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UTILISATION DU SOL ET COLONISATION DE LA RÉGION DES LAURENTIDES CENTRALES

P.B. Clibbon

Résumé: Au début du XIX[e] siècle, les autorités coloniales érigèrent des cantons sur le Bouclier canadien, au nord des seigneuries canadiennes-françaises des basses terres du Saint-Laurent. De nombreux colons irlandais s'y installèrent, mais la plupart émigrèrent peu après vers les villes des basses terres. Les Canadiens français, qui étouffaient dans les seigneuries surpeuplées, furent contraints par les circonstances à s'établir sur les terres abandonnées par les Irlandais et même plus loin à l'intérieur, derrière les cantons déjà constitués. La superficie défrichée dans la région des Laurentides centrales atteignit son maximum vers 1921, mais depuis de vastes étendues de terre à faible rendement ont été abandonnées ou reboisées. Le récent essor de l'industrie touristique dans la région provoque une vive spéculation foncière, notamment au voisinage des centres urbains.

Abstract: In the early nineteenth century, townships were erected on the Canadian Shield north of the French-Canadian seigniories of the St. Lawrence lowlands. These townships received considerable numbers of Irish colonists, most of whom, however, soon migrated to the towns of the lowlands. Increasing population pressure in the seigniories resulted in the settlement by French-Canadians of lands abandoned by the Irish and also of large interior tracts behind the original townships. Improved land attained its maximum acreage over most of the central Laurentian region in 1921, but since that time large acreages of marginal farmland have been abandoned or reforested. The recent influx of tourists into the region has resulted in land sale and speculation in the areas near urban centres.

INTRODUCTION

Les autorités britanniques, qui occupèrent la Nouvelle-France à partir de 1760, ne firent aucune tentative sérieuse de colonisation avant 1790. Les Loyalistes et les immigrants venant des îles Britanniques s'établissaient surtout dans le Haut-Canada et les provinces Maritimes, de sorte que les régions rurales du Bas-Canada demeuraient françaises. Au début du XIX[e] siècle, les autorités coloniales, pour faire contrepoids à la majorité canadienne-française, tentèrent d'encourager des colons de langue anglaise à venir s'établir dans les campagnes du Bas-Canada.

Les grandes seigneuries canadiennes-françaises occupaient les plaines fertiles de la vallée du Saint-Laurent, entre le piémont appalachien, au sud, et les hautes terres du Bouclier, au nord. Les autorités britanniques décidèrent de partager les hautes terres en cantons et de les occuper. La partie

Ms reçu en octobre 1962.

du Bouclier sise entre Montréal et Trois-Rivières, dite région des Laurentides centrales,* était l'une des principales zones destinées à cette colonisation.

Dans la présente étude, nous voulons démontrer que le système actuel d'occupation du sol s'explique en grande partie par cette pénétration de bûcherons et de cultivateurs, si caractéristique des débuts de la colonisation dans la région.

ASPECT PHYSIQUE

La région des Laurentides centrales est un vaste plateau dont le relief est par endroits relativement accidenté; il repose sur des roches précambriennes résistantes qui sont recouvertes de till rocailleux, lui-même vêtu par endroits de graviers et de sables stériles. Dans ces hautes terres se sont creusées de larges vallées, orientées vers le sud-est et partiellement comblées d'alluvions, sur lesquelles se sont formés des sols limoneux et argileux. Au débouché de ces vallées, on note la présence de dépôts Champlain. Au nord et au nord-ouest de Montréal, un abrupt marque le contact physiographique entre les roches cristallines du Bouclier et les calcaires solubles des basses terres. Plus à l'est, entre les comtés de Montcalm et de Maskinongé, le contact est partiellement voilé par des dépôts marins et fluvio-glaciaires parsemés d'îlots de roches cristallines.

La végétation naturelle est constituée de forêts denses de conifères sur les terrains alluviaux des vallées et d'essences feuillues sur les tills rocailleux des terrains plus élevés. Cette région jouit d'un climat tempéré et humide, avec une moyenne de 120 à 130 jours exempts de gel, soit quelques jours de moins que dans la plaine.

COLONISATION BRITANNIQUE

Avant 1800, la colonisation dans la région des Laurentides centrales avait été à peu près nulle: on avait établi quelques comptoirs de pelleteries sur le Saint-Maurice et défriché quelques arpents à la limite du Bouclier, dans le comté de Maskinongé. C'est à cela que se résumait l'occupation canadienne-française.

En 1803, on arpenta le premier canton, celui de Kildare. Il est situé au nord de la seigneurie de la Valtrie et comprend une partie de basses terres. On arpenta en partie, entre 1803 et 1815, les cantons de Rawdon, Kilkenny

*Brouillette, dans *Canadian Regions*, ajoute aux Laurentides centrales les comtés d'Argenteuil et de Portneuf.

et Abercromby, qui étaient déjà érigés, et ceux de Brandon, Peterborough, Hunterstown, Chilton et Chertsey, peu après 1815.* Chaque canton comptait 308 lots, dont 220 étaient vendus aux colons et 88 demeuraient propriété de la Couronne et de l'Église (anglicane).

En 1815, les autorités britanniques décidèrent de défrayer le transport et l'établissement de tous ceux qui voulaient venir au Canada. Ce décret provoqua l'immigration d'un grand nombre d'Irlandais protestants et catholiques. Nombre de ceux qui choisirent de s'établir au Québec obtinrent des lots dans la région des Laurentides centrales, en bordure du Bouclier. En 1824, un petit groupe de colons irlandais s'établissait aux environs du lac Maskinongé, dans le comté de Berthier, et d'autres, dans la région de Rawdon. Des groupes irlandais s'installèrent aussi dans les cantons de Kildare, de Hunterstown et de Kilkenny. Des immigrés écossais et irlandais colonisèrent le district de New Glasgow-Shawbridge, au nord de Montréal: ils coupaient le bois, défrichaient la terre pour la culture ou le pâturage à moutons, et fabriquaient de la potasse qu'ils vendaient aux fermiers des basses terres. Vers 1830, le canton de Rawdon comptait 850 colons, et l'on y dénombrait huit fabriques de potasse, quatre scieries et trois moulins à farine. C'était la plus prospère des colonies irlandaises du Bouclier (Galt, 1836).

L'expansion de l'industrie forestière dans les Laurentides centrales permit de pénétrer plus avant dans cet intérieur jusqu'alors difficile d'accès. Des hommes d'affaires anglais se firent les promoteurs de cette industrie. Dès 1825, l'un d'eux établissait à Hunterstown, sur la rivière du Loup, un camp de bûcherons qui comptait 300 hommes. Rawdon, sur la rivière Ouareau, ne tarda pas à prendre de l'importance comme centre de commerce du bois. Après 1830, l'industrie prit de l'ampleur dans la région du lac Maskinongé et, en 1832, un groupe d'Anglais établissait une scierie à St-Jérôme, sur la rivière du Nord.

Entre 1830 et 1840, la majorité des petites entreprises de bois s'amalgamèrent pour former de grandes compagnies. Ce nouvel essor permit de pénétrer encore plus profondément dans la forêt et de couper les réserves de pin blanc et de pin rouge. Les compagnies qui avaient leur base d'opérations sur la rivière Outaouais exploitèrent à fond ces réserves dans les bassins inférieurs de la rivière Rouge et de la rivière du Lièvre: dès avant 1840, les

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*Dans la province de Québec, un canton (township) couvre une superficie d'environ 61,000 acres formant un carré de dix milles de côté. Chaque canton est divisé en 11 rangs comprenant chacun 28 lots de 200 acres.

coupes atteignaient le confluent de la rivière Kiamika. Sur les grandes fermes de la vallée de la Lièvre, on cultivait le foin, les céréales et les légumes destinés au ravitaillement des camps de bûcherons. Ces fermes devinrent plus tard les villages de Wabassee, des Pins et de Ferme-Rouge.

La vallée du Saint-Maurice possédait les grandes réserves forestières de la région des Laurentides centrales. Cependant, ce ne fut que dans la seconde moitié du XIX^{e} siècle qu'on exploita ces richesses, à cause des grandes difficultés de transport que présentaient, au temps de la «drave», les nombreuses chutes et rapides situés à la limite du Bouclier. Il y avait des fermes près de l'embouchure du Saint-Maurice, aux environs de Trois-Rivières, et une petite entreprise métallurgique aux Forges. Plus en amont, à la rivière aux Rats et à la Tuque, on avait fait la traite des fourrures et à quelques rares endroits, dans la vallée, un peu de coupe de bois.

En 1852, les autorités coloniales fournirent des subsides pour la construction d'estacades, de barrages et de glissoires à billots sur le Saint-Maurice, au Rapide-des-Grès, à Shawinigan et à Grand'Mère, afin de faciliter le transport du bois coupé; on fit également d'autres améliorations plus en amont. Les bûcherons commencèrent à couper le pin blanc et le pin rouge près des rivières Bostonnais, Trenche et Croche, situées plus au nord.

Par suite de gaspillage et d'incendies désastreux, cette première période se solda par un appauvrissement général des ressources forestières. Il en découla tout de même un effet d'une extrême importance: «L'affluence des bûcherons entraînera bientôt l'établissement lent et plus sain des colons cultivateurs» (Dagenais, 1941, page 113).

Entre 1830 et 1850, les colons irlandais établis dans les cantons du Bouclier commencèrent d'abandonner les terres qu'ils avaient défrichées. Presque tous les centres irlandais se trouvaient près de la bordure du Bouclier, où les sols, très rocheux et peu profonds, se sont développés sur une mince couche de till. Pour obtenir quelque rendement de ces terres, il fallait travailler d'arrache-pied et avoir recours à l'engrais et au chaulage. Les propriétaires irlandais, vite rassasiés de tant de labeur, abandonnèrent leurs fermes pour aller s'établir à Québec ou à Montréal. Plusieurs, cependant, choisirent de demeurer à proximité des scieries installées dans les villages de New Glasgow, de Rawdon, et de Saint-Cuthbert. D'autre part, ce n'est que tout récemment qu'on abandonna quelques-unes des terres les plus fertiles des vallées.

COLONISATION CANADIENNE-FRANÇAISE

Les cultivateurs canadiens-français commencèrent à s'établir sur le Bouclier vers 1830. Les terres arables des seigneuries étaient presque toutes occupées et la population des paroisses augmentait toujours. Les jeunes gens devaient donc chercher ailleurs des terres libres. Les nouvelles routes ouvertes pour la colonisation irlandaise, et les chemins de chantier qui pénétraient vers l'intérieur, permirent aux jeunes cultivateurs des basses terres de remonter vers le nord. Par ailleurs, les curés encouragaient fortement la colonisation. Au début, les Canadiens français occupèrent les terres abandonnées par les Irlandais; cependant, dans plusieurs comtés, notamment ceux de Berthier et de Terrebonne, ils choisirent de vastes étendues vacantes de terrain ondulé à l'intérieur du Bouclier, où les sols sont limoneux et argileux.

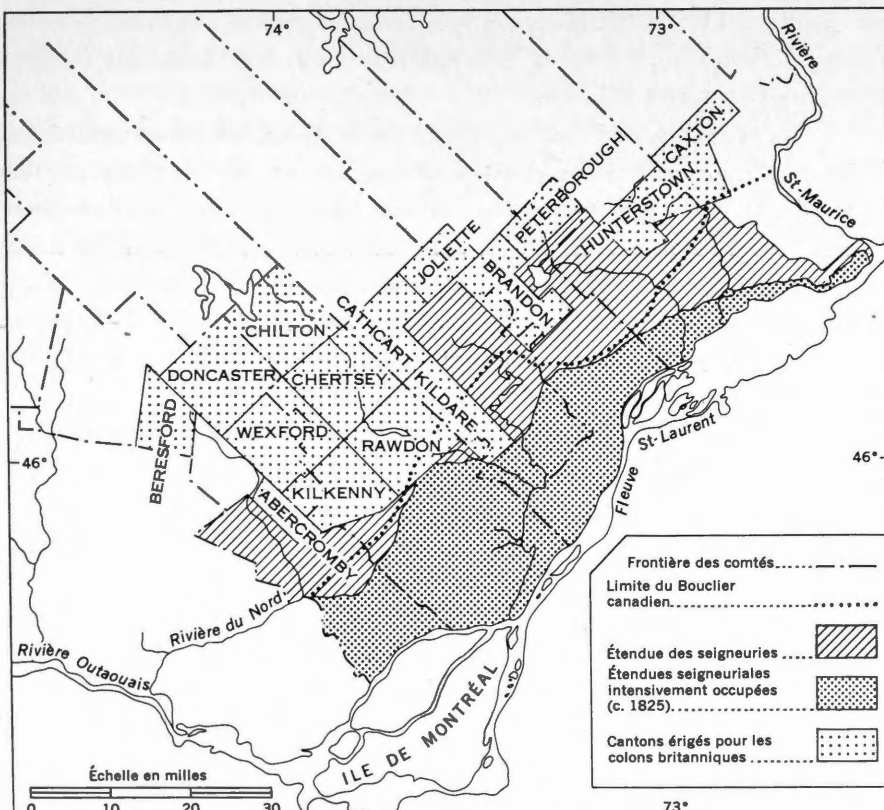

FIGURE 1. Disposition des terres le long de la côte Nord du St-Laurent, entre la rivière Outaouais et le St-Maurice, au début du XIX[e] siècle.

ZONE CENTRALE

La première tentative fructueuse de colonisation eut lieu entre la rivière Ouareau et la rivière du Loup. Cette région peut être considérée comme le «noyau» des Laurentides centrales. Elle fait partie aujourd'hui des comtés de Maskinongé, de Berthier, de Joliette et de Montcalm.

Les quelques Anglais qui s'étaient établis dans les cantons arpentés du comté de Maskinongé quittèrent leur terre dès le début de la colonisation canadienne-française. Les terres du canton d'Hunterstown, occupées par des Anglais, passèrent aux mains des Canadiens français à l'ouverture de cinq milles de chemin les reliant aux basses terres. Après 1860, on ouvrit de nouveaux chemins dans la région de Saint-Alexis-des-Monts, et les Canadiens français occupèrent les terres sableuses de la vallée supérieure de la rivière du Loup. Plus à l'ouest, le canton de Peterborough, difficile d'accès, n'avait pas été colonisé par les Irlandais. En 1859, on construisit un chemin qui traversait la plaine du lac Maskinongé et remontait la vallée de la Mastigouche à travers le canton; aussitôt, les Canadiens français occupèrent les terres voisines.

Dans le canton de Brandon, comté de Berthier, les colons canadiens-français prirent possession des terres rocailleuses abandonnées par les Irlandais. Ils défrichèrent également de nouvelles terres sur les sols sableux du nord-est du lac Maskinongé et, entre 1851 et 1861, l'étendue des terres en culture passa de 4,551 à 14,458 acres. L'industrie du bois se développa et des scieries s'ouvrirent. Vers 1861, 94 p. 100 de la population de la région de Saint-Gabriel était canadienne-française; on ne comptait plus que 192 colons irlandais.

Dans le comté de Joliette, les colons irlandais avaient pris possession de presque toutes les terres arables situées à la bordure du Bouclier. De nombreux groupes se trouvaient dans le canton de Kildare et dans les rangs Sud du canton de Cathcart. D'autres s'étaient établis en dehors des cantons, dans la région de Saint-Félix-de-Valois. Cependant, vers 1850, la plupart de ces Irlandais émigrèrent vers les villes et des Canadiens français s'installèrent sur leurs terres. En 1861, 75 p. 100 de la population du canton de Kildare était canadienne-française; dans le canton de Cathcart, la proportion était de 74 p. 100 et autour de Saint-Félix, de 96.5 p. 100.

Les Canadiens français occupèrent non seulement les terres abandonnées par les colons irlandais, mais, entre 1850 et 1860, ils s'établirent aussi à l'intérieur du comté de Joliette. Le gouvernement se chargea d'ouvrir des chemins de colonisation à partir du canton de Brandon jusqu'au canton de

Joliette et du canton de Kildare jusqu'au centre du canton de Cathcart, ce qui amena la fondation de paroisses canadiennes-françaises, notamment celles de Sainte-Émilie-de-l'Énergie et de Saint-Alphonse. Le clergé encouragea les fermiers des basses terres à s'établir dans la région de Saint-Jean-de-Matha, où les bûcherons avaient coupé le bois. Les colons améliorèrent le chemin par lequel les bûcherons avaient pénétré dans cette région, et une paroisse agricole prospère se développa.

L'Église catholique, toujours prête à encourager la colonisation dans le Canada français, fut grandement responsable du développement des régions reculées du canton de Joliette, qui ne pouvaient être atteintes que par de rudes chemins de chantier. Un prêtre se mit à la tête de 50 cultivateurs des basses terres et remonta la rivière l'Assomption jusqu'à l'endroit aujourd'hui appelé Saint-Côme. On déblaya le terrain, et on établit une scierie et une fabrique de potasse. En 1863, un autre prêtre dirigea un groupe de colons à travers les terres, à partir de Sainte-Émilie-de-l'Énergie jusqu'à la vallée de la rivière Mattawin, où il fonda la colonie isolée de Saint-Michel-des-Saints. L'année suivante, on ouvrit un chemin de chantier entre Saint-Michel et Sainte-Émilie, et on construisit un moulin à farine sur la rivière Mattawin. La colonie voisine de Saint-Zénon fut établie en 1866. En 1890, ces deux établissements étaient érigés en paroisses, et la population totale des terrasses sableuses de la Mattawin se chiffrait par 1200 âmes.

Le comté de Montcalm, et tout particulièrement le canton de Rawdon, fut longtemps la forteresse irlandaise du Bouclier. On y trouve de grandes étendues de terre argileuse arable et, sur la rivière Ouareau, des ruptures de pente favorables au harnachement des eaux. Dès le début de la colonisation, cette région possédait un bon réseau routier. Tous ces facteurs la rendirent attrayante aux Irlandais, et très peu quittèrent Rawdon durant les premières étapes de la colonisation française. En 1861, la population du canton de Rawdon comptait 1979 âmes, dont 63.3 p. 100 étaient des Irlandais ou des Anglais. Par ailleurs, avant le milieu du XIX^{e} siècle, les Irlandais avaient abandonné leurs petites colonies, situées dans les régions plus accidentées à l'intérieur des cantons de Chertsey, de Chilton et de Wexford, et nombre d'entre eux étaient venus travailler dans les scieries du canton de Rawdon.

Dans l'intérieur, les Canadiens français occupèrent plusieurs terres défrichées par les Irlandais. On construisit des routes de colonisation dans le canton de Kilkenny, à partir des villages de New Glasgow et de Sainte-Julienne, à la bordure du Bouclier, et les Canadiens français achetèrent

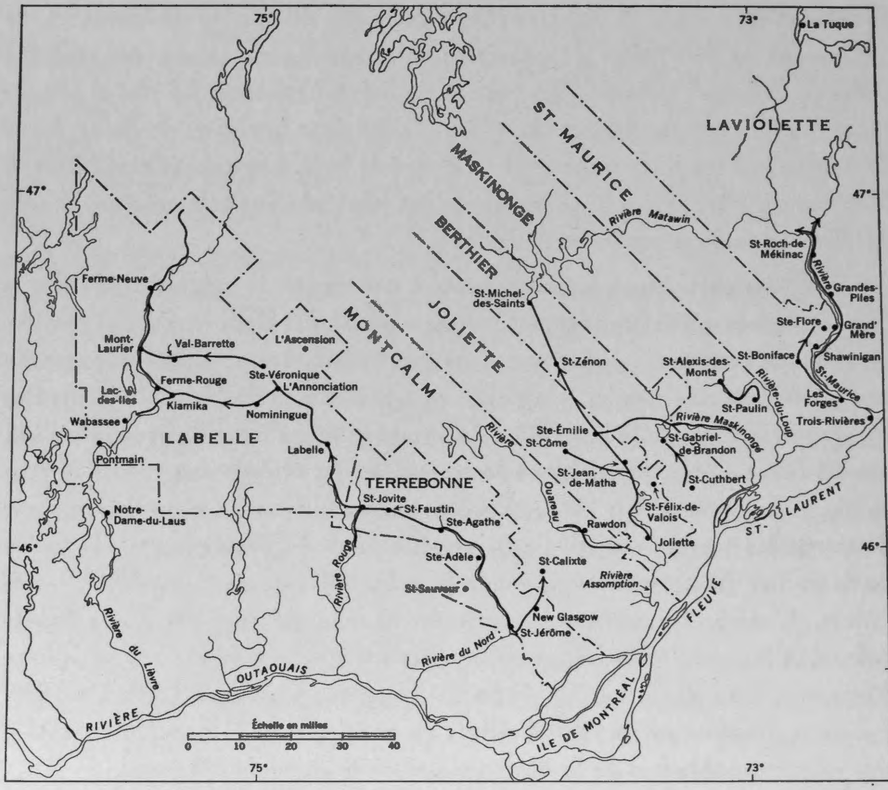

FIGURE 2. Principaux chemins de colonisation dans la région centrale des Laurentides.

presque tous les lots aboutant à ces routes. On érigea la nouvelle paroisse de Saint-Calixte-de-Kilkenny, et la petite poignée d'Irlandais qui y demeurait encore émigra vers Montréal. Quelques centres agricoles canadiens-français prirent naissance dans les cantons de Chilton et Wexford. En prévision de la colonisation, on arpenta certaines parties plus reculées du comté de Montcalm, et un petit groupe de Canadiens français défricha des terres sur la rive Est du lac Ouareau. Ce fut la limite de la colonisation dans cette zone.

ZONE ORIENTALE

La vallée du Saint-Maurice, située à l'est des cantons susmentionnés, contient de grandes étendues de terre qui peuvent facilement se prêter à la culture; mais avant l'arrivée du bûcheron, la culture était inconnue dans la partie de la vallée traversant le Bouclier. Après 1852, les colons suivirent les chemins nouvellement ouverts par les bûcherons pour atteindre les lopins de terre arable situés en amont. Les régions de Saint-Boniface et de Sainte-Flore se peuplèrent après 1850; puis, on occupa les rives de la rivière Shawinigan et la région de Saint-Jacques-des-Piles. Comme centres de ravitaillement pour les camps de bûcherons, on établit, encore plus en amont dans la vallée, plusieurs petits centres agricoles tels Saint-Roch-de-Mékinac et La Croche. Tout de même, l'étendue des terres en culture dans la vallée demeura toujours négligeable: on n'occupa jamais la rive Ouest, composée de sols sableux et argileux. La place mineure de l'agriculture dans l'économie de la vallée s'explique par le début tardif de l'exploitation forestière et le manque de chemins au début de la colonisation.

ZONE OCCIDENTALE

Du début du XIX^{e} siècle jusqu'au début du XX^{e}, il y eut un mouvement continu de colonisation dans les comtés de Terrebonne et de Labelle, au nord de Montréal. En 1823, les Canadiens français fondèrent le centre agricole de Saint-Jérôme, à la bordure du Bouclier. La rivière du Nord possédait de nombreux sites énergétiques et, en 1832, une scierie, un moulin à farine et une filature fonctionnaient déjà à Saint-Jérôme.

Quelques colons anglais défrichèrent des terres dans la région de New Glasgow, dans la vallée de la rivière Achigan, et un petit groupe d'Irlandais et d'Écossais fondèrent le village de Shawbridge, sur la rivière du Nord en amont de Saint-Jérôme. Dans l'espace de dix ans, les colons avaient abandonné toutes les terres les plus pauvres, pour aller s'établir à Montréal ou dans les petits centres de scierie des hautes terres.

En 1840, les colons canadiens-français s'établirent dans la région de Shawbridge sur les terres déjà défrichées; de là, ils poussèrent plus loin le long des terrasses forestières de la vallée de la rivière du Nord. Les terres y sont sableuses ou limoneuses, peu caillouteuses et plus ou moins fertiles. Par ailleurs, la colonisation fut plutôt lente dans cette vallée puisqu'il n'y avait pas de chemin de colonisation. Après 1840, on défricha les terres des rivières Simon et Saint-Sauveur; la paroisse de Saint-Sauveur fut érigée sur les hautes terres en 1854. On établit, dans la région de Sainte-Adèle, plusieurs grandes fermes, dont une qui mesurait 700 arpents et comprenait des moulins à farine et des scieries. En 1861, la paroisse de Sainte-Adèle comptait 1633 Canadiens français, et les paroisses environnantes de Sainte-Marguerite et de Saint-Hippolyte connaissaient également une très grande augmentation de leur population. C'est à ce moment-là que le gouvernement construisit un chemin carrossable entre Sainte-Adèle et le lac des Sables, dans le canton de Beresford. Vers 1861, 380 colons avaient défriché les terres autour du lac et fondé la nouvelle paroisse de Saïnte-Agathe-des-Monts.

En 1868, par sa nomination à la tête de la paroisse de Saint-Jérôme, le curé Labelle imprima un nouvel essor à la colonisation du Nord de Montréal. Une politique vigoureuse fut responsable de l'expansion rapide du peuplement canadien-français, de Sainte-Agathe jusqu'au Nord de Mont-Laurier. Le curé Labelle surveilla lui-même les travaux de construction du Chemin de la Repousse, qui traversait la région accidentée entre Sainte-Agathe et Saint-Faustin. Les bûcherons de la rivière Rouge avaient fait la coupe du bois dans la plaine s'étendant de Saint-Jovite à Saint-Faustin, et les colons canadiens-français purent s'établir sur ces terres déboisées. La paroisse de Saint-Faustin devint bientôt un centre forestier et agricole, mais la pauvreté du sol ne tarda pas à provoquer l'abandon de ces terres défrichées. Cependant, les terrasses alluviales sableuses de la rivière du Diable étaient toutes occupées, et le village de Saint-Jovite devint un centre important de ravitaillement pour les cultivateurs de la vallée supérieure de la rivière Rouge.

La colonisation continuait de s'étendre de plus en plus loin le long de la rivière Rouge. Après 1880, des colons habitèrent trois vastes fermes, qui appartenaient auparavant à des compagnies de bois; elles forment aujourd'hui les trois villages de la Conception, de Labelle et de l'Annonciation. Les fermiers défrichèrent aussi d'assez importantes étendues de terre à culture sur les rives sableuses du lac Nominingue et sur les hautes terres morainiques avoisinantes.

L'occupation des plaines argileuses, formant le lit majeur de la haute rivière du Lièvre, fut la plus importante des phases suivantes dans la colonisation du Nord-Ouest des Laurentides. Quelques colons étaient déjà arrivés par bateau de Notre-Dame-du-Laus dans la basse vallée. La construction du Chemin Chapleau entre Nominingue et la rivière du Lièvre favorisa également la colonisation dans cette région. L'interfluve qui sépare la rivière Rouge et la rivière du Lièvre comprend des sols improductifs de till rocailleux, de sables et de graviers. A cause de cette pauvreté, la colonisation y fut très dispersée. Cependant, en 1884, le village de Ferme-Rouge fut fondé dans la vallée et, l'année suivante, les premiers pionniers défrichèrent du terrain et construisirent un moulin à farine au Rapide de l'Orignal. Aujourd'hui, Rapide de l'Orignal est devenu la ville de Mont-Laurier, sur la route Montréal-Val-d'Or; c'est encore un centre agricole important. D'autres centres agricoles, tels l'Ascension, Sainte-Véronique et Lac-des-

Écorces, ne tardèrent pas à se développer dans les vallées supérieures des rivières du Lièvre et Rouge. Vers 1900, les bons terrains de cette région étaient tous occupés et, aujourd'hui, presque tous sont encore cultivés.

La construction de chemins de fer, dans la région des Laurentides centrales, stabilisa la population et la fit même augmenter dans certaines zones. En 1876, on construisit, entre Montréal et Saint-Jérôme, le Chemin de fer de la Colonisation du Nord. Par ses efforts infatigables, le curé Labelle en obtint son prolongement jusqu'à Sainte-Agathe peu avant 1890. En 1909, le chemin de fer allait de Montréal à Mont-Laurier, ce qui favorisa le développement agricole dans la haute vallée de la Lièvre.

Tentatives récentes de colonisation

Même au XX^e^ siècle, certains districts de la région des Laurentides centrales furent destinés à la colonisation. Le gouvernement établit des réserves de colonisation dans les comtés de Labelle et de Maskinongé et s'efforça d'attirer les colons vers ces régions nouvellement arpentées. En 1902, on construisit une nouvelle route, le chemin Gouin, au nord du chemin Chapleau, entre Nominingue et la rivière du Lièvre. On arpenta 419 lots qui furent pour la plupart occupés par des colons. Dans le comté de Labelle, le gouvernement distribua 138 lots de la nouvelle réserve du Lac-des-Îles. On érigea dans ces réserves plusieurs paroisses et missions, notamment celles de Notre-Dame-de-Pontmain et de Val-Barrette.

Dans les premières années du XX^e^ siècle, on établit dans le canton de Masson la réserve des comtés de Maskinongé et de Berthier. Des colons s'installèrent sur seulement 105 lots, à cause de la qualité inférieure du sol; quelques années plus tard, la plupart des cultivateurs les avaient abandonnés.

Durant la crise, on arpenta quelques petites étendues de terrain des comtés de Terrebonne et de Labelle, en vue de l'expansion agricole, mais les emplois offerts à Montréal durant la Seconde Guerre mondiale détournèrent les fermiers de ces terres.

Changements dans la population et dans l'utilisation du sol

Dans plusieurs cantons des Laurentides centrales, la population a beaucoup diminué depuis la fin du XIX^e^ siècle, et ce phénomène migratoire s'exerce toujours (Tableau 1).

Tableau 1

Population de quelques divisions de recensement, de la région des Laurentides centrales

	1871	1881	1891	1901	1911	1921	1931	1941	1951	1961
Hunterstown (Maskinongé)	1,238	798	727	553	604	571	477	402	344	253
Chertsey (Montcalm)	1,619	1,626	1,169	1,158	990	806	785	931	898	952
Saint-Didace (Maskinongé)	2,955	2,403	1,954	1,499	1,463	1,050	1,046	1,112	794	586

Les divisions susmentionnées ont connu une baisse de population vraiment exceptionnelle, mais on ne peut pas généraliser pour l'ensemble de la région des Laurentides. Par suite du développement industriel et de l'expansion de l'industrie touristique plusieurs paroisses ont vu le chiffre de leur population se maintenir et même augmenter. Cependant, dans presque toutes les paroisses de la région, ont beaucoup diminué: (a) l'importance de la population agricole par rapport à la population totale, (b) la population agricole en chiffres absolus, et, (c) la superficie des terres améliorées (Tableaux 2 et 3).

Tableau 2

La population rurale agricole dans six comtés du Québec en 1871 et de 1931 à 1956

		1871	1931	1941	1951	1956
Maskinongé	(a) Population totale	15,079	16,039	18,206	19,478	20,870
	(b) Population rurale agricole	15,079	9,077	8,566	7,283	7,422
	Rapport de (b) à (a) en pourcentage	100%	56.6%	47.0%	37.4%	35.6%
Berthier	(a) Population totale	18,371	19,506	21,233	24,717	26,359
	(b) Population rurale agricole	18,371	10,543	10,379	9,387	8,981
	Rapport de (b) à (a) en pourcentage	100%	54.0%	49.0%	38.0%	34.1%
Joliette	(a) Population totale	20,028	27,585	31,713	37,251	40,706
	(b) Population rurale agricole	20,028	11,309	11,652	10,870	10,747
	Rapport de (b) à (a) en pourcentage	100%	41.0%	36.7%	34.3%	26.4%

Tableau 2—fin

La population rurale agricole dans six comtés du Québec en 1871 et de 1931 à 1956—fin

		1871	1931	1941	1951	1956
Montcalm	(a) Population totale	12,742	13,865	15,208	17,520	18,670
	(b) Population rurale agricole	12,742	7,945	8,269	7,206	7,024
	Rapport de (b) à (a) en pourcentage	100%	57.3%	54.4%	41.1%	37.6%
Terrebonne	(a) Population totale	19,591	38,611	46,864	67,437	81,329
	(b) Population rurale agricole	16,300	12,025	12,468	9,708	7,910
	Rapport de (b) à (a) en pourcentage	83.2%	31.1%	26.6%	14.4%	9.7%
Labelle	(a) Population totale	336	20,140	22,974	27,197	28,492
	(b) Population rurale agricole	336	11,360	13,605	11,923	10,765
	Rapport de (b) à (a) en pourcentage	100%	56.4%	59.2%	43.8%	37.8%

Tableau 3

Superficie en acres des terres défrichées dans six comtés du Québec

	a. Année de superficie maximum des terres défrichées	b. Superficie défrichée: maximum	c. Terres défrichées: 1956	d. Superficie nette des terres abandonnées*	e. (en %)
Maskinongé	1921	123,644	91,326	32,318	26.1
Berthier	1921	150,628	112,267	38,361	25.5
Joliette	1921	164,808	125,774	39,034	23.7
Montcalm	1921	101,963	73,598	28,365	27.8
Terrebonne	1921	162,779	89,567	73,212	45.0
Labelle	1941	132,717	122,415	10,302	7.8

*Ces comtés, sauf celui de Labelle, comportent une partie de basses terres, mais la plupart des terres abandonnées se trouvent sur le Bouclier.

