GEOMORPHOLOGY AND GLACIAL HISTORY OF CENTRAL AREA OF NAHANNI NATIONAL PARK

THE GEOMORPHOLOGY AND GLACIAL HISTORY OF THE CENTRAL AREA OF NAHANNI NATIONAL PARK: A PRELIMINARY VIEW

by

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ABSTRACT

A preliminary study of the geomorphology and glacial history of the central portion of Nahanni National Park in the District of Mackenzie, N.W.T. was undertaken. To provide a context for the work a comprehensive review of the literature dealing with the glacial history of the entire Yukon-Western District of Mackenzie Region is attempted and the various chronologies for different areas within the region are correlated. The subject area itself, 2,600 sq. km. in size and constituting the central portion of the Park was studied through the use of aerial photographs supplemented by limited field work. A geomorphic map of the glacial, glaciofluvial, gluvial and peri-glacial features of the Central Nahanni has been prepared at a scale of 1:125,000. Of particular note is the presence of extensive deposits of lacustrine silts.

Detailed study of the extent, stratigraphy and lithology of the lacustrine deposits indicates that on two separate occasions in the past a large proglacial lake occupied the lower Flat and central South Nahanni river valleys to a minimum elevation of 610 meters. The younger lake has been named Lake Nahanni and the older lake, of considerably greater age, is herein named Lake Caribou. Evidence from within the study area in conjunction with results obtained in other areas within the region is utilized to present a glacial chronology for the Central Nahanni. In this chronology it is suggested that Lake Nahanni is early Wisconsin or older in age. Lake Caribou is considered to be pre-Wisconsin in age.

The study area from ERTS imagery

ACKNOWLEDGEMENT

I would like to take this opportunity to thank my supervisor Professor Ford for his support, guidance, encouragement and above all for his unending patience with a student who had much to learn and needed much time to learn it. My gratitude, moreover, must extend beyond the scope of this masters thesis. From Professor Ford I have learnt many of the lessons which enabled me to undertake the work upon which I am presently engaged.

TABLE OF CONTENTS

FIGURES

Page

TABLES

PLATES

INTRODUCTION

Hughes has remarked that "the great range in age of the glacial features displayed in the (Yukon - Western District of Mackenzie) area is unique in Canada", (Hughes, 1969). This view seems well founded for one finds in this single region, in addition to the present glaciers, evidence of Neoglaciation, Late Wisconsin glaciation, earlier glaciations, and an apparently unglaciated area. Moreover, there is also evidence which suggests early Pleistocene glaciation of the region. Such a situation makes the Yukon - Western District of Mackenzie extremely interesting for the study of both geomorphology and glacial history. At the same time, however, the area is also one of the most difficult to deal with for although the study of any area which has undergone multiple glaciations is often demanding, the inaccessibility of much of the Yukon prevents systematic study on the ground and has forced workers to rely heavily on aerial photography, often without adequate ground truth. The problem is further compounded by the complex nature of glacial processes in the region. Unlike areas such as Southern Ontario which had only one major source of glacial ice, the Yukon - Western District of Mackenzie underwent glaciation from three sources: (1) Laurentide ice; (2) the Cordilleran ice sheet; (3) valley glaciations. The resulting complexity, in conjunction with the difficulty of obtaining adequate information, is reflected in the fragmentary nature of current knowledge.

In the present discussion an effort will be made to: (a) briefly review the studies which have been made of the glacial history of the Yukon - Western District of Mackenzie Region; (b) focus upon one small area, that of the central part of Nahanni National Park, in an effort to study the geomorphic and in particular the glacial history in some detail; (c) attempt to incorporate the results of detailed study with the general review to produce some type of synthesis.

The thesis is divided into five chapters. The first chapter entails a discussion of the glacial history of the Yukon and the Northwest District of Mackenzie Region and is an attempt to bring together many diverse sources of information to provide a background for the work on the Central Nahanni. The second chapter focuses upon the general physiography and geology of the Central Nahanni study area. Geomorphic mapping of the study area is the concern of the third chapter, while the fourth deals specifically with one geomorphic feature; the lacustrine sediments found in the area. Finally, in the fifth chapter, an effort will be made to place the information gained from the study of Central Nahanni Park within the context of a general synthesis of the information currently available on the glacial history of the entire region.

The result will hopefully be a better understanding, not only of the geomorphology of the Central portion of Nahanni National Park, but also a greater insight into the glacial history of the entire Yukon - Western District of Mackenzie Region. It should be kept in mind, however, that the results of this study must be regarded as preliminary in nature. Only limited field time was available in the local study area and the regional picture is poorly understood. Much more information will be required before a precise chronology of events can be worked out for either the Central Nahanni Park area or the entire Yukon - Western District of Mackenzie region as a whole.

CHAPTER I

THE GLACIAL HISTORY OF THE YUKON - WESTERN DISTRICT OF MACKENZIE REGION

1. THE REGION AS A WHOLE

(A) PHYSIOGRAPHY AND CLIMATE OF THE REGION

The Yukon - Western District of the Mackenzie extends from the Alaska border east as far as the Mackenzie River and from the British Columbia border (at 60^{o} latitude) north to the Arctic Ocean. The major physiographic units of the area as delineated by Bostock (1948) are shown in Figure 1*. The Yukon portion consists basically of two major plateaus, the Yukon (in the south) and the Porcupine (in the north) isolated by various mountain ranges. The Yukon Plateau is bounded on the west by the St. Elias Mountains (and several ranges in Alaska associated with them) and on the east by the Selwyn and Mackenzie Mountains. It is limited in the south by the Pelly and Cassiar Mountains and is separated from the more northern Porcupine Plateau by the Ogilvie and Wernecke Ranges. The Porcupine Plateau extends from the Porcupine Ranges in the west to the Richardson Mountains in the east. The Yukon Coastal Plain and the Arctic Ocean form its northern limit.

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*For more detailed description the reader is referred to Bostock (1948), Bostock (1961), and G.S.C. Map 1254A.

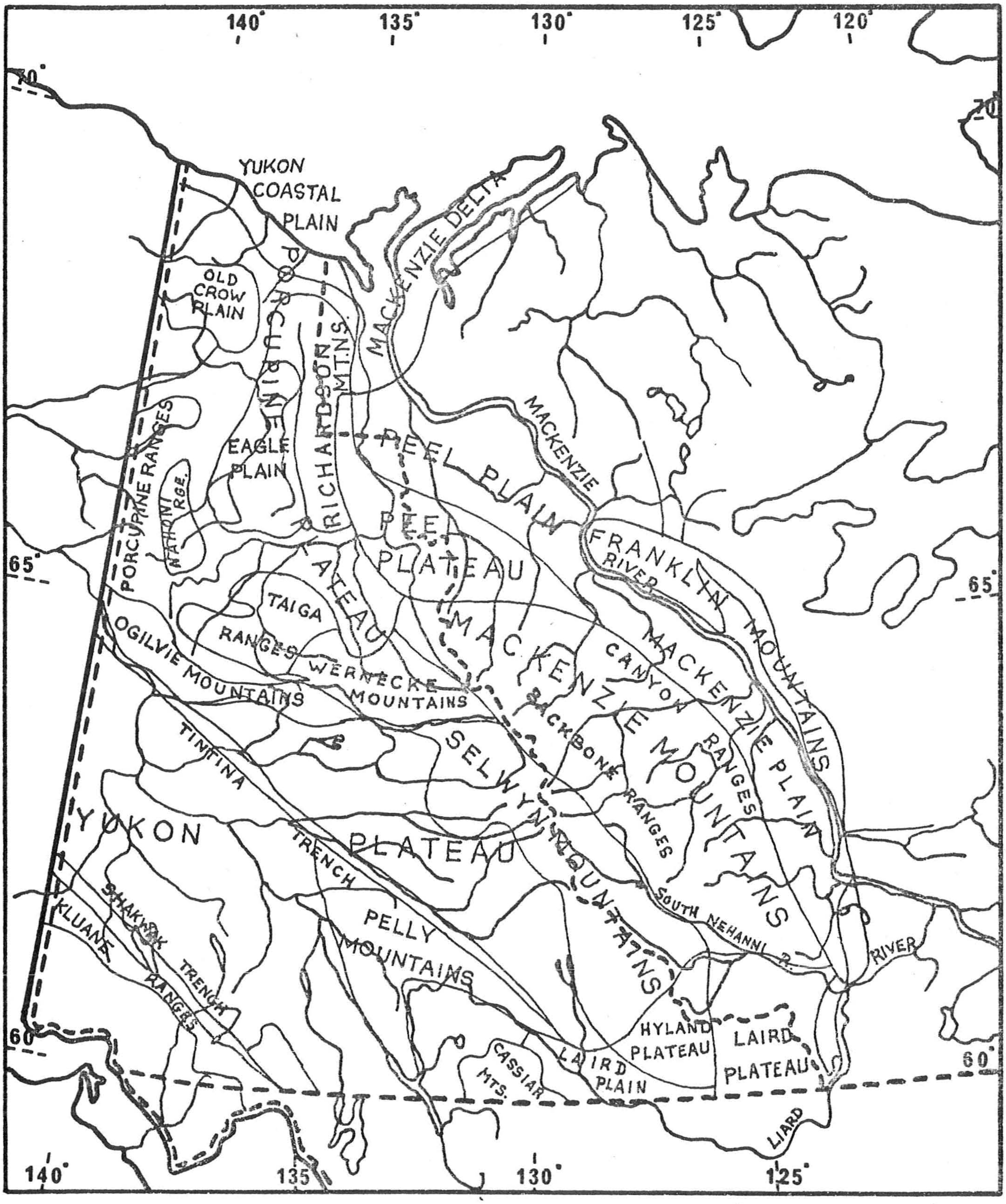

Figure 1. Phsiographic divisions of the region (from G.S.C. Map 1254A).

In the District of Mackenzie we find two lesser plateau areas, the Peel Plateau in the north and the Hyland-Liard Plateau areas in the south. Both abut against mountains on their western sides and merge with the vast Mackenzie Lowlands in the east. Finally, there is an isolated plain, the Mackenzie Plain, situated between the Canyon Ranges of the Mackenzie and the Franklin Mountains.

The contrast between these various physiographic units is quite extreme. The two plateau areas in the northern half of the region, the Porcupine and Peel, are both relatively low lying areas (1,000-2,000 ft. (305-610 m) a.s.l.) but they differ markedly with respect to the degree of isolation. Although limited in the north, south, and west, the Peel Plateau opens out onto and merges with the Mackenzie Lowlands in the east. The Porcupine Plateau, on the other hand, is virtually entirely enclosed and isolated from any major lowland area by mountain ranges reaching 8,000 ft. (2,440 m) a.s.l. The two southern plateau areas, the Yukon and Hyland-Liard, while partially hemmed in by mountains in the southwest and north open out onto the Mackenzie Lowlands. The Yukon Plateau, however, is ringed by mountain ranges reaching as high as 19,000 ft. (5,800 m) a.s.l. Thus the region contains both isolated and open plateau areas situated at low and high elevations with a complex and highly varied series of mountain ranges dispersed throughout.

The great variation in physiography has had a drastic effect upon the climate and this in turn has greatly affected the glacial history of the region. Of particular concern here is the effect of physiography on precipitation and especially snowfall. Figure 2 is a precipitation and snowfall map of the region based on 30 year means. The most striking features are the rain and snow shadow effects. It is apparent that the Coastal Mountains and the ranges in Alaska have severely limited the amount of moisture reaching the interior by cutting the area off from the maritime influences of the Pacific Ocean. Moreover, the other ranges within the region have reinforced the process. The Ogilvie and Wernecke Mountains have screened the Porcupine and Peel Plateaus. The Selwyn and western Mackenzie Mountains have shielded the eastern Mackenzie Mountains, and the Pelly and Cassiar Mountains have screened the Hyland-Liard area.

The actual effectiveness of this precipitation filtering process is dramatically demonstrated by some of the values shown in Figure 2. The eastern slopes of the Coastal Mountains and the coastal areas receive up to 350 cm. (138 in.) of precipitation including up to 325 cm. (128 in.) of snow annually. On the eastern side of these mountains the total precipitation is reduced to only 40 cm. (16 in.) annually. The secondary screening of the interior ranges reduces the precipitation to 30 cm. (12 in.) (below

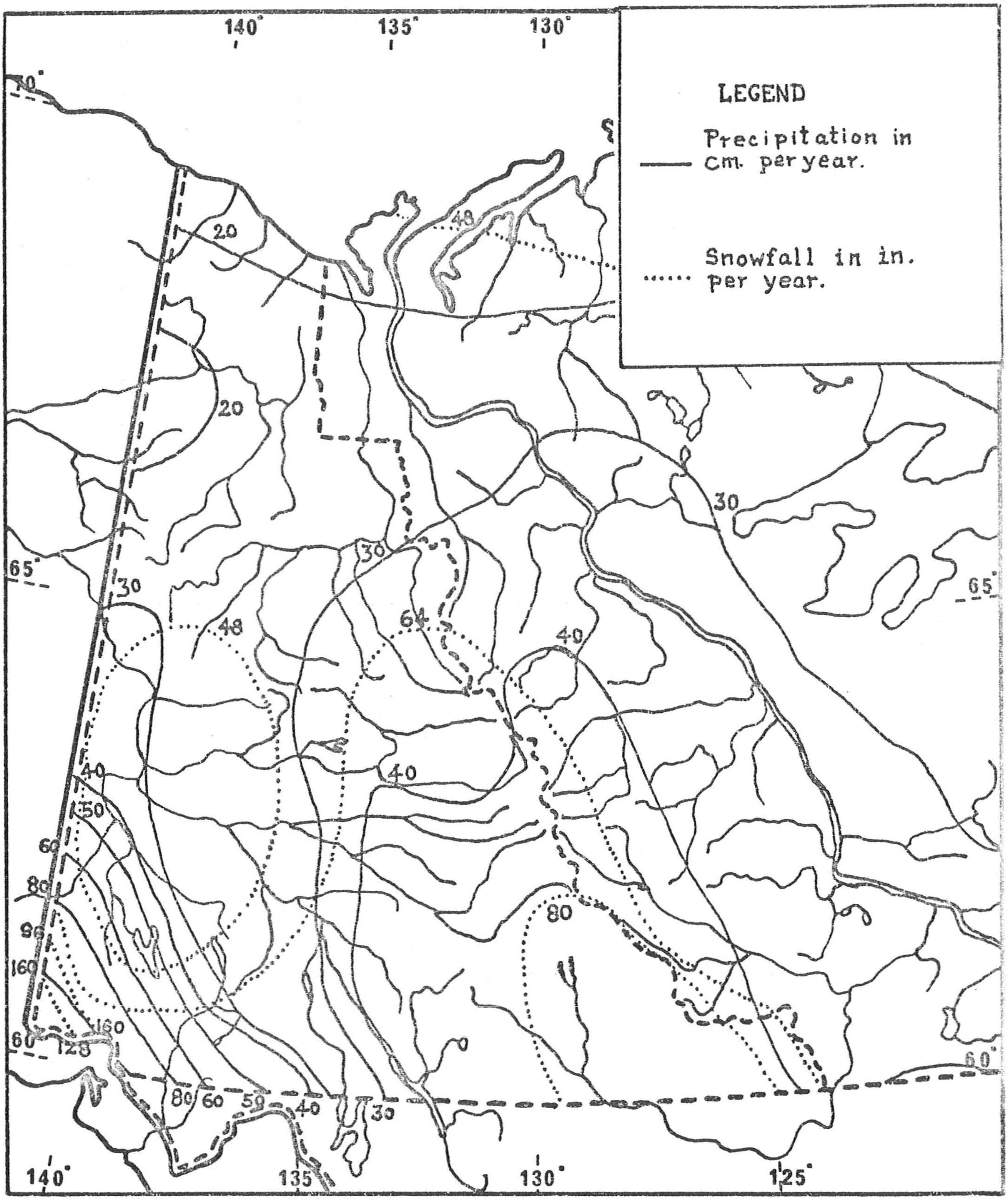

Figure 2. Precipitation and rainfall for the region (based on 30 years means, 1930-60). (See Figures 18 and 19 for source).

