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AN ANALYSIS OF SNOW COVER CHARACTERISTICS AT AKLAVIK AND RESOLUTE, NORTHWEST TERRITORIES

by

G. P. Williams

Report No. 91

of the

Division of Building Research

Ottawa

August 1956

PREFACE

This report analyses the snow cover characteristics measured at the two Arctic stations of Resolute and Aklavik from 1947 to 1954 under the sponsorship of the Associate Committee on Soil and Snow Mechanics of the National Research Council of Canada. Frequency diagrams show considerable difference between the snow properties at these two stations. Graphical comparisons are made to show depth-time variation of hardness, density, and grain size. The close relation between snow density, hardness, and temperature gradient is also shown graphically.

The author of this report, an Assistant Research Officer in the Snow and Ice Section, has used some of the results of the Snow Survey in order to make a detailed analysis of snow cover characteristics at two northern stations. These were selected as examples and in view of the special interest in northern climatic conditions in Canada.

It is hoped that all who read this report will feel not only free, but that they are invited, to submit to the Division any comments on the work herein described, particularly since it is in essence a pilot study in a field of research which is only now being opened up.

Ottawa
August 1956

Robert F. Legget,
Director.

AN ANALYSIS OF SNOW COVER CHARACTERISTICS AT AKLAVIK AND RESOLUTE, NORTHWEST TERRITORIES

by

G. P. Williams

Since 1947 regular observations of the physical characteristics of the snow cover have been taken at Aklavik, located on the Mackenzie River delta and at Resolute, Cornwallis Island, Northwest Territories. These observations were part of a general snow survey across Canada sponsored by the Associate Committee on Soil and Snow Mechanics of the National Research Council of Canada, and carried out through the close co-operation of the Division of Building Research, National Research Council, and the Meteorological Division of the Department of Transport.

The amount of snow cover, depth of snow, shape and size of crystals, snow surface conditions, along with essential meteorological data were recorded daily by observers of the Meteorological Division. Measurements of snow density, hardness, temperature, crystal size and shape were taken bi-weekly in different snow layers. The instruments used to measure the characteristics of the snow have been described previously by Klein et al (1).

Preliminary results from all stations were analysed by Pearce and Gold (2). Since their report, which includes data from 1947 to 1950, data for four additional years have been collected and therefore a more detailed analysis is warranted. The purpose of this present analysis is to show the variation of snow cover characteristics at the two Arctic stations of Resolute and Aklavik from 1947 to 1954. These two stations were chosen for study because data were quite complete and preliminary analyses showed marked difference in snow characteristics measured at the two sites.

COMPARISON OF SITES

Aklavik is located at latitude 68° 14' N. and longitude 134° 50' W. about 50 miles inland from the Arctic Ocean. Resolute is located at latitude 74° 30' N. and longitude 95° 40' W. on Cornwallis Island. Figure 1 is a map of the Canadian Arctic showing the location of these two stations.

Elevation of the observation site at Aklavik is 30 feet above mean sea level. The site is somewhat sheltered by the scrub brush found in this area. The terrain to the north of Resolute rises gently to a height of about 200 feet above mean sea level, one mile from the station. The test area at Resolute was chosen in a semi-sheltered location since completely exposed

areas are blown clear of snow.

As Aklavik is approximately 400 miles south and 1,000 miles west of Resolute, there is a considerable difference in climate between the two stations. The annual total snowfall is 47.1 inches at Aklavik and 30.2 inches at Resolute. The annual average of daily mean temperature is 16°F. at Aklavik and 3°F. at Resolute. These values were obtained from Addendum to Volume I, Climatic Summaries for Selected Stations in Canada, Meteorological Division, Department of Transport, Toronto, 1954, and are based on 22 years of observation at Aklavik and 6 years of observation at Resolute.

From 1949 to 1954 Resolute had an average of 16.3 days per month when the wind velocity exceeded 9 m.p.h. during the winter months. During the same period Aklavik had an average of 5.9 days per month when the wind velocity exceeded 9 m.p.h. A wind velocity of 9 m.p.h. was chosen as a critical velocity because according to Dmitrieva (3) it is the wind velocity at which snow begins to blow.

