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ERRATA

Page 109; line 14, *for* (R.C.A.), *read* (K.C.A.)

Page 111-112; *transfer* first para. on page 112
to follow "SURFICIAL GEOLOGY OF THE
LINDSAY-PETERBOROUGH AREA . . . . . " on page 111.

Page 111; *add* (I.J.) below last line.

Page 113; last line, *for* 1952, *read* 1955.

Page 114, line 12, *for* 1957, *read* 1956.

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Table of Contents

Table des matières

83627-0—1½

CHANGING LAND USES IN THE NIAGARA FRUIT BELT

*Ralph R. Krueger**

ABSTRACT: The Niagara fruit belt is first delimited on a township basis. An examination of 1931 and 1951 census data shows the township changes in agricultural land uses. A detailed analysis of changing land-use patterns is provided by a series of maps based upon 1934 and 1954 air photos.

The most significant changes are the continuing trend from general farming to fruit growing and the implications of urban expansion into the choice fruitland. It is suggested that, if urban development took place in a more orderly, compact manner, and if it was directed to the less valuable fruitland, there would be room for an urban population several times that of the present, without seriously reducing fruit production.

RÉSUMÉ: Afin de faciliter davantage l'étude de l'utilisation des terres de la Ceinture fruitière de Niagara, celle-ci a été fondée sur l'étude des cantons. L'étude des données des recensements de 1931 à 1951 démontre qu'il s'est effectué dans les cantons certains changements dans la mise en valeur agricole. L'analyse détaillée de ces changements de mise en valeur est illustrée par une série de cartes, résultant de la confrontation des photos aériennes des années 1934 et 1954.

Parmi les modifications les plus significatives, on note la tendance continuelle de l'agriculture en général à la fructiculture et les empiétements de l'expansion urbaine sur les terres fruitières les plus productives. Cependant, si le développement urbain s'effectue de manière plus ordonnée et plus compacte, et s'il est dirigé en direction de terres moins productives, il y aurait suffisamment d'espace pour une population urbaine beaucoup plus considérable, sans que cela réduise de façon appréciable la production fruitière.

The Niagara Peninsula of southern Ontario extends eastward between Lake Ontario and Lake Erie to the Niagara River. The Niagara fruit belt, which lies along the northern margin of the Niagara Peninsula, has long been known as one of the major fruit growing districts in Canada. It produces approximately nine-tenths of Canada's grapes, three-fifths of its peaches, and well over half of its pears, plums, and cherries.

The large amount of uprooting of orchards and vineyards for conversion to urban uses in some areas, and the large number of new orchards and vineyards in other areas, are evidences that land uses are rapidly changing in the Niagara fruit belt. It is the purpose of this paper to describe and explain the patterns of land use and land-use change in the Niagara fruit belt over a twenty-year period, and to assess the impact of the changes on the Niagara fruit growing industry.

*Ralph R. Krueger, Ph.D., Indiana, 1959, assistant professor of Geography, University of Waterloo. This paper is based on research done for the writer's Ph.D. dissertion (Krueger, 1958). Acknowledgment is made to the American Social Science Research Council for a fellowship to assist the completion of the dissertation research.

DELIMITING THE NIAGARA FRUIT BELT

Most of the regional geography written about southern Ontario identifies the Niagara fruit belt as a distinctive agricultural region, but no one has quantitatively delimited its boundaries. Putnam (1954) defines the Niagara fruit belt as the area "situated mainly between the Niagara escarpment and Lake Ontario, but including also some areas above the escarpment". Watson (1945) defines it on the basis of the proportion of farms which are fruit farms. However, he does not stipulate what proportion of a farm must be in fruit to be classified as a fruit farm, nor does he stipulate what proportion of the farms in an area must be fruit farms to be included with the fruit belt.

Different publications of the Ontario Department of Agriculture use different boundaries for the Niagara fruit belt. The Louth Report (Irving, 1957) defines it as "that part of the Niagara Peninsula north of the Niagara Escarpment, bounded by the City of Hamilton on the west, the Niagara River on the east, and Lake Ontario on the north". A study (Haslett and McInally, 1954) of the marketing of Niagara peaches uses Highway No. 20 as the southern limit of the fruit belt. A report (MacCharles, 1956) on production costs of grapes considers the Niagara fruit belt as all of Wentworth, Lincoln, and Welland counties (Figure 1).

Thus, in view of the variety, and in some cases vagueness, of the definitions of the Niagara fruit belt, the first task in attempting a study of land-use changes had to be a quantitative delimitation of the region (Figure 2).

First, published census statistics were used to delimit the fruit belt on a township basis. Statistics were collected and plotted in all of the townships of the four counties which compose the Niagara Peninsula (Figure 1). Parts of Wentworth and Haldimand counties actually lie outside of the Niagara Peninsula proper, but it was felt that the use of all of the townships would show better the sharpness of the western boundary of the belt. The *Census of Canada*, 1951, does not give a township breakdown of acreages for fruit crops as it does for field crops, so statistics used to delimit the fruit belt were derived by subtracting total area in field crops from total area in crops. This gives area in orchards, vineyards, small fruits, market gardens, tree nurseries, and greenhouses. Tree nurseries and greenhouses occupy such a small area that they are insignificant for the purpose of delimiting the fruit belt. Small fruits and market gardens comprise less than 10 per cent of the total area in horticultural crops.

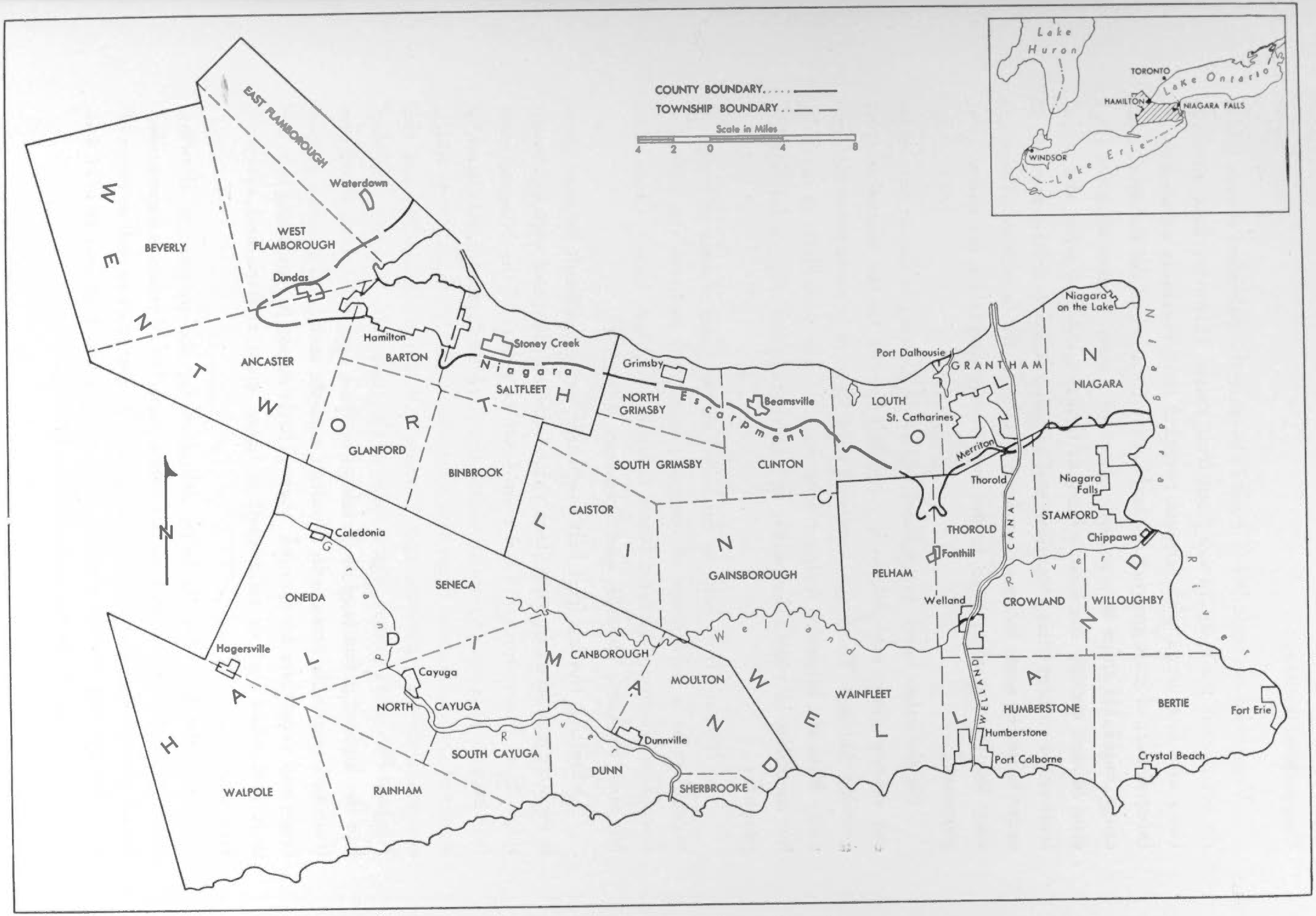


Figure 1. Location map of the Niagara Peninsula.

Vegetables are included (Figure 2) because the published census tables do not permit their separation from fruit crops. However, field observations and interviews with farmers revealed that vegetable growing is an integral part of fruit growing in the Niagara fruit belt. Like the small fruit crops, vegetable crops help provide alternate income in case of major fruit crop failure, occupy the labour force at times of the year when the major fruit crops require little attention, and are often used as inter-row crops in order to derive some income from land newly planted in orchard. There are very few fruit growers who do not grow some vegetables for commercial purposes.

On the other hand, commercial vegetable growing is almost non-existent among grain and livestock farmers adjacent to the intensive fruit growing districts. There are, however, some farmers in areas some distance away from the intensive fruit growing districts who grow little or no fruit, but specialize in vegetables either as a market garden crop, or for canning purposes.

The Niagara fruit belt, as delimited on the basis of area in fruit and vegetables as a percentage of occupied farmland, includes the following townships: Barton, Saltfleet, North Grimsby, Clinton, Louth, Grantham, Niagara, Pelham, Thorold, and Stamford (Figure 2).

Delimiting the ten fruit belt townships was not difficult because there is such a clean break in percentage value between them and adjacent townships. East Flamborough is not considered as a part of the Niagara fruit belt because it is not physically within the Niagara Peninsula, but is really a part of the "Lakeshore Fruit and Vegetable Belt" (Putnam, 1954) which extends between Hamilton and Toronto. Of the townships within the Niagara Peninsula proper, but outside of the fruit belt, Moulton township has the highest percentage of farmland in fruit and vegetables. Since the fruit and vegetable acreage in Moulton consists mostly of market garden crops and vegetables for canning, there is little reason for including it in the fruit belt when further refinement is based upon orchard and vineyard area only.

Since the fruit belt is being delimited for the purpose of showing changing land-use patterns within it over a period of 20 years, it was decided that it should be delimited on the basis of 1931 statistics as well as those of 1951. Fortunately, from a research point of view, the fruit belt in 1931 was composed of the same ten townships as in 1951.

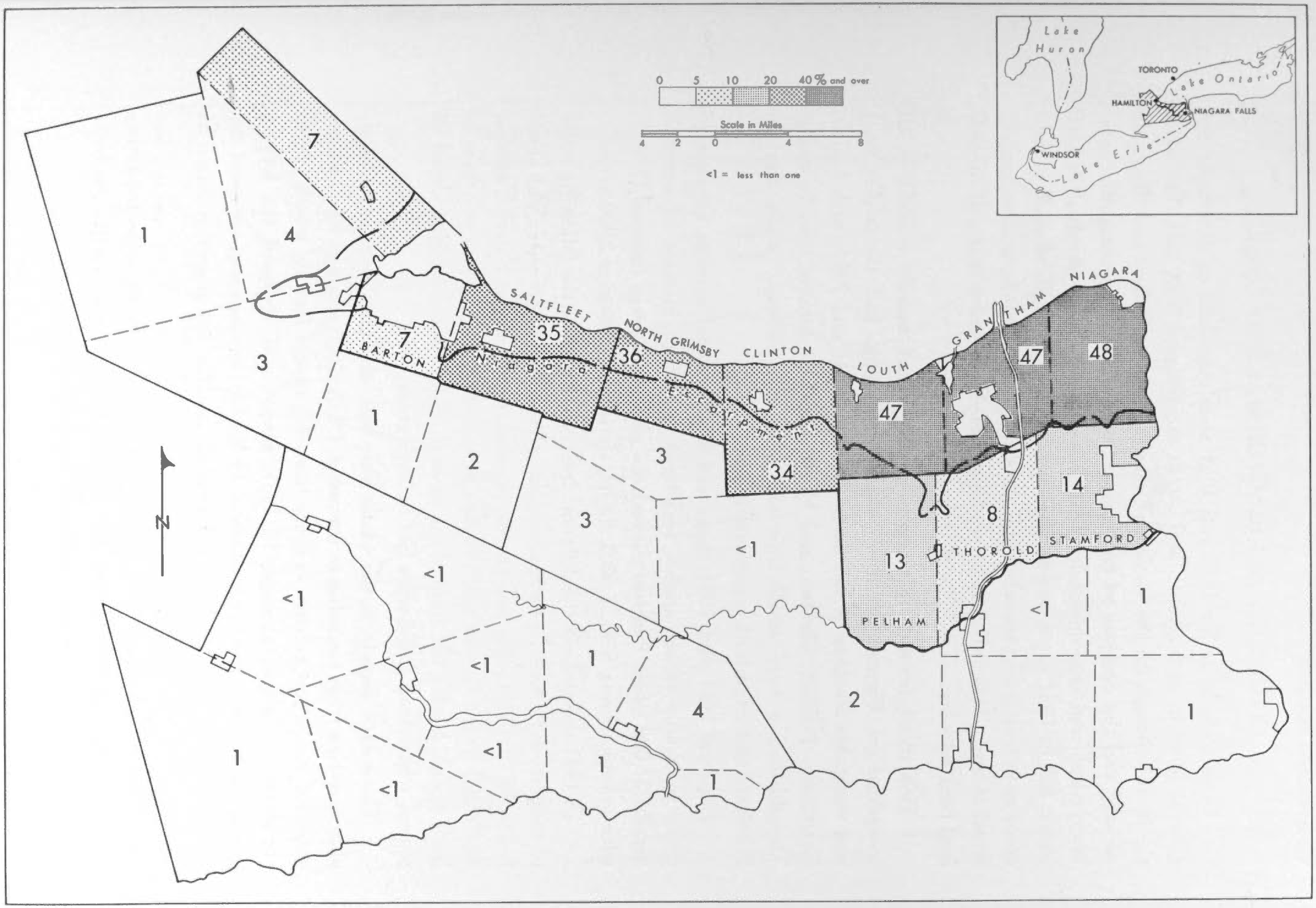


Figure 2. Fruit and vegetable acreage as a percentage of occupied farmland, 1951. The Niagara fruit belt, as defined in the text, includes the following ten townships: Barton, Saltfleet, North Grimsby, Clinton, Louth, Grantham, Niagara, Pelham, Thorold, Stamford.

CHANGING AGRICULTURAL LAND USES

Census statistics for 1931 and 1951 were examined to determine the general trend in agricultural land use in the Niagara fruit belt. The most significant changes for the whole belt were the increase of fruit and vegetable acreage and the decrease of field crop acreage. These two categories combined comprised approximately two-thirds of the occupied farmland in both years, but in 1931 there was approximately twice as much acreage in field crops as in fruit and vegetables, whereas in 1951 they were approximately equal in area. This indicates a trend away from general farming to specialized fruit farming.

This trend toward fruit specialization is not equally evident in all townships (cf. Figures 3 and 4). Niagara township had the largest fruit and vegetable increase (4,300 acres) between 1931 and 1951, with Louth, Grantham, Pelham, Clinton, and North Grimsby coming next in order. Thorold had a very small fruit and vegetable increase, while Barton, Saltfleet, and Stamford experienced losses.

Between 1931 and 1951 there was a substantial acreage increase of every fruit crop except apples, making a total fruit increase of approximately 21,000 acres. Peaches showed the greatest acreage increase (7,000), with grapes coming next (5,000). Apples showed a decrease of 2,400 acres.

In 1931 the areas in the different fruit crops were in the following order of magnitude: grapes, peaches, apples, plums, pears, cherries, and small fruits. In 1951 the order was grapes, peaches, pears, plums, cherries, apples, and small fruits. Grapes and peaches remained in the top two positions in both years. Apples fell from third to sixth place. Pears jumped ahead of plums, while small fruits were last in both years.

These data pertain to the whole fruit belt, although there is considerable variation from township to township. Of the fruit crops in 1931, grapes occupied the largest acreage in every township except Barton, where apples occupied the largest acreage. In 1951, grapes still occupied the largest acreage in seven of the ten townships. In Barton, apples again occupied the largest acreage. In Pelham and Stamford, peaches led grapes in terms of acreage.

Of the tree crops, in 1931 peaches led in acreage in six of the ten townships: North Grimsby, Clinton, Louth, Grantham, Niagara, and Stamford. In 1951, Pelham was added to this list (Figures 3 and 4).

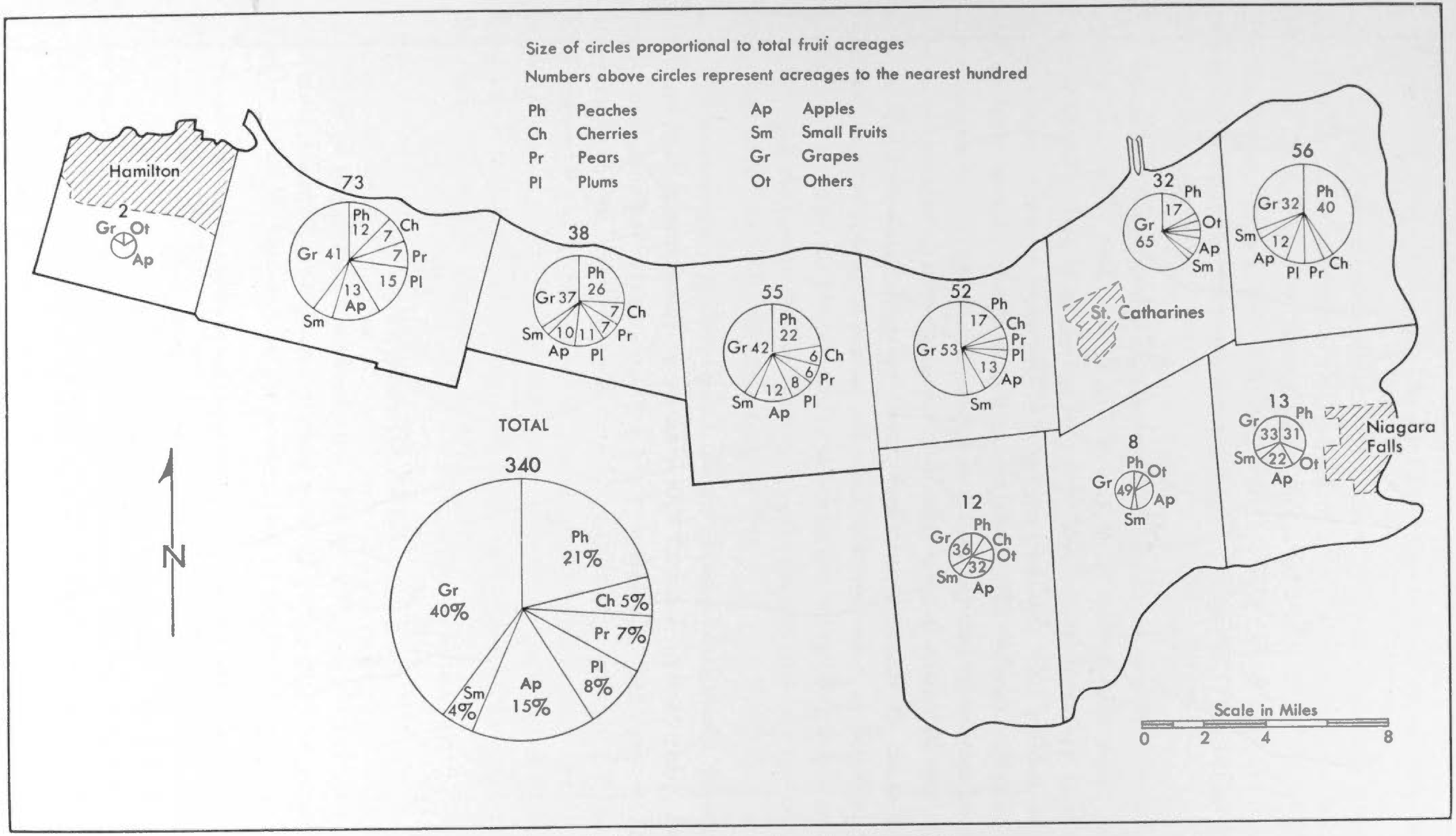


Figure 3. Percentage distribution of fruit crops, 1931.

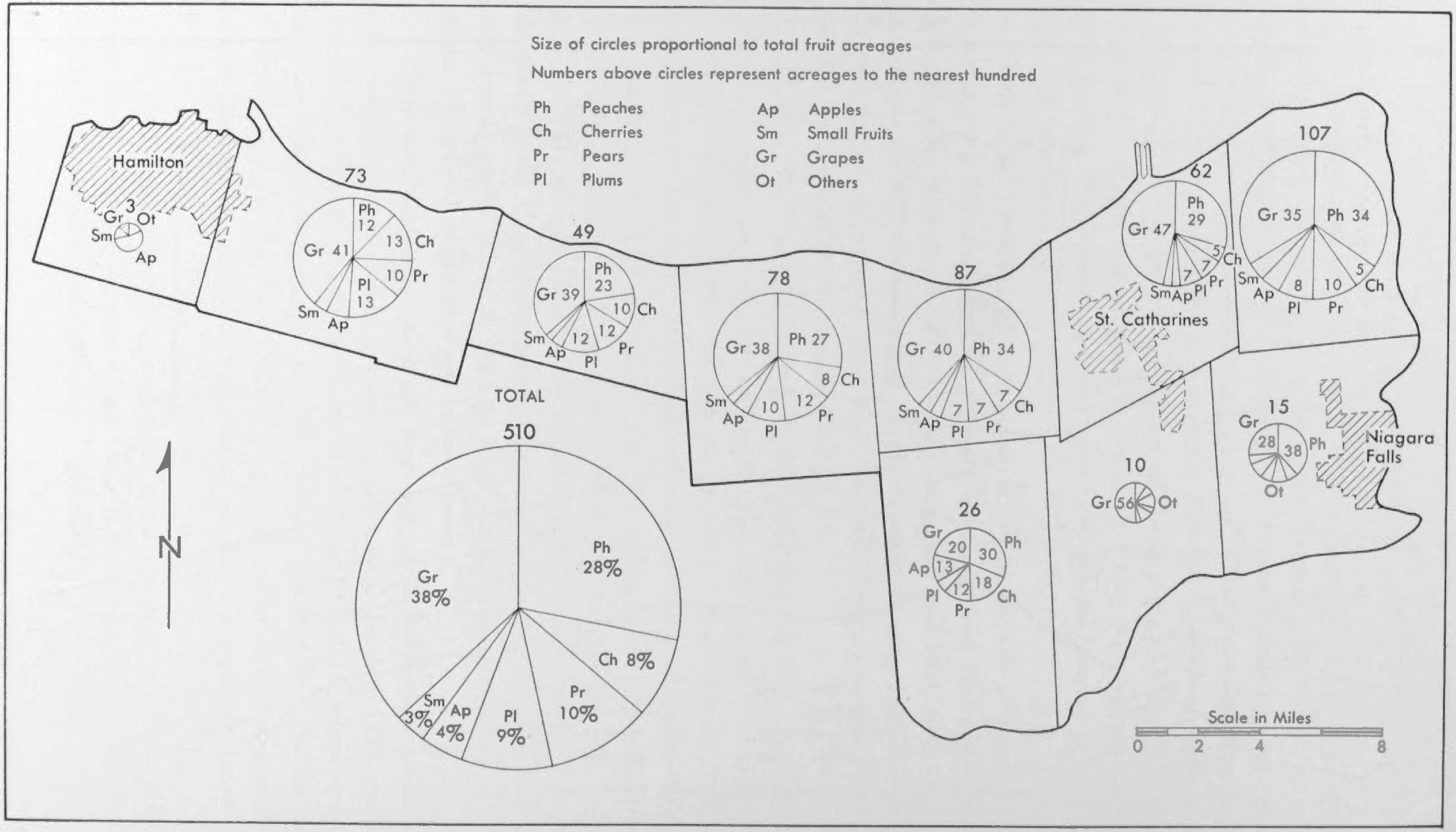


Figure 4. Percentage distribution of fruit crops, 1951.

In order to get a better picture of the areal distribution of fruit crops, complete air photo coverage of the Niagara fruit belt was obtained for both 1934 and 1954. The 1934 photos were procured from the National Air Photo Library, Ottawa; the 1954 photos from the Ontario Department of Lands and Forests. Both sets are vertical photos, at a scale of approximately four inches to the mile.

Because of the difficulty of transferring the intricate fruit belt land-use pattern accurately from the photos to a map of manageable scale, the various land-use data were plotted on a grid based upon the survey system which divides the townships into concessions and lots. This gridded map conveniently divided the fruit belt into about 1,000 "blocks". Although some irregularity in the survey pattern and the lake and river boundaries cause a substantial range in the size of blocks, most of them fall into the 200- to 250-acre class.* Because these blocks are bounded by roads (or rights-of-way for roads) in almost all cases, they are easy to identify on topographical maps, air photos, and in the field. Since the block boundaries coincide with concession and lot boundaries, it is easy to correlate township assessment-roll data with field and air-photo data.

The inconsistency of the scale of the air photos (particularly those of 1934) made it impracticable to measure area in acres. Consequently, the area of each land-use category within a block was calculated as a percentage of total area of that block. This was done for each block in both the 1934 and 1954 photos. Finally, the one set of percentages was subtracted from the other to obtain the 1934-1954 difference in land uses as a percentage of total area in each block. Maps were then drawn to show the 1954 pattern and the 1934-1954 change (Figures 5, 8, 9, 10).

ORCHARD AREA

Most of the intensive orchard area (blocks with over 10 per cent of total area) is located on the Scarpfoot plain north of the Niagara escarpment† (Figures 5 and 6). However, in the western part of the fruit belt, intensive

*An arbitrary grid would have had the advantage of more constancy in size of blocks, but attempting to get exactly the same grid on two sets of photos with slightly different scales would have been difficult. Also, the arbitrary grid would have been difficult to establish in the field.

†In Figures 1, 2, 5, and 7-12 the Niagara escarpment is represented by a broken line which follows the 500-foot contour. This is approximately midway up the north-facing scarp slope. For detailed maps and description of the physiography of the Niagara Peninsula see Chapman, L. J. and Putnam, D. F.: *The Physiography of Southern Ontario*, Toronto, 1951.

orchard areas spill up over the escarpment onto the Vinemount moraine, which runs parallel to the escarpment, at its very brow, almost continuously from Barton to the eastern edge of Louth township. Thus, in the western part of the fruit belt, a line drawn along the southern edge of the Vinemount moraine delimits the intensive orchard area better than does the Niagara escarpment.

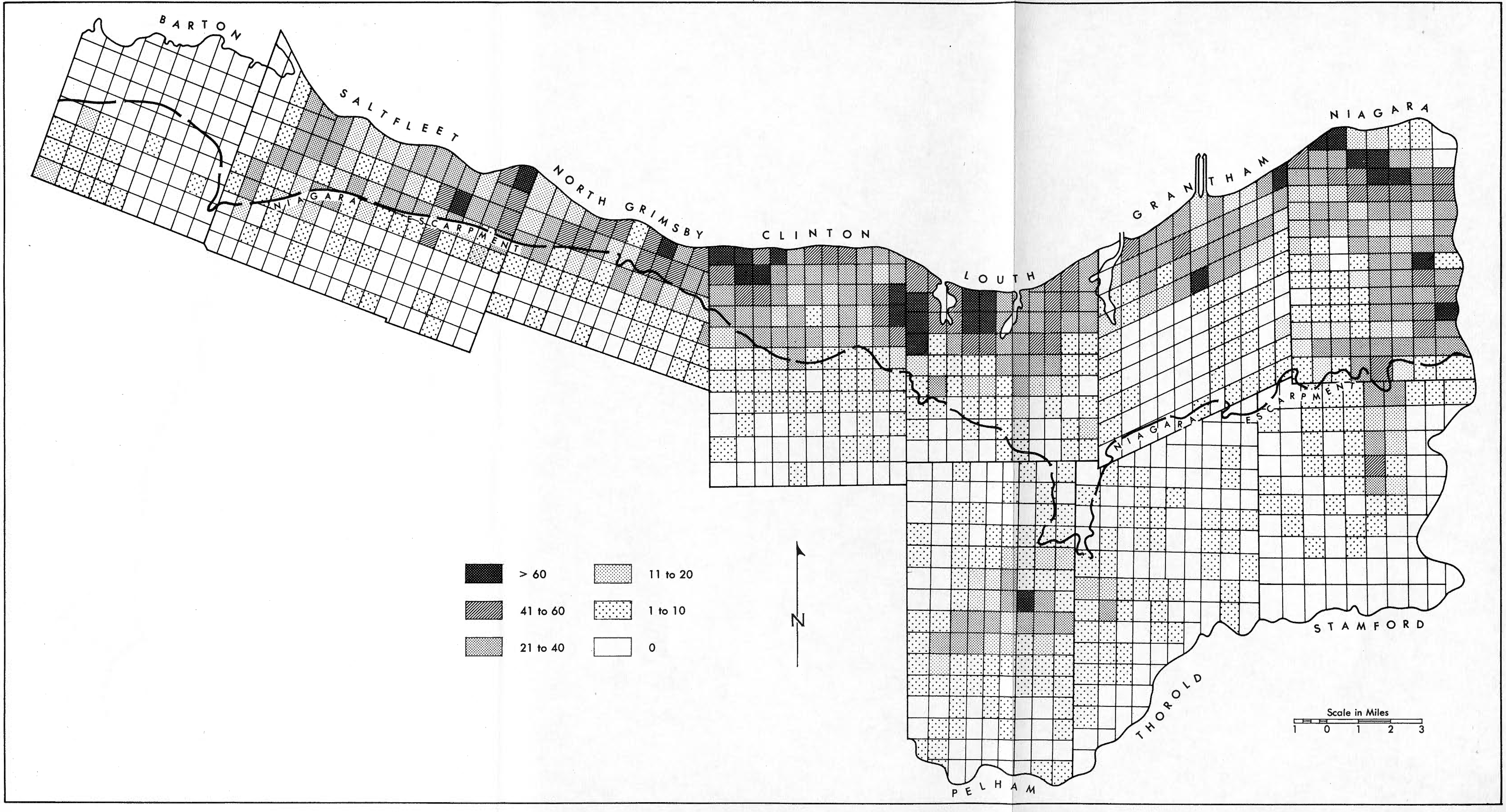
In Louth and Grantham, the southern limit of the intensive orchard area does not coincide nearly as closely with the escarpment. In Louth, where the escarpment changes from its almost precipitous nature in other townships to a steep undulating slope extending over several miles, and where the Vinemount moraine becomes discontinuous and less prominent, the shoreline of glacial Lake Iroquois forms the southern boundary of the intensive orchard area. In Grantham, the southern limit of the intensive orchard area has been pushed still farther north of the escarpment by the St. Catharines urban area.

Along the Niagara-Stamford township boundary, the Niagara escarpment, which again becomes steeper, forms the southern intensive orchard limit, with the exception of a tongue of intensive orchard area extending into Stamford just west of Niagara Falls.

Besides this Stamford orchard tongue, the Fonthill district, mostly in Pelham but overlapping slightly into Thorold, is the only large intensive orchard area any distance south of the escarpment. The boundaries of the Fonthill orchard "island" coincide very closely with those of the Fonthill kame (Figures 5 and 6).

Sloping sites are important for orchards because they promote the downslope movement of air—"air drainage"—which reduces risk of frost damage, and improves the natural soil drainage. By comparing the orchard areas with topographical maps, it appears that the Niagara orchard areas all have some degree of slope. All of the Scarpfoot plain slopes gently towards Lake Ontario. The Niagara Falls district has considerable slope both towards the Niagara River and the escarpment. The Fonthill district rises some 200 feet above the surrounding countryside. In the western part of the Scarpbrow plain, intensive orcharding is conspicuously limited to the slopes of the moraines. In contrast, the low-lying area between the Vinemount and Niagara Falls moraines, which is drained by Forty Mile Creek, has no commercial orchards at all, not even farmstead orchards.