20 cm. (8 in.) in some areas) and the snowfall to below 162 cm. (64 in.).*

This then is the physiographic-climatic setting. Clearly our knowledge of it is extremely limited. The physiographic divisions are somewhat arbitrary, and the climatic data in mountainous areas renowned for their variability in conditions, is based upon a very small number of sampling sites with the records from even these few sites being erratic, inaccurate and incomplete. Nevertheless, it does appear clear that there exists an unusually close interaction between physiography and climate in the region. Moreover, although the current physiographic and climatic information, and in particular the climatic data, is strictly speaking only applicable to the present, the general trend and the relative relationships between high and low precipitation areas certainly may be taken as an indication of past conditions in the region. More will be said concerning the significance of the above in Chapter V.

(B) PREVIOUS STUDIES AND CURRENT DATA

The suggestion that glaciation had occurred in the Yukon - Western District of Mackenzie was first made by

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*Similar effects are experienced with respect to temperatures. The coastal areas receive the expected maritime effects upon temperatures; the southwest portion of the region beyond the primary coastal screen has relatively mild winters while areas beyond the secondary screening of the interior ranges experience severe winter conditions.

Dawson in 1887 (Dawson, 1889). Others such as McConnell (1890), Bell (1900) and Cameron (1922a and b) made further observations. It was not until 1934 that Bostock first suggested multiple glaciation of the area. These initial observations had been prompted by the gold rush of the 1880's-1890's for it was apparent to the early workers that the location and nature of sand and gravels which contained the placer deposits of gold were closely bound up with the activity of previous glacial processes. Thus, in addition to making detailed observations of bedrock geology, they also had a keen interest in the surficial deposits.

In subsequent studies, although many other workers made contributions, these have usually taken the form of short notes in G.S.C. bedrock geology reports. There was a tendency to de-emphasize surficial deposits in favour of the bedrock geology, which was not surprising in light of the economic significance of the latter and the apparently diminishing relative economic value of the former. The result was scattered glacial information which was largely uncorrelated. More recently efforts have been made to bring this information together. The best current summaries appear to be: Bostock (1966), Craig (1965), Hughes (1972), Gabrielse (1973) and Prest (1968).

At the present time there is very little ground truth for the entire region. However, there are four locations where relatively detailed studies have been undertaken. These are: (please refer to Figure 3a)

(a) Kluane Lake area;

(b) Mayo area;

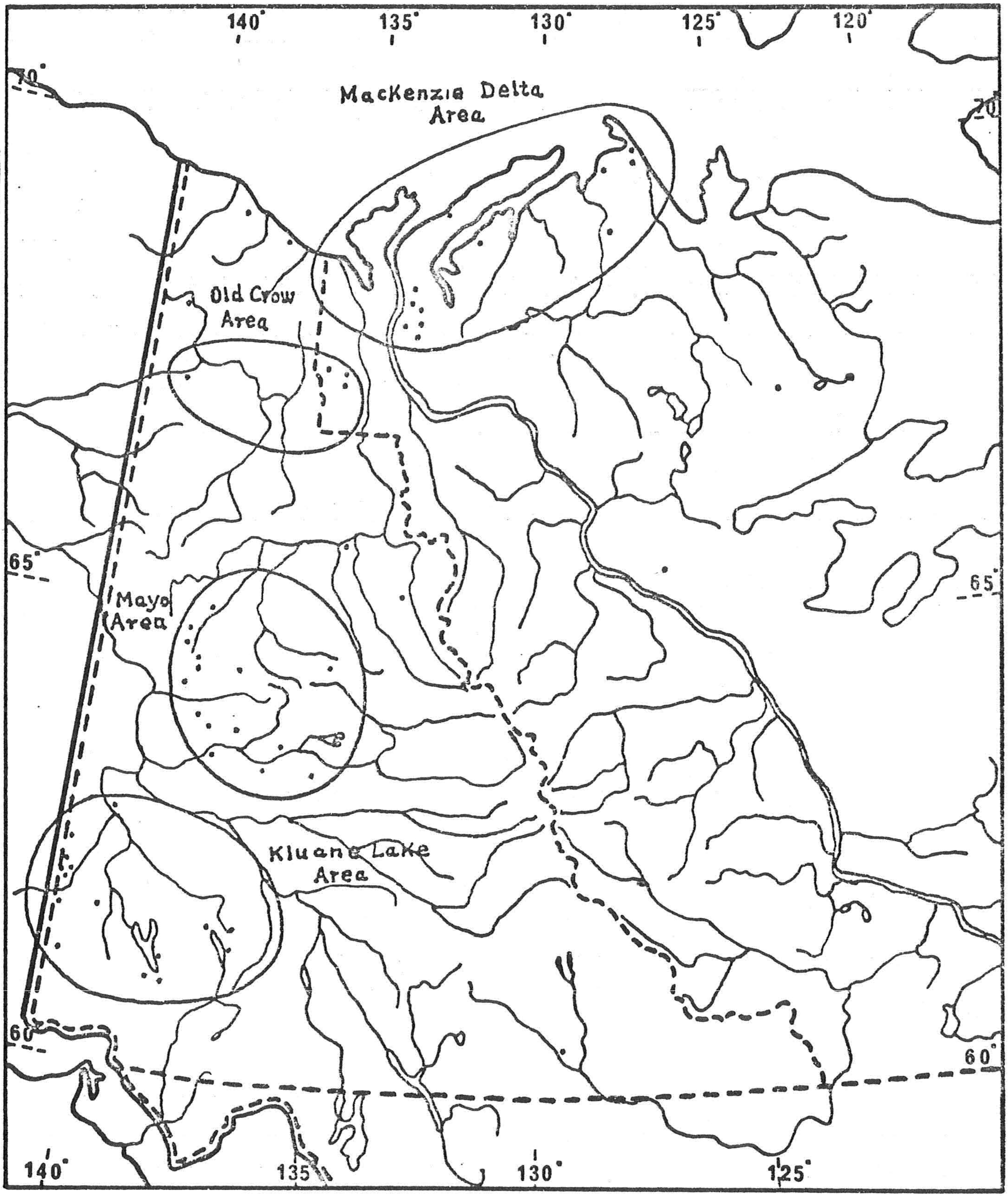
(c) Old Crow Basin;

(d) Mackenzie Delta area.

At these sites sections have been measured and studied, moraines have been mapped and the correlation of deposits have been undertaken.

It is also in these four areas that the vast majority of radiocarbon dates have been obtained. As indicated in Figure 3b, the total number of such dates for the region is quite small. In the areas listed above, however, it has been possible to obtain several dates which, because of site proximity, have enabled local correlation and the establishment of the sequence of glacial events at these specific locations. The overall paucity of such absolute dates, however, has severely limited the development of region wide correlations and sequences.

Palynological and paleoecological studies have also been concentrated in the four areas listed above. Of special interest has been: the Mackenzie Delta area ((Terasmae (1959), Mackay and Terasmae (1963), Mackay (1963)); the Old Crow Basin (Harrington and Irwin (1967); and the Klondike - Mayo area (Campbell (1952). While the results of such studies have certainly been significant the



Figures 3(a). Areas of detailed study.
(b). Radiocarbon date sites.

overall potential for these types of studies in this region is somewhat restricted. As Terasmae (1967) has pointed out, "because of the greater environmental tolerance of arctic species in general, climatic changes may be more difficult to detect by palynological means". Nevertheless, because of the isolated and unglaciated nature of much of the region, it is generally recognized that integrated studies of the paleoecological and glacial problems in the region may hold the key to the eventual development of the most complete and in particular the longest land-based record of the glacial history of North America.

2. GLACIATION IN THE DIFFERENT AREAS

For the purposes of the present discussion the entire Yukon - Western District of Mackenzie region may be divided into four physio-glacial areas or sectors: (Figure 4)

(A) Central and Southern Yukon;

(B) Northern Yukon and North-Western District of Mackenzie;

(C) Southwest District of Mackenzie;

(D) Eastern Mackenzie and Western Selwyn Mountains.

Each of these areas is a relatively distinct physiographic unit. Moreover, although glacial events in any two adjacent locations will be related, all of the glacial events occurring within each of these areas, largely because of

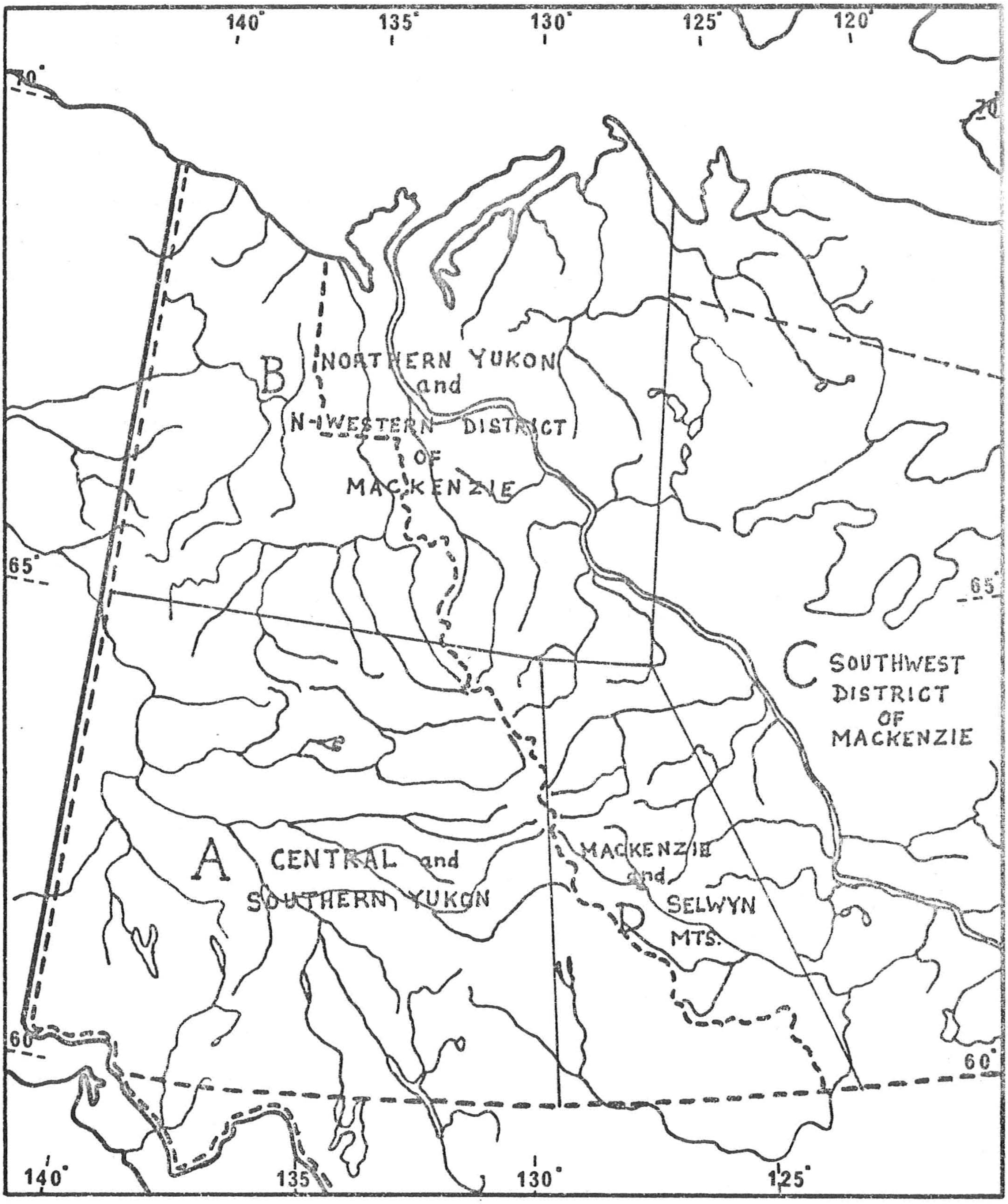


Figure 4. Division of the region for the purposes of the present discussion.

the interaction between physiographic and climatic factors within each area, bear unusually close relationships to the other glacial events within the same area or sector. It is for this reason that each of the above areas should be viewed, not merely as a physiographic unit, but also as constituting a distinct physio-glacial area. Each sector will be dealt with in turn.

(A) THE CENTRAL AND SOUTHERN YUKON AREA

This area encompassing the Yukon Plateau, part of the Liard Plain, and major portions of the Ogilvie, Wernecke, Selwyn, Cassiar, Pelly and St. Elias Mountains is by far the most intensively studied of the four areas. In fact, both the initial realization that glaciation had occurred in the entire Yukon - Western District of Mackenzie and the earliest recognition of multiple glaciation in the region occurred here. But despite this situation all the major papers dealing with the glacial history of the area (Vernon and Hughes, 1966; Boston, 1966; Hughes, 1969) are quick to point out the fragmentary nature of the information available.

(a) Sources and Extent of Glaciation

There appear to have been three major sources of ice in the area: (a) a Cordilleran ice sheet flowing north out of the Cassiar Mountains and west out of the Selwyn Mountains; (b) valley and alpine glaciers moving southward from the Ogilvie and Wernecke Mountains; (c) valley and alpine glaciers moving eastward out of the St. Elias Mountains, (Figure 5).

Most authors agree that the Cordilleran ice sheet consisted of two lobes; the Cassiar and the Selwyn (Hughes, 1969). The Cassiar lobe had its source in the Cassiar Mountains from about 60° 30'N and south into British Columbia. Ice from west of 132°W flowed northwest while ice from east of 132°W, although initially moving northwest, was deflected eastward by the Pelly Mountains. Eventually this ice appears to have joined ice from the Selwyn lobe and moved in a southeast direction into and across the Liard Plain (Hughes, 1969). The possibility that ice may also have moved directly from the Cassiar Mountains onto the Liard Plain cannot be discounted.