ANALYSIS OF DAILY SNOW COVER OBSERVATIONS

From 1947 to 1954 the maximum snow depth recorded at Aklavik was 16.0 inches. For three consecutive years, 1949 to 1950, 1950 to 1951, 1951 to 1952, Aklavik reported snow depths under 5 inches. The maximum depth recorded at Resolute from 1947 to 1954 was 28 inches. In areas subject to drifting, snow depth is of value in describing a particular site but does not give any indication of comparative amounts of seasonal snowfall.

Figure 2 shows frequency polygons for snow surface crystal shape, size, and surface conditions, recorded from October 1951 to December 1954. A detailed explanation of the symbols used is given by Klein et al.(1).

Aklavik shows a much greater variation in surface crystal shapes. Depth hoar or type "e" was reported 32 per cent of the time at Aklavik and 1.5 per cent of the time at Resolute. At Resolute type "d" was reported 65 per cent of the time.

The surface grain sizes recorded at Resolute were consistently smaller than at Aklavik even though the general shape of the frequency curve is the same. The large number of surface hoar observations is one explanation for the larger grain sizes at Aklavik.

The shape of the frequency curve for surface snow conditions is the same for both stations, with wind erosion being reported twice as often at Resolute, and a smooth surface being reported twice as often at Aklavik.

FREQUENCY DIAGRAMS FOR BI-WEEKLY SNOW PROFILE OBSERVATIONS

Figure 3 shows frequency polygons for snow crystal size, density, and hardness at Aklavik and Resolute from 1947 to 1954. Observations were taken bi-weekly at different layer intervals from the snow surface to the ground.

At Resolute 88 per cent of the grain-size observations were under 1.5 mm. At Aklavik the grain-size variation was much larger. The shape of the frequency diagram for snow density was quite similar at both stations, with a mean density of 0.242 at Aklavik, and a mean density of 0.356 at Resolute. Aklavik hardness values were smaller and the variation in hardness was less than at Resolute.

DEPTH-TIME VARIATION OF SNOW PROFILE PROPERTIES

Even under similar site conditions snow properties measured in one place will not be the same as properties measured in another place a few yards away. For that reason any comparison between characteristics of snow at stations several hundred miles apart must be on a broad basis.

Figure 4, showing the average variation of snow hardness, density, and grain size with depth, is a graphical comparison of over-all snow properties from 1947 to 1954. At Aklavik snow hardness generally increases with depth. At Resolute there is a sharp decrease in hardness down to 8 inches, and at greater depths the hardness is essentially constant. At both stations the average density remains essentially constant with depth. The average grain size increases with depth at Aklavik and remains essentially constant with depth at Resolute.

Figure 5 shows the variation of average monthly snow hardness, density, and grain size, and is another graphical comparison of snow properties on a broad basis. The grain size shows a marked increase with time at Aklavik and is almost constant with respect to time at Resolute. The density variation with time is very similar for both stations. The average hardness at Resolute increases to a maximum of nearly 2500 gm/cm.^{2} in March. The increase in average hardness for Aklavik is much less, reaching a maximum of 700 gm/cm.^{2} in February.

Figure 6 combines the data used to obtain Figs. 4 and 5 to indicate over-all depth-time variations. Figure 6 shows that the snow crystals at Aklavik increase markedly in size with respect to time and depth, undergoing the metamorphism reported by Richter (4). At Resolute there is a definite tendency for grain size to remain constant with respect to time and depth. Average density increases gradually with time, and remains essentially constant with depth at both stations. Both stations show an increase in hardness with time up to a maximum in February and March, and then decreasing hardness is evident at both stations in April and May.

RELATION BETWEEN DENSITY-HARDNESS AND TEMPERATURE GRADIENT

Figure 7a shows average monthly log of hardness plotted against average monthly density for both stations. There is a close relationship between these two properties as reported by Gold (5).

Closely related to density and hardness is temperature gradient. Figure 7b shows average monthly temperature gradient plotted against average monthly density from November to March.

During this period of continuous cold the difference in insulating value of snow cover at these two stations was quite marked. Several times at Aklavik the surface snow temperature was reported at least 20°F. colder than at a 12-inch depth. At Resolute the reported surface snow temperature was seldom 10°F. colder than at the 12-inch depth. This difference in insulating value is closely related to the difference in density, confirming studies of Kondrat'eva (6).

DISCUSSION OF RESULTS

The frequency diagrams on Fig. 3 emphasize the difference in snow properties at these two stations. Even though no proof is attempted in this report, much of this difference must be attributed to climatic factors. For example, observers at Resolute have noted that after a severe storm the snow was packed so hard that trucks could be driven over the snow drifts (7). This observation suggests that wind is one factor which might explain the large differences in snow hardness between these two stations.