Dès les premiers temps de la colonisation, les cultivateurs s'installèrent sur les terres argileuses et limoneuses des vallées de la région des Laurentides centrales. Ces terres sont assez fertiles et se prêtent bien à la culture générale et à l'industrie laitière, sans demander trop d'engrais et de chaulage. C'est pourquoi ces terres sont presque toutes encore cultivées de nos jours, notamment dans les vallées de la rivière du Loup, de la Maskinongé, de l'Assomption et les vallées supérieures de la Rouge et de la rivière du Lièvre. Les fermiers habitèrent également, dès les premiers temps de la colonisation, les terrains couverts de matériaux marins et fluvio-glaciaires, qui forment la région plus élevée entre Rawdon et Saint-Paulin. Ces sols sont de qualité un peu inférieure à ceux des vallées, mais seul un petit nombre de colons les abandonna.

Plusieurs projets de colonisation, préparés soit par le gouvernement, soit par l'Église, furent exécutés seulement après que les terres arables des vallées aient été occupées. Cette politique de colonisation eut comme résultat de déblayer de vastes superficies de hautes terres morainiques de rendement moyen ou médiocre. Depuis 1880, ces terres ont été abandonnées, reboisées, ou vendues comme terrains de récréation, et, aujourd'hui, seuls quelques lopins sont encore cultivés. Dans le comté de Terrebonne, on peut dire que toutes les fermes des hautes terres ont été abandonnées ou vendues aux villégiateurs et aux hommes d'affaires. De même, l'industrie touristique s'est approprié les terres moyennement fertiles de la vallée de la rivière du Nord. Ce phénomène ne s'est pas produit dans les autres vallées des Laurentides centrales, mais semble inévitable dans celles qui sont situées tout près des agglomérations urbaines.

CONCLUSION

Il y a beaucoup de similitude, dans l'évolution historique de la colonisation, entre les comtés de Maskinongé, de Berthier, de Joliette et de Montcalm. Ces comtés forment le noyau des Laurentides centrales.

1. Les autorités coloniales érigèrent des cantons à l'arrière des seigneuries du Saint-Laurent et des colons irlandais s'y établirent entre 1830 et 1840.
2. Presque tous les Irlandais abandonnèrent leurs terres, qui passèrent aux mains des Canadiens français.
3. La colonisation canadienne-française connut son plus grand essor là où le gouvernement construisit des routes.
4. Le colon succéda au bûcheron dans les régions les plus reculées.
5. L'Église encouragea grandement la colonisation: les prêtres furent les grands responsables de la colonisation de centres situés à l'intérieur des terres.

Les autorités britanniques divisèrent aussi en cantons les terres situées à la limite occidentale de la région des Laurentides centrales, mais un très petit nombre de colons anglais y fut attiré, à cause du manque de chemins. Même la colonisation canadienne-française y fut lente. Cependant, à la fin du XIX^{e} siècle, grâce à l'encouragement de l'Église et à l'ouverture de chemins, le peuplement de ces régions connut une augmentation considérable.

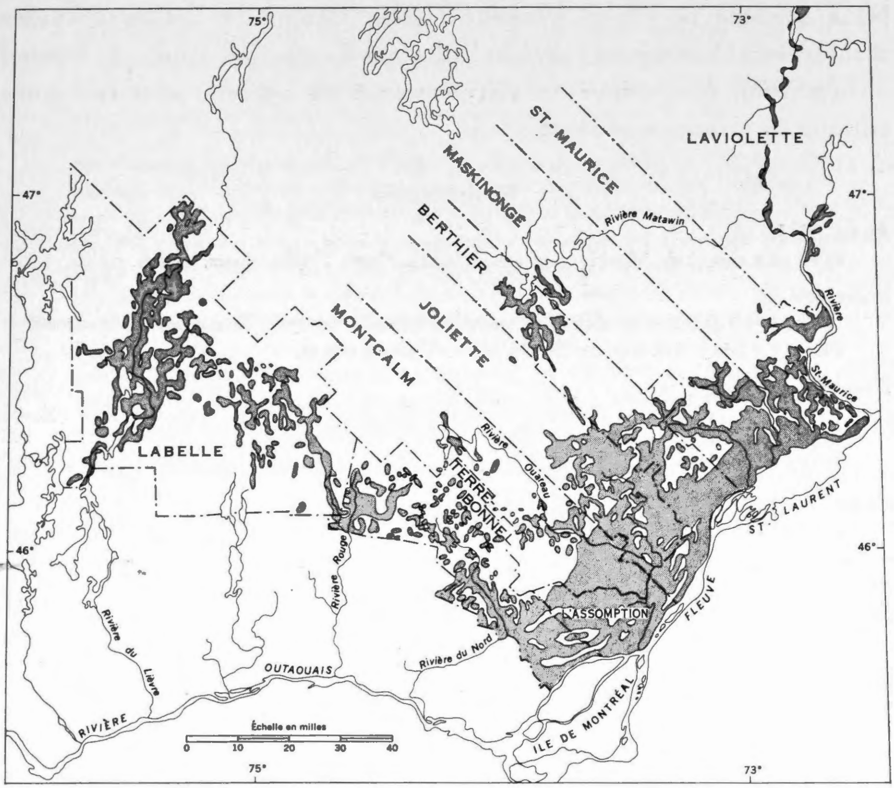

FIGURE 3. Superficie maximum des terres (défrichées) dans la région centrale des Laurentides et la région des basses terres des comtés de Terrebonne, Montcalm, L'Assomption, Joliette, Berthier, Maskinongé et St-Maurice (c. 1921).

Dans la région du Saint-Maurice, les autorités n'arpentèrent pour les colons britanniques aucun canton, et les nombreux obstacles naturels y retardèrent le progrès des opérations forestières. Les chemins tardèrent à s'ouvrir et, par conséquent, la vallée du Saint-Maurice ne connut pas l'ampleur du défrichement qui se fit sentir dans les autres comtés des Laurentides centrales pendant la dernière moitié du XIX^{e} siècle.

En 1921, la superficie des terres améliorées atteignit son maximum dans tous les comtés des Laurentides centrales, à l'exception du comté de Labelle (Tableau 3, Figure 3). Depuis cette date, de grandes superficies de terres à rendement médiocre ont été abandonnées, reboisées, ou vendues aux villégiateurs et aux hommes d'affaires.

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A METHOD OF MEASURING WATER DISCHARGE IN TURBULENT STREAMS

Gunnar Østrem

ABSTRACT: The Norwegian, R. Søgnen, developed a simple method of measuring water discharge in turbulent rivers that has special applications in glaciological and geomorphological research. In 1963 it was used for the first time in Canada when, in the North-central Baffin Island Survey of the Geographical Branch, the Lewis River was studied at the northeast corner of the Barnes Ice Cap. It consists in a sudden injection of salt brine into the river and downstream measurement of changes that occur in electrical conductivity as the salt wave passes. This paper is a detailed presentation of the theory and procedures of the method. A list of necessary field equipment is appended.

RÉSUMÉ: Un Norvégien, M. R. Søgnen, a mis au point un procédé simple pour mesurer le débit des cours d'eau turbulents, et le procédé trouve des applications particulières dans la recherche glaciologique et géomorphologique. C'est en 1963 qu'on l'a utilisé pour la première fois au Canada, alors que, dans le cadre du levé effectué par la Direction de la géographie dans le centre Nord de l'île Baffin, on a étudié la rivière Lewis au coin nord-est de la calotte glaciaire Barnes. Il s'agit d'injecter subitement de la saumure dans un cours d'eau et de mesurer en aval les changements qui se produisent dans la conductivité électrique à mesure que le sel s'écoule. La présente étude fournit des détails sur les aspects théoriques et pratiques du procédé en cause. L'annexe contient la liste des appareils nécessaires sur le terrain

INTRODUCTION

Measurement of water discharge in turbulent streams is often desired in glaciological and hydrological field studies. Difficulties in measuring procedures, however, have sometimes discouraged observations in the past, when results were of limited practical or economic interest. A simple method, the "relative salt-dilution measurement," was developed about 30 years ago by R. Søgnen, of the Norwegian Water Resources and Electricity Board (Aastad and Søgnen, 1928 and 1954), and is still in use in Norway. Its advantage lies in the fact that a high degree of turbulence in the river makes the results more accurate than those of most other methods of discharge measurement.

The salt method was employed during the summer field season of 1963 in studies of the Lewis River carried out at the northeast corner of the Barnes Ice Cap, north-central Baffin Island, N.W.T., as part of the North-central Baffin Island Survey of the Geographical Branch. As far as is known,

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MS submitted October 1963.

it was the first time this technique was used in Canada. Its introduction had a twofold purpose: (a) to measure the volume and flow pattern of the Lewis River as applied both to ablation studies of the Barnes Ice Cap and to geomorphological problems, such as the relation between the silt content of meltwater and erosion of glacial drainage channels, and (b) to provide the Geographical Branch with a nucleus of experience and trained personnel for expanded research in these fields.

The present paper may be regarded as a field manual describing the method in considerable detail for the use of glaciologists, geographers and others whose knowledge of chemistry and physics is not extensive (see also British Standards Institution, 1961). Other methods of water-discharge measurement are outlined, the theory and procedures of the salt method are presented, and a list of the necessary field equipment is appended.

OTHER METHODS

The float method

A very simple but approximate method is the use of a surface float. The linear velocity of the float gives the approximate velocity of the surface of the water, which will be higher than the mean velocity of the whole river mass. By using several floats in different sections, it is possible to calculate the surface velocity of different stretches of the river. The mean water velocity in each section can then be approximated from the formula:

$$Vm = 0.85\ v_s$$

where

Vm = mean water velocity in the vertical section

v_s = surface-water velocity

0.85 = constant

Then, by measuring the cross-profile of the river, it is possible to calculate the total water discharge. As the degree of accuracy is very poor and the constant 0.85 varies from one river to another, this method should be used only for a rough approximation of discharge.

A better result will be obtained by using a vertical floating dowel nearly as long as the water is deep. The speed of this vertical float should nearly approximate the mean water velocity in the vertical section of the river where it is placed. By using several floats, the mean velocity for different sections of the river can be calculated and a fairly close estimate of river discharge obtained. When the river bottom is uneven, it will be nearly impossible, however, to use this method, because the dowel may be easily fouled by the irregularities in the river bed.

Instrument methods

Two of the instruments commonly used by hydrologists for measuring water velocities are the Pitot tube and the current meter.

The Pitot tube measures the difference between the hydrostatic and the hydrodynamic pressure in the streaming river. It is used preferably for measuring high velocities in artificial water channels and turbine tubes and is not suitable for ordinary field use.

The current meter is widely used for measuring water discharge in natural rivers. It consists of a rotating part, usually a propeller, which is moved by the streaming water. When this meter is successively placed at different points in the whole cross-section, the water velocity can be found in a series of small sections and the total discharge calculated. A number of calculating methods have been developed (see U.S. Geol. Surv., 1943, for details) and under favorable conditions they are very accurate. In one comparative test, in which a big tank of known volume was emptied and a current meter used to measure the discharge, the error recorded was less than 3 per cent. The current meter was designed, however, for "laminary" streaming water and so cannot be used in turbulent streams.

Chemical methods

To overcome the difficulties of measuring discharge in turbulent streams, different chemical methods have been developed. If a known quantity of a chemical compound is added to the stream water at a constant rate, the dilution of this compound in the river will be a function of the volume of water discharge. The greater the river discharge, the greater the dilution of the chemical compound, provided that the injected brine is completely and evenly mixed with the river water. The method has been known for many years (Stromeyer, 1905; Groat, 1915), but the complicated procedure of constant injection and the difficulties of chemically analyzing highly diluted salt solutions have limited its use in field work.

The colorimetric method involves the use of a concentrated dye that is added to the river at a constant rate and the downstream measurement, by means of a colorimeter, of the color of water samples (Lütschg-Loetscher, 1945). Comparative experiments made in northern Sweden when colorimetric measurements were run simultaneously with other discharge measurements, gave good results (Haage and Maandi, 1961, page 11). In silty water, however, the readings of the colorimeter are affected by suspended particles, and its use in glacier streams presents some difficulties.

To overcome field difficulties of the constant-rate brine-injection method, several procedural changes have been proposed. Instead of chemical determination of the dilution, electric conductivity has been employed, on the basis of the fact that salt in solution increases the conductivity of the water. In addition, a sudden bulk injection of the brine into the river has been tried instead of constant-rate injection. By a combination of these two systems, the "salt-velocity" method has been developed and successfully used in rivers or channels of constant cross-section. A concentrated salt brine is injected into the river water, and the passage of the "salt wave" is observed by electric-conductivity meters at two points downstream. By measuring the time required for the passage of the bulk of the salt solution, the mean velocity of the stream water can be computed and the total discharge found by multiplication with the cross-sectional area of the river (U.S. Dept. Interior, 1953, pages 101–102).

Professor Barbagelata proposed the sudden injection of a known volume of salt brine into the river, followed by downstream measurement of the intensity of the salt wave by means of electrical instruments (Barbagelata, 1926, 1928). R. Søgnen, the Norwegian engineer, improved the method and demonstrated its applicability to full measurements (Aastad and Søgnen, 1928 and 1954; Klaeboe, 1958, pages 174–176; Arnold, 1959). In addition to discharge measurements, studies of turbulence in rivers have been undertaken by this method (Sundborg, 1956, pages 222–223). Radioactive tracers may eventually be used in a similar manner but are not discussed here (Hull and Macomber, 1958).

THEORY

In the range of concentration used for this purpose, conductivity is nearly proportional to the salt concentration in the water, and a conductivity-concentration graph will approximate a straight line. Additional conductivity readings are used to compare concentrations. Possible errors in the scale divisions of the instrument have no influence on the result, because the same instrument is used for both the calibration of the brine and the dilution measurement taken in the river when the sale wave passes.

To a river of unknown water discharge of q litres/sec, S litres of salt brine are added. The value of S is presumed to be small compared with that of q. At a point downstream the whole mass of water passing in n seconds is called Q.

$$Q = n.q$$

The mass of water passing this point consists of a very diluted salt solution of variable magnitude, and the concentration of salt will rise from zero at the beginning of the test, pass a peak value and then fall back to zero.

Each second, the river water at this point will contain different quantities of salt solution, $s_1, s_2, s_3, s_4 \ldots s_n$, originating from the injected salt brine:

$$S = s_1 + s_2 + s_3 + \ldots + s_n$$

Each second's mean concentration of salt solution in the river water will be $f_1, f_2, f_3, f_4 \ldots f_n$

As the river discharges in q litres/sec, the concentrations will be

$$f_1 = \frac{s_1}{q}, f_2 = \frac{s_2}{q}, f_3 = \frac{s_3}{q} \ldots f_n = \frac{s_n}{q}$$

or

$$s_1 = f_1.q, s_2 = f_2.q, s_3 = f_3.q \ldots s_n = fn.q$$

Summing:

$$S = s_1 + s_2 + s_3 + \ldots + s_n = q\,(f_1 + f_2 + f_3 + \ldots + f_n)$$

or

$$S = q \int_0^n f\,dn$$

The integration can easily be done mathematically by measuring the area A under the concentration diagram (Figure 8).

The unknown discharge q can be calculated:

$$q = \frac{S}{A}$$

To obtain correct dimensions for q, however, it is necessary to introduce correcting factors:

$$q = \frac{S}{A.a.b}$$

where

q = water discharge in the river
S = volume of injected brine

A = area under concentration (diagram)
a = correction for used units on x-axis
b = correction for used units on y-axis

It is seen that the calculation of discharge is independent of the distance between the injection and observation points, the duration of the injection, the water velocity or the size and shape of river cross-profile. The only condition that must be fulfilled is that the brine be completely mixed with the river water.

PROCEDURES

Choice of measuring reach

Great care is required in the choice of reach suitable for discharge measurement when the "salt method" is used. There should be no loss or gain of water between the injection point and the observation point, and the length of reach should be such that, with allowance for the natural mixing action, the solution is uniformly mixed throughout the whole cross-section of the stream at the observation point.

To reduce the duration of the salt wave, the distance between injection and observation points should be as short as practicable and the dead-water zones as small as possible. These conditions are easier to satisfy in relatively narrow channels, and mixing is improved by natural disturbances such as bends, narrows, shelves and falls. In particular, wide channels should be avoided, as should reaches in which the stream divides into a number of branches. A reach of 100 to 500 meters normally is adequate.

Preparation of the brine

Although any ionizing compound can be used, the most convenient and cheapest is common salt (NaCl). The amount of salt necessary will be about 0.5 kg per m^3/sec water discharge in the river, although a slightly greater amount is normally used. The brine should be prepared in a separate container to ensure complete dissolution of the salt, and the concentrated solution should then be decanted into a previously calibrated container. The resulting clear salt solution is called the "primary solution," and the same volume of it (30 to 50 litres for small streams) should be used in each measurement. In medium meltwater streams it is sufficient to use 3 to 5 kilograms of salt dissolved in 50 litres of water in preparing the primary solution, but for larger streams the amount of salt, or possibly even the amount of water, must be increased. Although the theoretical maximum proportion of salt that can be dissolved in water is about 3.6 kilograms to 10 litres, practical use requires that the quantity of salt dissolved in this amount of water be no more than 2 or 2.5 kilograms.

A small representative sample of primary solution (50 millilitres) should be retained in a clear, dry bottle for calibration purposes.

The calibration procedure

The equipment used in the calibration procedure is illustrated in Figure 1.

Each primary solution will have a slightly different salt concentration, and it is necessary to prepare a separate concentration-conductivity graph in each case. As the accuracy of the method depends on careful construction of the graph, the procedure is described in the following numbered paragraphs in some detail.

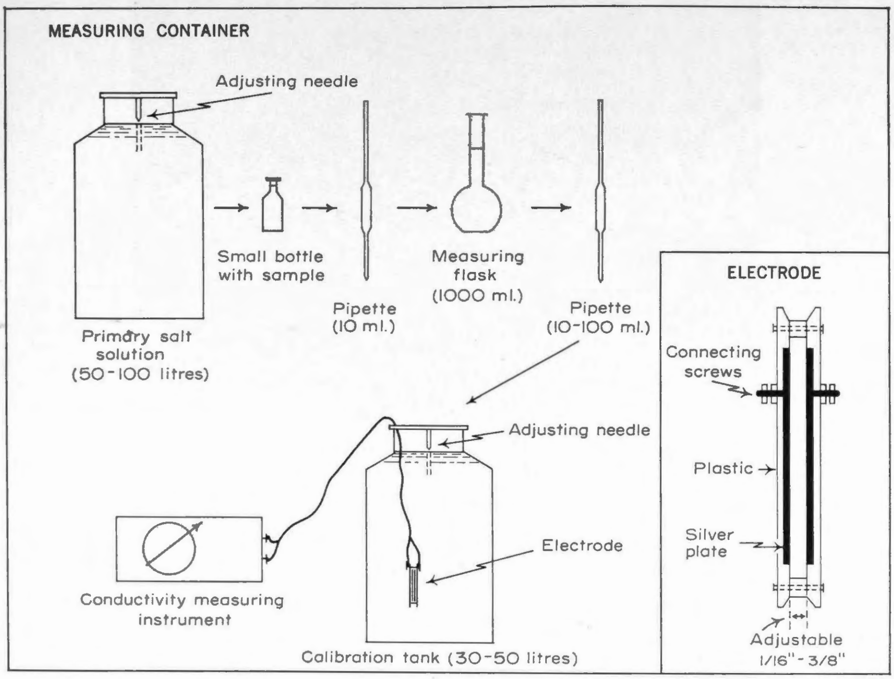

FIGURE 1. A diagrammatic sketch showing the dilution procedure followed before calibration. Note electrode in lower right corner.

1. Measure 10 millilitres of the retained primary solution in a calibrated pipette and put them into a 1,000-millilitre measuring flask (Figure 2). Fill the flask with river water. To ensure a representative sample, the

pipette should first be spooled with a small quantity of the primary solution. The arbitrary setting of the strength of the primary solution at 1 gives a solution of relative strength

$$\frac{10}{1000} \times 1 = 0.01.$$

This solution, the primary solution diluted 100 times, is called the secondary solution.

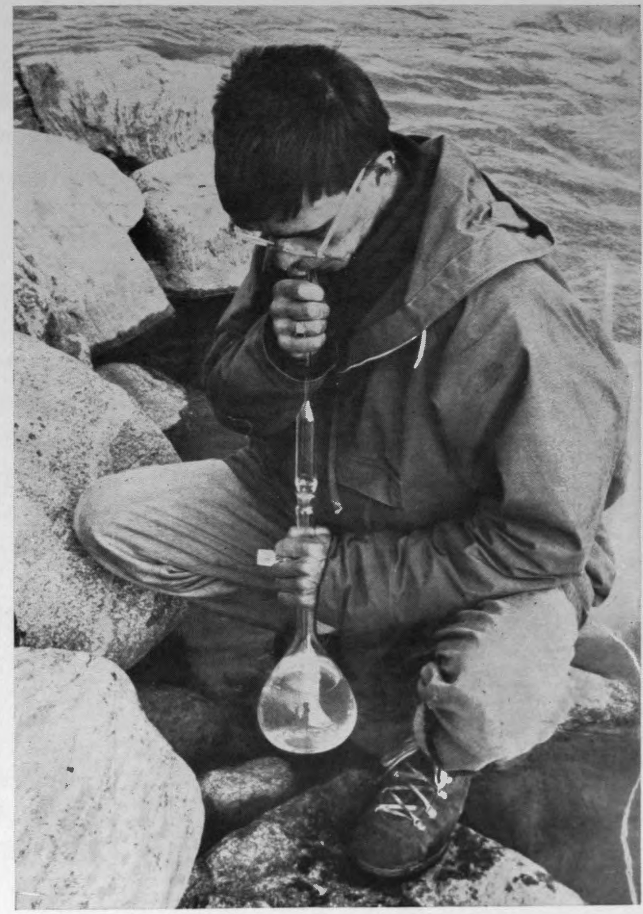

FIGURE 2 The secondary solution being prepared in a 1,000-millilitre measuring flask.

2. Into a wide-neck container (of plastic, aluminum or tinned steel) placed in the river so that its temperature variations will be as small as possible, put 40 litres of river water.

3. Place the electrodes to be used in the river in the container. Agitate the water and, when the electrodes become steady, take a conductivity reading (see the procedure given later). Theoretically, as the tank contains only clear river water, it should be expected to give the same conductivity reading as the river itself. In practice, however, it is normally found that the conductivity reading in the tank is from 5 to 15 per cent higher than readings taken simultaneously in the river. In extreme cases the river may give an even lower reading. These variations are due to electrical conditions in the tank and will not affect the measuring results because corrections will subsequently be made. Conductivity readings should be taken both in the tank and in the river water outside and the temperatures noted.

FIGURE 3 Small quantities of the secondary solution are added to the river water in the calibration tank, which is placed in the river for temperature control. After agitation of the solution, conductivity in the tank is measured.

4. Spool a clean pipette, measure exactly 10 millilitres of the secondary solution, and add it to the 40 litres of river water in the tank, thus making a solution of relative concentration

$$\frac{10 \times 0.01}{40{,}010} = 0.0000025$$

of the original primary solution (Figure 3). Agitate the mixture and take a conductivity reading.

5. Additional amounts of the secondary solution (10 millilitres, 10 millilitres, ... 50 millilitres) should be added consecutively in the same manner and conductivity readings taken. Prepare a calibration table as per example (Table 1), correcting conductivity readings for tank errors.

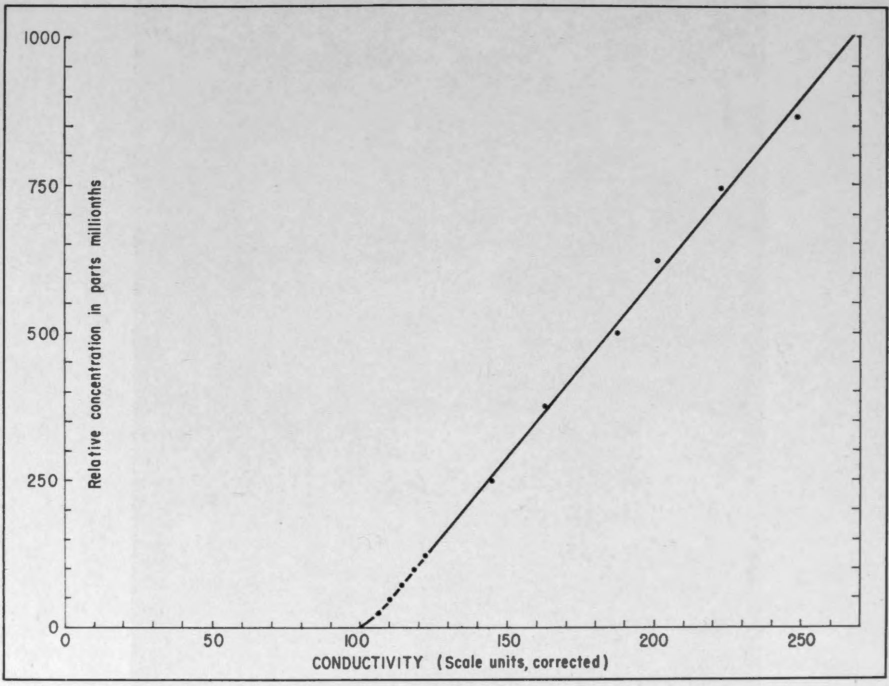

FIGURE 4. The calibration curve obtained from Table 1.

6. Stream water will always have a natural background conductivity caused by hydrolysis and a natural content of ions originating in matter dissolved in the water. The background conductivity is read before the test is carried out and becomes the base-scale unit (example: the 100

Table 1

Calibration

River: Tarafalajokk (Sweden)
Date: July 14, 1962
Stream water in stream: 100 conductivity units
Stream water in tank: 115 conductivity units
Temperature in tank before calibration: 5.40°C
Temperature in tank after calibration: 5.45°C

Reading no.	Added secondary solution (millilitres)	Relative concentration	Conductivity readings	Corrected for tank errors
1	0	0	115	100
2	10	$\frac{10 \times 0.01}{40.010} = 0.0000025$	122	106
3	10	$\frac{20 \times 0.01}{40.020} = 0.0000050$	127	110
4	10	$\frac{30 \times 0.01}{40.030} = 0.0000075$	131	114
5	10	$\frac{40 \times 0.01}{40.040} = 0.0000100$	136	118
6	10	$\frac{50 \times 0.01}{40.050} = 0.0000125$	140	122
7	50	$\frac{100 \times 0.01}{40.100} = 0.0000250$	166	144
8	50	$\frac{150 \times 0.01}{40.150} = 0.0000374$	185	161
9	50	$\frac{200 \times 0.01}{40.200} = 0.0000498$	215	187
10	50	$\frac{250 \times 0.01}{40.250} = 0.0000621$	235	204
11	50	$\frac{300 \times 0.01}{40.300} = 0.0000744$	255	222
12	50	$\frac{350 \times 0.01}{40.350} = 0.0000876$	285	248

units shown in Table 1). If temperature changes occur, or if different kinds of water from various ground-water sources—precipitation, melting snow, etc.—pass in the river, the background reading may vary from time to time. A new reading of the background conductivity must therefore be taken for each salt test. It is presumed, however, that the background conductivity is constant during the short time required for each test.

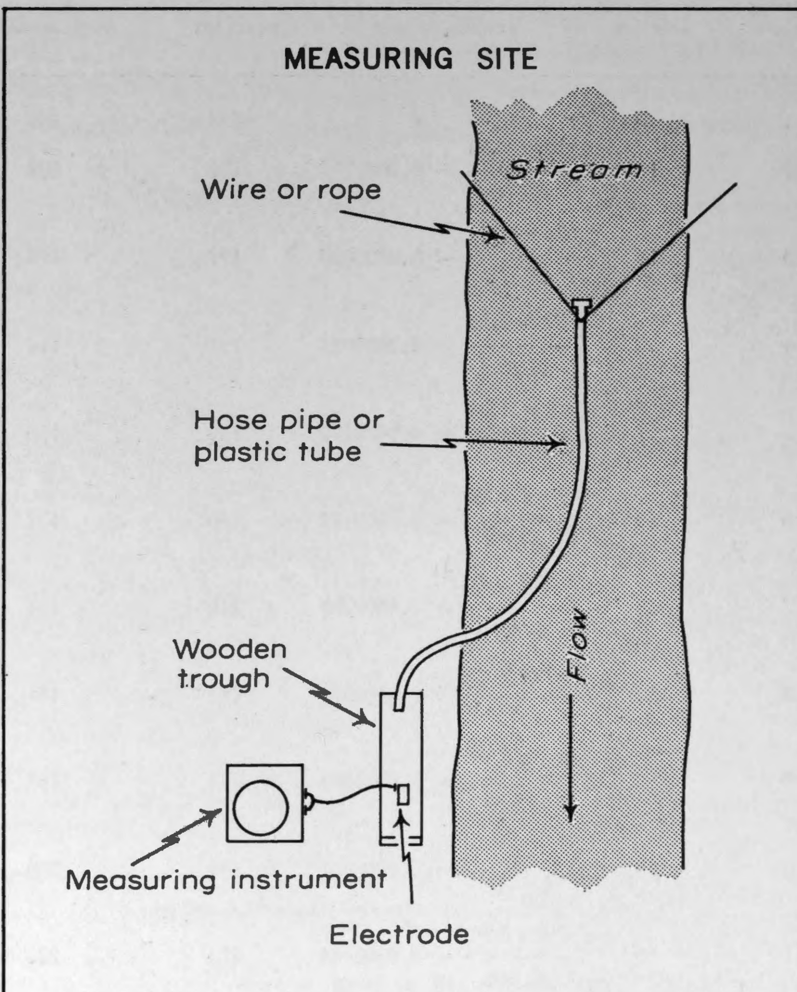

FIGURE 5. A sketch of the measuring point at the river. A continuous sampling of river water is obtained from a hose or pipe placed near middle of the river. The electrodes are flushed by water from the pipe. It is also possible to place the electrodes in the river proper, but air bubbles in the water will normally disturb the readings.

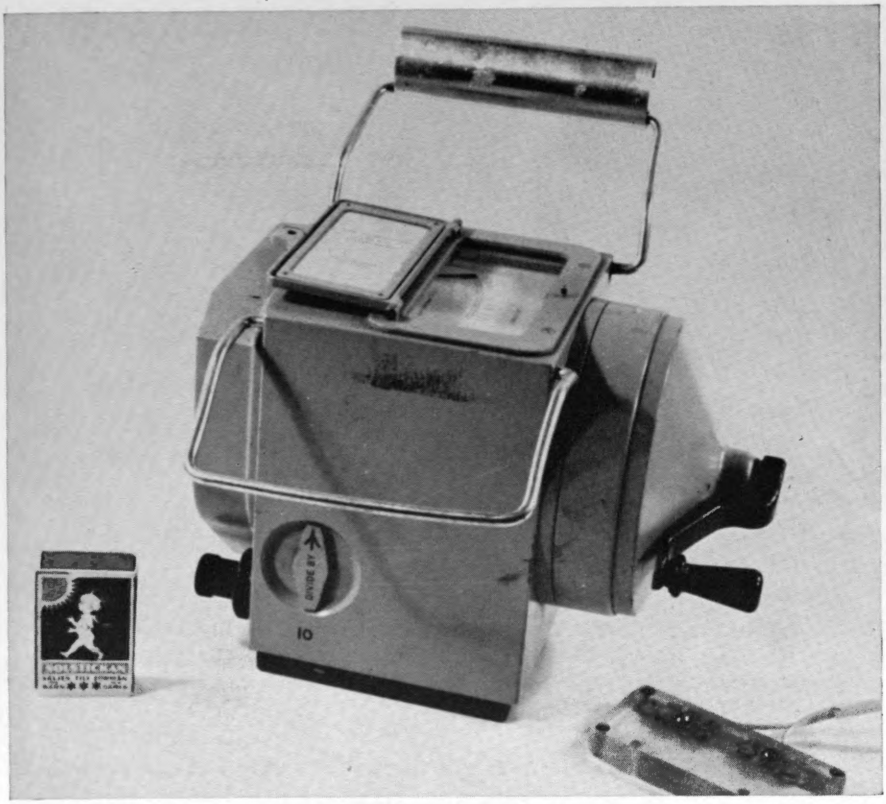

FIGURE 6. The conductivity meter and a small electrode. This meter is designed for use in waters that give a high conductivity reading.

7. The relative concentration readings are then plotted on the x-axis of the graph and the corrected conductivity readings on the y-axis (Figure 4). On the graph, the data should result in a straight line, broken only by a slight deviation near the bottom of the range. Should the data be widely scattered, the whole calibration procedure must be repeated.
8. The calibration procedure should be completed before the river test is made so that, if errors occur, the primary solution is not lost.

Measuring the salt wave—the "salt test"

The primary solution should be dumped as near the middle of the stream as possible so that no part of it is left on the banks. The salt wave is recorded downstream by placing the electrodes in the stream itself or, better, in a flume or trough of evenly streaming water, any disturbance that would result from the passage of air bubbles between the electrode plates thus being avoided (Figure 5).

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FIGURE 7. Conductivity readings are taken very frequently during the passage of the salt wave. One observer acts as timer and note-taker; the other simultaneously reads the conductivity meter by rotating the generator.

During the several minutes the salt wave will take to pass the measuring point, variations in conductivity can be observed either photographically, by filming the conductivity instrument (Figure 6) and timing it with a watch, or by using recording equipment. For field purposes, stopwatch readings taken every five seconds are sufficient (Figure 7). During the last part of the observation period longer intervals than five seconds may be used (Table 2). The conductivity readings should be continued until the initial water conductivity is regained.

