SURFACE COLORING OF GLACIERS FOR AIR PHOTOGRAPHY[1]

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ABSTRACT

To make glacier mapping possible in white firn areas where stereo-effect is difficult to obtain, a large number of surface markers were placed on the glacier before air photographs were taken. Experiments proved that 3- to 5-kg powdered dye (yellow or brown ochre, or lamp black), packed in paper bags, made excellent surface markers when thrown from between 50- and 100-m elevation above the glacier surface. Color circles, applied by hand, also proved to be a good means for identifying ablation stakes, etc., in the firn area. An example of a map is given where the construction of contour lines was based upon the easily determinable dye markers that were clearly visible on vertical photographs taken from 7 300-m altitude.

INTRODUCTION

Under normal circumstances when vertical air photography is used for mapping glaciers the firn areas will often appear completely white; it may be very difficult, or even impossible, to map and measure the glacier surface in the stereoscopic models. On large ice sheets especially, the lack of shadows, crevasses, debris, or dust causes featureless white areas for which the construction of contour lines is extremely difficult (Konecny 1965). This difficulty may be overcome to some extent by photographing the glaciers late in the fall when the summer warmth has established a crust that may appear less white owing to larger crystals and (or) wind-blown dust. Also, the time of day when the photographing is done can be chosen so that shadows appear on parts of the glacier surface, facilitating the construction of contour lines. However, there will still be numerous cases in which the firn area appears only as a white surface for which stereoscopic effect is impossible.

This paper describes a method of surface coloring that was tried in Norway in September, 1964; an example of a map based on the subsequent air photographs is included.

TESTING METHODS OF DYE APPLICATION

As the experiment was to be made on the Jostedalsbreen in western Norway (the largest glacierized area on the European mainland), it was necessary to place the dye by means of light aircraft. In the planning of the operation, dusting from the air (similar to plant protection operations made by agricultural organizations) or dropping the dye as "bombs" was considered. As no aircraft equipped for continuous spraying or dusting was available at the time, the latter method was chosen.

To obtain the most suitable kind of powdered dye and packing material, as well as the optimum flying speed and flying elevation, a number of different

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kinds of dye were packed in various kinds of paper and plastic bags and thrown from different elevations and at different flying speeds onto a small glacier in western Norway. These experiments showed that the packing material must be strong enough to prevent the dye from being distributed in the air before reaching the glacier. On the other hand, the bags must not be so strong that they do not tear immediately upon contact with the snow surface. A single paper bag containing 3 to 5 kg of dye proved to be the most suitable "dye bomb".

The size of the dye markers obtained on the glacier will vary according to the flying speed, the flying elevation (above the glacier surface), and the wind speed. In some cases, especially when the glacier has a cover of new-fallen snow, or if the firn is very soft, the "dye bomb" may fall into the snow without tearing, leaving an almost invisible hole in the snow surface. This will happen especially if the flying speed is very low or the elevation too high. If the dye is thrown from a very low height, the "bomb" will normally approach the snow surface at a low angle and, as the paper bag tears, the dye will be thrown forward in the flight direction making a long, narrow strip (Fig. 1). If the dye is thrown from a somewhat greater flying height (or at a lower speed) the dye will spread out like a fan (Fig. 2). In the former case the dye marker would be 20 to 30 m long and 1 to 2 m wide, and in the latter case 5 to 10 m long and 3 to 5 m wide.

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After the above experiments it was decided to try a large-scale coloring operation on the highest parts of the Jostedalsbreen, just before the air photography was scheduled. Top priority for mapping the area had been requested by the Norwegian Water Resources and Electricity Board, but unfortunately the summer of 1964 was relatively cold with new snow falling in some of the firn areas. The conditions for air photography were therefore very poor. Although the lower parts of the glacier showed bare ice and large crevasses that would make plotting fairly easy, a large part of the highest region was still completely white at the end of August.

More than 200 paper bags were filled with powdered dye (mainly brown and yellow ochre, a material which had shown the best mechanical properties) in quantities of 2 to 5 kg in each bag. These "dye bombs" were thrown on the highest firn areas of the glacier from two light aircraft (Cessna 185 and Cessna 206) on September 2 and 3, 1964. Only a few hours after the surface coloring was completed, vertical air photographs were taken from a height of 7 300 m. A few dye rings had been placed on the glacier surface by hand around some of the ablation stakes (Fig. 3) to ensure accurate mapping of the stakes as an aid to continuous glaciohydrological measurements (Østrem 1964). Similar dusting operations had been undertaken in Switzerland (Kasser and Roethlisberger 1966). As the photographs were taken at a time of comparatively low sun, shadows of ripples made some areas sufficiently distinct for plotting. The dye application was made at markers placed in areas where prior observation from

FIG. 1. Experiments in "dye bomb" throwing. By variations in powdered dye, packing material, and flying elevation, the size of the colored area on the glacier surface can be controlled. In this case the target is from 5-kg dye thrown from 50-m elevation.

FIG. 2. One of the dye markers seen from approximately 100-m elevation. This marker originated from a "dye bomb" thrown from a little more than 100-m elevation, and its size was roughly 5 m long and up to 3 m wide. Note the surface details originating from ripples ("sastrugi") in the new fallen snow.

FIG. 3. Dye circles with a radius of 10 m were located around some of the ablation stakes to obtain accurate location on the map. Approximately 2 kg of dye (or lamp black) is sufficient for an annular space 1 m wide.

