SOME RESULTS OF THE CANADIAN SNOW SURVEY

BY

L. W. GOLD and G. P. WILLIAMS

NATIONAL RESEARCH COUNCIL OF CANADA

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ABSTRACT

This report presents some preliminary results from the survey of the physical characteristics of the snow cover which has been carried on in Canada since 1947. Comparisons of the snow hardness and of the density data are made between selected stations. The snow density distribution plots exhibited a marked similarity especially for exposed stations. Other similarities were noted in the data. On the basis of this analysis, Canada can be divided into five main snowfall regions:

(1) The Arctic region.

(2) The northern tree-line region.

(3) The Prairie region.

(4) The western mountain and coastal region.

(5) The region classified as a freeze-thaw region in eastern Canada.

The Associate Committee on Soil and Snow Mechanics of the National Research Council of Canada initiated a snow survey in 1946 in recognition of the growing need for knowledge of the characteristics of the snow cover in Canada. The survey developed from investigations on aircraft skis conducted by G. J. Klein of the Division of Mechanical Engineering of the National Research Council and a member of the Associate Committee on Soil and Snow Mechanics.

FIGURE 1 — The National Research Council Snow Kit.

The fundamental features upon which the properties of snow depend and which distinguish one form of snow from another are: snow temperature, relative proportion of ice, water and air, shape and size of individual grains or crystals and degree of bonding between the grains. For the survey the National Research Council supply a kit of instruments (Figure 1) to measure the above features.[1] Snow temperature is measured with thermometers. The relative proportion of ice and air are found by taking density measurements. The amount of free water is estimated by means of simple observations set forth by the International Classification for Snow.[2] The shape and size of the individual grains or crystals are found using a magnifying glass and a standardized grain classification. The degree of bonding between grains is estimated by a snow hardness gauge which measures the "collapse" strength of snow in situ.

The snow observations were taken in wooded areas protected from wind and in areas where the snow cover was exposed to wind action. At first snow profile measurements were made weekly but in the past few years, observations have been made every two weeks. The first stations were established in 1947 and at a few stations, e.g., Aklavik and Resolute, there are continuous records from that time. Emphasis has shifted, however, from taking observations in exposed areas to the taking of observations at sheltered sites. Figure 2 shows the location of the active snow survey stations across Canada and also the stations where measurements have been discontinued.

The observations were taken through the kind co-operation of the Meteorological Division of the Department of Transport, the Department of National Defence and various private and public agencies across Canada.

Some papers have appeared giving results based on the observations made in the survey. [3,4] The papers appearing in 1948 and 1951 were essentially summaries of these observations. By 1955 sufficient data had been collected to warrant a more complete study. The results presented herein are based on the 1955 studies. Hardness and density measurements have been emphasized because these more objective tests can be analysed statistically and the results from different stations compared.

All available data were used in constructing the diagrams displayed in this report. For example, if a monthly density value is given for a specific place, it was obtained by averaging all the density values measured during that month at that specified location for all the years of observation. The results, from a statistical viewpoint, are therefore not entirely satisfactory in that averages from stations like Aklavik with a nine-year record are compared to averages from stations like Winnipeg with a three-year record. It was considered that this procedure was justified as it gave a general picture of snow properties across Canada which is the major objective of this report.

SNOW DENSITY DISTRIBUTION CURVES

Figure 3 shows density distribution diagrams for sheltered and exposed stations across Canada. Density data were taken from depths of 0 to 36 inches during months of continuous snow cover.

Table 1 shows calculated values of mean, standard deviation, skewness and peakedness as described by Hoel.[5] These values are useful in that distribution diagrams can be compared arithmetically.

A high mean density value indicates conditions of extreme exposure with cold temperatures and high winds. The mountain station of Old Glory and the Arctic station at Resolute have the highest mean snow density. However, the mean as a measure of exposure must be qualified by the fact that melting temperatures during the winter season can also produce high density values. For example, Ottawa has a mean density of .275 compared to a mean density at Aklavik of .242.

The standard deviation is generally higher at sheltered stations than at exposed stations. The standard deviation is not only a measure of snow density variation but it is also probably a measure of the variability of winter climate. For example, the stations in Eastern Canada – Goose Bay, Maniwaki, Forestville and Ottawa show a higher standard deviation than in Northern and Western Canada. Winnipeg, Edmonton, Resolute, Aklavik and Whitehorse have almost equal standard deviations.