Calculations

If the conductivity readings obtained by the salt test in the river (Table 2) were graphed versus time, they would show how conductivity varied as the salt wave passed. As it is necessary, however, to plot concentration versus time, all conductivity readings in the table must be converted into concentration figures. This conversion may be made from the calibration curve (Figure 4). Each reading (100, 120, 130, etc.) is converted by drawing a horizontal line from the x-axis (conductivity) to the graph and then drawing a vertical line from that point on the graph to the y-axis (relative concentration) of the diagram.

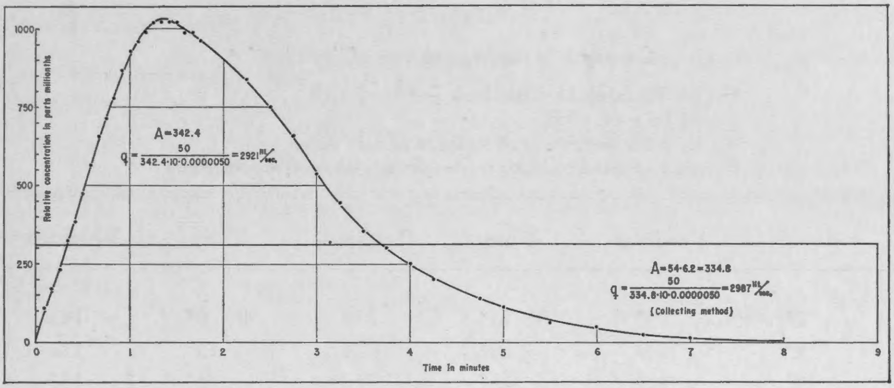

FIGURE 8. The passage of the salt wave, with conductivity measurements converted to units of relative concentration. The area under the curve can be measured by planimeter. The plotting of data from collecting method is illustrated in the rectangle.

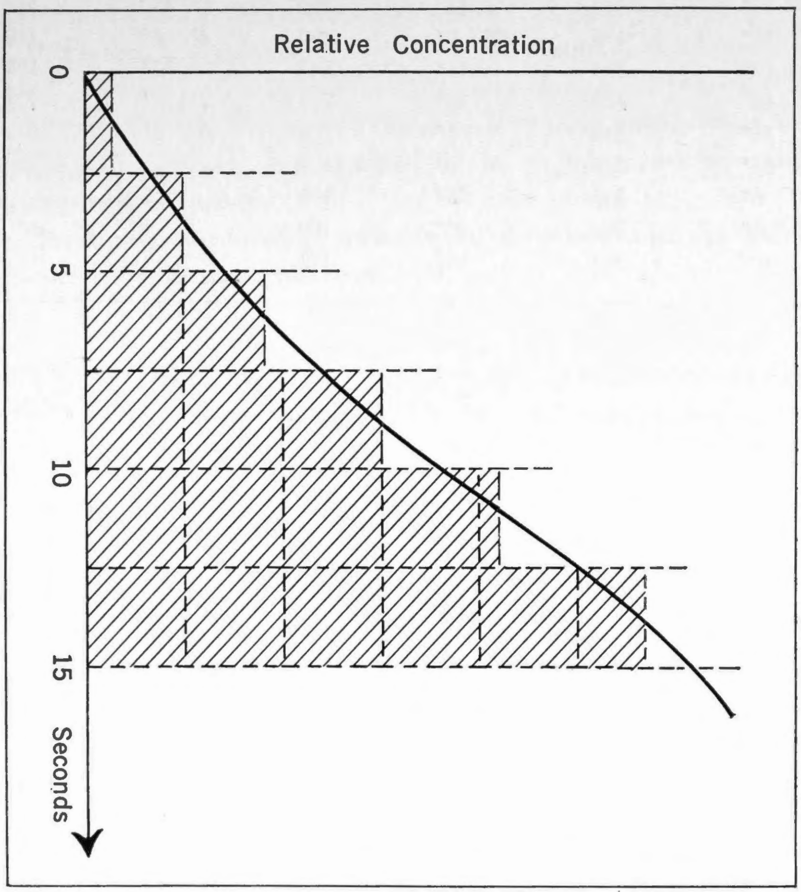

FIGURE 9. A histogram for measuring the area under the salt-wave curve.

Table 2

Conductivity readings at time of "salt test"

River: Tarfalajokk (Sweden)
Date: July 14, 1962
Time: from beginning of passage of salt wave
Reading of conductivity units: direct, on instrument scale

Time	Readings	Time	Readings	Time	Readings
0″	100	1′ 15″	270	4′ 0″	143
5″	120	20″	270	15″	135
10″	130	25″	270	30″	130
15″	140	30″	270	45″	125
20″	155	35″	265	5′ 0″	120
25″	165	40″	265	15″	110
30″	180	45″	260	30″	113
35″	195	2′ 0″	250	6′ 0″	110
40″	210	15″	240	30″	105
45″	220	30″	225	7′ 0″	103
50″	230	45″	210	8′ 0″	101
55″	245	3′ 0″	190		
1′ 0″	255	15″	175		
1′ 5″	260	30″	160		
10″	265	45″	152		

The concentration figures obtained are then plotted on a new graph, where the y-axis shows the relative concentration and the x-axis the time. The time divisions are normally 5 or 10 seconds per unit (Figure 8).

The units on the graph paper are arbitrary, but it is useful to apply the same concentration scale on the y-axis as previously used in the calibration diagram (Figure 4). It is then possible to combine the two diagrams on a single sheet of graph paper.

When the salt test has been graphed, the area under the curve can be computed either by means of a planimeter (Figure 8) or by conversion to a histogram with arbitrary divisions on the x-axis (Figure 9). The area under the curve, measured in square centimeters, is marked "A."

The volume of water discharge can be computed by the formula

$$Q = \frac{V}{A.a.b}$$

In this case (Figure 7)

V = the volume of the primary solution poured into the stream = 50 litres

A = the area in square centimeters under the curve

a = one centimeter division on x-axis = 10 seconds

b = one centimeter division on y-axis = 0.000005 centration units

Therefore

$$Q = \frac{50}{A \times 10 \times 0.000005} \text{ litres/sec}$$

If calibration procedures and all readings have been carefully carried out, the result should indicate with a high degree of accuracy the volume of discharge of the water passing the measuring point. Errors from temperature variations or other causes are discussed later.

If the river has a constant cross-sectional profile, it should be possible to erect a stream gauge and take simultaneous readings on it at the time of the salt test. A rating curve could then be constructed for the river. At least 10 different measurements over a period, and often considerably more, are required for this purpose.

To simplify the procedure, an abbreviated method called the "collecting method" can be employed. A constant flow of river water is collected at the measuring point, normally by means of a hose or pipe, during the passage of the salt wave, which can be ascertained by successive conductivity readings in the river. The water is then placed in a container and its conductivity measured. The conductivity, as in the longer method, is then converted into a relative concentration reading, which is assumed to be the mean concentration of the salt wave during the collecting time. A rectangle is constructed, its height being the mean salt concentration and its length equalling the collecting time (Figure 8). The collecting method should be used only by trained personnel.

Temperature changes

Field work has shown that changes in temperature cause variations in conductivity readings that will vary from place to place, arising perhaps from different chemical conditions in the river waters or from geometrical properties of the electrode itself. All temperature changes occurring during tests should be recorded, and corrections for all readings should be made at a common base from a temperature-correction graph.

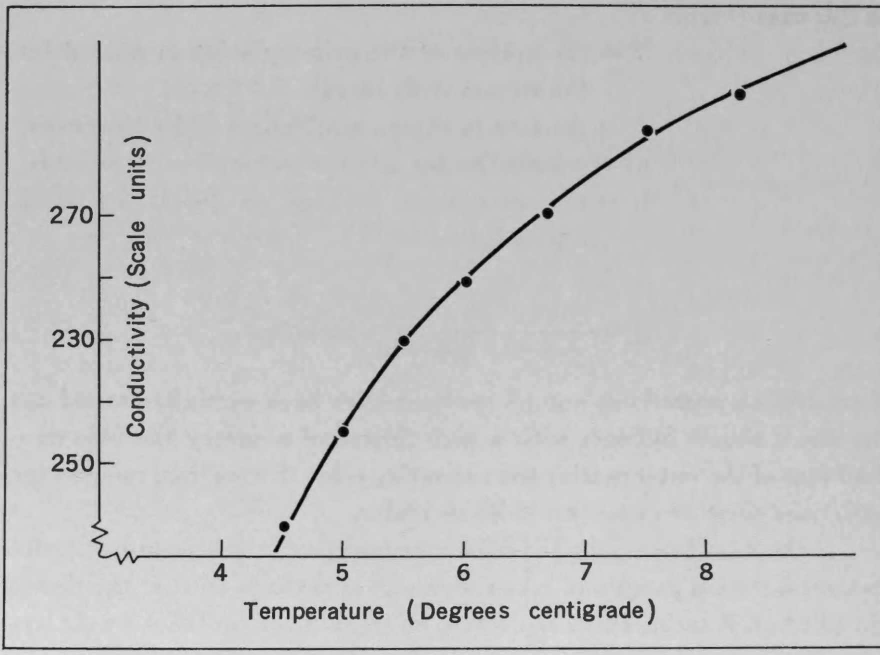

FIGURE 10. A temperature-correction curve. By numerical derivations of the curve, the percentile temperature corrections can be found at different temperature levels (Figure 11).

The temperature-correction graph is constructed in the following manner. A sample of river water (30 to 50 litres) is taken when the river temperature is as low as possible. This water is placed in a container, and simultaneous conductivity and temperature readings are made as the water is slowly warmed. Agitation should always take place when readings are made so that a natural and even-sediment distribution is maintained in the water sample. The conductivity values are plotted, and the best-fitting curve is interpolated (Figure 10). By numerical derivation, conductivity corrections in percentages can be obtained from the graph. In Figure 10, for example, a temperature change of 1 degree, between 5°C and 6°C, resulted in a change of 25 conductivity units, which is approximately 10 per cent within the conductivity range, or equivalent to a 1-per-cent increase for each change of 0.1 degree in temperature. Similar calculations can be made at different temperatures or in different rivers and graphed (Figure 11).

It is apparent that change in conductivity is greatest near the freezing point (0°C). It is, therefore, most difficult to employ the salt-dilution method for water discharge measurements in rivers where the water temperature is very near freezing. Then a minor change in temperature might cause a considerable change in conductivity and destroy the accuracy of the test. Care should be taken to keep the measuring tank at a constant temperature during the calibration readings. Should this not be possible, however, a linear rate of temperature change may be assumed and corrections applied accordingly.

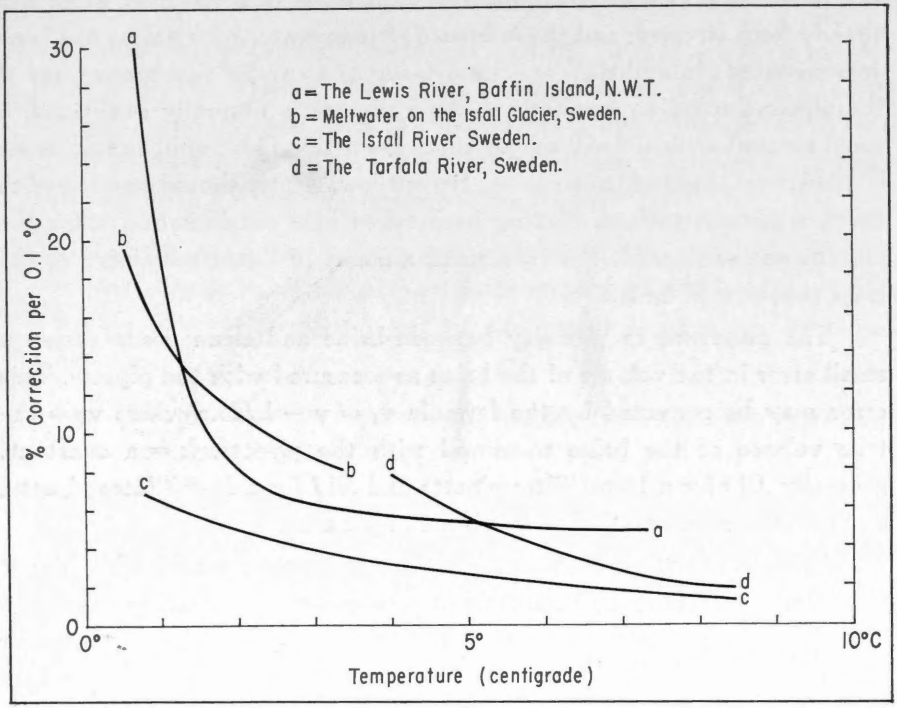

FIGURE 11. Temperature corrections obtained in different rivers and with different electrode constructions. If temperature-correction graph cannot be made, approximate values may be obtained from this figure.

If the river-water temperature at the time of the salt test differs from the water temperature in the tank when the calibration was done, the difference *should not* be corrected, since the actual background conductivity in the river is of no consequence in the result. The readings are made from a zero level in the river—for example, the 100 conductivity units in Table 1—and the calibration is based upon another zero level in the tank (for example, the 115 conductivity units in Table 1). The important point is that water temperature should be constant *in the tank* during the calibration procedure and *in the river* during the salt test. Otherwise temperature corrections must be made.

The time required for a complete salt measurement, from preparation of the primary solution until calculations are finished, should not exceed three hours. This period could be shorter with trained personnel.

Sources of error

The importance of a complete mixing of the brine with the river water has already been stressed, and the influence of temperature variations has been demonstrated. In addition, the importance of a careful and correct use of the pipettes must be emphasized. As a pipette is normally calibrated, a small amount of liquid will remain in its lower tip. This liquid should never be blown out. Instead, to facilitate the outflow, the tip should be allowed to touch a smooth surface. Having been taken into consideration when the pipette was calibrated, the very small amount of liquid remaining in the glass tube should be left.

The difference in viscosity between brine and clean water causes a small error in the volume of the brine as measured with the pipette. This error may be corrected by the formula $v_1 = v - k/25.c$ where v_1 = the true volume of the brine measured with the pipette, k = a constant, generally .015 for a 10-millilitre pipette and .017 for a 25-millilitre pipette, and c = the concentration of salt brine in per cent.

As most pipettes are calibrated at a temperature considerably higher than that of the brine to be measured, a temperature correction must also be made when very accurate measurements are required in cold rivers. In normal field use, however, both viscosity and temperature corrections can be omitted.

Polarization may occur at the electrodes (Daniels and Alberty, 1955, page 452). To avoid this effect, which can destroy the conductivity readings, the electrode plates should be made of pure silver or platinum.

Air bubbles in the river may also have a disturbing effect if they pass between the electrode plates. This difficulty may be avoided by placing the electrode in a trough into which a constant flow of river water is led through a flume or hose (Figure 5).

It is important to keep the electrode in the same position in the tank during the calibration procedure and to perform the agitation in the same manner for each reading.

If all these procedures are carried out carefully, the relative salt-dilution method may be considered as having at least the same degree of accuracy as the current-meter methods. It can be a very valuable field technique in northern research, as, for example, in glaciological studies, in which measurements of meltwater discharge are important.

APPENDIX

Equipment list

1. A sensitive conductivity meter. A "Dionic water tester" made by Evershed and Vignoles Ltd., Acton Lane Works, Chriswick, London W. 4, England, has been proved satisfactory, although for rivers with a higher background conductivity a less sensitive instrument or one with a variable range is recommended.

2. Electrodes consisting of pure-silver plates mounted on suitable plastic frames (Figure 4). They should be connected to a plastic insulated flexible wire long enough to permit readings at a convenient place on the shore.

3. Two 50-litre containers for preparing the salt brine (primary solution). One should be calibrated.

4. One calibration tank made of plastic, aluminum or tinned steel, of 30 to 50 litres in volume, calibrated, and with a large opening so that electrodes can be easily placed in the container and agitation carried out by hand.

5. Ordinary, fine-grained salt in suitable packages. Other chemicals can be used, even fluid acids such as sulphuric or hydrochloric acid, but field work has proved that common salt ($NaCl$) is most convenient. It should be noted that some brands of table salt are blended with other chemicals that may not be fully soluble in cold water. In the preparation of the primary solution, therefore, the salt should first be mixed in one container, and after it settles, 50 litres of clear solution should be transferred to the measuring bottle.

6. A measuring flask with a long narrow neck containing exactly 1,000 millilitres. Measuring pipettes, sizes 10, 25, 50 and 100 millilitres. A small glass bottle of about 50 millilitres with a glass cork. Paper towels for drying utensils and cleaning equipment.

7. Cylinders for measuring volumes when the aforementioned containers are being calibrated.

8. Graph paper in millimeters and centimeters. Semilogarithmic graph paper. Drawing equipment.

9. Thermometers on a scale of 1/10°C.

10. A wooden dowel or similar equipment for agitating the water in the calibration tank.

11. A small hand-operated calculating machine (not essential but useful in calculating relative concentrations when calibration diagrams are being drawn).

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EXAMINATION OF THE CARBONATE CONTENT OF DRIFT IN THE AREA OF FOXE BASIN, N.W.T.

J. T. Andrews and V. W. Sim

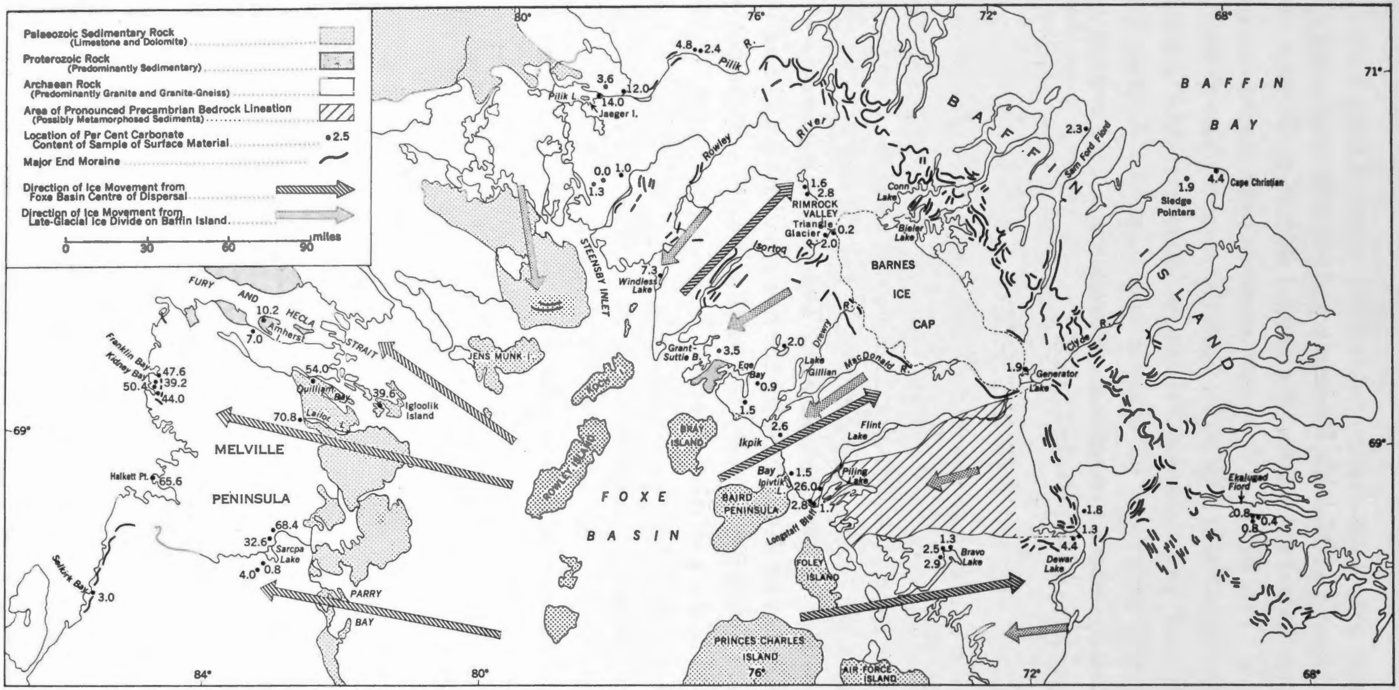
ABSTRACT: The Chittick apparatus has been used to examine the carbonate content of till from Melville Peninsula and the northern half of Baffin Island. Fifty-four samples have been examined. On Melville Island, east of the limestones, the fine-till fraction contains between 44 and 71 per cent carbonates; low values occur along the northern coast and south of Sarcpa Lake. On Baffin Island values are much lower, but it seems that they are slightly higher on the west coast than on the east coast. The high carbonate content across Melville Peninsula lends support to the hypothesis of a westward movement from Foxe Basin, but the Baffin Island samples, with the exception of one from Piling Bay (26-per-cent carbonate content), possibly indicate that the eastward movement across the island was followed by a later westward flow toward Foxe Basin.

RÉSUMÉ: L'appareil Chittick a servi à l'examen de la teneur en carbonates de till en provenance de la presqu'île Melville et de la moitié Nord de l'île Baffin. On a examiné cinquante-quatre échantillons. Dans l'île Melville, à l'est de la zone des calcaires, le till à grain fin contient de 44 à 71 p. 100 de carbonates, tandis que les teneurs sont inférieures le long de la côte Nord et au sud du lac Sarcpa. Dans l'île Baffin, les teneurs sont beaucoup plus faibles, mais il semble qu'elles soient un peu plus fortes sur les côtes Ouest que sur les côtes Est. La forte teneur en carbonates sur la presqu'île Melville tend à accréditer l'hypothèse d'un mouvement vers l'ouest à partir du bassin Foxe, mais les échantillons de l'île Baffin, à l'exception de celui qui provient de la baie Piling (26 p. 100 en carbonates), indiquent la possibilité que le mouvement vers l'est sur l'île ait été suivi d'un déplacement subséquent vers l'ouest en direction du bassin Foxe.

INTRODUCTION

Dreimanis (1962) has described a method he has been using since 1935 to determine the carbonate content in the matrix of Pleistocene glacial deposits. He points out that such quantitative information can be used "in deciphering regional glacial movements, in distinguishing products of different glacial lobes, in stratigraphic and provenance studies, and in evaluation of depth of leaching in weathering profiles." The first of these uses seemed particularly applicable in the Foxe Basin area of the eastern Canadian Arctic, where regional ice movements that occurred during the Pleistocene are still imperfectly understood.

MS submitted June 1963.



The proposed radial directions of ice movement from the centre of Foxe Basin across Melville Peninsula and Baffin Island. On Baffin Island this was later followed by a westerly movement. The areas of limestone and dolomite have been drawn from existing geological maps (Geol. Surv. Can.). In the Pilik River area old contacts have been revised from ground mapping (Falconer, Geog. Br.).Samples collected in 1963 just south of Windless Lake have up to 35 per cent carbonates in fine fraction.

It has been suggested (Ives and Andrews, 1963, page 38) that during the "Wisconsin" maximum, ice moved radially outward from Foxe Basin across Baffin Island and Melville Peninsula and possibly southward across Foxe Peninsula. Later, the centre of dispersal shifted to lie west of the Barnes Ice Cap. This led to a dominant southwesterly movement across west Baffin into Foxe Basin (Figure 1). Since the northern part of the Basin is surrounded and underlain by Palaeozoic limestones and dolomites, carbonate-content analysis of till samples might distinguish these movements, particularly where Precambrian igneous rocks were crossed as on Melville Peninsula and west Baffin Island.

THE METHOD

Dreimanis gave a complete account of the application of the method (Dreimanis, 1962). It involves the use of the Chittick gasometric apparatus to measure the volume of carbon dioxide driven off when the finer fractions (<.074mm) of a till sample of precise weight are allowed to react with a 20-per-cent solution of hydrochloric acid. The weight percentage of the carbonates can then be determined by the use of simple graphic relation. It is possible to determine not only the total carbonate content but also, by a refinement in the analysis procedure, the weight percentage of calcite and dolomite, the two most important carbonate minerals in Pleistocene deposits. Other carbonate minerals, such as magnesite and siderite, are usually present in such small quantities that they can be ignored. The fine-size fraction of the sample is chosen for analysis because most till-matrix carbonates occur in the very fine sand, silt or clay fractions and because the speed of reaction between the acid and the carbonates can be compared if the grain size of all samples is similar (Dreimanis, 1962, page 521). With reasonable care the percentage of carbonates determined by the use of the Chittick apparatus should be accurate to $\pm$ 0.3 per cent.

RESULTS FROM THE FOXE BASIN AREA

Chittick gasometric analysis was carried out on 54 samples of till from Melville Peninsula and central Baffin Island in the geomorphological laboratory at the Geographical Branch by means of a production-model Chittick apparatus manufactured by Fisher Scientific Company. The percentage, by weight, of calcite, dolomite and the carbonate total was determined for each sample (see table), and the last-mentioned was plotted on a bedrock geology map of the Foxe Basin area. What follows is a series of observations on the results obtained with the method.

Carbonate content of samples of surface material from northern Baffin Island and Melville Peninsula, N.W.T.

Sample no.	Location	Weight percentage		
		Calcite	Dolomite	Carbonates (total)
	Melville Peninsula			
VWS–58–8U	Baker Bay	14.6	29.4	44.0
VWS–58–9U	Kidney Bay (below marine limit)	20.8	18.4	39.2
VWS–58–10U	Kidney Bay	16.4	34.0	50.4
VWS–58–33U	Selkirk Bay (below marine limit)	2.5	0.5	3.0
VWS–58–38U	Mainland south of Amherst Island	2.8	4.2	7.0
VWS–58–41U	Franklin Bay	13.2	34.4	47.6
VWS–58–48U	Quillian Bay (below marine limit)	6.0	48.0	54.0
VWS–58–27U	North of Sarcpa Lake	37.2	31.2	68.4
VWS–58–28U	North of Sarcpa Lake	4.2	28.4	32.6
VWS–58–29U	South of Sarcpa Lake	0.0	0.8	0.8
VWS–58–31U	Southwest of Sarcpa Lake	0.9	3.1	4.0
VWS–58–32U	Amherst Island (below marine limit)	1.6	8.6	10.2
VWS–58–35U	Halkett Point (below marine limit)	26.0	39.6	65.6
VWS–58–43U	Igloolik Island (below marine limit)	0.8	38.8	39.6
VWS–58–45U	Lailor Lake	37.6	33.2	70.8
	Baffin Island			
JTA–62–9U	Triangle Glacier	0.2	0.0	0.2
JTA–62–10U	Upper Isortoq River	0.9	1.1	2.0
JTA–62–20U	Grant-Suttie Bay	0.9	2.6	3.5
JTA–62–21U	Eqe Bay	0.5	1.0	1.5
JTA–62–22U	Eqe Bay	0.9	0.0	0.9
JTA–62–23U	69° 56' N, 75° 32' W	0.7	1.3	2.0
JTA–62–24U	Windless Lake	1.4	5.9	7.3
JTA–62–25U	Longstaff Bluff (below marine limit)	1.0	1.8	2.8
JTA–62–26U	Longstaff Bluff (above marine limit)	1.1	0.6	1.7
JTA–62–27U	North of Steensby Inlet	0.8	0.5	1.3
JTA–62–28U	North of Steensby Inlet	0.0	0.0	0.0
JTA–62–29U	North of Steensby Inlet	0.3	0.7	1.0
JTA–61–20U	Rimrock Valley	1.0	0.6	1.6
JTA–61–27U	Rimrock Valley	1.1	1.7	2.8
VWS–61–3U	Generator Lake	1.3	0.6	1.9
VWS–61–5U	Bravo Lake	1.4	1.1	2.5
VWS–61–6U	Ekalugad Fiord (below marine limit)	0.8	0.0	0.8
VWS–61–8U	Ekalugad Fiord (moraine in front of ice tongue)	0.8	0.0	0.8
VWS–61–9U	Ikpik Bay (below marine limit)	1.0	1.6	2.6
VWS–61–10U	Piling Lake (below marine limit)	16.4	9.6	26.0
VWS–61–11U	Bravo Lake (below marine limit)	1.0	1.9	2.9
VWS–61–13U	Dewar Lake	1.3	3.1	4.4
VWS–61–15U	Dewar Lake	1.5	0.3	1.8
VWS–61–17U	Bravo Lake	0.8	0.5	1.3
VWS–61–20U	Dewar Lake	0.8	0.5	1.3
VWS–61–25U	East of Ipiutik Lake	1.0	0.5	1.5
VWS–61–27U	Ekalugad Fiord	0.4	0.0	0.4
GF–61–1U	Pond Inlet	1.2	5.3	6.5
GF–61–2U	Pond Inlet	1.2	1.2	2.4

Carbonate content of samples of surface material from northern Baffin Island and Melville Peninsula, N.W.T.—concluded

Sample no.	Location	Weight percentage		
		Calcite	Dolomite	Carbonates (total)
GF–61–4U	Pond Inlet	0.1	0.5	0.6
GF–61–8U	Arctic Bay	0.2	36.0	36.2
GF–61–10U	Sam Ford Fiord	1.3	1.0	2.3
GF–61–12U	Sledge Pointer	1.4	0.5	1.9
GF–61–15U	Cape Christian	2.0	2.4	4.4
GF–62–1U	Pilik River	2.0	10.0	12.0
GF–62–2U	Pilik River	0.7	1.7	2.4
GF–62–4U	Pilik River	2.0	2.8	4.8
GF–62–6U	Jaeger Island	2.6	11.4	14.0
GF–62–11U	Patlok Lake	1.2	2.4	3.6

First and most noticeable is the high carbonate content of the drift from Melville Peninsula. Of 15 samples tested only five contain less than 11 per cent carbonate. The one from the vicinity of Selkirk Bay, on the west coast of Melville Peninsula (3.0 per cent), and two from the area south of Sarcpa Lake (4.0 and 0.8 per cent) are the most southerly of the samples; two others, from Amherst Island and the mainland south of it (10.2 and 7.0 per cent carbonate respectively), are the most northerly samples tested. Of the remaining 10 samples, none contained less than 32.6 per cent carbonate, the greatest proportion being 70.8 per cent in a sample collected at the west end of Lailor Lake, in the north-central part of the peninsula. In contrast, of the 39 samples from Baffin Island only four contained more than 10 per cent carbonate. Two of these, from Piling Lake and Arctic Bay (26.0 and 36.2 per cent respectively), are explained farther on. The other two, from the Pilik River and Jaeger Island (12.0 and 14.0 per cent respectively), are comparable to the minimum values for Melville Peninsula.

Precambrian volcanic and intrusive rocks usually contain less than 10 per cent calcium and magnesium oxides (Reiche, 1950, page 45). A large part of these oxides may be converted to carbonates during the weathering process (Lyon, Buckman and Brady, 1952, page 302), though this is perhaps doubtful under Arctic climatic conditions. Any carbonate in glacial till overlying Precambrian bedrock in excess of this small proportion probably originated from nearby sedimentary areas, and the presence of the carbonates can be adduced as corroborative evidence of glacial movement determined by field techniques. Precambrian sedimentary rocks, of course, may contain considerable quantities of carbonate minerals, and known areas of these rocks must be considered in evaluating the source of carbonate tills (see map). Crystalline limestones have, for instance, been discovered in Isortoq Fiord, Baffin Island. Another possibility must be kept in mind: it is that high-carbonate tills may also result from the final glacial stripping of a younger limestone cover from a crystalline basement. Though no outliers of limestone are known to exist in the interior at present, Palaeozoic limestones probably once covered Melville Peninsula, and high-carbonate tills may have been derived from the final stripping of this cover from the Archaean basement during the glaciation. This would, however, involve perhaps greater glacial erosion than expected over this area of low relief. The same may be true of north-central Baffin Island. Palaeozoic outliers do, in fact, occur in the northern part of the region north of the Pilik River.

The carbonate content of the Melville Peninsula samples appears to be no higher than samples of limestone-derived till from southern Ontario examined by Dreimanis (1957, page 404).

It is believed that the carbonate content of Melville Peninsula samples supports the theory of relatively uncomplicated glacial transport from east to west across the peninsula (Sim, 1960). Swaths of carbonate-charged drift have been noted extending westward across the northern part of the peninsula from the geological contact between the Palaeozoic limestone and the Archaean granite-gneiss basement. It seems probable that the considerable amount of carbonate in the drift west of this contact and above the determined limit of postglacial marine submergence originated on the northeastern sedimentary lowland of the peninsula. No significant east-west difference in carbonate content was apparent in the small number of samples tested. Indeed, the sample from Igloolik Island contained a smaller percentage of carbonate (39.6) than many of the samples from the interior and west coast. The high carbonate content of the west-coast samples is probably a reflection of a westerly movement from the limestone in Foxe Basin to the sample locations. Air-photo interpretation and field evidence of glacial features indicate it is unlikely that any of the other possible areas—for example, Simpson Peninsula, the east coast of Boothia Peninsula or Brodeur Peninsula—could be the source of the carbonates on Melville Peninsula.

It is difficult at present to account for the particularly low carbonate content of the samples south of Sarcpa Lake and on the west coast at

Selkirk Bay. Drumlinoids and other streamlined till forms, as well as the visible swaths of limestone-charged ground moraine indicating ice movement from east to west, all occur north of the area of very low carbonate. This may indicate less intense ice movement and less effective glacial transport south of Sarcpa Lake. Even so, it still seems unusual that the carbonate content should be so low less than 20 miles from areas of limestone bedrock to the east. Dreimanis (1963: personal communication) has suggested that low values may result from the local incorporation of a friable Precambrian rock.