The relation between snow characteristics such as grain size, density, and hardness are complex, involving many diverse factors. The graphical comparisons of snow properties on a broad basis enable some general comparisons to be made. For example, the variation of average grain size with time and depth shown in Figs. 4 and 5, is different to the time-depth variation of density and hardness. If grain size, as measured by the observers, were closely related to hardness or density, the general time-depth pattern should show more similarity.

Figure 7 shows that a close relation exists between snow density, log of hardness, and temperature gradient. It was difficult to analyse this relationship in detail because temperature gradient fluctuates with daily air temperature changes whereas changes in density and hardness are gradual. For example, in March at both stations, the temperature gradient usually reverses and snow temperatures start to decrease with depth. This reversal of temperature gradient often coincides with a gradual decrease in hardness at both stations. More detailed studies will be needed to find out whether this reversal in temperature gradient can be related to the gradual decrease in snow hardness.

ACKNOWLEDGMENTS

The author wishes to acknowledge the work of the weather observers stationed at Aklavik and Resolute from 1947 to 1954. Without their co-operation and effort, often under adverse weather conditions, it would have been impossible to prepare this report.

The author also wishes to express his appreciation to L.W. Gold for guidance in preparing this report.

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FIGURE 1 SKETCH SHOWING LOCATION OF AKLAVIK & RESOLUTE

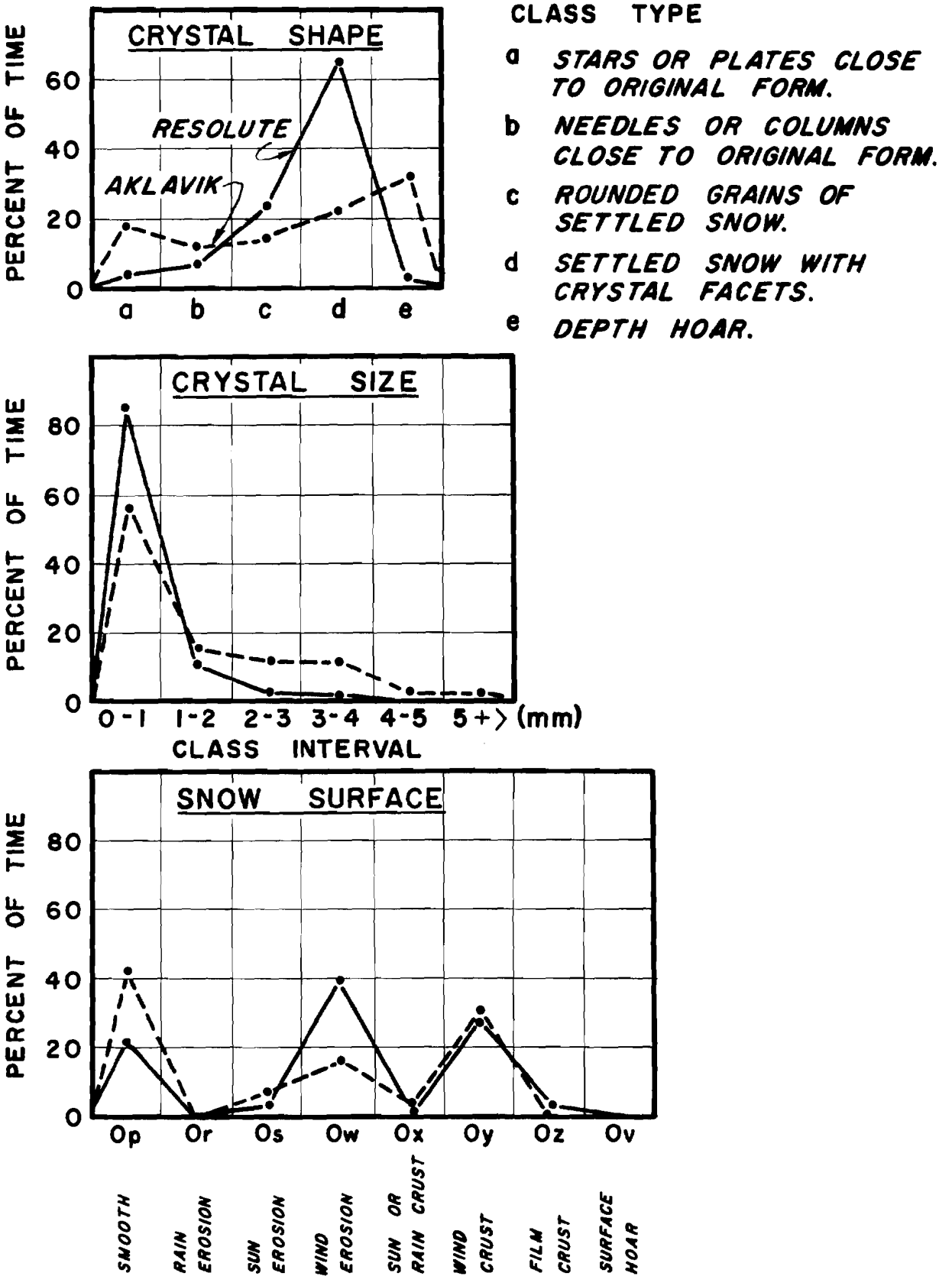


FIGURE 2 **FREQUENCY POLYGONS FOR SNOW SURFACE CRYSTAL SIZE, SHAPE AND SURFACE AT AKLAVIK & RESOLUTE.**

(1951-54)

