MICRO- AND MACRO- ANALYSES OF STRATIGRAPHIC SNOW PROFILES

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ABSTRACT

A method to prepare and investigate snow profiles is described and illustrated. Compared to the conventional and the dyed profiles, this new method has several advantages. A thin slab is prepared without mechanically disturbing weak layers or hard inclusions by using a tool with a heated wire as a cutter. The contrast is given by the sunlight from the back side of the profile. It is not falsified by damaged snow layers or an uneven distribution of the colour. Critical layers are easily detected, documented and investigated on site and samples for a micro analysis can be taken from the lateral walls. For a digital processing of the pictures, image enhancement techniques are applied. The contrasts and the results with the translucent profiles are better than with dyed profiles. Surface hoar, boundaries due to wind action and melted horizons are then subjected to a more thorough investigation by an analysis of thin sections or serial cuts. The enhancement technique uses high- and low pass filtering and edge detection algorithms. The features are then extracted by image segmentation, one of the few steps where the operator has to make subjective decisions. The structure and the texture are quantified by stereological and related parameters. The description of the relevant features, however, presents substantial problems. Moreover, the connection between structure and texture and parameters from physical experiments is not yet solved in a satisfactory way. This contribution illustrates the structural part and does not mention the physical and acoustical measurements performed on the same snow samples.

INTRODUCTION

Standard snow profiles are a valuable method to look into the natural snow pack. Many drawbacks with this technique exist, however, in preparing the snow pit and in visualising, analyzing and interpreting the available information. Because individual grains and grain complexes are obtained by brushing and scratching, the result of this operation is often rather subjective. The only non destructive technique so far is a profile obtained by using microwaves

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(Gubler, 1986). We illustrate an alternate method for preparing and evaluating stratigraphic profiles. Based on an old idea of translucent profiles - credited to many authors of the first generation of snow scientists - it is devised to be of use for investigating the stratification of homogeneously deposited snow as well as of an inhomogeneous snow pack, as on a leeward slope or in a forest stand, where the discharge of intercepted snow disturbs and alters the snow layers on the ground. As a modification of standard profiles, the method still needs snow pits (Good, 1991). This technique works as well in soft snow as with ice lenses and hard inclusions and does not disturb these features as is often the case with mechanical tools. Profiles from different winters and sites are used to illustrate the method and to point at significant details. Surface hoar, transitions between different snow qualities, ice lenses and percolation paths are given as examples. The results from parallel investigations of mechanical and acoustical properties (Buser, 1987) are not discussed here because of the still lasting difficulties to join the physical and geometrical parameter spaces.

EXPERIMENTAL

Two adjacent pits, separated by a wall of a few decimeters of snow are dug. They are oriented in order to provide optimal illumination of the separating wall. A tool that consists of a rectangular, metallic frame and of a guiding support is used (Figure 1).