The skewness and peakedness values of the distribution diagrams at exposed stations indicate normal distributions. The peakedness of a normal distribution equals 3.0 compared to peakedness of 3.55, 3·50, 3.32 and 3.15 for Winnipeg, Aklavik, Resolute and Edmonton respectively. The skewness of a normal distribution can be taken equal to zero which compares to the values of skewness found at these stations. The values of peakedness and skewness seem to vary with individual sites for sheltered stations. Unfortunately there were not enough data to warrant distribution curve analysis for Shipshaw, Shawbridge and Kapuskasing.

When it is considered that these stations are scattered across a continent, the pattern of density distribution diagrams is remarkably similar especially for exposed stations.

HARDNESS AND DENSITY VARIATION AT EXPOSED STATIONS

Figure 4 shows the average monthly density and log of hardness for snow layers 4 to 12 inches below the surface at exposed stations across Canada. The 4- to 12-inch layer was chosen for analysis because previous studies[6] have indicated that snow characteristics in the upper layers can be linked to snow trafficability. Figure 4 also shows the maximum and minimum monthly values for log of hardness and density. Unfortunately the data from the exposed stations at Edmonton, Whitehorse and Malton were too limited to be included in this analysis.

The mean density and hardness values are very nearly the same for Gander, Goose Bay and Ottawa. The maximum and minimum density values are also very nearly the same. The maximum and minimum hardness values are nearly the same at Goose Bay and Ottawa with somewhat lower minimum and higher maximum hardness at Gander. If these three exposed sites are representative, the results indicate that average and extreme surface snow conditions encountered in this area are likely to be within the same range.

The hardness values for Moosonee are comparable to the values from Gander, Goose Bay and Ottawa. The maximum, mean and minimum density values are somewhat lower at Moosonee. Probably the milder climate at the three stations results in somewhat higher density values.

The mean density and hardness values are higher at Winnipeg than in Eastern Canada, also the density and hardness variation is less.

Aklavik in the Far North has a mean density value lower than at Winnipeg. The mean hardness at Aklavik is higher than at Winnipeg or any of the stations in Eastern Canada. However, the minimum or limiting hardness value is lower than at Winnipeg and comparable to the values at Moosonee, Goose Bay or Ottawa.

The stations at Old Glory Mountain (7700 a.s.l.) in the West Mountain region and at Resolute in the Arctic show considerably higher mean density and mean hardness values. Even the minimum hardness values are comparable to the maximum values observed at the other stations.

HARDNESS AND DENSITY VARIATION AT SHELTERED STATIONS

The data on hardness and density in sheltered sites are much more limited and include only stations in Eastern Canada. Figure 5 shows monthly mean density and log of hardness at 4- to 12-inch layers for stations where records were available. There were not enough data to warrant calculating maximum and minimum values of hardness or density. The mean density and hardness are not too different from these various stations. Maniwaki and Fort Churchill have higher average hardness and lower average density than stations like Fredericton where wet snow can be expected more frequently during the winter season.

To investigate snow density depth changes, average density changes at various layer intervals were plotted as shown in Figure 6. Each line represents the average density change with depth at a station for a winter season – usually from December to March. The lines are staggered so that several stations could be put on the same figure.

At sheltered stations density increases with depth down to the 8- to 12-inch layer. Below 12 inches there is a slight increase with depth indicating that snow densification occurs largely in the first 12 inches of snow.

SNOWFALL REGIONS IN CANADA

During the analysis of the snow-survey data, it became apparent that some stations had many characteristics in common. The most obvious factors were amount of snowfall, temperature, time of first snowfall and the length of time the snow stays on the ground. A very good discussion of these factors has been presented by Boughner and Potter.[7]

As has been shown in this paper similarities were also noted in the physical characteristics of the cover such as density and hardness. Taking these factors into consideration, Canada can be divided into five main snowfall regions. The boundaries of these regions are very approximate and within each region can be found considerable variation in the snow-cover characteristics. The five regions are shown in Figure 7. The Arctic is a region of comparatively sparse snowfall. The continued unrestricted working of the snow by the wind is revealed in density and strength measurements. Resolute reported the highest densities and hardnesses recorded in the survey.

In the Prairie region, wind and temperature again play an important role. Snowfall is usually low but the drifting which occurs due to wind action results in major snow control problems. The densities and hardnesses do not reach the extremes reported at Resolute. Winnipeg is an example of Prairie conditions.