Figure 5. Orchard area as a percentage of total area, 1954. ➧



BARTON
SALTFLEET
NORTH GRIMSBY
CLINTON
LOUTH
GRANTHAM
NIAGARA
NIAGARA ESCARPMENT
NIAGARA ESCARPMENT
STAMFORD
THOROLD
PELHAM
> 60
41 to 60
21 to 40
11 to 20
1 to 10
0
N
Scale in Miles
1 0 1 2 3

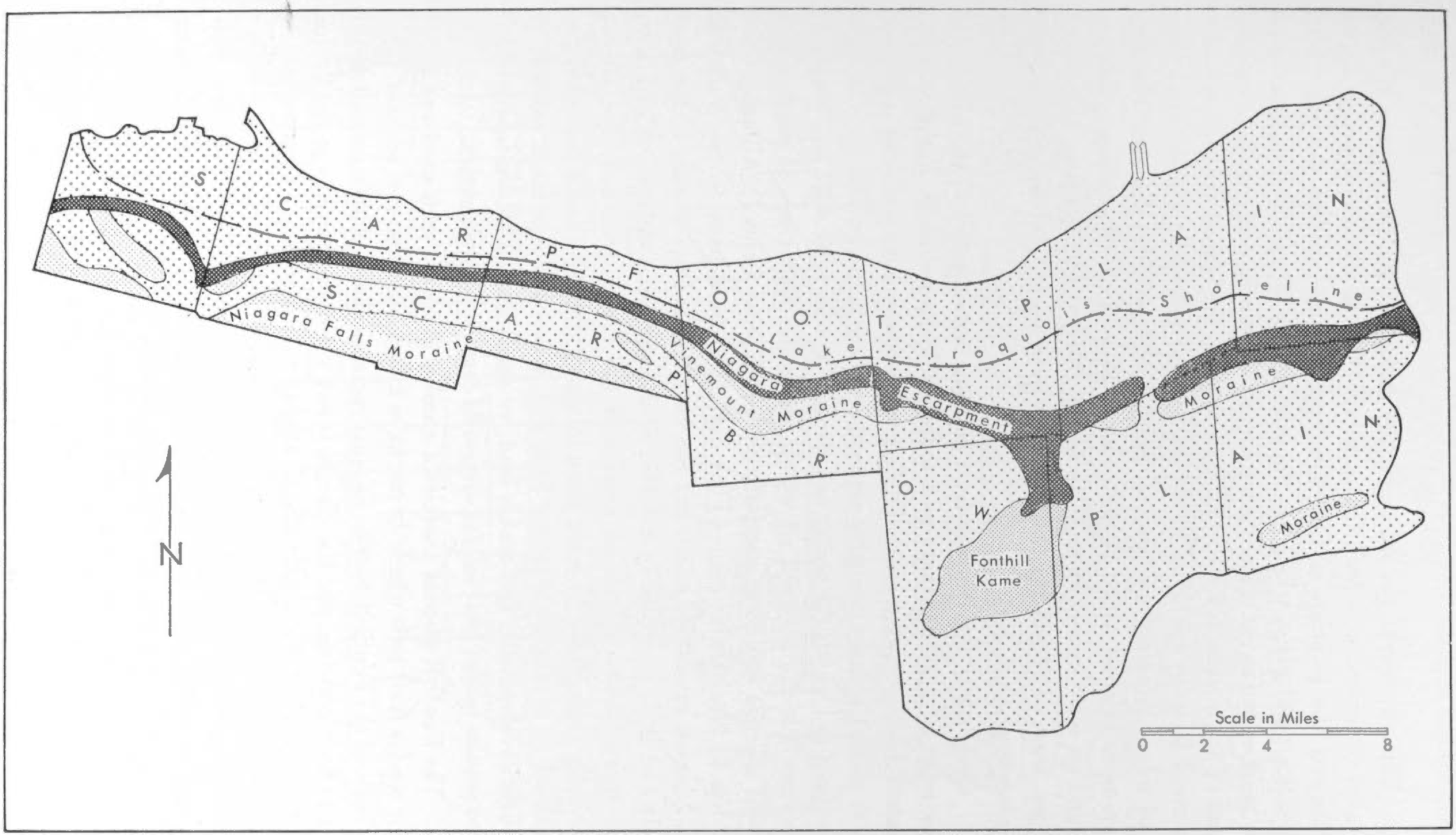


Figure 6. Physiography.

Climate, one of the major factors making it possible for the Niagara region to specialize in fruit (Mercier, 1955-56), is also an important factor affecting the location of intensive orchard areas within the fruit belt. The Scarpfoot plain, which has the best climate for tender fruit crops such as peaches and sweet cherries, contains more than 90 per cent of the orchard area of the fruit belt. On the Scarpbrow plain, the largest areas of intensive orchard growing are found at the eastern end where the winters are milder and where slope gives additional protection from frost damage. The only extensive orchard areas in the western part of the Scarpbrow plain are found on the Vinemount moraine where proximity to the lake, along with slope, seem to ameliorate the climate sufficiently for successful commercial orcharding.

Orchards in the Niagara fruit belt are concentrated in the areas with the most favorable climate and topographical conditions, but the actual distribution of orchard areas of different intensities is more closely associated with soils. The most intensive orchard areas are found on well drained, light textured soil which the writer has termed "tender fruit soil" (*see* Figure 7) because it is the only soil on which the tender fruit crops of peaches and sweet cherries can be successfully grown (Figures 5 and 7). All except one of the 81 blocks with over 40 per cent in orchard have tender fruit soil. In Niagara township, which has the best tender fruit climate of the fruit belt and little appreciable climatic or topographical differences within it, the most intensive orchard areas and the tender fruit soils are almost perfectly coincident. In most areas in which there is a small percentage of orchard in blocks with tender fruit soil, there is also a large amount of urban development, non-arable land, or small fruits and vegetables which also require tender fruit soil for successful commercial production.

The Fonthill district contains a number of blocks with good and excellent tender fruit soils which do not have a high percentage of orchard. This is because the Fonthill district has just recently changed from general farming to fruit growing, and the change is not yet as complete as in the Scarpfoot plain. That it is continuing to change to orcharding is attested by the large number of young orchards in the area. It will take at least another decade before the Fonthill district catches up to the Scarpfoot plain percentage of tender fruit soil in orchard, as the change from general farming to fruit growing is a slow and expensive process.

Intensive field investigations show that the orchards on tender fruit soil are predominantly peach. While there are some apple, cherry, pear, and

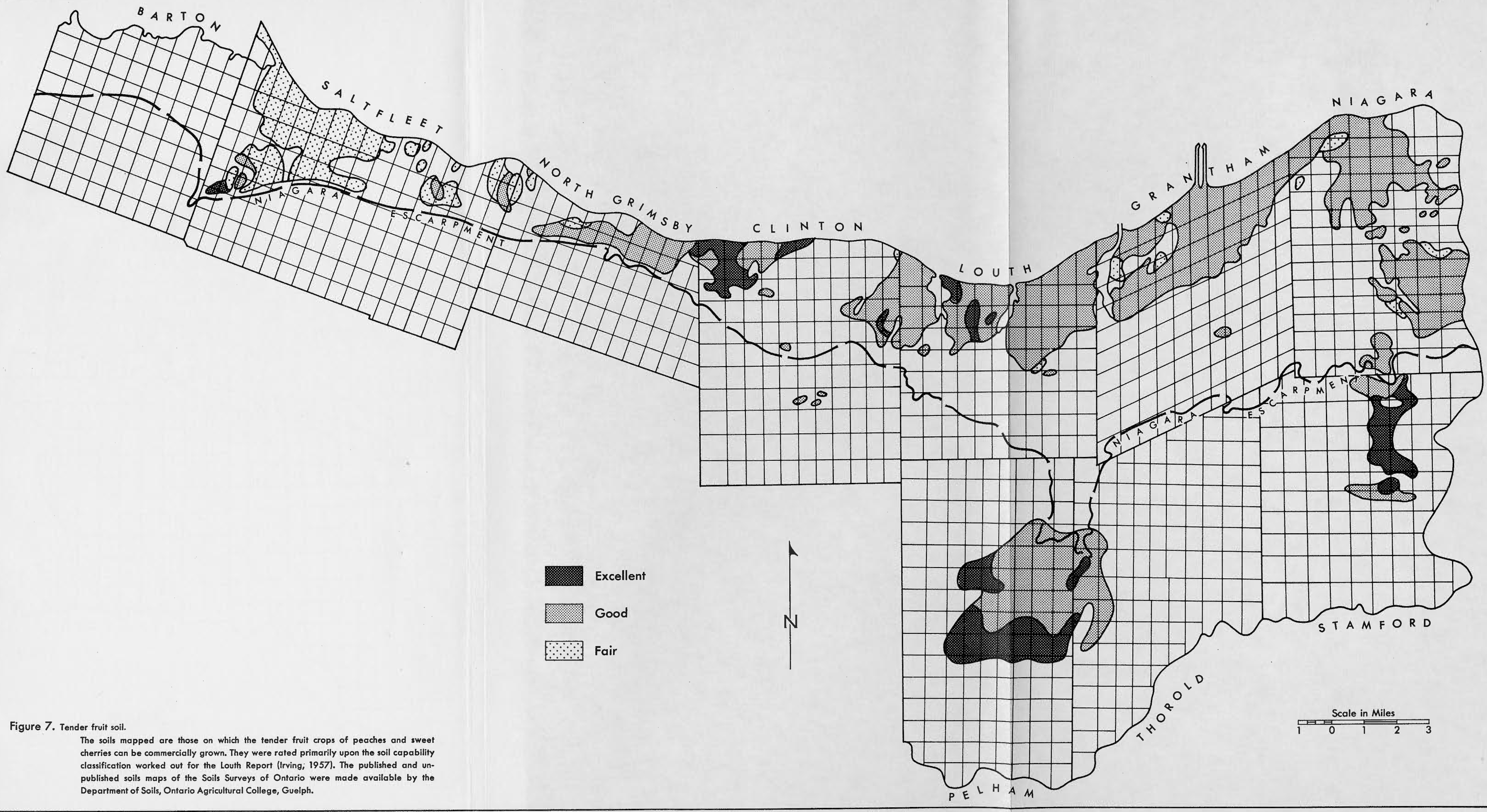


Figure 7. Tender fruit soil.

The soils mapped are those on which the tender fruit crops of peaches and sweet cherries can be commercially grown. They were rated primarily upon the soil capability classification worked out for the Louth Report (Irving, 1957). The published and unpublished soils maps of the Soils Surveys of Ontario were made available by the Department of Soils, Ontario Agricultural College, Guelph.

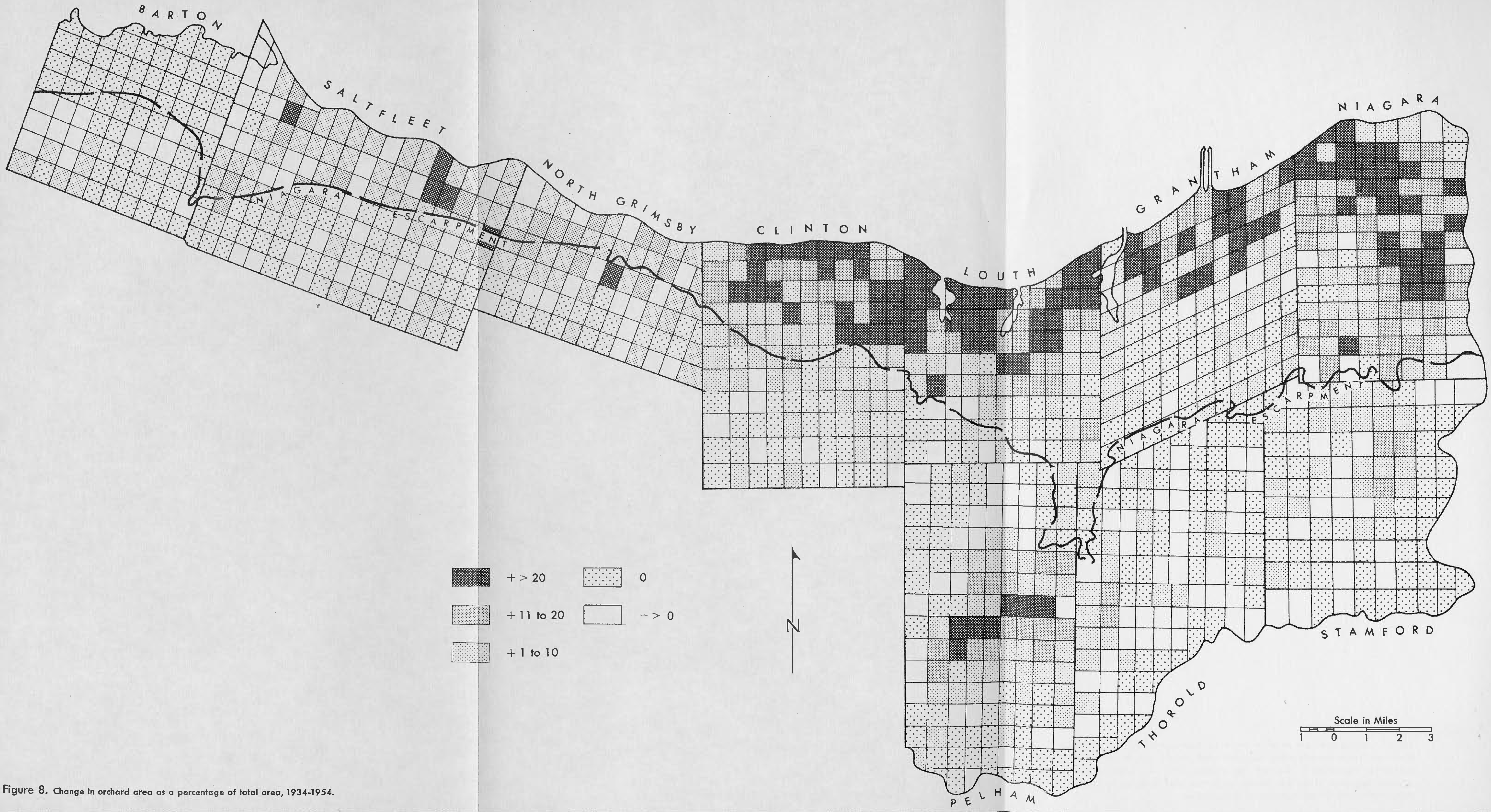


Figure 8. Change in orchard area as a percentage of total area, 1934-1954.

plum trees on such soil, these (except sweet cherry) are gradually being replaced with peach trees. New apple, sour cherry, pear and plum orchards are being planted on clay soils.

CHANGE IN ORCHARD AREA

Much of what has been said about present orchard patterns also applies to the patterns of orchard change (Figure 8). Most of the larger increases have occurred on the tender fruit soils below and above the escarpment, and along the Vinemount moraine in the western part of the Scarpbrow plain. On the Scarpfoot plain, there is more orchard increase east of the North Grimsby-Clinton township boundary. This is because east of North Grimsby the Scarpfoot plain becomes much broader, the areas of tender fruit soil become larger and their quality better, and the climate is more suitable for tender fruit.

The largest decrease in orchard acreage has occurred in the northeast corner of Niagara township, where the percentage of area in orchard in one block decreased from 49 per cent in 1934 to 9 per cent in 1954. This loss is due to a large hydro development project undertaken by the Hydro Electric Power Commission of Ontario. The next largest decreases occur in Barton and Saltfleet townships and are the result of Hamilton's suburban expansion. Much more orchard has actually been cleared for housing developments around the major cities than is indicated in Figure 8, but in many cases there has been enough new orchard planted elsewhere in the block to compensate for the loss. In a number of blocks where the 1934 photos show no orchard, the 1954 photos show orchards partially cleared for housing subdivisions. This means that orchards were planted after 1934 and were in the process of being replaced by housing in 1954. It is, of course, impossible to measure from the air photos how much orchard planted after 1934 has been completely replaced by non-agricultural land uses.

Most of the decreases above the escarpment have a value of 1 per cent or 2 per cent of total area. These small decreases indicate the clearing, or just natural thinning out, of farmstead apple orchards which once supplied the farmer's own needs as well as some cash income, but which now do neither. A farmer with 99 acres in general farm crops and 1 acre in orchard does not take time during the busy spring and summer months to do the spraying and thinning which is necessary to produce good sized, disease-free, and insect-free fruit. Even if he does have the interest and know-how,

83627-0—2

he soon finds that orcharding requires equipment that is too expensive for economic use on a small orchard. Thus, he usually decides to abandon the orchard completely.

In cases where the farmer does decide to look after his orchard, he is likely to increase the size of his orchard in order to make the operation economic. This explains a number of the small increases found above the escarpment.

VINEYARD AREA

As with orchards, most of the intensive vineyard areas are on the Scarp-foot plain (Figure 9). Of the 110 blocks with over 20 per cent of area in vineyard, 90 are found either partially or wholly below the escarpment. This possibly reflects the more favorable climate of the area below the escarpment with its longer growing season and less severe winters. Although grapes are more hardy than peaches, they need a longer growing season in which to mature, and also the young spring shoots can be severely injured by frost. Nevertheless, grapes are also grown successfully above the Niagara escarpment.

All of the blocks on the Scarpbrow plain with over 20 per cent vineyard are close to the escarpment. There is some concentration of vineyards along the slopes of the Vinemount moraine at the brow of the escarpment in Saltfleet and North Grimsby townships likely for the same reasons that orchards are found there. There is a conspicuous absence of vineyard blocks in the low-lying land between the Vinemount and Niagara Falls moraines. More vineyards are again found on the Niagara Falls moraine in the southern part of Saltfleet and straddling the North Grimsby-South Grimsby township boundary. Here, at the southern edge of North Grimsby, is the only place where the boundaries of the fruit belt, as delimited on a township basis, break down to any extent. A number of the blocks in the two northern concessions of South Grimsby have 1 to 10 per cent in vineyard. However, vineyards are very scarce south of the second concession of South Grimsby. Thus, an easterly continuation of the southern edge of Saltfleet township would delimit the actual fruit belt better than does the present southern boundary of North Grimsby.

The most intensive areas of vineyards in the fruit belt are found on soils other than the tender fruit soils around the edges of the intensive

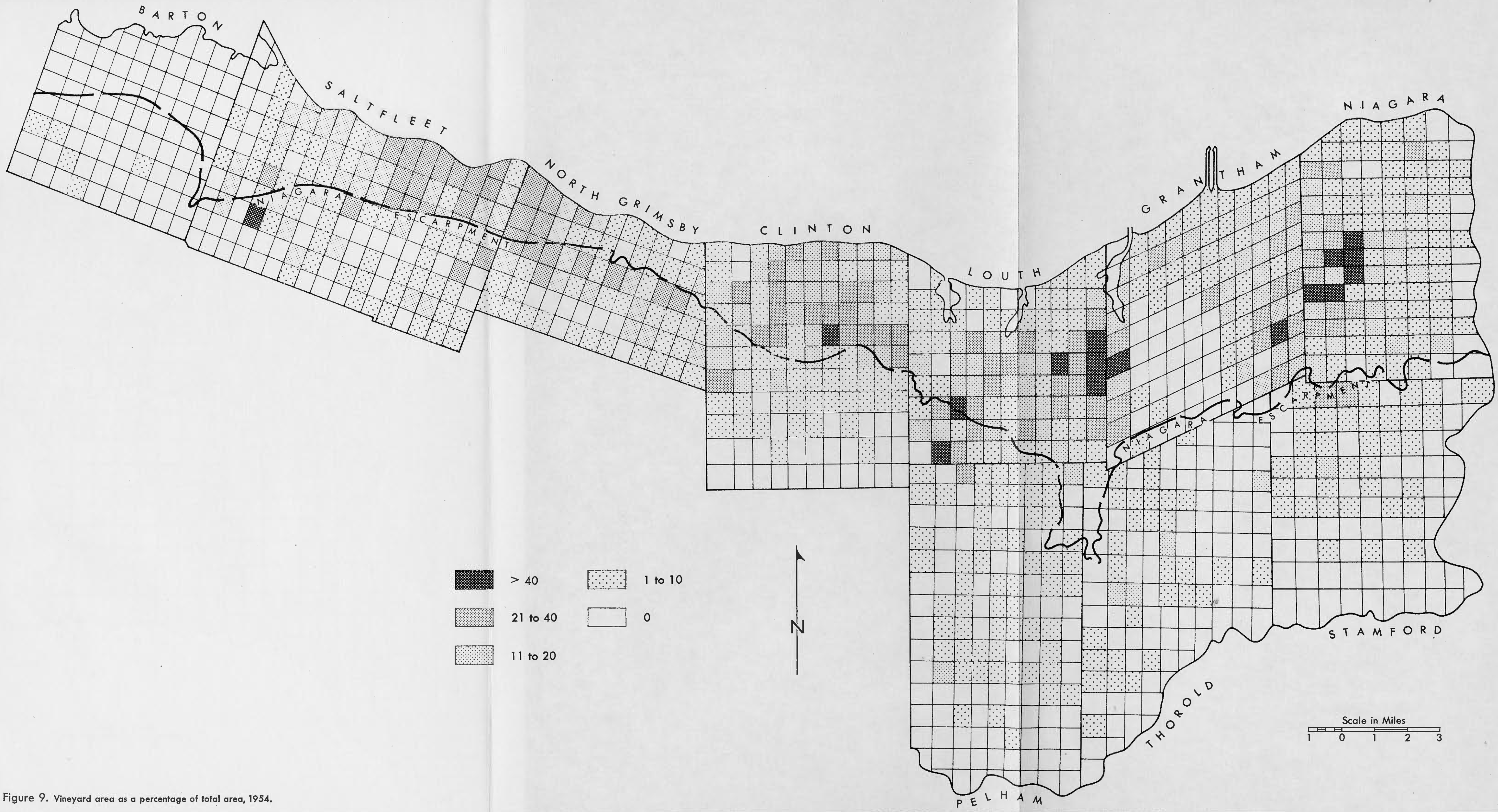


Figure 9. Vineyard area as a percentage of total area, 1954.

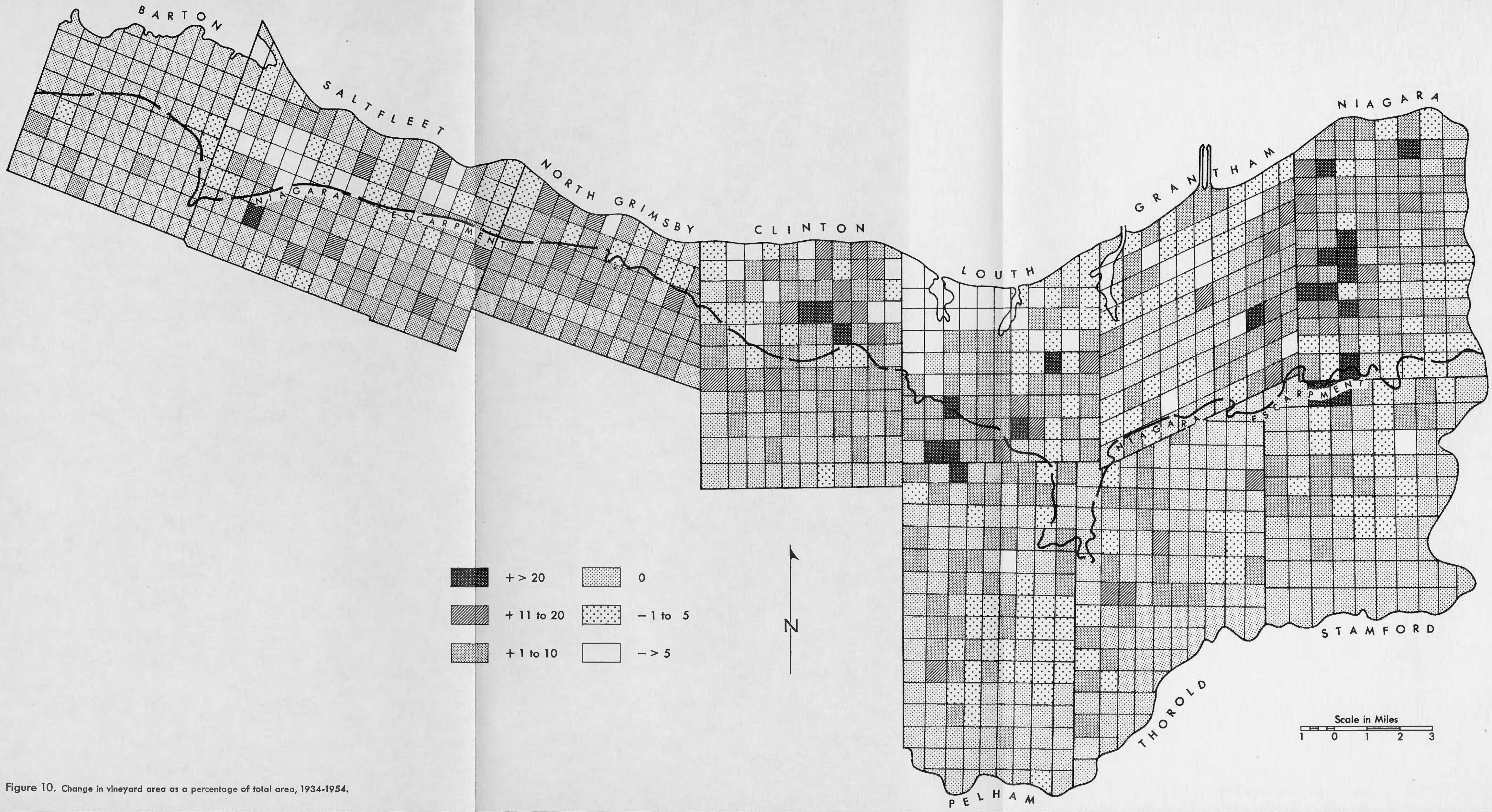


Figure 10. Change in vineyard area as a percentage of total area, 1934-1954.

orchard areas (Figures 5, 7, and 9). In the blocks with part sandy soil and part clay soil, the grapes are usually found on the latter, or where the sand is less than 18 inches deep over clay.

A number of reasons for grape growing on the clay soils rather than on the sands, despite the fact that yields on the latter are higher, have been given by fruit growers and horticulturists. Some claim that grapes mature earlier on clay than on sand. Others state that grapes grown on clay are more desirable for wine purposes. Still others claim that grapes are grown on clay because sand is too valuable for other crops, particularly peaches. It is likely that the real reason is a combination of these factors. Certainly the fact that on the average peaches gross $300 more and net $60 more per acre than do grapes, would influence farmers to plant peach orchards instead of vineyards wherever the soil is suitable for the former.*

CHANGE IN VINEYARD AREA

The most extensive area of large increases in vineyard acreages (Figure 10) shows up on the clay soils extending for several miles on both sides of the Grantham-Niagara township boundary. In that area is found one block with a vineyard increase of 70 per cent of total area, one of 62 per cent, two of 41 to 50 per cent, two of 31 to 40 per cent, four of 21 to 30 per cent, and fifteen of 11 to 20 per cent. Another extensive area of vineyard increase is found on the clay soils of Clinton township (below the escarpment). Other increases of varying amounts are fairly well scattered across the fruit belt with some concentration on the Vinemount and Niagara Falls moraines, and the long escarpment slope in Louth township.

A comparison of Figures 7, 8, and 10 gives support to the contention that orchards are pushing the vineyards off the tender fruit soils. Both increase of orchards and decrease of vineyards are occurring predominantly in areas with tender fruit soil. This is particularly evident in the northwest corner of Louth township.

The extensive area of vineyard decrease in the western part of Saltfleet (below the escarpment) and that in Grantham can be attributed both to the trend to move grapes off the sand, and to urban expansion.

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*Statistics are based on unpublished cost of production studies conducted by the Farm Economics Branch, Ontario Department of Agriculture, from 1951 to 1955.

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OTHER ARABLE AND NON-ARABLE LAND

A map of other arable land (predominantly field crops and pasture) looks like a reversal of the orchard and vineyard map combined.* The blocks with the highest values are found predominantly above the escarpment; the lowest values below. The acreage increases of other arable land are owing to the clearing of land which was classified as non-arable in 1934. The decreases are owing to orchard and vineyard expansion, or urban growth, and sometimes both of these combined.

The most extensive area of non-arable land is found along the Niagara escarpment, which for most of its length, is too steep to cultivate and is thickly wooded. Other areas of non-arable land are found along the creeks which have their sources on the Scarpbrow plain and cut down through the escarpment to empty into Lake Ontario. Outlets of most of these creeks are marshy.

The Scarpfoot plain has very little forest cover other than along some of the ravines. In fact, on the tender fruit soils of the Scarpfoot plain, woodlots are almost non-existent, although the farm woodlot is still common.

There was relatively little change in amount of non-arable land between 1934 and 1954. Some woodland and brushland on the Scarpfoot plain was converted to fruitland whereas other non-arable land was taken up by urban land uses. Most of the increases in non-arable land occurred on the Scarpbrow plain. Some of the increases resulted from farmers letting pasture fields grow up into brushland; others were a result of woodlots planted between 1934 and 1954.

The change in the Niagara fruit belt from general farming to fruit growing, which began in the nineteenth century, is still continuing. Peaches which around the turn of the century began to replace apples as the major fruit crop, are gradually pushing the other fruit crops (except sweet cherries and small fruits) from the tender fruit soils to the adjacent clay soils. This change is most complete on the Scarpfoot plain. The Fonthill district is at a much later stage in its evolution from grain to fruit farming.

Although the possible acreage of peaches, sweet cherries, and most small fruits is limited by the acreage of tender fruit soil, grapes and the other tree crops have large areas for expansion. The demand, as reflected in price, will determine how much these crops will increase in acreage in the future.

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*Maps showing other arable land and non-arable land for 1954, and for changes between 1934 and 1954 are not presented in this paper (*see* Krueger, 1958).

Any projection of fruit growing into the future, must, of course, take urban expansion into consideration.

URBAN LAND USE

The total population of the Niagara fruit belt increased by about 117,000 from 1931 to 1951. About two-thirds of this increase (81,000) resulted from the suburban growth of Hamilton, St. Catharines, Niagara Falls, and Welland. The remainder of the increase was made up by an increase of rural non-farm population (32,000) and an increase of farm population (4,800).

The patterns of built-up area, and increase in built-up area, are shown in Figures 11 and 12. The cities of the Niagara fruit belt are sprawling out in all directions, but with more concentration along the highways and main roads, and around the towns and villages. The Niagara escarpment appears to be a barrier to urban expansion, as evidenced in Saltfleet township. However, when the pressure becomes great enough suburban expansion spills up over the escarpment as it has done in Barton township. In addition to suburban growth, there are many rural non-farm dwellings scattered all over the fruit belt.

Between 1934 and 1954, about 11,700 acres in the Niagara fruit belt were put to urban land use, although this urban expansion did not begin reducing fruit crop acreage until 1951. Between 1931 and 1951 fruit growing expanded in all of the townships except Saltfleet (Table 1), but by 1951 urban land uses resulted in the uprooting of orchards and vineyards at a greater rate than they were being planted. Between 1951 and 1956 the Niagara fruit acreage was reduced by a total of 1,800 acres. Almost all of this reduction occurred in Saltfleet, Grantham, Niagara, and Stamford townships (Table 1).

The amount of tender fruit soil occupied by urban expansion is even more significant than the decrease of fruit crop acreage, because this soil, of which there is a limited amount in the Niagara fruit belt, is the only type on which the major tree fruit crop of peaches can be grown profitably (Table 2).

There are several factors which tend to make the loss of 2,700 acres of tender fruit soil more serious than it at first appears. The acreages given in Table 2 are the actual areas occupied for urban land use. This does not include many large areas in the path of urban expansion which lie idle, awaiting development. Nor do these figures indicate the loss of fruit production which results from subdivision of farms into small non-economic units around the cities. These farms, often operated on a part-time basis, are usually less productive per acre and constitute a source of disease and insect infection for surrounding orchards. Also, there is reluctance to plant orchards which take 5 years or more to mature when urban development is approaching.

TABLE 1.—Change in Fruit Crop Acreage*

	1931–1951	1951–1956
Barton	100	−100
Saltfleet	0	−600
N. Grimsby	1,100	0
Clinton	2,300	1,000
Louth	3,500	0
Grantham	3,000	−1,300
Niagara	5,100	−700
Pelham	1,400	400
Thorold	200	0
Stamford	200	−500
Total	17,000	−1,800

*Source is unpublished census data and the 1951 and 1956 census statistics for Barton and Saltfleet townships. The Census Division, D.B.S., adds the farmland acreage within the limits of cities to an adjacent township. Thus, when Hamilton annexed a large fruitland area of Saltfleet township between 1951 and 1956, it was added, in the 1956 Census, to the acreage of Barton township.

In the above table the acreage decrease for Barton has been estimated from air photos and field observations. This estimate, coupled with the census figures for loss of acreage in Saltfleet, result in the calculation for Saltfleet township indicated above, and presents a more accurate statement of fruitland acreage than does the 1956 Census.

TABLE 2.—Acreage of Tender Fruit Soil Occupied by Urban Expansion, 1934-1954
(Data from Air Photos)

Barton	0
Saltfleet	1,050
N. Grimsby	100
Clinton	40
Louth	140
Grantham	860
Niagara	140
Pelham	80
Thorold	10
Stamford	290
Total	2,700

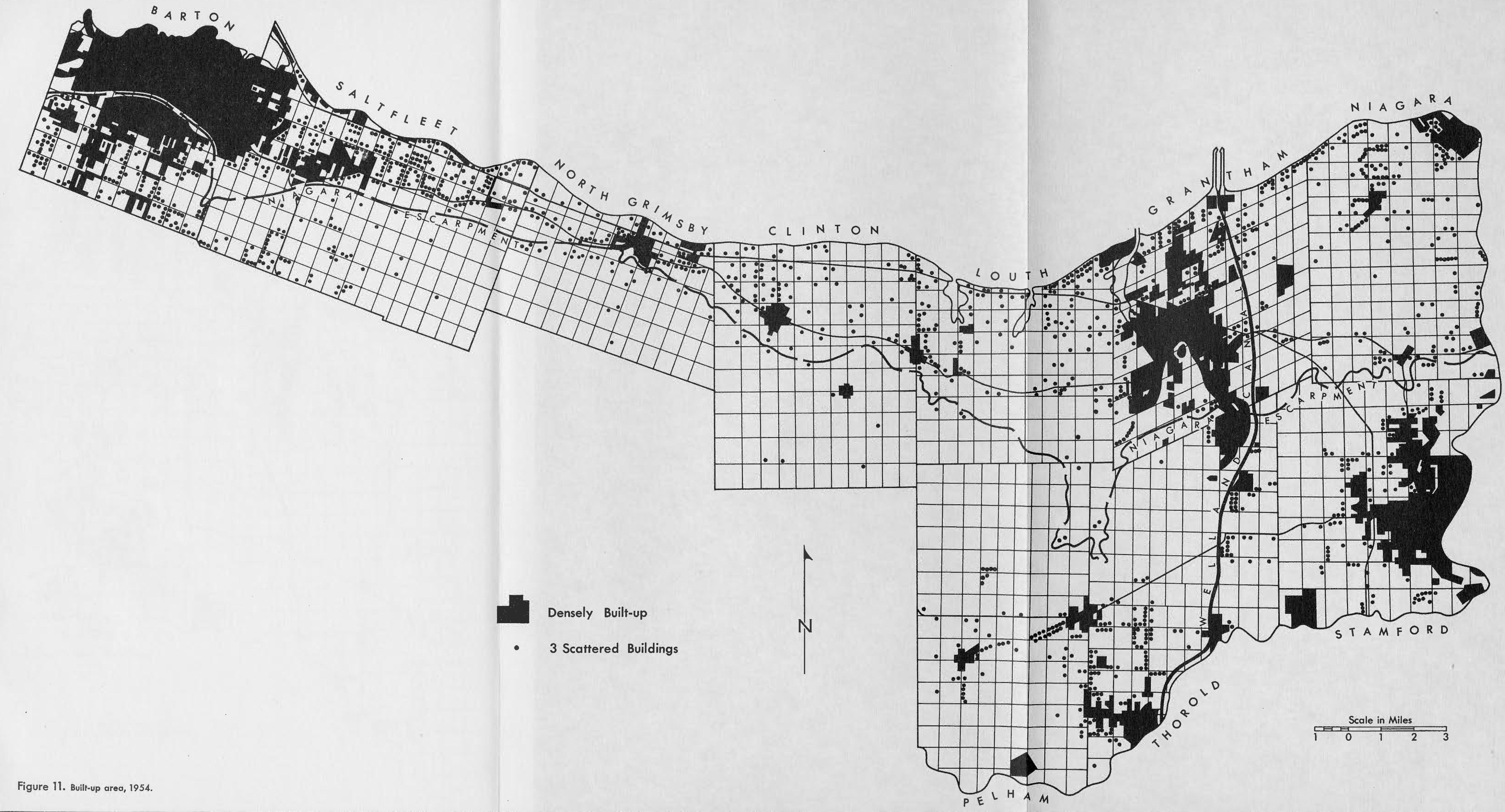

Figure 11. Built-up area, 1954.