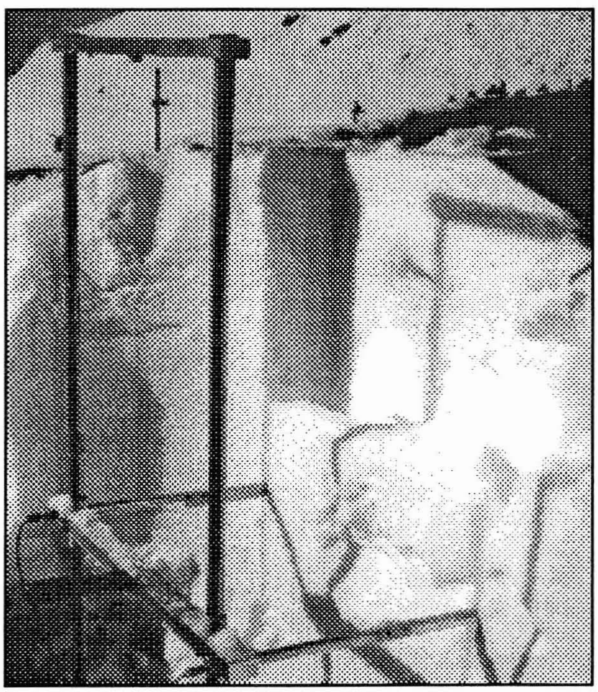

FIG 1 HOT WIRE CUTTING TOOL IN A PIT OF A CORNICE

The shorter sides of the frame are sharp blades and the side towards the snow is an electrically heated wire. It allows the preparation of very smooth surfaces of the remaining separation. It is adapted to cut one meter of a profile in a single operation. The separating slab in a deeper snowpack has to be prepared in several steps. It is thinned down to a few centimetres and becomes translucent. The mechanical stability of the slab is assured by the walls of the pits. The translucent separation contains the macro structural information of the snow pack. Typically, surfaces of half a square meter are analyzed. The slab is examined carefully and photographed with various equipment and film materials. Snow of different densities and textures as well as with critical layers and interfaces is easily detected. At these sites cylindrical samples are taken from the undisturbed lateral walls for a more thorough investigation. They are carefully carried to a shelter, where they are prepared for storage and later confection of cuts. The conservation of the samples is performed by filling the pore space with a liquid organic material. Cooled down to -

20 C, the whole compound can easily be transported and stored for a prolonged period. Thin sections of a few square centimetres for two dimensional and serial cuts for three dimensional analysis are manufactured. The same techniques of image enhancement and analysis are used for the large and the small samples. A typical image enhancement procedure consists of low pass filtering to remove artificial brightness variations, high pass filtering to accentuate transitions between features and the space in between (edge detection algorithms) and discrimination (segmentation) to define uniquely white areas (information) and dark ones.

METHOD OF ANALYSIS

A quantitative determination of the structures and textures is made with two sets of parameters and parameter distributions. They are computed by both sampling- and pattern recognition techniques (Good, 1989). The simpler parameters, evaluated in the horizontal and the vertical scanning direction are: Pixel densities (Fig 3, 6, and 7) and intercept lengths (Fig 15).

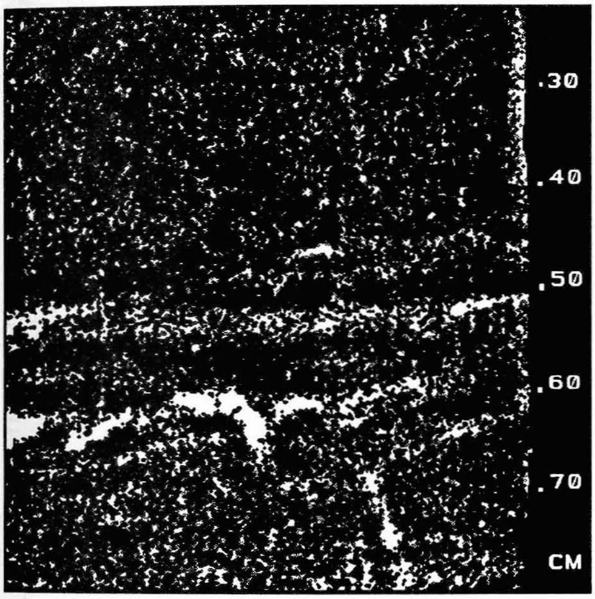

FIG 2 TRANSLUCENT SNOW PROFILE OF AN INHOMOGENEOUS CORNICE. WHITE CORRESPONDS TO HIHGER TRANSPARENCIES

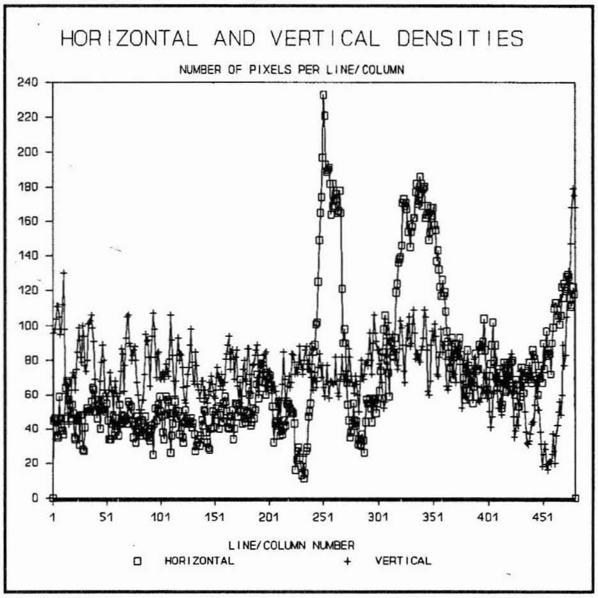

FIG 3 WHITE PIXEL DENSITY IN HORIZONTAL AND VERTICAL SCANNING DIRECTIONS.