The northern tree-line region extending from the Mackenzie Valley across southern Hudson Bay to Labrador includes a major portion of Canada. It is in this great forest area that over-snow transportation problems are perhaps the greatest.[8] The snow in this region is comparatively sheltered from wind action with the result that densities and hardnesses are generally lower than in the Arctic and Prairies. The stations at Aklavik and Moosonee lie in this region.

The region classified as the freeze-thaw area includes most of the Atlantic Provinces, southern Ontario and southern Quebec. Rain, sleet and above-freezing temperatures often occur during the winter. This area is also influenced by the Atlantic with the result that snowfall is often heavy. The rain and above-freezing temperatures tend to increase the density of the snow but decrease the hardness. Ice lenses within the snow cover are common. Snow control and icing problems are quite severe in this area. Ottawa, Goose Bay, Gander, Shipsaw, lie in this area.

In the regions designated as Western Mountain and Pacific Coastal, snow-cover data were collected at only one station, Old Glory Mountain. This region contains almost the complete range of snow-cover characteristics from the perpetual snow cover on the high mountains to the wet sporadic covers of the coastal plains and valleys.

It is a difficult task to establish snow-cover variations in a large area. Snow cover and hence snow-cover characteristics will have a seasonal variation. Topography and vegetation also influence the type of snow cover that is formed. However, on the basis of the snow-survey observations taken so far, the dividing of Canada into five main snowfall regions seems justified. However it must be remembered that these observations are but small samples from this vast area. As more snow-survey information is received it may be necessary to sub-divide the regions and alter the boundaries.