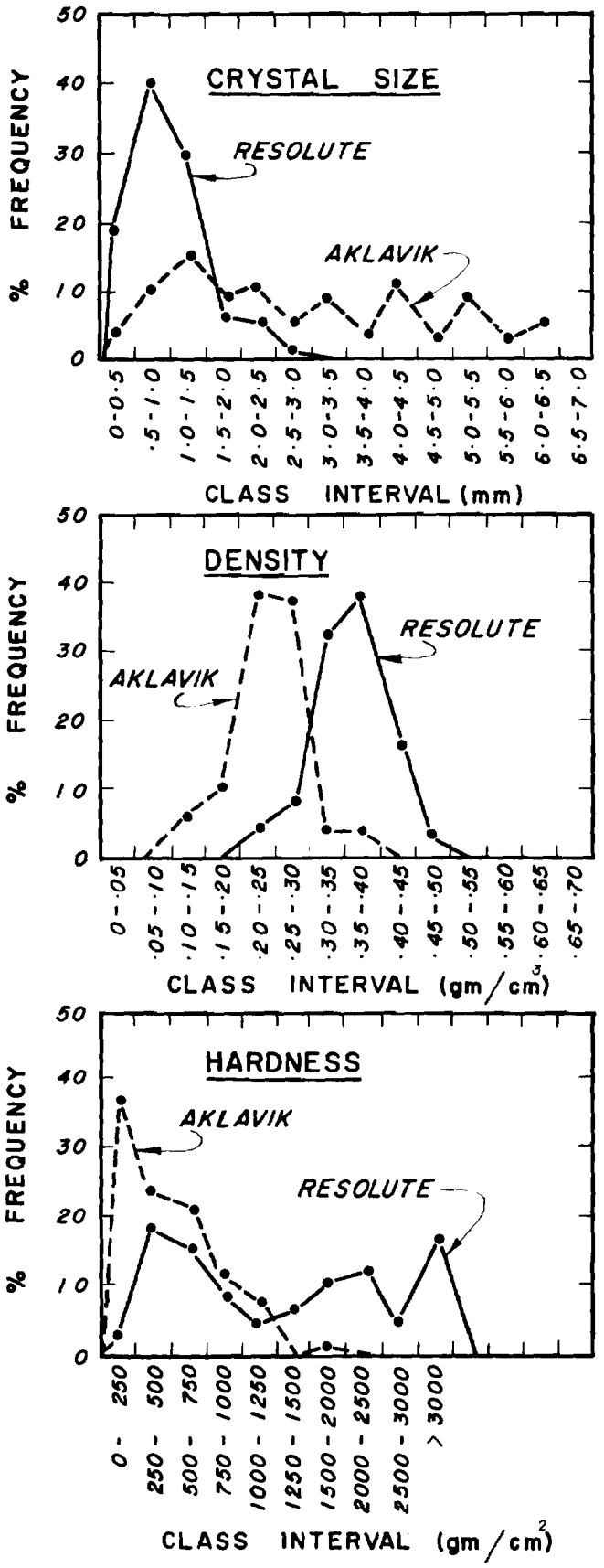


FIGURE 3 **FREQUENCY POLYGONS FOR SNOW CRYSTAL SIZE DENSITY, HARDNESS AT AKLAVIK & RESOLUTE. 1947-54.**

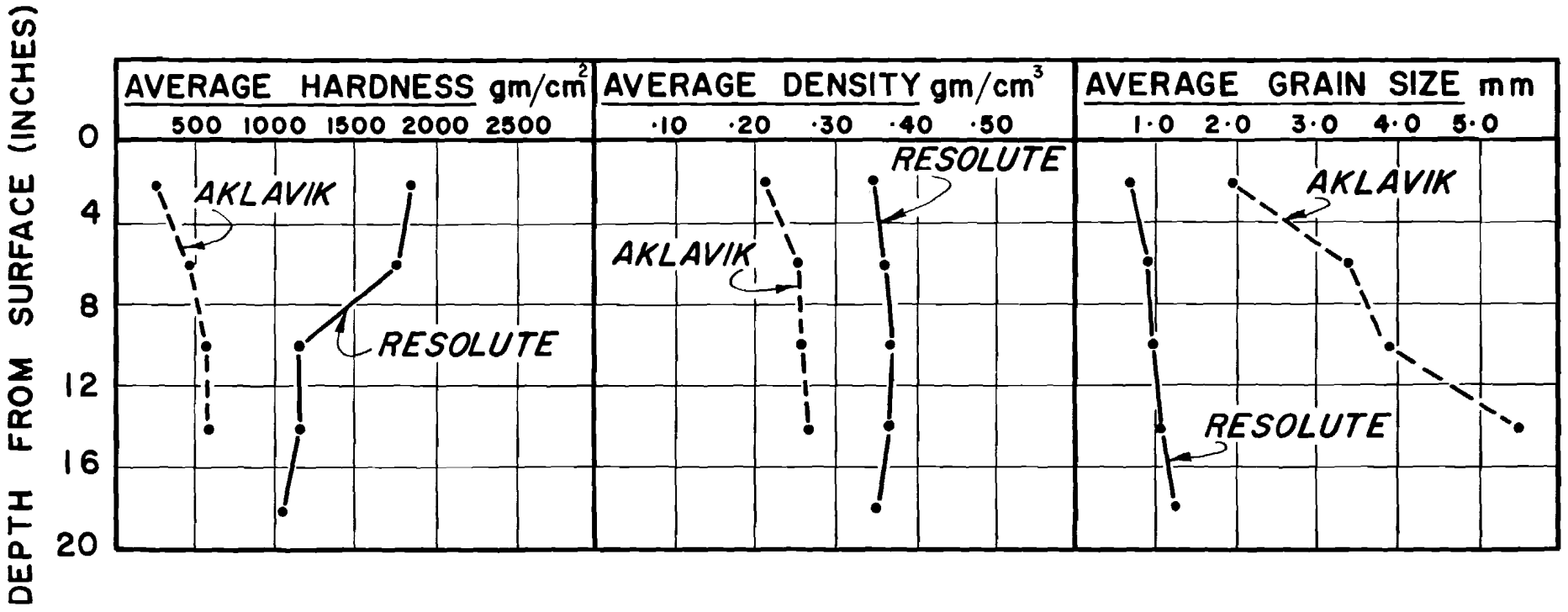


FIGURE 4 VARIATION OF AVERAGE SNOW HARDNESS, DENSITY & GRAIN SIZE WITH DEPTH AT AKLAVIK & RESOLUTE 1947-54.

