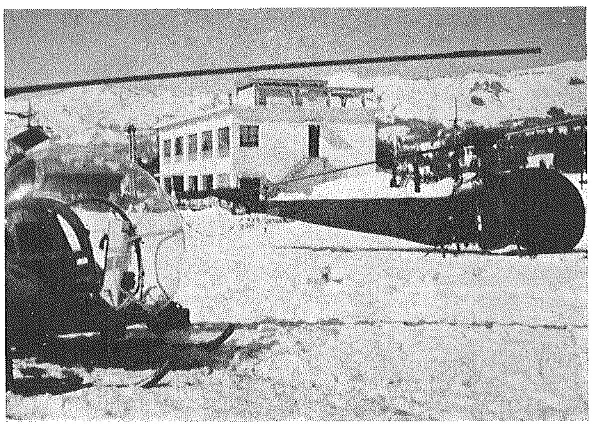

Fig. 1. JNR snow research station with observation helicopters

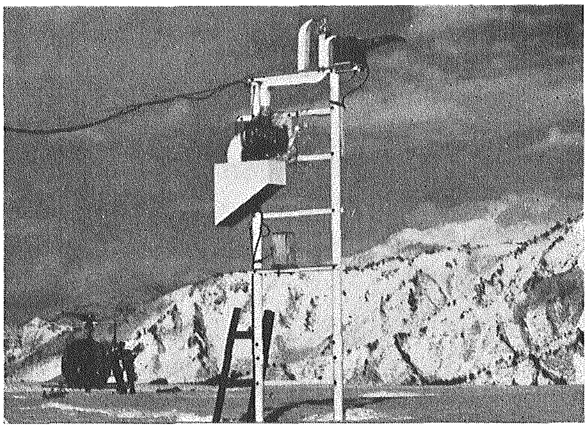

Fig. 2. Instruments to record the meteorological conditions

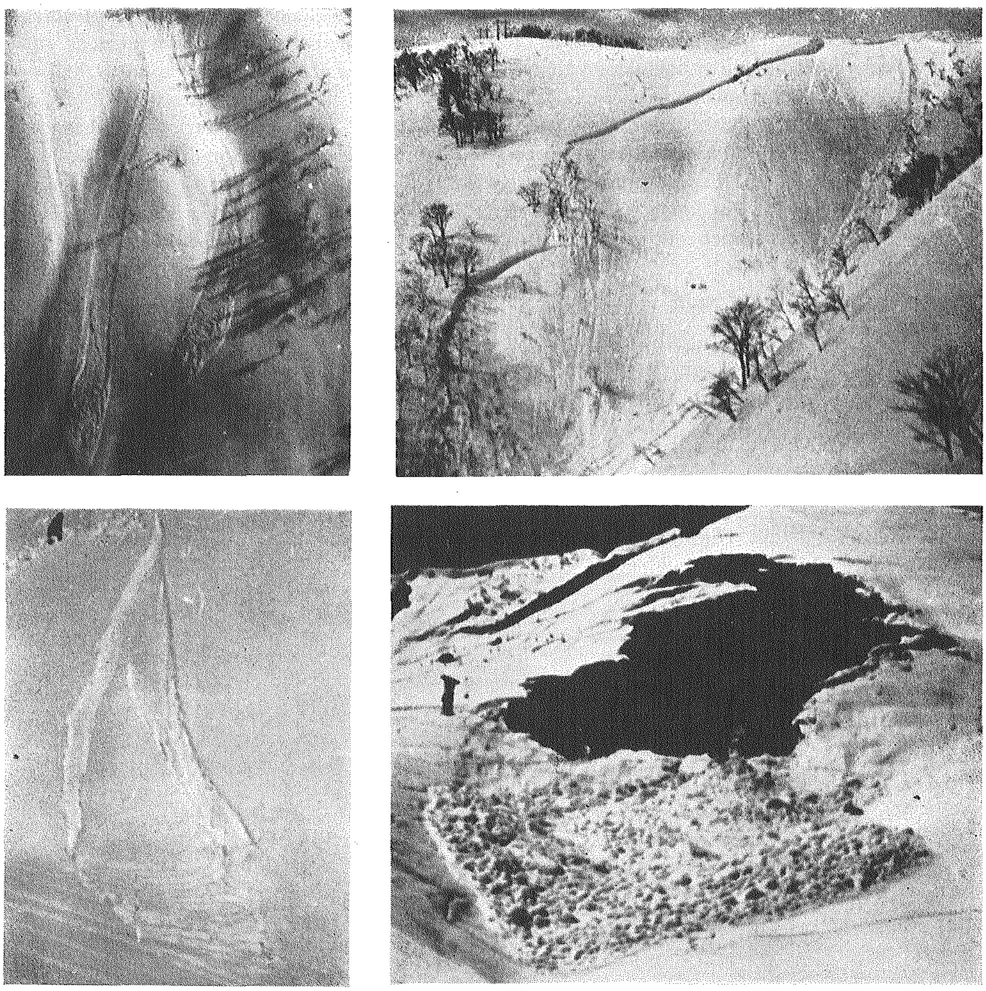

Fig. 3. Four types of avalanches

from 500 m to 2 000 m. More than thirty flights were made during each winter on fine days after any snowfall, and newly found phenomena relative to avalanches which had not been found in the previous flight were recorded by camera; later, more effective and direct observations were added. In addition, the meteorological conditions, such as the total sun and sky radiation received on a horizontal surface (global radiation), net exchange radiation of the snow surface, air temperature, snow temperatures, earth temperatures at 0, 25 and 75 cm under the ground, and snow data were observed at the research station by using an Eppley Pyrheliometer, a Beckman and Whitley Radiometer, a Yokogawa 60 ER–Type electronic recorder and other instruments (Fig. 2). The aerial photographs show that the recorded avalanches can be classified roughly into four groups according to the shapes and patterns of the avalanche traces, which coincide with the classification used by the author (Fig. 3) (Shoda, 1962).

II

In the winter 1962–'63, the first winter of the observation period, widening of snow cracks relative to the occurrence of ground avalanches were mainly observed and recorded from the observation helicopter (Shoda, 1963 a). These cracks were generally (at first) formed along the upper border of the starting zone. Figures 4 a–e are examples of successive changes of snow cracks correlated with the curves of air temperature, precipitation, sky and global radiation at Shiozawa (200 m above sea level), leading to the collapse. This slope is situated about 5 km east of Shiozawa, with a slope angle of 35°–40°, an altitude of 500 m, and a direction almost north. At first a course connecting slopes with snow cracks, leading to ground avalanches, was established, after which the observation flight was made along this course. The course was flown whenever the weather was suitable. The air temperature of the site is almost the same as that of Shiozawa. According to the daily variations in the temperature curve from March 13 to 23 in Fig. 4, this period can be devided into four parts as follows:

Mar. 13–15	the first spell of fine days (day temp. above and night temp. below freezing).
Mar. 15–18	the first spell of cloudy and rainy days (temp. always above freezing).
Mar. 18–21	the second spell of fine days.
Mar. 21–23	the second spell of cloudy and rainy days.

Hair cracks (Fig. 4 a) were formed initially on March 13, widening during the first spell of cloudy and rainy days (temperature above zero). Because the sky was overcast, heat was not lost by radiation, and therefore refreezing of melt water in the snow did not take place. New vertical cracks developed along the center ridge and the compression zone expanded downward. This fact shows that the shearing resistance at the ground surface of the starting zone has become too small to support the snow without the supporting force acting on the lateral and lower borders of the zone (Fig. 4 b and c). During the second spell of fine days, the snow refroze, but later the mean air temperature gradually increased and a part of the snow in the starting zone collapsed on March 20. The remaining part slid down during the second spell of cloudy and rainy days (Fig. 4 d and e).