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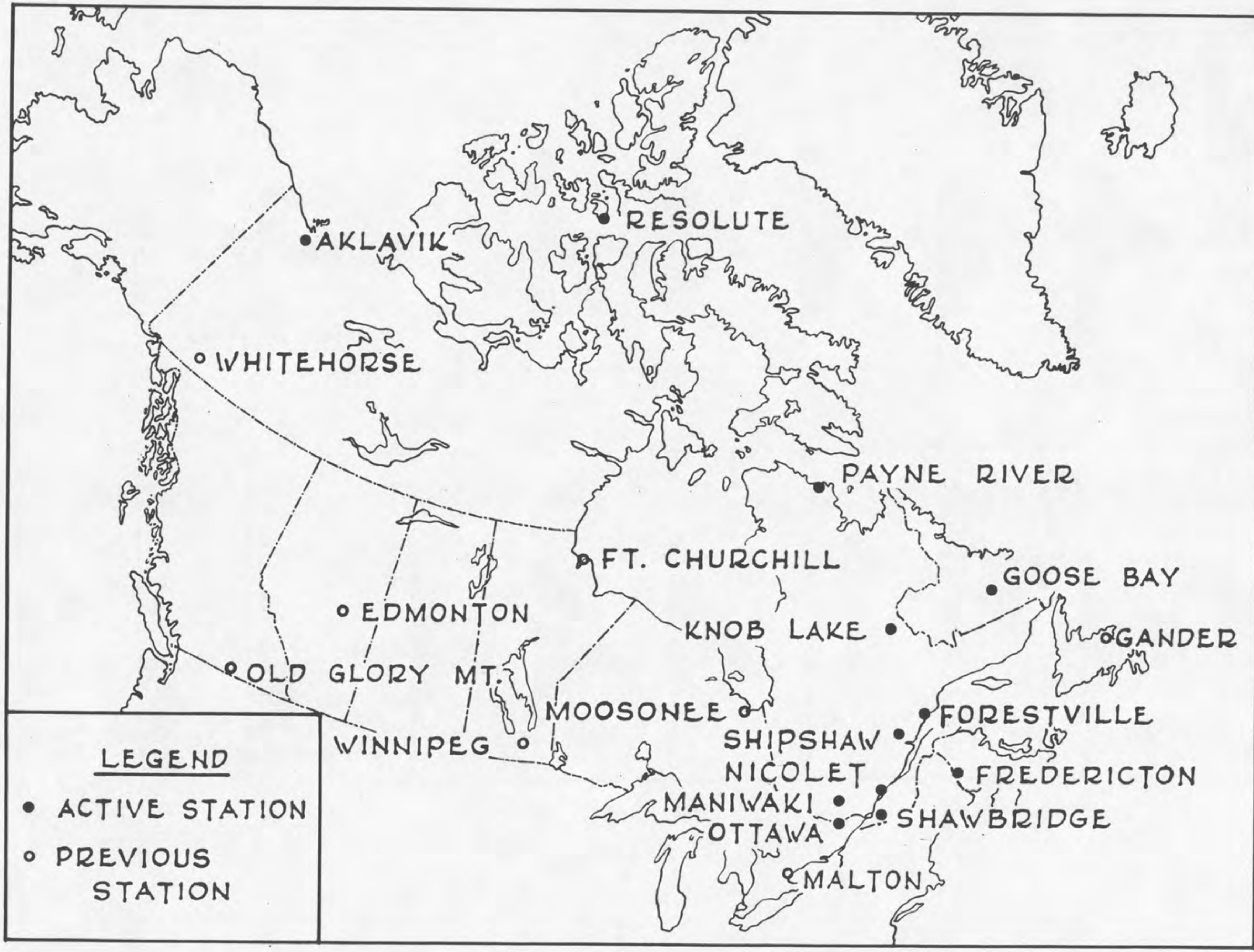
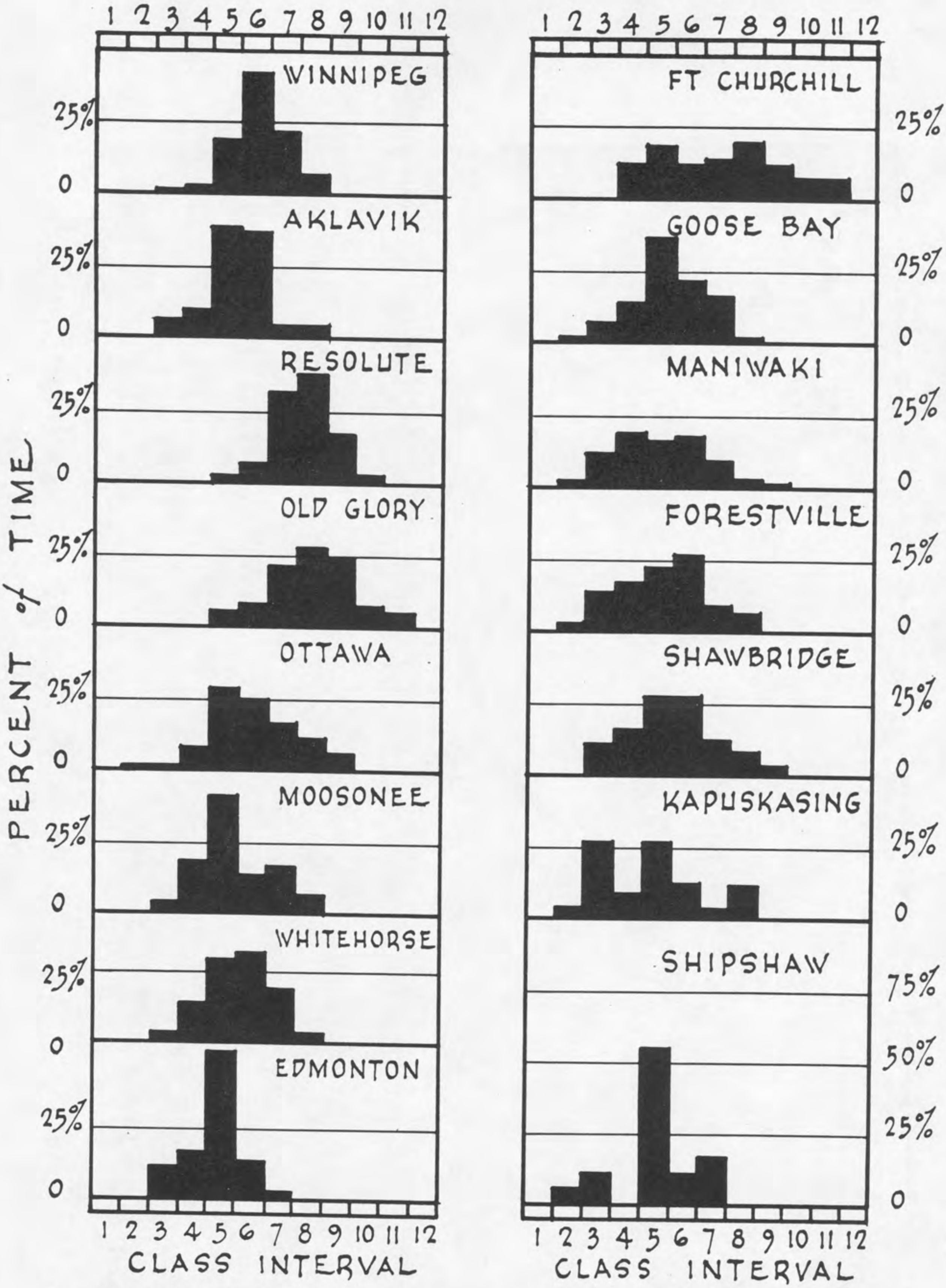