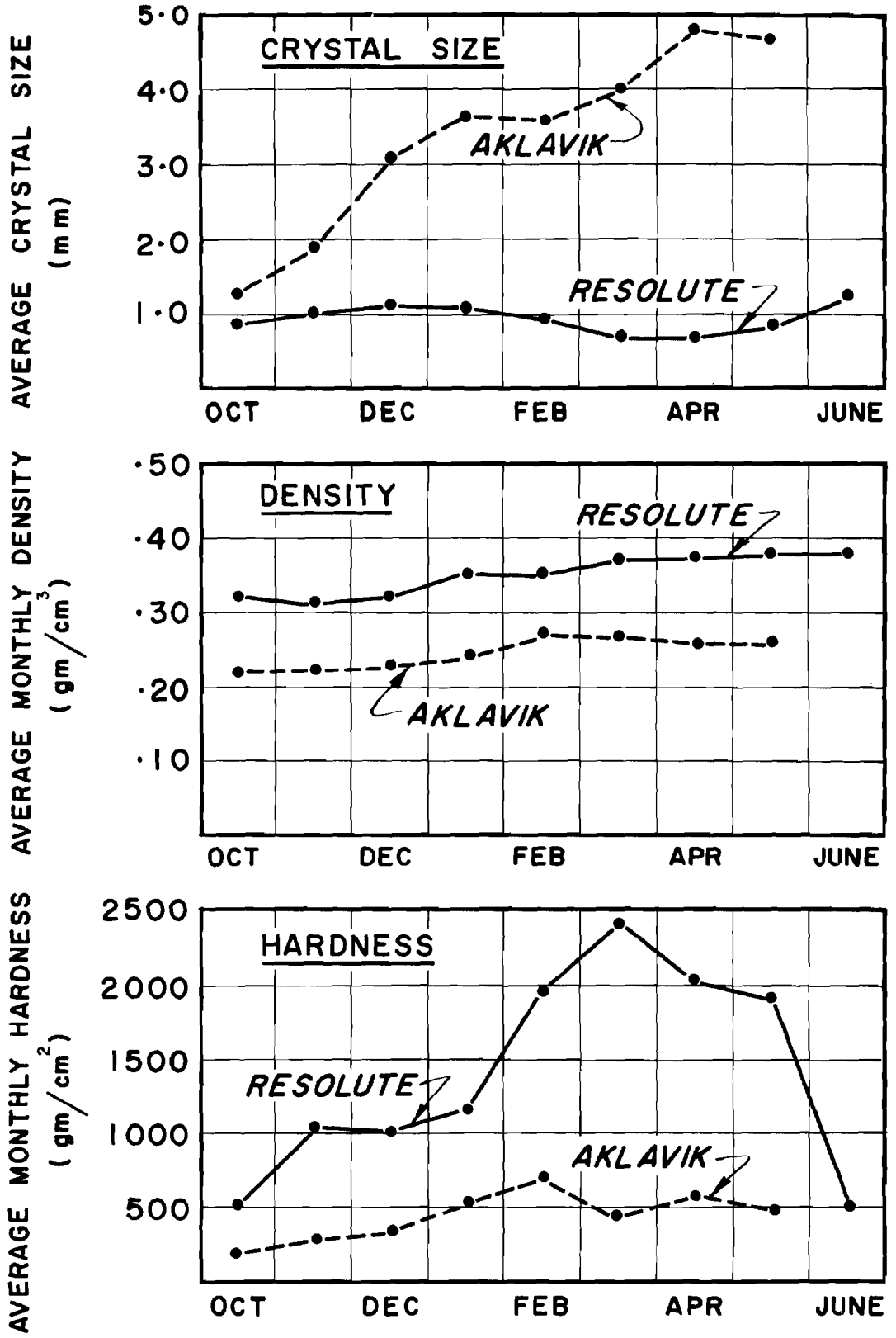


FIGURE 5 VARIATION OF AVERAGE MONTHLY SNOW HARDNESS, DENSITY & GRAIN SIZE AT AKLAVIK & RESOLUTE. 1947-54.