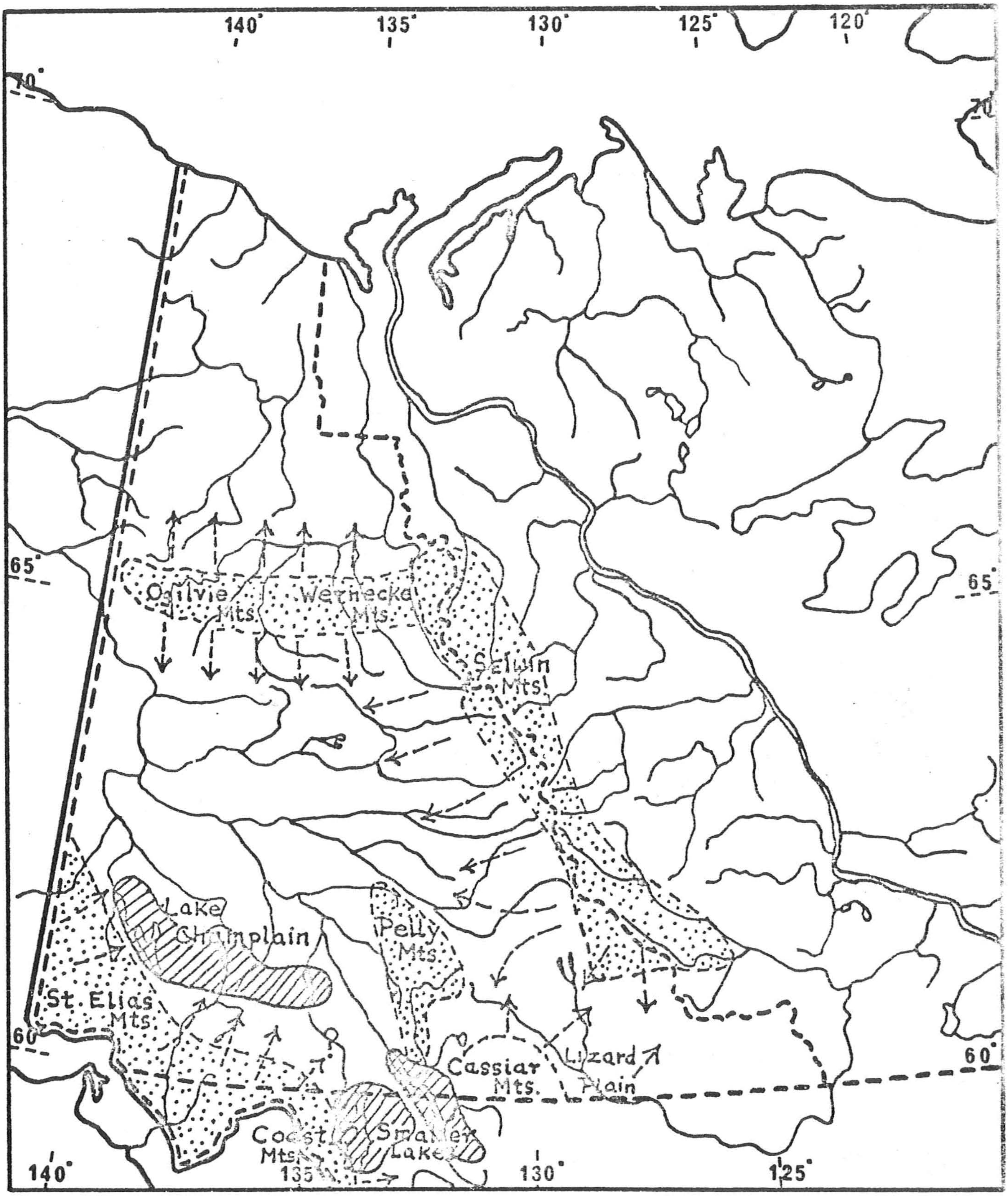
The Selwyn lobe of the Cordilleran ice sheet had its sources in the Selwyn and Northern Logan Mountains between 61° 31'N and 64° 00'N (Hughes, 1969). Ice from the Selwyn lobe moved predominantly westward (Campbell, 1967), however, part of the lobe originating in the Logan Mountains moved south and southwest onto the Liard Plain.

The second major source of glaciation was that of alpine and valley glaciers in the Coastal and St. Elias Mountains. The majority of the glaciers in these ranges flowed westwards towards the coastand into the Pacific Ocean and hence had little direct influence in the interior. Some glaciers, however, did flow east towards the interior.

These glaciers, although originating in the lee side of the mountain ranges and consequently receiving substantially less precipitation than those on the windward side, appear nevertheless to have received sufficient precipitation to enable them to merge and form eastward flowing ice sheets (Bostock, 1965), (Hughes, 1969).

The third major source of glaciation appears to be in the Ogilvie and Wernecke Mountains. Alpine and valley glaciers originating in these mountains, largely as a result of diminished precipitation, do not appear to have formed an ice sheet (Green, 1971). Instead they were confined to developing topographically controlled glaciation which moved out towards and onto the Yukon Plateau via the major valleys in the area (Green, 1972).

Although the three sources of glaciation indicated above are well documented the actual extent of glaciation in the area is understood only in the broadest of terms. Hughes et al. (1969) suggests that Cordilleran ice moved both northwestward towards and onto the Yukon Plateau and southeastward towards and across the Hyland-Liard Plateau (Figure 5). Ice from the Selwyn Lobe moving north and northwest reached at least into the Aishihik Lake map area while more southern elements of the lobe flowed south and southeast to merge with the Cassiar Lobe and cross the Hyland-Liard Plateau. Ice from both Selwyn and Cassiar Lobes also penetrated the Pelly Mountains. Moreover, elements of the



Figures 5(a). Summary of ice flow directions in area A.
(b). Proglacial lakes of area A.

Cassiar Lobe, moving north and west, merged and overlapped with the Selwyn Lobe creating a complex and often confusing pattern of meltwater channels and marginal features (Hughes, 1969). The Cordilleran ice sheets also appear to have met the St. Elias ice sheets at least once and then both moved onto the Yukon Pleateau (Green, 1972) (see Figure 6).

The valley glaciers of the Ogilvie and Wernecke Mountains were much less extensive than either the Cordilleran or St. Elias Sheets. Evidence is scattered and sparse. It does appear that some elements reached sections of the Yukon Plateau. Moreover, in the eastern areas these southward flowing valley glaciers did join with glacier tongues of Cordilleran ice moving northwestward along some of the major valleys (Hughes et al., 1969).

There is also growing evidence of proglacial and glacial lakes in the area. Kindle (1953) found lake silts and other evidence of a very extensive proglacial lake (named Lake Champagne by him) which formed between the Cassiar Lobe and the ice from the St. Elias Mountains during a retreat. It occupied the Dezadeash Valley and other tributary valleys to elevations of 2,800 ft. (85 m) a.s.l. A large glacial lake once occupied the area surrounding Kluane Lake to an elevation of 3,000 ft. (910 m) a.s.l. (Hughes et al., 1969). Numerous other lakes formed between the Cassiar Lobe and the Coastal Mountains (Wheeler, 1961) and

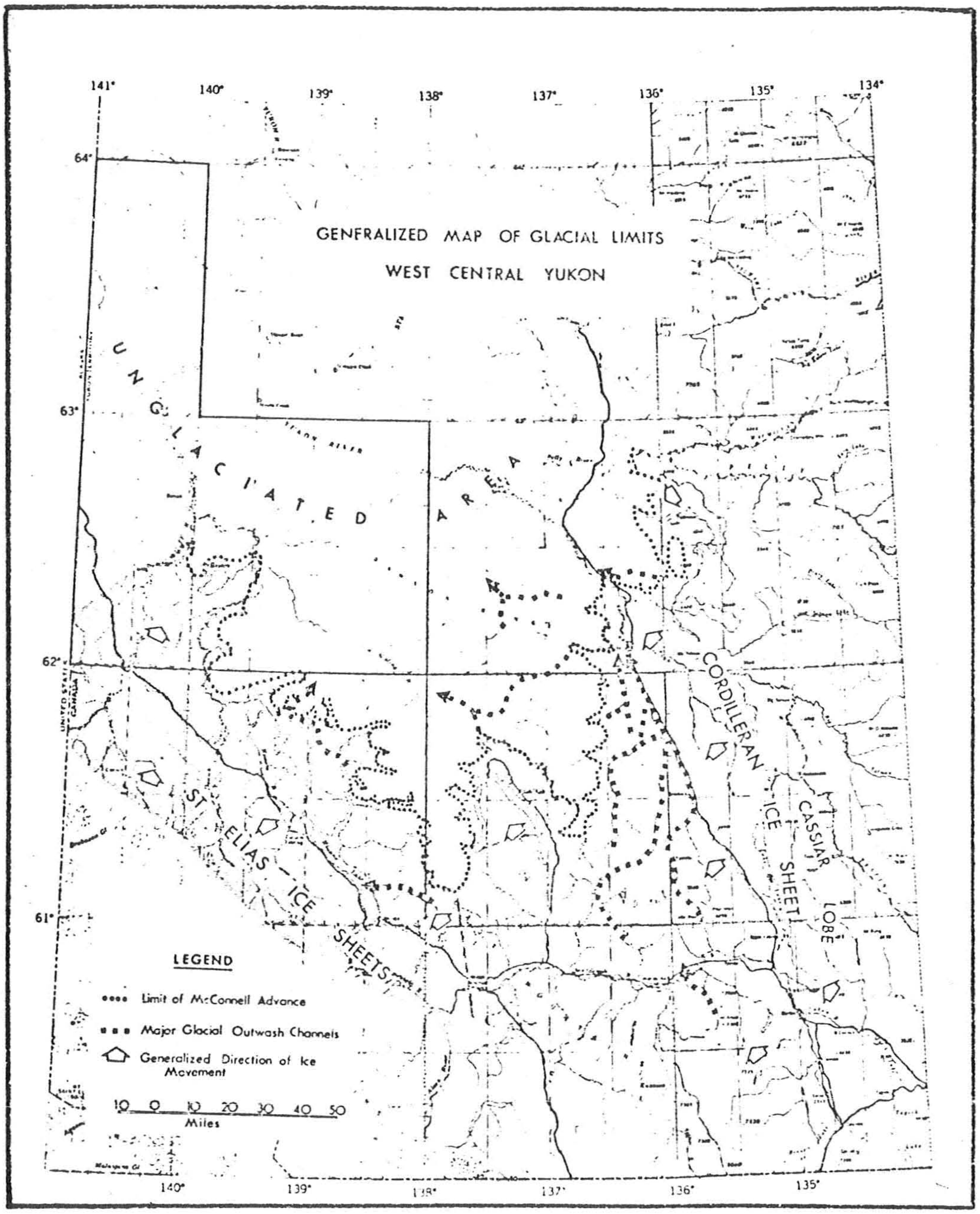


Figure 6. Extent of St. Elias and Cordilleran ice sheets and general flow directions in area A. (From Tempelman-Kluit (1973)).

in the Aishihik Lake area as well (see Figure 5). Templeman-Kluit (1973) and Green (1971), working in the Mayo and McQueston areas, also found extensive silt deposits indicating the presence of several large glacial lakes in the area. As more detailed studies are conducted it is to be expected that many other lakes of similar origin will be discovered.

(b) Multiple Glaciation

The first suggestion of multiple glaciation having occurred in the entire region was based on work in this area (Bostock, 1934). Since Bostock's initial suggestion detailed studies have been conducted in two areas: (i) the southwest portion in the area of Kluane Lake and the St. Elias Mountains; and (ii) in the northern part of the area near Mayo. From these two locations broader general patterns have been inferred.

(i) The St. Elias-Kluane Sites

Although many other previous studies had touched upon the glacial history of the Southwestern Yukon the first detailed investigation was initiated by Muller in 1963 (published in 1967). Using airphoto interpretation and a limited number of field observations he conducted a study of the Kluane Lake area. His work indicated three distinct ice advances; termed the "Nisling", "Ruby", and "St. Elias".

During the Nisling Advance, the oldest and most extensive of the three, ice flowed across the Shakwak Valley and succeeded in reaching elevations of 5,000-7,000 ft. (1,520-2,130 m) a.s.l. in the Kluane and Ruby Ranges. The advance is indicated by: high altitude meltwater channels on the side of the ranges (Muller, 1967); high level erratics reaching 5,400 ft. (1,650 m) a.s.l. just south of the confluence of the Kluane and Donjek Rivers (Muller, 1967); and some erratics at 7,200 ft. (2,200 m) a.s.l. ((Wheeler, 1963), (Muller, 1967)). One fairly well-defined end moraine is also ascribed to this advance (Muller, 1967).

The Ruby Advance, a younger event, covered almost the same area as the Nisling but was not quite as extensive and at its maximum it appears to have been 500-1,000 ft. (150-300 m) lower in elevation (Muller, 1967). The main advance, originated once again in the St. Elias Mountains, however, valley glaciers fed by ice caps which developed on the Kluane and Ruby Ranges appear to have also played a major role. Evidence for the Ruby Advance consists of morainic topography near the former ice margins (Muller, 1967).

The third and most recent major advance indicated by Muller, the St. Elias Advance, was much less extensive than the Nisling or Ruby. Apparently the ice front barely reached the Shakwak Valley (Muller, 1967). Evidence cited for this advance consists of a series of U-shaped troughs in several tributary valleys and some morainic deposits. Some writers (Hughes, 1969) prefer to consider the St. Elias Advance as merely a long stand-still in the retreat phase of the Ruby Advance.

Denton and Stuivers (1967) working at the southern end of Kluane Lake within Muller's limit for the Ruby Advance but beyond the limit of his St. Elias Advance developed the following chronology (based on radiocarbon dating of stratigraphic sequences):

Name	Time
Shakwak Glaciation	> 49,000 B.P.
Silver Nonglacial Interval	> 49,000 B.P.
Icefield Glaciation	49,000 B.P. and ends before 37,000 B.P.
Boutellier Nonglacial Interval	begins before 37,000 B.P. and ends after 30,100 B.P.
Kluane Glaciation	begins after 30,100 B.P. and ends after 12,500 B.P.
Slims Nonglacial Interval	begins before 12,500 B.P. and continues until Neoglacial
Neoglacial	begins 2,640 B.P.

It is tempting to suggest that the Nisling Advance of Muller correlates with Denton and Stuiver's Icefield Glaciation. Following the same line of reasoning the Ruby would then be correlated with the Kluane Glaciation and the St. Elias with the Neoglacial. Unfortunately, as Hughes et al. (1969) have pointed out, there are several problems with such an interpretation. It is generally suggested that local advances may have confused the historical record at these sites making the development of area wide assessments much more difficult.

(ii) Central Yukon

A second area of detailed study is in the Central Yukon centring on Mayo. Bostock's first suggestion of multiple glaciation of the Yukon was based on the presence of a very old till or boulder clay in the Carmacks area well beyond the then recognized limit of the last glaciation (Bostock, 1934). In 1965 he presented evidence indicating four ice advances in the area. These were designated the "Nansen", "Klaza", "Reid", and "McConnell" advances (Bostock, 1966). The latter two were indicated by morainic systems. The former two advances had no distinct limits.