Similarly, the low carbonate content of the samples from Amherst Island and the mainland immediately to the south (10.2 and 7.0 per cent respectively) are difficult to explain if the glacial movement was from the southeast. It is suspected that the most recent ice advance in this area was from the north across Fury and Hecla Strait (Blackadar, 1958; Sim, 1960). The area of Baffin Island extending for a considerable distance inland from the north side of the strait, as well as the extreme northern tip of Melville Peninsula, is underlain by Proterozoic rocks in which local areas of limestone and dolomite occur and are separated from the north coast of Melville Peninsula by 60 miles of Precambrian bedrock. The carbonate in the two samples mentioned may derive from these Baffin Island sources.

As has been pointed out, the carbonate content of the 39 samples from Baffin Island is very much lower than the carbonate content of the Melville Peninsula samples. Thirty-five have a carbonate content of less than 10 per cent, and only two a carbonate content of more than 20 per cent. The sample from Arctic Bay (36.2 per cent) comes from an area where Ordovician limestone outcrops on the Precambrian surface of Borden Peninsula whereas all of Brodeur Peninsula, lying to the west across Admiralty Inlet, is underlain by both Ordovician and Silurian carbonate rocks. The sample from Piling Lake (26.0 per cent) was collected from marine-reworked deposits only a few feet above the present sea level. The relatively high carbonate content in this sample can perhaps be explained as carbonate material transported to the area from other parts of Foxe Basin by ice-rafting and longshore processes during submergence, but the carbonate rocks of Baird Peninsula are also a possibility, especially as there is no significant difference in carbonate content between samples collected from below and above the marine limit at Longstaff Bluff and Ekalugad Fiord. At the latter location, indeed, the carbonate content above and below is exactly the same. Only two samples have a carbonate content between 10 and 20 per cent, and both, one on the upper Pilik River (12.0 per cent) and the other on Jaeger Island, in Pilik Lake (14.0 per cent), were collected a few miles east of an extensive area of Palaeozoic sediments that have a considerable carbonate content. Glacial movement from the southwest or northwest could also account for the carbonate content.

Among the samples from Baffin Island, those with a carbonate content of less than 10 per cent predominate, and most have less than 5 per cent. It is noticeable, however, that the west coast samples generally have slightly higher values than those on the east coast. It is possible that such a low content is not significant and cannot be used in the determination of the rocks that are the source of the drift. It was mentioned earlier that Precambrian volcanic and intrusive rocks, which underlie most of central Baffin Island, usually contains less than 10 per cent calcium and magnesium oxides. The fact that most of the Baffin Island samples contain less than this amount of carbonates means that the tills from which they were collected may have been derived from Precambrian crystalline country rock in the "waist" of the island and not from the carbonate-rich sedimentary rocks in Foxe Basin. This agrees with the preliminary interpretation of glacial events that has been proposed (Ives and Andrews, 1963). In particular, Andrews has stressed the interpretation that limited basal-ice movement in the central areas may be the cause of the highly angular and apparently locally derived characteristics of the bouldery till (Andrews, 1963).

The most recent glacial movement west of the Barnes Ice Cap was toward the southwest from an ice divide located between the present Foxe Basin coast and the ice cap. Whether earlier ice advanced northeastward across the island from a Foxe Basin centre and deposited carbonate-charged drift on the waist of the peninsula is not yet known with certainty. If this deposition occurred, it may have been subsequently removed during the southwesterly movement and replaced or overlain by the present drift. The large number of erratic limestone fragments discovered throughout central Baffin Island (Ives and Andrews, 1963) may have been left by the earlier movement.

The significance, if any, of the relative amounts of calcite and dolomite in the samples remains to be determined. Dolomite exceeds calcite in 11 of the 15 samples from Melville Peninsula. Whether this is simply a reflection of the predominantly dolomitic character of the bedrock in Foxe Basin is

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not known. The samples from Baffin Island cannot be so clearly distinguished. Twenty samples are predominantly of dolomite, and 17 are predominantly of calcite, while two samples contained equal amounts of both.

CONCLUSION

The relatively small number of samples and the large area from which they have been collected limit the reliability of the results of the present study. It seems likely, however, that careful collection and analysis of till samples from other Arctic areas will yield valuable information on source areas and the direction of ice movement where this information cannot be derived from more conventional field techniques. A number of areas come to mind. Scanty data from the Foxe Peninsula of southern Baffin Island suggest that the peninsula was glaciated by ice from a dispersal zone over Foxe Basin. Determination of the carbonate content of till samples from the peninsula might provide additional support for this hypothesis. This method may also be used to determine glacial movement in southern Baffin Island eastward from the Ordovician bedrock area on the east side of Foxe Basin via Nettilling Lake to Cumberland Sound and via Amadjuak Lake to Frobisher Bay. The applicability of this method to Baffin Island will increase, however, as geological reconnaissance mapping progresses (Blackadar, 1956 and 1958). The depth of leaching in carbonate-rich glacial deposits may be useful in determining the relative age of tills in the Arctic in the manner suggested by Dreimanis (1957, pages 403–404). The use of this factor has so far not been attempted in the Arctic, where the presence of permafrost, low precipitation and a short frost-free season restrict the leaching process. Another complicating factor is the upward movement of carbonates in lime-rich Arctic areas that leads to a precipitate on stones. This might enrich the near-surface drift more than the parent drift.

Finally, layers of drift of different ages and origins may be distinguished by their varying carbonate content (Dreimanis, 1960, page 1853).

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DEGLACIATION AND LAND EMERGENCE IN NORTHEASTERN FOXE BASIN,* N.W.T.

J. D. Ives

ABSTRACT: Between Longstaff Bluff and Steensby Inlet, western Baffin Island, late-glacial marine submergence does not exceed 345 feet, and decreases northward to 315 feet in Steensby Inlet. Five collections of marine molluscs between 290 and 30 feet above sea level yielded radiocarbon ages ranging from 6,725 ± 250 years to 2,050 ± 170 years. These ages allow construction of an uplift curve similar to others from different parts of Canada and Greenland. The 290-foot sample occurred close to the marine limit; its age (6,725 ± 250 years) is a good approximation for that of maximum marine submergence, which is recent compared with that found in other parts of Canada.

Geomorphological investigations revealed glacial outwash associated with morainic arcs, which are graded to various levels below the marine limit. That the evidence of submergence in coastal valleys and inlets is often restricted to levels below 200 feet implies the presence of late-glacial, and possibly "postglacial," glacier ice. Baffin Island inland ice, therefore, penetrated a high-level Foxe Basin more recently, perhaps much more so, than 6,725 years ago. At least 30 feet of land uplift has occurred in the last 2,000 years, and it seems probable that uplift is taking place today.

RÉSUMÉ: Entre la falaise Longstaff et l'inlet Steensby, dans la partie Ouest de l'île Baffin, la submersion marine de la fin de l'époque glaciaire ne dépasse pas 345 pieds et diminue, vers le nord, jusqu'à 315 pieds dans l'inlet Steensby. Cinq collections de mollusques marins prélevés entre 290 et 30 pieds au-dessus du niveau de la mer ont permis d'établir, à l'aide du procédé au radiocarbone, que leur âge varie de 6,725 ± 250 à 2,050 ± 170 ans. Les âges en question permettent de tracer une courbe de soulèvement semblable à d'autres ailleurs au Canada et au Groenland. L'échantillon prélevé à 290 pieds d'altitude se trouvait près de la limite marine, et son âge (6,725 ± 250 ans) indique d'assez près celui de la submersion marine maximum, ce qui constitue une date assez récente au regard d'autres points du Canada.

Les études géomorphologiques permettent d'établir qu'il y a eu déposition de matériaux de délavage proglaciaire associée à des moraines arquées qui s'échelonnent à divers niveaux au-dessous de la limite de submersion marine. La submersion dans les inlets et les vallées côtières s'est limitée souvent à des niveaux inférieurs à 200 pieds, ce qui prouve qu'il y avait de la glace de glaciers qui datait de la fin de l'époque glaciaire ou peut-être même d'une époque postglaciaire. En conséquence, les glaciers continentaux de l'île Baffin ont dû envahir le bassin Foxe à un niveau plus élevé il y a moins de 6,725 ans. Le terrain s'est soulevé d'au moins 30 pieds au cours des 2,000 dernières années, et il est probable que le soulèvement se poursuit encore de nos jours.

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*Paper presented at the 1963 annual meeting of the Canadian Association of Geographers, in Quebec City.

INTRODUCTION

Until very recently, glacial geomorphological investigations in the Canadian Arctic have been of a general and reconnaissance nature. Little attempt has been made to correlate marine and glacial phases, either relatively, by geomorphological methods, or absolutely, by the use of radiocarbon-dating techniques. Similarly, work on the extent of marine submergence and subsequent terrestrial recovery has been concentrated more on mapping the maximum extent of submergence, regardless of the chronological relation between differing marine levels, and less on the identification of strandlines, this term being used in its strict Scandinavian sense. Løken's work in

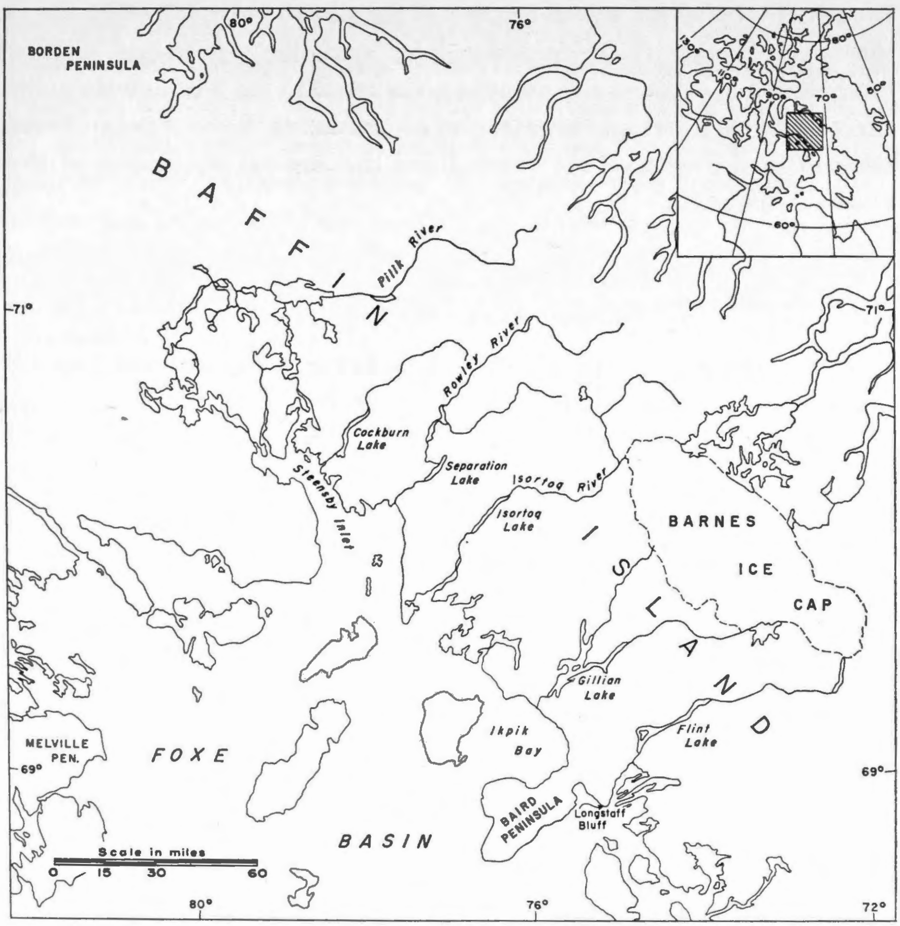

FIGURE 1. A location map.

northern Labrador constitutes the first Canadian attempt to define strandlines and relate them to glacial phases (Løken, 1962).

The current paper is a preliminary discussion of the problem of late-phase deglaciation and marine submergence in northeastern Foxe Basin (Figure 1).

Field work carried out in 1961 by the Geographical Branch forms the basis for the present report. Three radiocarbon dates and marine limit figures obtained by V. W. Sim have been utilized, although the area discussed is primarily restricted to Steensby Inlet. To provide an adequate background, the deglaciation of the Baffin Island–Foxe Basin area is briefly outlined from published (Ives, 1962; Ives and Andrews, 1963; Andrews, 1963, a and b) and unpublished material prepared by the Geographical Branch. There follows a brief account of the glacial and marine features of the lower Rowley River–Steensby Inlet area; the significance of their interrelation is outlined and an attempt is made to use a composite uplift curve to obtain a first approximation of precise dating. Some of the problems inherent in the methods are stressed and the regional significance of the results is discussed.

GLACIATION AND DEGLACIATION OF THE BAFFIN ISLAND–FOXE BASIN AREA

It is assumed that at the time of glacial maximum a major centre of dispersal was situated over Foxe Basin, either as a semi-independent dome or as an integral part of the North American continental ice sheet. During this phase the direction of flow was toward the northeast across the "waist" of Baffin Island: the eastern mountain rim projected above the inland ice, and mountain glaciation was rendered insignificant by large outlet glaciers that pushed along the fiords to coalesce in Baffin Bay. Progressive thinning resulted in relatively rapid loss of ice over Foxe Basin and the ultimate penetration of the late-glacial sea, which reached a height of more than 500 feet above the present level on the east coast of Melville Peninsula (Sim, 1960). Concurrently, the ice divide shifted northeastward from Foxe Basin to lie parallel with, and inland of, the southwest coast of Baffin Island. Sometime during this process, the northeastern boundary of the wasting inland ice stood at the Cockburn end moraines, which roughly parallel the heads of the Baffin Island fiords, while the southwestern margin calved into the late-glacial Foxe Basin (Ives and Andrews, 1963). Progressive shrinkage and further shifting of the ice divide toward the northeast occurred during the early phases of land uplift. Assuming that, during the glacial maxima, the ice thickness across the region was relatively uniform, it becomes significant that maximum marine submergence on the Foxe Basin coast of Baffin Island is 345 feet compared with more than 500 feet on Melville Peninsula (Sim, 1961 and personal communication).

The ultimate phases of shrinkage and shift of the ice divide are seen today in the Barnes Ice Cap; the sequence of changes has naturally resulted in a reversal of ice flow in the area between the ice cap and Foxe Basin. Local lobation and the movement of dispersal zones caused semi-radial flow into Steensby Inlet from an area centred over the base of Borden Peninsula. Thus, a zone extending inland for 80 miles and reaching as far north as the Rowley River bears obvious signs of a final, southwesterly ice-flow pattern whereas locally, along the east coast of Steensby Inlet, a northwest-southeast striation trend crosses the main trend. That the locally traced flow was toward the southeast is suggested by the abundance of limestone, dolomite and sandstone erratics in the same area, although the relative age of the two sets could not be determined. The skeleton local striation pattern, furthermore, indicates the former existence of a calving bay centred across Steensby Inlet and representing a concave ice-front that retreated in a general northerly direction concurrent with progressive isostatic uplift of the land.

This outline, for the sake of clarity, presupposes successive deglaciation from a theoretical maximum phase. In detail, the situation was much more complicated; its unravelling is scarcely begun. The simplified outline should perhaps be described as the schematic summing of all negative phases of deglaciation from a Pleistocene maximum to recent time. Peat, overlain by glacial deposits within 10 miles of the Barnes Ice Cap, has yielded radiocarbon ages of 24,600 and 30,000 years* (Andrews, 1963b), indicating that extensive areas were ice-free during this period and emphasizing how grossly simplified the discussion has been. Furthermore, the age of the peat adds weight to the hypothesis that, during parts of Wisconsin time, large areas in the high Arctic, hitherto assumed to have been glacially inundated, were ice-free. The extent of "classical" Wisconsin glaciation in high-Arctic areas also requires reassessment. The following sections primarily concern late-glacial and postglacial time—the last 12,000 years.

*Radiocarbon dates—J.T.A. 62–1P, 1–731: 24,600 ± 500 years before present.
J.T.A. 62–2P, 1–839: 30,000 ± 1,200 years before present.

THE GLACIAL FEATURES OF THE LOWER ROWLEY RIVER

This section is based largely upon analysis of Figure 2, which has been prepared from air-photograph interpretation and field work.

In the area roughly delimited by Separation Lake, Windless Lake and Steensby Inlet, the final movement of ice occurred toward the southwest and south. As yet, no relative age has been determined for the southeasterly flow already mentioned, evidence of which is restricted to the outer coast west of Windless Lake. In a local sense, both movements are presumably late-glacial. The trends of striations and other flow features range from due south near Cockburn Lake to west-southwest south of Separation Lake, thus suggesting that an arcuate flow pattern occurred over a distance of at least 20 miles. As the striations were all found on the tops of prominent hills, this flow pattern must have prevailed initially regardless of the topography. The strong relief (1,200 feet) and the pronounced system of valleys and gorges exerted appreciable control over ice flow at the lower levels. As the hilltops projected through the thinning inland ice, topographic control increased. During this later phase, extensive lateral and end-moraine systems were deposited, notably along the upper flanks of the Isortoq Valley and along the southeast side of Separation Lake. The latter system is especially important for the purpose of this discussion. It stretches almost continuously for 15 miles, rising more than 80 feet above the surrounding country and merging into a series of kame terraces and glacial drainage channels at the northern end of Windless Lake.

Below the Separation Lake moraine system, individual stretches of moraine occur, but glacial drainage channels and kame terraces increasingly predominate at the lower levels. The floor of the Separation Lake basin is occupied by massive kame terrace systems and glacio-fluvial deltas down to 230 feet above the present sea level. The lower terraces are pitted with kettle holes and the lake itself is a series of vast, interconnected kettles. The water level stands at 170 feet.

MARINE SUBMERGENCE IN STEENSBY INLET

The Rowley River flows from the southwest end of Separation Lake on its final 14 miles to Steensby Inlet and the sea. The main Separation Lake *sandur* parallels the river as a major body of pitted outwash ranging from half a mile to 2 miles in width. Its sands and gravels have been extensively terraced down to the existing river flood plain. The sequence comprises several glacio-fluvial and fluvial terraces graded to successively lower marine

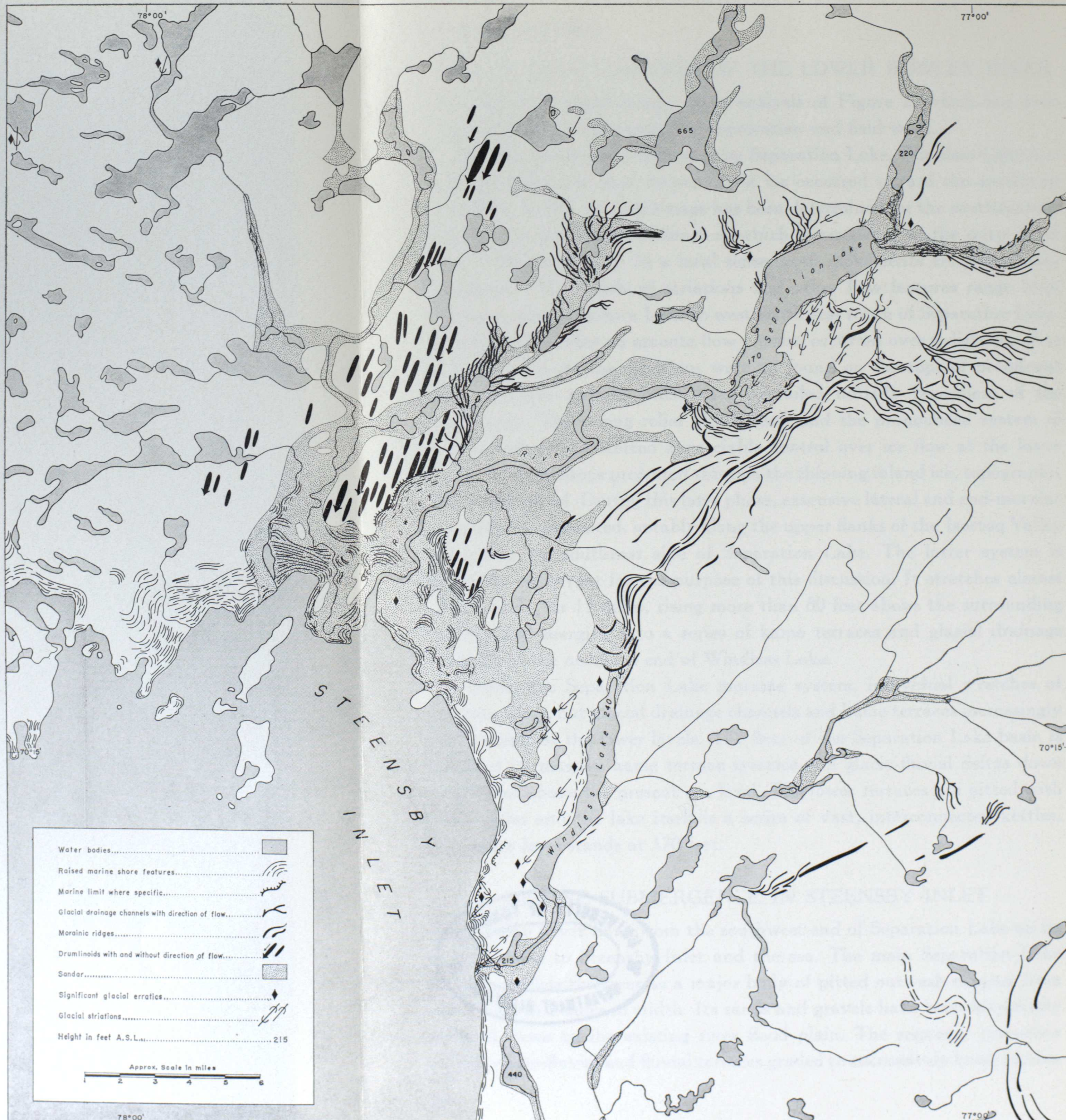

FIGURE 2. A detailed map of glacial geomorphology of northeastern Foxe Basin.

base levels. Within 5 miles of the sea, conspicuous marine terraces transect the middle and lower glacio-fluvial and fluvial terraces. The upper limit of marine action is most marked about 4 miles from the coast where a series of drumlinoids are abruptly truncated 175 feet above sea level. Below this series numerous marine shore features occur in bewildering abundance down to the present sea level. This is typical of the entire coastal zone of Steensby Inlet, but it is remarkable that evidence of marine submergence is not found on the lower Rowley terraces beyond the point 5 miles from its mouth. The main Separation Lake *sandur* is graded to a base level about the 175-foot level of marine submergence; and later, lower, terraces of glacio-fluvial origin are graded to levels between this and one about 80 feet above sea level. This is typical of the abundant glacio-fluvial and ice-contact features that occur in unmodified form down to levels well below the marine limit as representative of the outer coast.

As already stated, the marine limit in western Baffin Island ranges from 345 to 315 feet between Longstaff Bluff and Steensby Inlet. The 315-foot level of the Steensby Inlet area is related to the distinct lower limit of wave-washed ground moraine on the outer coast west of Windless Lake. It is the mean of six aneroid readings taken within 15 minutes of high-tide datum and is accurate within $\pm$ 5 feet. This range allows for instrumental error and possible solifluctional downhill creep of the wave-cut till face. The highest marine terraces were found at 295 feet above high-tide level, and prominent terraces at 95 to 110 feet and 65 to 75 feet. The lower of these two terraces is a pronounced constructional bench almost continuous along this section of the coast.

Marine molluscs, samples J.D.I. 61–3S and 61–4S, were collected at 180 and 70 feet in the same vicinity, the latter from the upper layers of the prominent marine bench. Their radiocarbon ages are respectively 5,750 $\pm$ 250 years and 4,700 $\pm$ 210 years.

The outflow from Windless Lake drains through a gap in the coastal cliffs and enters Steensby Inlet immediately south of the site used for determination of the marine limit. It cuts through the 65- to 75-foot terrace. Above it rises a series of fluvial and glacio-fluvial terraces that grade into marine terraces. Distinct kame terraces approach the coast and are graded to a datum well below the local marine limit of 315 feet. Precise levelling, however, is required before the relations between glacio-fluvial, fluvial and marine terraces can be fully determined.

Windless Lake lies 240 feet above sea level. Although it approaches to within $1\frac{1}{2}$ miles of the sea, no evidence of marine submergence was noted about its shores. It is concluded that glacier ice occupied the lake basin until the sea level had fallen, relative to the land, from 315 to at least 240 feet above its present level. The 315-foot marine limit was followed several miles northward along the coast, but there was not time to reach the Rowley River estuary, where the marine limit is only 175 feet. Thus, over a distance of less than 9 miles the marine limit falls 140 feet, whereas southward for a distance of about 100 miles there is a rise of no more than 30 feet. This rise can be accounted for by assuming that a straight line drawn between Windless Lake and Longstaff Bluff lies slightly oblique to the isobases or, alternatively, that Longstaff Bluff was deglaciated before the Windless Lake area. The difference of 30 feet in 100 miles is considered insignificant in the present context: that of 140 feet in 9 miles can be resolved only by assuming that glacier ice lay over the Rowley River estuary until the sea level had fallen from 315 to 175 feet. The assumption is supported by the persistence of the calving bay, the existence of which was indicated by independent evidence. During the final phases of ice withdrawal in the lower Rowley Valley and the basin of Separation Lake, marine incursion at the 175-foot level was restricted by glacier ice.

There is an alternative explanation of this disparity between the limits of marine submergence over a short distance. It is that complete withdrawal of the ice from the lower Rowley River basin permitting "normal" marine submergence to more than 300 feet could have been followed by a readvance of glacier tongues into Steensby Inlet. This readvance would form the lateral moraine systems and destroy the high-level marine features; final withdrawal of the ice tongues would result in submergence at the 175-foot level. The resulting landform assemblage, as understood at this reconnaissance level of study, would be the same. Detailed field work will be needed to solve this problem properly. For the purpose of the present paper, however, the major conclusion, that Baffin Island ice penetrated Foxe Basin tidewater well into postglacial time, would remain unchanged.

It now remains to discuss the significance of the five radiocarbon dates and to make the first approximate correlation between late-glacial and postglacial marine phases and deglaciation of the Steensby Inlet area.

RADIOCARBON DATES OF MARINE MOLLUSCS AND ISOSTATIC RECOVERY OF THE LAND

Five samples of marine molluscs, dated by radiocarbon methods, were collected by Dr. V. W. Sim and the writer. They range from 290 to 30 feet above the present high-water level.

Height above datum	Geographical Branch laboratory number	Locality	Age in years	Isotopes Incorporated laboratory number
1. 290 feet	V.W.S. 61–1S	Ikpik Bay	6,725 ± 250	I–406
2. 252 feet	V.W.S. 61–2S	Ikpik Bay	6,050 ± 250	I–405
3. 180 feet	J.D.I. 61–3S	Steensby Inlet	5,750 ± 250	I–486
4. 70 feet	J.D.I. 61–4S	Steensby Inlet	4,700 ± 210	I–487
5. 30 feet	V.W.S. 61–3S	Piling Lake	2,050 ± 170	I–489

To utilize all five dates in the construction of an uplift curve, it is assumed that the sites, despite a horizontal distance of 100 miles between them, lay along rather than across the local trend of the isobases. As actual isobases have not been drawn, specific strandlines not having been identified, the assumption* is based upon the general knowledge of the pattern of deglaciation and the supposition that maximum ice thickness was relatively uniform across the basin. Small discrepancies may arise from this method but they will probably be smaller than others associated with it. These other discrepancies are caused by the following:

1. Laboratory error in dating—There is only a 68-per-cent chance that a radiocarbon date will fall within the established range, and there is a 96-per-cent chance that it will fall within twice the range (Olsson and Blake, 1962).
2. Contamination of the molluscs.
3. The danger of redeposition of the shells.
4. The fact that different mollusc species and even individuals of the same species live in varying depths of water. Thus the sea level related to any date may have been appreciably higher than the actual height of

*Field work carried out in August 1963 has provided evidence in support of this assumption.

the mollusc. Because of this, the uplift curve must always lie above the graphed position of the mollusc (time versus altitude).

5. The fact that a variety of curves can be drawn through a series of five points and the point of origin. The provisional curve, however, is one of a number of possible curves that lie within a reasonably small range. The 290-foot sample, for instance, could not have lived in sea water deeper than 55 feet, as 345 feet is the local marine limit. The date 6,725 ± 250 is highly significant, therefore, because it gives a close approximation of the date of this limit.

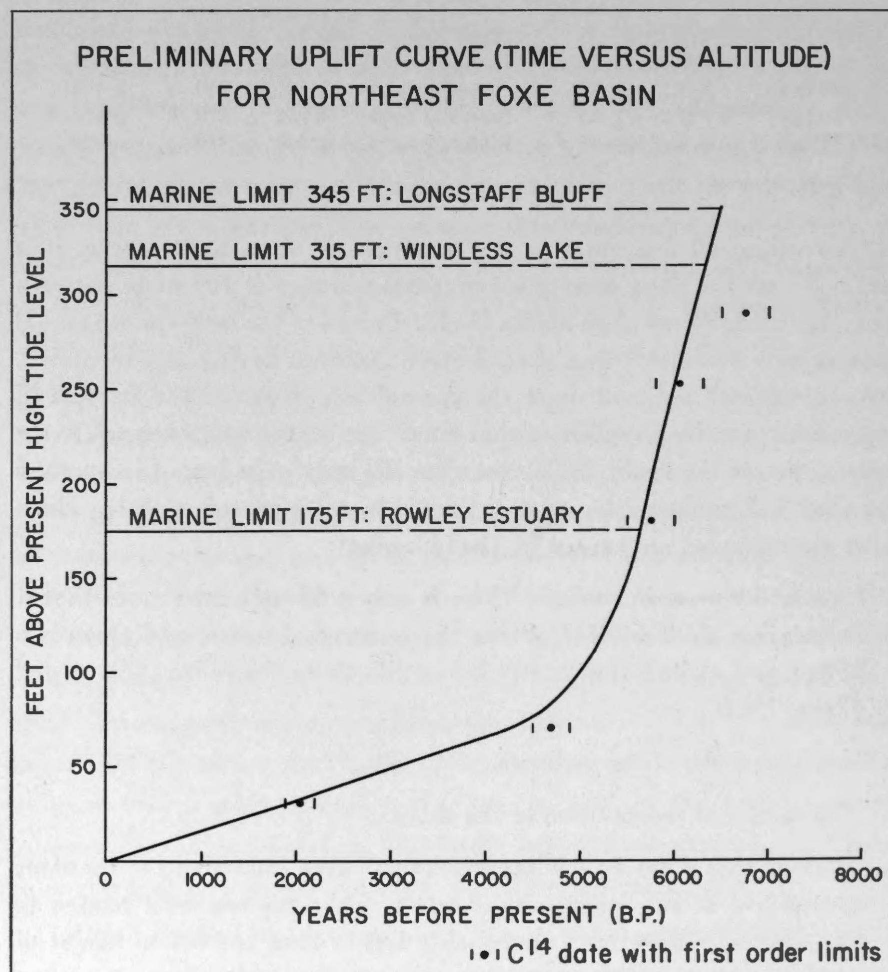

FIGURE 3. A provisional uplift curve.

The graph (Figure 3) indicates initial rapid uplift, between 6,700 and 5,000 years ago, and then much less rapid, although still steady, uplift to the present. It shows a rate of uplift of 1.5 feet a century over the past 4,000 years and suggests that uplift continues approximately at this rate today. Care must be taken not to use these figures too literally: more dates are required and the curve is only preliminary. An additional complication must be considered: Løken has established the occurrence of a postglacial marine transgression of some 50 feet in northern Labrador (Løken, 1962). This he tentatively equates with the Tapes transgressions of Scandinavia. Fragmentary evidence from localities as far afield as Sugluk, New Quebec and northern Baffin Island imply that Løken's Labrador transgression may have affected a wide area of the eastern Arctic. While this cannot be postulated without much more definite field evidence, the possibility must be entertained, specifically because a hypothetical transgression of about 50 feet would appreciably affect the rates of uplift as calculated from the foregoing data.

Taken in conjunction with the geomorphological data, and particularly in conjunction with the knowledge of the glacial and marine features, the series of dates does permit several general conclusions. First, the Baffin Island inland ice withdrew from sections of the outer Foxe Basin coast about 6,700 years ago. At that time it probably calved into a sea that stood 315 to 345 feet above its present level. Ice filled all the major valleys to within a mile or so of the present coast, namely, the valleys now occupied by Isortoq, Windless, Gillian and Flint lakes. It also covered the present site of the Rowley River estuary and the northern half of Steensby Inlet. This is highly significant, for the Keewatin and Labrador–Ungava final centres of glacier ice were completely deglaciated between 6,500 and 7,000 years ago (Lee, 1959; Ives, 1959; Grayson, 1956). A more tentative conclusion is that ice lay within 5 miles of the Rowley River mouth about 5,700 years ago. The final deglaciation of the basins of Separation, Isortoq and Gillian lakes may have occurred as recently as 5,000 years ago.