In an inverse video picture the space between the cut features is measured yielding, among others, a distribution of the free distance (Fig 16). The total border length is evaluated in a two step operation. The original features are eroded one pixel deep (Serra, 1982). The resulting image is subtracted from the original picture leaving the borders only. With the pixel density routine, the total border length is evaluated. Pattern recognition parameters are computed with one of several commercially available software packages. This program evaluates the number of features, and for each feature: Area, perimeter (Fig 17), centre of gravity, FERET diameters

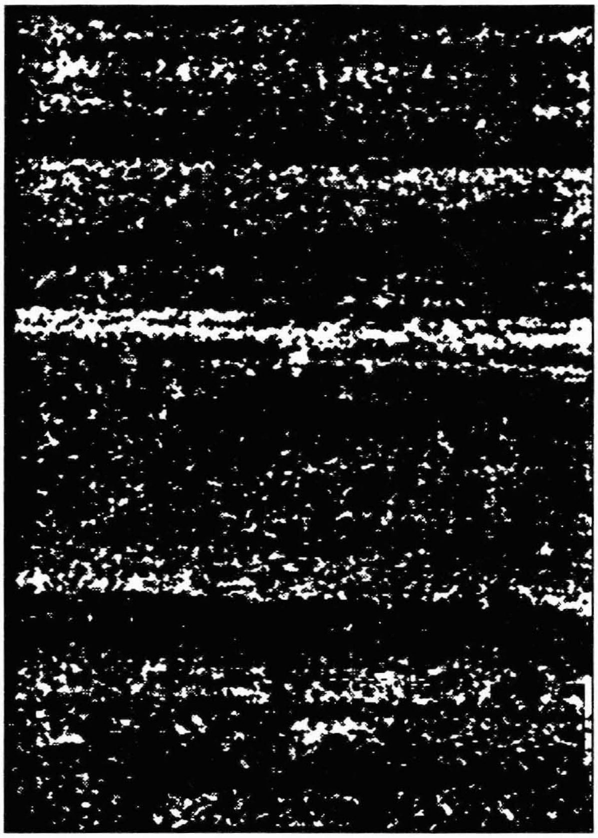

FIG 4 DPV_02_04_92 TRANSLUCID PROFILE [ENHANCED] FROM 2.APRIL 92 [0.4m*0.5m]