The McConnell Advance, the most recent major event, is evidenced by quite fresh ice-marginal features. The limit of the McConnell Advance is indicated by a moraine across the Stewart Valley a few miles below Mayo which

Bostock named the McConnell Moraine (Bostock, 1966). Forty miles further down the valley Bostock found evidence of an older moraine with accompanying kame terraces and other ice marginal features indicative of an older and more extensive glaciation. This was termed the Reid Moraine.

Beyond the Reid limit Bostock found evidence of two older advances. The younger of the two, the Klaza, is evidenced by the modification of glacial landforms in the Klaza River while the older, designated the Nansen, is indicated by the presence of deeply weathered deposits found in the Nansen Creek area. Since no distinct moraines have been attributed to either of these two older advances Bostock could not ascribe distinct limits to them. Evidence, however, did indicate that the Nansen, the older of the two, was also the more extensive.

Vernon and Hughes (1966) work in the Dawson, Larsen Creek and Nash Creek areas adjacent to Bostock's location suggested that evidence was present in their area for three distinct glaciations which they classified as: old, intermediate, and recent. The "old" glaciation was also the most extensive. Its existence was indicated by the presence of erratics at higher elevations and beyond the limits of the later glaciations. The "intermediate" glaciation and the "last" glaciation are indicated by moraines and changes in the freshness of the topography between the areas covered by each. It appears that the "intermediate" was more extensive than the "last glaciation.

In 1969 Hughes adopted Bostock's chronology and nomenclature and applied it to the entire region. In doing so he correlated the "old" glaciation to the Nansen or Klaza, the "intermediate" was associated with the Reid, and the "last" glaciation was related to the McConnell Advance. The absolute dating evidence available would tend to support Hughes but there are deficiencies in the dating evidence. The tendency is for surface materials to date at less than 12,000 or 10,000 B.P. and for the material such as silts and gravels immediately below to be beyond the radiocarbon range thus leaving clear evidence of some earlier glaciation but little indication of precisely when. The one exception to the above situation is a site on Hunker Creek. Here wood found at the base of a silty peat was dated at 9,520 ± 130 years B.P. (G.S.C. - 73) while wood found only 4 ft. (1.2 m) below it in a frozen silt was dated at 30,000 B.P. (G.S.C. - 88). This one finite dating earlier than 12,000 B.P. does indicate the presence of mid-Wisconsin interglacial in the area and hence provides some support to Hughes correlations.

As a consequence of the dating difficulties indicated above, most writers dealing with the Mayo area (Green, 1971) and the Ogilvie and Wernecke Mountains in general

(Green, 1972), while acknowledging the probable validity of Hughes correlations with Bostock's chronology, prefer to use the relative terms old, intermediate and last.

Correlating the chronologies of detailed studies in the Central Yukon with those of the Kluane-St. Elias areas also has its problems. Table 1 is an attempt at such a correlation. Needless to say it is tentative. In such a scheme the Ruby of Muller corresponds to the Kluane of Denton and Stuivers, the "old" glaciation of Hughes, and the McConnell of Bostock. The Nisling might be correlated with the Icefield Glaciation, and the Reid with the "intermediate" glaciation. Finally, the Shakwak Glaciation might be equated with the Nansen or Klaza of Bostock and the "old" glaciation of Hughes. Hughes (1969) caution concerning the chronology of Denton and Stuivers, however, must be taken heed of. Unfortunately the best, and in fact the only detailed absolute chronologies available in the entire area, are from sites which may have been subject to many minor and highly restricted local advances and retreats by St. Elias glaciers. Hence wide ranging correlations should be regarded with caution.*

In spite of the above difficulties it does seem reasonable, by way of a summary, to suggest a general sequence

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*It should be pointed out that many writers, following Hughes lead, have tended to adopt Bostock's terminology and the general sequence of events associated with it to describe the entire Central and Southern Yukon area or have attempted at least to correlate their own findings to his whenever possible.

Table 1. Correlation of Chronologies for Southern Yukon.

Vernon and Hughes (1966)	Bostock (1966)	Muller (1967)	Denton and Stuiver (1967)	Vernon and Hughes (1969)
		St. Elias	Neoglacial	
			Slims Nonglacial Interval	
Last	McConnell	Ruby	Kluane	McConnell
			Boutellier Non-glacial Interval	
Intermediate	Reid	Nisling	Icefield	Reid
			Slims Nonglacial Interval	
Old	Nansen			Pre-Reid 1. Nansen 2. Klaza
	Klaza			(undifferentiated)

of events for the area. The following sequence is based upon Bostock's nomenclature and the chronologies in Table 1. Although far from precise the general pattern indicated does appear to agree with most of the evidence available. Moreover, as will be seen in the third section of the paper, the following sequence agrees reasonably well with evidence from other areas of the region.

Glacial Advance	Time
Neoglacial Advance	2,000 B.P.
McConnell Advance	10,000-30,000 B.P.
Reid Advance	37,000-49,000 B.P.
Pre-Reid	
(i) Klaza	pre-Wisconsin?
(ii) Nansen	pre-Wisconsin?

(B) THE NORTHERN YUKON AND THE NORTHWEST DISTRICT OF MACKENZIE

This area includes the two northern plateaus (the Porcupine and Peel), the Mackenzie Delta, part of the Arctic Coastal Plain, the Peel and Anderson Plains, the Richardson Mountains, and northern elements of the Ogilvie, Wernecke, Selwyn and Mackenzie Mountains. As a result of inaccessibility and a general lack of interest by mining companies large tracts in the area have never been studied beyond a preliminary reconnaissance level. At present, studies associated with the proposed Mackenzie Valley Pipeline are beginning to provide more detailed information on the eastern parts of the area. Hughes (1972) remains the best current summary.

(a) Source and Extent of Glaciation

There were only two major sources of glaciation for the area. By far the more dominant was invasion of the area by Laurentide ice moving from the east across the Mackenzie Lowlands. This ice sheet succeeded in completely covering the Anderson Plain and the Mackenzie Delta. Present evidence suggests that the Richardson and Mackenzie Mountains served as effective barriers to further westward movement of the Laurentide ice and hence prevented direct penetration of the Porcupine Plateau. Two lobes of Laurentide ice did, however, make encroachments along the Arctic Coastal Plain and across the Peel Plateau. The second and lesser source of glaciation was ice emanating from alpine and valley glaciers descending from relatively low precipitation areas in the Ogilvie, Wernecke, Selwyn, and northern Mackenzie Mountains.

The actual extent of glaciation is shown in Figure 7. Generally speaking the extent of the Laurentide ice is known with much greater precision than that of the valley and alpine glaciations although there are serious deficiencies for both limits. In some locations only fragmentary and at times contradictory evidence has been found. In other locations the boundary has been based on an extrapolation with no

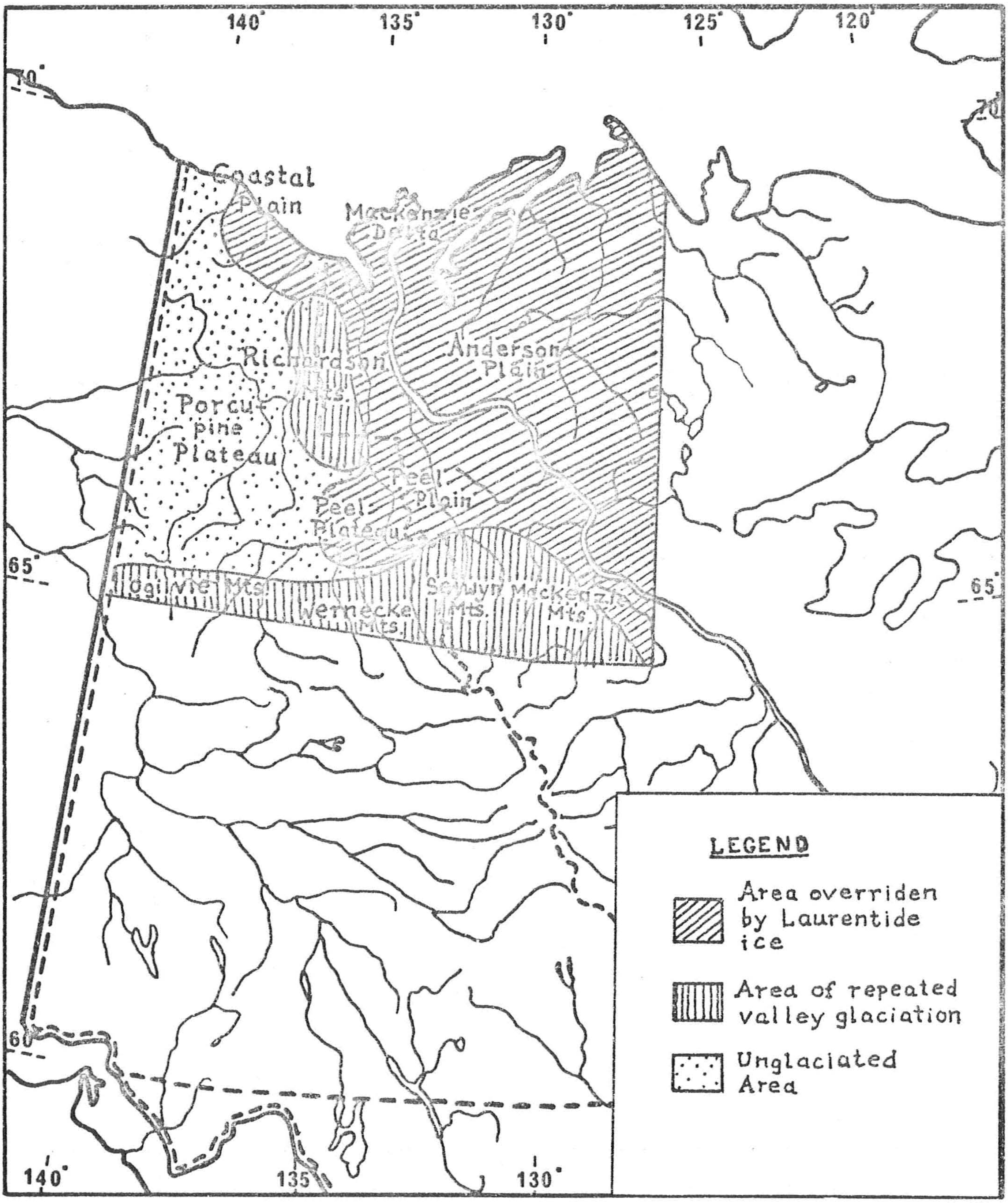


Figure 7. Extent of glaciation in area B.

supporting ground truth. These limits then must be regarded as provisional only. But despite such uncertainties over demarcation of exact limits the distinction of the three categories of Laurentide ice invasion, valley glaciated areas, and unglaciated areas is generally accepted.

The existence of large proglacial lakes is also indicated. Recent work by Federovich (1974) and supported by Hughes (1972) demonstrates the presence of a large proglacial lake in the Bell Basin (see Figure 8). Apparently Laurentide ice at some time blocked the McDougall Pass (#1 in Figure 8) and also blocked drainage across the Eagle Plain (#2 in Figure 8). This sealing of the eastward drainage routes resulted in the formation of a large proglacial lake which drained westward down the Procúpine (#3 in Figure 8, Hughes, 1972). The full extent of this lake is not yet known. The presence of other as yet undiscovered, proglacial lakes in this area would appear a certainty.

(b) Multiple Glaciation of the Area

As might be expected, evidence of the nature and extent of multiple glaciation of the area is limited. It is clear, however, that at least two invasions by Laurentide ice have occurred. Along the east side of the Richardson Mountains quite distinct and relatively "fresh" glacial features such as marginal channels, moraines, and drift are present at altitudes up to 3,500 ft. (1,070 m) a.s.l. (Hughes, 1972).

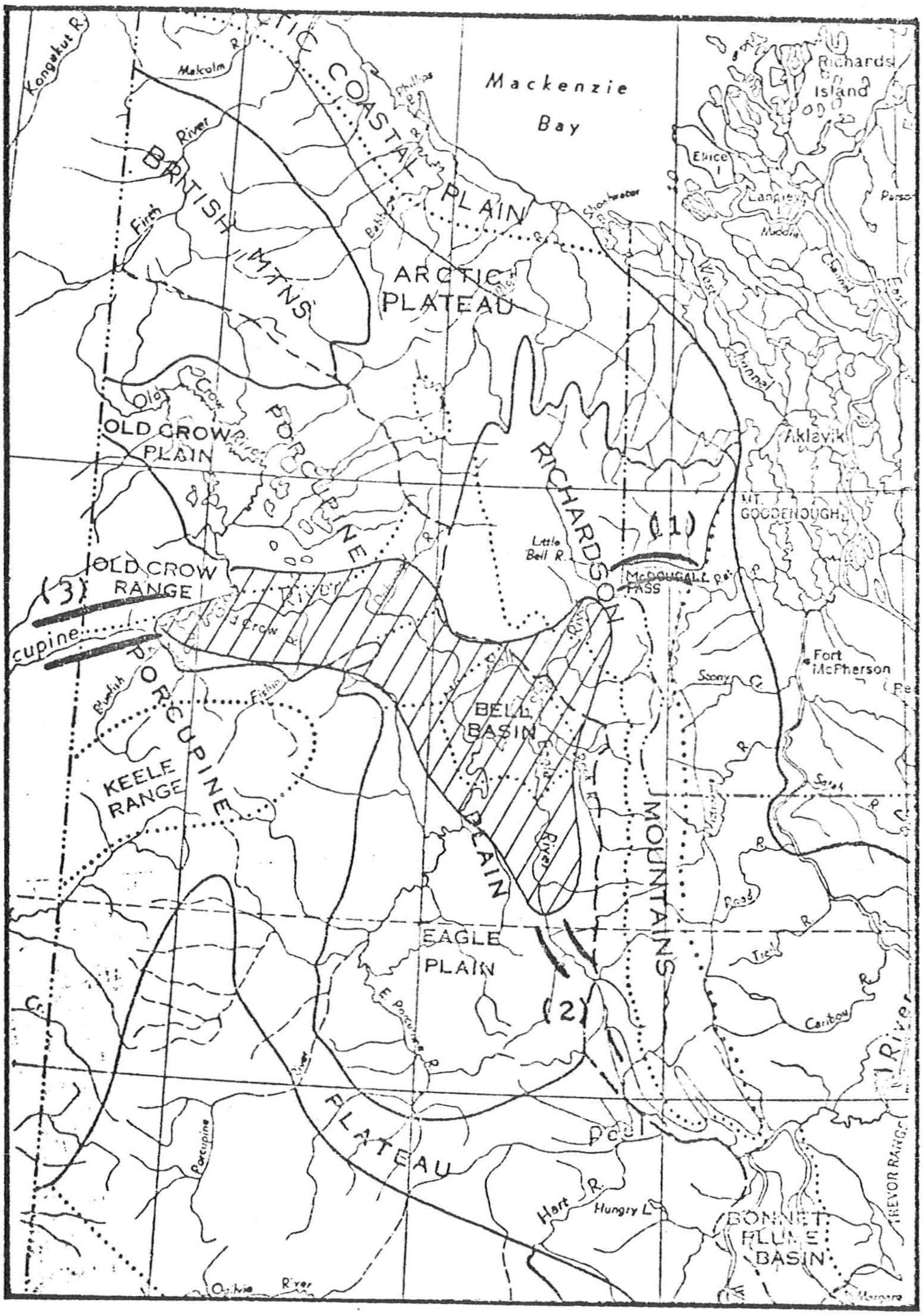


Figure 8. Glacial lakes and outlets in area B (based on information from Hughes (1972)).