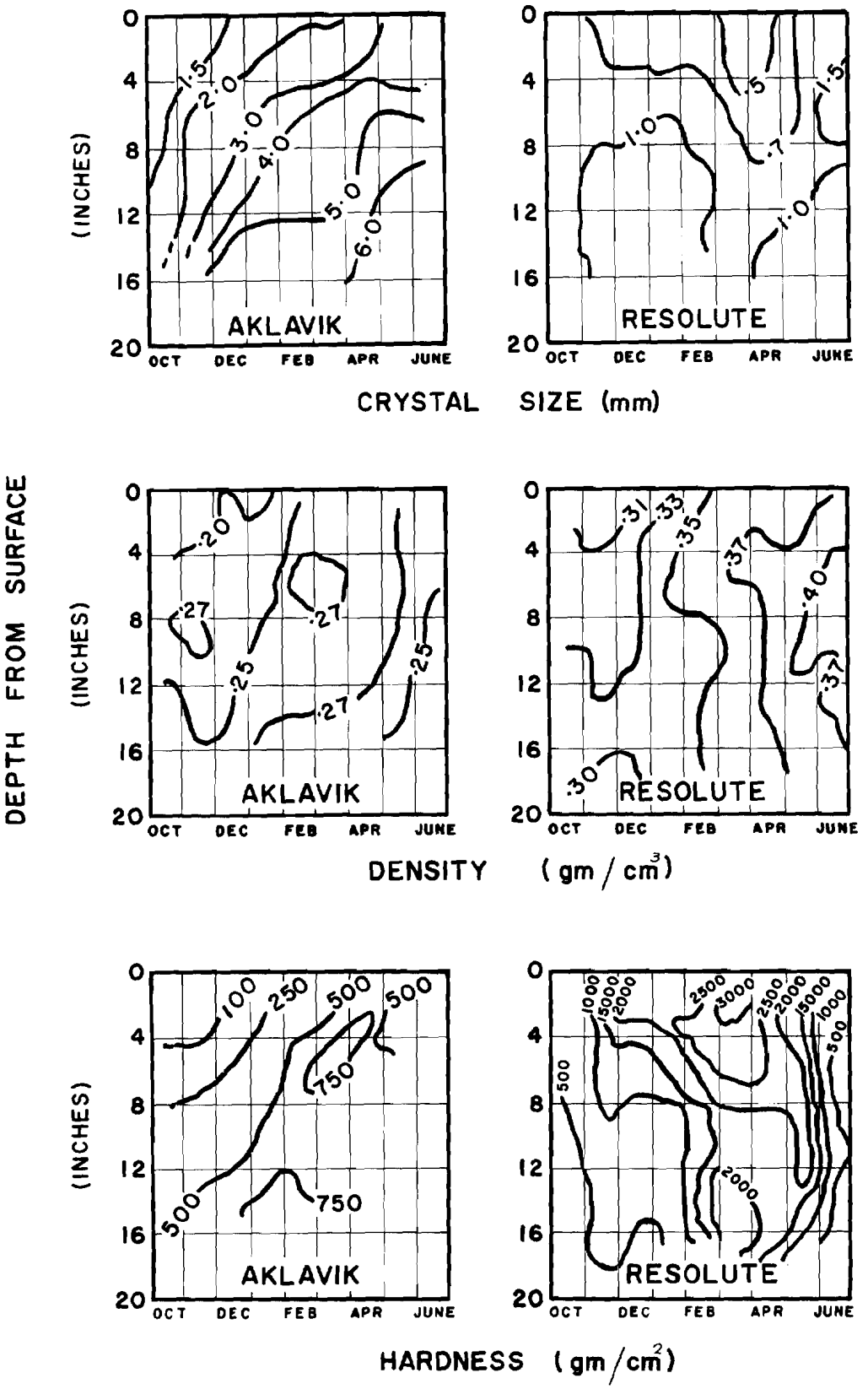