FIG 5 MATTA Fi_Lae_86 COLOURED PROFILE (INVERSE VIDEO) [ENHANCED] SIZE 0.5m*0.8m

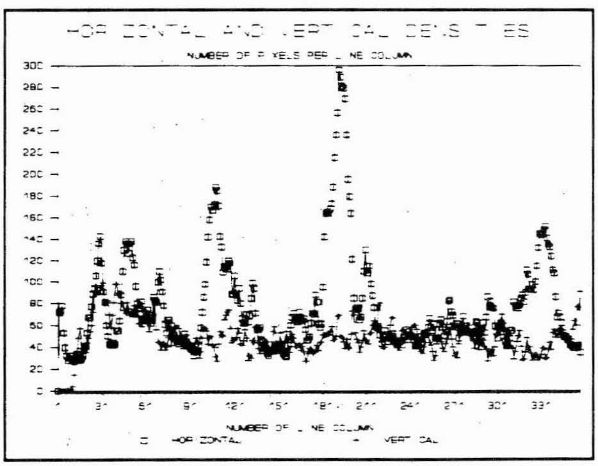

FIG 6 DPV_02_04_92 DENSITIES OF TRANSLUCENT LAYERS

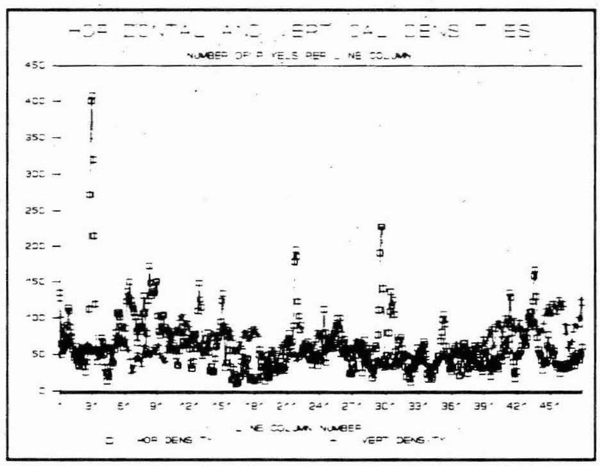

FIG 7 Fi_Lae_86, WHITE PIXEL DENSITIES OF COLOURED LAYERS [INVERSE VIDEO]

- i.e the sides of a circumscribed rectangle - the axes of a circumscribed ellipse, minimal and maximal diameter and different orientations of the features in the working coordinate frame. A very efficient qualitative analysis is performed by carefully looking at significant details of the original and the enhanced pictures. The details often are hidden in single or even multi valued parameters of the entire picture. An analysis of several sub parts of the image may then point at the significant differences (Table 1, figures 17 and 18).

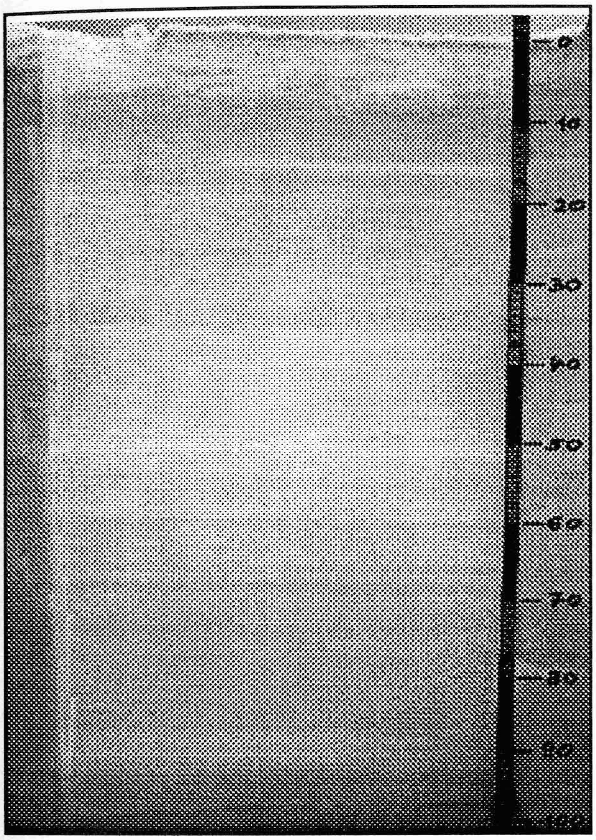

FIG 8 TRANSLUCENT PROFILE OF 02.APRIL 92. THE SIZE IS 0.4m * 1.0m.