Moving south along the eastern flanks of the Richardson Mountains the height of these features gradually increases. Crossing the gap created by the Peel Plateau the same system of fresh moraines, meltwater channels, and drift apparently continues along the eastern side of the Mackenzie Mountains gradually rising to an altitude of 4,000 ft. (1,220 m) a.s.l. (Hughes, 1969). These features are generally considered to indicate the limit of the last major Laurentide advance. Further evidence of this late Wisconsin advance is found on the Peel Plateau in the form of fresh moraines and other glacial features (Hughes, 1972).

Beyond the limit of the late Wisconsin advance there is considerable evidence of a more extensive early Wisconsin or even pre-Wisconsin Laurentide advance. In the northern sector of the Richardson Mountains current information suggests only one limit of Laurentide advance (indicating that any earlier advance would appear to have been at or below the same level as the late Laurentide level and hence indistinguishable from it). As one moves further south, however, two distinct limits begin to appear. One limit consists of fresh moraines, drift, and marginal channels marking the limit of late Wisconsin advance. The second and higher limit, marked by glacial erratics, indicates a second more extensive and earlier Laurentide glaciation (Rutter, 1974).

Even stronger evidence has been found in lower lying areas. Beyond the limit of the late Laurentide advance in the Peel Plateau, Bonnet Plume Basin, part of the Eastern Porcupine Plateau, and along the Yukon Coastal Plain, are found subdued features such as; moraines, kame terraces, and old but still recognizable ice marginal channels (Hughes, 1972). The sharp contrast between the fresh features within the late Laurentide limit and these much reduced forms strongly suggests that the latter are a product of a much older and more extensive glaciation.

Detailed studies have been carried out in only two locations: (i) the Mackenzie Delta; (ii) Porcupine River area. Both are of considerable significance.

(i) The Mackenzie Delta

The Mackenzie Delta is the better known of the two. As early as 1938 Porsild had noted the presence of 10 ft. (3.0 m) of peat and silt underlying 200 ft. (60 m) of drift near Reindeer Depot on the Mackenzie River (Porsild, 1938). Subsequently, and continuing over a period of many years, a considerable number of stratigraphic, and palynological studies supported by radiocarbon dating have been conducted in the Mackenzie Delta and nearby locations. These are summarized in Figures 9 and 10.

Terasmae conducted pollen analysis of material from the peat layers at the Reindeer Depot site. The

1) REINDEER DEPOT

200 ft. drift

x 10 ft. peat and sand

x=greater than 42,000 B.P. (L - 522A)

2) INUVIK

-wood from a delta-kame complex
x

x= greater than 39,000 B.P. (GSC 29)

3) RAT RIVER

x
40 silt
x:beaver chewed stick

older till

gravel

x= greater than 38,300 B.P.
x'= greater than 38,600 B.P.
(GSC-204 and GSC-120 respectivley)

4) ESKIMO LAKES

x
6 ft. surface peat

75 ft. gravel

x' Peat
silt

x= 7,120 B.P. (GSC-371)
x'= 50,900 B.P. (GSC-329)

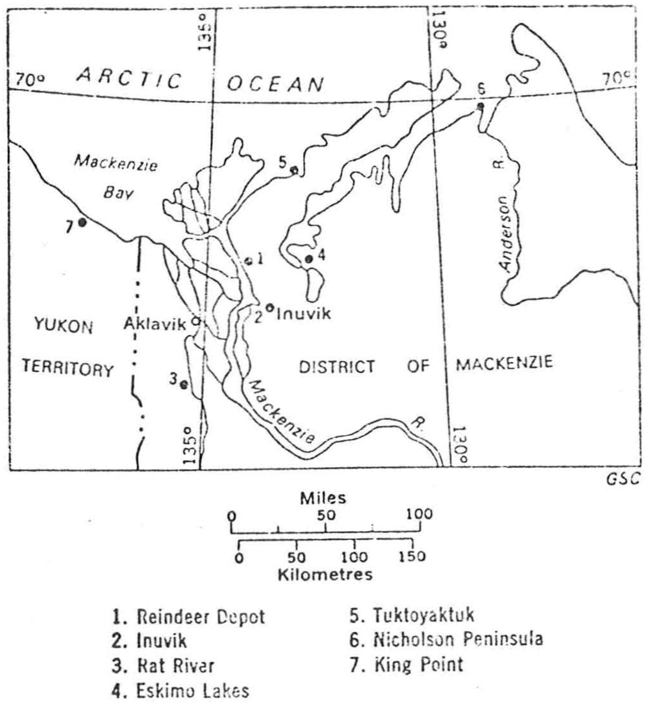
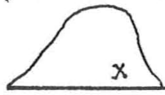


Figure 10. Location of sites.

5) TUKTAYUKTUK



x abraded wood in pingo

x= Greater than 33000 B.P.

6) NICHOLSON PENINSULA

20 ft. contorted sand
x

Wood at base

x= greater than 35,200 B.P.

7) KING POINT

3 ft. silt

8-15 ft. silt and sand
x

20-30 ft. till

organic marine sediments
x'

x= 9,510 B.P. (GSC- 159)
x'= greater than 51,000 B.P. (GSC- 151-2)

Figure 9. Sections studied in area B (after Prest (1972)).

analysis indicated an interglacial origin for the material (Terasmae, 1959) and the material was dated at greater than 42,000 B.P. Wood from a delta-kame complex at Inuvik was dated at greater than 39,000 B.P. (G.S.C. - 29) while abraded wood from a pingo at Tuktoyaktuk was greater than 33,000 B.P. (LA - 300A). Further to the east at Nicholson Peninsula wood from the base of 20 ft. (6.1 m) of contorted sand registered at more than 35,200 B.P. (G.S.C. - 34).

Multiple level sites have been uncovered at Eskimo Lake, along the Rat River, and at King Point. At Eskimo Lake Mackay (1963) found 75 ft. (23 m) of gravel overlying 46 ft. (14 m) of peat and organic silt. The gravel itself was covered by 6 ft. (2 m) of surface peat. The peat below the gravel was dated at greater than 50,900 B.P. (G.S.C. - 329) while the surface peat above the gravel was dated at 7,120 B.P. (G.S.C. - 371; #4 in Figure 9). There is a similar site along the Rat River (#3 in Figure 9). Here Hughes found gravel overlain by till which itself was covered by 40 ft. (12.1 m) of silt. A beaver chewed stick at the base of the silt was dated at greater than 38,600 B.P. (G.S.C. - 120) while organic silt 30 ft. (9 m) above the base in the same silt layer was dated at greater than 38,300 B.P. (G.S.C. - 204). In addition, a date of 9,970 B.P. (G.S.C. - 147) was obtained for silty material from a flow slide located above the bedded silt layer. Finally, further west at King Point (#7 in Figure 9) Hughes found organic marine sediment covered by 20-30 ft. (6-9 m) of till. Overlying the till was 8-15 ft. (2.5- 4 m) of silt and sand and above the silt and sand was 3 ft. (1 m) of silt. The organic marine deposits were dated at greater than 51,100 B.P. (G.S.C. - 151-2) while silt collected 4 ft. (1.2 m) above the till was dated at 9,510 B.P. (G.S.C. - 159).

The dates from Reindeer Depot, Inuvik, and Rat River, coupled with careful stratigraphic, botanical and palynological studies have led both Terasmae (1959) and Mackay (1963) to suggest the organic deposits at these sites represent interglacial episodes. Terasmae (1959) in fact attributes them to the Sangamon. The evidence from Eskimo Lake, Rat River and King Point, while supporting the above contention, goes even further. These sites provide strong evidence for at least two major Laurentide advances; one of early or pre-Wisconsin age and a second late Wisconsin advance. The first advance occurred sometime before 52,000 B.P. (and beyond the current limit of radiocarbon dating). It was followed by an interglacial. The exact beginning of the late Wisconsin advance in the area is not yet known with any precision. However the retreat appears reasonably well documented. The previously indicated date of 9,510 B.P. from King Point; a sample from the east flanks of the

Richardson Mountains dated at 9,970 B.P. (G.S.C. - 147); a sample from the Inuvik area dated at 8,200 B.P. (G.S.C. - 25); and two dates of 7,120 B.P. (G.S.C. - 371) and 7,400 B.P. (G.S.C. - 16) at Eskimo Lake all appear to be valid benchmarks documenting the retreat of the late Wisconsin Laurentide ice.

(ii) The Porcupine River Area

Work in the Porcupine Basin, while not as far ranging as the studies in the Mackenzie Delta area, has certainly been of equal significance. As early as 1891 McConnell (in Hughes, 1972) described lacustrine sediments along the Porcupine River. These had originally been attributed to the Tertiary. Terasmae (1965) however, examined the deposit and suggested a Pleistocene origin for it. Hughes (1972) found glaciolacustrine silts in exposures along the Wind, Bonnet Plume, and Peel Rivers. Federovich (1973) conducted palynological studies of six sections along the Old Crow River. More recently Federovich (1974) and also Hughes (1972) studied two sections along the Porcupine River. One of the Porcupine sections (termined section 1) is shown in Figure 11. It correlates reasonably well with the other sections in the Old Crow area and the remaining Porcupine section. Nine units are distinguished. Unit 1 and 2 are interpreted as fluvial and deltaic in origin. It is suggested that when these were deposited the water flowed eastward out the McDougall Pass (refer to

Figure 8 shown earlier). Later, ice blocked the eastern route and unit 3 represents a glaciolacustrine phase during which drainage was westward out through the Ramparts. Units 4 and 5 are considered the result of Laurentide retreat and the re-establishment of eastward drainage. A readvance of ice causing the renewed blockage of eastward drainage produced a second lacustrine phase evidenced by unit 6. Units 7, 8 and 9 are viewed as the result of retreat and post-retreat with eastward drainage once more reestablished. However, downcutting during the time of unit 6 resulted in the capture of much of the Porcupine drainage. It would appear then that two glaciolacustrine phases, indicating blockage of eastward drainage by advancing Laurentide ice, were separated by an interglacial phase.

This evidence agrees quite well with the interpretation of information from the Mackenzie Delta area. In addition, the radiocarbon dates are also in reasonable agreement. The date of 33,200 B.P. from unit 4 would indicate a minimum lower limit for the interglacial (something lacking in the Mackenzie area) while the other dates of > 37,000 B.P. and > 43,000 B.P. for the interglacial seem reasonable. The date of 10,744 B.P. from unit 8 and a similar date for a sample collected further east would also tend to support the retreat values for late Laurentide ice further east in the Mackenzie Delta area.

Evidence of multiple valley glaciations is much weaker. In some areas of the Wind, Bonnet Plume, and Peel Rivers only a single till is present. Farther east along the Snake River and near the limit of Laurentide ice three tills have been found (Hughes, 1972). No intervening non-glacial deposits or weathering zones were present in the exposures. Hughes (1972) suggests these could have been the result of minor fluctuations in the Laurentide advance. He also suggests a multiple valley glaciation as a possible origin.

Much stronger evidence of multiple valley glaciations is found in areas entirely beyond the Laurentide limit. In fact, Hughes (1972) suggests that remains of at least three valley glaciations are present in the Ogilvie Mountains. The most distinctive evidence appears to be fresh moraines, which are regarded as the product of the last glaciation. Beyond them are more subdued morainic deposits and other glacial features which are attributed to a more extensive and older glaciation. Finally, isolated patches of till beyond both the fresh and subdued morainic deposits are attributed to an earlier and still more extensive glaciation (Hughes, 1972).

Unfortunately work in these areas of multiple valley glaciations suffers from a lack of detail. Moreover, the same problem found in the valley glaciation area of section B, that of either very recent radiocarbon dates or else dates beyond the radiocarbon range, is present here as well.

Viewing this area as a whole then, it would appear that two Laurentide advances separated by an interglacial have occurred. The first advance, probably early Wisconsin in age (although a pre-Wisconsin age certainly cannot be dismissed), created a large glacial lake in the Porcupine - Bell - Bonnet Plume Basins. This was followed by an interglacial which began at some time before 52,000 B.P. Although no lower limit on the interglacial has yet been determined from evidence in the Mackenzie Delta area, the one finite date of 33,200 B.P. (G.S.C. -204) from the Porcupine site, if accepted as being generally applicable area-wide, does provide some indication of a minimum lower limit for the interglacial of approximately 33,00 B.P. At some time after 33,000 B.P. a second and less extensive late Laurentide advance began. Retreat was underway at least by 10,000 B.P. and the area was clear of Laurentide ice by 7,000 B.P. The number and timing of valley glaciations remains in doubt.

(C) THE SOUTHWEST DISTRICT OF MACKENZIE

This area includes eastern elements of the Mackenzie Mountains, the Mackenzie Plain, the Franklin Mountains, and parts of the Liard Plateau and the Liard Range. The largest component is a section of the

Mackenzie Lowlands.

The earliest work on glacial features in the area is that of McConnell (1890). Subsequent work by Bell (1900), Hume (1921), Camsell and Malcolm (1921), Williams (1922), Whittaker (1922, 1923), Cameron (1922a, 1922b) and Hage (1945) provided considerable information. Raup's (1946, 1947) work represents a significant synthesis and extension of the earlier studies. Although Cameron (1922b) first suggested a relationship between the general pattern of deglaciation for the area and related this to the presence of glacial lakes, the first detailed area-wide study was that of Craig (1965). Craig's work remains the best current summary available.

(a) Source and Extent of Glaciation

As in the case of area B there apparently were two potential sources of ice for the area. The major source was Laurentide ice moving into the area from the east. A second and lesser source was ice derived from valley glaciers emanating from the eastern Mackenzie Mountains. Current indications are that a third possible source, Cordilleran ice sheets, did not reach the area (Craig, 1965).

Although the western limit of glacial advance by Laurentide ice is not yet known with any precision, it does appear that the entire South-West District of Mackenzie, with perhaps the exception of the Mackenzie Mountains, was at some point covered to a depth of several thousand feet.

Craig (1965) suggests a depth of 2,000-4,000 ft. (610-1,220 m) a.s.l. near the eastern ranges of the Mackenzie Mountains. Rutter (1974) indicates a maximum ice surface elevation of 5,000 ft. (1,520 m) a.s.l. in the same area. Evidence for the extent and significance of valley glaciers is at present lacking.

Glacial lakes produced during deglaciation are a major feature of the area. Craig (1965) suggests that an extensive proglacial lake, ancestral to both Great Slave Lake and Great Bear Lake, once occupied the area between the Franklin Mountains and the retreating Laurentide ice front further east (see Figure 12). This lake, Glacial Lake McConnell (named after R.G. McConnell) is evidenced by numerous and extensive strandlines throughout the area. The presence of several other glacial lakes in the area was also noted by Craig (1965).