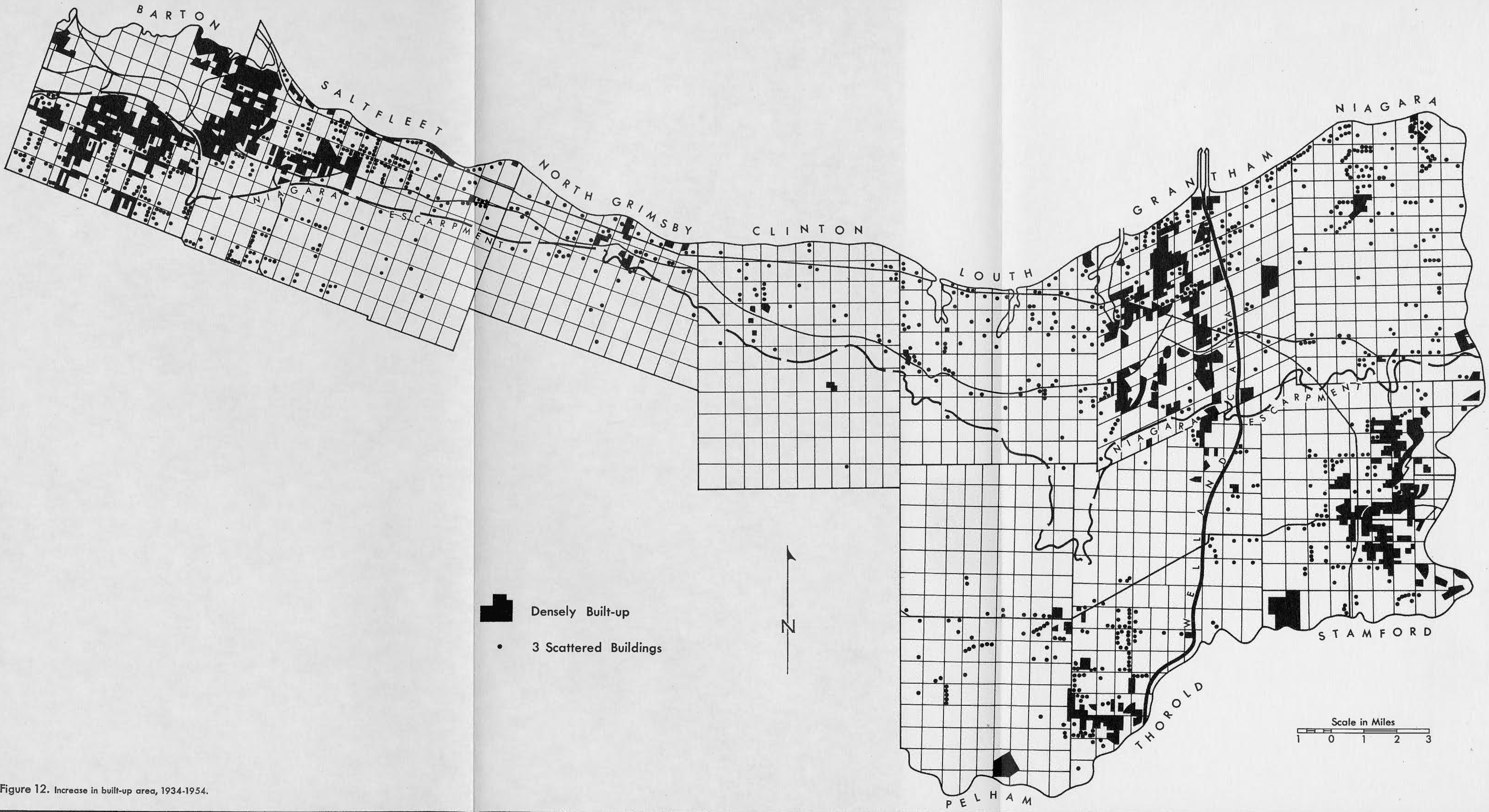

Figure 12. Increase in built-up area, 1934-1954.

High prices offered for land for urban uses encourage farmers to sell their farms. Often the land is sold to a speculator who either leases the land for a limited period, or holds it idle. If it is leased, productivity is reduced because a short-term lease provides no incentive for good farming practices. If held idle, the land supports damaging weeds and insects.

Non-farm people moving into a rural community bring with them a high demand for municipal services, including schools, and the farmers, with high land assessments, bear most of the resulting tax increases. Fruit growers cite this as one of the pressures forcing them out of business (Krueger, 1957).

Thus, it can be seen that urban expansion is more of a threat to fruit growing than the mere uprooting of orchards and vineyards. The real danger lies in spoiling the total area for fruit production because of the low density urban development spreading over most of the fruit belt.

The population of the Niagara fruit belt increased by 68,000 between 1951 and 1956, a growth rate about three times as great as that in the 1931-1951 period. Of this increase, 29,000 were rural non-farm. If this rate and pattern of urban growth continues, the Niagara fruit belt cannot survive as a major fruit producing area.

However, urban expansion and a continuing prosperous fruit growing industry in the Niagara fruit belt are not necessarily incompatible. If urban development were controlled so that it took place in a more orderly, compact manner, and if its growth were directed, where possible, to the less valuable fruitland, there would be room for an urban population of several times that of the present, without seriously endangering fruit production (Krueger, 1959).

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THE NATURAL VEGETATION OF THE SOUTHERN GREAT PLAINS OF CANADA

*F. B. Watts**

ABSTRACT: The distribution of the natural vegetation of the southern Great Plains of Canada is discussed in terms of the vegetation that existed before white settlement, and before crop production and grazing radically altered its nature. In place of preparing a map based on remnants of natural vegetation, the distribution is plotted from descriptions contained in land surveyors' reports prepared between 1870 and 1890, and from recent studies prepared by the federal Department of Agriculture. The classification adopted is similar to that used by Halliday in the preparation of the Forest Classification for Canada.

RÉSUMÉ: La distribution de la végétation naturelle dans le sud des Grandes Plaines du Canada est étudiée selon les conditions existantes avant la venue des Blancs, puisque les grandes cultures et le pâturage ont radicalement modifié l'aspect de la végétation primitive. Au lieu de dresser une carte fondée sur les reliquats de la végétation naturelle, celle-ci fut cartographiée à partir des descriptions centenues dans des rapports d'arpenteurs, préparés entre 1870 et 1890, de même que d'après de récentes études effectuées pour le compte du ministère fédéral de l'Agriculture. La classification adoptée à cette fin ressemble en plusieurs points à celle employée par Halliday, dans la préparation de la Classification forestière du Canada.

This paper is concerned with a description of the nature and distribution of the natural vegetation of the southern part of the Great Plains of Canada. The area involved lies wholly within the three Prairie Provinces.

The Forestry Branch of the Department of Northern Affairs and National Resources has published an excellent description of the forest types of Canada (Halliday, 1958), but the emphasis in this paper is on the vegetation types of the great grassland formation of the Canadian West. Only very brief descriptions of the forest types which form the eastern, northern, and western boundaries of the area under discussion have been included.

In this study "natural" means fundamentally unchanged by man. The ecological role of the aborigines of Western Canada is impossible to determine with any accuracy. It is well known, however, that white settlers have radically changed the natural vegetation of the southern Great Plains as their settlement is based upon crop production and intensive grazing. These activities have virtually destroyed the natural vegetation in some areas, and have profoundly altered it in others. Much of the mixed-grass prairie and virtually all the true prairie of the Canadian West have been

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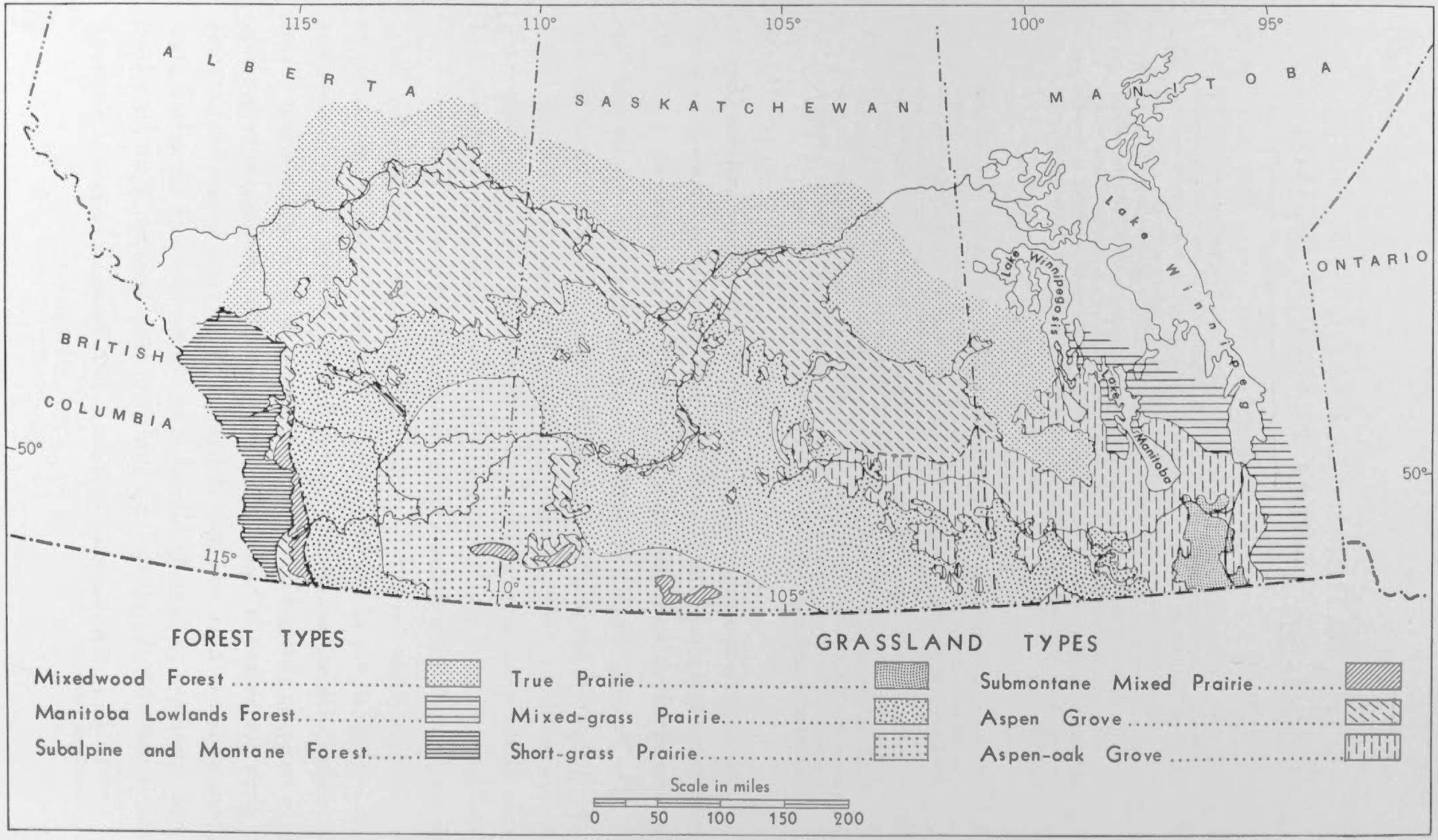

Figure 1. Distribution of grassland and forest types, southern Great Plains of Canada.

put to the plough, as have large stretches of the aspen grove country. Overgrazing has radically altered much of the short-grass prairie. A map of natural vegetation must therefore be a pre-white settlement or 'pre-plough' vegetation map.

Halliday's map of forest types has, for some years, been accepted as the standard natural vegetation map of Canada (Halliday, 1958). It was constructed in areas that are now under cultivation on the basis of remnants of the original vegetation that existed at the time of mapping. Over much of Canada, the natural vegetation has been only slightly changed by man, but in the area involved in this study, man has been an ecological factor of importance. Patches of aspen cannot everywhere be taken as evidence of a former widespread aspen cover. Some tree species, especially aspen, have invaded areas where they did not exist before the advent of white settlement. However the natural vegetation zones were not static in pre-white settlement times. Aspen was invading grassland areas and spruce was invading parts of the aspen-grove country (Löve, 1959). Nevertheless, cultivation has removed grass competition and prepared a seed bed allowing aspen to invade areas formerly far beyond its range. Furthermore, so much of the natural vegetation has been removed by man that it is difficult to determine boundaries between associations on the basis of remnant patches of the original cover.

Except for a small part of southern Manitoba, the land was surveyed before white settlement took place in the Canadian West, mainly in the 1870's and 1880's. The land surveyors not only laid out the cadastral grid, but also described natural features that would aid prospective settlers. It is largely on such descriptions that this natural vegetation map is based.

The descriptions of vegetation in the townships vary in quality and detail with the various reports, but do contain much valuable information.

The surveys of the Canadian West were of the township and range variety, that is, a grid of townships was laid out east and west from fixed meridians called principal or initial meridians. Each township was laid out 6 miles on a side except where convergence of meridians narrowed the boundaries. Generally speaking, therefore, each contained 36 one-square-mile sections. As well as laying out the township grid, the surveyors described the following features in each township.

1. The vegetation visible from the boundaries of the township, plus any conspicuous feature within the township that required special investigation.
2. Surface water such as creeks, sloughs, etc.

3. Soil texture determinable by quick reconnaissance.
4. Slope conditions.

Some surveyors made mention of trappers' or hunters' trails, the presence of squatters, and included comments on wildlife. Because most surveyors were not conversant with botanical classification, the value of their descriptions is limited when used as a basis for a natural vegetation map. Among these limitations, the following are the most important:

1. Great variation in the quality of the descriptions.
2. Lack of conformity in the use of descriptive terms, especially vegetation terms.
3. No identification of grass and forb species.

Despite the variable quality in descriptions of the vegetation, it has been possible to verify this information by comparing the descriptions of the borders of adjacent townships. As each field party surveyed a strip of townships it has been possible to supplement inadequately reported information.

Some vegetation terms used by the surveyors were ambiguous; such terms as "bush" or "brush" had more than one meaning. However, once a vegetation pattern developed on the map, the meaning usually could be determined.

Within the grasslands, the surveyors frequently overstressed the infrequent trees that occurred along water courses but did not differentiate between grass and forb species. Accordingly, the reports are not satisfactory for plotting the distribution of various grassland associations, such as the short-grass prairie, and mixed-grass prairie. Some surveyors did mention grass height and the presence of certain drought-resistant species such as cactus and sagebrush, but not enough of this type of information was recorded.

Surveyors' reports for some of the northern parts of the area were not available, and accordingly a second source of information was used to fill these gaps. These were the Land Classification Surveys of the Department of the Interior completed between 1900 and 1925, with very detailed township maps in color at a scale of 40 chains to the inch. The maps portray details of land use, conditions of drainage, and natural vegetation. In each township mapped, enough of the natural vegetation is shown to classify the township or parts of it into broad natural vegetation types. Quite large sections of the mixed-wood, aspen grove boundary were mapped from this source.

The land surveys were of little help in mapping the boundary between short-grass prairie and mixed-grass prairie because no differentiation of species was made. This vegetation boundary was therefore derived from the work of more recent investigators, notably officers of the Swift Current Agricultural Station of the federal Department of Agriculture, who mapped the distribution of the short-grass prairie in great detail (Clarke *and others*, 1947).

The Classification

The classification adopted in this work is similar to that of Halliday (1958), who, in turn, adapted the basic classification of Weaver and Clements (1929) to Canadian conditions.

This classification of natural vegetation areas has been developed in three stages. Primarily two broad formations are recognized in the southern Great Plains of Canada, the grasslands and the forests. Within each of these are several associations, or large areas of natural vegetation, each with a different set of dominant plants, and therefore presenting a characteristic appearance. It is these associations that appear on the vegetation map, and which in this report are called vegetation types. A type may be in any stage of climax development, and hence at any place the dominants of the climax may be absent. In theory of course the entire area under one type is progressing towards a common climax characterized by a given group of dominants.

Within each vegetation type, there are variations in cover created by differences in exposure, run-off, soil type, site, etc. These variations are called communities, and in theory, they too are all working towards the climax.

Essentially, the different vegetation types are the result of differences in macroclimate within the broad formations, and the different communities within each formation are due to local differences in site. The communities occupy only a few square feet and therefore cannot be mapped on the scale of this study. However, descriptions of the principal community types are presented.

The method used by the writer in mapping the natural vegetation was to categorize the descriptions taken from the sources available into one of a number of natural vegetation types recognized by Halliday and others in the Canadian West. Then, by means of colored area symbols, the types were recorded on a map of the townships of the Prairie Provinces at a scale of 1 inch to 35 miles.

The surveyors almost invariably recorded the tree species. The recognition of vegetation types from these descriptions required the use of indicator tree species. For example, the mention of white spruce mixed with aspen marked the occurrence of the mixed-wood vegetation type, and the mention of clumps of aspen in the grasslands marked the presence of the aspen-grove vegetation type.

The resultant map was a patchwork of different colored symbols on which the boundaries between vegetation types stood out clearly. From the colored work map, a final black and white map was prepared.

Because the source information was gathered prior to appreciable settlement it is felt that the map closely represents the pattern of "natural" vegetation. The boundaries between vegetation types in this mapping are considered to be more accurate than would be boundaries interpolated between remnants of the original vegetation remaining after extensive cultivation had begun.

Natural Vegetation of the Southern Great Plains

The area of Western Canada south and west of the boreal forest and east of the subalpine forest contains six clearly marked vegetation types: the true prairie, the mixed-grass prairie, the short-grass prairie, the submontane prairie, the aspen grove and outliers of the boreal forest.

Each of these natural vegetation types comprises a number of communities of plants that give distinctiveness to various sites; however, each vegetation type does possess a high degree of homogeneity which is essentially the result of a set of climatic conditions which reign throughout the area under that type.

THE GRASSLAND FORMATION

In the southern Great Plains within a semi-circle resting on the Canada-United States border, grass was the dominant cover prior to settlement. However, the vegetation cover was far from uniform within the grassland zone; it ranged from a lush cover, shoulder high, or higher, in the true prairie of southern Manitoba, to a sparse cover a few inches high in southwestern Saskatchewan and southeastern Alberta. These differences resulted from wide differences in climate.

The True Prairie

At the time of white settlement part of southern Manitoba was covered with tall grass; this area forms a northern extension of the prairie of the American midwest. The term 'true prairie' (Weaver 1954) as used in this study sets off this natural vegetation type from the grassland associations farther west.

The small portion of the 'true prairie' of the American midwest which lay within Canada occupied part of the heavy textured soils of the Lake Agassiz plain, and covered an area of some 2,500 square miles. It lay almost wholly west of the Red River, extended north to approximately the Assiniboine River, and west to the rising ground of the Manitoba escarpment.

The 'true prairie' of Manitoba was characterized by a covering of tall grasses, few shrubs and no trees except for those along river courses. The height of the grass cover sets this association apart from the other grasslands of the Canadian West. Many early explorers commented on the grass heights in this prairie. In Palliser (1863) the statement is found "... level plains with long rich grass, being an Ancient Lake Bottom".

Differences in drainage, height of water table, soil, and slope result in the development of different communities in this association. On the better drained soils of the Lake Agassiz plain, the big bluestem community is the most common. "Westward, big bluestem is the most important dominant of the grasslands which occupy the broad lowland valleys of Lake Winnipeg and the Red River...." (Weaver, 1954). The community is dominated by the single species big bluestem (*Andropogon gerardi*).* This plant is a sturdy grass reaching a height of from 5 to 8 feet. It represents one of the two most important species found in the true prairie of North America, and, along with little bluestem (*Andropogon scoparius*), comprises some 75 per cent of the plant cover of the association. The fibrous root development of big bluestem forms a dense mass from 5 to 8 feet deep. Pallister (1864) remarked, of the Agassiz plain "It is overlaid by a great thickness of vegetable mould, varying from two to four or even five feet in depth". The very deep root development indicates the favorable soil-moisture conditions which prevail where big bluestem is dominant. The soils, very rich in organic materials, form the basis of one of the richest agricultural areas in the Canadian West.

*Botanical nomenclature used in this work is after H. J. Scoggan, *Flora of Manitoba*, Bulletin 140, National Museum of Canada, Dept. of Northern Affairs and National Resources, 1957.

A number of grasses of lesser importance are associated with the dominant big bluestem. Among the more important of these are: Canadian wild rye or nodding wild rye (*Elymus canadensis*), northern wheat grass or blue joint (*Agropyron dasystachyum*), little bluestem, June grass (*Koeleria cristata*) and needle grass (*Stipa spartea*).

Associated with the grasses in this community are a number of forbs; chief amongst these are: the willow aster (*Aster praealtus*), Canada anemone (*Anemone canadensis*), tall golden rod (*Solidago canadensis*), western red lily (*Lilium philadelphicum var. andium*), and wild prairie rose (*Rosa arkansana*).

The community under virgin conditions is said to have reached a height of close to 8 feet. Remnants of it along the roadsides in southern Manitoba reach shoulder high, and give some indication of the former landscape.

Much of the Lake Agassiz plain to the southwest of present-day Winnipeg was low and wet, with a dense, fine textured soil, supporting a slough grass community of the true prairie. The slough grass or cord grass (*Spartina pectinata*) is a tall marsh grass. It makes a much poorer hay than big bluestem, but in the early years of white settlement in the Red River valley, large quantities were cut in early summer for hay. Associated with the slough grass are a number of grasses of lesser importance, among which are switch grass (*Panicum virgatum*), Canada wild rye, cord grass (*Spartina gracilis*) and northern reed grass (*Calamagrostis inexpansa*). A number of forbs were also important such as tall golden rod and Baltic rush (*Juncus balticus*).

Intermediate between the well-drained sites of the big bluestem community and the very wet sites of the slough grass community, exist the moderately wet sites of the Agassiz plain. These areas support a growth 5 to 6 feet high at maturity which is dominated by switch grass and Canada wild rye. Weaver (1954) estimates that from 20 to 30 per cent of the Red River area was covered by this community. Associated with these grasses are the big bluestem and slough grass communities as well as a number of forbs common to the other two lowland communities.

On the higher, coarse-textured ground, along the front of the Manitoba escarpment, soil water is less abundant. On these sites upland communities of the true prairie develop, the most widespread being the needle grass community. It is a community of more drought-resisting grasses dominated by needle grass (*Stipa spartea*), a grass with foliage fifteen to thirty-six inches high; in this community it is associated with other stipa grasses, little bluestem, June grass, side oats gamma (*Bouteloua curtipendula*) and western wheat grass (*Agropyron smithii*). A number of forbs are associated with these grasses on the drier sites. Especially numerous in Manitoba are: lead plant (*Amorpha canescens*), stiff sunflower (*Helianthus laetiflorus*), smooth golden rod (*Solidago missouriensis*), silver-leaf psoralea (*Psoralea agrophylla*), western red lily and wild prairie rose.

Along the river courses, on the narrow valley slopes and flood-plains in the true prairie, ribbons of forest develop. The American white elm (*Ulmus americana*), in a natural state, is confined almost exclusively to the river valleys of the prairie, and is associated with a number of other trees which occur with approximately equal frequency, namely; Manitoba maple (*Acer negundo*), basswood or linden (*Tilia americana*) and green ash (*Fraxinus pennsylvanica var. subintegerrima*). Several varieties of willows commonly form a low thicket along the borders of the streams.

The Mixed-grass Prairie

In Manitoba, the prairie to the west of the first prairie level is the so-called mixed-grass prairie. This vegetation type forms a great arc from southern Manitoba through Saskatchewan and Alberta around the dry grasslands of southwestern Saskatchewan and southeastern Alberta. The mixed-grass prairie climax is the product of a dry climate intermediate between that of the short-grass and true prairie. This grassland consists of a mixture of short grasses from 6 to 18 inches high at maturity and mid-grasses with a height of 2 to 4 feet at maturity. The dominance of the mid-grasses gives this prairie a different appearance from that of the more sparse and shorter grass cover of the drier areas of southwestern Saskatchewan and Alberta.

Almost all the grasses of the short-grass prairie are present in this vegetation type, although they occupy much less of the cover. A few of these grass types are of a xeric nature not to be found in the mixed-grass prairie.

The common shrubs and forbs of the short-grass prairie such as pasture sage (*Artemisia frigida*), broomweed (*Gutierrezia diversifolia*), silver sage (*Eurotia lanata*), Nutall's atriplex (*Atriplex nuttallii*) and hoary sagebrush (*Artemisia cana*) are uncommon and are confined to very dry sites in the

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mixed-grass prairie. Furthermore, a number of grass species of the mixed-grass prairie are absent, or very rare, in the short-grass prairie. These include needlegrass, northern wheatgrass, awned wheatgrass (*Agropyron trachycaulum var. unilaterale*), rough fescue (*Festuca scabrella*), little bluestem and green needlegrass (*Stipa viridula*).

There is a wide variety in site conditions within the sandgrass (*Calamvilfa longifolia*) vegetation type, hence, a number of different communities are present. On upland areas with sandy loam soils speargrass and blue gamma grass (*Bouteloua gracilis*) are dominants, whereas on the clay loams of more restricted drainage, speargrass and western wheatgrass (*Agropyron smithii*) are the most important of the grasses. On heavy clay lowlands northern wheatgrass or blue joint alone is the dominant, and in places forms pure stands. The sandy soils usually develop a grass community dominated by speargrass and sandgrass. Certain areas with strongly alkaline soils support halophytic grasses such as alkali grass (*Districhlis stricta*), Nuttall's alkali grass (*Puccinellia nuttalliana*) and cordgrass.

A number of forbs achieve considerable importance. On well-drained sites the involute-leaved sedge (*Carex eleocharis*) and the sun-loving sedge (*Carex pennsylvanica var. digyna*) are the most abundant. On the lower, moister areas near sloughs, the sedges (*Carex atherodes*) and (*Carex rostrata*) are encountered. The Baltic rush frequently borders the sloughs.

Shrubs and low tree forms add variety to the mixed-grass prairie. Western snowberry (*Symphoricarpos occidentalis*) and several species of roses are common to upland sites. On porous soils, such as those of the great sandhills of Saskatchewan, the deep-rooted chokecherry create a cover up to 15 feet high. The low bush wolfwillow (*Elaeagnus commutata*) is found in areas near sloughs, frequently backed by a shrub-form of poplar (*Populus tremuloides*).

The mixed-grass prairie displays a rich and varied flora, but possesses a unity based on the dominance and height of the grasses.

The Short-grass Prairie

A rough triangle based on the Canadian-United States border and having its apex on the Alberta-Saskatchewan border outlines the short-grass prairie of Western Canada. This semi-arid grassland is sometimes wrongly referred to as the 'Palliser Triangle'. Palliser included much of the mixed-grass prairie in the area he considered ill-suited to cultivation.

This vegetation type is dominated by short-grass species, and the mid-grass species which do occur are considerably shorter than they are in the neighboring mixed-grass prairie. The most common grass is the blue gamma grass (*Bouteloua gracilis*), which, according to a study made at the Experimental Farm at Swift Current, Saskatchewan, occupies, on the average, some 37.8 per cent of the total cover (Clarke *and others*, 1947). Common speargrass, a mid-grass, is an important constituent of this plant association which includes western wheatgrass, northern wheatgrass and June grass. The short grasses, Sandberg's bluegrass (*Poa secunda*) and niggerwool (*Carex filifolia*) are also important species. Grasses dominate the vegetation type, and form some 82 per cent of the cover (Clarke *and others*, 1947).

The sages and other xeric plants which occur only on excessively dry sites in the mixed-grass prairie in this vegetation type, assume a role of much greater importance, and the common cactus (*Opuntia polyacantha*) occurs frequently. The sparseness and shortness of the vegetation cover and the occurrence of marked xerophytic species such as pasture sage and cactus was noted by many of the land surveyors operating in this area.

Clarke, Tisdale and Skoglund measured the proportion of cover contributed by various species in several hundred square metre quadrants. They found the most abundant species of grass to be blue gamma grass and common speargrass. Others found to be important are western wheatgrass, June grass, Sandberg's blue grass, and niggerwool. These six grasses comprised 80 per cent of the cover. The most common forbs are pasture sage and dwarf phlox (*Phlox hoodii*). This information was derived from measurement on various sites, and represents an average condition throughout the vegetation type. Variations in site cause a change in composition and one can recognize several communities within the vegetation type.

On shallow soils of eroded uplands, blue gamma grass is the dominant, and common speargrass is very rare. On the deeper upland soils with better soil moisture conditions, common speargrass is the dominant. The coulee bottoms are usually lined with willows, especially the sandbar willow (*Salix interior*), and cottonwood (*Populus deltoides*) is frequently scattered along the river valleys. In poorly drained meadows or around sloughs the spike rush (*Eleocharis palustris*) and Baltic rush abound.

Most of the species involved in this vegetation type are well adapted to the aridity of the area. The dominants are low-growing perennial grasses

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with extensive and finely branched root systems. Plants with more exposed perennial portions such as shrubs and bushes are normally confined to sites where soil moisture conditions are better than average.

The principal non-grass forms are low-growing perennial forbs and dwarf shrubs, most of which exhibit reduced leaf surfaces, abundance of epidermal hairs and other xeromorphic features.

The annual growth cycle of most of the grasses is well suited to the climatic conditions. Most of the species begin growth early in April and develop rapidly during the relatively favorable period, April, May and June. Plant development is, in most cases, complete by July 1st. The period of marked moisture deficiency is mid-summer, and by this time the grass growth is largely completed. The grasses dry or cure when soil moisture is exhausted, and the plant is essentially at rest so far as the production of new growth above the surface is concerned.

As demonstrated by A. H. Laycock (unpub. ms.), the short-grass prairie is an area of great variability in moisture conditions. In the past, series of moister than average years have led to incursions into the area by grain growers, with disastrous results when moisture conditions returned to normal or below normal. At present, the area is devoted largely to grazing and is most suited for that use. The cured grasses remain erect, providing good fodder for livestock until snow cover forces supplementary feeding.

The Submontane Mixed Prairie

This vegetation type occupies a narrow band along the foothills of the Rocky Mountains and also covers parts of the Cypress Hills and adjacent hill country. Its presence is a reflection of better soil-moisture conditions than are present in the mixed-grass prairie. These moisture conditions are associated with the lower evaporation rates due to the cooler summers of the higher areas and somewhat higher precipitation of the foothills and Cypress Hills.

The submontane mixed prairie is sometimes termed the festuca-danthonia association after the dominant grasses, rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), Parry's oatgrass (*Danthonia parryii*) and wild oatgrass (*Danthonia intermedia*). Associated with these grasses, June grass and awned wheatgrass occupy minor roles. Several other grasses occur but never in abundance; among these are: nodding wild rye (*Elymus canadensis*) and marsh reedgrass (*Calamagrostis canadensis*). Blue gamma grass and common speargrass, characteristic of the short-grass prairie are not present.

The most abundant forb is the shrubby cinquefoil (*Potentilla fruiticosa*); this species is invariably present, and, in places provides an almost complete ground cover.

Along the coulees and in minor draws on the north slopes of hills, aspen, willows and wild roses are often abundant.

The Aspen Grove and Aspen-oak Grove

These vegetation types form a transition between the treeless grasslands and the closed boreal forest and consist of grasslands dotted with clumps of trees. The trees are principally aspen (*Populus tremuloides*) over most of the zone; however, in the southeast, the bur oak (*Quercus macrocarpa*) becomes important along with aspen. For this reason, two vegetation types are recognized: the aspen grove and the aspen-oak grove. In the Canadian West the term parkland is used for the two types.

As these types are transitional between grassland and forest they possess characteristics similar to those of the boreal forest formation and of the grasslands. The strong summer water deficiency of the mixed-grass prairie and the short-grass prairie is apparent within the parkland. The soils are dark brown to black grassland types, and the area covered by grassland is greater than that covered by trees. Accordingly these vegetation types are included within the grassland formation.

This vegetation type consists of a mixture of grasses and copses or groves of trees. The most important tree is the trembling aspen (*Populus tremuloides*), which, in places, forms virtually pure stands. Towards the margins of the boreal forest, aspen occupies an increasingly larger part of the surface, until along the boreal margin the grassland openings become small and rare. Towards the prairie margins, the tree copses are small and widely scattered.

On the drier tree sites bur oak is associated with the aspen. In places, especially along the crests of ravines, steep river slopes and shale knolls, the oak is dominant. Examples of such areas are the steep slopes of the Pembina River valley in southern Manitoba and along the shaly hills of the Manitoba escarpment. This oak occurs occasionally on alluvial flats, and on these sites, attains a height of nearly 70 feet and a diameter of 3 feet. Much more typical is the scrubby form of the more xeric sites. The tree is much sought for fence posts because of its great durability, and over much of its range its numbers have been greatly reduced.

Along stretches of alluvial soils where drainage is restricted, the white elm, basswood, green ash and Manitoba maple are associated with the poplar and oak. This river flat community is found throughout the association.

The regional atmospheric climate appears to be at a balance between grassland and forest tolerance, so that locally dry sites are in grasses and less well-drained places, if not saline, are occupied by a limited development of specific native trees.

Within the aspen-oak vegetation type, the sites which favor tree growth rather than prairie growth are as follows:—

(a) sites of locally moist atmospheric conditions due to higher altitude resulting in lower summer temperatures and higher moisture effectiveness,

(b) sites of locally humid soils or soils with more than regionally normal moisture such as found in northeast exposures of hills, ravines and river flats,

(c) in snowtraps, such as depressions and ravines,

(d) in low spots in the prairie where run-off collects and where the water table is higher, and,

(e) sandy areas with moist substrata.

The dry exposures of hills (i.e. south and west exposures) in areas of thin or eroded soils and highly alkaline areas, are normally in grass.

The Aspen Grove

This association is essentially the same as the aspen-oak grove vegetation type except for the absence of the bur oak. It consists of clumps of aspen scattered over the true prairie. The same site types as in the aspen-oak grove are conducive to tree growth.

The size of the aspen varies from the prairie margins to the boreal margins of the vegetation type. On the prairie side the normal grove consists of aspen a few inches in diameter and up to 12 feet high. The trees in these groves are virtually all young trees. This is a reflection of the high mortality rate of trees near the prairie margin. Doubtless drought is a major cause of tree death, but other factors play a role. Bird (1930) points out that at the peak of their cycle, rabbits kill thousands of young aspen by girdling them in winter.