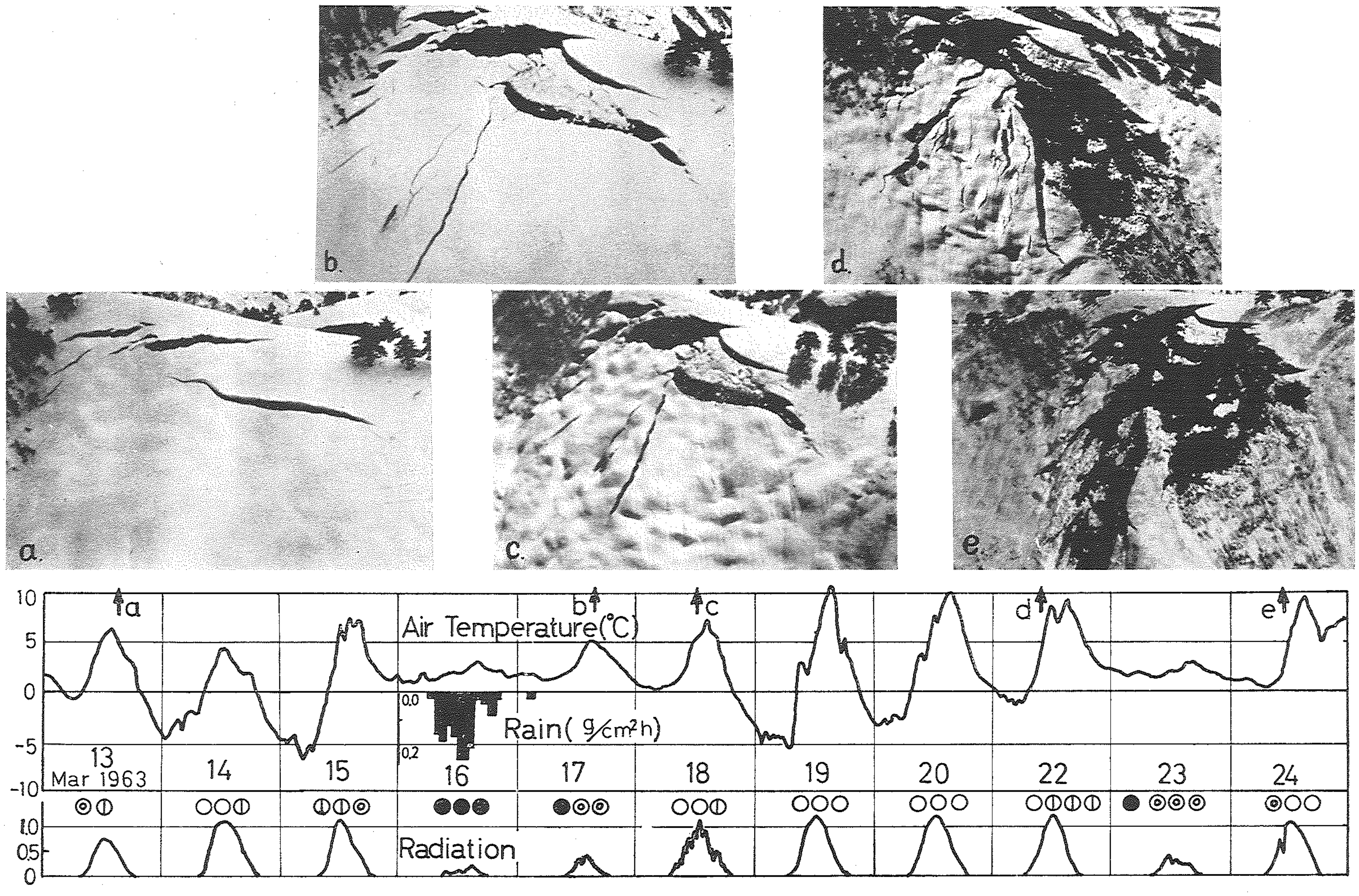

Fig. 4. Photos a–e show snow movement related to meteorological conditions (Unit of radiation: cal/cm²·min)

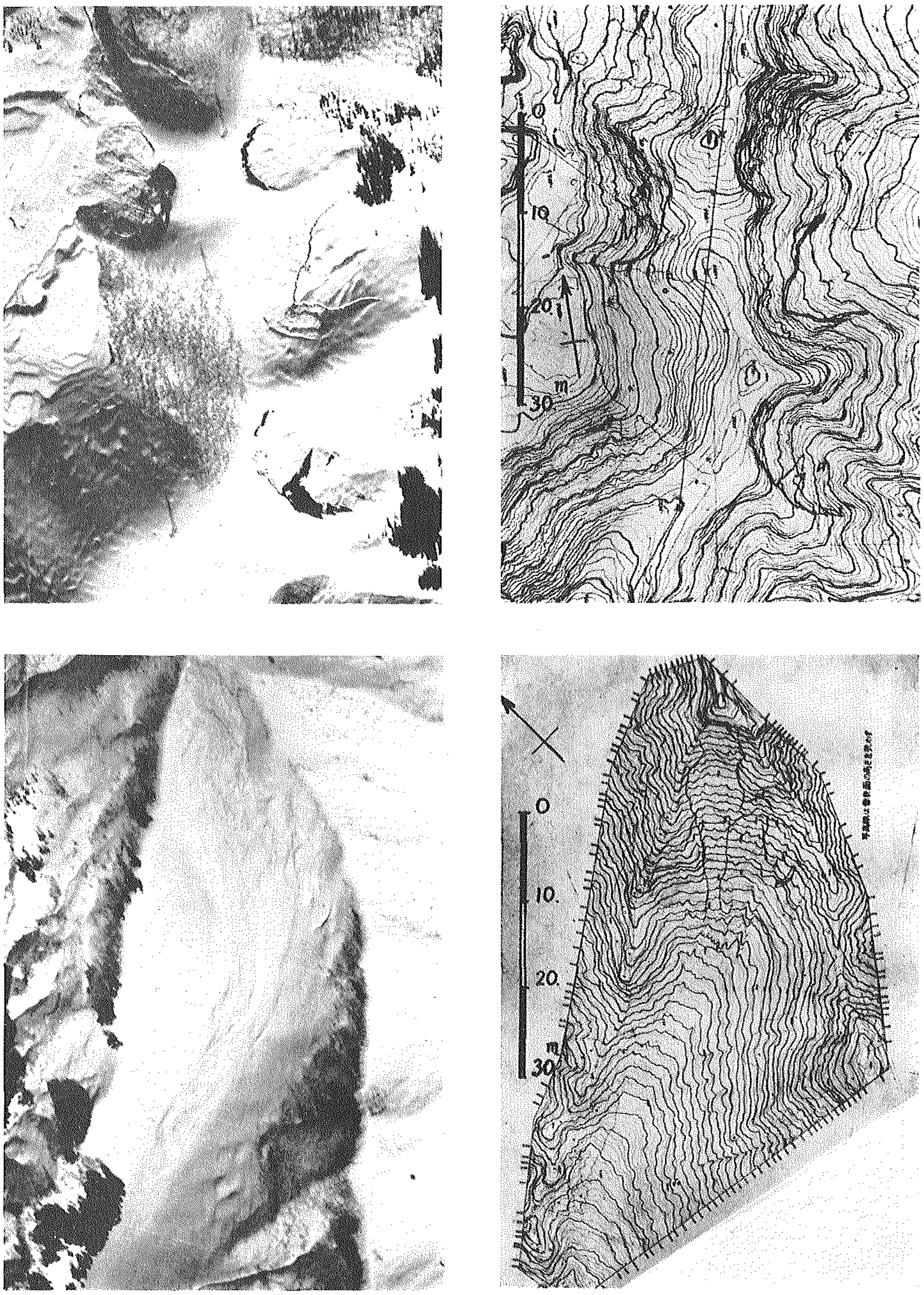

Fig. 5. Photographs on the left show avalanche sites. These photographs are taken vertically. The pictures on the right are contour maps of the areas compiled from a stereomodel. Contour interval is 2 m in the upper figure and 1 m in the lower