REGIONAL SIGNIFICANCE OF THE RESULTS

The generally low marine limit for the coast from Longstaff Bluff to Steensby Inlet (315 to 345 feet) is explained by assuming that it was deglaciated later than the coasts of Melville Peninsula and Hudson Bay and Strait. While the general form of the uplift curve is comparable to those constructed for other parts of northern Canada and Greenland (Lee, 1960; Farrand and Gajda, 1962; Farrand, 1962; Washburn, 1962), it is somewhat displaced in time. Thus deglaciation of the outer coast about 6,700 years ago actually occurred in postglacial time (if the term "postgalcial" is used in its application to North America as a whole). Final deglaciation of the lower valleys probably did not occur until as recently as 5,000 years ago. Thus a major ice cap persisted in Baffin Island during the Thermal Maximum, when the general area of glacier ice in the better-known parts of the world was smaller than it is today. Another important point is that the delay in deglaciation appears, as the uplift curve suggests, to have retarded the process of isostatic recovery of the land. It seems likely that the delay in isostatic recovery has been protracted to the present; if it can be substantiated that a minimum of 30 feet of uplift has occurred in the past 2,000 years (sample VWS 61–3S), a continued uplift of 1.5 feet a century may be expected. A comparison may be drawn with the Hudson Bay area, where uplift of the same order of magnitude may be occurring today (Lee, 1960; Fyles, personal communication).

In conclusion, it is stressed that the interrelations of glacial and marine phases in northeastern Foxe Basin are complex. Their preliminary examination has yielded significant results and has suggested the need for a precise levelling program.

ACKNOWLEDGMENTS

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TERRAIN ANALYSIS OF WEST-CENTRAL BAFFIN ISLAND, N.W.T.

*V. W. Sim**

ABSTRACT: Air-photograph interpretation and field work done in 1961 have been combined to provide a descriptive appraisal of terrain conditions in an area of west-central Baffin Island represented on the 1:500,000 Foxe Basin North map sheet. Geomorphic features and surface conditions have been mapped and are described in the text, which is illustrated by two large maps (Maps 1 and 2) at a scale of 1:500,000. The area is divided into five physiographic regions, each of which is described in some detail. The final subsection gives an outline of the extent of postglacial marine submergence and some of the research problems associated with the analysis of subsequent emergence of the land.

RÉSUMÉ: L'interprétation de photos aériennes et les travaux exécutés sur le terrain en 1961 ont été coordonnés pour fournir une analyse critique des conditions du terrain dans le secteur Ouest de la région Centrale de l'île Baffin, représentée sur la feuille Foxe Basin North, au 500,000^{e}. Les traits géomorphiques et les conditions en surface sont décrits dans le texte, qu'accompagnent deux grandes cartes (cartes 1 et 2) dressées au 500,000^{e}. L'auteur a divisé l'aire à l'étude en cinq régions physiographiques, dont chacune est décrite en détail. La dernière partie du texte traite de l'importance de la submersion marine postglaciaire et de certains des problèmes que pose l'analyse de l'émersion subséquente de la croûte terrestre.

INTRODUCTION

During the summer field season of 1961 the Geographical Branch began a long-term study of the physical geography of central Baffin Island (Ives, 1962). A preliminary report with maps covering the Cockburn Land 1:500,000 map sheet (Ives and Andrews, 1963) has already presented an analysis of field and air-photograph data and has established a tentative chronology of deglaciation. The study was concentrated on the northern section of the project area, although the general conclusions refer to the entire central Baffin Island–Foxe Basin region. The present paper, which concerns the Foxe Basin North 1:500,000 map-sheet area, is a companion study. Although less detailed, it shows the distribution of glacial landforms and provides an outline of the physical geography. The map-sheet area is divided into physiographic regions and a description of each is given.

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*Dr. Sim completed this work while a member of the Geographical Branch. He is currently assistant professor of geography at the University of Western Ontario.

Previous work within the area has been extremely limited. In the late 1930's an expedition led by T. H. Manning completed the primary exploration of the coastal sector between Steensby Inlet and Piling Bay. Manning again visited the area as leader of the Geographical Branch "Nauja" expedition in 1949 and made the first landfalls on the newly discovered Air Force and Prince Charles islands (Fraser, 1953). In 1950 the Baffin Island Expedition of the Arctic Institute of North America undertook extensive glaciological, geological and geomorphological work over an area lying on, and adjacent to, the southern lobe of the Barnes Ice Cap and overlapping the northeast corner of the Foxe Basin North map sheet. Finally, the Research and Development Corporation (Rand) of the United States contracted out to the Geography Department, McGill University, the job of compiling the physical geography of central Baffin Island on the basis of air-photograph interpretation and existing sources (Rand, 1962).

Detailed geographical studies are entirely lacking, and the lack is emphasized by the considerable disagreement between the physiographic breakdown of this paper and that of the Rand report of 1962. Some of these differences are brought out in the latter half of this text.

PHYSICAL SETTING

The Foxe Basin North map sheet covers the western part of the "waist" of Baffin Island and includes most of the islands in northern Foxe Basin. Only two of the four major physiographic provinces of central Baffin Island lie within the map area. The mainland section of the map area, together with North and South Tweedsmuir and Anderson islands, falls within the Baffin uplands province. Baird Peninsula, the area in the vicinity of Cape Thalbitzer, and the remaining islands are part of the Foxe Basin lowlands.

The interior uplands are characterized by broadly rolling terrain at elevations ranging from 500 feet near the Foxe Basin coast to about 2,000 feet near the Barnes Ice Cap. Although much of the area, particularly south of Flyway Lake and around the present margin of the ice cap, has a broadly rolling appearance, the local relief may reach 500 to 1,000 feet. The surfaces of Gillian Lake and Flint Lake, for example, which lie less than 200 feet above the present sea level, are surrounded by hills rising to 800 feet. All of this physiographic province is underlain by a complex of Precambrian granite-gneiss rock that has not yet been mapped. Metamorphosed Precambrian sediments have been identified, however, in the vicinity of Longstaff Bluff and can be traced, with interruption, eastward across Baffin

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Island south of the Barnes Ice Cap. The strong east-west lineation, which gives a characteristic topographic pattern, differentiates this area from the gneissic area to the north. In the north a subparallel drainage system extends in a northeast-southwest direction between the margin of the ice cap and the Foxe Basin shore. South of 69°N the drainage system is poorly integrated in an area of lower elevation and smaller relative relief. Anderson Island and North and South Tweedsmuir islands, lying across Clarke Sound from the mainland, rise to maximum elevations of between 350 and 400 feet and are similar in appearance to the mainland.

A geologic and topographic break constitutes the boundary between the interior uplands and the Foxe Basin lowlands. The contact between the Precambrian crystalline rocks and the horizontally bedded Palaeozoic sedimentary strata extends across the base of Baird Peninsula east of Ipiutik Lake, while around the east shore of Ikpik Bay and northeast of Tikerarsuk Point it probably lies beneath superficial glacial and marine deposits. Elsewhere the contact lies beneath the waters of Foxe Basin, and the boundary of the province is formed by the present shoreline. Topographically, the boundary extends along the line of an irregular scarp of variable height, which roughly follows the Foxe Basin coast. The scarp is most clearly apparent where it rises to more than 600 feet along the shore of Rushmore Bay north of Longstaff Bluff and around the east shore of Ikpik Bay. It is also visible on the east shore of Steensby Inlet north of Cape Jensen. The structural history of this scarp remains to be determined.

The Foxe Basin lowlands are characterized by low, flat terrain underlain largely by limestone and dolomite of Ordovician and Silurian age. Outcrops of Precambrian crystalline rocks have been reported, however, on Foley Island and on Fee Peninsula of Air Force Island. Outcrops are rare, since most of the area is covered by superficial glacial materials reworked during postglacial submergence. Elevations are generally low. Most of Baird Peninsula and the islands in the basin are less than 80 feet in height. Bray Island does not generally exceed 40 feet. Local maximum elevations reach 280 feet on Foley Island (Anderson Bluff), 135 feet on Rowley Island and 190 feet on Prince Charles Island. In general, the lowland terrain is monotonously flat and the poorly established drainage pattern consists of numerous, irregularly shaped lakes, frequent marshy areas and shallow stream channels that carry water for only a brief period in the spring.

TERRAIN-ANALYSIS MAPS

Map compilation

Air-photograph interpretation of the area covered by the Foxe Basin North map sheet (National Topographic Series at a scale of 1:500,000), coupled with reconnaissance field checks made during the 1961 field season has made possible the publication of the two accompanying terrain-analysis maps (Maps 1 and 2, in pocket). They show the distribution and pattern of glacial landforms and surface materials in this area of central Baffin Island.

Preliminary air-photograph interpretation and plotting at the published scale were carried out during the spring of 1961. At that time the available vertical photograph coverage was not of uniform quality. Photographs taken from an altitude of 30,000 feet during the summers of 1958 and 1960 often showed a considerable snow cover, which amounted in some cases to as much as 70 per cent. Coverage was particularly poor in the southern map area and east of Steensby Inlet.

During July 1961, most of the northern mainland portion of the map area was re-photographed. The excellent quality obtained prompted the complete re-interpretation of the map area and a new compilation at the scale of 1:250,000.

Field checks on the terrain interpretation were limited to only a small area of the map sheet. They were sufficient, however, to establish confidence in the mapping at the published scale. Comparatively detailed field examination was made of the Foxe Basin coast and adjacent inland area between Longstaff Bluff and Tikerarsuk Point and in the area north and west of Bravo Lake. Brief examinations were made near the lower end of Flint Lake and in an area just off the east edge of the map sheet. Flights over more northern areas provided opportunity for only brief aerial examination.

Map of glacial features (Map 1)

End moraines

End moraines are neither as well developed nor as numerous on the Foxe Basin North map sheet as they are on the Cockburn Land sheet. They occur most commonly in the northeast corner within a few miles of the present margin of the Barnes Ice Cap. They are particularly prominent on the interior upland surface between the headwaters of the Drewry and

MacDonald rivers and northwest of Flyway Lake, where a clearly defined arcuate ridge is separated from the present margin of the ice cap by a broad belt of hummocky ground moraine.

The western margin of the Barnes Ice Cap from 69° 40' N to the northern edge of the map is defined by a particularly prominent sharp-crested morainic ridge. Although not examined on the ground, this ridge is no doubt similar to those examined by Goldthwait (1951) and is ice-cored. Østrem has shown that much of the ice core is not composed of glacier ice but represents the recrystallization of former linear proglacial snowbanks (Østrem, personal communication).

End moraines occur less commonly in other areas; north-south-trending linear ridges north of Grant-Suttie Bay appear to be parts of an end-moraine system. In two places on the western flank of this system a number of small, sinuous marginal drainage channels are visible.

End moraines are virtually absent south of 69°N and on the low islands in Foxe Basin. A system of small morainic ridges has been plotted east of Straits Bay in latitude 69° 34' N. Two small areas of minor subparallel moraines in series have been plotted south of Piling Bay and on the shore east of Clarke Sound. As neither area was examined in the field, it is not known whether they are comparable to the De Geer moraines described by Mawdsley (1936) and Hoppe (1959).

The morainic ridges adjacent to the Barnes Ice Cap extend into the area covered by the Cockburn Land sheet. Their relation to the Cockburn end-moraine system is not yet clear (Ives and Andrews, 1963).

Glacial flow features

Extensive areas of obvious glacial flow features are uncommon on the map sheet. As they are usually found singly or in small groups, air-photograph interpretation is difficult. It was usually difficult, moreover, to determine the direction of glacial flow at the time of their formation. True drumlins do not occur in the map area. Glacially fluted till ridges and elongated till hills are sparsely distributed, however, over the mainland portion, and glacial lineation is faintly visible on Bray Island.

From 10 to 15 miles east of Piling Bay a number of linear drumlinoid features have been plotted. While they vary in length and width, they are generally low and short. Occasionally they are difficult to distinguish from short segments of terminal moraine, and it is not possible to determine the direction of ice movement from them.

Ice-moulded drift-forms occur in small numbers south of Gillian Lake and occasionally in other widely separated areas. They are a minor landscape feature and are never so well developed as, for example, on Melville Peninsula. A small area of drumlinoids a few miles from the western edge of the Barnes Ice Cap (latitude 69° 58' N, longitude 74° 35' W) is a southward extension of similar linear features shown on the Cockburn Land map sheet; their form indicates ice movement to the northeast.

Roches moutonnées and rock drumlins occur within the area of the map sheet but are not abundant. In general, such ice-scoured forms have a roughly northeast-southwest orientation. Some of the larger features of this type may have been formed by ice moving from southwest to northeast. A particularly large rock drumlin on the west side of Bravo Lake trends east-west and has a gentle sloping ice-scoured slope toward the west and a rough, plucked face to the east.

Air photographs of central Bray Island reveal an interesting linear pattern trending northeast-southwest. The pattern is composed of low, short ridges of unconsolidated materials that were modified by marine processes during emergence. The individual features are so small that they would probably escape detection on the ground. In the air photographs it is only their cumulative effect that makes them apparent. Although most occur on the land surface, some are visible as grey-toned features on the bottoms of the ponds.

Striations and grooves

Information on striations and grooves is naturally restricted by the pattern of the field work. Observations in addition to those of 1961 were made in the western sector by J. D. Ives and G. Østrem in 1962 and 1963. In general, the striations are oriented in a northeast-southwest direction, roughly parallel to the direction of the *roches moutonnées* and rock drumlins.

Limestone erratics

Erratics of limestone and dolomite were found widely distributed across the mainland area (Figure 1). These light-toned boulders stand out in contrast to the Precambrian granites and gneisses that normally compose the ground moraine. Similar erratics were found across the "waist" of the island as far east as Home Bay.

Limestone boulders were discovered above the limit of marine submergence—apparently as a constituent of the ground moraine—at Longstaff Bluff and the base of Baird Peninsula and northeast of Tikerarsuk Point.

They are also common north of Bravo Lake. Their origin is of considerable importance in understanding the deglaciation of the island. Two sources are possible: one lies in northwestern Baffin Island where Palaeozoic limestone occurs over a wide area between Brodeur Peninsula and the west side of Steensby Inlet; the second is in Foxe Basin.

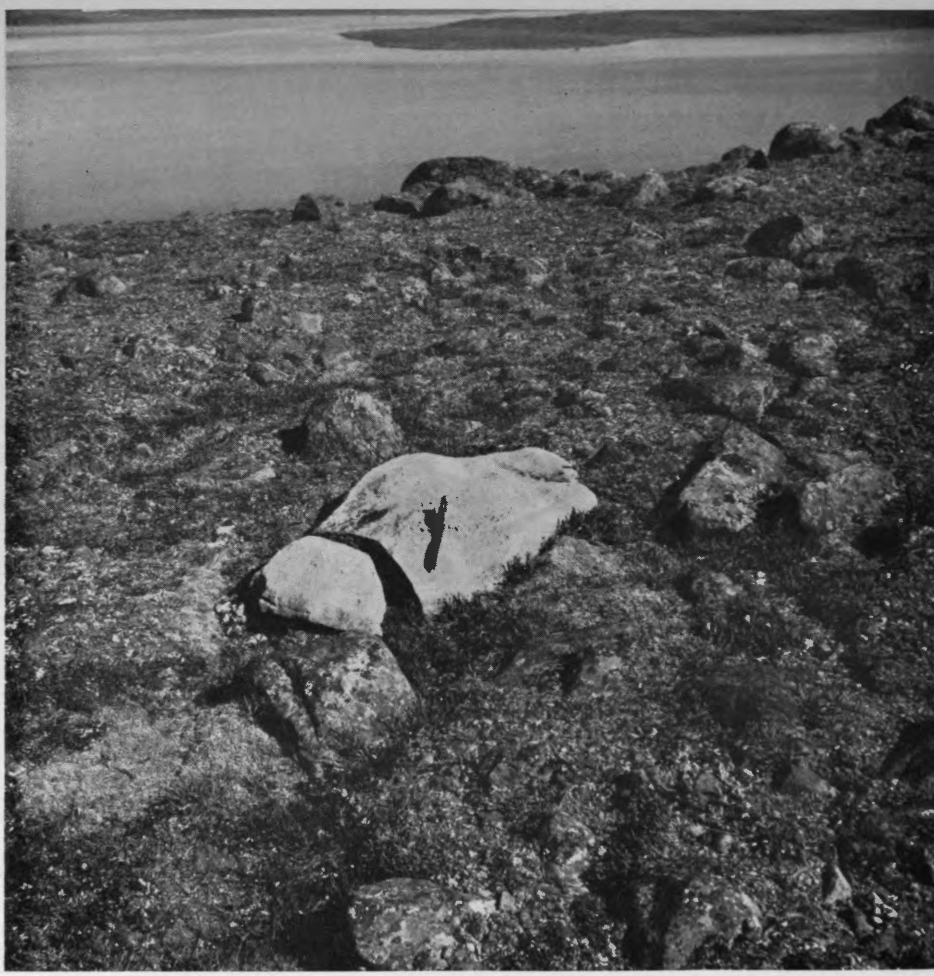

FIGURE 1. A limestone erratic on ground moraine near Foxe Basin. Similar limestone blocks occur throughout central Baffin Island. Photo: VWS 1961-21-8 (July 25).

Limestone boulders are common below the marine limit on the western Baffin Island coast. They were frequently noted, for example, around the shores of Ikpik Bay and on Baird Peninsula but may be the result of ice-rafting that occurred during the period of late-glacial marine submergence. Above the marine limit, however, the only likely mechanism for transport over long distances is glacial. In the absence of any evidence of southeastward glacial movement from northern Baffin Island, it is concluded that the boulders were transported from Foxe Basin by ice moving eastward and northeastward onto the mainland. This movement probably took place at an early phase of the Wisconsin glaciation, possibly at the time of the Clyde phase (Ives and Andrews, 1963, page 40). It is unfortunate, however, that the limestone boulders discovered on the mainland are unfossiliferous and so cannot be directly related to the bedrock in Foxe Basin.

Glacio-fluvial deposits

Glacio-fluvial deposits form one of the most extensive landscape elements on the map sheet (Map 2). Two types have been plotted. The most widespread are the extensive *sandar* (outwash and valley train) that occupy all the major valleys between the Barnes Ice Cap and the Foxe Basin coast. These deposits are most common north of 69°N and range in appearance from extensive areas of glacio-fluvial sand and gravel in the large valleys to discontinuous, hummocky accumulations in the tributary valleys. They are also common as discontinuous deposits in fracture valleys. Eskers are the second main glacio-fluvial feature plotted. Although widely distributed over the map sheet, they are generally short and inconspicuous.

Outwash deposits are particularly large along the course of the Drewry River, which drains into the northeast arm of Gillian Lake, and along the MacDonald River, which drains into the east arm of the same lake. Deposits of a similar type extend along the Flint River to the eastern end of Flint Lake. Other glacio-fluvial deposits—for example, those northwest of the Drewry River and along the streams draining into Grant-Suttie and Eqe bays—begin abruptly in the upper reaches of the valleys and extend to the present sea level. Finally, large amounts of glacio-fluvial materials occur in the form of perched deltas close to the limit of postglacial marine submergence around the shores of Ikpik Bay. These deltas have been graded to a sea level up to 340 feet higher than the present. Outwash deposits occur much less frequently in the southern part of the area. Here, too, the materials are more nearly oriented in an east-west direction.

All the plotted glacio-fluvial deposits are various forms having the same generic origin. They were deposited under a variety of conditions, and their quantity and precise nature depend upon the topography at the ice margin at the time of their deposition.

FIGURE 2. The outwash deposits at the lower end of Lake Gillian. Note the absence of outwash gravel or features of marine submergence within the lake basin. A prominent ice-contact face is indicated near the lake outlet. Photo: RCAF vertical A 16040-26.

During a late phase of ice recession in western Baffin Island the regional ice divide shifted northeastward from a position over central Foxe Basin to within a few miles of the Barnes Ice Cap. After this shift (the Cockburn II phase of Ives and Andrews), much of Foxe Basin probably became ice-free, and the ice remaining over western Baffin Island thinned rapidly. Ice was probably thickest in the main preglacial valleys leading southwest toward Foxe Basin and thinnest over the plateau surface. It is suggested that still later the remaining ice cover was in the form of ice tongues or lobes within the main valleys while the intervening plateau surface was at least partially ice-free.

While the ice margin lay close to the present Foxe Basin coast, the sea level was more than 300 feet higher than at present. Glacial drainage was directed southwestward into the high-level Foxe Basin and the meltwater was probably concentrated in the main preglacial river valleys. The melt streams carried a heavy load of glacio-fluvial material and deposited much of it at the ice margin. This outwash often graded downstream to a delta at the higher sea level. Several outwash deltas on the east coast of Ikpik Bay and northeast of Tikerarsuk Point have been plotted. In particular, the large area of sand and gravel between Gillian Lake and Ikpik Bay is a feature of this type. At the time of its formation and that of similar nearby features, the ice margin lay close to tidewater.

At the same time, subglacial meltwater was depositing glacio-fluvial sand and gravel in many of the smaller valleys and depressions near the ice margin. Some of these deposits formed well-developed eskers. Often, however, the glacial drainage occupied a particular channel for only a short time: the eskers are short and the gravels are discontinuous. This is probably a reflection of the dissected, irregular topography of the upland, where Precambrian bedrock is frequently cut into blocks separated by short, linear, fracture depressions.

With continued melting, ice gradually disappeared from the plateau surface and became concentrated in the larger lake basins and river valleys. In particular, ice tongues probably lay along the valley of the Isortoq River (of which only the lower portion appears on the map sheet) and in the Gillian Lake and Flint Lake depressions. As marginal retreat continued, glacial melt streams deposited sand and gravel in lakes, which were impounded in the lower, ice-free parts of the basins.

Occasional ice-marginal positions in the lake basins can be interpreted from air photographs. Midway along the north arm of Gillian Lake, for example, a mass of outwash almost completely blocks the basin. On the surface of this material are numerous dry channels and two water-filled kettle holes, one of which has been breached by the waters of the present lake. On the northern side, the material appears to be steeply sloping and has a scalloped outline suggestive of an ice-contact face. It seems probable that an ice tongue lay upstream from the ice-contact face while the outwash was being deposited.

Finally, the ice margins retreated east of the lake basins and the outwash material was deposited on the valley floors. With this retreat, the ice edge once again assumed the character of a continuous front extending from northwest to southeast parallel with the southwest margin of the Barnes Ice Cap.

Glacial drainage channels

Glacial drainage channels are common in the northeastern area and occupy a belt 20 to 30 miles wide around the margin of the Barnes Ice Cap. Few channels occur west of 76°W. Almost all are situated north of 69° 20' N and are found only in restricted areas. With few exceptions, channels are found on the valley sides of the Drewry, MacDonald and Flint rivers and in association with some of the tributaries of these rivers. Some also occur along the valley sides of a smaller southeast-flowing stream at 69° 00' N, 73° 00' W.

Although it has not yet been possible to examine the channels in the field, it is known that such channels, where they have been described for other areas (Mannerfelt, 1945; Hoppe, 1957; Ives, 1959), form during deglaciation when quantities of meltwater drain from the ice in marginal, submarginal and subglacial courses. Many of the channels in the field area, particularly those that are deep, well-formed and isolated, may have carried meltwater directly away from the ice margin. Such channels usually run directly down the slope of the valley sides or across the interfluves. They are common west of Flyway Lake and on the valley sides of the Flint River.

True glacial drainage channels occur across the field area in all stages of development and in many combinations. They often occur singly as shallow depressions trending obliquely downslope, or as well-developed flights of anastomosing channels. What appear to be marginal channels are occasionally found on the upper valley sides above a zone of apparently undisturbed ground moraine.

An examination of the distribution of the channels suggests that they were formed in association with ice tongues in the upper valleys of the Drewry, MacDonald and Flint rivers. Channels in the upper reaches of the MacDonald River appear to be freshly cut, and some are forming close to the present ice margin. It is possible, however, that most of them formed close to a retreating ice front similar to, but south and west of, the present margin of the Barnes Ice Cap.

Raised marine shore features

Baird Peninsula, the islands in Foxe Basin, the coastal area of Baffin Island between Tikerarsuk Point and the mouth of Eqe Bay, and the small area of Baffin Island in the northwestern corner of the map sheet, are all underlain by Palaeozoic rocks composed of flat-lying and comparatively thin-bedded limestones and dolomites. In most parts of this low, flat region the bedrock is covered by a thin mantle of shattered limestone rubble. All of the lowland was submerged in late-glacial and immediate postglacial time,

FIGURE 3. Contact between undisturbed ground moraine to the left and reworked glacial gravel on the right, near Foxe Basin. Photo: VWS 1961-24-10 (July 27).

when most of the surface features that are apparent today were formed (Figure 3). Shallow ponds occur frequently and the most common landforms on the lowland are the linear, embankment-like ridges that extend throughout the area.

These ridges have been identified and plotted as emerged offshore bars. They are broad-based limestone-rubble ridges that seldom rise more than 20 feet in height. They occur in parallel belts separated from each other by intervening depressions, which may be occupied by shallow ponds. These ridges formed in shallow water as submerged offshore bars and were raised above sea level during the postglacial land emergence. Many of them, in emerging, impounded shallow, brackish lagoons, a few of which are preserved on the surface today as broad, flat, poorly drained marshes. Lagoons partially enclosed by offshore bars can be seen in air photographs of the present coastal areas.

Simple raised beaches are widely distributed in the map area. They occur near the marine limit around the shore of Ikpik Bay and at the heads of small coves in Grant-Suttie Bay. They are particularly common in the vicinity of Longstaff Bluff. The scale of the map has made it possible to show only a small part of the total number.

On the Baffin Island section of the lowland in the northwestern corner of the map sheet there are a number of "chevron" ridges. These are similar to offshore bars but trend down the coastal slope at right angles to the contours. Associated with the trunk bar and joining it at acute angles are numerous shorter, curved tributary bars; a glacio-fluvial origin is suggested. The trunk bars are possibly eskers or crevasse fillings later modified by shore processes during emergence.

Oriented ponds

A small number of oriented ponds exist on Prince Charles Island. They are shallow, oval-shaped and oriented with their long axes in a northeast-southwest direction and are up to half a mile in length and 1,000 feet in width. They occur singly or as coalescing pairs and are similar to oriented lakes near Point Barrow, on the Arctic coastal plain of Alaska. Similar features are found on the Great Plain of the Koukdjuak (Baffin Island) and in the Mackenzie Delta region; these have been discussed by Mackay (1956), who suggests that they may be oriented in the direction of the prevailing wind.

High-level lake shorelines

Shorelines above the present lake level are found around Blanchfield Lake, which borders the Barnes Ice Cap in longitude 73°W. They are clearly apparent in the air photographs and mark water levels a few tens of feet above the present lake surface. Similar features have been mapped by Ives and Andrews on the Cockburn Land sheet. Shorelines are also apparent in the northeasternmost corner of the map-sheet area.

Cross-valley moraines

In the area northeast of the ice cap are found a number of features that are well developed on the Cockburn Land map sheet but of limited occurrence on the Foxe Basin North sheet. These are the cross-valley moraines described by Andrews (1963, a and b).

Map of surface materials (Map 2)

The surface materials plotted on this map are in six main categories, which are described briefly in subsequent paragraphs. The use of three of them requires some explanation of their distinguishing criteria. The "mainly bare crystalline rock" category was plotted wherever the Precambrian granite and gneiss formed more than 75 per cent of the surface area. "Mainly glacial till" was applied wherever more than 75 per cent of the surface consisted of till. "Mixture of glacial till and crystalline rock" was used as the transitional category between these two extremes. The category into which any area fell was subjectively determined during the preparation of the map from air photographs.

Mainly bare crystalline rock

Areas of this type occupy about 25 per cent of the mainland part of the map sheet. They occur as rocky plateau surfaces broken into hill units by joint and fracture lines or as low rolling hills separated by fracture depressions.

Such areas usually occur on the mainland where the Precambrian granite and gneiss underlie the interior upland. They are found around the basins of Flint and Gillian lakes and inland from Grant-Suttie and Eqe bays. Bare crystalline rock occurs much less commonly in the southern mainland area of the map, where it is restricted largely to the vicinity of Straits and Wordie bays. Areas of crystalline rock are also found on Anderson and South Tweedsmuir islands and on Fee Peninsula of Air Force Island.

Although glacial drift does occur within these crystalline-rock areas, it is never of such quantity or distribution as to obscure the essentially rocky nature of the landscape.

Mainly bare sedimentary rock

Although sedimentary rocks almost entirely underlie Baird Peninsula and the islands in Foxe Basin, they seldom outcrop over any considerable area. This surface type is restricted to a few small areas in the northern interior of Prince Charles Island. Elsewhere the sedimentary rocks are masked by superficial material that is largely of glacial origin that has been modified by marine action.

Mixture of glacial till and crystalline rock

Areas falling within this classification have a surface cover in which neither bare crystalline rock nor glacial till is sufficiently common to dominate the appearance of the photograph. It is estimated that about 34 per cent of the mainland area of the map is included in this category. In general the till cover, where it occurs, is thin and discontinuous and rock outcrops are frequent. Hills are often topped by areas of bare rock while their slopes are till-covered. In some areas—for example, east of Wordie Bay—the terrain is a rolling till plain from which frequent Precambrian rocky hills project.

The mixed category is widely distributed over the map sheet. It is most common south of Flint Lake. Major areas also occur between the MacDonald and Flint rivers and inland from Baird Peninsula and Tikerarsuk Point but are less common north of Gillian Lake, where bare crystalline rock predominates.

Mainly glacial till

Areas in which the surface material is predominantly glacial till cover some 20 per cent of the mainland section and are largely restricted to the interior. Extensive stretches of till-covered upland occur in a belt varying in width from 2 to 10 miles around the present margin of the Barnes Ice Cap. There is a second extensive area south of Flyway Lake. In both areas the till almost completely obscures the underlying bedrock. In the southern, erosional processes seem to have modified the till relatively little since its deposition. More extensively dissected drift cover is found north of Bravo Lake and east of Piling Bay.

The constituent material of the glacial till varies considerably within the map sheet. The belt around the present margin of the ice cap is extremely coarse-textured and large boulders predominate. In the vicinity of Blanchfield Lake, for example, the boulders are subangular and, over wide areas, range from 6 inches to 2 feet in diameter. Wheeled or tracked vehicles would have great difficulty on this terrain, and even foot travel is often extremely difficult. In contrast, the till south of Flyway Lake and in the vicinity of Bravo Lake is of a much finer texture. The boulders are smaller, and the proportion of fines is much higher.

Sand and gravel

The sand and gravel plotted on the map sheet are almost entirely of glaciofluvial origin and cover the same area as the *sandar* plotted on the map of glacial features and described in an earlier section. They are found almost exclusively in the river valleys in the northern parts of the map area. The perched outwash deltas along the shore of Ikpik Bay are particularly prominent.

Unconsolidated surface materials modified by marine submergence

Surface material, usually glacial drift, modified by marine processes is restricted to the islands in Foxe Basin and to parts of the mainland below the marine limit. This category covers approximately 7 per cent of the mainland area of the map sheet. Its greatest extension inland occurs in the vicinity of Bravo Lake, east of Straits Bay.

Surface material on the low islands in Foxe Basin consists of silt mixed with glacial drift and weathered sedimentary-rock fragments. Former marine beaches and bars are common landforms on the lowland. East of Straits and Wordie bays, silt flats between the low Precambrian hills are carpeted in summer with cotton grass.

Physiographic regions

Examination of recent air photographs, combined with reconnaissance field checks, has made it possible to divide the Foxe Basin North map sheet into five physiographic regions. One of these lies within the Foxe Basin lowland physiographic province while the other four are contained within the Baffin uplands. The classification of the physiographic regions appears in the table. It differs considerably from the regional classification included in the Rand report of central Baffin Island (Rand, 1962, pages 87–227).

Physiographic Regions

Province	Region
A. Foxe Basin lowland	1. Foxe Basin islands and peninsulas
B. Baffin uplands	2. Gillian Hills
	3. Barnes Plateau
	4. Piling Ridges
	5. Wordie Hills

1. *Foxe Basin islands and peninsulas*

This region is almost entirely restricted to the islands in Foxe Basin (Figure 4). Baird Peninsula, the southern extremity of Thalbitzer Peninsula, in the northwest corner of the map sheet, and a narrow coastal belt east and north of Ikpik Bay are the only mainland areas included.

The region is one of low relief underlain by relatively flat-lying Palaeozoic limestones and dolomites. No part of the area rises more than 300 feet above sea level and most of the surface is below 100 feet. The present drainage pattern is poorly integrated, and much of the surface is covered with shallow ponds and broad marshy depressions. Rock outcrops are infrequent though limestone partially masked by angular rock fragments has been mapped in north-central Prince Charles Island and low limestone scarps occur at sea level around the coasts of Baird Peninsula.

The islands and peninsulas were veneered with thin deposits of till during glaciation and submerged and modified during the subsequent marine transgression. Isostatic recovery has only recently raised them above sea level, and the surface bears the marks of marine action. Emerged offshore bars composed of the coarser fractions of till are characteristic features of the terrain. They are particularly well developed on Rowley Island and Bray Island.

The narrow coastal belt extending north from the base of Baird Peninsula to the mouth of Eqe Bay forms the easternmost limit of this region. Its terrain is similar in all essentials to that of the offshore islands. Raised marine bars composed of sedimentary-rock fragments separated by sparsely vegetated depressions and shallow ponds are characteristic surface features. Within a short distance of the shore, the land rises to the Baffin uplands through a low scarp-like transition zone often masked by perched outwash deltas. It seems probable that this coastal lowland is underlain by Palaeozoic limestone similar to that which occurs on the offshore islands.