The copses of young aspen frequently have an understorey of shrubby growth composed principally of snowberry (*Symphoricarpos albus*), hazelnut, chokecherry and wild roses.

Towards the boreal forest, the percentage of the total cover represented by aspen increases greatly. Over much of its northern margin, this vegetation type might well be described as aspen forest with prairie openings. Practically pure stands of aspen cover large stretches of the country. The trees attain a height of up to 55 feet and a diameter of about 18 inches at waist level; they tend to be very closely spaced and present a branchless trunk up to 30 feet or so.

The aspen has provided fuel and fencing over thousands of square miles of the Canadian West. The species is not well suited for either purpose, but in the absence of other species has been a great boon to the prairie settler. A few good copses of aspen on a section of land made it preferred land for settlers.

An understorey of low bushes 4 to 5 feet high normally is associated with the aspen on the boreal margin of the association. The chief species involved in this understorey are: hazelnut, (*red-osier*) dogwood (*Cornus stolenifera*), high-bush cranberry (*Viburnum trilobum*), roses, chokecherry, and snowberry.

Numerous herbs also occur in the understorey, principal among them being: sarsaparilla (*Aralia nudicaulis*), wintergreen (*Pyrola asarifolia*), mayflower (*Maianthemum canadense*), Solomon's seal (*Smilacina stellata*) and strawberry (*Fragaria virginiana*).

The prairie openings are usually classified as communities of the true prairie, and the chief dominants are the wheatgrasses (*Agropyron sp.*). However, others are important, principally speargrass and June grass. On some of the drier sites of Saskatchewan and Alberta, blue gamma grass is a dominant.

THE FOREST FORMATION

A number of forest types border the area with which this study deals, or form fingers penetrating the area, or isolated forest islands within it. These forest types are: the mixedwood forest, the Manitoba lowlands forest and the subalpine forest. This division of the forest is after Halliday, who divides the forest into types based on a broad uniformity of composition within each type. This does not mean that differences in site within a forest type do not involve a difference in vegetation, but on the same site type within any one class, the same vegetation response is normally apparent. Halliday recognizes several forest regions within the forest formations of Canada. Within each of these he normally discerns several forest types which may be termed associations according to the definition of the term used in this study. The forest region is a useful classification for describing the forests of Canada, but for limited areas it is a complicating factor, so in this paper the breakdown used for grasslands will be used, i.e. the formation (forest) within which a number of vegetation types or associations are recognized.

The Mixedwood Forest

In general, the mixedwood forest forms the northern boundary of the area studied. However, on higher areas, such as Riding Mountain, it penetrates far south into the prairies and aspen parkland. The occurrence of the mixedwood forest far south of the main belt is due to higher elevations which duplicate the climatic conditions along the northern margins of the parkland.

The mixedwood forest derives its name from the fact that it is composed of a mixture of coniferous and deciduous species. The two dominants are representatives of two tree types; white spruce (*Picea glauca*) and aspen (*Populus tremuloides*). Other tree species of importance are balm of Gilead or balsam poplar (*Populus balsamifera*), paper birch (*Betula papyrifera*), balsam fir (*Abies balsamea*), jackpine (*Pinus banksiana*), black spruce (*Picea mariana*) and tamarack (*Larix laricina*). It is the presence of the coniferous element which sharply distinguishes this forest type from the parkland.

Within this vegetation type, a number of communities have developed. Over much of the area repeated fire makes any discussion of climax communities a problem, but sufficient untouched forest remains to describe the communities.

On porous soils only two species, jackpine and white spruce, contribute significantly to the tree cover. The aspen, paper birch and black spruce, are poorly adapted to droughty sites and fir, balsam poplar and tamarack are entirely unsuited and never appear. Jackpine on sandy soils is frequently the dominant, and this is the only site where it assumes any great importance.

Along the southern margins of the mixedwood, the white spruce competes with prairie grasses on the sandy soils of kames, eskers, old beach ridges and deltaic deposits. The jackpine, although assuming importance within the mixedwood on sandy soils, very rarely is able to invade prairie openings on sandy soils along the southern margin of the mixedwood. Frequently single white spruce of considerable age are found in the prairie openings; these represent invasions of the grassland in wetter years. The seeds of these trees, however, were unable to germinate in normal or drier than normal years.

On deep, comparatively warm soils, the aspen is frequently dominant, and is normally associated with white spruce, balsam poplar, and birch. The aspen is a prolific producer of light airborne seed, and, hence, rapidly invades fire-cleared areas of deep, warm soils. The species, because of its pioneering ability after fire, is often called the fire tree. It matures very rapidly, and, in the mixedwood, reaches a height of close to 100 feet and attains a diameter of some 20 inches at waist height. On these areas white spruce and other important trees of the community rarely pioneer a site. They are preceded by aspen and less frequently birch. The mixedwood has suffered so severely from fire that many of the upland sites are clothed in the pioneer aspen. Frequently it may be observed, however, that young white spruce are coming up under the aspen crown, and if undisturbed by fire will become an important element in the cover, even achieving a role of dominance. On well-drained sites, the white spruce of the mixedwood reaches merchantable timber size. Heights up to 125 feet are common and diameters of 18 to 35 inches at waist height are attained.

The moderately dry sites are clothed in a poplar, white spruce, jackpine community. Jackpine is usually a lesser dominant.

Wet organic soils usually have a sphagnum, black spruce, tamarack community. The typical bog is a sphagnum bog with an inner rim of tamarack and an outer rim of black spruce. Both tamarack and black spruce are moisture-loving species, and are very tolerant to acid organic soils.

On very moist mineral soils, such as are found on flood-plains of rivers, the balsam poplar may form pure stands.

Manitoba Lowlands Forest

This forest type occupies the eastern part of the Lake Agassiz plain, and forms the eastern boundary of the area under study. The plain has a gradual slope towards the northeast, and is crossed by low ridges at right angles to the northeast slope. Hence the surface is characterized by low parallel gravelly ridges with swampy depressions between. The general levelness of the Agassiz plain and the thinness of the lake deposits over the bedrock in it eastern section makes for poor soil drainage except on the gravel ridges.

Two communities repeat themselves over and over again across this plain. The depressions are characterized by sphagnum bogs rimmed with tamarack and black spruce, and the gravelly ridges have a community dominated by jackpine. In the south, a few bur oak may be associated with the jackpine and in southeastern Manitoba an area of sand hills is clothed in almost pure stands of jackpine. Within this area, the sandilands forest reserve, black spruce, tamarack and poplar occupy some wetter depressions. Also in the area are a few scattered red pine or Norway pine (*Pinus resinosa*). These occurrences mark the westward limit of this species.

The alluvial soils along the rivers, especially in the south, have good stands of aspen and balsam poplar.

The Subalpine Forest

In the foothills of Alberta and forming the western boundary of the area under study lies the subalpine forest. In places, this forest type joins the prairie directly, but normally a narrow zone of parkland clothes the middle altitudes of the foothills and separates it from the prairie. The subalpine forest commences at approximately 4,000 feet and reaches its upper limit at the tree line. Small outliers of this forest type exist in the higher sections of the Cypress Hills.

The dominant trees are lodgepole pine (*Pinus contorta*) and Engelmann spruce (*Picea Engelmanni*). Large sections have been burned and these are usually occupied by lodgepole pine almost exclusively.

In parts of the foothills of southern Alberta, some blue Douglas fir (*Pseudotsuga taxifolia*) is associated with Engelmann spruce, and, towards the upper limits of the forest type, alpine fir (*Abies lasiocarpa*) and white-bark pine (*Pinus albicauli*) become associated. The Forestry Branch of the Department of Northern Affairs and National Resources recognizes this later association as a distinct forest type, the douglas fir and lodgepole pine section of the montane forest region.

SUMMARY

The foregoing descriptions of the natural vegetation types of the southern Great Plains of Canada were prepared on the basis of observations which took place over several years and from the extensive literature on the flora of the area.

The map of natural vegetation types was constructed, in large part, on the basis of verbal descriptions of the plant cover found in the reports of the original land surveyors. Further vegetation information was extracted from the maps of the land classification surveys. The information gained from the land surveyors' reports was gathered before white settlement greatly disturbed the natural flora. In those areas where the land classification maps were the chief source of information, only a small percentage of the areas had been ploughed. Since the precise ecological role of the North American Indian is impossible to determine, the patterns portrayed on the map are as close to undisturbed or natural patterns as is practicable.

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FORMER ICE-DAMMED LAKES AND THE DEGLACIATION OF THE MIDDLE REACHES OF THE GEORGE RIVER LABRADOR-UNGAVA

*J. D. Ives**

ABSTRACT: A combination of field work and air photo interpretation forms the basis of this paper which is a study of the glacial features of the middle George River and the plateau country on either side. Particular emphasis is placed upon a precise survey of the extent and tilt of a spectacular series of glacial lake shorelines. The extrapolation of the data obtained by parallax methods from this survey allowed for the coverage of a much larger area than could be covered on the ground. The glacio-fluvial and glacio-lacustrine features are interpreted in the light of existing topographical knowledge of the northeastern sector of the peninsula and this allows the broad outlines of the deglaciation to be drawn. It is concluded that glacial lakes, hundreds of miles in extent, were dammed between the Atlantic watershed and ice masses to the west and north. Ungava Bay was occupied by a large mass of ice in late-glacial time.

The George River drains the eastern sector of the 'lake plateau' of Labrador-Ungava, rising a few miles north of Lake Michikamau and following a northerly course for almost 300 miles to discharge into Ungava Bay. The estuary was discovered in 1812 by the Moravian missionaries Kmoch and Kohlmeister; John McLean, of the Hudson's Bay Company, travelled the river in the mid-century in his overland journeys between Ungava Bay and Hamilton Inlet, and for a short period a trading post was maintained in the middle section, although soon abandoned because of difficulty of access. After the turn of the century Mrs. Leonidas Hubbard and Dillon Wallace led separate canoe parties downstream from Lake Michikamau to the settlement of George River on the estuary. From Mrs. Hubbard's account the first reliable descriptions of the George River were obtained. Its headwaters consist of a series of irregular lakes connected by short passages of swift-flowing water. The stream quickly gathers size and momentum, however, and 80 miles from its source it is a considerable, rapid-strewn river flowing in its own valley. Downstream a further 50 miles its main tributary, Rivière de Pas, enters from the west; 5 miles north of the confluence the combined streams widen out into Indian House Lake. The lake has a greatest width of less than 3 miles, extends northwards for 60 miles, and is surrounded by 900-foot hills. Beyond this it becomes a series of rapids, often contained within gorges.

*Field Director, McGill Sub-Arctic Research Laboratory, Schefferville, Que. This report forms part of the central Labrador-Ungava survey carried out in 1958 by the Geographical Branch.

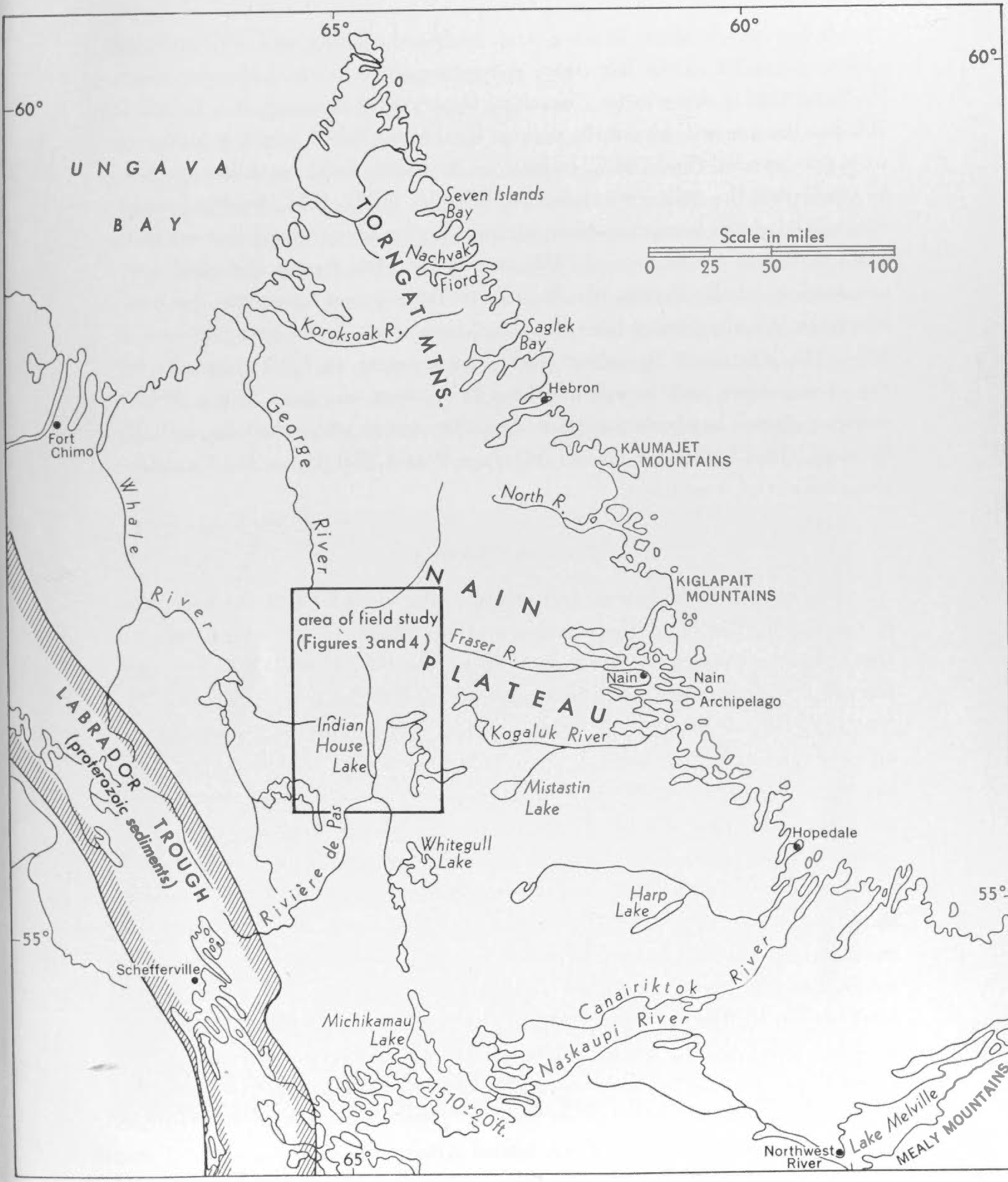

Figure 1. The northeast sector of the peninsula of Labrador-Ungava showing location of field study and major geographic features referred to in the text.

Secteur NE de la péninsule du Labrador-Ungava montrant la situation de la région étudiée et les grands traits géographiques mentionnés dans le texte.

A few years after Wallace and Hubbard, Cabot and Prichard led parties overland to the lake from different points on the Labrador coast. Prichard (1911) described a "beach of clear gravel elevated at a height of 700 feet (by aneroid) above the present level of the lake", which is compared with the 'parallel roads' of Glen Roy, in Scotland. Later travellers are few. In particular, the writer is indebted to Wheeler (1935, 1938) for his description of the glacio-lacustrine features seen during his overland journey from Nain to Whale River post in 1936, and to Dr. Paul Bevan (personal communication) of the British Newfoundland Exploration Company, for comments on the abandoned lake shorelines seen when flying over the area in 1954. The journey of Rousseau (1949) the botanist, in 1947 completes the list of scientists and travellers who have visited the lake. Since 1942 a weather station has been maintained on the west shore of the lake, initially by the United States Air Force, and since World War II, by the Canadian Department of Transport.

Physical Setting

The area is little-known and infrequently visited, with the exception of the supply flights to the weather station. The area is covered only by trimetrogon photographs flown in 1948 by the RCAF at 21,000 feet, and the best base map available is on a scale of 1:506,880 with form lines of 500-foot intervals sketched from radar profiles. Geologically and geomorphologically, the area has received no detailed attention. Indian House Lake lies some 75 miles east of the Precambrian sedimentaries and volcanics of the Labrador Trough in the Archaean sector of the Canadian Shield. The bedrock composition is unknown in detail but in general may be described as a suite of granitic gneisses and schists of sedimentary and igneous origin. Basic intrusions of diorite, diabase and anorthosite have been reported in the headwater section of the George River, but only minor dykes and sills were encountered in the field in the Indian House section. The minor relief features are closely controlled by the structure, joint patterns, faults and foliation. The foliation of the gneisses trends slightly west of north and north-south ridges and vales are conspicuous. Major scarps and lake lineaments are probably related to fault-lines and the great depression of the George River itself may be tectonically controlled (Cooke, 1929).

The major relief features are the erosion surfaces which clearly exist independent of structural control. The Ungava Bay-Atlantic Ocean divide is generally indeterminate, lost in a maze of lakes and streams that occupy a broad upland area, referred to here as the Nain plateau. The summit of the plateau attains a height of close on 2,500 feet above sea-level near the Labrador coast and falls gradually westwards. Elevation in the George River area is 1,650 to 1,800 feet above sea level, with a few low monadnocks rising higher; it slopes gradually westwards into the Whale River depression. Various writers, and especially Tanner (Tanner, 1944; Cooke, 1929), have referred to the great uplifted block of the northeast sector of Labrador-Ungava which is described by them as bounded on the west by a major topographical and structural break. This break is said to have formed the western limit of the Torngat Mountains and to have followed a southerly trend represented by the general course of the George River. The writer does not subscribe to this theory, as, in the Abloviak and Koroksoak sections of the Torngat Mountains (Ives, 1957 and 1959a), the summit surface can be seen to pass without a break westwards to fall beneath the level of Ungava

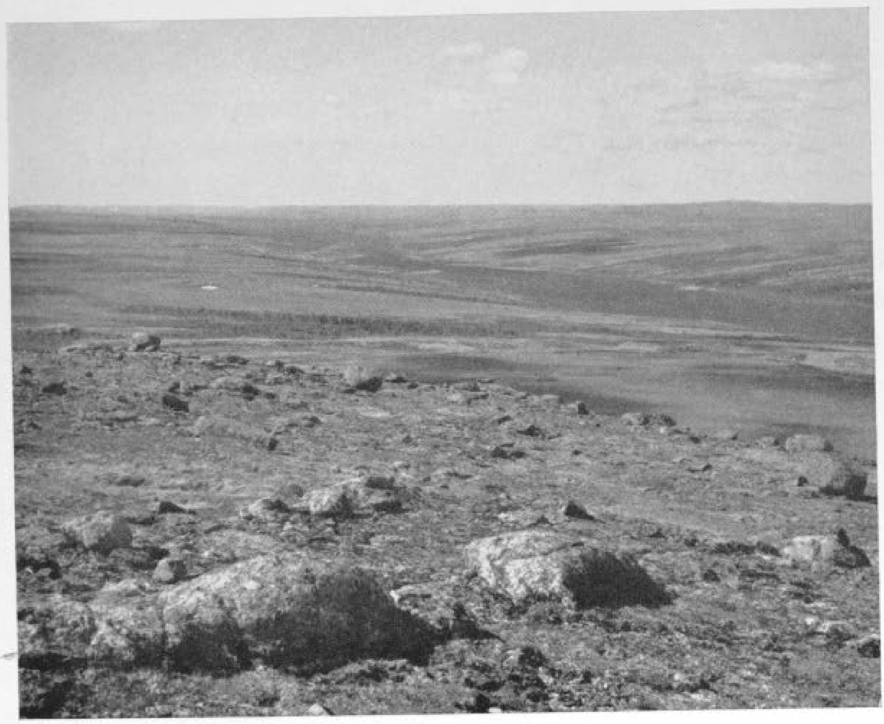

Figure 2. Looking northwards from the summit of 'High Bluff' across the northern section of Indian House Lake. Note the even nature of the skyline which passes over the lake trough without a break.

Vue vers le N, prise du sommet du 'High Bluff' et montrant le secteur N du lac de la Hutte-Sauvage. A noter la régularité de la ligne d'horizon à l'arrière-plan de la dépression du lac.

Bay. Similarly, in the Indian House Lake area the skyline, viewed carefully from numerous vantage points, passes across the river trough without a break (Figure 2), except, of course, for the trough itself which is cut into it. This major erosion surface is certainly warped, and probably broken in places, but its continuity across the entire area of study appears to be its main characteristic. The age of this erosion surface is not known, although it is probably very old and may have been exhumed. Nearer the Atlantic coast it is only slightly dissected, although the river gorges, notably those of the Fraser and Kogaluk rivers, make great incisions for distances of up to 60 miles from the coast. The sharp-cut nature of these gorges indicates that they are relatively recent features (late Tertiary: *see* Cooke, 1929, and Tanner, 1944). The George River trough is cut into the summit surface to a depth of 900 feet and has formed the local base level for a second erosion cycle which has resulted in the development of a sub-mature landscape in the vicinity of the main stream. This dual cycle effect provides a rolling upland topography in the main area of study and it is only as the watershed is approached that large, undissected sections of the summit surface occur. This surface is referred to by the Eskimo as 'sikkoyavik'—'level like the land-fast sea ice'.

The major elements of the landscape have played important parts in both glaciation and deglaciation. Rolling hill country rising gradually eastwards and becoming high plateau country east of the watershed provided the base upon which the last Pleistocene ice sheet rested, and upon which it wasted back from the Labrador coast. Important also are the George River trough, the generally low country west of the river, and the relatively low col between the Ungava Bay drainage system and the Naskaupi and Hamilton river systems. Unfortunately, no precise topographical data exist, although widely spaced radar profiles give a useful guide; Wheeler's* aneroid estimate of the height of Indian House Lake above sea level, an estimate which he carried overland from Nain, has not until now been seriously challenged. These obscurities in the topographical control have been described in some detail because they have an important bearing upon the over-all interpretation of the evidence of the glacial lake shorelines discussed later in this report.

*Personal communication dated March, 1958, in which Wheeler gave an aneroid estimate of 890 feet for the lake in 1936. Radar spot heights are scattered between 960 and 995, the mean of 980 being used in the present report.

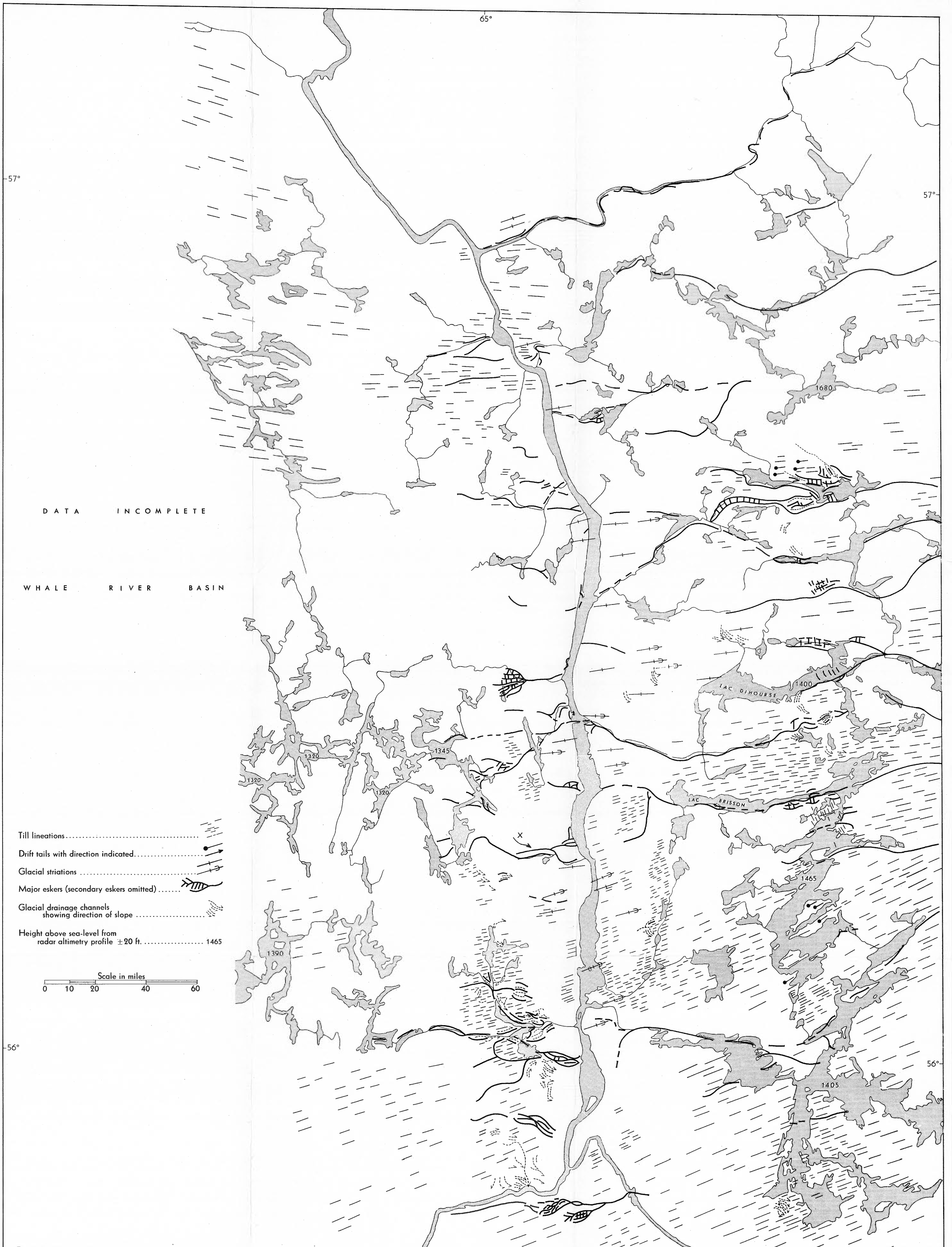

Figure 3. The area of the field study showing the complex of glacial lake shorelines.
Complexité du tracé des rives des lacs glaciaires dans la région étudiée.

Glaciation

Throughout the area evidence of large-scale glacial erosion is either indistinct or entirely lacking. Minor features, such as *roches moutonnées* striations and drift tails, are abundant, and the west sides of hills, in some instances, may have been rounded by the onset of glacial ice, in contrast to their more abrupt east faces. Glacial modification of east-west valleys and cols is more evident, but again, relatively slight.

Lack of evidence of large-scale glacial erosion is to be anticipated in an area which has experienced continental rather than local glaciation, where the relief is relatively slight, and where the major features trend across the direction of ice movement. That ice moved across the area, however, is readily apparent, and the glacial trends are plotted in Figure 3. Throughout the north-south distance of 60 miles the trend of striations and *roches moutonnées* shows a remarkable parallelism. Variation from north 50° east to due east represents the maximum range and the ice appears to have passed somewhat obliquely across Indian House Lake without having suffered any marked deflection. Erratics of Proterozoic volcanics and dolomite were discovered amongst the preponderance of gneissic and basic intrusive blocks and probably originated 75 miles west of the area in the 'Labrador Trough'. Drumlinoid features and small-scale lineations are abundant, especially on the higher plateau areas and, apart from zones of slight divergence and convergence, they follow the trends represented on the bedrock.

The consistency of trend and the far-travelled nature of the Proterozoic erratics indicate that the entire area was deeply mantled by ice which moved outwards from the central lake plateau area towards the Labrador coast. The writer has examined air photos for more than 40 miles west of the George River, and does not question the drumlin pattern depicted on the Glacial Map of Canada (Wilson, 1958), but it is the interpretation of the flow pattern with which the writer takes issue. Certainly the area under study lies to the east, or along, the ice-divide shown on the glacial map so that the general easterly flow, indicated in Figure 3 is not necessarily contradictory. On the other hand, it seems likely that erratics have been moved from the Labrador Trough across this 'divide'. The evidence is slight, especially as the geology of the intervening area is virtually unknown.

Deglaciation

Evidence of the full sequence of events from active flow to final disintegration of glacier ice is rarely obtainable from a single area and invariably

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some aspects are much more complete than others. In this instance emphasis is placed upon evidence associated with the existence of a complicated and major series of glacial lakes, although a variety of glacio-fluvial features is also discussed because of their bearing upon an appraisal of changing conditions attendant upon glacial wastage.

ESKERS AND ASSOCIATED FEATURES

The distribution of the major esker systems is indicated in Figure 3. Major ridges trend easterly across the area to form a sub-parallel pattern comparable with the till lineations and other flow features that were formed before them. The most significant fact is that the George River trough has had little effect upon the process of their formation, and they appear to cross the trough almost perpendicular to its trend. The presence of the trough produced only minor modifications upon the eskers which generally follow the floors of the major tributary valleys, passing directly across the floor of Indian House Lake to ascend the nearest east-facing tributary. On several occasions east and west tributaries reach the lake directly opposite each other, and in these cases the general course of the esker is unmodified, even in detail, and the sub-lacustrine sections are continuous (Figure 4). Sub-lacustrine sections of the eskers were detected during the sounding of sections of the lake. Where there is no east-shore tributary opposite the mouth of a west-shore stream, the eskers either die out in a pitted sand plain, or else their courses are off-set for some distance with discontinuous north-south sectors fringing the lake until they turn abruptly eastwards again along the floor of the nearest valley, through which they proceed onto the plateau farther east.

The eskers are generally of the simple, embankment type (Figure 5) and easterly bedding was observed in several places. Complications occur on steep downslopes (east-facing) where the esker ridge often becomes a reticulated net associated with an extensive pitted sand plain extending across the lower slopes. In some sectors the eskers pass through a series of roughly aligned cols in successive north-south ridges. On the steep up-slopes below the cols the eskers frequently thin out and degenerate into erosion features, particularly at the col itself, supporting the sub-glacial hypothesis of esker formation. On the plateau in the vicinity of the headwaters of rivers flowing to the Atlantic very complicated patterns are found and the "rippled till" pattern (Ives, 1956) is frequently associated with the eskers. In this sector also, the eskers tend to converge upon the major river gorges of these

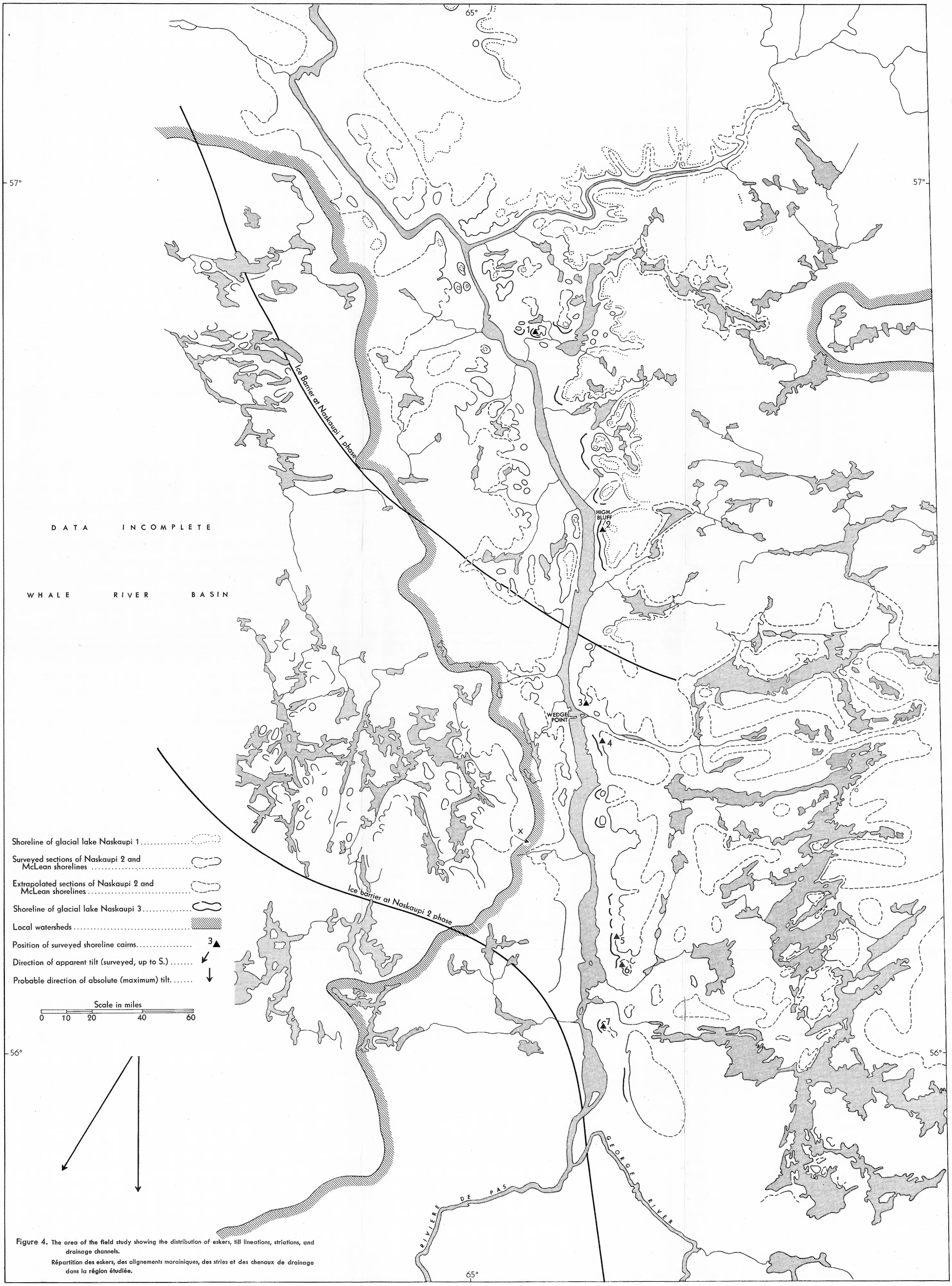

Figure 4. The area of the field study showing the distribution of eskers, till lineations, striations, and drainage channels.
Répartition des eskers, des alignements morainiques, des stries et des chenaux de drainage dans la région étudiée.

Figure 5. The Wedge Point esker is of the simple embankment type for most of its length. This view was taken looking westwards from a point 5 miles west of the lake.

L'esker de la pointe Wedge est, sur presque toute sa longueur, à bourrelet unique. Vue en direction W, à partir d'un point sis à cinq milles à l'W du lac. Le personnage indique l'échelle.

streams, notably those of the Kogaluk and Fraser rivers, which indicates the extent of sub-glacial control exerted on esker formation where the slope of the ice corresponded approximately with that of the sub-glacial topography. This is in marked contrast to the drumlin patterns which have been seen from the air to trend obliquely across the gorges as though they had been choked with stagnant ice at the time of drumlin formation, indicating the lack of control that the gorges exerted on ice movement. This conclusion is also supported by the sharp-cut nature of the walls and the V-shaped incisions which form the heads of the gorges. It is in direct contrast to the effective control on basal flow exerted by the Torngat troughs where the modifying effects of the ice on the bedrock is readily apparent.