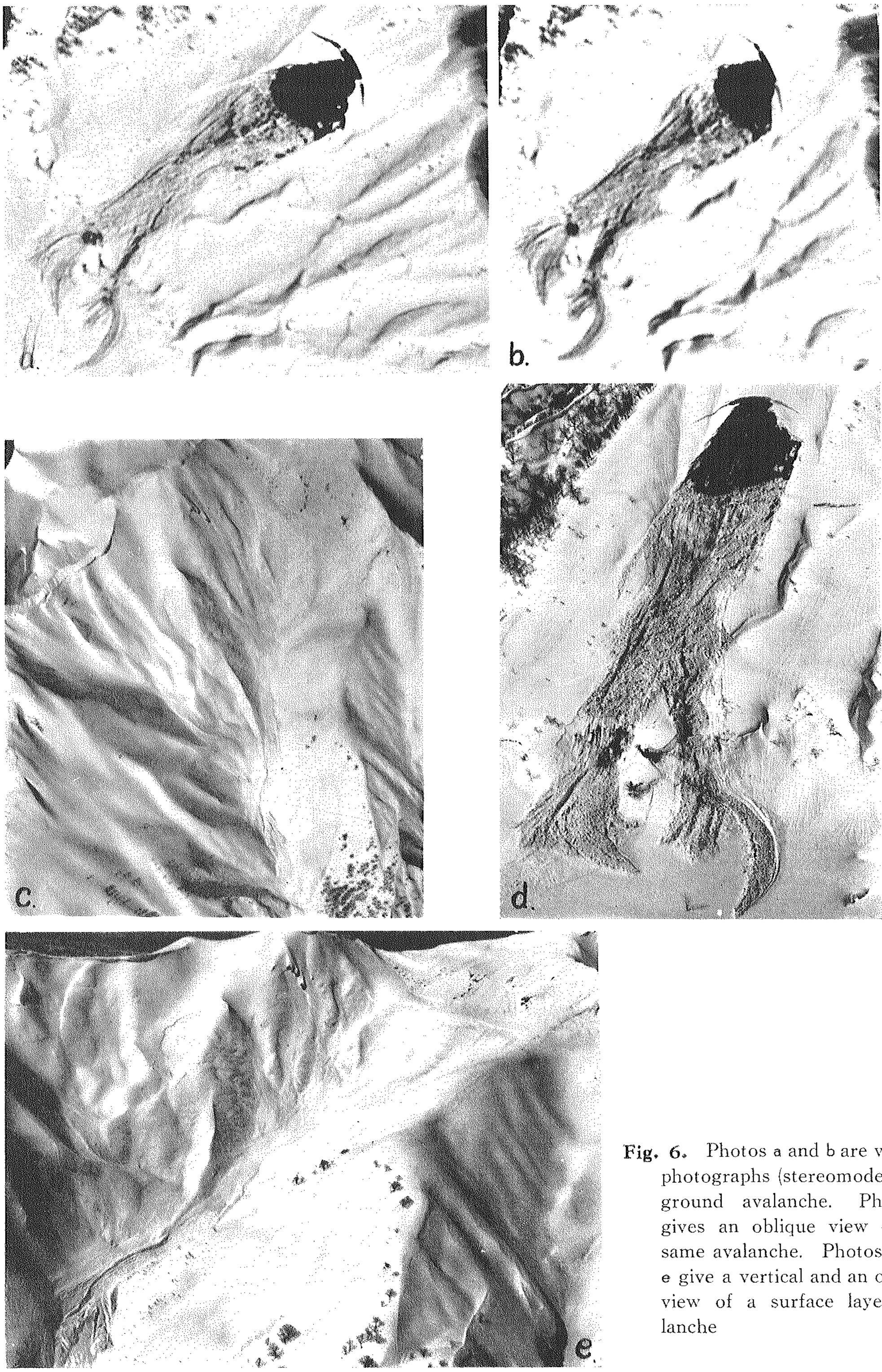

Fig. 6. Photos a and b are vertical photographs (stereomodel) of a ground avalanche. Photo d gives an oblique view of the same avalanche. Photos c and e give a vertical and an oblique view of a surface layer avalanche