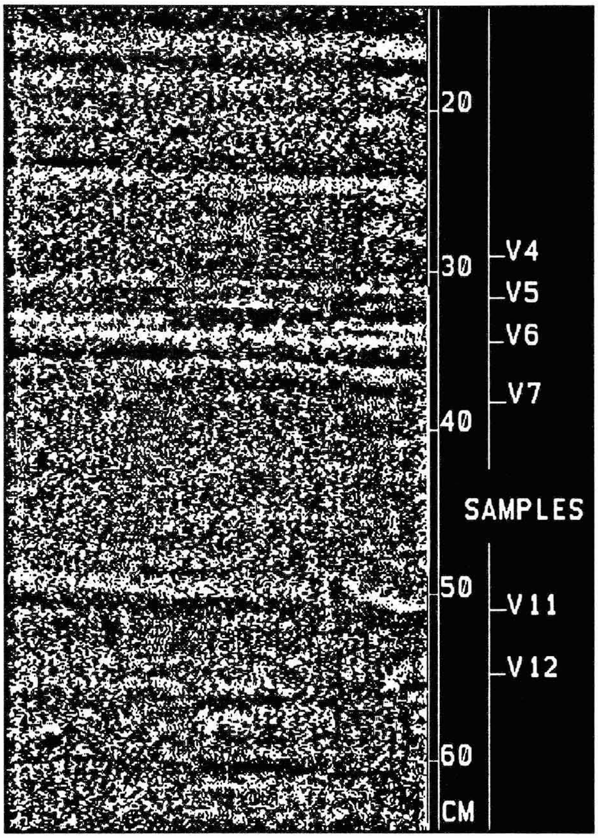

FIG 9 ENHANCED PROFILE FROM 02.APRIL 92 WITH LOCATIONS OF MICRO SAMPLES

DISCUSSION OF RESULTS

Information obtained from macro samples

A visual comparison of the two techniques, translucent profile (Figure 4) versus dyed profiles (Figure 5), shows a similar quality. The preparation in the field, however, is very different. The heated wire having cut through the snow of various qualities, the smooth surface already reveals the important discontinuities. Relevant details with the colouring method appear only after the application of the diluted dyestuff and the subsequent treatment with a heat source to have the dye displaced towards the weaker parts of the profile. The digital image enhancement is then the same for both. According to the filtering operations, different results may be obtained from a given original (figure 8). It is up to the operators experience which one to use for a specific purpose (Figures 4, 9). The three snow profiles (fig 2,4,5) illustrate various snow conditions: Figure 2 is a fraction of the profile of the site of figure 1. It was taken in vicinity of buildings in a cornice, deposited under very turbulent conditions. A layering and weaker (more translucent) zones in the shape of cavities are displayed. The vertical pixel density is rather smooth compared to the horizontal density. A Typical layering from a standard test site is shown as a photograph in figure 8. Figures 4 and 9 are the results of different enhancement routines applied to the original image and point to various levels of details of this "homogeneous" profile. The true nature of the visible transitions and discontinuities is elucidated in the analysis of the corresponding micro samples (fig 10, 11, 12). The coloured profile from a larch - pine stand was obtained by dispersing diluted dye which was then treated with heat. The less dense parts of the snow profile become darker and contrast with the denser ones. Figure 5 is the inverted picture and the narrow dark band that corresponds to the position of a vertical pole shows the inclination of the slope. Compared to other tree species, the snowpack near larch trees is almost undisturbed. The method of translucent profiles allows a reproducible, semi quantitative documentation of the stratification of the snowpack.

Information obtained from micro samples

A careful visual inspection after having cut the profile slab permits to select the sites with critical layering. Figure 10 is a contiguous series of thin sections from the upper part of the profile showing different layers of new snow. The cut particles are white, the void is black. The two samples in the middle show critical layers. Figure 12 is the enlarged sample V11 (V is for vertical) with more details. Figures 11 and 12 are examples of the profile from the experimental site at Weissfluhjoch from 2. 4. 1992. Figures 13 and 14 are from two different profiles at Pierrefort, France from 19. 3. 1989 and 20. 2. 1990 (Page, 1990) analyzed with the same techniques. All of them show an initial new snow situation. V6, figure 11, is from a snowfall with different intensities and or with changing wind conditions. It needs a more complete analysis, including 3D reconstruction, to decide whether the discontinuity in the lower part is due to melting or wind action. Figure 12, 13, and 14 con-