It is generally agreed that eskers were formed along the 'line of least resistance' and the lack of control exerted by the George River trough implies that the ice in the northern section of the trough was thick enough

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and compact enough (?) to withstand penetration by sub- or en-glacial melt-waters.

GLACIAL DRAINAGE FEATURES

Generally distinct from the major eskers, channels and terraces eroded by glacial melt-waters are found throughout the higher land of the Nain plateau, and represent a phase of deglaciation contemporaneous with, or subsequent to, that of esker formation. The channels are principally of the lateral and sub-lateral variety (Mannerfelt, 1949) and usually occur on hillsides in groups of less than twelve. Their direction of slope has a strong easterly component, variations from this resulting primarily from topographical control on the former margins of the wasting ice mass. Vertical spacing is fairly regular and of the order of 20 to 25 feet and, in contrast to the channels in the Helluva Lake area north of Schefferville (Ives, 1959b and 1960), these are simple channels and terraces in sub-parallel sequence with few tributaries and with a mean gradient of 1:140. They provide an indication of the regional direction of slope of the ice, the possible rate of annual ablation, and the mode of emergence of the higher land from the glacial mantle.

Detailed examination of a number of selected localities appeared to indicate that the regional inclination of the ice surface at the time the channels were formed was somewhat south of west. One of the most revealing localities in this respect was a high basin situated 8 miles east of Wedge Point. The basin was open to the south, and the steep easterly ridge was breached by two broad cols, the northerly col being the higher of the two. A series of glacial drainage channels and terraces was traced southwards along the west face of this ridge, the higher ones passing through the northerly col, the lower ones through the southerly col, and so across the ridge to the east. Immediately below the level of each col were sections of lake shoreline implying the former presence of small ice-dammed lakes which formed when the marginal melt-water was unable to penetrate the nearest col once the ice margin had fallen below its level. From an examination of these features and the general topography it was possible to estimate that the ice surface sloped upwards south, 65° west. Similar occurrences in neighboring areas gave the same approximation.

Study of the slope and distribution of the glacial drainage features seemed to indicate that the higher land near the coast first emerged from the inland ice, and that even at this stage the regional snowline was above the surface of the land, as melt-water features could be observed in the highest sectors—about 2,500 feet. Recessional moraines appeared to be entirely lacking and deglaciation appeared to have taken place primarily by down-wasting.

The glacial drainage channels and terraces combine with the eskers to indicate that the ice 'dam' in the lower George River valley was more than adequate to prevent sub- and en-glacial drainage northwards down this major drainage duct, and it is believed that the main body of the ice, except the stagnating margins, was active physically, even though it may have been moving only slowly and was climatically 'dead'.

THE ICE-DAMMED LAKES

The presence of a former extensive system of ice-dammed lakes was anticipated from earlier field work in the southwestern sector of the Torngat Mountains (Ives, 1959a). Examination of the air photos, however, revealed that glacial lakes are more extensive than was expected, and the preserved shorelines provide a major key to the study of deglaciation of the entire northeastern quadrant of the peninsula. The shorelines are seen on the air photos to cross the site of the theoretical ice-divide, and well developed shorelines extend at least from latitude 57° 30′N., southwards to the area north of Lake Michikamau. These are not indicated on the Glacial Map of Canada.

Knowledge gained from a study of the photographs largely determined the program for the 1958 field work. Lakes at many levels have definitely existed, both contemporaneously and in sequence and, in order to establish the extent of any single body, relative and absolute heights and a precise measurement of isostatic tilt (if any) were fundamental requisites. It was also realized that the field work could only be of a reconnaissance nature because the limited air photo coverage available would make correlation over wide areas impossible until large scale and reliable topographic maps were produced. Consequently, Indian House Lake was selected because it was thought to provide a datum for the levelling program, and because it allowed rapid north-south movement by water.

The Field Work

Height above lake level and an estimate of the direction and amount of tilt were initially ascertained by aneroid measurements along the northern half of the lake. Three major shorelines were observed at altitudes of approximately 700, 500 and 350 feet above present lake level and it was seen that they were tilted up towards the south by varying amounts. On account of the pronounced tilt, generalised altitudes are given for convenience of comparison. The former lakes, inferred from these shorelines, are referred to in the text as N-1, N-2 and N-3 (glacial lakes Naskaupi 1, 2, and 3). The shorelines of N-2 were by far the most extensive and well developed so that most of the levelling was confined to this series and most of the following discussion is based upon them. Precise profiles were levelled from present lake level to the N-2 shoreline on a 40-mile base along Indian House Lake, giving initially six points marked on the graph (Figure 6). From these control points sections were levelled along the shoreline for

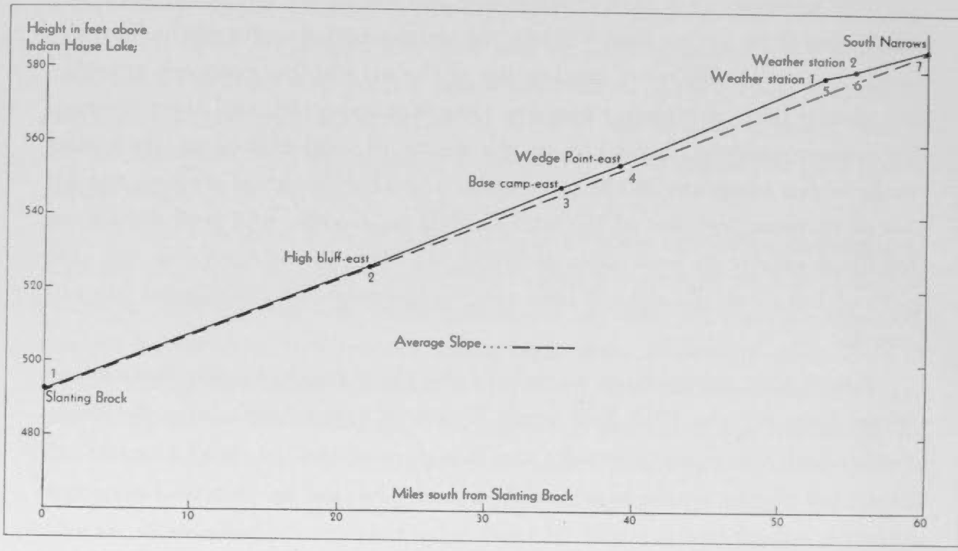

Figure 6. Graph showing the tilt of N-2 shoreline, together with the positions of the beach cairns, corrected for variations in water level and for over-all slope of lake level from S to N (3.6 feet).
Difference in beach altitude in 60 miles = 94.30 feet.
Tilt of shoreline average = 1.57 feet per mile.
Slope of lake level = 0.06 foot per mile or 3.6 feet in 60 miles.
Maximum variation from average slope = +3.5 feet.
Maximum range of variation, average slope = 4.0 feet.

Dessin graphique illustrant l'inclinaison du rivage de Naskaupi-2, de même que la localisation des cairns sur la plage; corrections faites en fonction des variations du niveau des eaux, et de la pente moyenne du niveau du lac, allant du S au N (3.6 pieds).
Dénivellation de la plage sur une distance de 60 milles 94.30 pieds.
Déclivité moyenne du rivage = 1.57 pied par mille.
Déclivité du niveau du lac = 0.06 pied par mille ou 3.6 pieds par 60 milles.
Variation maximum à partir de la pente moyenne = −3.5 pieds.
Écart maximum des variations par rapport à la pente moyenne = 4.0 pieds.

distances of up to 3 miles as a check on the computed slope (tilt). Similarly, the best developed sections of the N-1 shoreline were tied in and levelled longitudinally for computation of degree and direction of slope. Apart from the spot heights on the six initial profiles, the N-3 shoreline was ignored because of its intermittent nature, its relatively poor development, and because of limited time in the field. Rough terrain necessarily limited the amount of precise levelling, and furthermore the nature of many sections of the shorelines indicated that a high degree of accuracy would be spurious. Thus levelled cairns are believed to be accurate to within 2 inches and the calculated height of any particular beach section to be accurate to within ± 18 inches. The two aneroid stations that were most satisfactorily computed agreed to within 4 feet of the precisely levelled heights, an aneroid error of less than 1 per cent. Thus it was considered reasonable to extend the levelled shoreline base from 40 to 60 miles by incorporating aneroid heights beyond the farthest surveyed beach cairns.

From the air photos it had been assumed that Indian House Lake was one body of water on a single plane but in the field it was found to be a series of lakes connected by narrow sections of fast-moving water. Thus the lake level could not be used as an absolute datum but a precisely levelled section of the middle reaches of the George River was obtained from a survey party* in the area, from which the datum was adjusted. This survey party was not able to complete its work to tidewater on Ungava Bay, but when this is done it will be possible to obtain the absolute heights of the southern beach cairns which were tied in to bench marks established by this party.

Following the detailed levelling program trips were made eastwards from the lake onto the plateau to within a few miles of the headwaters of the rivers flowing to the Atlantic. These journeys were made in order to correlate (by aneroid estimate) isolated sections of shoreline detected on the air photos with the shorelines, N-1, N-2, and N-3. Similarly, shorter journeys were made westwards from the lake and the field work was completed by sounding the lake from a canoe.

The Extent and Character of the Lakes

Three major stages of glacial lake Naskaupi can be recognised. N-1 was traced from the northern end of the present lake southwards to the

*Quebec Dept. of Hydraulic Resources river survey party under M. Guy Beaudoin. Actual data were provided by M. Paul Pelletier consulting engineer, Montreal, organizer of the survey under contract.

vicinity of Wedge Point, beyond which it was entirely absent. Gentle drift-covered slopes and esker deposits above the N-2 shoreline were found to be mostly unwashed. Thus the presence of an ice dam was indicated, depicted on Figure 4 crossing the lake just north of Wedge Point. The northern margin of the lake at this stage is not known, although the lake extended many miles northwards from Indian House Lake, and westwards it passed over the summits of the highest hills.

The overflow of N-1 could not be detected and is believed to be far beyond the area accessible on foot. The lake level was close to that of the present height of land, about 1,700 feet. An allowance must be made for tilt, however, and it is believed that the watershed near the headwaters of the Fraser River rose a few tens of feet above the lake level. The most likely outlet appears to have been one of the headstreams of the Kogaluk River, depending on the contemporaneous status of the ice in that area.

Evidence of lacustrine activity below N-1 and above N-2 is abundant north of Wedge Point although no pronounced shorelines exist, implying that the new outlet, uncovered by continued thinning of the inland ice, was appreciably below the level of N-1 and that the water level fell rapidly for almost 200 feet. South of Wedge Point evidence of washing is found up to 50 feet above the N-2 shoreline for the first few miles, gradually falling until, within 8 miles of the postulated dam site, the N-2 shoreline marks the absolute upper limit of wave action*. This implies a relatively slow recession of the initial ice dam in the early stages and its subsequent rapid withdrawal.

The shorelines of N-2 were traced in the field for 60 miles in a north-south direction and for 45 miles east-west. The western margin was formed by a high ridge which rises a few miles back from the present lake. At the extreme south end of Indian House Lake, however, hills on the west shore which rise above the former level of N-2 carry no shorelines. This area is also conspicuous for its relative abundance of low-level glacial drainage channels and unwashed eskers (Figure 3) and it is proposed that it was occupied by ice which fronted the lake. A second large lake at a slightly higher level, referred to as glacial lake McLean (Figure 7), occupied the eastern section of the Whale River depression and spilled through a low col (X in Figure 4) into N-2. The western boundary of this lake cannot be

*Exceptions to this occur in many areas but invariably the fragmentary shorelines can be ascribed to very minor water bodies at all levels that were trapped between the down-melting ice and the emerging hills. Frequently they are associated with spillways and glacial drainage channels.

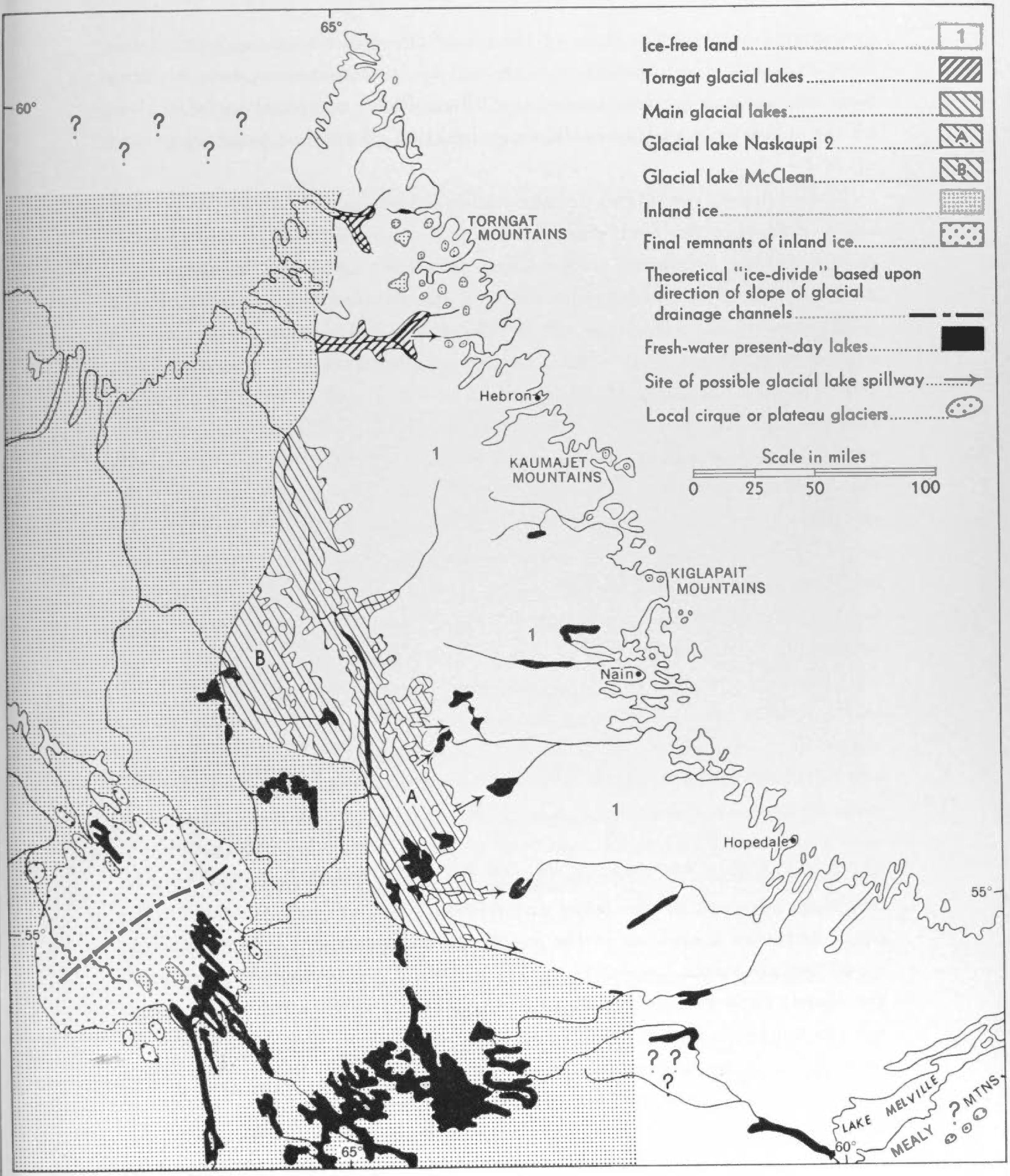

Figure 7. Northeastern Labrador-Ungava giving the more general setting of glacial lake Naskaupi-2, the inferred position of the ice barrier and the possible spillways.

Localisation approximative du lac glaciaire Naskaupi-2 dans la région du NE du Labrador-Ungava, de la position présumée du front du glacier et des déversoirs possibles.

determined because the plane of the shorelines rises above the level of the land. It clearly must have been contained by an immense ice dam trending from the western headstreams of the Whale River northeastwards to close off the entire Ungava Bay coast, a continuation of which is required to hold up N-2.

Northwards the N-2 shoreline extends at least to latitude 57° N, beyond which it has not yet been possible to continue the detailed examination of the air photos. Similarly, well-marked shorelines at about the same level as those of N-2 extend 60 miles south of the Rivière de Pas-George River confluence. If the calculated tilt of 1.57 feet per mile can be assumed to continue as far south as this, it seems incontestable that the shorelines, which extend southeast of Whitegull Lake and south of Resolution Lake, are the equivalent of N-2*. The detection of the overflow (or overflows) at this stage of the study leaves much to the imagination. Allowing for tilt, the lower headstreams of the Kogaluk, Canairiktok and the Harp Lake systems are rival claimants, while it is significant that the water plane probably would have passed over the George River-Michikamau divide, implying that this area of lower land must have carried glacier ice. Unfortunately no precise heights are available for these areas; neither is it reasonable to assume a uniform tilt.

The extent of N-3 can be estimated with even less certainty. It clearly had a shorter life than its two predecessors and it may have used for its outlet the George River-Michikamau col, or it may have spilled laterally and northwards into Ungava Bay. Following this stage it appears that the main ice dam over the present George River estuary dispersed rapidly for, with minor exceptions at the south end of Indian House Lake, no prominent beaches were detected. Once the George River was free to drain northwards, complete dispersal of the lakes occurred and the unequal isostatic uplift continued until shorelines at the south end of the present lake were raised up 60 feet above the present level. These slope down towards the north and are absent from the northern end of the lake. In other words, post-glacial tilt has tended to empty the present lake northwards. This conclusion contrasts with the hypothesis put forward by Cooke (1930) that Indian House Lake, and also Cambrian Lake on the Kaniapiskau, owe their existence to isostatic warp which displaced the extremities upwards in relation to the central section. The writer believes that the George River Lake expansions

*Since completing the text it has been possible to refer to vertical air photos and accurately contoured maps on a scale of 1:50,000 in lat. 55° N. From scrutiny of these the assumption appears to be well founded.

are largely dammed by glacio-fluvial deposits. This conclusion is supported by the fact that over 300 soundings give a range of depth from 145 feet in the lake expansions, to 12 feet in the narrows, which are located where esker systems and pitted sand plains approach the lake.

Figure 8. A section of the N-2 shoreline east of 'High Bluff' virtually coincides with the tree-line in this area.

Section du rivage N-2 située à l'E du 'High Bluff' et coïncidant avec la limite des arbres en cette région. Le personnage indique l'échelle.

The Nature of the Shorelines

Figures 8 and 9 give a good indication of the degree of development of the glacial lake shorelines in the Indian House Lake area.

The formation and preservation of shorelines of former ice-dammed lakes depend upon a number of factors, all of which have been important in the George River area:

1. Presence of an ice barrier beyond the margin of which the land rises.
2. Preservation of the status quo for long enough to allow for the development of shorelines.

Figure 9. Part of a complex recurved spit associated with the N-2 shoreline east of 'High Bluff'. View looking southwards along the length of Indian House Lake and taken from approximately the same position as that taken by Prichard in 1911.

Partie d'un crochet littoral complexe et incurvé, associé à la ligne de rivage N-2 à l'E du 'High Bluff'. Vue en direction S, parallèle au lac de la Hutte-Sauvage, et prise d'une position presque identique à la photographie de Prichard en 1911.

3. Ground characteristics.
   - i. presence of bedrock or drift.
   - ii. aspect in relation to prevailing winds.
   - iii. presence of land rising above lake level to form islands and peninsulas.
   - iv. proximity of ice barrier, climate, and presence or absence of bergs.
   - v. absence of post-formational factors leading to destruction of shorelines, e.g. solifluction.

Factors 1 and 2 occurred in a special combination to allow the development of innumerable small lakes which gradually formed into three successive large lakes. The degree of development, location, and aspect of the ensuing shorelines allow a number of deductions concerning the various points in factor 3.

Perhaps the most conspicuous factor is that the shorelines are invariably best developed on west-facing slopes. This was so pronounced that all the survey work was restricted to west-facing slopes and a comparison of Figures 10 and 11 clearly illustrates this point. Minor shoreline features, and particularly the development of spits and bars at the south end of ridges which rise above the level of the shorelines, indicates that the prevailing constructional winds were westerly and northwesterly, comparable with those of today. Almost complete absence of ice-push features and gouges, such as may be caused by icebergs being driven onshore, also assist an evaluation of conditions. It appears in the first instance that the open-water season was sufficiently lengthy to permit wave-action to destroy ice-push features. Also, the absence of iceberg gouges can be correlated with the assumption that the western boundary of much of N-2 was dry land, and that the ice dam was distant, and the lake relatively free of icebergs.

Figure 10. The shorelines as best developed on west-facing slopes. View looking east from 'High Bluff' showing N-1 and N-2 with faintly preserved sections of N-3 below.

Les lignes de plage apparaissent mieux développées sur les versants orientés vers l'W. Vue vers l'E prise du 'High Bluff' et montrant les lignes de plage N-1 et N-2; au bas de la photo, quelques sections mal conservées de la ligne de plage N-3.

Figure 11. View looking west from section of N-2 shown on Figure 10. Shoreline development is most inconspicuous on east-facing slopes. The lower slopes are mantled with secondary (sub-glacially engorged) eskers.

Vue vers l'W, prise de la section N-2 apparaissant sur la figure 10. L'évolution des lignes de plage est très peu apparente sur les versants orientés vers l'E (voir figure 10). Les pentes inférieures sont recouvertes d'eskers secondaires (dépôts sous-glaciaires).

The main shorelines are cut deeply into the steep west-facing hill slopes and have an average vertical amplitude of 15 feet. Both fore-slope and back-slope are usually lined with a great boulder barrier (Figure 12) and occasionally wave-cut cliffs occur. These latter features have usually suffered severe degradation due to frost-splitting and attendant rock falls, so that the base of the cliff, usually cited as the ideal point for altitudinal correlations, is rarely well preserved and some generalisation of altitude has been unavoidable.

These small-scale features allow only qualitative generalisations concerning natural conditions attendant upon shoreline development, the more important of which are enumerated below:

1. Initial haphazard formation of many lakes with rapidly changing levels.

2. Three distinct periods of long still-stand allowing the formation of shorelines N-1, N-2 and N-3.
3. Long open water season and relative freedom from icebergs.
4. Prevailing westerly and northwesterly constructional winds.
5. The presence of an immense ice barrier closing off the natural outlets of the George and Whale rivers.
6. Coarse material on beaches resulting in general absence of solifluction modification.

Figure 12. The foreslope of the shorelines are frequently marked by massive boulder barriers. This view shows a section of the N-1 shoreline east of 'High Bluff'.

Les versants adjacents aux rivages sont souvent recouverts de boulders. Vue d'un secteur de la ligne de plage du N-1, à l'est du "High Bluff".

The Significance of the Shorelines

The direction and amount of apparent tilt of the N-1 shoreline was measured, and is about 2 feet per mile upwards to the south; that of N-2 was 1.57 feet per mile in the same direction. As the surveyed base of N-2 is much greater than that of N-1 (60 compared with 4 miles) further discussion is restricted to the former.

Examination of the graph (Figure 6) shows that throughout the distance of 60 miles flexures or warps in the tilted surface are either absent, are compensated for between beach cairns, or else possess a north-south strike. It seems most likely that the entire area was uplifted and tilted en masse without any detectable break. The seven points on the graph fit the generalised line so closely that any deviation might be entirely accounted for by error in estimation of the position of the wave-cut cliff where it has been largely obliterated (cairn 5 is a case in point and represents the maximum deviation from the generalised line—3.5 feet). It is argued, therefore, that the computed rate of apparent tilt may be extended north and south of the surveyed section, for some distance at least, until future field work may contradict this. This will considerably assist the extrapolation over wider areas by parallax methods on the air photos and will also assist in the detection of possible spillways. This method of extrapolation of the field data is being conducted at the time of writing in order to extend the knowledge of

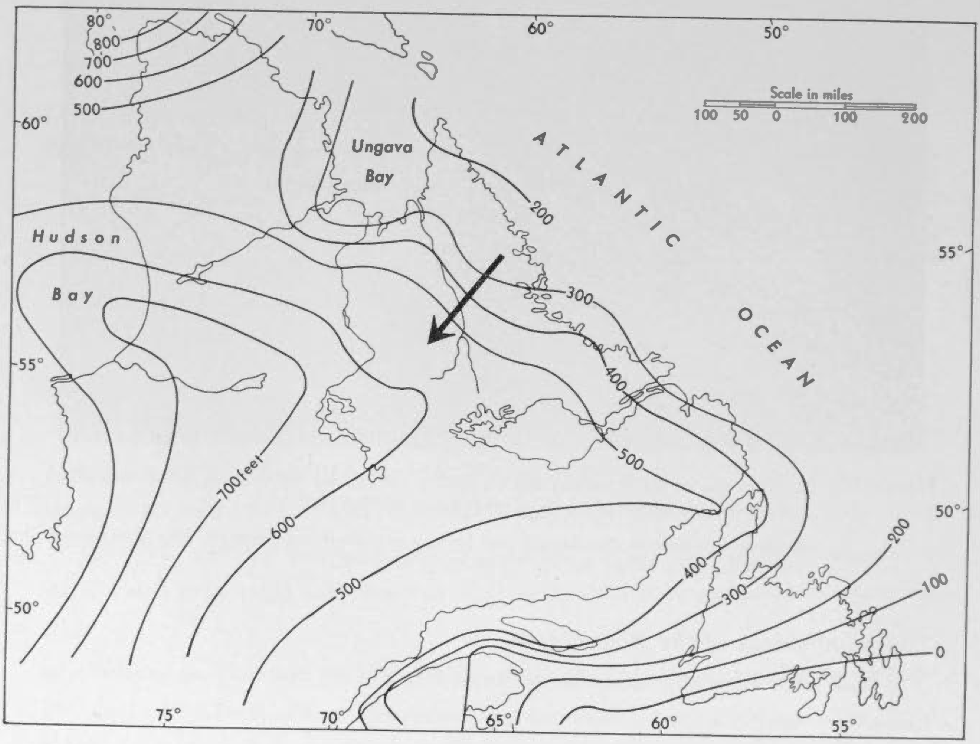

Figure 13. Lines of equal isostatic recovery (isobases) as drawn for Labrador-Ungava by Cooke (1930).

Lignes isobases indiquant le réajustement isostatique, telles que tracées par Cooke (1930), pour la région du Labrador-Ungava.

glacio-lacustrine conditions and because such work should help to isolate the more critical areas for future field work.

It is realised that the tilt has been measured only in one direction which is not necessarily the direction of maximum, or absolute, tilt, Detailed levelling revealed that the direction of absolute tilt is probably well west of south. The conclusion is drawn from the detected increase in tilt where the longitudinally levelled beach profile trended more westerly and where the corresponding decrease in tilt trended more southerly, or southeasterly. The statistics of these measurements are not presented because they are within the observational error, owing to the fact that difficulty was experienced working along a representative section of the beach, and the possibility of minor subsidence (solifluction?). Cooke's isobases are reproduced as Figure 13 (Cooke, 1930) and although these were based upon very sparse evidence, the comparison with the expected relative thickness of the inland ice on the lake plateau and the generally accepted theory of post-glacial isostatic recovery seems reasonable. These factors are taken into account in the following examination of the general deglaciation of this sector of Labrador-Ungava, but it is obvious that much more field work is required.

Emergence of the Nain Plateau from the Last Ice Sheet

It seems highly probable that thinning of the inland ice prevailed over normal retreat once the snowline had risen above the land surface. That this occurred is attested by the presence of glacio-fluvial features on the highest land nearer the coast and across wide areas of the plateau in general. Minor exceptions to this general rule may have occurred, and Wheeler* speaks of recessional moraines on the floors of the main valleys in the Okak and Nain sections. However, general absence of recessional features such as terminal moraines is conspicuous on the plateau.

From examination of the glacial drainage channels and the innumerable minor sections of lake shoreline in the higher areas of the plateau, it is concluded that the regional slope of the ice in the sector east of Wedge Point was upwards towards the west-southwest. It is significant that this agrees to within 45 degrees of the estimated direction of isostatic tilt. It is also concluded that the annual wastage was 20 to 25 feet, and that the higher land nearer the coast first emerged, leaving the deeper valleys choked with ice which eventually stagnated and decayed.

*Personal communication, Feb. 1958. See also, Wheeler, 1935.

With continued thinning and accompanying recession of the ice margin, extensive areas west of the George River-Atlantic divide became ice-free and the lower-lying areas flooded with melt-water to the level of their lowest eastern cols through which they spilled into the Atlantic drainage system. A chaos of interconnecting lakes can be readily envisaged from a glance at the complexity of lakes existing today in this area. The sequence of drainage will probably never be worked out, nor is it of more than local significance once the general pattern is known.

Gradually this system of lakes fell in level as the lower outlets were successively uncovered. Temporary blockages also were probably caused by the separation of stagnant ice masses from the main body of the inland ice. At the same time, recession and thinning of the ice made available wider areas west of the watershed for the accumulating melt-waters. Thus a large lake, N-1 was formed, extending over the northern half of the present Indian House Lake and presumably draining through a series of lakes southeastwards into the Kogaluk River. The uncovering of a lower outlet resulted in the dramatic fall in level of some 200 feet and the formation of the more extensive lakes, N-2 and McLean Lake*, the combined drainage of which also passed eastwards across the plateau to the Atlantic. At this stage water bodies over 100 miles in extent existed and, somehow, were prevented by an ice barrier from discharging into Ungava Bay, the natural outlet of the area. The proven former existence of these water bodies throws doubt on the postulated site of the ice-divide on the Glacial Map of Canada, as they extend completely across it. Large masses of ice over Ungava Bay, and possibly also Hudson Straits and Frobisher Bay** are required for the existence of these water-bodies, whose presence in late glacial time is not compatible with the existence of an ice-divide within 25 miles of Indian House Lake. Glacial lakes in the western Torngat valleys (Ives, 1957 and 1959a) also indicate the existence of a large mass of ice over part of Ungava Bay in late glacial time.

Doubt is also expressed on the validity of the crescentic drumlin- and esker-free area showing on the Glacial Map, and/or, the assumption that

*Three successively lower shorelines can be seen on the air photos below the main shoreline of glacial lake McLean so that it must be anticipated that this lake had a history independent of the Naskaupi lakes. No correlations are attempted, partly because the area was not visited in the field, and partly because there is insufficient topographic and photographic control to obtain reliable results by parallax methods.

**Mercer's 'marine' shorelines up to 1,400 feet above present sea level are probably shorelines of fresh-water bodies dammed laterally to an ice mass in the bay (*see* Mercer, 1956).

Figure 14. Close-up of beach material, N-2. (Note exposure meter for scale.)

Gros plan du matériel de plage N-2. (Le photomètre indique l'échelle).

it depicts the former site of an ice-divide. Certainly, large areas that are completely blank on the map, particularly the Torngat, are known to have an abundance of small, but nevertheless distinct, eskers and associated features such as extensive systems of lateral and terminal moraines.

An alternative explanation of the drumlin and esker pattern is not proposed, except for stating that radial movement outwards from Ungava Bay, and the existence of a second major centre of dispersal over the Kaniapiskau highlands may be a satisfactory, though purely hypothetical, interpretation. Certainly conditions of glacial dispersal have changed throughout the various stages of glaciation as was initially suggested by Low (1896). It is considered more appropriate to acknowledge the lack of field data and the existence of conflicting evidence, and to leave the drumlin and esker distribution patterns devoid of interpretation until a more opportune moment.

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Figure 15. View looking northeastwards along part of a major overflow channel from a former ice-dammed lake. The channel lies 22 miles east of Wedge Point and at an appreciably higher level than the N-1 shorelines, so that it presumably drained one of the smaller lakes formed prior to the development of the Naskaupi glacial lakes.

Vue vers le NE d'un secteur d'un chenal d'écoulement d'un ancien lac de barrage glaciaire. Ce chenal est situé à 22 milles à l'E de la pointe Wedge et à un niveau supérieur aux rivages N-1, et dont s'écoulaient probablement certains lacs formés avant le développement des lacs glaciaires Naskaupi.

Conclusions

The foregoing work represents the first attempt known to the writer to use one of the extensive Labrador-Ungava systems of glacial lake shorelines to outline phases of the deglaciation of a large area of the peninsula. References in the literature, particularly Tanner (1944) and Low (1896), and rapid perusal of a large number of air photos, reveal that several other extensive glacially-dammed lakes have existed in Labrador-Ungava during phases of the deglaciation. Attention is drawn to the abundance of shorelines to be found on the south side of the Wolstenholme highlands in the extreme northwest and the interminable systems which appear to fringe the entire north flank of the Laurentide escarpment. In each instance large bodies of water appear to have been dammed between ice remaining on the plateau and the higher land nearer the coasts.

Particular reference is made to the Lake Michikamau shorelines described by Low. Michikamau lies virtually on the height of land and even today has two outlets at times of high water. Tanner (1944) has already commented upon the intricate ice dam needed to hold up a body of water 35 feet above present lake level. Compared with the George River data such a dam presents an enigma and it is tentatively suggested here that the abandoned shorelines might possibly have been caused by isostatic tilt rather than by glacial damming, although this can only be checked by field data.

It is suggested that if the methods of study outlined herein were extended to adjacent areas, existing knowledge of the deglaciation of Labrador-Ungava would be considerably enhanced.

Acknowledgments

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ANCIENS LACS DE BARRAGE GLACIAIRE ET DÉGLACIATION DANS LE COURS MOYEN DE LA RIVIÈRE GEORGE (LABRADOR-UNGAVA)

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RÉSUMÉ: A partir de l'interprétation des photographies aériennes et d'observations effectuées sur le terrain, il a été possible d'étudier les diverses formes glaciaires du cours moyen de la rivière George et des hauteurs voisines. Cette étude fait grand cas d'un levé très détaillé se rapportant à l'étendue et à la déclivité des lignes de rivage de lacs glaciaires de même qu'à l'extrapolation, par la méthode du parallaxe, des données obtenues des photos aériennes dont l'examen a présenté le grand avantage de couvrir une aire de beaucoup supérieure à celle qui a pu être observée conventionnellement sur le terrain. Par ailleurs, les formes fluvio-glaciaires et fluvio-lacustres, interprétées à partir de la connaissance du relief du secteur nord-est de la péninsule, permettent de préciser les traits principaux de la déglaciation. L'auteur affirme que des lacs de barrage glaciaire, dont certains atteignaient une superficie de quelques cent milles carrés, étaient retenus entre le bassin hydrographique de l'Atlantique et les masses de glace situées à l'Ouest et au Nord. La baie d'Ungava a été pour sa part occupée par les glaces durant la dernière partie de l'ère glaciaire.