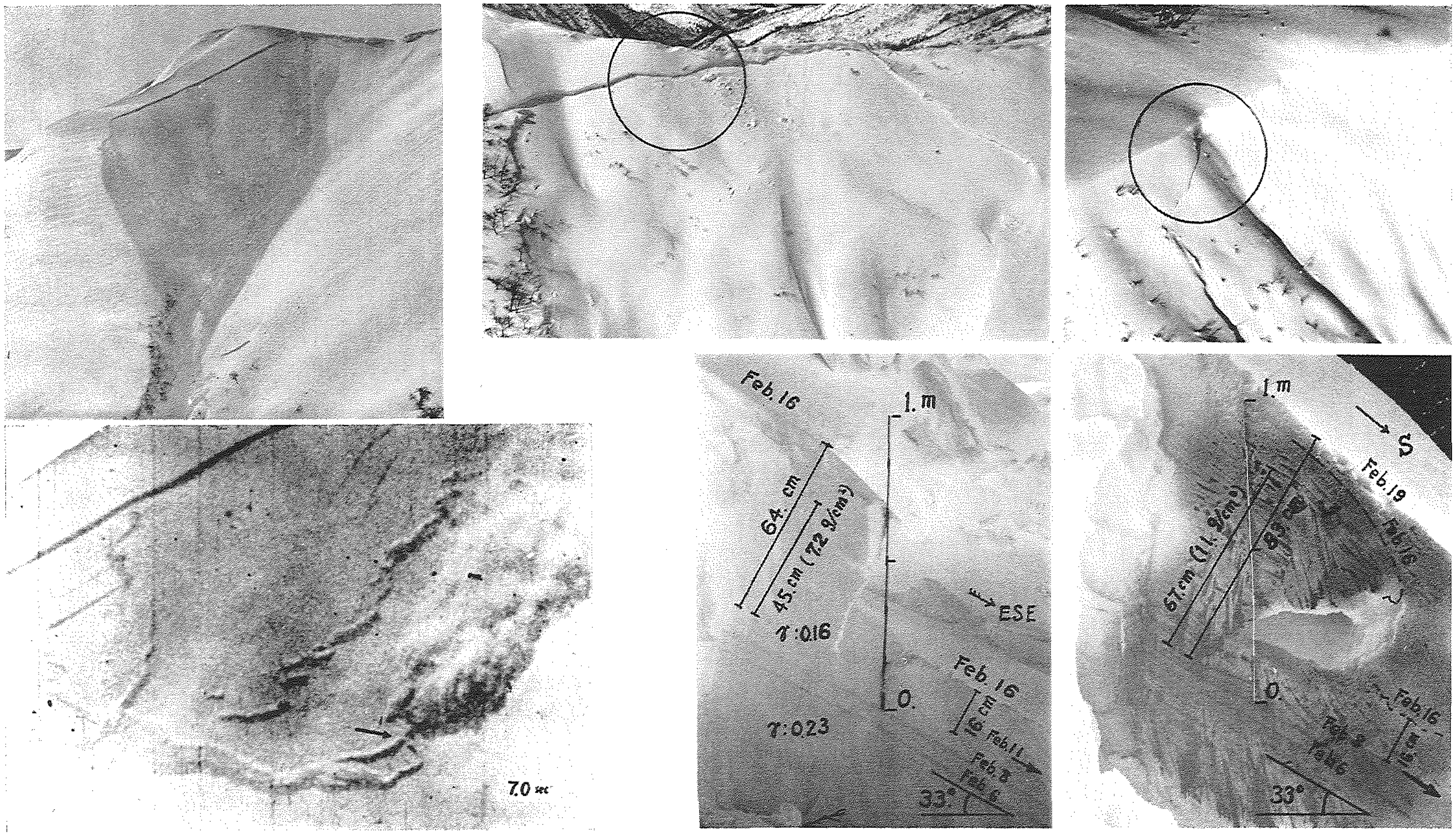

Fig. 7. The photographs on the left show pictures of artificially released avalanches using a helicopter. The lower shows the state 7 sec after detonation

The photographs on the upper right give the examples of surface layer avalanches. The enlargements at the bottom show profile data to estimate the shearing stress in the direction of the slide