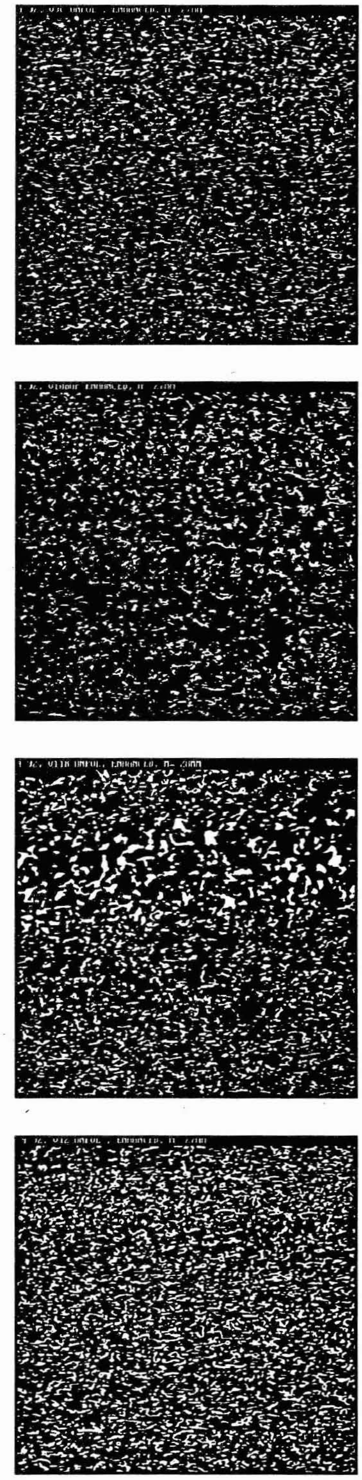

Fig 10 12 CM OF THE PROFILE OF FIG 8,9 FROM V9 TO V12 SCALE: 1.625 : 1

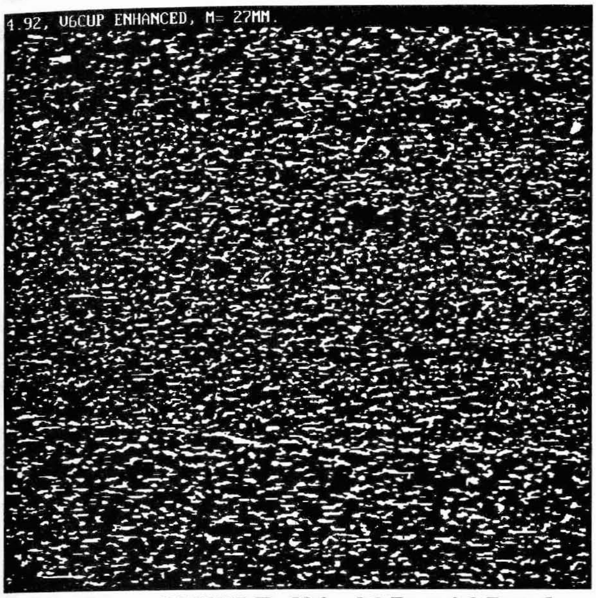

FIG 11 SAMPLE V6 [27mm*27mm]

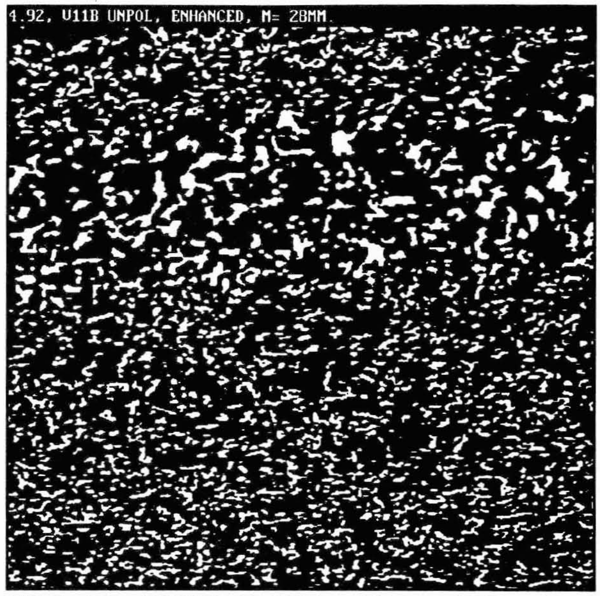

FIG 12 SAMPLE V11 [27mm*27mm]