The presence of these proglacial lakes has also left clear evidence of the significance of isostatic rebound in the area. At Fort Simpson strandlines reach an elevation of 600 ft. (180 m) a.s.l. To the southeast, in the area of Hay River, the same strandlines are at 900 ft. (270 m) a.s.l. (Craig, 1965). This indicates a rate of rebound on the order of 2 ft./mile (0.4 m/km) - quite a substantial rate! The significance of this situation for subsequent drainage patterns should be considerable.

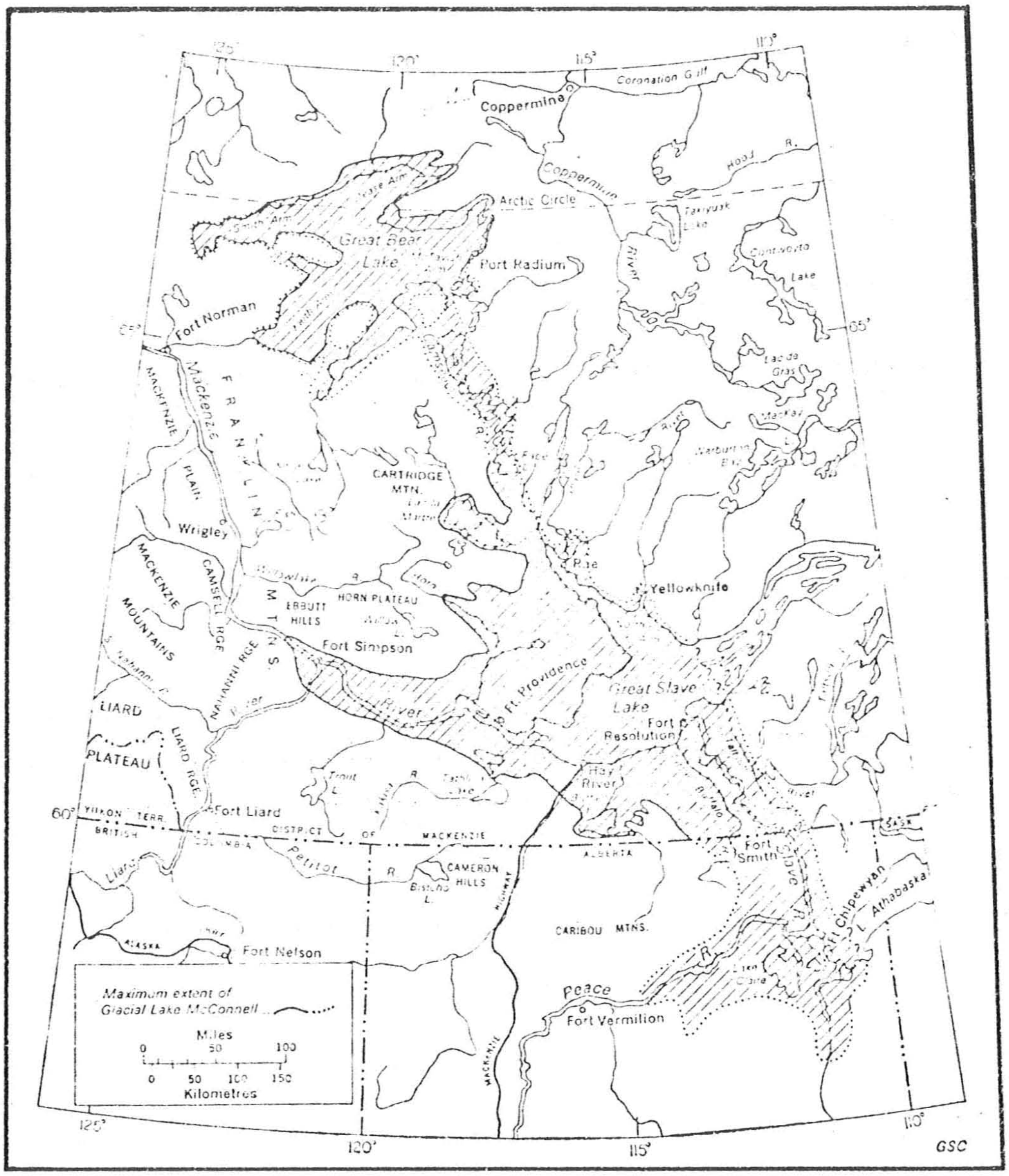


Figure 12. The limits of Glacial Lake McConnell (from Craig (1965)).

(b) Multiple Glaciations

The extreme deficiency of information on the Eastern Mackenzie Mountains and the relatively low elevation of most of the area has resulted in the elimination of evidence of earlier glaciations by the later glaciations. This has hampered the development of a clear understanding of the limits and nature of multiple glaciations of the area. Recent work by Rutter (1974) has however been encouraging. He suggests evidence for two Laurentide advance limits in the northern and central portions of the eastern flanks of the Mackenzie Mountains. Starting north of the subject area, in the southern Richardson Mountains, Rutter distinguishes two limits. One consists of fresh glacial features and the second, at a higher elevation, is indicated only by erratics. As one moves south across the gap created by the Peel Plateau, the distance between the two limits gradually increases until in the Wrigley Map area the late Wisconsin limit is set at 4,250 ft. (1,300 m) a.s.l. while the earlier and older limit is at 5,000 ft. (1,520 m) a.s.l. in the same area. Moving further south Rutter indicates that the limits tend to converge towards a maximum level of about 5,000 ft. (1,520 m) a.s.l. (Rutter, 1974).

The above evidence, although significant, cannot be considered conclusive. However, stronger evidence for multiple Laurentide advances is found in several sections in lower lying locations. Three sites are of particular note. Near the Mackenzie Highway, about 23 miles (37 km) south of Hay River, is a section in which 15-67 ft. (4.6-20.4 m) of gravel lying directly on bedrock is overlain by 5-15 ft. (1.5-4.6 m) of till which is itself covered by 0-5 ft. (0-1.5 m) of alluvial sand. A similar site on the Cameron River in the Cameron Hills contains 17-65 ft. (5.2-19.8 m) of sand and fine gravel resting on bedrock and overlain by 0-17 ft. (0-5.2 m) of grey till. In both cases the gravel contains a large percentage of Shield derived fragments. Craig suggests these fragments, underlying the till, were transported by a glaciation predating the late Laurentide advance (Craig, 1965). A third site along the Petitot River (Hage, 1945) suggests a similar origin.

Finally, a fourth section along the Liard River (Prest, 1972) contains 100 ft. (30 m) of brown till overlying 100 ft. (30 m) of crossbedded sand. The till itself is covered by a relatively thin soil zone which includes a volcanic ash horizon. Wood from 30 ft. (9.1 m) above river level and in the sand unit has yielded one of the few absolute dates for the area. The date of greater than 40,100 B.P. (G.S.C. - 412) supports the suggestion of an interglacial occurring about that time (Prest, 1972).

Evidence for multiple valley glaciations is at present lacking. The lack of absolute dates has further compounded the problem. It does appear, however, that two major Laurentide advances did occur with a major interglacial between them. The latter, a late Wisconsin advance, left numerous and extensive glacial lakes in the process of its retreat, Of the earlier advance, only till and high level erratics have as yet been found to indicate its presence in the area.

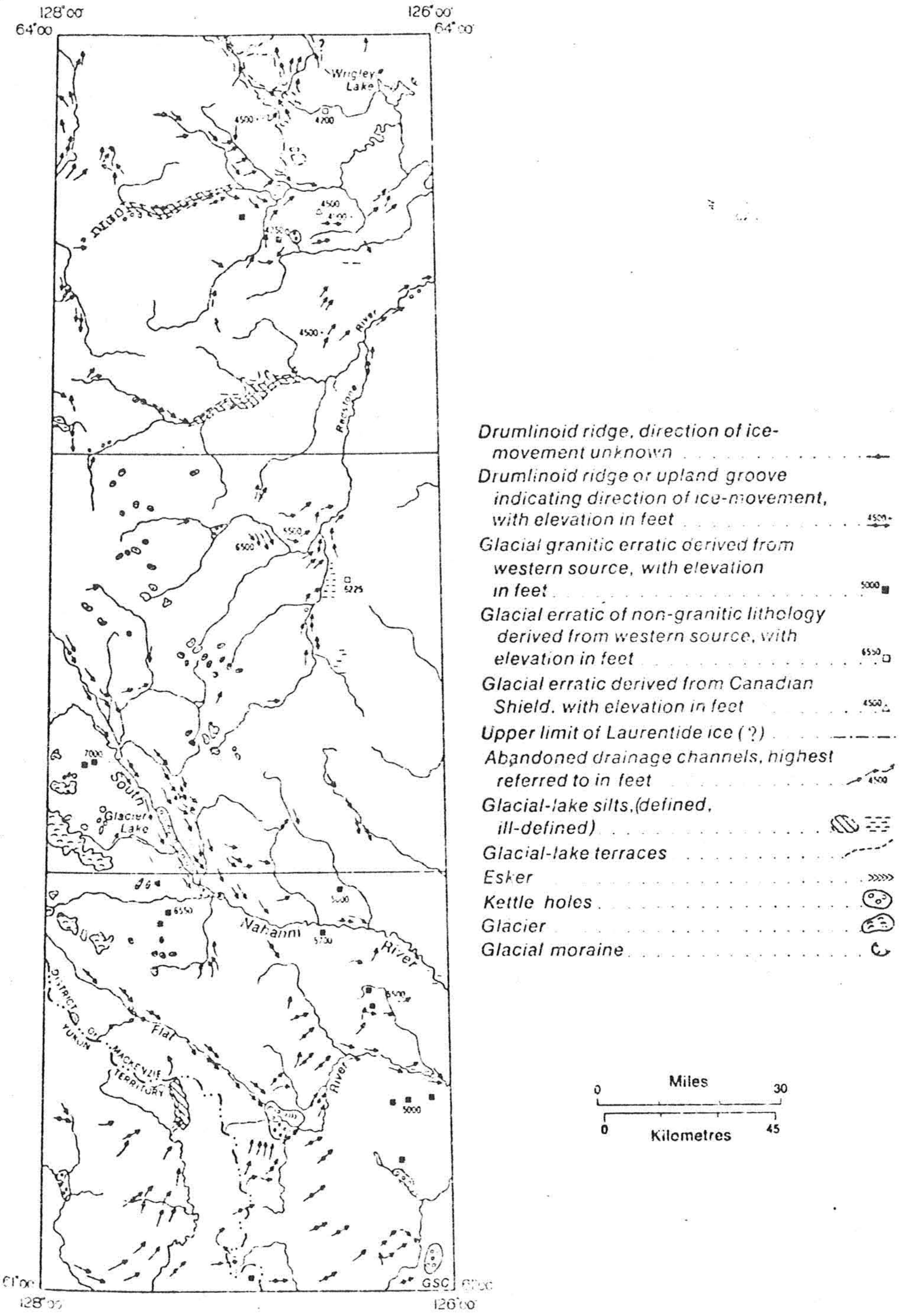
(D) THE WESTERN DISTRICT OF MACKENZIE AND THE EASTERN SELWYN MOUNTAINS

This area, wedged between areas A and C incorporates eastern elements of the Selwyn Mountains, the western half of the Mackenzie Mountains, part of the Hyland-Liard Plateau, and a small portion of the Mackenzie Plain. It is extremely isolated and in areas quite rugged. This may in part account for the deficiency of information available on the area. Indeed, despite the fact that reconnaissance of the area was conducted by workers such as Cameron (1936), it was not until the work of Douglas and Norris in 1960 that systematic mapping was undertaken. The first synthesis and utilization of the scattered glacial information on the area did not take place until Ford (1972) and Gabrielse's (1973) studies appeared.

(a) Source and Extent of Glaciation

The presence of several potential sources of glaciation in the area and the very incomplete knowledge of their extent make this area the least well understood of any of the four areas constituting the region. It is clear, however, that Laurentide ice could have been a source affecting the area, at least in the southeastern part. The Cordilleran ice sheet, both the Selwyn and Cassiar lobes could have affected the southwestern portion of the area. Finally, alpine and valley glaciation certainly had a role to play but exactly what the significance of that role is not clear present.

Until quite recently attempts to determine the actual extent of glaciation in the area have remained on a speculative level. Recent work by Gabrielse (1973), while not defining clear limits, has provided some useful indications. Evidence appears to show that the area near Skinboat Lake and reaching an elevation of 6,415 ft. (1,955 m) a.s.l. was completely overridden by Cordilleran ice from the southwest (Gabrielse, 1973). Moreover, the presence of glacial erratics in the area east of Irvine Creek clearly indicates that the same Cordilleran ice which covered the Skinboat Lake area and which originated in the Cassiar Mountains covered the Irvine Creek area to at least a height of 5,500 ft. (1,680 m) a.s.l. The Cordilleran origin of this ice sheet is also supported by abandoned drainage channels indicating the southwestward retreat of the ice sheet (see Figure 13).



Glacial features of Flat River, Glacier Lake, and Wrigley Lake map areas.

Figure 13. Extent of glaciation in area D (from Gabrielse (1973)).

There is also clear evidence that valley glaciers, originating in the Selwyn Mountains descended the Flat and South Nahanni Rivers. The presence of strong grooving and the slope of kame terraces indicates the intensity of this valley glaciation. Abandoned drainage channels give evidence of a northwestern retreat direction (Gabrielse, 1973).

The presence of erratics derived from a western source is also significant. Erratics at a height of 7,000 ft. (2,130 m) a.s.l. northwest of Glacier Lake, and at a height of 5,600-5,700 ft. (1,710-1,740 m) a.s.l. on either side of the South Nahanni River Valley at a point just down river from where the Irvine Creek Valley and the South Nahanni River join, give some indication of the size of the valley glaciers (Ford, 1975). Furthermore, a predominantly northern and eastern movement of valley glaciers out of the Backbone Ranges is also indicated by erratics. Maximum heights of 6,255 ft. (1,906 m) a.s.l. and 6,500 ft. (1,980 m) a.s.l. is indicated by erratics and abandoned lateral channels respectively in the Dal Lake area (Gabrielse, 1973). Both the erratics and the channels indicate a southwesterly source of ice.

Finally, and perhaps most puzzling of all, is the problem of the extent of Laurentide advance from the east. A large westwardly convex moraine in the area of Wrigley Lake and containing granitic rock apparently originating in the Canadian Shield is considered to be an indication of the extent of a Laurentide advance in the northern part of area D in the Wrigley Lake area. Gabrielse (1973) reports erratics up to 4,500 ft. (1,370 m) a.s.l. In addition, a series of abandoned marginal channels on the northeast slope of Tigonskweine Range at an elevation of 4,500 ft. (1,370 m) a.s.l. is also viewed as evidence of the minimum limit of a Laurentide ice sheet.