Le bassin de la rivière George comprend la partie est du plateau lacustre du Labrador-Ungava. La rivière prend sa source à quelques milles au nord du lac Michikamau et coule en direction nord sur une distance de

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300 milles environ, avant de se jeter dans la baie d'Ungava. Deux missionnaires moraves, les pères Knoch et Kohlmeister découvrirent en 1812 l'estuaire de la rivière George. Vers 1850, John McLean, de la Compagnie de la baie d'Hudson, emprunta son cours dans ses voyages entre la baie d'Ungava et l'inlet Hamilton. Pendant un certain temps, la Compagnie maintint un poste de traite sur le cours moyen de cette rivière, mais, la région étant d'accès trop difficile, cet établissement ne tarda pas à être abandonné. Au tournant du siècle, Mme Leonidas Hubbard et Dillon Wallace, chacun à la tête d'une équipe, descendirent en canot le cours de la rivière depuis le lac Michikamau jusqu'au hameau de George River, sis à son embouchure. C'est à Mme Hubbard que l'on doit les premières descriptions détaillées de ce cours d'eau. Ses sources consistent en un chapelet de lacs irréguliers reliés par d'étroits chenaux en cascades. Le cours d'eau ne tarde pas à se gonfler et à descendre rapidement: après 80 milles de parcours, il devient une importante rivière coupée de rapides encaissés dans sa propre vallée. Elle reçoit, 50 milles plus bas, les eaux de la rivière De Pas, son principal affluent; à 5 milles en aval du confluent, la rivière s'élargit pour former le lac de la Hutte-Sauvage. D'une largeur maximum inférieure à 3 milles, ce dernier s'étend vers le nord sur une distance de 60 milles et est entouré de collines d'une altitude de 900 pieds. Plus loin, la rivière George continue de former une suite de rapides, souvent encaissés dans des gorges.

Quelques années après les deux voyageurs précités, Cabot et Prichard partirent, chacun avec une équipe, de deux points différents de la côte du Labrador et atteignirent le lac. Prichard (1911) décrivit "une plage de gravier pur, située à 700 pieds (hauteur enregistrée à l'anéroïde) au-dessus du niveau actuel du lac"; cette plage est analogue aux "*parallel roads*" de Glen Roy, en Écosse. Les voyages subséquents furent rares. Toutefois, l'auteur doit à Wheeler (1935, 1938) la description des dépôts glaciolacustres que ce dernier a observés, au cours d'un voyage effectué de Nain au poste de la rivière de la Baleine, en 1936; et à M. Paul Bevan, de la *British Newfoundland Exploration Co.*, il doit une communication personnelle sur les lignes de rivage d'un lac fossile observé lors du survol de la région en 1954. Le botaniste J. Rousseau (1949) a été le dernier des scientifiques et voyageurs à visiter ce lac. Depuis 1942, le service d'une station météorologique, sur la rive ouest du lac, a été assuré d'abord par l'Aviation des États-Unis et, depuis la Seconde Guerre mondiale, par le ministère fédéral des Transports.

Cadre physique

Cette région est peu connue et n'est guère visitée que par les aviateurs qui viennent ravitailler la station météorologique. Les seules photos de la région sont les photos trimétrogones prises, en 1948, à une altitude de 21,000 pieds par l'Aviation royale du Canada. La meilleure carte de base disponible est au 506,880°; les courbes hypsométriques dessinées à partir de profils de radar ont des équidistances de 500 pieds. Des points de vue géologique et géomorphologique, cette région n'a pas encore fait l'objet d'une étude approfondie. Le lac de la Hutte-Sauvage se situe à environ 75 milles à l'est des roches sédimentaires et volcaniques de la fosse du Labrador (secteur archéen du bouclier canadien). Les formations rocheuses y sont assez mal connues, mais on peut inférer qu'elles se composent pour la plupart d'une succession de gneiss granitiques et de schistes d'origine sédimentaire et ignée. On a signalé, dans le cours supérieur de la rivière George, la présence de diorite, de diabase et d'anorthosite intrusives et basiques, tandis que, dans le secteur du lac de la Hutte-Sauvage, on n'a rencontré que peu de dykes et de sills. Les formes mineures dépendent étroitement de la structure des roches, des systèmes de joints, des failles et de la schistosité. La schistosité des gneiss est orientée légèrement vers le nord-ouest, alors que les crêtes et les vallons ont une orientation nord-sud. Il est probable que de grands escarpements et l'orientation des lacs soient liés aux lignes de faille et que la profonde dépression de la rivière George soit elle aussi d'origine tectonique (Cooke, 1929).

Les formes majeures sont constituées des surfaces d'érosion, qui, elles, ne dépendent pas de la structure. La ligne de partage des eaux entre la baie d'Ungava et l'Atlantique est ordinairement vague: elle se fond en un enchevêtrement de lacs et de cours d'eau qui occupent une large bande de terrain élevé surnommée "plateau de Nain". Le sommet de celui-ci atteint, non loin de la côte du Labrador, une altitude de près de 2,500 pieds et s'abaisse graduellement vers l'ouest. Dans la région de la rivière George, le plateau a une altitude variant entre 1,650 et 1,800 pieds; seuls quelques monadnocks émergent du plateau, qui, en cette région, s'abaisse peu à peu vers l'ouest jusqu'à la dépression de la rivière de la Baleine. Divers auteurs, notamment Tanner (Tanner, 1944; Cooke, 1929) ont fait mention du grand bloc faillé du nord-est du Labrador-Ungava, qui semble, selon toute évidence, être limité à l'ouest par une importante rupture topographique et structurale. Cette rupture aurait formé le rebord ouest de la chaîne des Torngat et suivi une direction sud, presque identique au cours de la rivière

George. L'auteur ne peut souscrire à cette théorie, car, dans les sections Abloviak et Koroksoak de la chaîne des Torngat (Ives, 1957 et 1959a), on peut voir les sommets s'abaisser graduellement vers l'ouest à un niveau inférieur à celui de la baie d'Ungava. Examinée soigneusement de plusieurs points d'observation, la ligne d'horizon de la région du lac de la Hutte-Sauvage traverse sans interruption la dépression de la rivière (figure 2). Cette vaste surface érodée est sans doute bombée et probablement rompue par endroits, mais il semble que sa continuité à travers toute la région considérée ici soit sa principale caractéristique. On ignore à quelle époque cette surface d'érosion remonte, mais elle est probablement très ancienne et a peut-être été exhumée. A proximité de la côte atlantique, elle n'est que faiblement fissurée, bien que certaines gorges, dont celles des rivières Fraser et Kogaluk, soient très encaissées sur des distances allant jusqu'à 60 milles du littoral. Les formes anguleuses de ces gorges indiquent qu'elles datent d'un âge relativement récent (fin du Tertiaire: *voir* Cooke, 1929; et Tanner, 1944). La dépression de la rivière George s'enfonce de 900 pieds et forme le niveau de base régional d'un second cycle d'érosion qui aboutit à un relief presque mûr dans les environs du cours d'eau principal. Ce double cycle a donné un moyen pays onduleux dans la région principale à l'étude. Ce n'est qu'aux abords de la ligne de partage que subsistent les vastes superficies intactes du sommet.

Les principaux éléments de la configuration du terrain ont joué un rôle important lors de l'englaciation comme de la déglaciation. Les collines onduleuses, qui vont en s'élevant peu à peu vers l'est jusqu'à former le haut terrain tabulaire situé à l'est de la ligne de partage, servaient d'assiette à la dernière calotte glaciaire du Pléistocène. Celle-ci a fondu sur place à partir de la côte du Labrador. La dépression de la rivière George, le bas pays sis à l'ouest de la rivière et le col plutôt bas qui sépare le bassin hydrographique de la baie d'Ungava et ceux des rivières Naskaupi et Hamilton ont joué un rôle également important. Par malheur, nous ne disposons pas de données topographiques exactes sur cette région. Bien que les profils du radar à longs intervalles donnent d'utiles indications, il nous est impossible de contester sérieusement la valeur de l'altitude approximative du lac de la Hutte-Sauvage, relevée à l'anéroïde par Wheeler* lors de l'expédition par terre qui le conduisit de Nain à ce lac. Nous nous sommes quelque peu étendus sur des données topographiques imprécises, justement parce qu'elles

*En mars 1958, Wheeler rapportait à l'auteur qu'il avait relevé à l'anéroïde, comme altitude approximative du lac, 890 pieds en 1936. L'altitude des profils du radar varie entre 960 et 995 pieds; nous avons pris 980 pieds comme moyenne, dans le présent rapport.

jouent un rôle important dans l'interprétation générale des vestiges de lignes de rivage des lacs de barrage glaciaire dont il sera question plus loin.

Glaciation

Dans toute la région à l'étude, les indices d'une érosion glaciaire étendue sont vagues ou inexistants. Cette région abonde en nombreuses formes mineures: roches moutonnées, stries glaciaires, traînées de débris glaciaires, etc. Le versant ouest de certaines collines est, par endroits, arrondi par le frottement du glacier, tandis que le versant est se révèle abrupt. Bien que les vallées et les cols orientés de l'est à l'ouest aient, sans conteste, subi certaines modifications glaciaires, rien n'y paraît tellement.

Il ne faut pas tenir rigueur du manque d'indices d'une érosion glaciaire étendue, dans une région où la glaciation avait une amplitude plutôt continentale que locale. En effet, le relief de cette région n'est pas très accentué et ses formes majeures sont transversales à l'écoulement glaciaire. Il est cependant facile de retracer la direction de cet écoulement à travers la région, comme le démontre la figure 3. Sur toute la distance nord-sud (60 milles), l'orientation des stries glaciaires et des roches moutonnées présente un parallélisme remarquable. L'écart maximum de cette orientation se situe entre 50° nord-est et l'est franc. Il semble que le glacier ait traversé le lac de la Hutte-Sauvage, obliquement, mais sans déviation sensible. On a découvert, parmi les blocs erratiques de roches intrusives, gneissiques et basiques, d'autres blocs moins abondants de roches volcaniques et de dolomie protérozoïques provenant probablement de la fosse du Labrador, soit de 75 milles à l'ouest de cette région. Les drumlins de forme irrégulière et les formes alignées y abondent, surtout sur les parties supérieures du plateau. Sauf dans certaines zones de divergence et de convergence faibles, ils suivent la même direction que la roche en place.

L'uniformité de direction et la présence de blocs erratiques charriés de fort loin indiquent que toute la région était recouverte d'une épaisse couche de glace qui cheminait du plateau lacustre central vers la côte du Labrador. Après avoir examiné les photos aériennes d'une étendue de plus de 40 milles, à l'ouest de la rivière George, l'auteur ne conteste pas la disposition des drumlins signalée sur la Carte glaciaire du Canada (Wilson, 1958), mais il n'admet pas celle des lignes de flux. Il est certain que la région à l'étude se situe à l'est ou en bordure de la ligne de partage glaciaire qui apparaît sur les cartes glaciaires, de sorte que l'orientation générale de l'écoulement glaciaire vers l'est représenté à la figure 3 n'est pas nécessairement contradictoire. D'autre part, il paraît probable que les blocs erratiques ont été charriés à partir de la fosse du Labrador, transversalement à la ligne de partage glaciaire. Cela n'est cependant pas prouvé, d'autant plus que la géologie de la région intermédiaire n'est pratiquement pas établie.

Déglaciation

Il est assez difficile de relever, dans une seule et même région, les traces des séquences glaciaires et de la progression des glaciers jusqu'à leur disparition. Certains indices sont toujours plus apparents que d'autres. Nous insistons ici sur ceux qui marquent la présence d'une suite longue et compliquée de lacs d'obturation glaciaire. Cependant, nous traitons aussi des divers dépôts fluvio-glaciaires caractéristiques et de leurs influences sur les modifications concomitantes à l'amincissement des glaciers.

ESKERS ET FORMES ASSOCIÉES

La figure 3 illustre la répartition des principaux réseaux d'eskers. Les principaux remblais traversent la région en direction est dans une position quasi parallèle aux alignements de till et aux lignes de flux de formation antérieure aux eskers. Il est à noter que le phénomène le plus important, soit la dépression de la rivière George, n'a guère influé sur le processus de leur formation; ils paraissent d'ailleurs traverser cette dépression presque perpendiculairement à sa direction. Du fait de sa présence, les eskers n'ont subi que de légères modifications; la plupart d'entre eux longent le fond des vallées des principaux affluents et traversent directement celui du lac de la Hutte-Sauvage, pour ensuite remonter le plus proche des affluents, orienté vers l'est. Plusieurs affluents venant de l'est et de l'ouest se jettent dans le lac l'un vis-à-vis de l'autre sans modifier le moindrement l'orientation générale de l'esker et la continuité des tronçons sous-lacustres (figure 3). On a découvert l'existence de ces tronçons au cours de sondages effectués dans certaines parties du lac. Devant l'absence d'affluents opposés l'un à l'autre sur les rives est et ouest, respectivement, les eskers meurent dans une plaine de sable alvéolée, à moins que leur direction ne soit déviée sur une certaine distance, là où ils bordent le lac, en formant des secteurs nord-sud discontinus; puis, de nouveau, ils tournent brusquement à l'est en suivant le fond de la vallée la plus proche jusqu'au plateau situé plus loin à l'est.

La plupart des eskers sont du type à remblai simple (figure 5) et l'on a remarqué en plusieurs endroits l'inclinaison de leurs couches vers l'est. Ils deviennent complexes sur les pentes raides exposées à l'est, où les remblais forment souvent un réseau de ramifications dans une grande plaine de sable alvéolée qui borde les pentes inférieures. Dans certains secteurs, les eskers coupent une série de cols alignés tant bien que mal entre des remblais successifs d'orientation nord-sud. Sur les contre-pentes raides, plus basses que les cols, plus d'un esker disparaît et fait place à des formes d'érosion, plus particulièrement au col même, ce qui confirme la théorie de l'origine sous-glaciaire des eskers. Sur le plateau, à proximité des eaux d'amont des rivières qui se jettent dans l'Atlantique, on observe des formes de terrain très complexes: ainsi, le till ridé souvent associé aux eskers (Ives, 1956). Dans le même secteur, plusieurs eskers convergent vers les grandes gorges des rivières, notamment celles de la Kogaluk et de la Fraser. Ce phénomène indique l'influence des torrents sous-glaciaires sur la formation des eskers là où la pente du glacier se conformait à la topographie sous-glaciaire. Il s'agit là d'un contraste frappant avec les différentes formes de drumlins, qui, vus du haut des airs, coupent les gorges obliquement, comme si, à l'origine, ils avaient été obstrués par de la glace stagnante, preuve que les gorges n'ont pas influé sur le cheminement du glacier. La raideur des parois et les entailles en V de l'entrée des gorges corroborent cet avancé. Ceci va en contradiction avec l'action fortement exercée sur le mouvement des glaciers par les dépressions de la chaîne des monts Torngat, où il est facile de noter les modifications opérées sur la roche en place par le glacier.

Il est généralement admis que la formation des eskers coïncide avec "la ligne de moindre résistance" et que, si la dépression de la rivière George n'a pas exercé d'effets, c'est que, dans le secteur nord de cette dépression, la glace était assez épaisse et compacte pour empêcher les eaux d'écoulement sous-glaciaires et intra-glaciaires d'y pénétrer.

FORMES ATTRIBUÉES AUX ACTIONS FLUVIO-GLACIAIRES

Sur toute la partie supérieure du plateau de Nain, on trouve, séparés en général des eskers principaux, des chenaux sous-glaciaires et des terrasses burinées par les eaux de fonte sous-glaciaires; ces formes représentent une phase de retrait contemporaine de la formation des eskers ou postérieure. Les chenaux, dont la plupart sont plus ou moins latéraux (Mannerfelt, 1949), se présentent d'ordinaire à flanc de coteau, en groupes de moins de 12. Ils s'inclinent fortement vers l'est, sauf là où s'est surtout exercée l'influence du terrain sur les anciennes parois du glacier en retraite. Étagés assez régulièrement à des intervalles de 20 à 25 pieds, ils diffèrent des chenaux de la région du lac Helluva, au nord de Schefferville (Ives, 1959b et 1959c), en ce que la suite presque parallèle de simples chenaux et de terrasses n'a que peu de tributaires et que leur gradient moyen est de 1:140. Ils renseignent sur la direction régionale vers laquelle s'inclinait la calotte glaciaire, sur le degré possible d'ablation annuelle et sur le mode d'émergence des sommets à travers la couverture glaciaire.

L'examen détaillé de certains endroits choisis permet de croire qu'à l'époque de la formation des chenaux d'écoulement le glacier s'inclinait quelque peu vers le sud-ouest. Un bassin élevé situé à 8 milles à l'ouest de la pointe Wedge fournit de précieuses indications à ce sujet. Ce bassin était ouvert vers le sud et la crête est, en pente raide, était coupée de deux larges cols, dont le plus élevé était situé au nord. Un réseau de chenaux et de terrasses glaciaires a été retracé vers le sud, le long du versant ouest de cette crête; on a constaté que les plus élevés passent par le col du nord, les moins élevés, par celui du sud, pour couper ensuite la crête en direction est. Juste au-dessous du niveau de chaque col, on a pu observer des tronçons d'une ligne de rivage lacustre, preuve qu'il y avait là de petits lacs d'obturation glaciaire dont la formation remonterait au moment où l'eau de fonte pro-glaciaire ne pouvait envahir le col le plus proche, la bordure du glacier s'étant affaissée à un niveau inférieur à ce col. L'examen morphologique a permis d'estimer que la surface du glacier s'inclinait de 25° vers le sud et de 65° vers l'ouest. On a relevé, dans le voisinage, des données numériques à peu près identiques chez d'autres formes du même type.

L'étude de l'inclinaison et de la répartition des formes fluvio-glaciaires semble indiquer que les hautes terres sises à proximité du littoral aient été les premières à émerger de l'inlandsis et que, même alors, la ligne des neiges dépassait, dans la région, les plus hauts sommets. On a pu relever la présence de formes fluvio-glaciaires dans les secteurs les plus élevés, soit à environ 2,500 pieds. Apparemment, il n'y a eu aucune moraine de retrait, la déglaciation s'étant opérée essentiellement par amincissement.

Les chenaux d'écoulement sous-glaciaires, les terrasses, de même que les eskers, indiquent que le "barrage" de glace de la vallée inférieure de la rivière George a plus que suffi à entraver l'écoulement sous-glaciaire et intra-glaciaire vers le nord, le long de cette grande voie d'eau. On croit savoir qu'à part la glace stagnante de contact la masse glaciaire principale était encore active, et que, même si elle cheminait peut-être très lentement, elle était déjà "morte" climatiquement.

LACS DE BARRAGE GLACIAIRE

Des études effectuées dans la partie sud-ouest de la chaîne des monts Torngat (Ives, 1959a) ont déjà accrédité l'hypothèse de l'existence d'un réseau étendu de lacs d'obturation glaciaire. L'examen des photos aériennes a cependant révélé que ce réseau était encore plus vaste qu'on ne le supposait, et que les lignes de rivage de ces anciens lacs fournissent un élément essentiel à l'étude de la déglaciation sur tout le secteur nord-est de la péninsule. Ces photos démontrent que les lignes de rivage en question traversent l'emplacement théorique de la ligne de partage glaciaire et que certaines de ces lignes, bien formées, s'étendent vers le nord au moins jusqu'à 57°30′ de latitude de même que vers le sud, jusqu'à la région située au nord du lac Michikamau. Ces lignes de rivage n'apparaissent pas sur la Carte glaciaire du Canada.

Les renseignements tirés de l'examen des photos ont servi à établir en grande partie le programme des travaux sur le terrain pour 1958. L'existence de lacs, les uns contemporains, les autres successifs, situés à des niveaux différents ne laisse planer aucun doute. Afin de mesurer l'étendue d'une ancienne nappe d'eau donnée, il était essentiel d'obtenir au préalable des altitudes relatives ou absolues et des mesures précises sur le redressement isostatique, s'il s'en est produit un. On s'est rendu compte de l'aspect préliminaire des travaux sur le terrain, car le nombre restreint de photos aériennes disponibles rendait impossible la mise en corrélation des diverses régions, tant qu'on n'aurait pas dressé de cartes topographiques satisfaisantes à grande échelle. C'est pourquoi l'on a choisi le lac de la Hutte-Sauvage: on a estimé qu'il fournirait une base de référence pour les nivellements prévus tout en favorisant les déplacements par voie d'eau du nord vers le sud.

Travaux sur le terrain

On a d'abord mesuré à l'anéroïde l'altitude du secteur nord du lac, puis évalué la direction et le degré du redressement post-glaciaire. On a ensuite calculé l'altitude de 3 grandes lignes de rivage, à environ 700, 500 et 350 pieds au-dessus du niveau du lac actuel, et constaté qu'elles se relevaient plus ou moins vers le sud. En raison de ce redressement prononcé, on a alloué des altitudes approximatives pour faciliter les comparaisons. Les lacs fossiles dont on a ainsi déduit l'existence sont identifiés dans le texte par les sigles N-1, N-2 et N-3 (lacs de barrage glaciaire Naskaupi 1, 2 et 3). Les lignes de rivage du lac N-2 étant de beaucoup les plus longues et les mieux marquées, ces lacs ont fait l'objet de la plus grande partie du nivellement et ont servi de base au gros de la description suivante. Des profils de niveaux précis ont été tracés sur une ligne de base de 40 milles, le long du lac de la Hutte-Sauvage, à partir du niveau actuel du lac jusqu'à la ligne du lac N-2, ce qui a d'abord fourni les 6 points figurant sur le graphique (figure 6). A partir de ces repères, on a nivelé certains secteurs de la rive sur une distance de trois milles, afin de vérifier l'inclinaison de la pente obtenue. De même, pour en calculer le gradient et la direction, on a rattaché et nivelé en longueur les secteurs les plus nets de la rive du lac N-1. Compte tenu du facteur temps, l'on ne s'est occupé de la rive du lac N-3 que pour établir les points cotés figurant sur les 6 premiers profils, car sa ligne est intermittente et plutôt imprécise. La nature accidentée du terrain a nécessairement limité le nombre des nivellements de précision; de plus, la nature de nombreuses parties des lignes de rivage rendait superflue une haute précision. Ainsi, la hauteur des tumulus nivelés est considérée comme exacte à 2 pouces près, et celle d'un secteur donné de plage, à environ 18 pouces près. Les 2 stations dont l'altitude a été le mieux estimée à l'anéroïde concordent à 4 pieds près avec les hauteurs calculées par nivellement de précision, l'erreur marginale de l'anéroïde s'étant avérée inférieure à 1 p. 100. On a donc jugé bon de prolonger de 40 à 60 milles la longueur de la ligne de plage mesurée par nivellement, en y incorporant les hauteurs calculées à l'anéroïde et situées plus loin que les tumulus de plage les plus éloignés.

Les photos aériennes portent à croire que le lac de la Hutte-Sauvage ne constituait qu'un seul lac de niveau uniforme, mais les observations faites sur place démontrent qu'il s'agissait d'une série de lacs reliés par d'étroits passages au cours rapide. On ne pouvait donc prendre le niveau de ce lac comme niveau de référence pour calculer l'altitude absolue, mais celle-ci a été corrigée grâce aux données obtenues d'une équipe* d'arpentage qui a effectué des nivellements de précision dans un secteur du tronçon moyen de la rivière George. Cette équipe n'est pas parvenue à achever son

*Équipe de levés du ministère des Ressources hydrauliques du Québec, dirigée par Guy Beaudoin. Données fournies par Paul Pelletier, ingénieur conseil, de Montréal, qui a organisé les travaux à forfait de l'équipe.

travail jusqu'aux abords de la baie d'Ungava, mais on pourra calculer, une fois ce travail terminé, les altitudes absolues des tumulus de la plage sud que l'équipe dirigée par l'auteur a rattachés aux repères géodésiques établis.

Après le parachèvement des travaux de nivellement de précision, on a effectué des cheminements vers l'est, du lac jusqu'au plateau, à quelques milles des eaux d'amont des affluents de l'Atlantique. On voulait ainsi mettre en corrélation (par des données estimées à l'anéroïde) certaines parties isolées de rives examinées sur les photos aériennes, avec les lignes de rivage des lacs N-1, N-2 et N-3. On a procédé à d'autres observations du côté de l'ouest, à partir du lac, et, pour compléter les travaux sur le terrain, on a fait des sondages dans le lac.

Étendue et caractère des anciens lacs Naskaupi

On peut y distinguer trois stades principaux. On a suivi à la trace le lac N-1, de l'extrémité nord du lac actuel vers le sud, jusqu'aux abords de la pointe Wedge, au-delà de laquelle il ne reste plus aucun vestige. On a constaté que la plupart des dépôts morainiques recouvrant les pentes douces et les eskers supérieurs à la ligne du rivage du lac N-2 étaient demeurés intacts. C'est là l'indice de l'existence d'un barrage glaciaire représenté sur la figure 4; ce barrage traversait le lac juste au nord de la pointe Wedge. On ignore jusqu'où s'étendait le lac vers le nord, à cette époque, même si sa limite, de ce côté, se trouvait à plusieurs milles du lac de la Hutte-Sauvage et si sa limite ouest dépassait les sommets des collines les plus élevées.

On n'a pu découvrir l'exutoire du lac N-1; on croit savoir cependant qu'il était situé bien au-delà de la région accessible à pied. Le lac atteignait presque le niveau de la ligne de partage actuelle, soit environ 1,700 pieds d'altitude. Déduction faite pour l'inclinaison, il semble que cette ligne, près des sources de la Fraser, dépassait de quelques dizaines de pieds le niveau du lac. L'exutoire du lac était fort probablement l'une des branches de tête de la Kogaluk, selon l'état des glaciers contemporains de la région.

Bien qu'il ne reste pas de rives nettes, on relève, au nord de la pointe Wedge, de nombreux indices d'un lac situé plus bas que le lac N-1 et plus haut que le lac N-2: il appert que le nouveau déversoir, mis à jour par l'ablation continue de la calotte glaciaire, était à une altitude moindre que le lac N-1 et que le niveau de l'eau s'est abaissé rapidement de près de 200 pieds. Au sud de la pointe Wedge, on trouve, sur les quelques premiers milles, des traces de délavage jusqu'à 50 pieds au-dessus de la ligne du rivage du lac N-2; puis elles s'abaissent peu à peu jusqu'à la ligne de rivage du lac N-2, soit à la limite supérieure absolue de l'action des vagues*, à moins de 8 milles du barrage glaciaire présumé. Le recul du barrage initial aurait donc été plutôt lent au cours des premiers stades et se serait accentué dans la phase subséquente.

Les rives du lac N-2 ont été suivies à la trace en direction nord-sud, sur une distance de 60 milles, et sur 45 milles, de l'est à l'ouest. Leur limite ouest était constituée par une haute crête située à quelques milles derrière le lac actuel. Cependant, à l'extrémité sud du lac de la Hutte-Sauvage, on n'a pas retracé de lignes de rivage sur les collines de la rive ouest qui surplombent l'ancien niveau du lac N-2. La région est remarquable aussi par l'abondance relative des chenaux d'écoulement sous-glaciaires peu élevés et des eskers demeurés intacts (figure 3). Nous croyons que la région, face au lac, était submergée par la glace. Un deuxième grand lac, situé plus en amont, appelé lac d'obturation glaciaire McLean (figure 7), recouvrait la partie est de l'auge de la rivière de la Baleine et se déversait dans le lac N-2 par un canal (marqué d'un x sur la figure 4). On ne peut fixer la limite ouest de ce lac, car le plan des lignes de rivage dépasse le niveau du sol, à cet endroit. Le lac semble avoir été retenu par un immense barrage glaciaire qui s'étendait vers le nord-est à partir des eaux d'amont observées à l'ouest de la rivière de la Baleine jusqu'à une région adjacente au littoral de la baie d'Ungava, où il devait forcément se prolonger pour retenir les eaux du lac N-2.

La rive du lac N-2 s'étend, vers le nord, au moins jusqu'au 57° de latitude; on n'a cependant pas encore examiné en détail toutes les vues aériennes prises au-delà de cette ligne. De même, des lignes de rivage bien nettes situées presque au même niveau que celles du lac N-2 s'étendent jusqu'à 60 milles au sud du confluent des rivières De Pas et George. Si l'on peut présumer que l'inclinaison calculée de 1.57 pied par mille se poursuit, au sud, jusqu'à ce confluent, il semble incontestable que les lignes de rivage, qui s'étendent au sud-est du lac Whitegull et au sud du lac Resolute, sont équivalentes à celles du lac N-2**. A ce stade de l'étude, on ne peut

*Plusieurs endroits font exception à cette règle, mais, dans tous les cas, les lignes de rivage brisées peuvent être attribuées à des lacs minuscules alors emprisonnés entre la glace en fusion et les collines qui émergeaient. Ces lacs étaient souvent reliés à des déversoirs et à des chenaux sous-glaciaires.

**Après la rédaction du texte, nous avons pu examiner des vues aériennes plongeantes et des cartes en courbes de niveau exactes (1:50,000, lat. 55°N.). Un examen approfondi de ces cartes semble confirmer cette hypothèse.

83627-0—6

que conjecturer sur l'emplacement du ou des effluents. Compte tenu de la déclivité, les branches de tête inférieures des bassins des lacs Kogaluk, Kanairiktok et Harp ont autant de droits à ce titre les unes que les autres. D'autre part, il faut remarquer que le niveau hydrostatique a probablement été supérieur à la ligne de partage George-Michikamau, ce qui signifie que cette région plus basse a dû être submergée par les glaciers. Malheureusement, les points cotés manquent, dans ces régions, et, d'ailleurs, l'on ne peut affirmer que la pente y a été uniforme.

Il est encore plus difficile d'estimer l'étendue du lac N-3. Il est évident que sa durée fut plus courte que celle de ses deux prédécesseurs et il se peut qu'il se soit déversé par le col George-Michikamau, ou encore latéralement, par le nord, dans la baie d'Ungava. Il semble qu'après ce stade le principal barrage glaciaire qui obstruait l'estuaire actuel de la rivière George n'ait pas tardé à disparaître, car on n'a pas trouvé de plages bien marquées, sauf quelques-unes à l'extrémité sud du lac de la Hutte-Sauvage. Une fois la rivière George libre de s'écouler vers le nord, les lacs se vidèrent complètement et le soulèvement isostatique inégal se poursuivit jusqu'au stade où les rives de l'extrémité sud du lac actuel dépassaient de 60 pieds le niveau actuel. Ces lignes de rivage s'inclinent vers le nord et disparaissent à l'extrémité nord du lac. C'est dire que, par suite du basculement postglaciaire, les lacs tendaient à se vider vers le nord. Cette conlusion infirme l'hypothèse de Cooke (1930) selon laquelle le gauchissement isostatique, après avoir exhaussé les deux extrémités, donna naissance au lac de la Hutte-Sauvage, ainsi qu'au lac Cambrian, sur la Caniapiscau. L'auteur croit que les lacs formés par la rivière George sont en grande partie obstrués par des dépôts fluvio-glaciaires. Cette conclusion est corroborée par le fait que plus de 300 sondages, effectués là où les réseaux d'eskers et les plaines sablonneuses alvéolées sont aux abords du lac, ont donné des profondeurs allant de 145 pieds, dans les lacs formés par la rivière, à 12 pieds dans les passes.

Nature des lignes de rivage

Les figures 8 et 9 permettent de se faire une bonne idée du caractère plus ou moins net des lignes de rivage des anciens lacs de barrage glaciaire de la région du lac de la Hutte-Sauvage.

Leur formation et leur conservation dépendent de plusieurs facteurs, qui ont tous influé fortement sur la configuration de la région de la rivière George:

1. Il y avait un barrage de glace au-delà duquel le terrain s'élevait.
2. Le niveau est resté stationnaire assez longtemps pour permettre la formation de lignes de rivage.
3. Particularités du terrain:
   i. Présence de roche en place ou d'apports glaciaires.
   ii. Aspect en fonction des vents prédominants.
   iii. Présence de sommets plus hauts que le lac et qui forment des îles et des presqu'îles.
   iv. Proximité du barrage de glace, climat, présence ou absence d'icebergs.
   v. Absence de facteurs ayant causé, après leur formation, l'oblitération des lignes de rivage, par exemple, la solifluxion.

Les facteurs 1 et 2 ont donné naissance à un faisceau de petits lacs qui se sont peu à peu fusionnés en 3 grands lacs successifs. Le degré de formation, l'emplacement et l'aspect des lignes de rivage résultantes permettent un certain nombre de déductions en ce qui a trait aux particularités du facteur 3.

Il est en effet remarquable que toutes ces lignes soient plus nettes sur les versants est. Cette caractéristique était si frappante que tous les travaux ont porté sur ces pentes, comme on peut s'en rendre compte en comparant les figures 10 et 11. Les formes mineures de plages, notamment le grand nombre de flèches barrantes et d'épis, à l'extrémité sud des crêtes qui dominent les rives, dénotent que les vents efficaces dominants soufflaient de l'ouest et du nord-ouest, à peu près comme de nos jours. L'absence presque complète de formes dues à la poussée du gel et aux coups de gouge parfois causés par les icebergs chassés vers la rive aide aussi à se faire une idée des conditions prévalantes d'alors. Dans le premier cas, la saison d'eau libre était peut-être assez longue pour que les vagues puissent oblitérer ces formes. Quant à l'absence de coups de gouge, elle peut s'expliquer par la théorie selon laquelle la limite ouest d'une grande partie du lac N-2 était à sec, le barrage glaciaire, éloigné, et le lac, relativement libre d'icebergs.

Les rives principales pénètrent profondément dans les pentes raides des collines orientées vers l'ouest; leur amplitude verticale est de 15 pieds en moyenne. L'avant et l'arrière des pentes sont le plus souvent garnis d'un alignement de blocs erratiques (figure 12). Ici et là, on rencontre des falaises sapées par les vagues et pour la plupart fortement abaissées, le gel

83627-0—6½

ayant provoqué des fentes puis des éboulements rocheux; en conséquence, le pied de la falaise, indiqué d'ordinaire comme point idéal de comparaison des altitudes, est rarement bien conservé, au point qu'il a fallu, dans une certaine mesure, généraliser les altitudes.

Ces formes mineures n'autorisent que des généralisations qualitatives sur les conditions naturelles qui existaient à l'époque de la formation des lignes de rivage et dont voici les plus importantes:

1. D'abord, la formation fortuite de nombreux lacs dont les niveaux variaient rapidement.
2. Trois phases distinctes de longue inaction qui expliquent la formation des lignes de rivage des lacs N-1, N-2 et N-3.
3. Longue saison d'eau libre et absence presque complète d'icebergs.
4. Vents efficaces dominants, soufflant de l'ouest et du nord-ouest.
5. Un immense barrage glaciaire fermait les exutoires naturels des rivières George et de la Baleine.
6. La présence de matériaux grossiers sur les plages empêchait en général les modifications dues à la solifluxion.