FIGURE 4. A lineation pattern in reworked glacial drift on Bray Island in the Foxe Basin lowland province. Individual features are short and low, and it is only the cumulative effect that reveals the northeast-southwest pattern. Note the raised marine beaches to the left centre and above the right centre. Photo: RCAF oblique T222 L9.

The Rand report (Rand, 1962, page 95) groups Thalbitzer Peninsula, Rowley Island and the eastern sedimentary portion of Jens Munk Island as a distinct subdivision of the Foxe Basin lowland, primarily on the basis of greater topographic prominence. Thalbitzer Peninsula and eastern Jens Munk Island reach maximum elevations of 300 feet and 100 feet respec-

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tively. Rowley Island has a maximum elevation of 135 feet, attained in a number of its mesa-like features. In spite of this slightly greater height, these areas are similar in all other respects to the rest of the region, and there seems to be no justification for subdividing it.

2. *Gillian Hills*

Examination of air photographs taken in 1961 indicates that physiographic differences throughout this region are not sufficient to warrant subdivision (Figure 5). In the west, hills of Precambrian rock rise steeply to heights of 800 to 900 feet around the irregular shores of Grant-Suttie and Eqe bays and on the east coast of Steensby Inlet. East of Ikpik Bay the regional boundary is formed by the low and, in places, poorly defined scarp that drops to the narrow lowland described in the previous section. The southern boundary is sharply defined over most of its length by the northern limit of a zone of pronounced topographical and geological lineation—the Piling Ridges. This break is probably a physiographic reflection of a major geological contact. To the east the Gillian Hills give way gradually to the Barnes Plateau, a higher, drift-covered region of relatively low relief.

Elevations reach 800 to 1,000 feet within a short distance of the Foxe Basin coast and thereafter continue to increase gently to the eastern boundary. Summit elevations seldom exceed 1,400 feet. Local relief of 800 to 1,000 feet is usual throughout the area, however, and the region has an irregular, dissected appearance resulting from pronounced structural control of the topography. This structural control is reflected in the drainage pattern and is clearly apparent in the orientation of the bays and arms of Gillian Lake.

Expcsed Precambrian rock forms much of the surface of the region, particularly east of Grant-Suttie Bay and around the upper portion of the Gillian Lake basin. Inland from Ikpik Bay and Baird Peninsula the rock surface is partly covered with glacial drift.

The principal streams in the region all drain southwestward toward Foxe Basin. It is obvious from the size and form of the lake basins and river valleys that the drainage system has not formed in the relatively short time since the retreat of the last ice sheet. The Drewry, MacDonald and Flint rivers all occupy broad, mature valleys of considerable size. Radar altimeter profiles indicate that these valleys are 600 to 1,000 feet deep and up to 2 miles wide. Erosion on this scale must have been initiated no later than Tertiary time, and the present rivers therefore utilize portions of a

FIGURE 5. A view west onto the Gillian Hills with an arm of Gillian Lake in the foreground. Note the structural control of the drainage and the greater relief and dissection of the area as compared with the Barnes Plateau (Figure 6). Photo: RCAF oblique T238L69.

preglacial drainage system. Gillian and Flint lakes have been impounded in the lower sections of two of these preglacial valleys. The upper sections of the valleys extend beneath the Barnes Ice Cap and reappear as the drowned basins of Conn, Bieler and Generator lakes east and northeast of the ice cap.

It has not yet been possible to determine to what extent the valleys were overdeepened or otherwise modified by glacial action. Glacio-fluvial deposits occur commonly along most of the streams. Today the main streams carry much of the drainage from the Barnes Ice Cap. They are laden with silt, and the upper reaches of the larger lakes have been extensively infilled.

3. *Barnes Plateau*

The terrain upon which the Barnes Ice Cap sits has been named the Barnes Plateau; only a small part of it occurs within the area of the Foxe Basin North map sheet. It is generally a rolling area at elevations ranging from 1,400 to 1,900 feet and is primarily distinguished from the Gillian Hills to the southwest by its much smaller degree of dissection and by a more extensive glacial-drift cover. Its western boundary is indefinite and it merges gradually into the Gillian Hills.

In general the region has a broadly rolling aspect (Figure 6), broken only by the headwaters of the Drewry, MacDonald and Flint rivers, whose valleys appear on the radar altimeter profiles as broad, mature forms 300 to 500 feet deep. Associated with the valleys are the large numbers of well-developed glacial drainage channels described on page 76.

The Precambrian bedrock seldom outcrops over wide areas. Most of the surface is covered by a veneer of ground moraine of variable depth. Except near the northern edge of the map-sheet area, this drift is unoriented. In the north, however, a trace of east-west lineation is apparent. Terminal moraines mapped in the same area are of a type that is much more extensive on the Barnes Plateau north of the map-sheet area (Ives and Andrews, 1963, Figure 1). Between Blanchfield and Flyway lakes a former ice-marginal position is marked by a prominent morainic arc within which there is an extensive deposit of ablation moraine.

The drainage net on the Barnes Plateau is much less developed than that of the Gillian Hills. With the exception of the valleys of the Drewry, MacDonald and Flint rivers, which are probably preglacial, few stream channels or lakes occur on the rolling surface of the region. The major interfluves have very slight relief. The streams that drain these interfluves occupy shallow valleys, many of which have not yet cut through the drift to the underlying bedrock. Only one important lake lies entirely within the region. Blanchfield Lake, at the margin of the ice cap, is partially formed by

FIGURE 6. A view southeast over the Barnes Plateau showing the southern tip of the Barnes Ice Cap and the impounded drainage that causes Blanchfield Lake (left middle distance), Generator Lake (beyond the ice cap) and Flyway Lake (to the right of the ice cap). Note the degree of contrast between this area and the Gillian Hills in the extent of dissection (Figure 5). Photo: RCAF oblique T254 R 78.

an ice dam across the upper valley of the MacDonald River. Former shorelines can be clearly seen around the shores of the lake above the present level.

FIGURE 7. A view west of the Piling Ridges region showing the east-west structural control indicated by Piling Bay and the numerous elongated lakes. Note the Baird Peninsula (centre background), which is part of the Foxe Basin lowland province. Longstaff Bluff is at the left centre (arrowed). Photo: RCAF oblique T221 L17.

4. *Piling Ridges*

This region, in which east-west bedrock lineation is a prominent surface feature (Figure 7), gradually widens eastward from the Longstaff Bluff-Piling Bay vicinity toward the eastern edge of the map, where it is about 50 miles wide. Its physical characteristics are so distinctive that it has been considered a separate region. Its limits are defined by the clearly apparent structural orientation. In the north the boundary extends from a few miles north of Longstaff Bluff via the lower end of Flint Lake to Flyway Lake. The southern boundary extends from the shore of Clarke Sound via the north shore of Straits Bay to the eastern edge of the map-sheet area.

The region has not yet been geologically mapped, but it seems to be one of metamorphosed Precambrian sediments and volcanics and may be related to a similar region in southern Melville Peninsula. Kranck has examined structures east of the map-sheet area that may represent an eastward extension of the Piling Ridges (Kranck, 1951, page 683). He reports that the rocks between the head of Macbeth Fiord and the south end of the Barnes Ice Cap are metamorphosed and strongly folded east-west-striking sediments. He particularly mentions black schists rich in sulphides associated with an iron formation east of the ice cap. A sample of the bedrock from Longstaff Bluff has been identified as chlorite schist (Geol. Surv. Can.).

The roughly east-west linear trend of the topography prevails throughout the area, being obscured only where glacial or marine sediments overlie the bedrock. The ridges vary in length from a mile or less to many miles. The prominent ridge that appears on the map extending west from Flyway Lake is about 20 miles long. Some are partially covered by drift and often resemble drumlinoids. Others project as peninsulas into lakes or rise as islands above the lake surface. The well-developed low, parallel ridges in Piling Lake and Piling Bay are examples of the type. The structural trend also exerts control on the drainage pattern. This is particularly apparent east of Piling Lake and Piling Bay, where many small lakes and streams have an east-west orientation.

The region is lowest in the west, rising inland toward the eastern boundary of the map. Though elevations in the vicinity of Longstaff Bluff are more than 500 feet above sea level, much of the terrain east and southeast of Piling Lake does not exceed 100 feet in height. Eastward elevations gradually rise to between 1,200 and 1,400 feet. Relief is seldom so pronounced as it is, for example, in the Gillian Hills. It is about 200 feet in the west, increases to a maximum of between 400 and 500 feet in the centre and declines again in the east. At the eastern extremity, which is at the same height as the Barnes Plateau, the amount of till cover is greater and the drainage pattern is less developed.

The topographic expression of the linear features is more pronounced near the northern boundary of the region, where the ridges are higher and the intervening vales are wider. It becomes much less apparent toward the south. Across the entire region the ridges are extremely variable in height. The fingers in the vicinity of Piling Bay and Piling Lake are 100 feet high and similar heights occur over much of the western part of the region. Ridge heights are somewhat greater in the north and central areas, where individual ridges may exceed 500 feet. In the east and south the relief decreases and in many places gives way to a slightly undulating landscape.

5. *Wordie Hills*

This region extends inland from Clarke Sound and Wordie Bay to beyond the eastern edge of the map sheet. It includes a number of offshore islands, of which North and South Tweedsmuir and Anderson islands are the largest. While much of the surface, particularly in the coastal areas, lies below 200 feet, it is irregular and has considerable local relief. Close to the east shore of Straits Bay and north of Wordie Bay the land is very low. Within a few miles of the coast, however, hills rise from the marine sediments, and Precambrian outcrops project through the shallow drift cover. In the vicinity of Bravo Lake the rolling hills have reached a height of from 400 to 500 feet but are separated by broad, often marshy, depressions. The slopes are not steep. The coastal area was submerged in postglacial time, and the evidence of marine action is visible as far as 20 miles inland. Bravo Lake was submerged and the sea extended some distance up the small river draining into its eastern end. Within this submerged area the glacial drift has been modified by marine action and in the lower areas has been overlain by marine silt. The hills are low and broad and intervening depressions are marshy. Unmodified drift is more widespread in the interior, where the hills become higher and closer together. Here too, the valleys are shallow, poorly developed and often choked with glacio-fluvial deposits. Eskers and outwash are common. The drainage pattern in this area is very poorly integrated. Lakes are numerous, and streams are short and irregular.

Marine submergence

Throughout the coastal zone of the area under discussion there is abundant evidence that the sea formerly stood much above its present level (Figure 3). The submergence of the land occurred in late-glacial and postglacial time as the normal result of a eustatic rise in world sea level, due to the melting of the Wisconsin ice sheets and the delayed isostatic recovery of the land. Maximum submergence occurred about 7,000 years ago,* and since then the land has been gradually rising in relation to the sea. At first the rise was rapid, but it later became much slower. This process is continuing today at the rate of about 18 inches a century (Ives, 1964).

Numerous observations were made in 1961 on the maximum height of marine submergence, principally in the Bravo Lake and Longstaff Bluff-Ikpik Bay areas. The degree of submergence, calculated from aneroid observations, varies from about 260 feet in the inland sector of Bravo Lake to about 360 feet along the coast north of Longstaff Bluff. Differences in the degree of submergence are probably due to progressive tilt of the land, which accompanied uplift.

The upper marine limit is shown on Map 2, together with radiocarbon-dating localities and raised marine shore features. The effects of this submergence, and subsequent emergence, are highly significant in terms of terrain conditions. Individual references have been made in the descriptions of the different physiographic regions; now, in conclusion, the over-all pattern of former submergence is emphasized.

Where the coasts are steep, submergence has been insignificant in its effect upon the general land surface. Thus modification of the Gillian Hills region by marine action has been slight, except in the vicinity of Grant-Suttie Bay. The entire island and peninsula region has, however, been submerged, and one of its most significant terrain factors is the distribution of marine shore features and silts. The westernmost section of the Piling Ridges has also been extensively submerged: here wide marshy plains, underlain by marine silts, are prominent landscape types. The same is true of the western section of the Wordie Hills, and the offshore islands in this region have been almost entirely modified by marine processes.

Scientific evaluation of the pattern of submergence in relation to wastage of the Baffin Island ice sheet awaits more-detailed field studies. It is already apparent, however, that glacier ice occupied some of the deeper lake basins, including Gillian, Flint and Piling lakes, and thus prevented ingress of the sea. Precise levelling of raised shore features should ultimately facilitate the unravelling of their relations, an essential step in the resolution of the physiographic history of the area.

*This result is obtained from the radiocarbon dating of marine molluscs collected from heights of 290 and 252 feet above sea level along the east coast of Ikpik Bay. Samples VWS 61–1S and VWS 61–2S (I–406 and I–405).

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AGRICULTURAL LAND UTILIZATION IN THE DIXONVILLE-FORT VERMILION AREA OF ALBERTA

J. W. Maxwell

ABSTRACT: The Dixonville-Fort Vermilion area of Alberta's Peace River region contains the most northerly extensive commercial farmlands in Canada. Settlement developed here without the aid of rail transportation in the immediate vicinity, and the settlement pattern that has emerged is formed by a series of isolated districts differing in ethnic character and agricultural emphasis. At present, some 30 years after the main influx, a rail line is being laid through the area. This paper describes the present land-use pattern and outlines the part played by microclimatic variations, distances to railhead and ethnic character as the principal causes of the existing differences in land utilization among the area's several districts.

RÉSUMÉ: Le secteur de Dixonville–Fort Vermilion, dans la région albertaine de la rivière de la Paix, renferme les terres arables commerciales les plus septentrionales au Canada. La colonisation s'y est poursuivie sans l'aide du transport ferroviaire dans le voisinage immédiat, et le mode de colonisation qui en est résulté prend la forme de territoires isolés qui diffèrent les uns des autres au double point de vue ethnique et exploitation agricole. Aujourd'hui, quelque 30 ans après l'arrivée des premiers colons, on est en train de construire un chemin de fer dans la région. L'auteur décrit le mode actuel d'utilisation des terres et étudie le rôle joué par les variations microclimatiques, par les distances entre les agglomérations et les voies ferrées, ainsi que par le caractère ethnique; ce sont là les trois facteurs dominants de l'utilisation des terres dans les divers territoires de la région.

INTRODUCTION

The Dixonville-Fort Vermilion area lies in northwestern Alberta in the drainage basin of the Peace River. It forms a northern extension of agricultural settlement within the Peace River region and, as such, is the most northerly area of extensive commercial farming in Canada (Figure 1).

The Great Slave Lake Railway, now being built north from the Northern Alberta Railways to the Pine Point base-metal deposits on the southern shore of Great Slave Lake, will pass through this area, providing rail transportation for the first time. In anticipation of the resulting changes in the land-use pattern, a Geographical Branch field team investigated the present land-use pattern during the summer of 1962. The objective of the study was to determine the extent and nature of land utilization prior to the initiation of railroad operations with a view to establishing a land-use "bench mark" against which future development might be measured.

MS submitted September 1963.

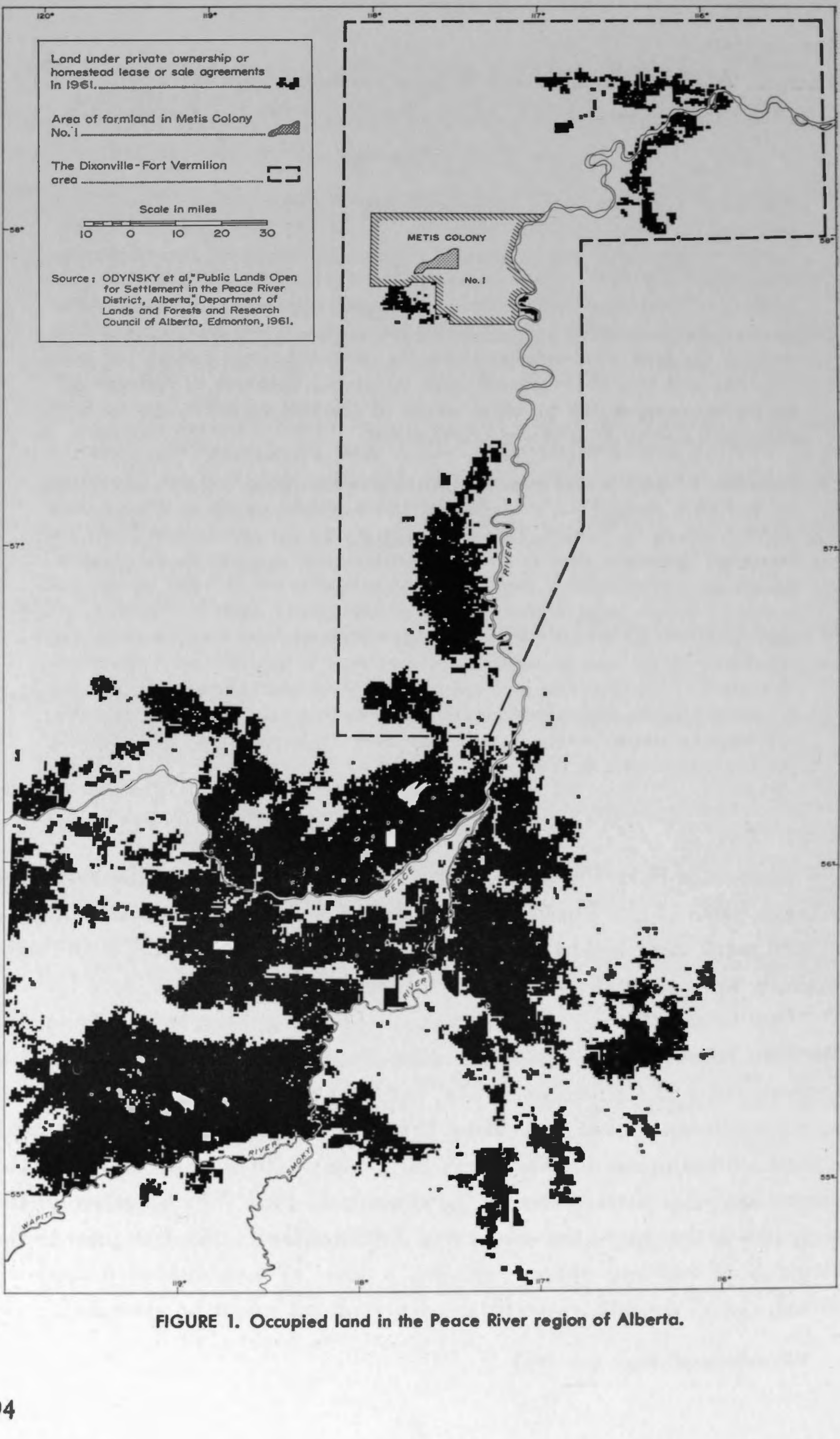

FIGURE 1. Occupied land in the Peace River region of Alberta.

GENERAL DESCRIPTION

Settlement pattern

Settlement of the area has resulted in a series of agricultural districts located on predominantly lacustrine lowlands extending for a road distance of 230 miles between Grimshaw and Fort Vermilion (Figure 2). The settlements differ to varying degrees in terms of land utilization, development rates and ethnic character.

About 500,000 acres of farmland, more than 50 per cent of which are cultivated, are situated in the Dixonville-Fort Vermilion area.* This land is divided among some 1,200 farms and supports a population of about 7,500 including 900 persons in Manning and about 500 in Fort Vermilion, the two largest centres in the area.

Both livestock and cash crops are produced, but the relative importance of each of these types varies greatly from district to district. Variations in microclimatic conditions, in distances to railhead and, to some degree apparently, in the cultural traditions of the ethnic groups are largely the cause of the contrasts among districts in agricultural emphasis. The scale of farm enterprise ranges from subsistence levels to large, highly specialized commercial operations.

(i) The most southerly district, that centred on Dixonville, is in the Whitemud River valley 20 miles north of Grimshaw. It is separated from other farm areas to the south by rough topography that is unsuitable for agriculture, but that does produce commercial stands of white spruce (*Picea glauca*). A distinct "fringe area" only 30 years ago, this district now exhibits a degree of development similar to that found in older districts of the Peace River region. Almost all land suitable for cultivation has been occupied, and most of the farms are fully established. The cropland is utilized for feed-grain and forage-crop production, which supports a livestock-oriented (beef-cattle) economy.

(ii) To the north, another zone of rough and poorly drained terrain separates the Dixonville district from the Battle River settlement, which is the largest agricultural district in the study area. This district occupies a large pocket of level-to-undulating land that extends for the approximately 40 miles between the Whitemud and Meikle rivers.

*Unless it is otherwise stated, all agricultural statistical data have been compiled from material in the files of the Edmonton office of the Prairie Farm Assistance Act administration. The statistics covering the Fort Vermilion districts are for 1961. Those for the remaining districts refer to 1958.

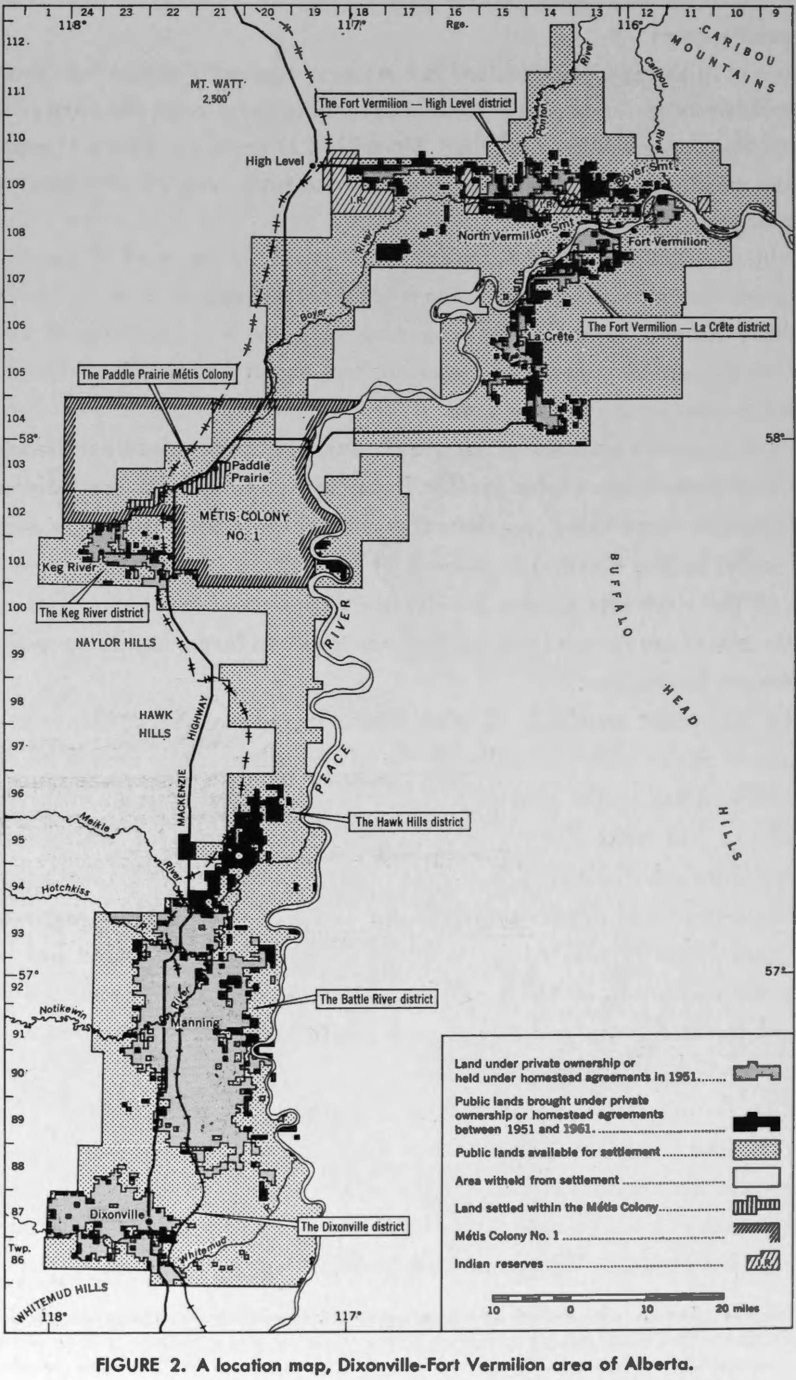

FIGURE 2. A location map, Dixonville-Fort Vermilion area of Alberta.

Here, as in the Dixonville district, farming began about 30 years ago. The combination of a demand for cheap land, the possible availability of rail service, and the existence of lightly vegetated and level land brought most of the potentially arable land under cultivation shortly after initial settlement. The present landscape is mature and stable. Market roads are in relatively good condition, farmsteads are similar in type and quality to those on the southern plains, and log buildings that once served as homes are now storage sheds or have been abandoned. The original agricultural emphasis on grains for cash crops has continued; wheat is the chief grain grown.

(iii) In the past decade, settlement has been extending north of the Meikle River along the southeast fringe of the Hawk Hills. This district exhibits most of the features associated with the "pioneer fringe": little and very recent road development, much clearing and breaking of virgin land, and temporary buildings. It is contiguous to the larger Battle River district, and its farming emphasis is similarly on cash crops. In essence, the Hawk Hills district forms a new northern extension of the Battle River district.

At present, about three quarters of both the cultivated land and the commercial farms* of the study area are in the Dixonville, Battle River and Hawk Hills districts. These, however, with the exception of the Hawk Hills district, are almost completely developed in terms of agriculture. Their proportion of the area's cultivated land and large farms will decrease as the new areas of homesteading in the northern districts are further developed.

(iv) A 30-mile stretch of hilly upland lies between the Hawk Hills district and the next agricultural district to the north. The latter, known as the Keg River settlement, is in parkland at the base of the Naylor Hills. In terms of population, it is the smallest district within the study area, being essentially an agricultural "outpost" in the forest expanse. Although isolated, the farms of the settlement are well developed. The agricultural emphasis is on feed grain and associated swine production.

(v) In the districts already described no one ethnic group is dominant in influence, but in the remaining districts, the "dominance" of particular groups of this kind is pronounced. The next agricultural district to the north is populated by one ethnic element: the métis. It is in Métis Colony No. 1 and is centred on the hamlet of Paddle Prairie. Although it lies on an extension of the Keg River parkland and contains good soils, it has only 7,000

*Commercial farms: those whose sales of agricultural products are worth $1,200 or more per annum.

acres in farm and is thus the smallest district in terms of farm area. Cropland is used primarily for feed grains. The farms, largely undeveloped, are for the most part in poor condition. With agricultural productivity in its present state, the operators seem to need part-time nonfarm work to maintain themselves.

(vi) The last two districts are situated in the Peace River lowland north of latitude 58°N, where settlement straddles the Peace River between the Caribou Mountains and the Buffalo Head Hills. It is in these and the Hawk Hills district that most of the recent homesteading has been undertaken. In addition to the regular homestead-type development, large highly specialized operations have been established in these two most northerly districts by three forage-seed producers.

In the district north of the Peace River, the farmland is in the Boyer River basin, where it forms an east-west ribbon of settlement along the northern fringe of a large aeolian sand deposit. This farm area is here termed the Fort Vermilion-High Level district. It stretches westward for about 50 miles, from the Caribou River to the hamlet of High Level, on the Mackenzie Highway. Apart from settlement associated with the fur-trading era, the first purely farm-oriented occupation was initiated some 30 years ago by persons of Ukrainian descent who entered the area by drifting down the Peace River on rafts. In the principal agricultural lands, centred on the hamlet of Rocky Lane, the Ukrainian influence is still much in evidence. These people have been successful in adapting themselves to the special circumstances associated with farming in this isolated community. The farms are well developed, modern farm machinery is utilized, and most of the original log buildings have been abandoned or are used for storage. West of the Rocky Lane neighborhood, the Ukrainian influence diminishes, and the ethnic composition of the population is more heterogeneous. In both these areas oilseed production is the chief agricultural activity.

Providing vivid contrast to the farms in the oilseed areas are the métis-inhabited farms in and near the North Vermilion and Boyer settlements. Like the farms in the Paddle Prairie district, these are in poor condition.

Two large forage-seed farms are located in the Fort Vermilion-High Level district. One is on the Bushe River Indian Reserve on leased land 1½ miles east of High Level; the other is on partly leased, partly owned land at Prairie Point in Township 107, Range 15 west of the fifth meridian. Both operations have approximately 2,000 acres in seed production and are owned by nonresidents.

(vii) Settlement south of the Peace River is found on the adjacent lowland between Lamberts Point, 6 miles downstream from Fort Vermilion, and the Buffalo Head Hills, which terminate in a north-facing scarp 25 miles south of Fort Vermilion. This is the second largest agricultural district in the study area in terms of both farm area and population. It is here termed the Fort Vermilion-La Crête district.* Two quite distinct communities make up its settlement pattern. The farm area centred on Fort Vermilion is largely undeveloped. Occupants of this area, primarily of English or French origin, seem to consider farming secondary to nonfarm work with the various private and government agencies operating out of Fort Vermilion. The few well-developed farms that do exist emphasize oilseed and forage-seed production. Another large forage-seed producer leases several parcels for seed production.

South of Township 108, the district is inhabited almost entirely by Mennonites, the first of whom arrived in the late 1920's. Suspicious of formal education and avoiding it if possible, the original Mennonite settlers built up a community structure which, until the recent new homesteading, was extremely insular. Traditional farming methods consequently prevailed, and the search for techniques and types of farming more adaptable to this isolated northern environment was not encouraged from within. Thus, although the first settlement was made more than 30 years ago, development has been slow and some of the original log houses are still inhabited (Figure 3). Road development is poor and living standards are generally low. Recent homesteading, however, has changed the old landscape. For example, many new, unpainted frame buildings have been constructed, and virgin land is being cleared and broken. A feed-grain and livestock program supplemented by a small sale of wheat as a cash crop forms the basis of the Mennonite farm economy. Until lately oilseed production was restricted to the few non-Mennonite farms.

At latitude 57° 47' N, another settlement stands on the alluvial soils of the Peace River flood plain. It is known as Carcajou and in 1961 consisted of seven farms. Neither Carcajou nor the settlements on the several Indian reserves are considered in this paper.

Transportation

The installation of modern transportation facilities has only recently come abreast of the growth of the area. Not until 1952 was an all-weather highway

*For a detailed account of land utilization in this district see J. H. Lovering (1963).

system serving all the settlements completed. Until that time, winter roads and the Peace River were the principal traffic arteries. The first link in the all-weather road system was built in the late 1920's and penetrated northward as far as the Battle River district. The second was completed in 1948 with the construction of the Mackenzie Highway from Grimshaw to Hay River, N.W.T. Access to the Fort Vermilion districts was provided in 1952 with the construction of a gravel road from High Level, on the Mackenzie Highway, to Fort Vermilion. In 1961 a second access route entered the Fort Vermilion-La Crête district, which it connects with the Mackenzie Highway at a point 5 miles north of Paddle Prairie. The crossing of the Peace River on both routes is made on small ferries (Figure 4), which must cease operation during freeze-up and break-up, thus isolating the Fort Vermilion-La Crête district for about a month in spring and fall.

Although many of the settlers who established themselves in this northern area in the 1920's and 1930's believed that the railroad would soon follow them, it was not until 1962 that the installation of rail facilities was started. Even then, construction was motivated by mineral exploitation rather than the needs of agriculture. The Great Slave Lake Railway, now being built from Roma, on the Northern Alberta Railways near Grimshaw,

FIG. 3. A recently abandoned log shack in the Mennonite area of the Fort Vermilion-La Crête district. Earthen floors and roofs are normal in these structures. Photo: JWM 62-3-10 July 13, 1961.

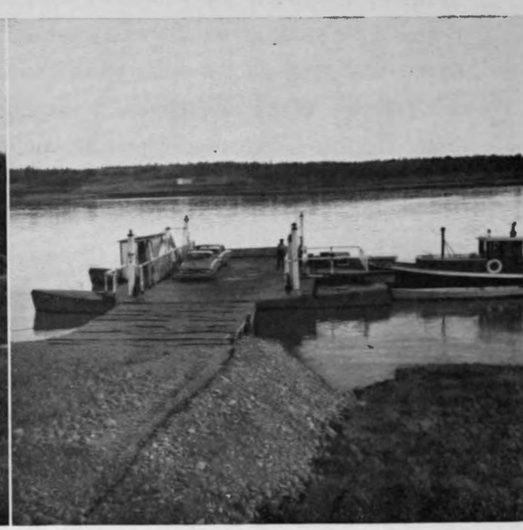

FIG. 4. The Peace River car ferry at Fort Vermilion. Fluctuations in the water level make it difficult to maintain ferry approaches. Large crawler tractors are stationed at the crossings to adjust the approaches to varying water levels and to assist vehicles off the ferries. Photo JWM 62-11-2, August 28, 1962.

to the Pine Point base-metal deposits on Great Slave Lake, will closely parallel the Mackenzie Highway through the study area. The completion of this line, scheduled for 1965, will greatly alter the relative position of the districts in terms of distances to railhead and grain-elevator facilities. For farmers in the Fort Vermilion districts, distance to rail facilities will shrink from 230 miles to between 40 and 60 miles.

Since shipping charges have been one of the most important determinants of agricultural emphasis in each district, rail transportation will, without doubt, greatly alter the present pattern of land utilization. The effects of present trucking costs on crop shipments to Grimshaw vary greatly from district to district and are largely the reason why oilseed, forage-seed and livestock are emphasized in the northern districts.