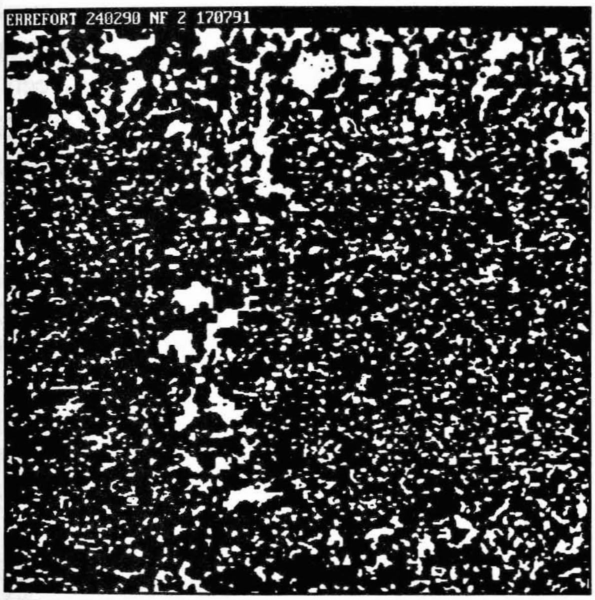

FIG 13 SAMPLE V1X2 [15mm*15mm]

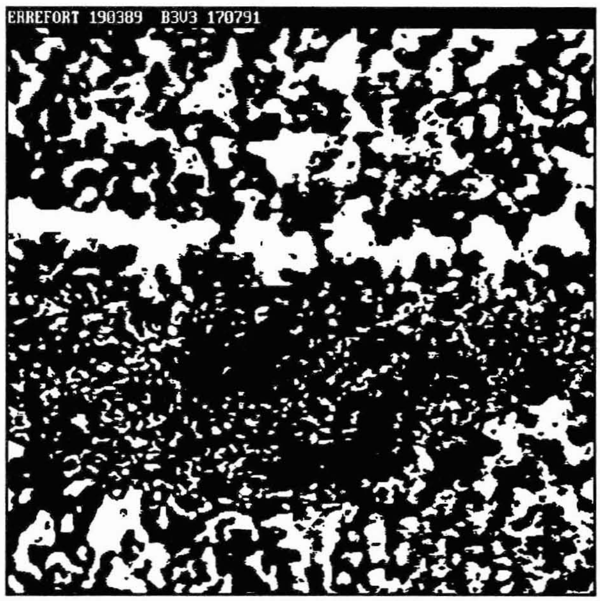

FIG 14 SAMPLE V317 [15mm*15mm]

TAB 1 CHARACTERISTIC PARAMETERS FOR SUB SAMPLES (ROI) OF V6

ROI	DENSITY	NUMBER/CM^2	AREA (MEAN)	PERIMETER(M)
1	0.106[pixel/pixel]	531	13.01 [pixel]	14.83 [pixel]
2	0.115	641	11.76	14.46
3	0.095	461	13.50	15.38

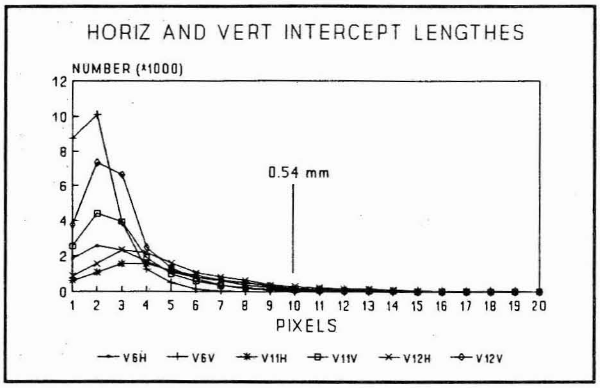

FIG 15 MICRO SAMPLES V6, V11, AND V12 [SEE FIG 8,9,11]