Importance des lignes de rivage

On a mesuré la direction et le pendage apparent du lac N-1: il est d'environ 2 pieds par mille, en direction sud; dans le cas du lac N-2, il est de 1.57 pied par mille, dans la même direction. Comme la base mesurée du lac N-2 a une longueur de 60 milles comparativement à celle du lac N-1, qui est de 4 milles seulement, les explications suivantes ne s'appliquent qu'à la première.

Le graphique de la figure 6 montre que, sur toute la distance de 60 milles, les flexures ou les bombements de la surface redressée sont absents ou neutralisés entre les tumulus de plage, ou, encore, qu'ils ont une orientation nord-sud. Fort probablement, toute la région a subi un soulèvement et une bascule en bloc, sans interruption discernable. Les 7 points du graphique concordent de si près avec la ligne généralisée que tout écart pourrait fort bien s'expliquer par une erreur de localisation de l'escarpement sapé par les vagues, où l'écart est presque inexistant (le tumulus 5, par exemple, représente un écart maximum de 3.5 pieds par rapport à la ligne généralisée). On soutient donc que la proportion calculée de ce basculement apparent se prolonge peut-être vers le nord et le sud de la section mesurée, sur une certaine distance tout au moins; et ce, tant que cette thèse n'aura pas été contredite par des travaux ultérieurs sur le terrain. Ce travail facilitera grandement l'extrapolation faite sur de plus grandes régions et basée sur les méthodes d'utilisation de la parallaxe tirée sur les vues plongeantes; il aidera aussi à découvrir les exutoires possibles. On applique actuellement la méthode de l'extrapolation des données recueillies sur le terrain pour mieux se renseigner sur le régime glacio-lacustre: ce travail devrait contribuer à isoler les régions qui appellent des travaux subséquents sur le terrain.

Il est entendu que ce gauchissement n'a été mesuré que dans une seule direction, qui n'est pas toujours celle de l'inclinaison maximum ou absolue. Un nivellement de précision a révélé que la déclivité absolue est probablement orientée vers le sud-ouest. Telle est la conclusion qu'on tire du relèvement plus marqué découvert là où le profil du nivellement de plage en longueur se dirigeait plus à l'ouest et où le profil correspondant moins marqué s'orientait plus au sud ou au sud-est. Nous ne fournissons pas de données statistiques là-dessus, car ces mesures sont sujettes à des erreurs d'observation; d'ailleurs, on a éprouvé de la difficulté à travailler le long d'un secteur-type de la plage, et il se peut que la solifluxion ait produit un léger affaissement. Les isobases calculées par Cooke (1930) sont reproduites à la figure 13. Bien qu'elles soient fondées sur des données plutôt maigres, il paraît raisonnable de les comparer avec l'épaisseur relative prévue de l'inlandsis du plateau lacustre et d'admettre la théorie généralement acceptée du réajustement isostatique post-glaciaire. On tient compte de tous ces éléments dans l'étude qui suit sur la déglaciation générale de cette partie du Labrador-Ungava, mais il est évident que cette étude doit être complétée par de nombreux autres travaux sur place.

Émersion du plateau de Nain à travers le dernier glacier continental

Il est fort possible qu'avec l'élévation de la ligne des neiges au-dessus de la surface terrestre, l'inlandsis ait fondu sur place, plus que ses fronts n'aient reculé; à preuve, les formes fluvio-glaciaires rencontrées sur la plus haute terre, près du littoral, et à travers de larges secteurs de l'ensemble du plateau. Il peut s'être présenté de légères exceptions à cette règle: c'est ainsi que Wheeler* affirme qu'il y a eu des moraines de récession au fond

*Communication personnelle, fév. 1958. *Voir* aussi Wheeler, 1935.

des principales vallées des secteurs d'Okak et de Nain. Cependant, sur le plateau, il n'y a guère de formes de récession semblables aux moraines terminales.

Il ressort de l'étude des chenaux sous-glaciaires et des innombrables petits tronçons de lignes de rivage lacustres des hautes terres du plateau que la calotte glaciaire du secteur situé à l'est de la pointe Wedge remontait vers l'ouest-sud-ouest. Il est intéressant de noter que ce phénomène concorde jusqu'à moins de 45 degrés avec la direction estimative du redressement. On en conclut aussi que l'épaisseur de la nappe de glace a fondu sur place, soit de 20 à 25 pieds par an, et que les hautes terres voisines du littoral ont été les premières à émerger, pendant que, dans les vallées plus profondes, la glace subsistait encore, puis finit par devenir stagnante et "mourir".

L'amincissement continu et le recul concomitant de la bordure externe des glaciers mirent à nu de vastes régions situées à l'ouest de la ligne de partage rivière George—océan Atlantique, tandis que les terres plus basses furent submergées par l'eau de fonte jusqu'au niveau de leurs plus bas cols de l'est, par lesquels leurs eaux se déversaient dans le bassin hydrographique de l'Atlantique. Il suffit de jeter un coup d'œil au complexe chapelet de lacs qui existe aujourd'hui dans cette région pour comprendre qu'il y avait là autrefois un réseau compliqué de lacs glaciaires. Il est probable qu'on n'arrivera jamais à comprendre les séquences successives de cet écoulement; d'ailleurs, cette question, une fois la disposition générale des lacs connue, n'a qu'une importance toute régionale.

Peu à peu, le niveau de ce réseau de lacs s'abaissa, à mesure que les effluents inférieurs se libéraient de la glace. Il est probable que les culots de glace stagnante qui se détachaient de la masse de l'inlandsis aient formé des obstructions glaciaires temporaires. En même temps, l'amincissement et la fusion sur place de la calotte glaciaire ont permis à l'eau de fonte de s'épandre sur de plus vastes étendues, à l'ouest de la ligne de partage. C'est ainsi que prit naissance le lac N-1, grand lac qui occupait la moitié nord de la superficie actuelle du lac de la Hutte-Sauvage et qui se déversait sans doute, par une suite de lacs, vers le sud-est, dans la rivière Kogaluk. La mise à nu de cet effluent fit baisser, avec une rapidité extraordinaire, le niveau marin d'environ 200 pieds et favorisa la formation de deux lacs plus grands, le lac N-2 et le lac McLean*, dont les canaux combinés de drainage traversaient le plateau, vers l'est, et se déversaient dans l'Atlantique. A ce stade, il y avait des lacs de plus de 100 milles de longueur, que quelques barrières de glace empêchaient de se déverser dans la baie d'Ungava, leur exutoire naturel. Étant donné qu'elles occupaient toute cette superficie, l'existence reconnue de ces anciennes nappes d'eau fait mettre en doute le présumé emplacement de la ligne de partage pré-glaciaire qui figure sur la Carte glaciaire du Canada. On est fondé à croire que la baie d'Ungava et peut-être aussi le détroit d'Hudson ainsi que la baie Frobisher** étaient alors recouverts de glace, car la présence d'immenses étendues d'eau, vers la fin du Pléistocène, laisse planer des doutes sur l'existence d'une ligne de partage glaciaire à moins de 25 milles du lac de la Hutte-Sauvage. L'existence de lacs de barrage glaciaire dans les vallées occidentales de la chaîne des Torngat (Ives, 1957 et 1959a) indique qu'à la même époque une partie de la baie d'Ungava était recouverte par les glaces.

On doute aussi de l'avancé selon lequel l'aire en forme de croissant, dépourvue de drumlins et d'eskers, qui figure sur la Carte glaciaire, soit l'ancien emplacement d'une ligne de partage glaciaire. Il est certain que de vastes régions laissées en blanc sur la carte, notamment celle de la chaîne des Torngat, contiennent de nombreux eskers, petits mais séparés, ainsi que de nombreuses formes associées, telles que des réseaux étendus de moraines latérales et terminales.

Nous ne proposons pas d'autre explication de la disposition des drumlins et des eskers. Disons cependant que l'existence de deux grands centres de dispersion des glaces, l'un à partir de la baie d'Ungava, l'autre à partir des hautes terres de la Caniapiscau, constitue une explication peut-être satisfaisante, quoique encore hypothétique. Il est certain, comme l'a d'abord prétendu Low (1896), que le régime de la diffluence glaciaire a varié d'un stade de glaciation à l'autre. Mieux vaut, à notre avis, reconnaître le manque de données recueillies sur le terrain, admettre l'existence de preuves contradictoires et attendre un moment plus opportun pour expliquer le mode de répartition des drumlins et des eskers.

*Les vues aériennes permettent de distinguer, plus bas que la ligne de rivage principale du lac glaciaire McLean, trois lignes étagées; de sorte qu'il faut supposer que l'évolution de ce lac n'était pas reliée à celle des lacs Naskaupi. Il ne saurait être question d'établir de corrélation, car la région n'a pas fait l'objet d'une étude sur le terrain et, d'ailleurs, le nombre des points déterminés par la topographie et la photographie ne permet pas d'obtenir des résultats sûrs par les méthodes de la parallaxe.

**Il est probable que les lignes de rivage que Mercer appelle "marines" et qui s'élèvent jusqu'à 1,400 pieds au-dessus du niveau actuel de la mer sont des lignes de lacs d'eau douce, dont le barrage glaciaire latéral aboutissait à un amas de glace, dans la baie d'Ungava (*voir* Mercer, 1956).

Conclusions

L'auteur considère cette étude comme la première tentative qu'on ait faite pour donner un aperçu des stades de la déglaciation dans une grande partie de la péninsule du Labrador par l'étude des formes glacio-isostatiques laissées par des lacs de barrage glaciaire dans la région de la baie de l'Ungava. Différents auteurs, notamment Tanner (1944) et Low (1896), ainsi qu'un grand nombre de vues aériennes révèlent qu'au cours de ces stades la région de l'Ungava contenait plusieurs autres lacs glaciaires étendus, du genre étudié ici. Soulignons qu'on trouve de nombreuses lignes de rivage sur le versant sud des hautes terres de Wolstenholme (partie le plus au nord-ouest du Labrador), et que tout le versant nord de l'escarpement des Laurentides semble être bordé d'innombrables chapelets de lacs. Dans les deux cas, de grandes nappes d'eau ont vraisemblablement été retenues entre la glace résiduelle du plateau et le pays plus élevé voisin du littoral.

Mentionnons en particulier les lignes de rivage du lac Michikamau, décrites par Low. Ce lac se situe presque sur la ligne de partage et, même aujourd'hui, quand ses eaux sont hautes, il se déverse de deux côtés. Tanner (1944) a déjà souligné que seul un barrage glaciaire compliqué avait pu retenir les eaux d'un lac dont le niveau était supérieur de 35 pieds à celui du lac actuel. Compte tenu des renseignements qu'on possède sur la rivière George, le phénomène reste énigmatique. Nous formulons ici l'hypothèse suivante, à savoir que les anciennes lignes de rivage seraient le résultat, non d'un barrage glaciaire, mais du redressement glacio-isostatique, hypothèse qui d'ailleurs ne peut se vérifier que par l'étude sur le terrain.

Il faut donc reconnaître que, si l'on étendait aux régions voisines les méthodes d'étude précitées, nos connaissances sur le déglacement de cette région de l'Ungava s'en trouveraient grandement enrichies.

Remerciements

L'auteur désire remercier le professeur J. Brian Bird et le docteur E. P. Wheeler d'avoir parcouru le manuscrit et soumis d'utiles avis. Il est également redevable à M. Wheeler pour ses nombreuses descriptions de régions attenantes, pour les données qu'il lui a fournies sur la région du lac de la Hutte-Sauvage ainsi que pour ses précieux encouragements.

NOTA.—*Voir* les pages 69 et 70 pour les références.

CREVASSE FILLINGS AND ABLATION SLIDE MORAINES, STOPOVER LAKE AREA, N.W.T.

J. Ross Mackay

ABSTRACT: A complex pattern of crevasse fillings, eskers and ablation slide moraines resembling dead-ice landscape occurs in an area of 40 square miles in the vicinity of Stopover Lake, 80 miles north of Smith Arm, Great Bear Lake, N.W.T. Open fissures and crevasses of stagnant ice appear to have received deposits of sediment which were transported into the area by a large river whose abandoned channel lies to the east of Stopover Lake. At the time of deposition the controlling water level was from 1,150 to 1,250 feet above sea level. Following a rapid lowering of the water level to below 1,150 feet, ablation slide moraines, which may be annual features, were formed by the chuting, sliding and slumping of ablation material down the sides of wasting ice-blocks left by the retreating ice front.

RÉSUMÉ: Dans une région couvrant environ 40 milles carrés à proximité du lac Stopover, situé à 80 milles au Nord du bras Smith du Grand Lac de l'Ours, T. N.-O., il existe un assemblage assez compliqué d'éléments morphologiques de nature différente comprenant des moraines de fond, des dépôts de crevasse, des eskers, des moraines d'ablation et des moraines solifuées, le tout présentant l'aspect d'un paysage issu de la fonte d'anciens culots de glace morte. Des fissures béantes et des crevasses morcelant un culot de glace semblent avoir recueilli des alluvions apportées dans la région par un ancien collecteur important d'eaux de fonte dont l'ancien cours abandonné est aujourd'hui visible un peu à l'Est du lac Stopover. A l'époque où ces matériaux ont été déposés, l'altitude des eaux lacustres qui leur servait de niveau de base local était de 1150 à 1250 pieds au-dessus du niveau de la mer. A la suite de l'abaissement rapide de ce niveau au-dessous de 1150 pieds, des moraines d'ablation et de glissement, qui sont peut-être des formes annuelles, ont été mises en place le long des flancs de culots de glace morte, par éboulements, glissements ou mouvements de bascule des matériaux accumulés à la surface de ces culots de glace morte abandonnés à l'avant du front de l'inlandsis en retraite.

A particularly intricate pattern of unusual ridges and terraces covers 40 square miles of the Stopover Lake area, 80 miles north of Smith Arm, Great Bear Lake (Figure 1). The complex network of ridges, enclosed depressions, pitted flat-topped terraces, scalloped ice-contact slopes, overflow melt-water channels, and associated features have probably resulted mainly from deposition of sediment against stagnant ice, seamed with fissures and penetrated by tunnels. Most of the larger ridges are believed to be crevasse fillings (Flint, 1928; 1929; 1930; cf. Kupsch 1956) although a few seem to be eskers. Some of the small sub-parallel ridges occupying the floors of kettle depressions may be ablation slide moraines left by seasonal chuting of ablation moraine down the slopes of wasting ice-blocks onto dry land. The entire assemblage of topographical forms has many points of similarity with the dead-ice landscapes described by Hoppe (1952),

Figure 1A The map shows the distribution of the principal linear elements of the Stopover Lake area.

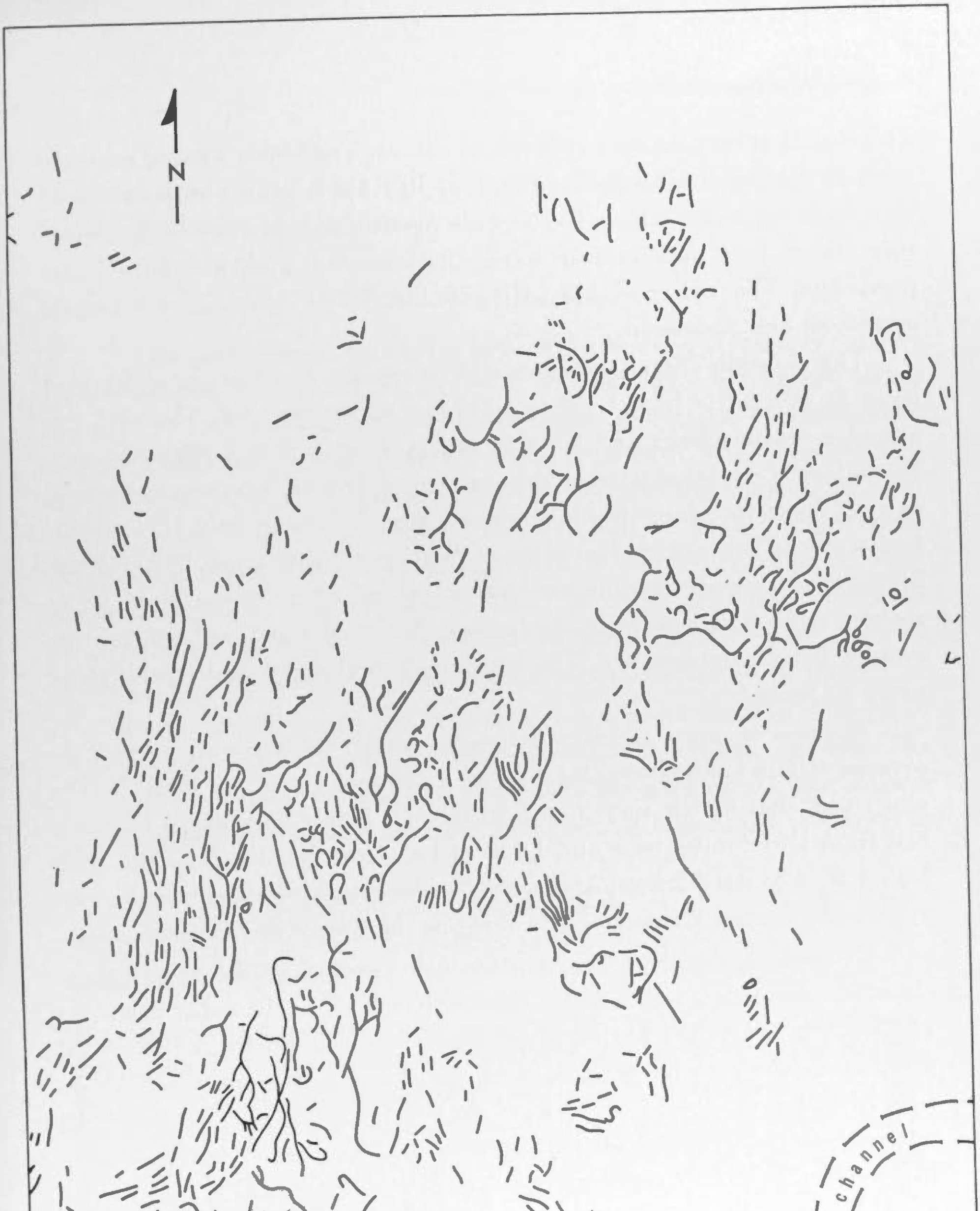

Figure 1B At centre left, most of the north-south trending ridges are part of an extensive corrugated morainic belt. The most prominent area of crevasse fillings extends from northeast to southwest as a band, one mile wide, marked by numerous looped and branching ridges. The remaining linear elements are eskers, ice-contact slopes and ablation slide moraines. The large abandoned channel crosses the area in the southeast.

Mannerfelt (1945), Tanner (1944) and others. The writer carried out field work in the area during the first week of July 1951, when a stop was made on a flight from Great Bear Lake to the Arctic coast. In the preparation of this report field observations were supplemented with air-photo interpretations. The writer wishes to thank Dr. W. H. Mathews for helpful comments and discussions.

The crevasse fillings, ablation slide moraines, and associated features lie at an altitude of from 1,150 to 1,250 feet above sea level. The sand and gravel crevasse fillings and terraces are well drained and relatively dry. Permafrost is doubtless present although frozen ground was not encountered in a pit dug 6 feet deep on a south-facing gravel slope on July 3. However, frozen ground lay within a foot of the surface in wet peaty areas. The crevasse fillings and terraces support an open woodland cover of scattered white spruce, aspen and balsam poplar copses, bush alder and willows, heaths, mosses, lichens, grasses, etc. The bottoms of swales and basins tend to be sedgy to peaty.

The area of ridges and terraces grades northward into a higher tundra-covered rolling landscape rising to over 1,300 feet above sea level. To the south and west of the ridged area, there is a higher corrugated morainic belt from 1 to 2 miles wide and 1,250 to 1,450 feet in altitude. Thus, with higher land to north, west, and south, a blockage of drainage to the east apparently caused a large lake to form in the Stopover Lake depression.

To the east, there is a large north-south trending, abandoned drainage channel, whose flow entered the Horton River about 10 miles northeast of Stopover Lake. The abandoned channel formerly carried a substantial flow, as shown both by the length of the abandoned channel and by its size. Although the total length of the channel is unknown, it can be traced upstream from Stopover Lake for over 80 miles with virtually no diminution in size. The abandoned meander scars and oxbows have radii of 1 to 2 miles, a size fully equal to the meander loops and scrolls of the lower course of the modern Horton River which has a length exceeding 330 miles.

In the section east of Stopover Lake, flow in the abandoned channel started when the river was at the present 1,100 to 1,150 foot level, as shown by the highest terraces that bear flow marks at that altitude. The absence of higher river terraces is in keeping with the view that flow from the channel was initially into a water body, 1,150 to 1,250 feet in altitude, occupying the Stopover Lake depression. Only after the lowering of the lake(s) to about 1,150 feet did river flow to the east, past Stopover Lake, commence. As the area became partially drained and the river began downcutting, incised meanders developed to a depth of 50 to 75 feet below the upper river terrace levels. Eventually, the channel was abandoned.

CREVASSE FILLINGS

The crevasse fillings, which are believed to be sand and gravel casts of former fissures in stagnant ice, resemble undulating to flat-topped eskers (Figure 2). They have a preferred north-south orientation, nearly at right angles to the last regional direction of ice movement which was west to northwest. Some of the ridges are relatively straight and occur singly, but most of them branch in wishbone fashion, loop or hook around kettle depressions, intersect in an irregular network, or merge into pitted outwash plains at accordant levels (Figure 3). Many of the looped ridges have a flat terrace-rim on the inner side, encircling the kettle depressions or dead-ice hollows. The hollows are often lake-filled, or wet and sedgy in the centres.

The network ridges lie in a mile-wide, north-south band to the west of Stopover Lake, with a small concentration on the east side of the lake. The ridge junctions are not distributed at random but are grouped into clusters with a range of from two to eight junctions. A significant tendency to

Figure 2. Curving and branching sand and gravel ridges, believed to be crevasse fillings, are shown at the northwest end of Stopover Lake.

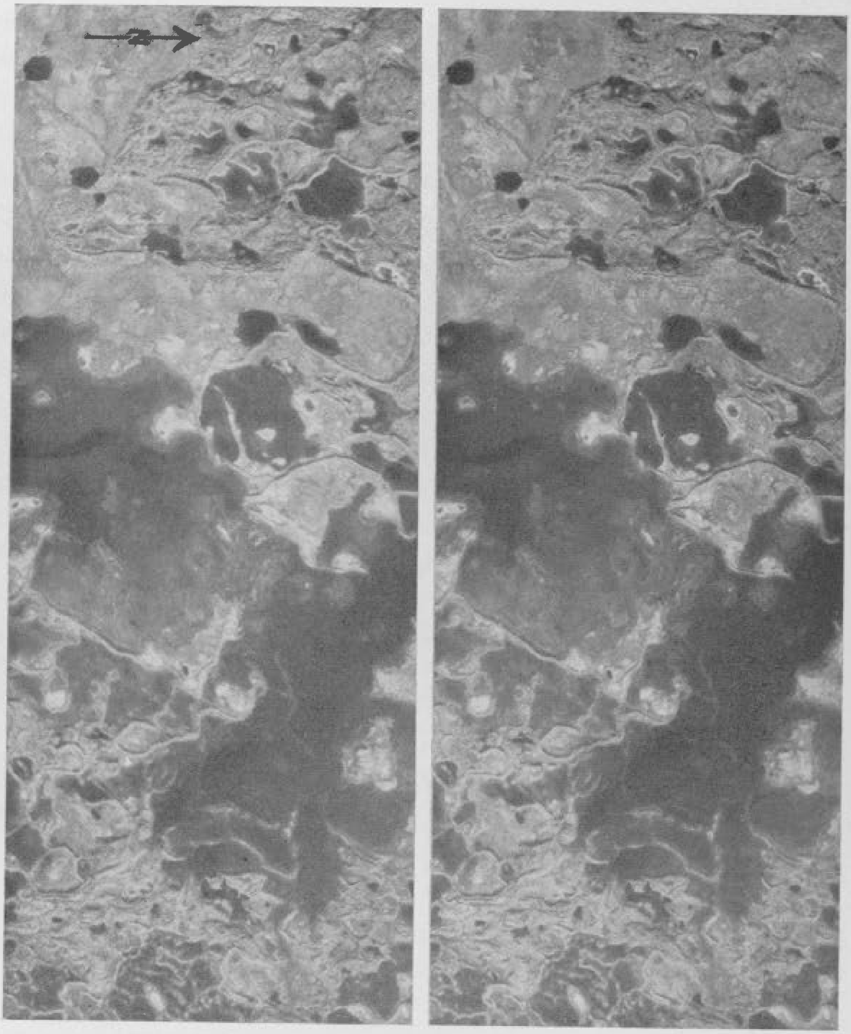

Figure 3. Note the numerous looped and branching ridges with many enclosed depressions. The ridges, most of which are considered to be crevasse fillings, are of sand and gravel.

clustering or grouping is observed in statistical tests (Clark, 1956). The tendency towards clustering of ridge junctions shows that local conditions which favored one junction also favored others. As the ridges are interpreted as crevasse fillings, the ridge junctions appear to locate the intersection of two crevasse systems, the north-south ridges reflecting transverse crevasses, and east-west ridges longitudinal crevasses.

So far as could be ascertained from surface exposures, natural sections, and excavations, the ridges and terraces are of sand and gravel without a veneer of glacial till, although scattered erratics, bearing striations and facets, occur on their surfaces. Most of the ridges range from 20 to 50 feet in altitude. The long profiles of the smaller and narrower ridges are usually irregular, but many of the larger ridges have even crests. Some of them broaden to merge, with an accordant level, into flat-topped terraces. A single massive ridge may show, in cross-profile, several parallel ridge crests, of which the centre-most one is typically the highest.

The crevasse fillings are believed to have formed during the last stage of deglaciation when a mass of fissured, crevassed, and tunneled stagnant ice lay immobile in the Stopover Lake depression with the interconnecting passageways between the ice-blocks filled with water up to the level of closure of the depression. As there is higher land to the north, west, and south of the depression, ponding of waters would probably have occurred if there were an ice dam to the east, towards Horton Lake. Under such conditions, debris from the wasting stagnant ice-blocks would have been washed into the fissures, crevasses, tunnels, ponds, etc. to form ice-contact features such as crevasse fillings, kame terraces, outwash deposits, and so forth. If there were many interconnecting passageways, as the pattern of ridges indicates, there would have been a controlling water level over large areas of the Stopover Lake depression. Thus, at any one time, deposition of sands and gravels would have had an effective upper limit determined by this water level. This would explain the flat crests of many ridges and the accordant levels at which they merge into flat-topped terraces.

About 25 to 30 per cent of the Stopover Lake area is covered with sand and gravel terraces and ridges with an estimated thickness of 20 to 45 feet. If the material were spread uniformly over the entire depression, the thickness would range from roughly 5 to 15 feet. Although little is known about the thickness of till in adjacent areas, there is some doubt as to whether it would average as much as 5 to 15 feet. This suggests, therefore, that some of the sand and gravel comprising the ridges and terraces may have been transported into the Stopover Lake depression by inflowing streams. This suggestion is supported by the fact that the most extensive and continuous systems of ridges and terraces occur in the south, bordering the large abandoned drainage channel, previously mentioned, which could have provided a major source of transported sediments. Significantly, the ridges and terraces become smaller and more isolated with increasing distance away from the abandoned channel.

Inasmuch as the upper limit of terrace and crevasse deposition was determined by the prevailing water level, any lowering of the water level would have left the depositional features above it high and dry. At Stopover Lake, there is a series of terraces and crevasse fillings whose tops lie between 1,150 and 1,250 feet in altitude—the range is probably smaller, but it cannot be determined more accurately with existing maps. Once the level fell below 1,150 feet, most of the area would have acquired its present over-all lake pattern because of drainage by the river that formerly flowed in the abandoned channel to the east. The lowering of the water level seems to have been rapid, because there are no successive flights of terraces and crevasse fillings as would have been expected to develop in a lake with a gradually lowered water level. Rapid lowering may have been caused, for instance, by the failure of an ice dam to the east or the uncovering of a lower outlet. As the water level was lowered in the Stopover Lake depression the margins of ice-blocks melted back from the sand and gravel banked against them to give ice-contact terraces and crevasse fillings. Narrow crevasse fillings slumped and lost their altitude upon removal of the ice support, the broader ones remaining flat-topped. Melt-water from some of the ice-blocks escaped in overflow channels across terraces and crevasse fillings. Melt-water courses are now preserved as high level, abandoned, channels extending across terraces and linking one kettle hole with another. The channels are typically less than 10 feet deep and 200 feet wide.

ABLATION SLIDE MORAINES

Groups of sub-parallel ridges, here referred to as ablation slide moraines, occur on the sloping to flat bottoms of some depressions formerly occupied by stagnant ice (Figure 4). The ridges average only a few feet in height and about 50 feet in width. Their steepest slopes, when discernable, tend to face towards the position of the former ice-block from which the material is believed to have slid. The ridges curve in response to the relief of the ground and, in general, follow the contour. Ridge spacings range from about 70 to 110 feet. For example, at the southwest side of Stopover Lake there are 12 ridges in a horizontal distance of 1,050 feet, the average spacing being 88 feet.

An ablation slide moraine is believed to have formed by the chuting, slumping, and sliding of ablation material down the slope of a stagnant ice-block onto dry land, or, at least, onto the ground with a minimum of reworking by water. With annual wastage of ice-blocks, a series of sub-parallel ablation slide moraine ridges would have been formed. The ridges would have reflected the general ground plan of the ice-block from which their material came. Large ice-blocks that wasted away to form two or more smaller ice-blocks would be so shown by the eventual separation of ridges around two or more centres.

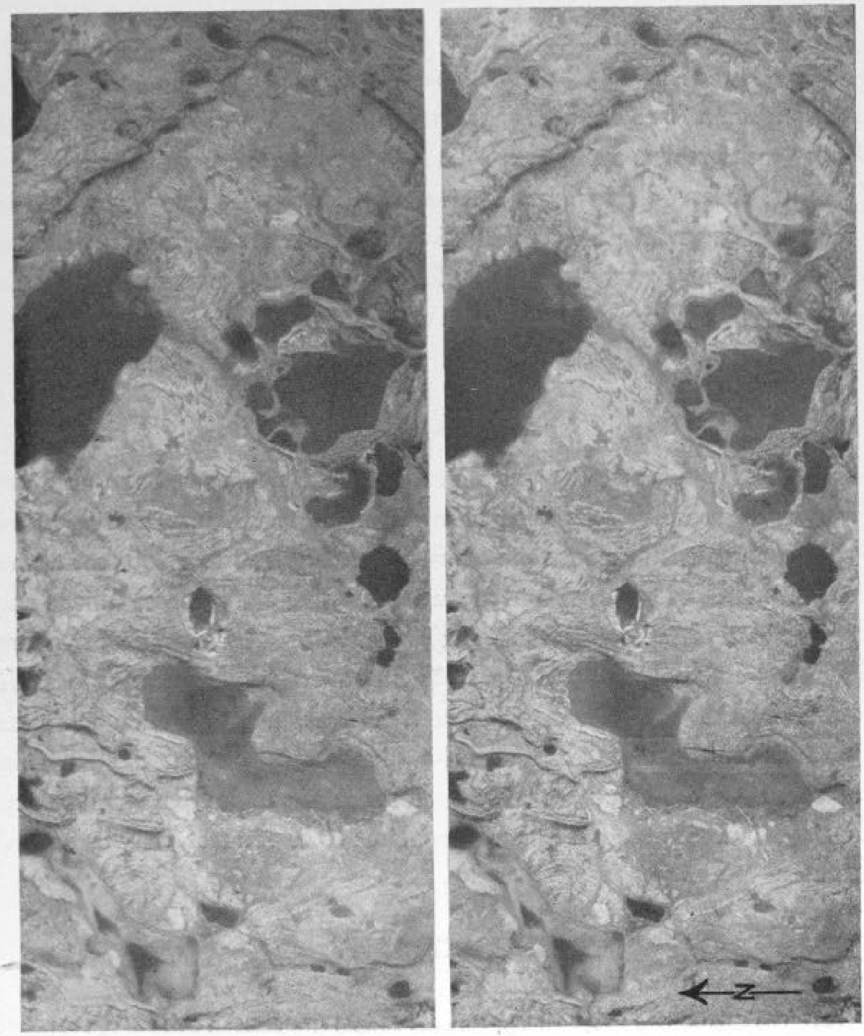

Figure 4. An ice-contact face, scalloped by kettle depressions, lies below (to the east) of Stopover Lake. A matching ice-contact face crosses the centre of the photograph above (to the west) of Stopover Lake. A series of low sub-parallel ridges, believed to be ablation slide moraines, occupies the low land between the lake and the foot of the ice-contact slopes. Note how the ablation slide moraines are parallel to the ice-contact slopes in the first stage of their formation; the pattern of subsequent melting is shown by the arrangement of the ridges about separate centres.

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The formation of the ablation slide moraines is believed to have been, in general, as follows. A rapid lowering of water level left many large and small ice-blocks high and dry. For awhile, there was flow from some ice-block-occupied areas to others, as is shown by abandoned melt-water channels crossing terraces and linking kettle depressions. In time, the ice-blocks melted back from the ice-contact faces and the chuting, sliding, and slumping of ablation material built a series of sub-parallel ridges which, initially, closely followed the trend of the ice-contact faces. As the spacing of the ridges are some 70 to 110 feet apart, this suggests a retreat of the ice-block edge by that amount each year. This is in reasonable agreement with rates of melting observed elsewhere (Charlesworth, 1957). As recession would be expected to occur on all sides of the ice-block, the net horizontal reduction in size would be roughly 140 to 220 feet a year. On this basis, most of the ice-blocks in the Stopover Lake basin would have lasted no more than 10 to 20 years.

CONCLUSION

Most of the sand and gravel ridges in the Stopover Lake area are crevasse fillings built by deposition of sediment in open fissures and crevasses of stagnant ice with a controlling water level of 1,150 to 1,250 feet above sea level. Much of the sand and gravel comprising the crevasse fillings and the associated terraces was transported into the area by a large river whose abandoned channel lies to the east of Stopover Lake. Following a rapid lowering of the water level to below 1,150 feet, ablation slide moraines formed by the chuting, sliding, and slumping of ablation material down the sides of wasting ice-blocks, to build up a series of sub-parallel small ridges. The ridges, whose spacings range from about 70 to 110 feet, may be annual features.