Rutter (1974) suggests a slightly different interpretation. He reports that discontinuous meltwater channels in the Wrigley area are at an elevation of 4,250 ft. (1,295 m) a.s.l. and that these channels represent a Classical Wisconsin advance. In addition, there are eastern origin erratics at 5,000 ft. (1,520 m) a.s.l. in the same area. He suggests that these erratics are the evidence for an earlier glacial advance. These two distinct limits, one of fresh marginal channels attributed to a Classical Wisconsin advance, and a second and higher limit marked by erratics were traced from locations in the Richardson Mountains south into this area. Tracing the limits further southwards Rutter suggests that the lower limit gradually rises and that in the Sibbeston Lake area the two limits merge at an elevation of approximately 5,000 (1,520 m) a.s.l. Erratics at such elevations have been found in the Sibbeston area.

Further south and west behind the Front Range, in an area referred to as the North Karst, G. Brook has found erratic material up to an elevation of 4,500 ft. (1,370 m) a.s.l. (Ford, 1975). The North Rim of First Canyon in Nahanni National Park contains erratics also at an elevation of 4,500 ft. (1,370 m) a.s.l. Finally, further reconnaissance in 1974 indicated the presence of more erratics, again only up to an elevation of 4,500 ft. (1,370 m) a.s.l. All of these erratics were greenstones, diorites, and granites (Ford, 1975) and all were apparently derived from the Canadian Shield.

(b) Multiple Glaciations

Gabrielse (1973) indicates that the area has been affected by at least one stage of alpine and valley glaciation, a Cordilleran glaciation, and at least one Laurentide advance. Rutter (1974) suggests at least two Laurentide advances; one of late Wisconsin age and an older, more extensive early or pre-Wisconsin advance. Ford (1975) in discussion with the present author suggests a somewhat more complex scenario. Utilizing evidence from erratics, moraines, glaciolacustrine deposits, and uranium series dating, Ford (1975) suggests a seven stage sequence of major glacial events which includes three Laurentide and two Cordilleran glaciations. The sequence is summarized in Table 2.

The first major event is the "First Canyon Glaciation". This consisted of a Laurentide advance which apparently completely covered the Nahanni Range and the Ram

Table 2. Sequence of Events in Area D. (Based on Ford (1975) and Ford (1976) and Somewhat Modified).

	Event	Age (Years B.P.)	Correlation
	Post-Glacial	<10,000	Post-Glacial
7.	Jackfish Glaciation, Glacial Lake Tetcela	30,000- 10,000	(Classical) Wisconsinan
	-pene-contemporaneous cordilleran glaciation-		
6.	No evidence of early Wisconsin		Early Wisconsin
5.	Virginia Falls Interglacial	140,000- 80,000?	Sangamon Interglacial
4.	Clausen Glaciation, Glacial Lake Nahanni		Illinoian?
3.	Flat River Glaciation	<180,000	
2.	Grotte Valerie Interglacial I and II -first Virginia Falls (Interglacial II)	>350,000- 200/180,000	
1.	First Canyon Glaciation -pene-contemporaneous cordilleran glaciation?	>350,000	Kansan?
	-Beginning of preserved antecedent canyons	<2,000,000	Lower quaternary
	-Prolonged erosion, mainly fluvial		Tertiary
	Quartz Monzonite Injection	c.110,000,000	Cretaceous

Plateau and reached as far west as the flanks of the Nahanni Plateau and Tlogotsho Tableland now located at 4,500 ft. (1,370 m) a.s.l. (Although it is suggested that the area may have been at a lower elevation at the time of glaciation). The strongest evidence for this glaciation is that of remnant winnowings of till cemented by calcite precipitate found in Grotte Valerie. Stratigraphic work and dating has led to the suggestion that the glaciation occurred shortly before 350,000 B.P. Other evidence cited is that of erratics found scattered about the Nahanni and Ram Plateaus and present even at the rim of First Canyon (Ford, 1975).

Approximately contemporary with the First Canyon Glaciation Ford indicates an accompanying Cordilleran Glaciation. This Cordilleran advance is credited with producing major drainage changes affecting the Irvine and Borden areas, and the breaching of several divides. Although the First Canyon and the Cordilleran Glaciation need not have occurred at the same time they are considered to have occurred within the same general glacial period as both are tentatively correlated with the Kansan Glaciation.

Following the First Canyon Glaciation Ford suggests an interglacial, the Grotte Valerie Interglacial, lasting from approximately 350,000 B.P. until 200,000 - 180,000 B.P. This is evidenced by the growth during this period of stalactites and stalagmites first in Grotte Valerie and later in

Grotte Louise (Ford, 1975).

The third and fourth major events in the sequence, the Flat River Glaciation and the Clausen Glaciation, consisted respectively of a major Cordilleran advance from the west followed by a Laurentide advance from the east. Ice from the Ragged Range as well as ice from the Selwyn Mountains (part of the Selwyn Lobe) moved down the trunk valleys and met an ice sheet emanating from the Cassiar Mountains (the Cassiar Lobe). The ice filled the Borden and McLeod Valleys and moved down the Caribou Valley. The retreat of the Cordilleran advance was followed closely by a Laurentide advance from the east. Not as extensive as the First Canyon Glaciation, this advance only reached 2,000 (610 m) a.s.l. at the eastern edge of the Nahanni Plateau. The presence of this ice front resulted in the creation of an extensive glacial lake, Lake Nahanni, which reached 2,000 ft. (610 m) a.s.l. and which subsequently left lacustrine deposits of upwards of 600 ft. (180 m). Using uranium dating evidence from Grotte Valerie it is suggested that the Flat River, the Calusen Glaciation, and Lake Nahanni date from 100,000 - 140,000 B.P. and are correlated with the Illinoian mid-continental glaciation.

The next major event in the area was an interglacial lasting approximately 20,000 years from 140,000 - 120,000 B.P. and termed the Virginia Falls Interglacial.

During this period, major re-excavations of valleys by fluvial processes took place. In fact, the interglacial's name is derived from the re-excavation of Virginia Falls which took place during this time.

The sixth major glacial event in the area, is the early Wisconsin glaciation. This glaciation left little apparent evidence which could be distinguished from the preceding interglacial. It is suggested that no major Cordilleran advance occurred during this period (Ford, 1975).

The seventh event in the sequence, the Jackfish Glaciation, consisted of a third Laurentide advance into the area. This advance was stopped by the Nahanni Range. Although it could not push through the range it did occupy Jackfish Gate and built a lateral moraine to 2,500 ft. (760 m) a.s.l. on the north flank of Mattson Mountain. The renewed blocking of drainage by the ice front resulted in the creation of another glacial lake, named Lake Tetcela, which extended from just above the entrance to Third Canyon down to the Jackfish Compartment and which left deposits up to 1,300 ft. (400 m) a.s.l. Retreat of this ice began between 14,000 and 12,000 B.P. and the lake was apparently gone by 8,000 B.P.

The above constitutes a brief attempt to bring together information on the glacial history of the region. We shall return to the regional view in Chapter V. The next three chapters, however, will focus upon one small section of area D: the central portion of Nahanni National Park beginning, in the next chapter, with the general physiography and geology of the detailed study area.

CHAPTER II

PHYSIOGRAPHY AND GEOLOGY OF CENTRAL NAHANNI NATIONAL PARK

The detailed study area, of approximately 1,000 sq. miles (2,600 km^2) is shown in Figure 14. Somewhat irregular in shape it extends from latitude 61° 15' to latitude 60° 45' and from longitude 125° 00' to longitude 127° 45' and occupies portions of Top Sheets 95 E/7, 95 E/8, 95 F/5, 95 F/6, 95/E/10, 95 E/9, 95 F/12, 95 F/11. Geologically the Central Nahanni Park Area extends over two map areas: Flat River (95 E) and Virginia Falls (95 F). The former was mapped as part of "Operation Mackenzie" (Douglas, 1959a) with the most comprehensive geological report issued being that of Douglas and Norris (1960). The latter area was mapped as part of "Operation Nahanni" and reported on initially by Gabrielse, Roderick and Blusson (1964) and later was discussed in more detail by Gabrielse (1973). More recently Ford (1975) has attempted a synthesis and simplification of the information contained in the above reports.

The emphasis here will not be on the extensive revision of the geological maps or even an attempt to reconcile the differences in mapping units and the ascribed ages of the different formations. The limited time available in the field and the inaccessibility of many parts of the

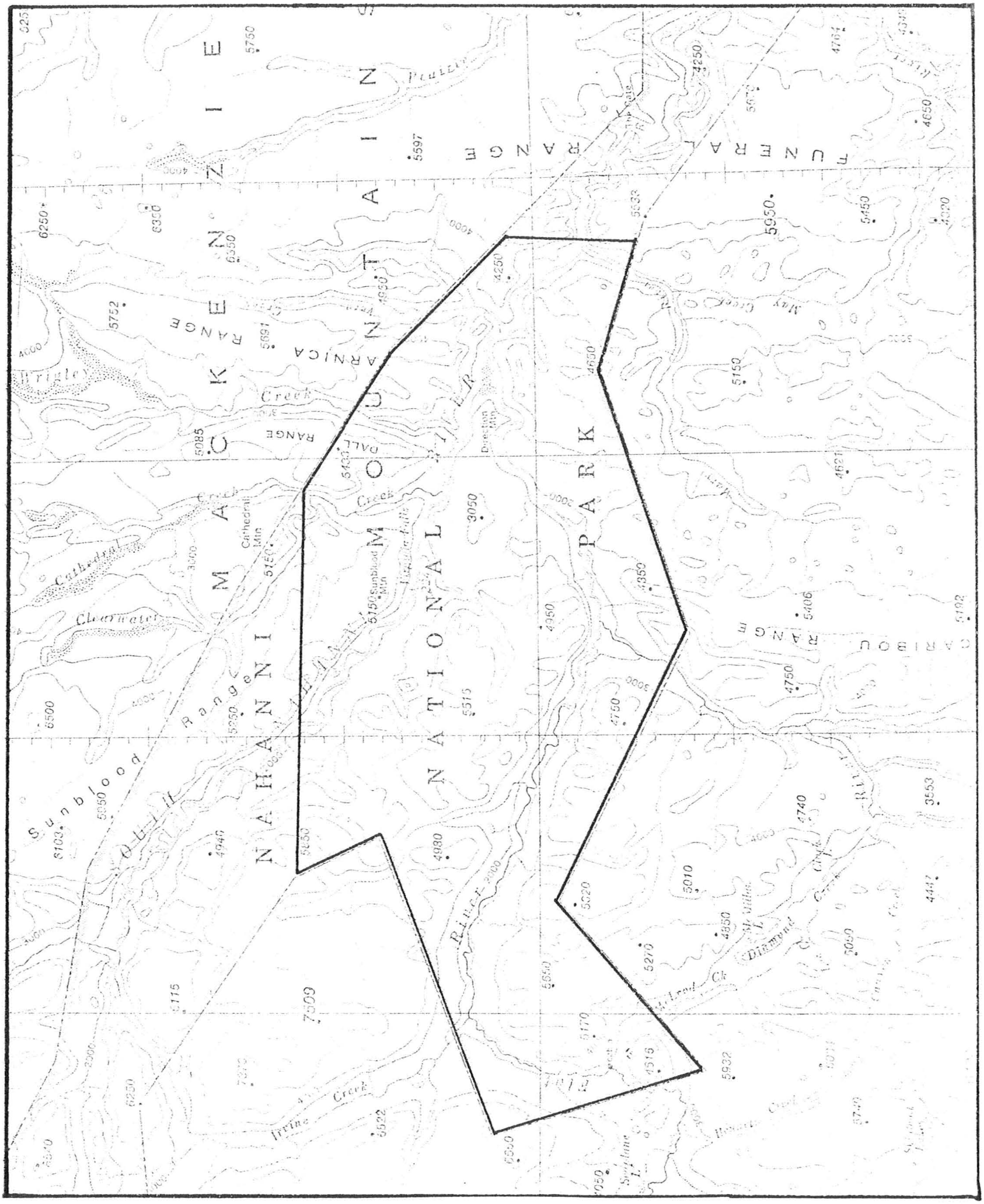


Figure 14. Physiography and location of the study area.

study area precluded such an attempt. Instead attention will centre upon: (1) discussing the general physiography of the area; (2) the geological formations present; and (3) the geological history of the area. Moreover, for those limited areas covered on the ground during the field season an effort will be made to supplement the geological information contained in the published reports.

1. GENERAL PHYSIOGRAPHY AND GEOLOGY OF THE STUDY AREA

The major physiographic and geologic features in the study area are shown in Figures 14 and 15* respectively. The area is bounded on the east by Funeral Range and on the west by the Logan Mountains. To the north are the Mackenzie Mountains and to the south the Liard Plateau. In fact, the South Nahanni and Flat rivers, the principle rivers in the area, are regarded as the boundary between the Mackenzie Mountains and Liard Plateau. Five other major streams: the Clearwater, Wrigley, Marengo, the Irvine and the Caribou are also present in the study area. The major faulting and structural features occur in a N.E. - S.E. direction with the Caribou, Mary, Arnica, Funeral and Manetou thrusts; the Mary, Vera, Dall and Wrigley synclines; and the Wrigley and Dall anticlines, being the most prominent structural features affecting the area.

*Figure 15 located in pocket at back.

The relief, which ranges from below 1,400 ft. (430 m) a.s.l. to above 5,600 ft. (1,710 m) a.s.l., varies greatly. The Direction Mt. area, in the central part of the study area, at approximately 2,500 - 3,500 ft. (760-1,070 m) a.s.l., is an area of gently rolling uplands; the area extending north from the South Nahanni River is one of well dissected and rather distinct ridges with intense folding in places; while the area between the Caribou River and the South Nahanni consists of uniform fold forms with gently or moderately dipping beds.

2. DESCRIPTION OF MAP UNITS

For the purposes of the present discussion the study area will be divided into two sections: the east half and the west half. Such a division is useful in view of differences in description and chronology between the geological reports covering the two map areas involved.

(A) WEST HALF OF STUDY AREA

The western half of the study area contains 4 of the 36 map units described by Gabrielse, Roddick, and Blusson (1964) in their report on the entire Flat River Map area. The youngest of these, Map unit 36 (coloured yellow on Figure 15), consists of unconsolidated deposits. More will be said concerning these deposits later in the present discussion and in subsequent chapters, but it should be noted at this point that these deposits are more extensive than the geological map indicates. Map unit 35 (Green) consists of quartz monzonite and granodiorite and is considered to be Cretaceous in age. Although present at only one location in the study area (south of Irvine Creek) this unit is quite prominent in the Logan Mountains further to the west. Samples collected within the Flat River Map Area have been dated at 110 m.y. The outcrop in the map area appears to be a stock associated with two large batholiths; one to the north and northwest and a second to the south. These are regarded as plutons of Mesozoic-Tertiary age which intruded the paleozoic platform sediments.