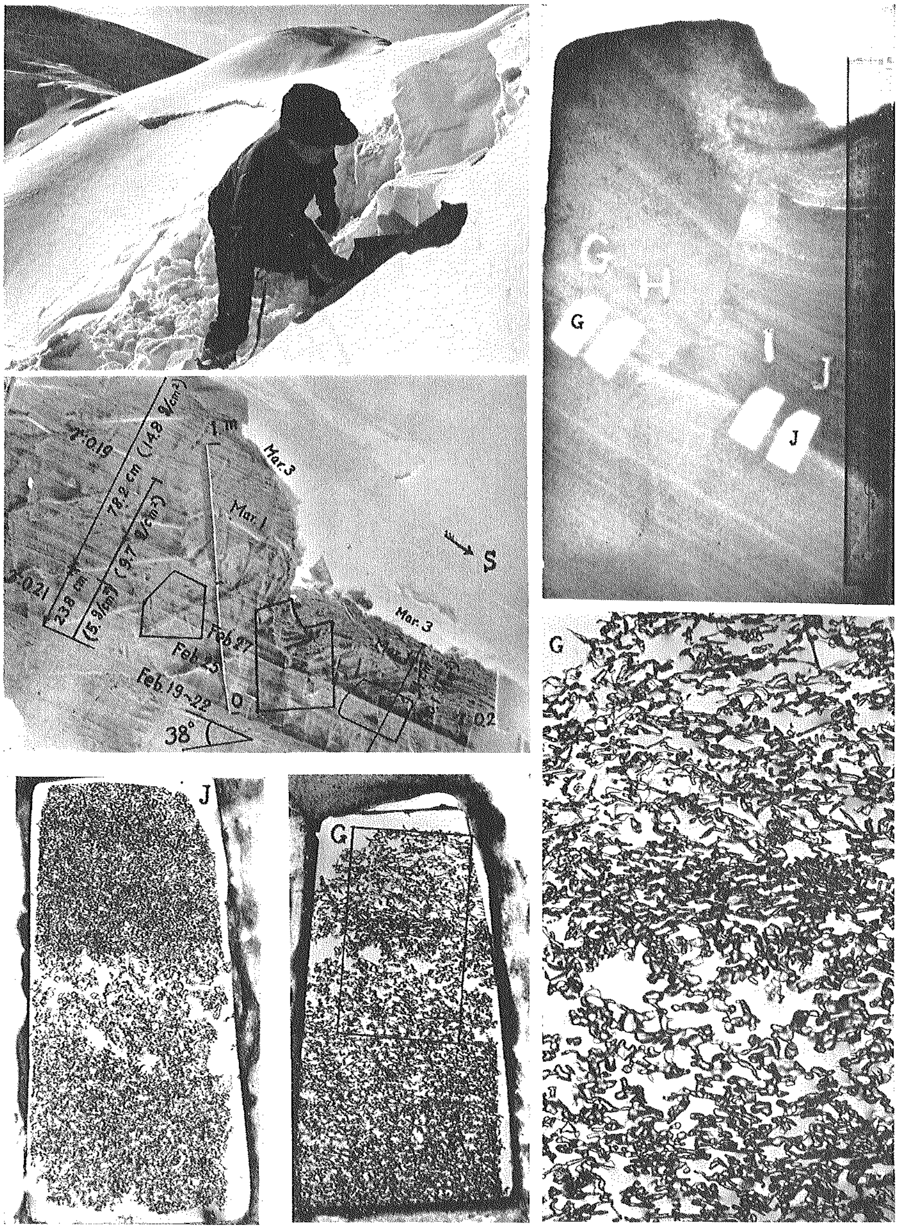

Fig. 8. The upper left photograph shows snow sampling at a fracture line. The picture below is the profile perpendicular to the fracture line showing the exact location of the sampled block. On the upper right an enlargement of the block is shown with the location of the thin section samples G and J (bottom left). Photo G shows the layer with weak interconnections which acts as a slide surface of the avalanche