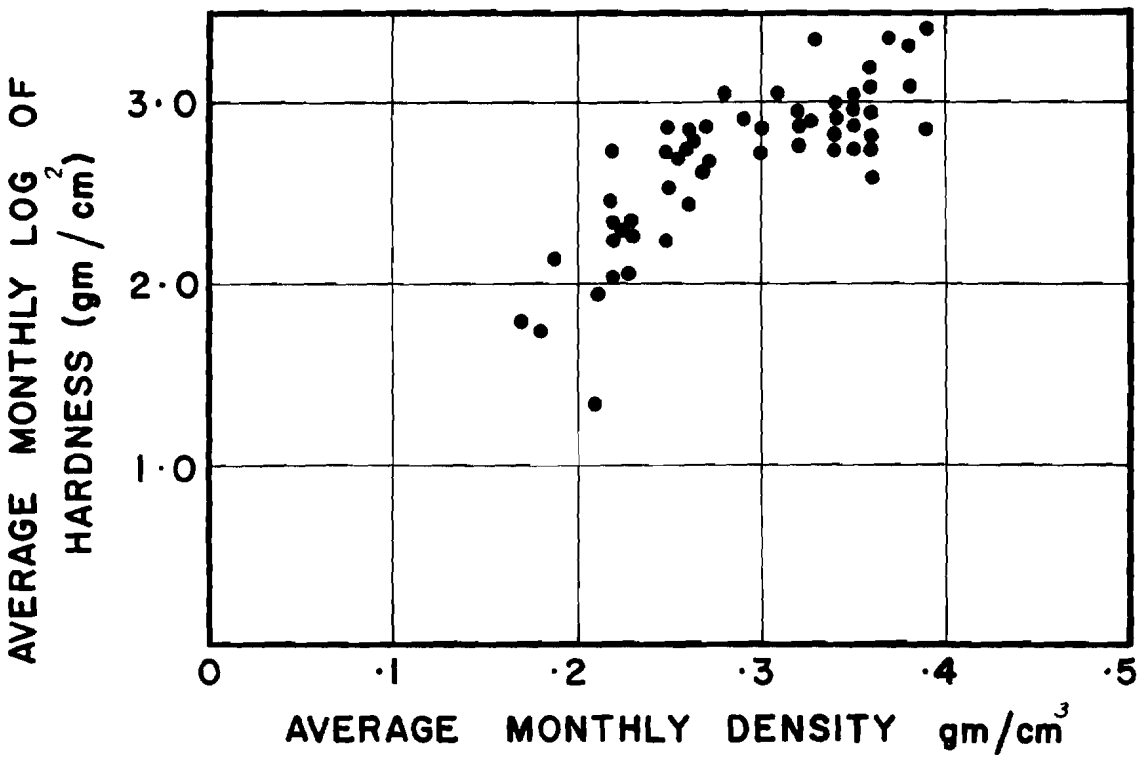