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SHORELINES OF NORTHUMBERLAND STRAIT

*Charles N. Forward**

The coasts along both sides of Northumberland Strait have been studied in connection with the feasibility of the construction of a causeway between Prince Edward Island and the mainland. Shorelines were classified by height of erosion face, varying from 1 to 100 feet, and by type of material exposed, such as rock, or glacial till.

The rocks bordering Northumberland Strait are flat-lying sedimentaries, chiefly sandstone, with some shale and conglomerate. On the whole they are soft and easily eroded compared with more resistant igneous and metamorphic rocks, such as those found along the south coast of Nova Scotia. Northumberland Strait shorelines, however, are protected by Prince Edward Island from the severe wave attack generated in the open Gulf of St. Lawrence and, as a result, the bays and headlands on either side of the strait are little altered from their initial pattern of irregularity. In contrast, the exposed shorelines from Miscou Island to Buctouche and along the gulf shore of Prince Edward Island are comparatively smooth, and baymouth bars are well developed. Within the strait, a substantial rock cliff of 20 to 30 feet in height may retreat only a few inches annually, but where the rock is of shallow thickness it may retreat at rates of several feet per year. Sections of shoreline composed wholly of unconsolidated material are also quite extensive. In locations exposed to severe wave action an unconsolidated bank less than 10 feet in height may retreat at rates of up to 12 feet a year.

The persistent erosional processes of the sea are a constant threat to valuable shoreline property. Much of the land along these coasts is cultivated to the edge of the bank and in certain areas, particularly along the mainland coast, hundreds of cottages line the shores. Waterfront properties in Shediac, Pugwash, Summerside, Charlottetown and other towns are occupied both by residences and by industrial or commercial buildings. Various methods have been used to protect shoreline properties from erosion, some more effective than others. The following photographs illustrate a number of shoreline types, and examples of protective measures intended to check erosion.

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*Other members of the 1958 field party investigating shorelines were C. W. Raymond and J. A. Rayburn of the permanent staff and R. C. Geen and D. A. Rapson of the seasonal staff.

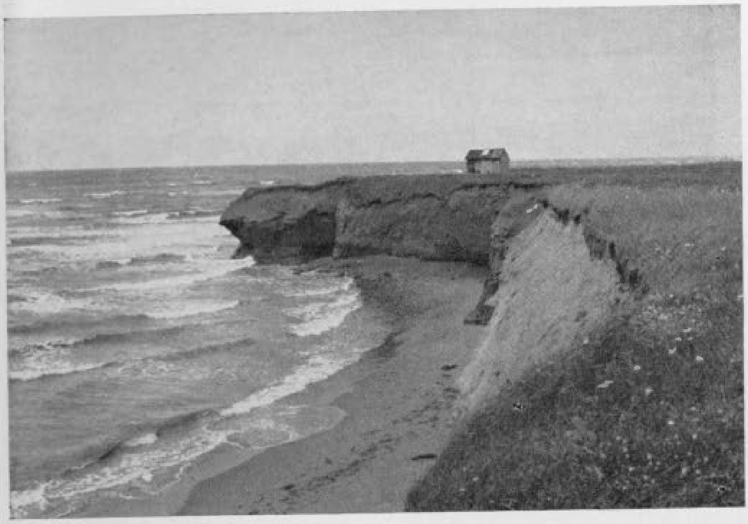

Figure 1. This erosion face 15 to 20 feet high is composed of sandy loam based on layers of hard, red clay. Debris eroded from the bank is washed away readily by wave action, producing a smooth, sandy beach at the base of erosion face.

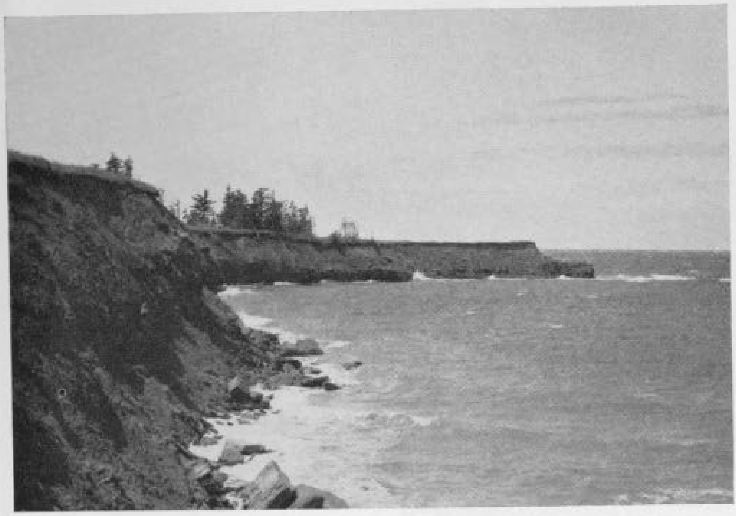

Figure 2. On headlands such as this wave action is quite severe because both sides of the point are exposed. As a result, unconsolidated material on the point is frequently removed before the underlying rock has been eroded away and a protruding rock bench is produced.

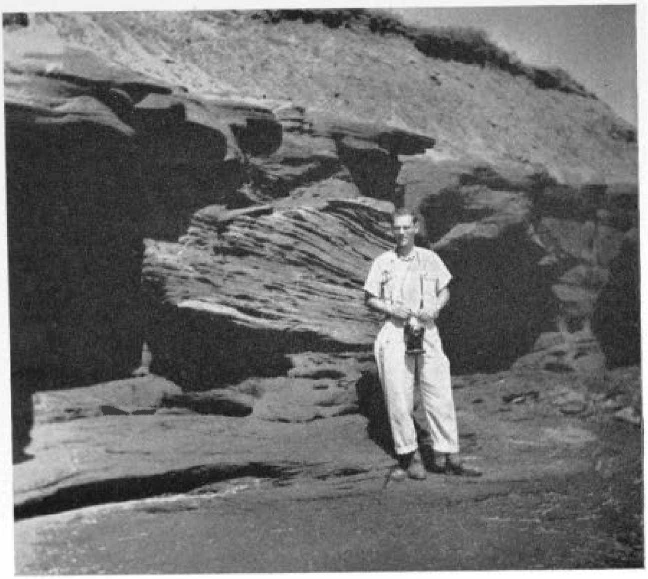

Figure 3. The sandstone varies considerably in resistance to sea erosion, depending on the strength of the cement that bonds the sand particles. Where the rock is massive and resistant, undercutting often forms caves of this type.

Figure 4. Undercutting is illustrated in this view of sea stacks. It is likely that weaknesses in the rock formation along the necks of the narrow headlands enabled the sea to carve these erosional remnants.

Figure 5. A large gully has been cut by running water in the unconsolidated material of a sea erosion face.

Figure 6. This narrow headland is suffering severe wave attack. The rock has been undercut and the bouldery till has been removed in large quantities, leaving the surface sod well back from the rock face. The large, quarried sandstone and granite blocks on the right have been placed there to check erosion.

Figure 7. Unconsolidated material with many boulders is exposed along the erosion face. The large sods that have slipped down the bank are evidence of rapid shoreline retreat. The boulders are washed away less readily than the finer material and tend to accumulate at the base of the slope.

Figure 8. This bank of heavy clay loam underlain by gravelly loam shows evidence of retreat in the slumping of sods. Under conditions of more active sea erosion these sods would be washed away more readily.

Figure 9. This unconsolidated bank 1 to 2 feet high is retreating at the extremely rapid rate of 12 feet per year, as determined by measurement of field boundaries. During the last 30 years a complete fenced field has been removed.

Figure 10. In river estuaries such as this the shoreline is protected from severe wave action and a defined erosion face may not exist. Luxuriant marsh grasses generally fringe the shore and help to retain the soil.

Figure 11. The cottage is threatened by the sea as the erosion face has retreated to within inches of the structure.

Figure 12. The placement of tree branches along the erosion face of unconsolidated material overlying rock is an attempt to retain the soil.

Figure 13. An example of a pile retaining wall in good condition.

Figure 14. This wall of vertical posts has been so badly damaged that it is completely ineffective.

Figure 15. This stone and concrete retaining wall protecting a house is well maintained and quite durable.

MAP NOTES—FICHES CARTOGRAPHIQUES

CANADA. 1:15,840,000. Canada, Ministère des Mines et des Relevés Techniques, Division des Levés et de la Cartographie. Canada, Dept. Mines and Tech. Surv., Surveys and Mapping Br., Ottawa, 1958.

Préparée originellement pour la section de l'Annuaire du Canada, Bureau fédéral de la statistique, cette carte politique en couleur du Canada est publiée en français et en anglais. Bien que de format plus petit puisqu'elle ne mesure que 12 pouces de largeur par 14 pouces de longueur, cette carte est la réplique de la carte officielle du Canada à 100 milles au pouce. Les principales voies de communication y sont indiquées par des traits de couleur noire et rouge. Les premiers indiquent les chemins de fer principaux tandis que ceux en rouge montrent les principales lignes aériennes du pays.

Prepared originally for the Canada Yearbook Section, Dominion Bureau of Statistics, this political map in color is published in French and English. Although of smaller dimensions, this map is the replica of the official map of Canada at a scale of 100 miles to an inch. The main communication routes are indicated by the use of black and red lines. The black lines show the main railways while the red indicates the main airlines.

CANADA. 1:4,055,040. Canada, Dept. of Mines and Tech. Surv., Surveys and Mapping Br., Ottawa, 1959.

This map supersedes the 64-mile map of Canada, originally published in 1947 and revised in 1949. It is similar in form and content to the previous edition except for the northern extension which is now published in a single sheet instead of two.

BERYLLIUM IN CANADA; METALLOGENIC MAP. 1:7,603,200. Canada, Dept. of Mines and Tech. Surv., Geol. Surv. Canada, Ottawa, 1958.

The main purpose of this map is to show the locations of known occurrences of beryllium in Canada and to relate this information to the principal geological features. Geological comparisons may be made by superimposing this transparent map on the Geological Map. of Canada (No. 1045A).

The information shown is based on the plotting of about 60 reported occurrences of beryllium minerals. In areas where the occurrences are grouped too closely, a ruled pattern has been used to indicate their locations. Many occurrences appear to be small and the occurrences of scientific interest only, but the map provides useful information on the general distribution of beryllium. References to published accounts of occurrences are listed to aid those who desire to obtain additional information on an occurrence or area.

MOLYBDENUM IN CANADA; METALLOGENIC MAP. 1:7,603,200. Canada, Dept. Mines and Tech. Surv., Geol. Surv. Canada, Ottawa, 1959.

This map is similar in form to the previous map and shows the locations of known molybdenum occurrences in Canada, and differentiates between the various types of deposits found. In this map, emphasis is on occurrences that are most likely to prove of economic importance. A fairly comprehensive selection of the literature relating to the geology of Canadian molybdenum deposits is listed.

IRON IN CANADA; METALLOGENIC MAP. 1:7,603,200. Canada, Dept. Mines and Tech. Surv., Geol. Surv. Canada, Ottawa, 1959.

This transparent map designed for use with the Geological Map of Canada (No. 1045A) and shows the distribution and general trends of the major ranges of iron formation and the locations of various types of iron deposits. Information has been summarized from more than 100 iron formation ranges and well over 1,000 iron deposits or individual properties. The iron deposits are separated into three main groups: (a) iron formations and deposits directly related to iron formations; (b) deposits directly associated with plutonic igneous rocks; (c) other types of deposits not well known or defined. Principal producing areas or deposits are listed in a marginal note, but due to limited space many deposits marked on the map are omitted from the list. The map includes selected references to the literature.

(J.-P.C.)

BOOK NOTES—FICHES BIBLIOGRAPHIQUES

FOREST REGIONS OF CANADA. J. S. Rowe. Canada, Dept. of Northern Affairs and National Resources, Forestry Br., Bulletin 123. Ottawa, 1959. 71 p., map, glossary.

The publication in 1937 of W. E. D. Halliday's "A Forest Classification for Canada" (Forest Service Bulletin 89) was a notable achievement; the work has been the standard reference on Canadian forests for over 20 years. The publication of this new bulletin, based on the earlier work, but incorporating much additional knowledge, is equally noteworthy.

The approach to the problem is geographical, the author outlining the areal extent of the forests described. Many changes in boundary lines have been made as forest regions were redefined in the light of new information. Eight major Forest Regions are recognized: Boreal, Subalpine, Montane, Coast, Columbia, Deciduous, Great Lakes-St. Lawrence and Acadian. The major regions are further divided into a number of distinct sections. In addition to a wealth of information on forests and forest conditions, the description includes reference to topography, geology, soils and climate.

(F.A.C.)

EIGHTH REPORT OF THE COMMISSION FOR THE STUDY AND CORRELATION OF EROSION SURFACES AROUND THE ATLANTIC. IV. Researches in North America. International Geographical Union, Ninth General Assembly and Eighteenth International Geographical Congress, Rio de Janeiro, 1956. 64 p., illus.

This report of the Commission on erosion surfaces of the International Geographical Union includes eight studies on the regional cyclic morphology of some chosen areas of North America. One of these, by Professors Bird and Hare of McGill University, is concerned with a Canadian area, eastern Canada and the eastern part of northern Canada. The report also includes a ninth article, which is a critical review of fourteen recent papers published between 1952 and 1955 on the same subject. One of these is Professor Bird's summary of his studies on the post-glacial marine transgression in the central Canadian Arctic, which were carried on between 1948 and 1953 for the Geographical Branch.

In their studies, the eight authors, after a survey of the literature and their own research, are concerned with taking the census of the multiple planation or erosion surfaces present today in the landscape of the different parts of the North American continent. A serious attempt is made by the authors to identify, localize, limit, and name the various upland surfaces. The numerous criteria used for this purpose are well enumerated and fully described. An attempt is also made to date these planation surfaces, to correlate them from region to region, and to understand their mode of origin, i.e., to find traces that would reveal the morphogenetic systems under which each one was elaborated.

(S.H.R.)

CANADIAN ICE DISTRIBUTION SURVEY. Publications of the Geographical Branch, Ottawa. (See Geographical Bulletin No. 11: 96-97 for previous ice reports).

Gulf of St. Lawrence area

Gulf of St. Lawrence Ice Survey, Winter, 1958. W. A. Black. Geographical Paper No. 19, 1959.

Gulf of St. Lawrence Ice Survey, Winter, 1959. W. A. Black. Geographical Paper No. 23, 1959.

The Gulf of St. Lawrence ice surveys, winter of 1958 and 1959, represent the third and fourth aerial ice reconnaissance, respectively, of ice conditions in the Gulf of St. Lawrence region. Increased attention has been paid to the influence of climatic factors as they affect ice distribution and coverage. In 1959 the complete development and decay of ice in the St. Lawrence region, including the St. Lawrence River, was studied for the first time. The last report also contains a photographic record of ice distribution as it affects shipping.

Ice conditions in the Gulf of St. Lawrence during the Spring Seasons 1953-1957. C. N. Forward. Geographical Paper No. 16, 1959.

In 1954 the Geographical Branch published a report on ice distribution in the Gulf of St. Lawrence which was based on observational data collected for the years 1940 to 1952, inclusive (Geographical Bulletin No. 6: 45-84). This report proved to be of great use to many agencies concerned with extending the navigation season in the gulf. The new report brings the information up to date, studying ice conditions during the spring season from 1953 to 1957. The analysis of temperature records from 1940 to 1957 shows that a moderating influence on ice conditions has occurred during the past two decades, and suggests that, in general, ice conditions have been favorable to navigation during the last eighteen years.

Sea Ice conditions in the Northumberland Strait Area. C. N. Forward. Geographical Paper No. 21, 1959.

Special studies are made from time to time by the Geographical Branch on ice conditions in specific areas. This report summarizes ice conditions in the Northumberland Strait area for the period 1940 to 1957, and was prepared in an attempt to assess the possible effect of ice conditions on the projected Northumberland Strait causeway.

La dynamique et l'état des glaces de l'Estuaire et de la partie nord-est du golfe St-Laurent pour l'hiver 1957-58. Michel Brochu. Étude Géographique no 24, 1959. (Text in French).

In 1957 a network of shore-based ice observation stations was established around the Gulf of St. Lawrence and in the Strait of Belle Isle. This report analyses observations for the winter season, 1957-58. The localization of ice distribution in relation to topographic features such as islands, shore-lines and river mouths received attention. The object of the study, primarily, was to provide information of use to agencies interested in winter navigation in harbours of the region.

Eastern Arctic Area

A Report on Sea Ice Conditions in the Eastern Arctic, Summer, 1958. W. A. Black. Geographical Paper No. 20, 1958.

This report is the result of the third ice reconnaissance survey of the Eastern Arctic carried out during the summer of 1958 from *C. G. S. d'Iberville* during the annual resupply mission to northern stations. As in previous surveys, ice observations were made from the ship's helicopters as well as from the ship, and meteorological and oceanographic data incorporated into the report. The purpose of the report is to record the special problems that ice presents to ships navigating in Canada's Eastern Arctic waters.

(F.A.C.)

TABLES OF TEMPERATURE, RELATIVE HUMIDITY AND PRECIPITATION FOR THE WORLD. Part I. North America, Greenland and the North Pacific Ocean. Air Ministry, Meteorological Office, M. O. 617a. London, H.M.S.O., 1958. Eight shillings net.

The World Climatology Branch of the Meteorological Office has compiled these tables for a "carefully chosen and representative selection of places, making climatic data for the whole world readily available at a moderate cost". Part I is the first of six volumes that will also be available in one composite volume. The frontispiece shows the areas covered by the different volumes, and a map is included showing the positions of the stations for which climatic tables are given. The explanatory notes discuss the details of techniques of observation, standards of time, position and height of the stations and the number of years of observations available. The volume includes a bibliography and index.

(R.C.A.)

GAZETTEER OF CANADA (NEW BRUNSWICK). Canadian Board on Geographical Names, Ottawa, 1956, 84 p., map. Price $1.00.

GAZETTEER OF CANADA (SASKATCHEWAN). Canadian Board on Geographical Names, Ottawa, 1957, 92 p., map. Price $1.00.

Seven in this series have been published since 1952, of which these are numbers 4 and 5. The first covered Southwestern Ontario (see Geographical Bulletin No. 4), the second British Columbia (see Geographical Bulletin No. 7), the third Manitoba (see Geographical Bulletin No. 9) and the sixth and seventh Alberta and Northwest Territories and Yukon (see Geographical Bulletin No. 13).

The names of the geographical features and settlements are listed alphabetically and in the gazetteer for New Brunswick located by parish and county as well as by geographical coordinates. For Saskatchewan, the features and settlements are located by section, township and range as well as by coordinates. Location maps are included in all the gazetteers with the exception of the Northwest Territories and Yukon volume.

(J.K.F.)

THREE CENTURIES AND THE ISLAND, A Historical Geography of settlement and Agriculture in Prince Edward Island, Canada. A. H. Clark. University of Toronto Press, Toronto, 1959. 287 p., maps, tables. Price $10.00.

Justly acclaimed as an outstanding contribution to Canadian historical geography, this book provides an exhaustive study of the evolution of settlement and land-use patterns in the landscape of a province where agriculture remains the dominant economic activity. After a concise treatment of the physical geography and the areal differentiation of agricultural land use and land value in 1951, the author describes the occupance and land culture patterns during successive periods since the Island's discovery by Cartier in 1534 The period of Acadian French settlement from 1719 until the expulsion of 1756, subsequent British rule, and the grey influx of Scottish, Irish, Loyalist and English stock during the 19th century are described, showing the effect of each on the Island's agriculture. The remainder of the book deals with changing land use and population patterns since Confederation, a period during which immigration ceased and the pattern of emigration, which still continues, became established. No less than 165 maps and 16 tables are included to illustrate such factors as the origin and distribution of the inhabitants, changes in crop type and emphasis, and a number of interesting livestock ratios. The author makes clear "The necessity for careful consideration of the background of habit and prejudice of groups of different origin when studying the changing geographies of land use".

(C.W.R.)

A PRELIMINARY STUDY OF FOXE BASIN BOTTOM SEDIMENTS. F. D. Gorgeron. Manuscript report series (oceanographic and limnological) No. 45, Fisheries Research Board of Canada, Atlantic Oceanographic Group, St. Andrews, N.B., September 21, 1959. 41 p., maps, tables, references.

This report gives "a general description of the size, distribution, and mineralogy of bottom sediments in Foxe Basin and adjacent areas based on 174 bottom samples collected by the Atlantic Oceanographic Group during the 1955 and 1956 summer cruises of H.M.C.S. (now C.G.S.) *Labrador*." The greater part of the report, following a résumé of the analytical methods used, is occupied with tables detailing the grain size fractions by percentage weight; the values of statistical parameters used in analysing the samples (including median diameter of particles and the coefficients of sorting and skewness); and detailed lithologic composition by particle size for all samples. Faunal assemblages and carbonate content have been determined for a small number of the samples. Among the 5 maps which are included are two which show the distribution of coarse and fine sediments in the study area.

(V.W.S.)

BOTANICAL EXCURSION TO THE BOREAL FOREST REGION IN NORTHERN QUEBEC AND ONTARIO. W. K. W. Baldwin *et al.* Canada, Dept. of Northern Affairs and National Resources, National Museum of Canada, Ottawa, 1959. 119 p., maps, photos.

This guide book was planned primarily for touring members of an excursion through a part of the boreal forest region in northern Quebec and Ontario, which took place before the Ninth International Botanical Union Congress in Montreal (1959). The book should be of interest to geographers, agriculturalists, foresters and anyone planning a field excursion into the same area. Concise and informative sections deal with physiography, the forests, agriculture, settlement and climate, written as a general background to the route followed in the course of the 3,000 mile tour from Montreal to Moosonee and back. A check list of the vascular plants and a bibliography is also included.

(G. F.)

IRON DEPOSITS OF EASTERN ONTARIO AND ADJOINING QUEBEC. E. R. Rose. Canada, Dept. of Mines and Technical Surveys, Geol. Surv. Canada, Bull. 45, Ottawa, 1958. 120 p., tables, maps. Price $1.00.

The iron deposits of eastern Ontario and adjoining Quebec are receiving renewed attention because of the depletion of other sources of iron and as a result of the iron developments of Marmora, Ontario, and Bristol, Quebec. Data on all reported deposits are gathered together in this bulletin with the results of new, minute studies of the more important occurrences. Detailed maps, tables, photographs and microphotographs complete the work. The study of iron deposits, in connection with their host rocks, suggests a certain relationship between ore and rocks as an aid to exploration and development.

(I. J.)

THE IMPACT OF THE ST. LAWRENCE SEAWAY ON THE MONTREAL AREA. Montreal Research Council, Montreal, 1958. 128 p., tables. Price $2.00.

The study of the impact of the Seaway on the Montreal area represents an initial effort of Montreal Research Council, the economic research centre sponsored by McGill University.

The evaluation of changes in traffic patterns, after the completion of the St. Lawrence Seaway, is based on analyses of the earlier data concerning transport costs, tonnage and directions of cargoes, comparative freight rates and port facilities. Bulk cargoes, namely, iron ore, grain, coal, oil, and general cargo have been selected as the key elements for this study. In conclusion, the work suggests that economic benefits may be expected for the Montreal area by an increase in the traffic of grain, coal and iron ore, but with probable losses in the handling of general cargo. The extent of benefits will depend upon the plans and actions of both private industry and government rather than upon the impersonal economic forces.

(I. J.)

PROGRÈS INDUSTRIEL, LA PROVINCE DE QUÉBEC—1958, Québec, Department of Trade and Commerce, Québec, 1959. 116 p., tables, graphs.

This bilingual publication is a short review of the progress made in Quebec's economy during 1958, a year of an unprecedented peak attained in the industrial output of the province. General data concerning investments, production, population, employment, personal income and standard of living, are accumulated to illustrate the industrial development of the province. They are also intended to prove that optimistic views in the future economic rise are justified. The lists of manufacturing establishments erected in the province in 1958, and those enlarged during this year, complete the publication.

THE PROVINCE OF ONTARIO—an Industrial Study. Canadian Pacific Railway Company, Dept. of Industrial Developments, Toronto, 1959. 92 p. mimeo.

This concise work summarizes the economic base of the Province of Ontario. Beginning with an interesting historical and geographical background, the work deals with the developments in the economic fields of manufacturing, electric power, agriculture, forestry, mining, fisheries, trapping and fur farming. Transportation is described in detail and includes all the railroad, canal, and pipeline origin and destination points. In addition, each C.P.R. section receives a brief regional discussion, but no detailed location map is given. The banking, recreational and governmental fields are then discussed. The work concludes with a brief sketch of many Ontario cities and towns interested in industrial promotion.

(D. L.)

SURFICIAL GEOLOGY OF THE LINDSAY-PETERBOROUGH AREA, ONTARIO, VICTORIA, PETERBOROUGH, DURHAM, AND NORTHUMBERLAND COUNTIES, ONTARIO. By C. P. Gravenor. Canada, Dept. of Mines and Technical Surveys, Geol. Surv. Canada. Memoir No. 288, Ottawa, 1957. 60 p., maps, illus. Price $1.00.

PROGRÈS INDUSTRIEL, LA PROVINCE DE QUÉBEC.—1958, Québec, Ministère de l'Industrie et du Commerce, 1959, 116 p., tableaux, graphiques.

Cette publication bilingue passe en revue les progrès qu'a connus l'économie québécoise durant 1958, et au cours de laquelle la production industrielle de la province a atteint des sommets sans précédent. Afin d'illustrer cet essor, cette publication présente des statistiques sur les investissements, la production, la population, la main-d'œuvre, les revenus des particuliers et sur le niveau de la vie. Ces données corroborent en quelque sorte les vues optimistes que l'on peut avoir sur l'avenir économique du Québec. La liste des établissements manufacturiers construits ou agrandis dans le Québec au cours de l'année 1958 complète cette publication.

Following a brief description of the physiographic divisions of this area of some 2,000 square miles in south-central Ontario, the general geology is discussed, in particular that of the Pleistocene. The glacial history is examined and summarized in the final chapter Maps and selected outstanding photographs illustrate the memoir.

(J. K. F.)

THE NATIVE FLORA OF CHURCHILL, MANITOBA, with notes on the history, geology and climate of the area. H. J. Scoggan, Dept. of Northern Affairs and National Resources, National Museum of Canada, Ottawa, 1959. 51 p., maps, photos, illus.

This guide book was produced for a botanical field excursion held in conjunction with the Ninth International Botanical Union Congress (1959). It forms an interesting introduction to the geography of the Churchill area, and contains notes and useful descriptions of the history, physiography, climate, flora and vegetation, a check list of the vascular plants, and a bibliography of the Churchill and North Eastern Manitoba area.

(G. F.)

GLACIAL GEOLOGY OF THE SWIFT CURRENT AREA, SASKATCHEWAN. A. E. Christiansen. Report 32, Sask. Dept. of Natural Res., Regina, 1959. 62 p., diag., photos, map.

The glacial geology of an area of about 3,000 square miles in southwestern Saskatchewan is discussed in this report. Following a chapter on physiography, which includes glacia, proglacial, aeolian, post-glacial and bedrock land forms, is a chapter on stratigraphy. The report concludes with an interpretation of the glacial history. It contains photographs, diagrams and tables, and has an appendix detailing five sections. An endpaper map at a scale of 3 miles to 1 inch accompanies the report.

(J. K. F.)

CLIMATIC ANALOGS OF FORT GREELY, ALASKA AND FORT CHURCHILL, CANADA, IN EURASIA. Technical Report EP—77, December 1957.

CLIMATIC ANALOGS OF FORT GREELY, ALASKA AND FORT CHURCHILL, CANADA, IN NORTH AMERICA. Technical Report EP—111, May 1959. U.S. Army Quartermaster Research and Engineering Center, Environmental Protection Research Division, Natick, Massachusetts.

These interesting reports show the distribution in North America and Eurasia of climatic factors analogous to those experienced at U.S. Army test stations at Fort Greely and Fort Churchill. A statistical definition of analogy for the purpose of these reports is given in the commentaries.

The maps included show that some single elements of climatic analogy have a wide distribution, but areas of similarity are much diminished when one considers a combination of several analogous climatic elements. This is of considerable interest to those making tests of field equipment, and these reports would be most valuable for anyone who would choose the most favorable location for a test station for trials of equipment in yet more extreme conditions than those considered here.

The reports include a commentary on the selection of stations that were used in compiling the data, the major physical features of the areas covered, the climatic elements considered and the limitations of the reports. This is followed by tables of data used, extensive bibliographies and maps of climatic analogues.

(K.C.A.)

THE NORTH ALASKAN ESKIMO: A STUDY IN ECOLOGY AND SOCIETY. Robert F. Spencer. Smithsonian Institution, Bureau of American Ethnology, Bulletin 171. U.S.A. Printing Office, 490 p. Washington, 1959.

This book is based on ethnographic studies among the North Alaskan Eskimo, completed during the summer and early fall of 1952 and 1953. It is a study of social structure and social culture of a group of Eskimo. Two different ways of life, those of inland and maritime Eskimo, within a framework of common culture, are recognized. The interdependence of these two groups is examined, and the impact of the introduction of money economy is evaluated. The scope of the study includes the following main headings: The land and the people; Language; Houses and settlements; Family and kinship; Customary law; Economy and society; The individual and the life cycle; The supernatural; Shamanism; The cults; Culture change; Folklore.

(W. E. S. H.)

NOTES ON POTENTIAL BUILDING SITES IN THE BATHURST INLET AREA, N.W.T. J. B. and M. B. Bird. Canada, Dept. of Mines and Technical Surveys, Geog. Br., Geographical Paper No. 8, Ottawa, 1957. 14 p., map. Price 25 cents.

Based on a survey in 1954, this paper contains an outline of the geography of Bathurst Inlet and describes the characteristics of eight potential settlement sites in the area.

(J. K. F.)

NOTES ON SMALL BOAT HARBOURS, N.W.T. J. Ross Mackay. Canada, Dept. of Mines and Technical Surveys., Geog. Br., Geographical Paper No. 13, Ottawa, 1957. 11 p., illus. Price 25 cents.

Seven small boat harbours are described between Tuktoyaktuk and Cape Bathurst along the western Arctic coast, from observations made during a survey in 1955. Diagrammatic maps of each shelter supplement the brief descriptions of the navigational and physiographic characteristics.

(J. K. F.)

A SUBSURFACE ORGANIC LAYER ASSOCIATED WITH PERMAFROST IN THE WESTERN ARCTIC. J. Ross Mackay. Canada, Dept. of Mines and Technical Surveys, Geog. Br., Geographical Paper No. 18, Ottawa, 1958. 21 p., illus. Price 50 cents.

Discontinuous organic layers are described from the coastal region near the Firth and Blow rivers west of the Mackenzie delta from observations carried out in 1956 and 1957. The distribution, characteristics and origin of the organic layers are discussed. The paper is illustrated by maps, diagrams and one photograph.

(J. K. F.)

THE ANDERSON RIVER MAP-AREA, N.W.T. J. Ross Mackay. Canada, Dept. of Mines and Technical Surveys, Geog. Br., Memoir 5, 1958. 137 p., maps, diag., illus., bibliography. Price $2.00.

This memoir is one of the series of detailed terrain analyses being prepared for selected areas of the Canadian North by the Geographical Branch. It is based on field research carried out during 1951 and 1952 in the Anderson River Map-area, and includes work based on the interpretation of the aerial photographs. In the first chapter the author reviews the history of exploration and previous work concerning the area. The following chapters deal with physical geography, regional physical geography, climate, vegetation and human geography. In discussing the features such as pattern ground, pingos, and various types of lakes the writer considers the most important works on the subject of their morphogenesis.

(W. E. S. H.)

NOTES ON THE GLACIATION OF KING WILLIAM ISLAND AND ADELAIDE PENINSULA, N.W.T. J. K. Fraser and W. E. S. Henoch. Canada, Dept. of Mines and Technical Surveys, Geog. Br., Geographical Paper No. 22, Ottawa, 1959. 39 p. Price 75 cents.

As a result of field work in 1957 and aerial photo interpretation, landforms produced by glacial erosion and deposition are located and described and post-glacial processes are discussed. From these features a chronology of events during and after the final stages of Pleistocene glaciation has been proposed. The description and explanation of glacial and post-glacial phenomena is preceded by a short history of exploration and a summary of the geology of the area.

(J.G.)

WESTERN QUEEN ELIZABETH ISLANDS, DISTRICT OF FRANKLIN, N.W.T. R. Thorsteinsson and E. T. Tozer. Canada, Dept. of Mines and Technical Surveys, Geol. Surv. Canada, Paper 59-1, Ottawa, 1959. 7 p., maps. Price 50 cents.

This report presents brief descriptive notes on the accompanying geological map (1"=8 mi) which covers Melville, Prince Patrick, Mackenzie King, Borden, Brock and Eglinton islands. An index map shows the structural provinces in the western Queen Elizabeth Islands.

(J. K. F.)

PILOT OF ARCTIC CANADA. Canada, Dept. of Mines and Technical Surveys, Surveys and Mapping Br., Canadian Hydrographic Service, Vol. 1, 1st ed., Ottawa, 1959. 183 p., maps. Price $5.00.

This Pilot consists of three volumes. Volume I includes sections on descriptive physiography, population, transportation and communication, economic development, administration, vegetation and wildlife, ice distribution and navigation, exploration, submarine topography, tides and currents, climate, aurora and magnetic storms. Regional descriptions of the coasts and waters will be contained in Volume II (Eastern Arctic) and Volume III (Western Arctic). Volume I is well illustrated with locational and distribution maps, and a useful windchill chart.

(J. K. F.)

OCEANOGRAPHIC ATLAS OF THE POLAR SEAS, PART II, ARCTIC. U.S. Navy Hydrographic Office, Washington, D.C., 1958. 150 p., maps, tables, bibliography.

The 132 maps, charts and diagrams in this atlas, most of them completed in early 1957, summarize the knowledge of the Arctic Basin available prior to the International

Geophysical Year, 1957-58. Oceanographic and related climatic data have been charted on polar projection maps for semi-monthly, monthly, seasonal and, occasionally, annual periods. The atlas includes sections on tides and currents; physical properties of sea water; ice distribution; seasonal variations in winds, sea and swell; marine geology; and marine biology. Each major section is preceded by a short but valuable introductory section, and inset maps indicating the reliability of the data are included whenever possible. All oceanographic stations occupied in the basin from the period of exploration to the present have been plotted on two large fold-out maps. These will be of particular value to those interested in historical aspects of oceanography. It is unfortunate that the base used for these maps is inaccurate for the Canadian Arctic. The islands in Foxe Basin, for example, are omitted although they are included on most of the other charts. A fold-out bathymetric map of the polar basin is included. A bibliography of 124 of the most important references completes the publication.

(V. W. S.)