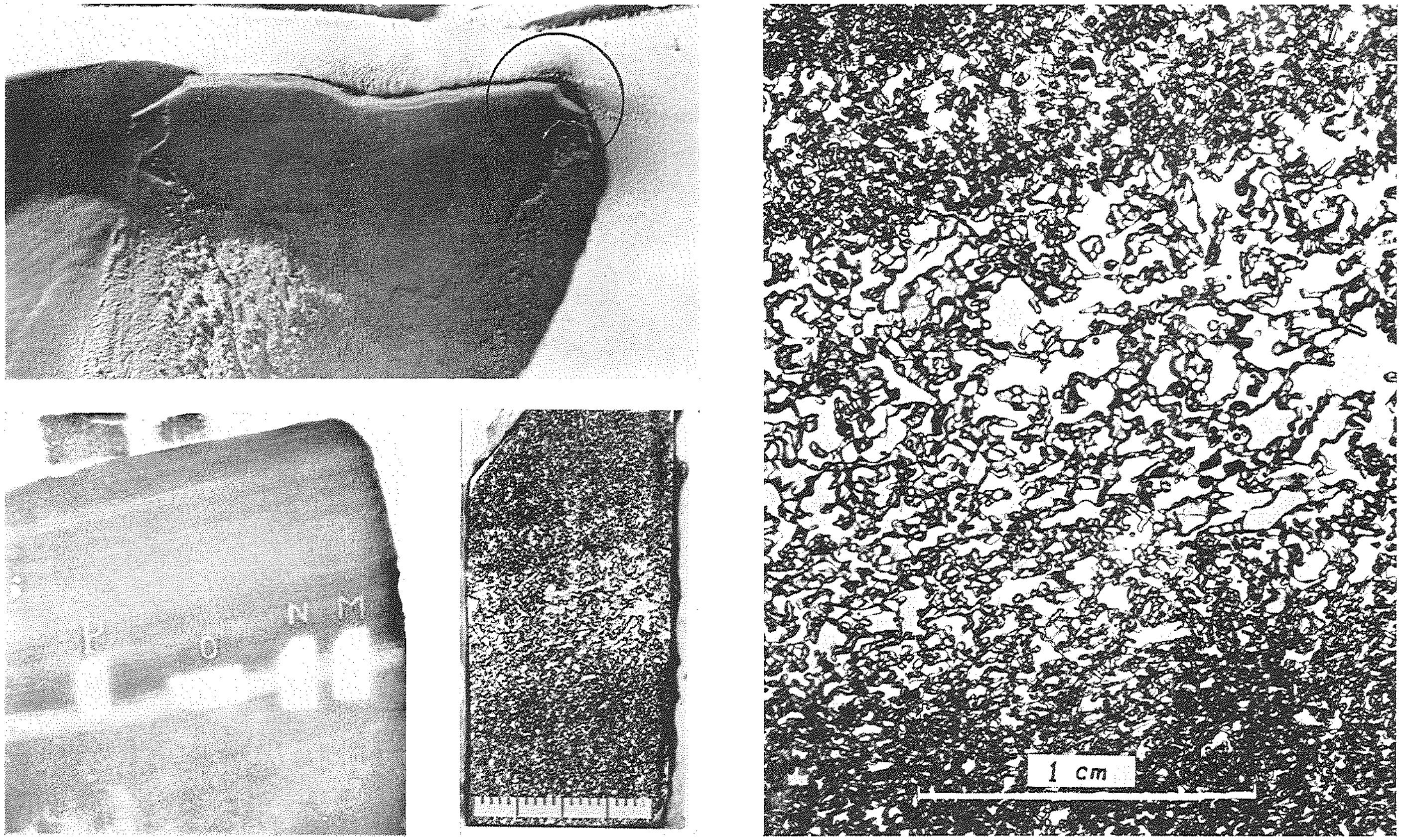

Fig. 9. Another example of a slide layer. The coarse-grained layer is caused by melting and refreezing

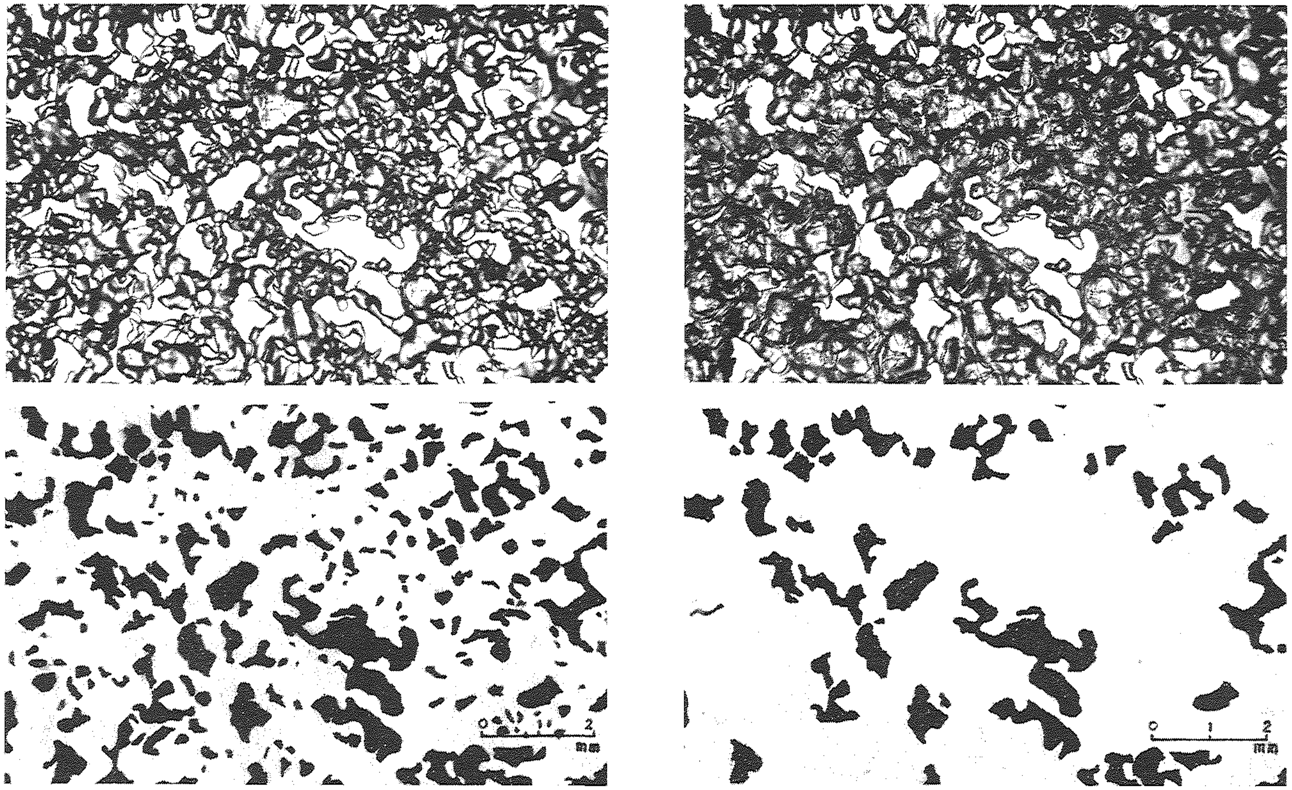

Fig. 10. The left picture shows the original network. The right picture shows the result using gasoline (convenient for the experiment) to test the capillarity. The fine holes are saturated with gasoline, which shows a higher intensity of capillarity. In the process of refreezing (for water) the fine grained part will become coarse grained