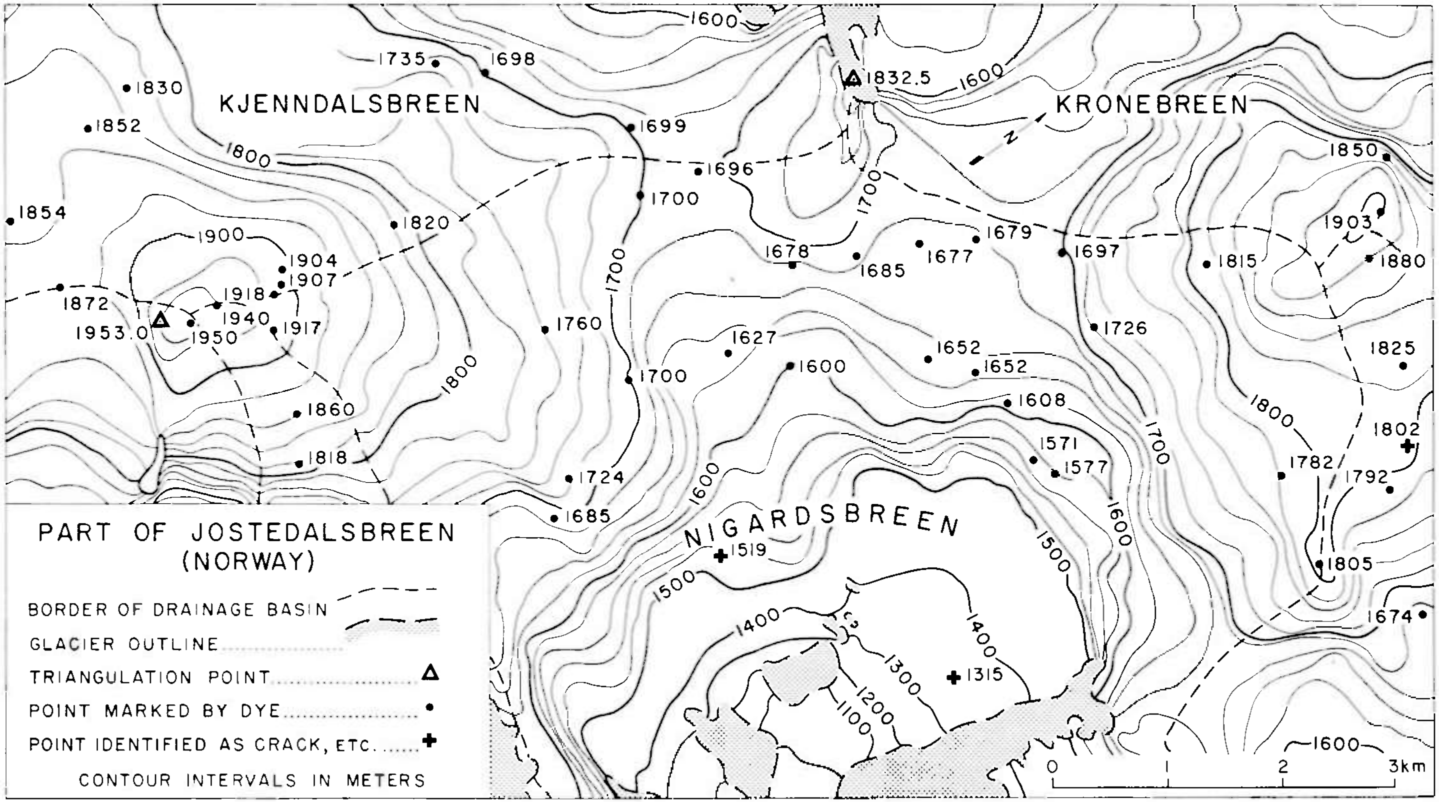

FIG. 4. Reproduction of part of original manuscript map based upon vertical air photographs. Each dye marker and a few other reference points (cracks, etc.) were plotted and their altitude determined. The "dye bombs" were preferably thrown in areas where it was anticipated that contour line construction would be difficult. Thus, a concentration of dye points can be found on the highest ridges in the firn area.

the light aircraft showed that it would be difficult to construct contour lines, that is, only on the whitest areas and along the highest crests. Crevassed areas and areas with numerous ripple marks, etc., were not dyed.

The average flying height was 50 to 100 m above the glacier surface, the speed varying between 100 and 150 km/h. Such a low flying height is possible only when no obstacles occur within the operation area. On glaciers in very mountainous areas it might be necessary to fly at greater heights, causing difficulties in the spread of the dye, especially if there was a surface of soft new snow.

RESULTS

The air photographs at 1:40 000 show all the dye markers very clearly, and it proved very easy to determine their accurate position and elevation in each stereoscopic model. Together with the above-mentioned tiny shadows originating from ripple marks, and with nunataks and crevassed areas, the dye points made the plotting of contour lines relatively easy in spite of the unfavorable snow conditions. A map at a scale of 1:50 000 (Pytte and Østrem 1965) was prepared of the areas considered to be in the catchment area for a future hydroelectric power plant. As an illustration of the distribution of color markers on the glacier, a part of the original map manuscript is reproduced in Fig. 4. As the location of the water divide between different catchment areas was considered important in connection with the hydrological project, it was of special interest to obtain good accuracy in the highest parts of the glacier. Therefore, a considerable number of dye markers were placed along the highest ridges in the firn area.

The total cost of the surface coloring operations amounted to approximately 25% of the cost of the air photography in this case. As the cost of the air photography is only a fraction of the total cost of the map production, the increase caused by the coloring operations could be said to be almost negligible.

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