PHYSICAL FACTORS AFFECTING LAND USE

Physiography

The principal physiographic feature in this section of northern Alberta is a broad, north- and northeast-sloping lowland of preglacial origin. Interrupting this lowland expanse is a series of flat-topped erosional remnants. The Whitemud, Hawk and Naylor Hills, west of the Peace River; the Buffalo Head Hills, east of it; and the Caribou Mountains and Mount Watt, north and northwest of it, constitute such residual highland areas. The lowland dips from an elevation of about 2,000 feet near Dixonville to about 900 feet in the vicinity of Fort Vermilion; the highland units reach altitudes ranging from 2,500 feet to more than 3,000 feet. The system of lowland and highland units gives a regional surface of moderate relief.

During deglaciation, both highland and lowland areas were mantled with glacial drift composed largely of pebbly clay till in the form of hummocky dead-ice moraine and level-to-undulating ground moraine. These till deposits underlie lacustrine materials of proglacial origin and of varying thicknesses, which make up the surficial material over most of the lowland and over smaller, discontinuous parts of the highland areas (Lindsay *et al.*, 1959).

The topographic surface of the lowland ranges from level to gently rolling except where downcutting and lateral erosion caused by the streams are pronounced. Steep walls, slumping and terrace development characterize most of the major stream valleys. Both surface slope and drainage are dependent on the nature of surface materials. Where lacustrine sediments are relatively thick and uniform, as in the Fort Vermilion-La Crête and Keg

River districts, the surface is level to depressional. Where the sediments are shallow and the underlying material is hummocky dead-ice moraine, the terrain is undulating. Examples are found to the east of the level deposits in the Battle River district, and in the unsettled areas on both sides of the Peace River around Carcajou. Undulating topography also occurs in the Whitemud River valley, where ice-rafted glacial drift has been intermixed with the lacustrine deposits. On the lowland, gently rolling topography is restricted to the aeolian sand deposits adjacent to the Peace River.

FIGURE 5. A section of the Dixonville district. Numerous and extensive depressional areas, frequently occupied by organic deposits, interrupt the areas of cultivation, thus creating a low ratio of arable to nonarable land, which has promoted the formation of large farm units. This pattern is in marked contrast to the almost continuous area of cultivation in the more level farm areas of the Battle River district, where organic deposition has been less extensive. The hamlet of Dixonville, on the Mackenzie Highway, can be seen in the centre. Photo: RCAF vertical A14481-86, 1954.

The most distinctive physical features in the settled portions of the lowland are the numerous organic deposits, with their associated bog vegetation, that interrupt the cultivated fields (Figure 5), and the deeply cut stream valleys, with their terraces and meandering streams. Many of the river terraces are cultivated, especially in the Battle River district (Figure 6).

FIGURE 6. A section of the Battle River district. Continued downcutting and lateral erosion by the Notikewin River (formerly the Battle River) have developed an intricate pattern of noncyclic terraces along the floodplain. Most of the terraces are cultivated and are characteristic of many of the rivers of northwestern Alberta. The relative homogeneity of the terrain and a light cover of vegetation have made most of the land arable. The land has been improved to a greater degree in this district than in any other in the area. The town of Manning, situated on a meander spur, is in the lower left-hand corner of the photograph. Photo: RCAF vertical A14007-94, 1954.

The arable and potentially arable lands are restricted to the relatively level, well-drained, lowland terrain. Unfavorable slope, drainage and soil conditions preclude the cultivation of arable land in the highland areas, on the aeolian deposits, or in the level lowland areas of poor drainage. In some instances, up to 70 per cent of these lowland surfaces are covered with bog (Lindsay *et al.*, 1958).

Beyond the present areas of cultivation in the two most southerly districts, the terrain in the zones open for settlement becomes progressively rougher, stoniness is more of a problem as the parent material of the soil changes from predominantly lacustrine sediments to glacial till, and the frequency and size of organic deposits increase. In the northern districts, however, there are extensive potentially arable lands. The Alberta Soil Survey has tentatively classified about 6 million acres in northwestern Alberta north of latitude 57°N and west of longitude 114°W as "potential arable land" (Lindsay *et al.*, 1958, 1959 and 1960). All this potentially arable land is on the lowland. The provincial government has as yet opened only a relatively small part of the total land suitable for agriculture. It makes Crown lands available for settlement as the demand for additional farmland becomes apparent and services can be supplied to the new areas at reasonable cost. This lowland zone is the largest single block of potentially arable land in Canada that remains to be settled.

Climate

The climate of the area is transitional between the humid continental, cool-summer (Dfb) and the subarctic (Dfc) types of the Köppen classification. Thus, in terms of climate, agricultural activity is in a near-marginal position. Precipitation totals are low and the frost-free season is relatively short (Table 1). In addition, annual variability in the distribution and amount of precipitation and in the length of the frost-free season is marked. The result is occasional crop damage caused by periods of drought, excessive moisture or unseasonable frosts. These more unfavorable characteristics of temperature and precipitation are somewhat offset during the growing season by the combined effects of high precipitation efficiency and long days. These two advantages so improve the climatic situation that most cool-season crops can be produced successfully, subject to occasional damage due to extreme conditions.

Table 1

Precipitation and frost-free period at weather stations in the north Peace River region

Station	Average annual precipitation (inches)	Average frost-free period (days)	Shortest frost-free period (days)	Longest frost-free period (days)
Fort Vermilion	12.76	72	5	119
Buffalo Head Prairie[1]	14.61	73	35	97
Keg River	14.95	57	29	79
Fairview[2]	17.92	105	78	139

[1]Buffalo Head Prairie is the southernmost area of settlement in the Fort Vermilion-La Crête district.

[2]Fairview is south of the study area. It is about 25 miles southwest of the Whitemud Hills in Township 81, Range 3 west of the sixth meridian.

Note: The climatic data in this table are taken from *Temperature and Precipitation Normals for Canadian Weather Stations Based on the Period 1921-1950*, Meteorological Branch, Department of Transport, and *Progress Report 1949-1958* Fort Vermilion Experimental Station, Experimental Farm Service, Canada Department of Agriculture.

About 60 per cent of the annual precipitation occurs during the period from May to September. Rainfall builds to a maximum in July and then decreases for the rest of the period. The maximum coincides with the time of plant growth, when the need for moisture is most critical. For example, almost two thirds of the water consumed by spring wheat is taken up between mid-June and mid-July (Can. Dept. Agr., 1959a). Precipitation efficiency is further improved by the relatively low evaporation rates in this northern area. Additional advantages accrue to agriculture through the decrease in precipitation that occurs after July. This decrease hastens maturity and facilitates harvesting.

Restrictions on agriculture due to the shortness of the frost-free season are not as much of a hindrance as they might appear. The period free from killing frost is longer than the frost-free period, since killing frosts do not occur until the temperature drops to 28°F or lower. At Fort Vermilion the average period free from such frosts is 32 days longer than the average frost-free season: 104 days as opposed to 72 days (Can. Dept. Agr., 1960). Further, the possibility that frost damage will occur during the night is greatly decreased by the long periods of daylight and the corresponding short periods of darkness. The long daylight hours also hasten crop maturity and decrease the likelihood of damage due to early frosts. At Fort Vermilion, Olli barley matures in 83 days, while at Lacombe, south of Edmonton, it requires 102 days to ripen (Can. Dept. Agr., 1960 and 1954).

The length of the frost-free period varies over the area, being influenced largely by local topographic control. The average frost-free season at the Keg River settlement is 15 days shorter than that at Fort Vermilion even though the latter is farther north. While this difference is undoubtedly accounted for in part by elevational differences—Keg River settlement is about 500 feet higher than Fort Vermilion—air drainage also seems to have an effect. It is apparent, although unsubstantiated, that the shorter frost-free season at Keg River results partly from the drainage of cold air from the Naylor Hills highland to the adjacent settled lowland. A similar situation is believed to exist in the Dixonville district. No data on the frost-free season are available for the district, but several farmers in that vicinity say that in most years it is impossible to mature wheat successfully there because of the frost hazard. Relief in the Dixonville district is generally similar to that at Keg River: cultivation is carried out in a small lowland area that is surrounded by highland units. It is plausible that air drainage and ponding occur, thereby greatly increasing the possibility of unseasonable frosts in the valley bottom on cold, clear summer nights.

These phenomena have also been noted in the settled area immediately north of the Buffalo Head Hills (the Buffalo Head Prairie), although it is not as pronounced there and does not limit the production of wheat and oilseeds as it does in the Keg River and Dixonville districts.

Soils

Grey Wooded* soils are dominant in this mixed-wood section of the Boreal Forest Region. Having developed under a dense forest cover, these soils have a natural fertility inferior to that of grassland soils and require special management to produce effectively over a long period. Dark Grey and Black soils have developed under the grassland and sparsely wooded areas of the parkland zones. These zones occur as "islands" distributed throughout the forest expanse of the study area (Figure 7). Although they are less extensive than the Grey Wooded soils, the Chernozemic soils of the parklands have been more significant in the agricultural development of the area because of their greater fertility and the relative ease of preparing them for cultivation.

With the exception of cultivation carried out on the terrace alluvia near Fort Vermilion during the fur-trading era, the first farming in all districts was undertaken on the Dark Grey and Black soils of the parklands. To secure land in one of these parkland parcels was the objective of the first settlers in the Peace River region. Thus the distribution of the parkland units determined the pattern of settlement. The occurrence of large parkland zones in the Battle River, Keg River and Fort Vermilion districts largely explains why settlers chose as farm sites these isolated northern areas many miles from transportation facilities. The largest parkland units open for settlement are now being farmed, and cultivation has expanded beyond the parkland boundaries to the adjoining forest-covered, less fertile, Grey Wooded soils.

Although the parent material is similar over most of the cultivated land, the soils differ markedly in texture and in some aspects of morphology. In general the soils of the lowland are relatively coarse along the Peace River

*Color terminology spelled with initial capitals is that used in the *Report of the Meeting of the National Soil Survey Committee of Canada*. This meeting was held at the Ontario Agricultural College, Guelph, Ont., in 1960.

and become progressively finer with distance away from the river. Textures vary from sandy loams to clay loams and clays. The coarsest soils are found in the Fort Vermilion-La Crête district and the finest in the Battle River district. The soils of the remaining districts are medium to moderately fine in texture.

Within the study area, textural differences have a profound effect on agriculture, especially in abnormally wet or dry years. The 1962 growing season was excessively wet. In the localities of fine textured soils, notably in the northern part of the Battle River district, many fields could not be seeded nor summer fallow worked. Where fields were seeded, crop damage was severe. In contrast, the crops on the sandy and silt loams of the Fort Vermilion-La Crête district, although late in maturing, were relatively undamaged by the excessive rainfall.

FIGURE 7

(A) This photograph illustrates the high tree density in the mixed forest of the study area. Trembling aspen (*Populus tremuloides*) and white spruce (*Picea glauca*) are the main species. Aspen, quick-growing, is the first to regenerate in burned-over areas and dies out (it rarely reaches 60 years in age); then a white-spruce dominance emerges. Large tracts of forest land have been fire-killed in the Peace River region. These areas are often suitable for settlement since the aspen is easier to clear than large stands of white spruce. Next to the areas of natural prairie in the parkland zones, the lightly covered aspen areas have the greatest settlement potential in terms of clearing costs. Surveyors' cut-lines are visible. Photo: JWM 62-13-7, September 7, 1962.

(B) A small stretch of parkland near Fort Vermilion. Fire seems to be the principal cause of these parcels, which occur throughout the mixed-wood forest of this area. The existence of such parklands was the reason for the Dixonville-Fort Vermilion agricultural development. Having to clear their land largely with hand tools, the first settlers placed high priority on natural prairie or lands that were sparsely wooded. Photo: JWM 62-12-2, September 7, 1962.

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Certain morphological characteristics of these soils are of particular concern to the settler. As Grey Wooded soils are brought under cultivation, special care must be taken to maintain and improve their fertility and physical properties. Because of deficiencies in organic matter, they are often of poor tilth and deficient in nitrogen. The use of legumes in crop rotations carried out on these soils is necessary to improve tilth and increase the store of available nitrogen. Special problems are encountered in dealing with the solonetz-like soil profiles that have developed on saline parent materials occurring intermittently throughout the study area. In such soils, the "B" horizon is hard and relatively impermeable. This feature limits the penetration of water and plant roots, thus making crops more susceptible to damage in periods of drought or excessive moisture. Commercial fertilizers, although shown to be beneficial in improving yields and, more significantly, in hastening maturity in certain crops (Can. Dept. Agr., 1960), are not widely used in the study area.

PRESENT AGRICULTURAL DEVELOPMENT

Agricultural emphasis and farm enterprise

The type of farming in the Dixonville-Fort Vermilion area, taken generally, is typical of that found throughout the Peace River region. Sales of grain, including oilseeds, account for more than half the farm income on about two thirds of the commercial farms in both the study area and the region. Livestock sales occupy a similar position on about one fifth of the commercial farms in both areas (Table 2). The level of farm prosperity, as indicated by the percentage of farms classified as commercial, is slightly lower in the Dixonville-Fort Vermilion area than in the Peace River region and is appreciably lower than in the province.

Although generalized statistics suggest that the farming character of the area is similar to that of the region, considerable variation in both farm emphasis and prosperity exists among the districts within the area, as indicated in Tables 2 and 3. Emphasis on grains as cash crops is much more pronounced in Improvement District 138, which includes the Dixonville and Battle River districts, than in the more northerly districts. Specialization in cash-cropping, particularly in wheat production, is even more pronounced than Table 2 indicates, since almost all wheat and oilseed production in Improvement District 138 is confined to the Battle River and Hawk Hills districts. In the more northerly improvement districts (nos. 146 and 147), greater emphasis is placed on livestock production, notably on hog production. Cash crops, which are dominant in only one of the northern districts, the Fort Vermilion-High Level, are limited to those crops that yield a high return in relation to bulk—for example, oilseeds and forage seed. This is a direct consequence of the high cost of marketing goods from these isolated lands.

Farm prosperity, like agricultural emphasis, varies greatly from district to district. The southern settlements (Improvement District 138) enjoy a standard of living almost as high as the Peace River regional average, but in 1961 in the most northerly settlements fewer than half the farms were

Table 2

Commercial farms, by type of farm, 1961[1]
(percentage)

Product type	Peace River region (Census Div. 15)	Dixonville-Fort Vermilion area (I. D. 138, 146, 147)	Dixonville, Battle River districts and part of Hawk Hills district (I. D. 138)	Part of Hawk Hills district, Keg River and Paddle Prairie districts (I. D. 146)	Fort Vermilion-High Level and Fort Vermilion-La Crête districts (I. D. 147)
Dairy products	1.1	1.0	1.2	—	—
Cattle, hogs and sheep (excluding those on dairy farms)	20.3	22.2	15.5	52.9	43.0
Poultry	0.3	0.5	0.5	—	0.7
Wheat	21.0	36.9	46.7	5.9	3.0
Small grains[2] (excluding those grown on wheat farms)	41.5	32.5	28.6	38.2	47.4
Field crops other than small grains	2.5	0.4	0.2	—	1.5
Fruits and vegetables	0.1	—	—	—	—
Miscellaneous specialties	1.4	0.1	0.2	—	—
Mixed-farm products					
Livestock	2.9	1.2	1.4	—	0.7
Field crops	7.3	3.2	3.9	2.9	0.7
Other	1.6	1.9	1.8	—	3.0

[1]Dominion Bureau of Statistics classification of commercial farms by type of farm. For this classification a criterion of 51.0 per cent or more of the total of sales was used. If, for example, a farm obtained 51.0 per cent or more of its total of agricultural sales from the sale of wheat, it was typed as a wheat farm.

[2]"Small grains" includes oilseed.

Note: The information in this table is derived from data supplied by the Census Division, D.B.S.

Table 3

*Economic classification of farms, 1961**
(percentage of all census farms)

Economic classification of farms	Alberta	Peace River region (Census Div. 15)	Dixonville-Fort Vermilion area (I.D. 138, 146, 147)	Dixonville, Battle River districts and part of Hawk Hills district (I.D. 138)	Part of Hawk Hills district, Keg River and Paddle Prairie districts (I.D. 146)	Fort Vermilion-High Level and Fort Vermilion-La Crête districts (I.D. 147)
Commercial	80.0	69.2	61.9	67.0	54.0	48.2
Small-scale Part-time	5.3	9.1	9.9	11.3	17.5	3.9
Other small-scale	8.0	11.8	15.9	11.4	20.6	28.6
Residential	6.0	9.6	12.1	10.2	6.4	18.9
Institutional	0.7	0.2	0.2	—	1.6	0.4

*For the Dominion Bureau of Statistics economic classification of farms see Census of Canada, 1961, D.B.S. Bulletin 5, 3–3, page xii.

Note: The information in this table is derived from data supplied by the Census Division, D.B.S.

classified as commercial. The low level of prosperity in the northern districts arises from the high cost of transportation, the presence of many newly established, undeveloped farms and the low standards of living prevailing on the métis farms. The financial situation of the northern farmers is made more difficult by the relative scarcity of channels of nonfarm work open to them. In these relatively isolated districts, apart from those localities immediately adjacent to Fort Vermilion and High Level, the opportunity of obtaining such work to supplement farm income is not so great as in the more southerly districts. Part-time work in highway construction, oil exploration, forestry and sawmill operation is more readily available to farmers in the southern districts. The fact is well illustrated by the low proportion of "part-time farms" and the high proportion of "other small-scale farms"* in the Fort Vermilion districts (Table 3).

*Farms whose reported agricultural sales were worth $250 to $1,199 and whose operators (1) worked off the farm less than 100 days and (2) reported the value of their agricultural sales as greater than the income they received from other sources.

Farm size and land improvement

The farmland in the area has been settled almost entirely through homestead sale and lease agreements administered by the provincial government; consequently, the size of initial holdings has been fairly uniform in all districts except the Paddle Prairie Métis Colony, where homestead regulations do not apply. Allotments are normally 160 or 320 acres—in recent years they have usually been the latter—but in special cases up to three quarter-sections (480 acres) may be granted. The median farm size (320 acres) is the same for all the districts where the homestead regulations apply; this reflects the uniform size of homestead grants.

In the more mature districts—the Keg River, Battle River and Dixonville—farm size has increased through consolidation. Because in the early period of homesteading, however, 160-acre grants were the most common, the consolidation has not made the farms in these districts much larger than those in the more recently settled localities, where the half-section allotments are now prevalent (Table 4).

Table 4

Farm size, period of occupancy, and condition of farmland, Dixonville-Fort Vermilion area

District[1]	Average farm size (acres)	Average period of occupancy[2] (years)	Average cultivated area per farm (acres)	Percentage of total farm area cultivated	Percentage of farms with 160 acres or more cultivated	Percentage of farms with 50 per cent or more of farm area cultivated	Average area of new breaking per farm (acres)
Fort Vermilion-La Crête	320	5	141	44	30	35	6.4
Fort Vermilion-High Level	482	11	192	40	44	25	8.5
Paddle Prairie (Métis Colony)	244	11	100	41	17	37	0.7
Keg River	467	11	219	47	49	37	2.1
Hawk Hills	382	6	170	45	41	36	9.3
Battle River	389	16	255	66	61	72	3.0
Dixonville	456	16	198	43	49	32	4.0
Dixonville-Fort Vermilion area	393	12	211	54	50	52	4.6

[1]The Fort Vermilion districts, 1961; all others, 1958.

[2]The average period farm operators have spent on their present farms.

About one fifth of the farms in all three mature districts have each 160 acres or less, while fewer than 11 per cent of the farms in the Hawk Hills and Fort Vermilion-High Level districts are in this size group. The Fort Vermilion-La Crête district has the highest percentage of small farms of any district except the Paddle Prairie. These originated primarily through the Mennonite practice of dividing farm holdings among members of the family. This practice, however, is no longer prevalent because additional Crown lands have been made available for settlement in the Mennonite area.

Farms in the Métis Colony are not comparable to those in the other districts in terms of size or most other farm characteristics. They are, for the most part, residential and lack both the size and the state of development necessary to make them capable of producing to maintain reasonable standards of living.

Although more than 50 per cent of the farmland in the study area is under cultivation, there is considerable variation among districts in the proportion of farm area cultivated (Table 4). Land improvement has been greatest in the Battle River district, where two thirds of the farmland is under cultivation. Here, because of the early emphasis placed on wheat for cash-cropping, the development of potentially arable land received priority. At the same time, favorable terrain conditions and the light vegetation cover permitted the utilization of a greater proportion of the farmland than in some other districts. Seventy-two per cent of the farms in this district have at least half their farm area under cultivation in contrast to 25 and 32 per cent, respectively, of the farms in the Fort Vermilion-High Level and Dixonville districts. The farms in these two districts are relatively well developed, their average cultivated areas being only a little smaller than those of the farms in the Keg River and Battle River districts, but their terrain conditions have led to a low ratio of potentially arable land per unit area. Unlike the other farmlands, the Dixonville and Fort Vermilion-High Level districts have no large unbroken blocks of potentially arable land. The lacustrine deposits are relatively shallow; till, frequently stony, occurs often as the surficial material; very poorly drained areas are frequent and of major extent. The resulting irregular and patchy distribution pattern of cultivated land contrasts markedly with the continuous pattern of arable land found in the farm areas on thicker lacustrine deposits. These conditions have created a tendency toward the formation of large farm units in the

Fort Vermilion-High Level and Dixonville districts since, to obtain equivalent areas of potentially arable land, a larger farm area is normally required there.

As expected, land improvement has not been as great in the Hawk Hills and Fort Vermilion-La Crête districts as in the older settlements. In view of the recency of most development in these districts, however, the cultivated area per farm is large and not far removed from the corresponding values for the older districts. Actually, the correlation between farm development and the age of settlement is not high, since factors other than the length of residence are important. Most of the métis farms and many of the original Mennonite farms, although as much as 30 years old, have been surpassed in area cultivated by many of the newly established homesteads. In the Hawk Hills district, where no farms existed in 1951, the average cultivated area per farm is only 28 acres smaller than the corresponding acreage for the Dixonville district. The amount of capital available for development, the type of equipment utilized in the clearing and breaking of land and the nature of the vegetation cover are more significant in farm development than the period of occupancy alone.

The first farmers in the study area had little capital and had the long and arduous task of clearing their land largely by hand. Present-day homesteaders are able to develop their farms more quickly and with relatively greater ease than the original settlers, although the need for capital is perhaps more crucial for the modern pioneer. This need for greater financial resources has been somewhat alleviated by improved farm-credit facilities, but many homesteaders are still short of capital. With adequate capitalization, the new homesteader, in the first few years of residence, can clear and make ready for cropping all the land he has available for cultivation.

The cost of clearing, piling, breaking and preparing land for cropping by the use of modern power machinery runs from $20 to $30 an acre, depending on tree cover (Can. Dept. Agr., 1959b). In areas of heavy vegetation, the cost of clearing alone can be four times as great as the cost of the same kind of work in lightly vegetated areas. Recent experiments made by the Prairie Farm Rehabilitation Administration with the "ball-and-chain" method of bush-clearing have indicated that clearing costs may be greatly reduced by introducing this new technique. When clearing large tracts of land by this method, the P.F.R.A. reduced the cost of clearing to about $3 an acre (*Western Weekly Supplement*, 1962). The widespread introduction of this clearing technique would radically change the outlook for farm

Table 5

Land-use and livestock statistics, Dixonville-Fort Vermilion area

District*		Number of farms	Farm area	Unimproved land	Area of new breaking	Cultivated land	Wheat	Oats	Barley	Flaxseed	Rapeseed	Cultivated grasses and legumes	Summer fallow	Number of cattle	Number of hogs
			(acres)												
Fort Vermilion-La Crête	Total	226	72,470	39,114	1,439	31,917	4,494	10,098	3,120	3,376	2,746	3,409	4,674	2,266	5,780
	Per farm		320	173	6.4	141	19.9	44.7	13.8	14.9	12.2	15.1	20.7	10.0	25.6
Fort Vermilion-High Level	Total	131	63,201	36,937	1,118	25,146	1,439	2,354	803	6,288	6,462	3,264	4,536	936	1,182
	Per farm		482	282	8.5	192	11.0	18.0	6.1	48.0	49.3	24.9	34.6	7.1	9.0
Paddle Prairie (Métis Colony)	Total	30	7,310	4,275	20	3,015	70	710	757	70	—	120	1,288	120	168
	Per farm		244	142	0.7	100	2.3	23.7	25.2	2.3	—	4.0	42.9	4.0	5.6
Keg River	Total	49	22,866	12,042	101	10,723	652	1,425	4,822	512	—	539	2,773	160	1,276
	Per farm		467	246	2.1	219	13.3	29.1	98.4	10.4	—	11.0	56.6	3.3	26.0
Hawk Hills	Total	75	28,669	15,222	701	12,746	1,333	317	2,179	980	1,761	700	5,476	36	367
	Per farm		382	203	9.3	170	17.8	4.2	29.1	13.1	23.5	9.3	73.0	0.5	4.9
Battle River	Total	595	231,681	78,171	1,775	151,735	38,307	13,676	27,634	7,251	3,403	12,812	48,652	2,352	8,595
	Per farm		389	131	3.0	255	64.4	23.0	46.4	12.2	5.7	21.5	81.8	4.0	14.4
Dixonville	Total	142	64,738	36,105	570	28,063	1,369	5,675	9,482	215	446	4,753	6,123	2,943	2,300
	Per farm		456	254	4.0	198	9.6	40.0	66.8	1.5	3.1	33.5	43.1	20.7	16.2
Total (Dixonville-Fort Vermilion area)	Total	1,248	490,935	221,866	5,724	263,345	47,664	34,255	48,797	18,692	14,818	25,597	73,522	8,813	19,668
	Per farm		393	178	4.6	211	38.2	27.4	39.1	15.0	11.9	20.5	58.9	7.1	15.8

*The Fort Vermilion districts, 1961; all others, 1958.

development in the Boreal Forest Region, where tree cover is one of the major physical impediments to agricultural development. The adoption of the ball-and-chain method of clearing will probably be restricted, however, since the cost of the equipment is beyond the reach of individual farmers.

As indicated in Table 4, virgin lands are being prepared for cropping in all districts of the study area, but as expected, the greatest areas of new breaking per farm are in the districts with the most recent homestead developments.

UTILIZATION OF IMPROVED LAND

Six basic crops are grown in the study area. Ranked by decreasing acreage they are barley, wheat, oats, forage grasses and legumes, flaxseed, and rapeseed (Table 5). Wheat and the oilseeds serve primarily as cash crops, while almost all the oat and barley production is associated with livestock programs. Some farms produce the feed grains as cash crops to be sold to livestock producers within the area. The grass and legume acreage yields both a cash crop for "export" to the "outside" as forage seed, and hay, which is used in the area by livestock producers.

As variation exists in agricultural emphasis from district to district, so there is considerable variation from district to district in the areal distribution of crops and in the relative importance of individual crops within districts (Figure 8).

Wheat

Postwar agricultural development in the study area has witnessed diversification in crop types. Wheat, although still very significant, has had to share its reputation as the frontier cash-producing crop with other crops, notably with the oilseeds.

It is physically possible to produce spring wheat successfully throughout most of the area. Spring wheat, however, still requires a growing season of 95 to 100 days. Production in most of the districts is therefore just within the climatic margin. In the Dixonville and Keg River districts, wheat-growing is severely limited by what seems to be great variability in the occurrence of frost.

Wheat is heavily concentrated in the Battle River district, the only one in which this crop ranks first in acreage. Here, from initial settlement to the present day, wheat has continued to play its traditional role of principal cash crop because physical conditions are, for the most part, favorable for

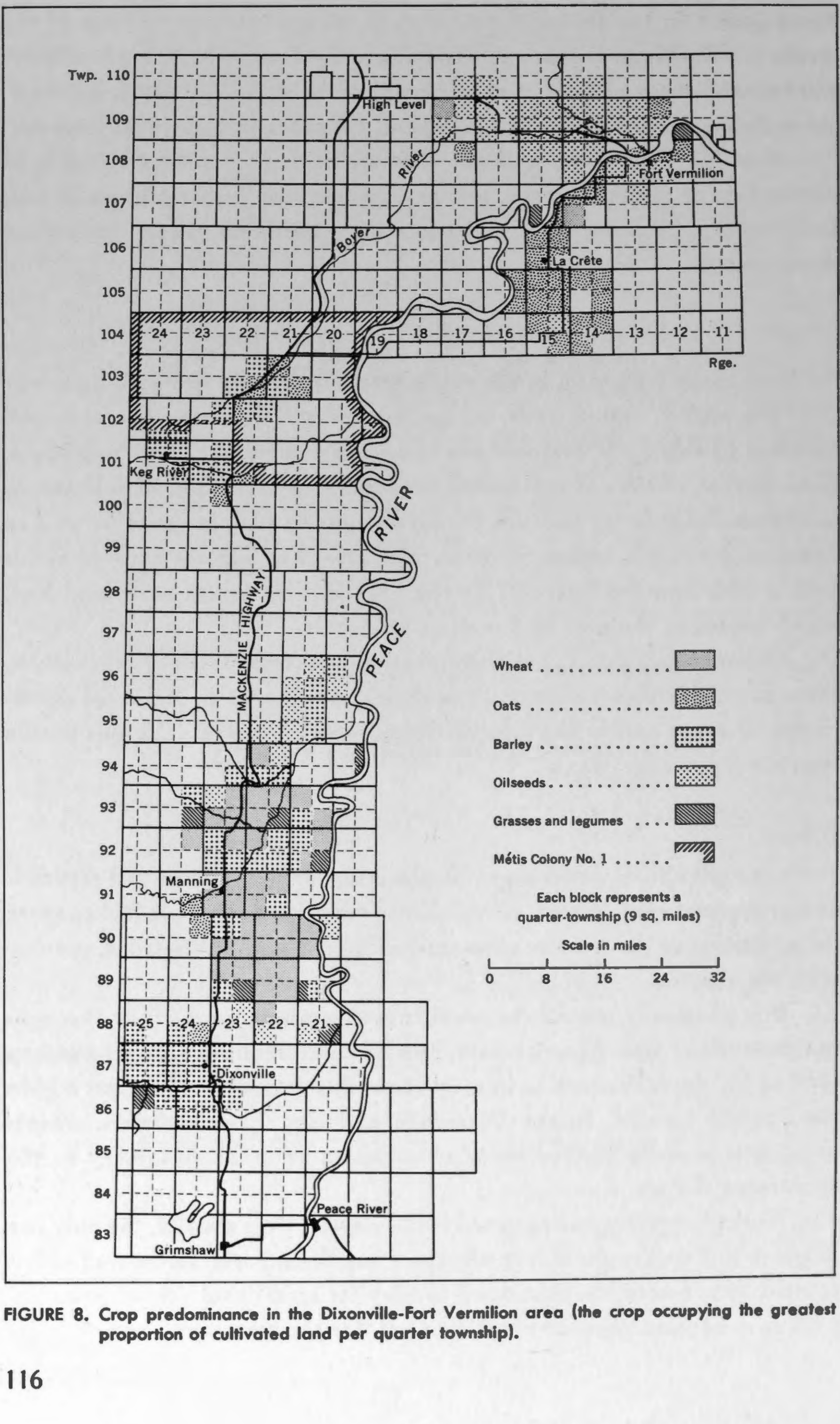

FIGURE 8. Crop predominance in the Dixonville-Fort Vermilion area (the crop occupying the greatest proportion of cultivated land per quarter township).

wheat production. From the first days of major settlement, access to the outside—over the market road built in the late 20's from the district to Grimshaw—has been comparatively easy. Moreover, because of the relative proximity to railhead, the effect of transportation costs on returns is less than in more northerly districts, and other crops have no marked advantage over wheat in terms of returns.

For both physical and economic reasons, the relative importance of wheat is much less outside the Battle River district. In the Dixonville and Keg River districts, as already noted, wheat production is restricted by climate. In the Hawk Hills district wheat is moderately important but, even though the net returns seem to be almost as favorable, it is not so dominant as in the Battle River district. In the remaining districts, where transportation costs work against the production of wheat as a cash crop, it ranks lower as a moneymaker, although some is grown as feed. The one exception is the Fort Vermilion-La Crête district, which has a high proportion of improved land in wheat. Although an estimated 20 to 25 per cent of the gross return for wheat* is required to ship the grain to railhead, some shipping *is* done, mainly by Mennonites. Economics suggest that it would be more profitable to concentrate wholly on livestock production or, as has been done in the Fort Vermilion-High Level district, to produce cash crops, which have higher values in relation to bulk. The strong cultural traditions of the Mennonites seem, however, to have prevailed over purely economic considerations, with the result that the farming practices generally follow the traditional livestock and wheat economy of the mixed-farming areas of the southern plains.

Oilseeds

Large-scale production of flaxseed and rapeseed is relatively new to western Canada, having developed only since about 1950. The introduction of these crops has been highly significant for farmers in the Dixonville-Fort Vermilion area, not only because their production involves the use of traditional grain-farming techniques and equipment but because they often yield a greater net return than wheat when high transportation costs are encountered.

Oilseeds have had their greatest impact in the northern districts, but their acreage is also significant in the Battle River district, where they supplement wheat as a cash crop. Specialization in their production is

*This estimate is based on information supplied by the elevator agent, United Grain Growers Ltd., Grimshaw, Alta.

greatest in the Fort Vermilion-High Level district, where they occupy more than 60 per cent of the land in crops. Here the concentration of rapeseed output is especially high. Although the last-mentioned district has roughly only 10 per cent of the study area's farms and cultivated land, it has more than 40 per cent of the rapeseed acreage. This heavy emphasis on oilseed production has resulted from attempts of the Ukrainian-dominated community to minimize the effects of high transportation costs on their farm operations.