FIGURE 2 SNOW SURVEY OF CANADA OBSERVATION STATIONS



LEGEND: *CLASS 1 LIMITS = 0 - ·05, CLASS 2 LIMITS = ·05 - ·10 (DENSITY)*

FIGURE 3

SNOW DENSITY DIAGRAMS AT SELECTED STATIONS ACROSS CANADA.

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EXPOSED STATIONS	$\bar{x}$ MEAN DENSITY	s STANDARD DEVIATION	a_3 SKEWNESS	a_4 PEAKEDNESS
WINNIPEG	.279	.050	−.565	3.55
AKLAVIK	.242	.053	.042	3.50
RESOLUTE	.356	.052	−.260	3.32
OLD GLORY	.369	.070	−.075	2.74
OTTAWA	.275	.076	−.006	3.45
MOOSONEE	.242	.063	+.400	2.32
WHITEHORSE	.254	.056	−.157	2.59
EDMONTON	.224	.045	−.372	3.15
SHELTERED STATIONS				
FT. CHURCHILL	.325	.108	.212	2.02
GOOSE BAY	.243	.068	.705	5.40
MANIWAKI	.233	.073	−.098	2.52
FORESTVILLE	.237	.077	−.012	2.28

TABLE 1

CALCULATED STATISTICAL VALUES FOR DENSITY DISTRIBUTION DIAGRAMS SHOWN ON FIGURE 2

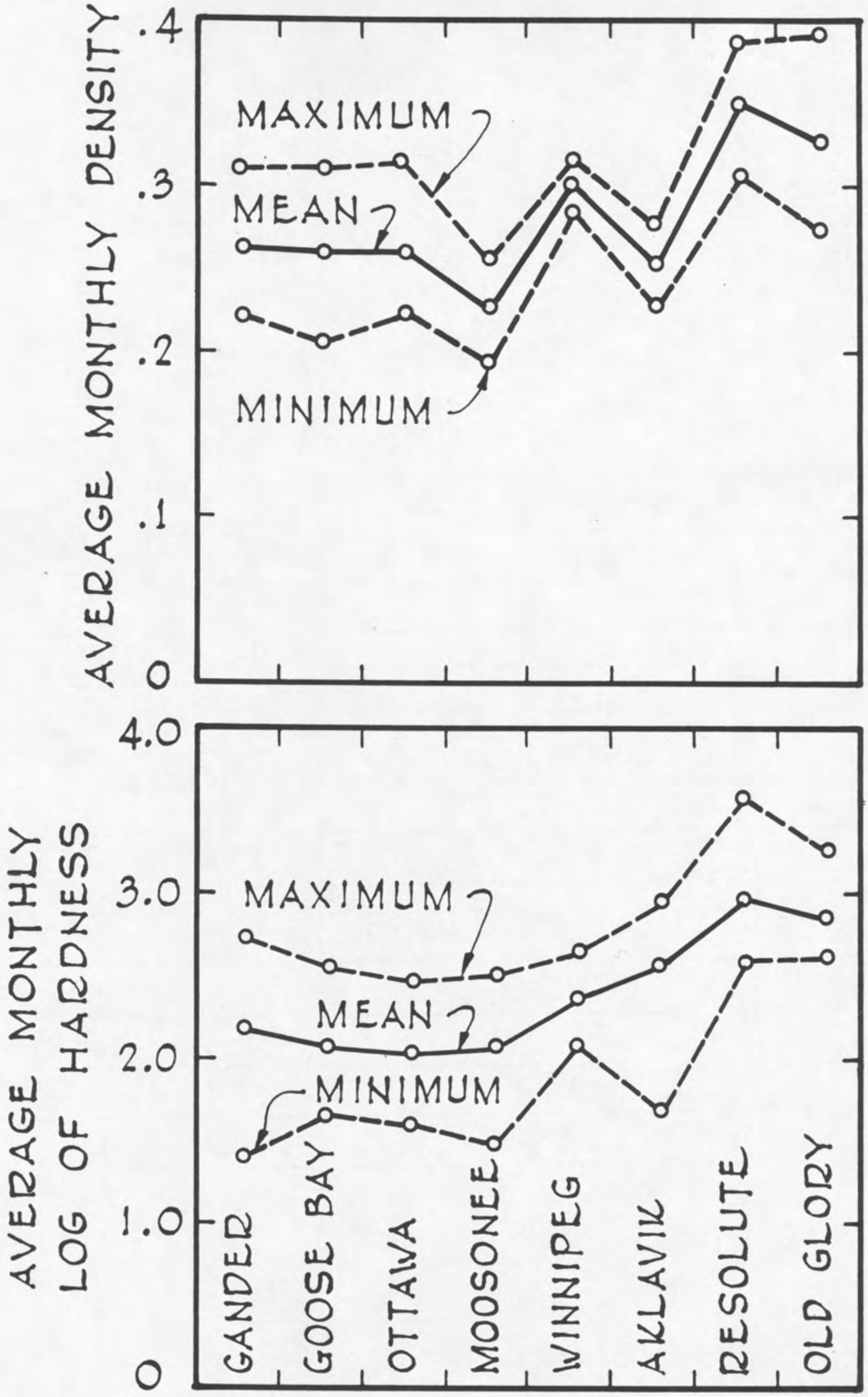

FIGURE 4

MONTHLY HARDNESS AND DENSITY VARIATION AT EXPOSED STATIONS ACROSS CANADA 4"-12" LAYER

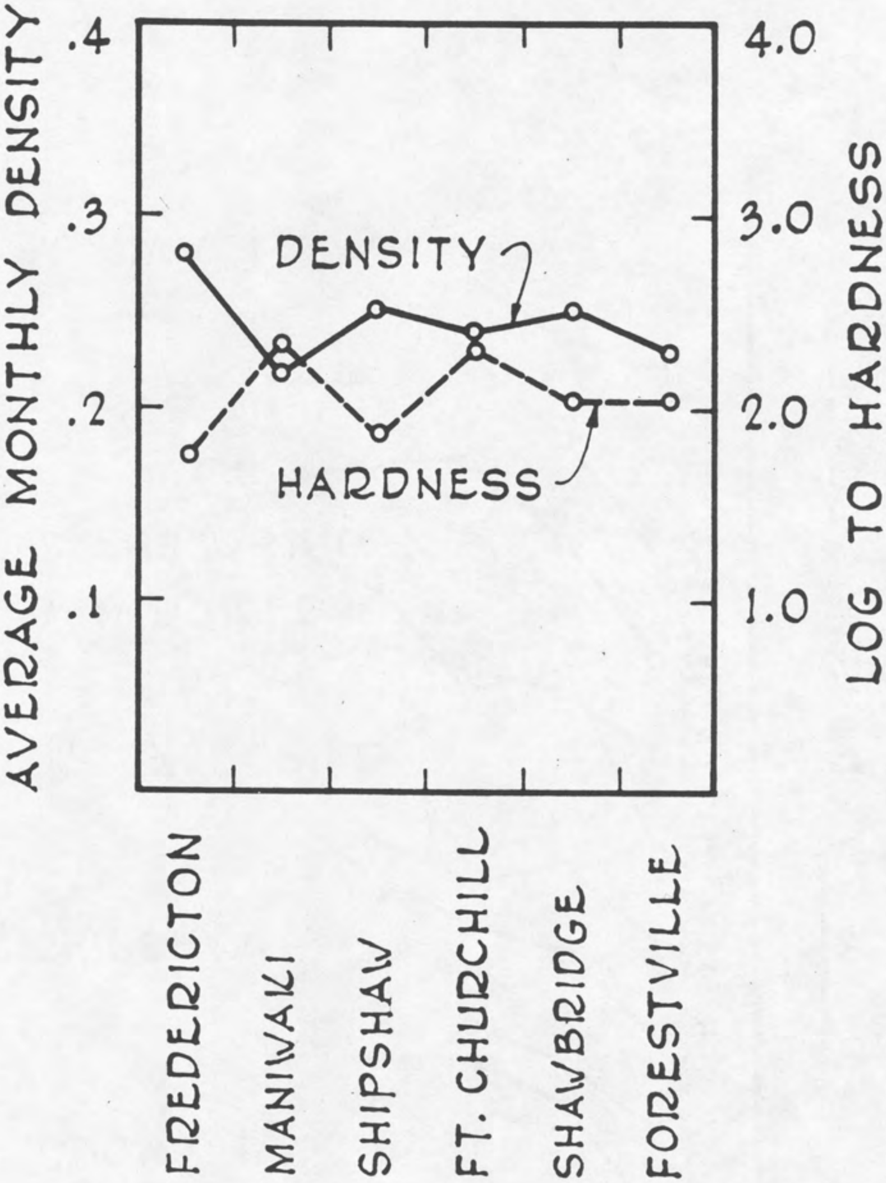

FIGURE 5