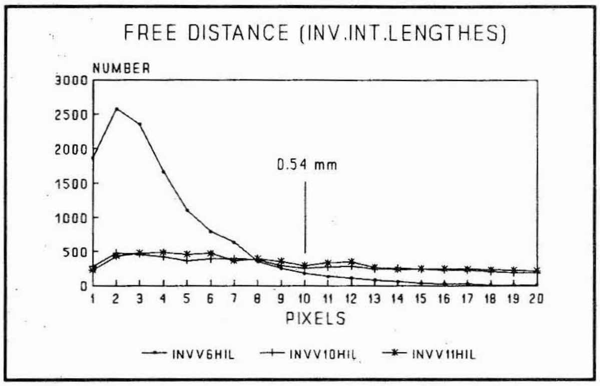

FIG 16 MICRO SAMPLES V6,V10, V11 [FIG 9,10,11,12]

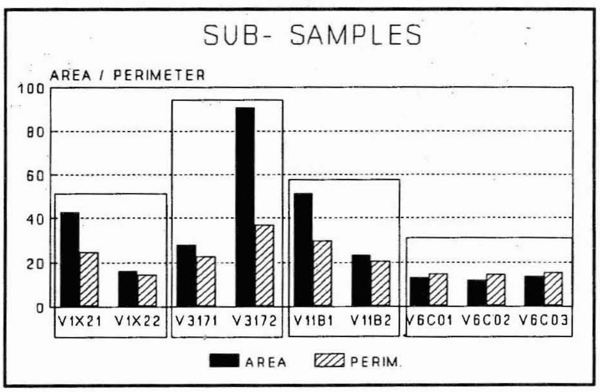

FIG 17 MICRO SAMPLES V1X2,V317, V11, AND V6 WITH AREA, PERIMETER OF FEATURES

tain structures due to more or less intensive action of heat and or radiation. Taking into account the scale of the micro samples, these structures have similar appearance as in macro samples. The "percolation fingers" and surface crusts are on or embedded within fine grained new snow. Results of more quantitative analyses for the six snow samples V6, V10, V11, V12, V1X2, and V317 are illustrated in table 1 and figures 15 to 17. The smallest intercept lengths in figure 15 are found in the vertical scanning direction and the number of small values peaks for V6. These results together with the ones from figure 18 show a horizontal layering of the snow deposit. Samples with small and large distances between particles are illustrated in figure 16. Regions of interest (ROI) can be defined to look at inhomogeneous samples. Three ROI's or sub samples of 7 mm by 27 mm have been chosen for V6. For 90% of the snow particles of sub sample V6.1, the angle between the longer diameter and the horizontal snow surface (X - axis), is between 0 and 14 degrees. Table 1 shows the variability over the sample with the smallest particles. The maximal vari-

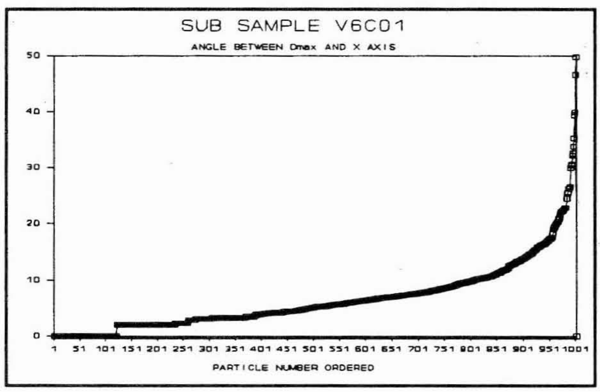

FIG 18 SUB SAMPLE V6.01 ORIENTATION OF NEW SNOW PARTICLES VERSUS SURFACE(X)

ation for the number of particles is 28% and 17% for the densities. The mean particle area has a variation of 13% between the sub samples. The mean perimeters vary by 5%. Figure 17 illustrates the mean areas and the mean perimeters of four samples. For very small particles the area and the length of the perimeter (in pixels) have similar values. The marked transition in the lower third of the sample, however, is only detected by visual inspection and the mechanical effect of such a discontinuity is not yet known.

CONCLUSION

It is not the aim of the method of translucent profiles to compete with non destructive techniques to investigate the snow cover. This method may be used, already in the field, to find instability horizons that are hardly detected with standard means. It is also suitable as a geometric gauge for electromagnetic or acoustical probing of the snowpack. To become a fully quantitative method many problems have still to be solved.

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