Significant oilseed production in the Fort Vermilion-La Crête district is restricted almost entirely to the non-Mennonite farms. The Mennonite community, apparently because of its insular character and its adherence to traditional crops, has largely neglected the oilseeds as supplemental or alternative to wheat despite the structure of transportation costs and its effect on returns.

Moderate oilseed emphasis exists also in the Hawk Hills district, where rapeseed ranks first among crops in acreage.

Feed grains

A combination of factors has contributed to give the feed grains the greatest acreage in the area. Livestock and feed grains are produced in association in all districts, but their importance in relation to cash-cropping varies from district to district.

The widespread distribution of oats and barley is explained largely by climate and the physical characteristics of the crops. Barley, which has a short maturing period, can be grown where wheat and oilseeds are limited by frost hazard. Oats have a longer growing season than barley but mature more quickly than wheat and are less specific than barley in their soil requirements. Together, oats and barley occupy almost 44 per cent of the land under crop. They have significant acreages everywhere and are dominant in four of the seven districts. Specialization in feed-grain production is greatest in those districts where the growth of wheat and oilseeds is limited by climatic hazards. Feed grains occupy 69 and 78 per cent, respectively, of the crop acreage in the Dixonville and Keg River districts; 85 per cent of the small acreage under crop in the Métis Colony is occupied by feed grains. The Fort Vermilion-La Crête district is the remaining area of feed-grain dominance.

Barley exceeds oats in acreage by varying margins in all except the Fort Vermilion districts, where the oat acreage is about three times that of barley. The over-all emphasis on barley can be attributed largely to its short maturing period and its usefulness as both a cattle and a swine feed. Barley is much higher in nutrients than oats and is at about the same level in protein. As a single feed for swine-raising, barley is more efficient than oats. The heavy emphasis on oats in the Fort Vermilion-La Crête district is partly due to the conventionally oriented Mennonite farm practices. Oats, the traditional feed grain, holds first place in Mennonite crop acreage. In addition, barley is not regarded as a reliable crop in this district.

Economic necessity requires that almost all the feed grain produced be utilized within the study area. The high transportation costs that make the marketing of wheat and oilseeds almost marginal make the cost of shipping the low-value bulky feed grains to elevators prohibitive. As livestock-raising provides a means of disposing of the feed grains, a relatively strong correlation exists between the distribution of these grains and livestock.

Livestock specialization is greatest in districts far from railhead or where the production of wheat and oilseed is limited by climate. Lacking significant wheat or oilseed output the Dixonville and Keg River districts specialize heavily in feed grains and livestock. In the Dixonville district are maintained the largest and best-quality herds of beef cattle in the study area. The livestock program in the Keg River settlement leans strongly toward swine.

In the Fort Vermilion-La Crête district, especially in its Mennonite section, livestock plays an important part in the farm economy. The large oat crop on the Mennonite lands can be marketed only through livestock. Both cattle and swine are raised. Here, as elsewhere in the study area, cattle serve the dual purpose of beef and cream production. Some cream is shipped to southern creameries; the remaining skim milk is used in swine rations. Although there is livestock production in the Fort Vermilion-High Level district, it is secondary to cash-cropping in the farm economy. Large numbers of cattle and swine are also raised in the Battle River district, but here also livestock-raising is definitely secondary to grain production for cash crops. Water shortages in the district limit the scale of beef and swine production on many of its farms. Only the Hawk Hills district seems to be "livestock-deficient": since its initial settlement, not enough time has elapsed for the development of large herds.

Cultivated grasses and legumes

Grasses and legumes are utilized in the area in two basic ways. They are important in cash-cropping because of the high value of their seed; and they provide the basis for cattle-raising in their role as cheap and abundant roughages. In addition, legumes play a significant role in maintaining and improving soil fertility by increasing the available nitrogen in the generally nitrogen-deficient soils.

The production of grasses and legumes for seed is most attractive to the farmers in the Fort Vermilion districts, since forage seed has a higher value in relation to bulk and can withstand the high marketing costs much better than the other cash crops grown. Most of the farms producing forage seed in these districts lie around the settlement of Fort Vermilion and in the Rocky Lane-High Level neighborhood. Very little forage seed is produced in the Mennonite and métis sections of the districts.

Despite its high value, forage seed is subject to extreme variations in yield from year to year. Alfalfa-seed yields in particular undergo major fluctuations because of changes in the wild-bee population, the main pollinating agent. Occasionally the seed crop is a total failure, and the coarse, mature grass or legume plants can be used only as low-quality hay or green manure. For this reason forage-seed production does not reach a high degree of specialization on the individually operated farms. Grass and legume crops are best combined with others in crop rotation, in which they serve not only as potential cash crops but also as soil conditioners. Only on the large corporate farms is the production of forage seed the sole agricultural activity. These farms have the financial resources to withstand crop failure and the trained personnel and equipment to carry out the promotion of more efficient pollination, the selection of more suitable varieties and the improvement of grades.

The Dixonville district is where the forage crops reach their greatest acreage in relation to other crops. There they are utilized as roughages for cattle.

Cultivated pasture is not extensively used in the study area, and even the large beef farms have only relatively small areas of it. The deficiency seems due, in part, to the abundance of unimproved land that serves as "bush pasture" and to the low priority given improved pasture when the small available amounts of improved acreage are allocated. This is especially true in the areas of recent homesteading.

TRENDS IN AGRICULTURAL LAND UTILIZATION

Two of the three basic factors that have led to the present land-utilization pattern of the Dixonville-Fort Vermilion area are undergoing major modification. One factor, the structure of transportation costs, is being altered dramatically by the coming of the railway; the other, the distinct ethnic traits, notably those of the Mennonite community, are rapidly breaking down under the diversified influences of new settlers, who continue to flow in. Only the climatic limitations remain unchanged. Even these, however, are in some respects relative because newly developed crop varieties increase the scope of agriculture and make types and methods of farming more diverse and adaptable.

The most important factor to consider in predicting the future land-use trends of the area is the effect of rail transport on shipping charges. The new railroad will not affect all types of farming in the same way: while promoting some types of production, it will have little or no influence on others. Least affected will be the livestock production, because truck transport can compete effectively with railways in livestock-hauling. Most favorably affected by the new tariffs should be the production of cereal grain, since the existing Crowsnest Pass statutory freight rates may be expected to apply on grain shipments for export. It has been stated that when shipping is switched from road to rail, the freight rates on grain for export will drop from $7\frac{1}{2}$ cents to $\frac{1}{2}$ cent a ton mile (Manning, 1960). This decrease will provide a strong economic incentive for the cash-crop production of cereal grains. While it thus reinforces the present agricultural pattern of the Battle River district, it will undoubtedly cause production to shift away from oilseed, forage-seed and livestock programs in the northern districts.

Recent road development and the coming of the railway will end the era of the outpost community and the isolated agricultural settlement and will initiate full integration with the outside world. The savings that will accrue to grain farmers from rail transportation will permit a faster rate of land improvement on present farms and will stimulate further settlement. In time, the standards of living in most of the districts will approximate those enjoyed in other parts of the Peace River region and in the rest of the province. Only the members of the original Mennonite community, who can no longer live in isolation unaffected by the "ways of the world," will suffer from greater integration with the outside. Many have already left, seeking refuge in the few remaining parts of the world where "modernism" has yet to penetrate.

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DIFFERENT METHODS OF CALCULATING MEAN DAILY TEMPERATURES, THEIR EFFECTS ON DEGREE-DAY TOTALS IN THE HIGH ARCTIC AND THEIR SIGNIFICANCE TO GLACIOLOGY

K. C. Arnold and D. K. MacKay

ABSTRACT: When the range of temperatures is close to the freezing point, different methods of determining mean daily temperatures can cause disparities in melting and freezing degree-day totals. On the basis of data collected under such conditions, the disparities are examined and their relevancy to glaciological studies is considered.

RÉSUMÉ: Lorsque la gamme de températures oscille autour du point de congélation, différentes façons de déterminer les moyennes de températures quotidiennes peuvent entraîner des écarts dans les totaux des degrés-jours de dégel et de gel. Compte tenu des données recueillies dans de telles conditions, les auteurs examinent les écarts en cause et tentent de déterminer l'influence qu'elles pourraient avoir sur les études glaciologiques.

The concept of the degree day was introduced by Réaumur in relation to the growth of plants (Landsberg, 1958). He assumed that growth starts when temperatures rise above 5°C, and that it is proportional to the accumulated temperatures above this chosen threshold. Heating engineers in North America have used 65°F as a threshold below which differences of temperature are accumulated to estimate the severity of a heating season.

The temperature at which fresh or salt water freezes is an obvious natural threshold, and the concept of melting and freezing degree days has been used in freeze-up and break-up studies. On glaciers, the number of melting degree days is a useful measure of the intensity of an ablation season, and the concept may be used in relating long-term temperature records to observed historical fluctuations of glaciers.

The glaciologist, however, should be cautious in applying this concept to his studies, which so often deal with marginal freezing or thawing conditions. In the critical periods before freeze-up and break-up, and in the short ablation seasons typical of the high Arctic, degree-day totals are small, and errors in determining these totals have greater relative significance. In this study, using data collected under such marginal conditions, the authors examine disparities caused by different methods of calculating mean daily temperatures.

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The usual method of determining degree-day totals involves summing the departures of published mean daily temperatures from the desired base. In Arctic areas, however, the national methods of calculating mean daily temperatures are not uniform.

Table 1

Methods of calculating mean daily temperatures in arctic and subarctic areas

Alaska, Canada	1/2 (daily maximum plus daily minimum)
Greenland (Upernavik)	1/9 (2(08 + 14) + 5(21))
Iceland (Grimsey) 1941–48	1/10 (5(08) + 14 + 17 + 3(21))
1948 onward	1/8 (total of 3 hours observed—02, 05 and 20 interpolated by diagram)
Norway	"Means were obtained by the formula m = n-k(n-Min) in which m is the mean temperature; n is the average temperature for the hours 1/3(08 + 14 + 19) during 1941 to 1948 and 1/3(07 + 14 + 19) during 1949 to 1950, 15° E. meridian time; Min is the mean of the daily minima; and k is a factor which differs by months. (See Köppen's formula, Jahrbuch d. Norway Met. Instituts für 1929, pp. IX-X.)"
U.S.S.R.	1/3 (07 + 13 + 21)

Source: *World Weather Records*, 1941–50, Weather Bureau, U.S. Department of Commerce.

A mean based on the daily maximum and minimum may be representative of temperature conditions throughout the day if the diurnal range of temperature is large in comparison with the changes due to shifting weather patterns. In the high Arctic, however, conditions are different. There is little diurnal range in the radiational heat supply, and a thermograph trace shows periods with little variation that are broken only by occasional rises and falls in temperature. Under these conditions a mean based on extreme daily values places undue emphasis on the rises and falls of temperature, which are not necessarily characteristic of the climatological day.

The approximation to the mean improves as the number of values, observed at regular intervals, increases. As a degree day is essentially an integration of temperature with time, a continuously recording device will give the best estimate of the mean. If allowance is made for instrumental limitations, an accurately and frequently calibrated thermograph trace will give a good result.

The observations discussed were taken during June, July and August of 1961 and 1962, near the summit of the small ice cap on Meighen Island, N.W.T. (80°N, 99½°W). The mean cloudiness during the summer months is high, and fog is frequent. These conditions lower air temperatures, but sudden rises do occur with a break in cloud cover or a shift in wind direction, or in periods of very light winds. Sudden drops in temperature can also occur but are not as frequent during the summer. On the ice cap the summer temperatures are close to freezing, and the melt season is from four to six weeks long.

The thermometers and thermohydrograph used on Meighen Island were exposed in a standard Stevenson screen. The screen was unaspirated. The maximum and minimum thermometers were mounted some 20 centimeters above the dry-bulb thermometer, which was in turn some 40 centimeters above the sensing element of the Lambrecht thermohydrograph. In this type of screen some thermal stratification may develop when wind speeds drop, and a real difference may occur between readings at the different levels. It is an assumption of this study that changes of temperature at the three levels will be the same and that the thermograph trace provides the best estimate of the trend of dry-bulb temperatures between synoptic observations.

These observations were taken at three-hour intervals in 1961 and at six-hour intervals in 1962. The thermograph traces were adjusted with reference to the dry-bulb readings at each observation, and care was taken to apportion the corrections properly to melting and freezing degree days. Each thermograph trace was enlarged and placed on graph paper. Areas were calculated both by using a planimeter and by counting squares. The counting error on a weekly trace is about half a Fahrenheit degree day. Errors inherent in the trace, such as the thickness of the pen line and the lag of the instrument, have been largely allowed for in the method of adjusting the trace. The time on the chart could be identified accurately by the surge marks made when the screen was opened. Any residual errors tend to be compensatory.

The summer of 1961 was one of the four coolest summers since 1948, when records were begun at Isachsen weather station. On the ice cap of Meighen Island no month had an average temperature above freezing, that for July being 31.8°F. The number of degree days calculated from the mean daily temperature based on extreme readings was less than that given by the calibrated thermograph trace. The mean of the synoptic observations came very close, and there was little difference between the totals of the observations taken six hours and three hours apart. The freezing degree-day totals also showed that the coldness of the season had been exaggerated by the mean daily temperatures (Table 2).

Table 2

1961—Melting and freezing degree days during ablation season

Date	Melting, calculated from:				Freezing, calculated from:			
	½(max.+min.)	6-hr. obs.	3-hr. obs.	Trace	½(max.+min.)	6-hr. obs.	3-hr. obs.	Trace
June 12–19	0.0	0.2	0.4	0.4	25.3	19.8	19.9	21.4
19–26	1.0	1.4	1.4	1.4	11.0	10.1	10.9	10.1
26–3	0.0	0.6	0.7	0.9	18.4	17.6	16.9	15.8
July 3–10	7.1	6.1	6.3	6.2	3.8	4.7	4.4	5.8
10–17	3.8	5.2	5.5	5.3	6.4	5.5	5.4	6.0
17–24	7.3	10.2	9.8	9.4	1.2	3.2	2.6	3.0
24–31	6.1	6.6	6.6	6.7	17.2	16.0	15.4	15.4
31–7	37.1	39.7	38.4	40.9	2.6	5.2	5.4	5.4
Aug. 7–14	1.9	4.4	4.2	3.5	12.4	8.6	8.6	8.5
14–21	9.7	9.4	9.2	9.7	15.4	17.8	17.9	17.7
21–28	0.0	0.0	0.0	0.0	65.4	62.2	64.2	63.1
28–31	0.0	0.0	0.0	0.0	59.6	54.3	52.5	51.3
Totals	74.0	83.8	82.5	84.4	238.7	225.0	224.1	223.5

Table 3

1962—Melting and freezing degree days during ablation season

Date	Melting, calculated from:			Freezing, calculated from:		
	½(max.+min.)	6-hr. obs.	Trace	½(max.+min.)	6-hr. obs.	Trace
June 5–11	3.1	3.6	4.7	5.2	5.8	6.1
11–18	10.5	13.4	10.7	6.9	5.9	5.5
18–25	8.0	3.8	5.3	12.0	13.2	14.2
25–2	1.6	1.6	1.6	12.0	12.9	13.5
July 2–9	25.5	26.0	26.2	1.5	0.6	0.6
9–16	75.8	77.2	75.4	0.0	0.0	0.0
16–23	73.5	58.9	60.8	0.0	0.8	1.0
23–30	0.0	3.3	2.9	9.6	8.0	7.8
30–6	17.2	21.6	17.7	1.4	2.6	3.6
Aug. 6–13	10.6	7.0	8.3	10.9	11.8	12.2
13–20	0.0	0.0	0.0	39.5	39.2	38.9
Totals	225.8	216.4	213.6	99.0	100.8	103.4

In contrast, the summer of 1962 was very warm. Isachsen recorded its all-time maximum temperature of 72°F on July 21. This was a very warm month on the Meighen Island ice cap, with a mean monthly temperature of 37.2°F. The melting degree-day totals were about three times as high as those of the year before. It is interesting to note that the standard method of computing the mean exaggerated the warmth of this summer (Table 3).

The diagram accompanying this text shows maximum and minimum temperatures, six-hourly dry-bulb temperatures and the adjusted thermograph trace for the warmest period on the ice cap during the summer of 1962. The maximum and minimum temperatures do not apply to the same time intervals, but overlap by 12 hours (Can. Dept. Transp., *MANOBS*). The maximum temperature is for the 24-hour period ending at 1200 hours GMT (0500 hours next local date), and the minimum is for the 24 hours ending at 0000 GMT (1700 hours local date). The trace indicated that the maximum temperatures had been influenced by surges of temperature that occurred on July 17 and 20. The one that occurred on July 17 was probably due to the opening of the screen at the time of the observations and to a lapse in time between the readings of the dry-bulb and maximum thermometers, the dry-bulb thermometer always being read first. As the area under it is negligible, such a sharp peak has little effect on the totals shown by the thermograph trace.

When daily freezing and thawing cycles occur, the use of daily extreme values may eliminate some freezing or melting degree days altogether, as in the trace for July 23-30, 1962. This is a source of error when the intensity of the melt season is computed by the standard means. The error has great significance for the glaciologist where the melt season is marginal or when ablation seasons are abnormally cold.

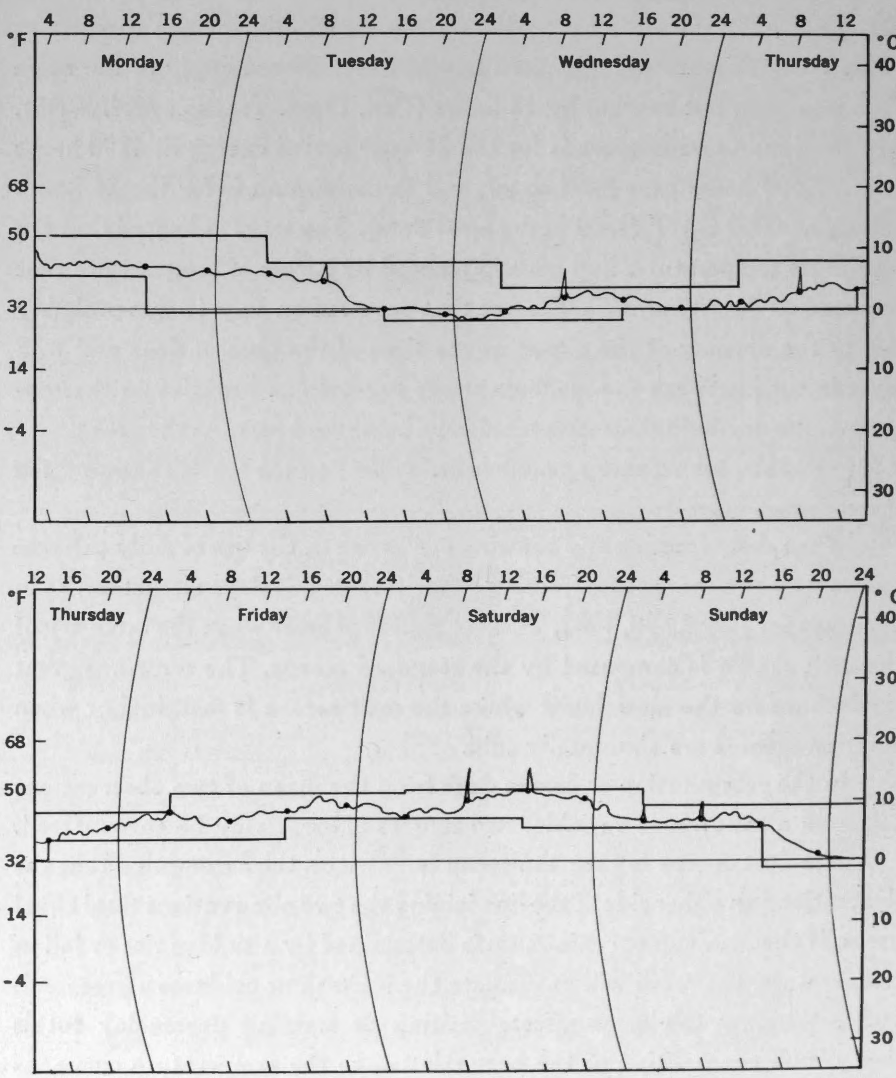
In the computation of degree days from the mean of two observations taken on a continuous variable, two sources of error may be encountered.

The first source is that the mean is based on the assumption that the fluctuations on either side of the line joining the two observations total equal areas. If the maximum or minimum is determined by a sudden rise or fall in temperature, the mean will exaggerate the warmth or coldness correspondingly. Whether the error affects melting or freezing degree-day totals depends on the position of the base relative to the temperature curve, as shown in Table 4.

Table 4

Effect of peakedness on degree-day totals

	Sharp rise at maximum	Sharp drop at minimum
Base above curve, freezing degree days	Decreased	Increased
Base below curve, melting degree days	Increased	Decreased



The week of July 16-23, 1962, with maximum and minimum temperature, six-hourly dry-bulb readings and an adjusted thermograph trace.

The second source of error arises when the base lies between the maximum and minimum temperatures. The error can eliminate some freezing or melting degree days, depending upon the daily range and the proximity of the base to the maximum or minimum. For example, with a maximum of 33°F and a minimum of 31°F, a day is shown without melting or freezing degree totals. The same result is given by a day of entirely different character, with a maximum of 42°F and a minimum of 22°F.

When the base lies within the daily extremes, errors can occur as shown in Table 5.

Table 5

Effect of daily fluctuation about the base on degree-day totals

Mean	Melting degree days	Freezing degree days
At base	Eliminated	Eliminated
Above base	Over– or underestimated*	Eliminated
Below base	Eliminated	Over– or underestimated*

*The over– or underestimate decreases as the maximum or minimum temperature approaches the base, but the amount and its plus or minus value are greatly influenced by the shape of the temperature curve. There seems to be no simple relation.

If these conditions are likely to occur, it is better to compute degree-day totals from the dry-bulb synoptic observations. There seems to be little advantage in using three-hourly observations, since six-hourly observations give a good approximation. The international differences in methods of calculating mean daily temperatures might also be considered when long-term temperature records are being compared. A record from Upernavik, in West Greenland, might not be strictly comparable with one from a station on the west side of Baffin Bay. The data from Meighen Island suggest that the degree-day totals based on daily extreme values have exaggerated the intensity of warm and cold seasons. As Table 5 shows, however, a small shift in mean temperature could have produced a different result.

It follows that in glaciological studies a more careful estimate of degree-day totals is justified, particularly when air temperatures fluctuate across the base from which the totals are calculated.

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CANADIAN PERMANENT COMMITTEE ON GEOGRAPHICAL NAMES

J. Keith Fraser

In 1897, after receiving recommendations from surveyors, cartographers and others who were concerned with the lack of standardization of geographical names in Canada, the federal government established the Geographic Board of Canada. The Board was intended not only to supervise and standardize geographical nomenclature but also to carry out research on the geography of Canada. Over the next 30 years, the Board's annual reports contained occasional geographical studies, mainly toponymic, but its function was gradually reduced to the verification to nomenclature for the increasing program of map production and to the recording of names. Formed initially of senior federal civil servants, the Board was soon altered to include provincial representatives who were aware of particular regional problems and acted as advisers on contentious matters.

Mainly owing to this change in emphasis from geographical research to more strictly nomenclatural work, the Geographic Board of Canada was reorganized in 1948 as the Canadian Board on Geographical Names. Over the next decade, this body published the *Gazetteer of Canada* series, which began in 1953 with the volume for British Columbia. By 1962, gazetteers of all the provinces except Quebec and Newfoundland had been published, and a provisional gazetteer had been issued for the Yukon and the Northwest Territories. The gazetteer for Newfoundland is in preparation.

To provide for geographical research in Canadian toponymy and to accommodate the authority of the provinces in the matter of place names, the Canadian Board on Geographical Names was replaced in 1961 by the Canadian Permanent Committee on Geographical Names. The present composition of the Permanent Committee is as follows: the Director, Geographical Branch, Department of Mines and Technical Surveys; the Director, Surveys and Mapping Branch, Department of Mines and Technical Surveys; the Director of Military Survey, Department of National Defence; the Superintendent, Bureau for Translations, Department of the Secretary of State; the Dominion Archivist; a representative for the Territories, appointed by the Minister of Northern Affairs and National Resources; and a representative appointed by each of the provincial governments. Quebec, Alberta and Newfoundland have established provincial name boards, the secretaries of which act as representatives on the Permanent Committee. The recording unit, formerly with the Topographical Survey, was transferred to the Toponymy Division of the Geographical Branch, which is also equipped to enable professional geographers to undertake research in Canadian toponymy.

It is the responsibility of the Permanent Committee to deal with all questions of geographical nomenclature affecting Canada, and to undertake research on the origin and usage of geographical names. All decisions made by the Permanent Committee become official when approved by the Minister of Mines and Technical Surveys or the appropriate provincial minister, according to the jurisdiction concerned. The Permanent Committee meets in plenary session annually. Names are investigated and recorded by the Toponymy Division. The processing of new names and name changes is facilitated by means of the Executive Committee of the Permanent Committee, which acts on the advice of the Toponymy Division and the recommendations of the provincial representatives.

A number of nomenclatural principles have been evolved since 1897 to guide the decisions of the names authority. Certain tenets were formulated through experience and in 1963 were adopted in a form acceptable to all the provinces and agencies represented on the Permanent Committee. It should be emphasized that these are not mandatory regulations but carefully considered guiding principles by which the standardization of Canadian geographical names is controlled.

Inquiries concerning names, or proposals concerning new names, name changes or changes in the application of existing names, should be submitted in writing to the Chairman, Canadian Permanent Committee on Geographical Names, Geographical Branch, Department of Mines and Technical Surveys, Ottawa. The guiding principles* should be studied to ascertain the suitability of the proposed names, each of which must be accompanied by adequate information on its origin or usage and identified on a map, sketch or air photograph. The Permanent Committee welcomes reliable, preferably documented information concerning corrections of nomenclature appearing on Canadian maps and charts.

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*A booklet outlining the organization and functions of the Canadian Permanent Committee on Geographical Names and listing the guiding principles is obtainable on request from the Director, Geographical Branch, Department of Mines and Technical Surveys, 601 Booth Street, Ottawa.

GUIDING PRINCIPLES

1. *Names governed by statutory authority*

The names of cities, towns, villages, post offices, counties, townships, districts, reserves, parks and other legal divisions as created by, or resulting from, legislation passed by the appropriate government shall be accepted by the Committee.

2. *Names given by railway companies or resource-development companies*

Railway companies, major utilities and resource-development companies should seek the advice of the Committee concerning the use of geographical names connected with their operations.

3. *Names in public use*

First consideration should be given to names well established in public use.

Unless there are good reasons to the contrary, this principle should prevail when it conflicts with any of the following principles. Local usage should be the prime consideration in settled areas, whereas historical significance should be emphasized in unpopulated areas.

4. *Uniformity of names*

Names applying to features in a given locality should be in conformity.

Examples of disconformity are:

(a) A difference in the name as applied to the post office, town or railway station for the same settlement.

(b) A difference in the spelling of a name of the same origin as applied to related features.

(c) A difference in the name as applied to different sections of the same feature, as when the different sections of a river are separated by natural or artificial lakes.

5. *Duplication of names*

Duplication of names to the extent that it may cause confusion should be avoided.

A major feature should not be duplicated, at least within a province, whereas a very minor feature in a settled area need not be restricted beyond the area of a smaller administrative unit, such as a township or parish.

6. *Personal names*

Personal names should not be used unless it is in the public interest to honor a person by applying his name to a geographical feature.

The application of a personal name during the lifetime of the person concerned should be made only in exceptional circumstances. Ownership of land should never in itself be grounds for the application of the owner's or donor's name to a geographical feature included therein.

7. *English and French names*

The adoption of both an English and a French form of a name for the same feature should be avoided unless both forms have the sanction of well-established usage.

This applies generally to major features; minor features should be named in one language only.

8. *Indian and Eskimo names*

(a) Indian names for which there are no accepted forms will be recorded according to a recognized local orthography or according to the considered opinion of a recognized linguistic or ethnographic authority.

(b) Eskimo names for which there are no accepted forms will be recorded according to a recognized national orthography.

9. *Form and character of names*

Names should be concise, euphonious and in good taste.

Forms that should usually be avoided are:

(a) Unnatural or incongruous combinations of words, including combinations of words of different languages.

(b) In the case of a personal name, the use of both Christian name and surname or a combination of the two.

(c) Inclusion of the apostrophe in the English possessive form.

(d) Qualifying terms such as "Upper," "South," "West Branch," etc.

(e) Double naming—for example, Red (Green) Creek.

(f) Long and difficult Indian or Eskimo names.

(g) Corrupted or modified names.

(h) A name with a connotation of obscenity or blasphemy.

(i) A name that would seem discriminatory or derogatory from the point of view of race, color or creed.

(j) A name that could be construed as advertising a particular commercial or industrial enterprise.

10. *Generic names*

The generic name must be appropriate to the nature of the feature, and its position shall be as dictated by euphony and usage.

The choice of the language used in any given publication is at the discretion of the publisher, but the generic name shall be recorded only in the language having priority in local usage or origin.

11. *Names outside Canada*

For the European area, the form used shall conform to the rules prescribed by the NATO Military Agency for Standardization, which include the nomenclature regulations of the International Hydrographic Bureau. For other areas, usage should be based on that of the national names authority or that of the United Nations.

Conventional names in English or French may be used on maps of very small scale and in textual material at the discretion of the publisher.

12. *Origin of names*

No name shall be accepted unless the Committee is provided with adequate information on its origin and usage.

MAP NOTES—FICHES CARTOGRAPHIQUES

CANADIAN LAND-USE SERIES. Geog. Br., Dept. Mines and Tech. Surv., Ottawa.

Eight additional multicolored land-use maps have been published in this series: two of Prince Edward Island at a scale of 1:126,720; two of the Niagara Peninsula area at a scale of 1:50,000; and four of southeastern British Columbia at a scale of 1:50,000.

Prince Edward Island (1:126,720)

Queens County
Kings County

Colored land-use maps of Prince Edward Island are complete with the publication of these two sheets. Prince County was published in 1962, and the scale of the maps, 2 miles to the inch, corresponds to the scale of the soil maps of the province. The 20 land-use categories, identified by field investigation in 1959 and 1960, are superimposed on National Topographic System bases. The information on the areas covered by oyster leases was provided by the federal Department of Fisheries.

(A. R.)

Ontario (1:50,000)

Dunnville West (30L/13W) and Grimsby West (30M/4W)

The Dunnville and Grimsby sheets are the seventh and eighth to be published in the series of 11 (1:50,000) land-use maps that will cover the Niagara Peninsula.

The Dunnville West sheet shows a portion of the Haldimand clay plain, a large lowland of poorly and imperfectly drained clay soils that includes most of the peninsula south of the Niagara escarpment. Hay, grain and improved pasture occupy practically all the agricultural land shown on the sheet, reflecting the emphasis placed on dairying and mixed farming throughout the area. The Lake Erie shore is lined with summer cottages; most are owned by residents of the Buffalo and Hamilton areas.

The Grimsby West sheet shows the impact of the expansion of Hamilton on the surrounding countryside. The city's built-up residential area, expanding rapidly to the south above the escarpment, is separated from the bordering farms by a belt of open grassland that represents idle farmland awaiting urban development. Below the escarpment the Fruit Belt is being squeezed out by urban expansion from Hamilton in the west and Stoney Creek in the east.

(J.B.M.)

British Columbia (1:50,000)

Sidney (92B/11/W) and Sooke (92B/5/E)

With the publication of the Sidney and Sooke sheets, the land-use map coverage of southeastern Vancouver Island is complete. These sheets, with the Shawinigan and Victoria land-use maps, show the pattern of land-use in greater Victoria and the surrounding area, the second most densely populated area of British Columbia.

The Sidney sheet, covering the Saanich Peninsula north of Victoria, shows clearly the horticultural zones for which the peninsula is noted. It also provides a good illustration of urban-sprawl patterns penetrating a rich agricultural area. Urban areas occur almost continuously from Victoria north through the horticultural areas to the northern parts of the peninsula.

Most of the area covered by the Sooke sheet is mountainous, with settlement restricted to the coast and a few valleys. Settlement is primarily nonagricultural and is concentrated in a small number of centres. Large cut-over areas in the mountains indicate the important economic activity of the area—forestry.

Vancouver South (92G/5) and New Westminster East (92G/2E)

The Vancouver South and New Westminster East sheets are the first to be published of six land-use maps covering the lower Fraser Valley of British Columbia.

The Vancouver South sheet presents an excellent study in urbanization since it covers part of a metropolis and the surrounding area, where urban expansion has been pronounced in recent years. Shown are: completely built-up urban areas, urban sprawl zones that have undergone relatively uncontrolled urban expansion and subsequent disturbance to agricultural activities, and relatively good agricultural areas where sprawl conditions are still embryonic in character.

The area covered by the New Westminster East sheet, approximately 15 miles east of Vancouver, is within the urban shadow of the metropolis. Agricultural activity and urban development are intermixed throughout the area. Two urban-sprawl patterns characteristic of the region are well illustrated: intermittent urban development along major traffic arteries—the familiar "ribbon development"; and scattered, low density, nonfarm residential development in the highland areas.

(J.M.)

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