FIGURE 6 AVERAGE VARIATION OF CRYSTAL SIZE, DENSITY, HARDNESS, WITH DEPTH & TIME AT AKLAVIK & RESOLUTE. (1947-54)



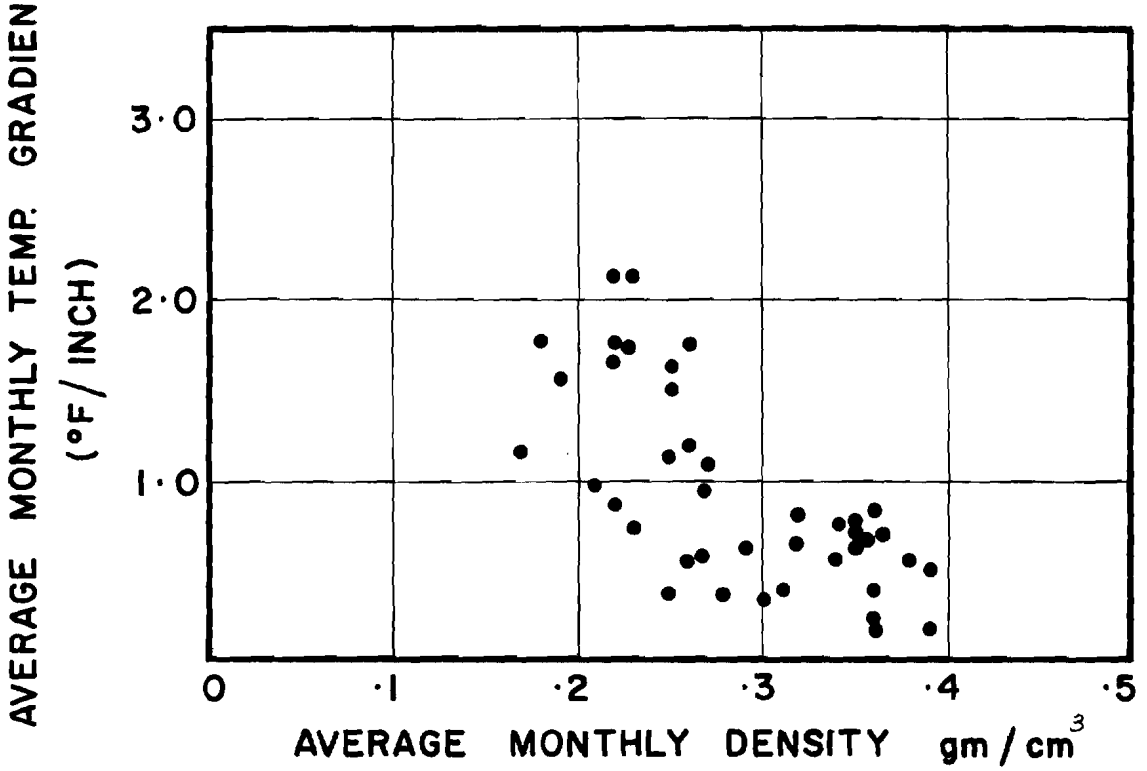


FIGURE 7

RELATION BETWEEN AVERAGE MONTHLY DENSITY, HARDNESS, TEMPERATURE GRADIENT, AT AKLAVIK & RESOLUTE. (1947 - 54)