MEAN HARDNESS AND DENSITY VALUES AT SHELTERED STATIONS ACROSS CANADA

4"-12" LAYER

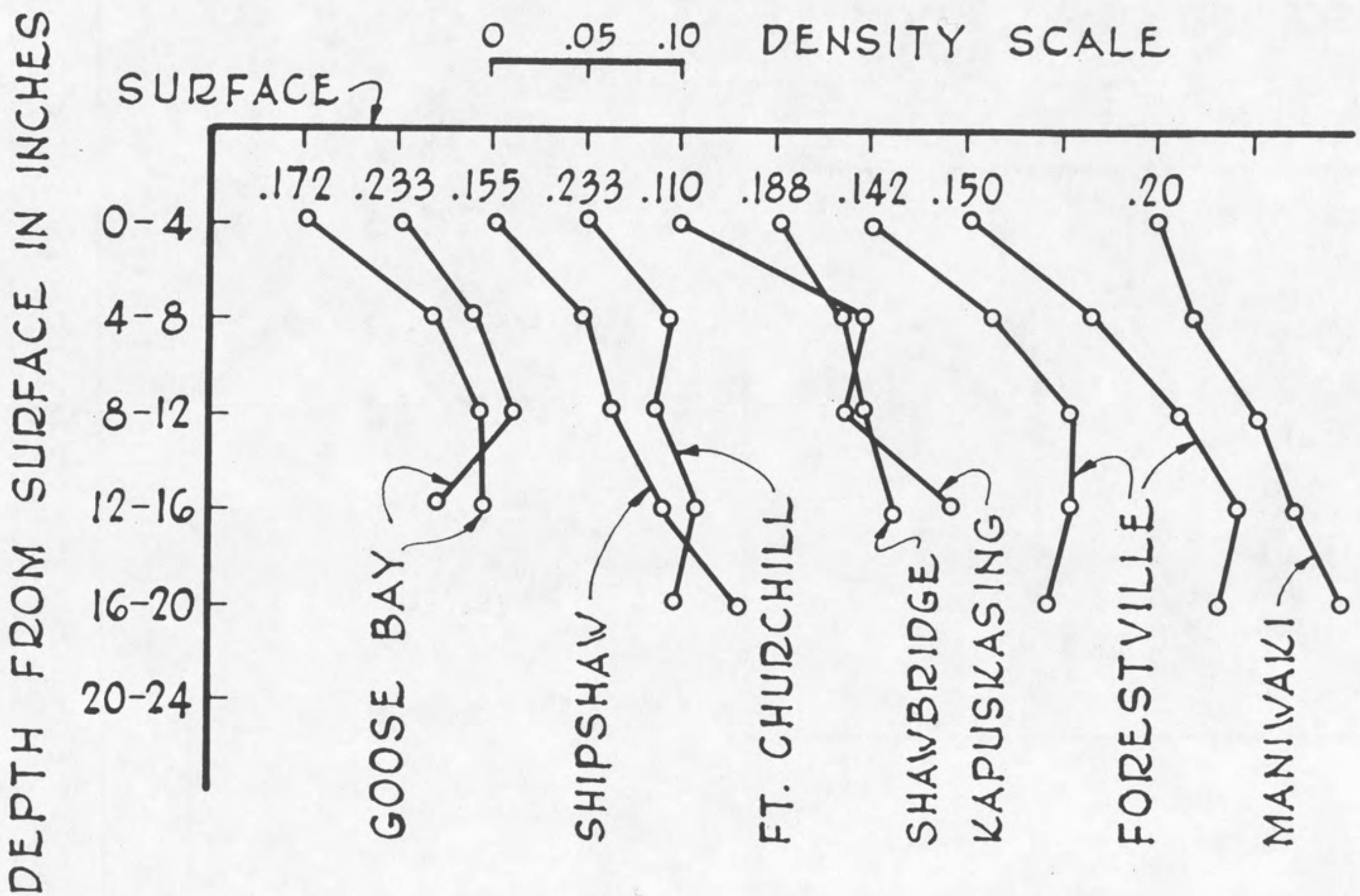

FIGURE 6

AVERAGE SNOW DENSITY DEPTH CHANGES AT SHELTERED STATIONS ACROSS CANADA

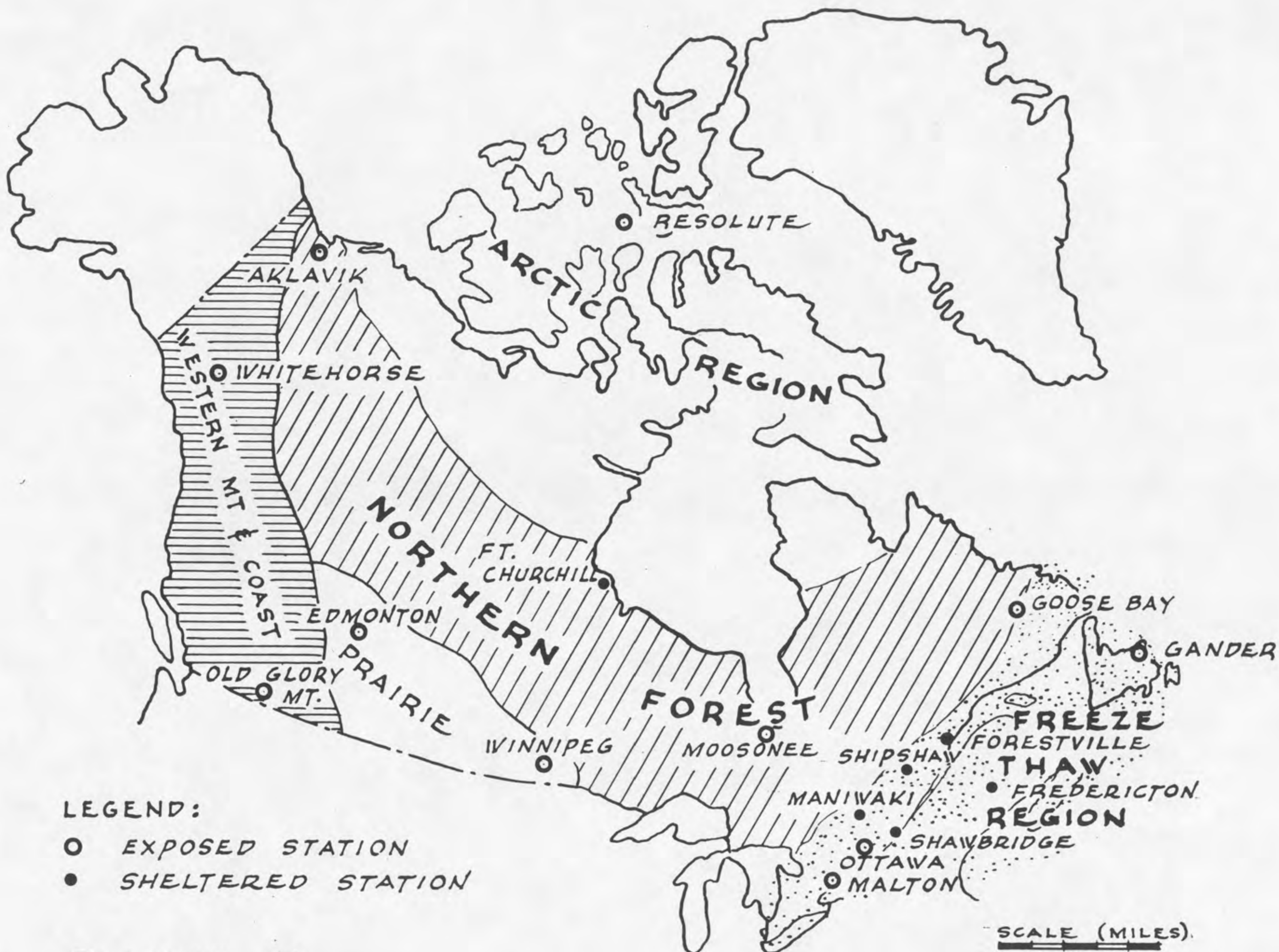

FIGURE 7

GENERAL SNOW REGIONS IN CANADA SHOWING STATIONS USED IN SNOW SURVEY of CANADA