III

In February 1962, previous to the three-year project of aerial observation, the author suggested that it was useful and indispensable to take aerial photographs to analyse avalanches for the engineers of the Japanese Construction Ministry and Nippon Kokan Co., one of the three big steel makers in Japan. Nippon Kokan Co. contracted an aerial survey company to survey a strip along the No. 17 National Highway (Shoda, 1963 b). Till then, it had been said in Japan that aerial survey of a snow covered land was useless (Shino, 1963). In order to be able to record new snow avalanches, the airplane had to be kept ready for a week untill a snow storm stopped and photographs could be taken. Two photographs showing snow cracks and a trace of surface layer avalanche are shown in the figure together with the contour maps compiled from photographs of this area (Fig. 5). The contour interval is 2 m in the first case and 1 m in the second. As can be seen, the contour lines cross each other sometimes, which proves that a higher accuracy cannot be obtained. Quantitative and statistical analysis of the topography of avalanche sites is possible only by using vertical photographs of snow cracks and avalanche traces. In the second and third winter, oblique photographs of a region of avalanches were taken using a helicopter (Shoda, 1964 a, 1965 a); at the same time the same region was photographed vertically by an airplane (Fig. 6). These photographs will be used for the analysis of the topography of avalanche sites, whereas the oblique photographs provide additional information.

IV

A typical slab avalanche about 2 km long could be released easily and observed successfully by using the helicopter. The initial stage especially of the avalanche movement could be clearly recorded on a 16 millimeter film (Fig. 7 left) (Shoda, 1964 b). In order to be able to release a surface layer avalanche easily, the snow layer must be unstable, and at the same time the sky must be clear to take photographs. However, the instability of the snow cover and the fine weather does not continue very long after a snow storm, therefore nimble and rapid action by the observers is necessary. The rapid and unristricted movement of helicopters is best fitted for this experiment.

V

During the observation flights, a fracture line of the slab avalanche (surface layer avalanche) was noticed close to a ridge that was approachable, and therefore a landing was made on the summit and cross-section photographs of the rupture surface were taken. Profile investigations of stratification, gradient and thickness of the snow layers and density measurements were made at the same time (Fig. 7 right) (Shoda, 1964 a, 1965 a). The purpose was to calculate the magnitude of the stress which caused the avalanche to start. Snow blocks from several parts, including the sliding surface and fracture line, were cut from the profile (Fig. 8) and brought directly to a cold room in the Research Station by helicopter.

VI

In order to get more definite information of the structure of the layers where rupture occures, thin sections were made from sample pieces cut off from a snow block just above the fracture lines (Fig. 8). In this case, the exact location of the final thin sections in the cross-section, that is, relative location of the thin section to the sliding surface, is most important. Stratification of the rupture layers actually observed consisted of a clearly distinguishable layer about 5 mm thick of coarse and rounded grains of ice formed through melting and refreezing, lying between fine feltlike settled snow layers (Fig. 9). Probably this may have originated from sun crust, formed when it was at the surface and subjected to sun radiation and warmth. The vertical gradient of the temperature in the range lower than 2 500 m, was measured with a thermometer attached to the helicopter and read repeatedly. The result has proved that even in mid-winter, the snow surface of mountain side, 1 700 m in altitude, can be subjected to thawing on fine days with southerly wind. So far, no depth hoar has been found in the rupture layers in this district.

VII

Now, it is necessary and important to develop a method of interpretation of snow structures aided by a record of the prevailing meteorological conditions used in conjunction with sampling of the rupture layers, *i.e.* artificial production of the structures of deposited snow should be attempted under controlled conditions. A correlation between microphotographical structures of snow and the history of meteorological conditions affecting the snow has not yet been clarified. In this connection, the author have attempted to make microphotographical observations on the behaviour of water between the ice network of snow using thin sections of snow and some suitable liquids (Fig. 10). When water penetrates an ice network of fine-grained dry snow (at 0°C), it will not distribute itself homogeneously, but will concentrate in dense and complicated parts of the network. This leads to a spontaneous growth of snow particles through refreezing of the water after penetration. The size of the snow particles after refreezing will depend on the original structure and the quantity of water. Therefore the author intended to take the photographs showing how and in what part the water will stay in a thin-sectioned ice network of snow. However, water is not suitable for a first attempt of an experiment of this kind, because it is too difficult to keep the temperature exactly at freezing and gasoline (Petrole Benzine A) was mainly used. In this experiment, though the ice networks used were not three dimensional, as is that of natural snow and though the values of the surface tension and contact angle of these liquids are different from those of water, this trial seemed to be valuable as a first step before making an experiment with water. For example, the distribution of the intensity of capillarity within the ice network of snow could be estimated to some extent. Further Benzine A was very convenient to observe where the liquid envelops a part of the ice network successively in the course of the vaporization. For a clear explanation of this phenomenon, schematic drawings corresponding to each photograph are shown (Fig. 10).

VIII

As mentioned briefly in this report, systematic studies on avalanches have been carried out in the years following the experimental studies on the dynamics of avalanching snow by the artificial release method presented in the Avalanche Symposium at Davos 1965 (Shoda, 1966 b). In future, cooperation of scientists and engineers who have an interest in these problems will be greatly needed.

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* In Japanese.

† TEKKEN means Railway Technical Research Institute, Japanese National Railways.