Map unit 23 (Black) in Figure 15 consists dominantly of black pyritic shale with some dark argillaceous limestones and black cherty dolomite also present. It is considered Middle and Upper Devonian in age. In the geological report this formation is located in the westernmost corner of the study area although it has been associated (Gabrielse, Roddick and Blusson (1964)) with map unit 5 at Virginia Falls. During our reconnaissance down the Flat River we found numerous outcrops of shale along the river which closely correspond to Map Unit 23. These shale deposits, taking the form of benches, were extremely difficult to recognize because of overlying till and could readily have gone undetected in an extensive reconnaissance such as that conducted by the G.S.C. The location of these shale outcrops is noted in Chapter III of the thesis.

Map Unit 22 consists of orange weathering and pink mottled limestone and dark and light grey dolomite (light blue in Figure 15) and is considered Cambrian and Ordovician in age. It covers most of the western half of the study area attaining a measured stratigraphic thickness of 2,800 ft. (850 m) (Gabrielse, Roddick and Blusson, 1964).

(B) THE EASTERN HALF OF THE STUDY AREA

The eastern half of the study area contains 8 map units out of the 36 described by Douglas and Norris (1960). The youngest of these (yellow in Figure 15) and numbered map unit 36 by them consists of unconsolidated deposits of recent age. As was the case in the western half of the study area the extent of these deposits is not fully indicated on the geological map. A better indication of their extent may be found in Chapter III.

Map unit 29 consists of dark grey shale Middle to Upper Devonian in age. It is quite extensive covering most of the area of the Direction Mt. Upland south to the park boundary and is quite prominent along sections of the Flat River. Although measured sections over 3,000 ft. (910 m) in thickness have been examined (Douglas and Norris, 1960) indicating this is a major unit, it must be realized that Map unit 29 is really a composite of several other map units which could not be differentiated (Douglas and Norris, 1960).

Map unit 20 (black in Figure 15) which is sometimes grouped with unit 29 as a basal component, is in effect a composite of two other map units. Unit 20 is dominantly a grey calcareous shale weathering to a pale yellowish grey with some shaly limestone also being present. It is located in the extreme eastern part of the study area as well as in the area north of the South Nahanni River.

Map unit 16 (pink in Figure 15) is a fine-grained dolomite dark in colour, which weathers to a medium grey. It extends north from the South Nahanni River to the Park boundary. The formation reaches a thickness of 2,600 ft. (790 m) at Cathedral Mt. (Douglas and Norris, 1960) and is considered Middle Devonian in age.

Map unit 15 (orange in Figure 15) is again a composite unit consisting of undifferentiated limestone, shale and dolomite. Generally the formation is poorly exposed and has not been studied in any detail. It is considered to be Devonian or older in age.

Map unit 5 (black in Figure 15) is located between Sunblood and Cathedral Mountains and consists of dark grey to black calcareous and graptolitic shales reaching a measured thickness of 3,800 ft. (1,160 m). The unit which is generally thinly bedded may contain dark bedded limestones. It is classified as Ordovician or Silurian in age by Douglas and Norris (1960).

Map unit 3 (light blue in Figure 15) is a formation containing dark grey limestone with some massive dolomite and grey shale present. 2,500 ft. (760 m) of section have been measured on the dip slope of Sunblood Mt. (Douglas and Norris, 1960). The unit extends from the Virginia Falls area along the north shore of the South Nahanni and constitutes a major part of the Sunblood Range. The unit is considered Middle Ordovician in age.

Finally, map unit 1 (dark blue in Figure 15) has been named the Sunblood Formation (Kingston, 1951) after the type section located near Virginia Falls and on the slopes of Sunblood Mt. The unit has been measured at 3,500 ft. (1,070 m) in thickness (Douglas and Norris, 1960) and consists of cryptograined orange and pink weathering limestone. The top is a brilliant orange coloured limestone. At the base is a massive grey limestone in which Virginia Falls is located. The formation is considered Ordovician in age.

It should be noted that unit 1 in the eastern half of the study area may be associated with unit 22b in the western half. Similarly unit 5 in the east may be associated with unit 23 (Ford, 1975).

3. THE GEOLOGIC HISTORY OF THE STUDY AREA

The geologic history of the study area based on Douglas and Norris (1960) and Gabrielse, Roddick and Blusson

(1964) and summarized by Ford (1975) consists of two major phases: one of deposition and a second of deformation. The first, during the Paleozoic consisted of the deposition of upwards of 20,000 ft. (6,000 m) of strata. The second major period began during the Cretaceous and consisted of volcanic and tectonic activity which resulted in the emergence of batholiths and stocks and the folding, upwarping, and general deformation of the strata. The latter processes are considered to be continuing today.

CHAPTER III

A PRELIMINARY GEOMORPHIC MAPPING OF THE STUDY AREA

THE QUESTION OF METHODOLOGY

Producing a geomorphic map for an area such as the Central Nahanni presents some serious mapping problems. One of the more significant ones involves the lack, to date, of a broadly accepted and proven mapping scheme. Although the need for geomorphic mapping as a distinct branch of geomorphology was recognized as early as 1914 it was not until the late 1940's and early 1950's that concerted efforts were made to develop complete and readily applicable mapping schemes. Several different mapping systems with varying degrees of complexity have been developed since then, of which the Polish, French, Russian, Belgium and Canadian are the most widely known.

Such mapping schemes, however, often tend to be extremely complex and the legends developed differ markedly depending upon whether the authors wish to emphasize morphology, morphometry, morphogeny or morphochronology. Moreover, such schemes often can have difficulty accommodating the "special features" found in a given area. Finally, such mapping systems generally require a fairly complete and detailed knowledge of the area being mapped if they are to be effective.

The need in the Central Nahanni was for a general geomorphic mapping technique which would have the flexibility to handle some unique features while still remaining relatively straight forward. A further, and perhaps the most serious consideration, was the limited amount of data which could be collected in the field. It was decided therefore to not make use of one of the "standard" mapping schemes. Instead it seemed more appropriate to develop a fairly simple preliminary mapping scheme which would deal only with those features found in the study area.

The result of this effort is Figure 16.+ It must be stressed that this map is preliminary in nature. Only ten days were spent in the field in the subject area and because of the extreme difficulty of travelling in the Central Nahanni, only a very restricted area could be groundtruthed. The map no doubt will be altered considerably as more data become available.* For the present mapping however, the features have been grouped into four categories: (1) physiographic and geologic; (2) fluvial and fluvioglacial; (3) glacial; and (4) periglacial. Each group of features will be discussed in turn.

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*Some of the information contained on the map was incorporated into a report for the National Parks Board (Ford, 1975). The present map however already contains new information which this writer could not supply at the time of the writing of the Parks report.

+Figure 16 located in pocket at back.

1. PHYSIOGRAPHIC AND GEOLOGIC FEATURES

The general physiography and bedrock geology of the area have been discussed in the previous chapter. In the geomorphic map the relief and bedrock features are shown in black. Ridge crests and prominent peaks (see Plate 1) are indicated by continuous lines and sharply pointed peaks. More subdued mountain tops are shown with more rounded peak symbols.

The use of hachures of varying thickness, spacing and length has been employed to indicate the length and severity of slopes. The longer the hachures, the longer the slopes. The thicker and more closely spaced the lines, the greater the steepness. Although no absolute slope angles may be ascribed to this scheme it does provide a relative scale and is a useful indicator of the general pattern of relief.

Rolling uplands, which might be described as subdued topography (see Plate 2), and plateau areas at considerable elevation above river level (see Plate 3) have been indicated on the map by the use of light green and black shading respectively. While present in several parts of the study area these features are most prominent in the area extending west from Direction Mountain between the Flat and South Nahanni Rivers. Such features may well reflect the effect of glaciation upon relatively weak strata.

Finally mention should be made of the presence of numerous bedrock benches (consisting dominantly of shale and

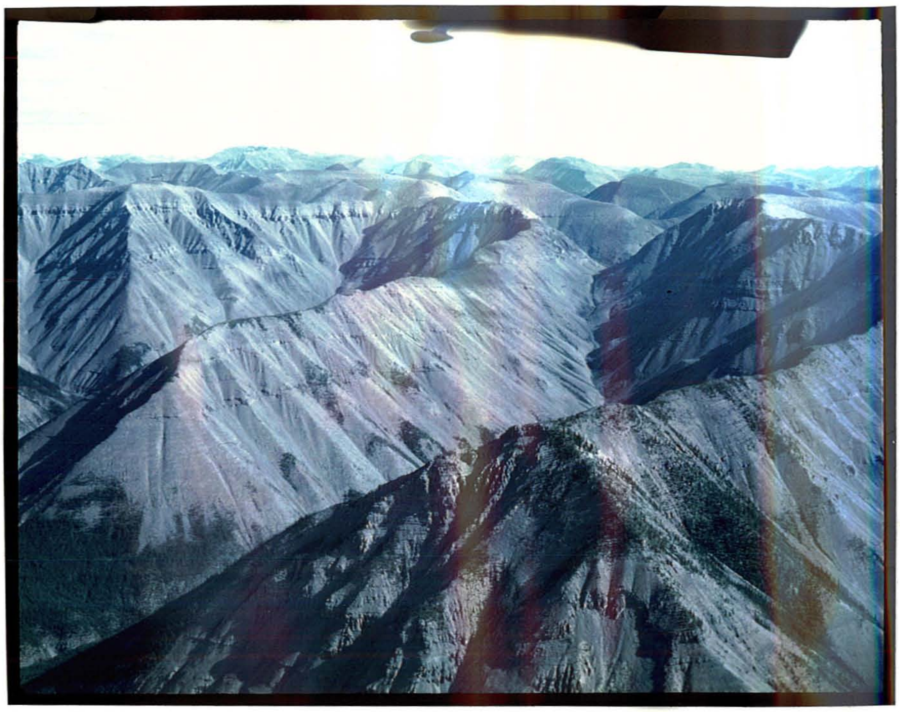


Plate 1. Sharp peaks and crests.

Plate 2. Rolling uplands near Direction Mountain.

limestone) (see Plate 4) which are present throughout the study area and are indicated on the map by grey shading. They occur at several elevations and in numerous locations. Their presence is extremely difficult to detect both from the air and on the ground because of the presence of overlying till and vegetal cover. As a result, the actual extent of such benches is, in all likelihood, much greater than is indicated on the map.

2. FLUVIAL AND FLUVIO-GLACIAL GEOMORPHOLOGY

The fluvial and glaciofluvial features have been indicated with the use of blue and yellow colours and symbols. Dark blue has been used for fluvial features and light blue for glaciofluvial features. Flood plains (see Plate 5) are shown in dark yellow and boulder bedded creek beds (see Plate 6) are indicated by light yellow shading. As can be readily seen from the map, the fluvial and glaciofluvial geomorphology of the area is extremely varied and, as will become more apparent later in the discussion, reflects a very dynamic environment.

The present drainage pattern has been indicated with broad dark blue lines for the two major trunk streams of the South Nahanni and the Flat. The major tributary streams; Marengo, Clearwater, Wrigley, Vera, the Irvine and the Caribou are shown in dark solid blue. The remaining watercourses have been indicated in thin solid

Plate 3. Plateau areas between Flat and South Nahanni.

Plate 4. Example of bedrock benching along the Flat River.

Plate 5. Typical floodplain area.

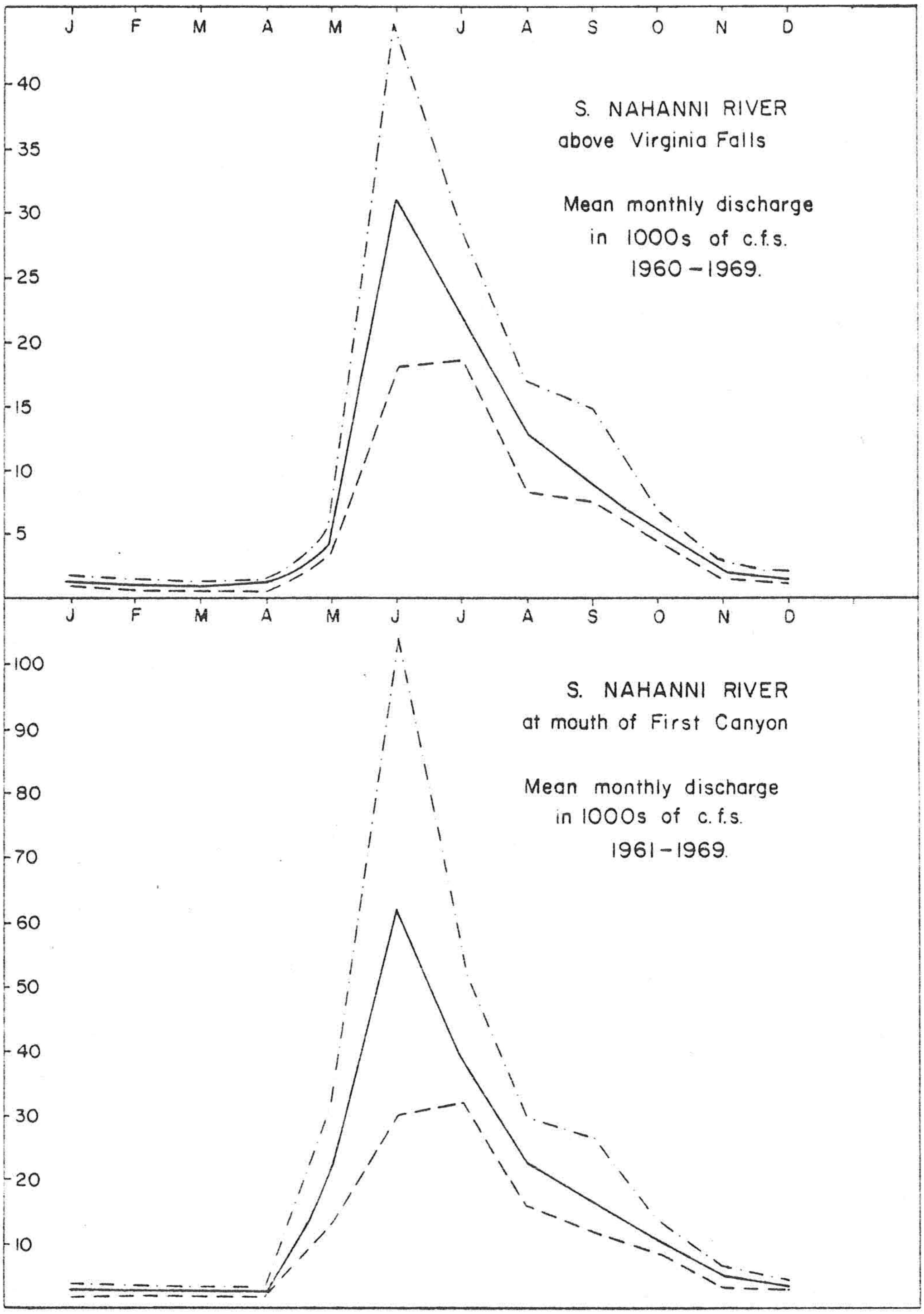
Plate 6. Example of boulder bedded creek.

blue if they appear perennial and broken blue lines if they are intermittent. Since only limited air photo coverage was available and the fieldwork was restricted to a short summer season it was difficult to distinguish between perennial and intermittent streams. Where there was doubt, it was determined to class the streams as intermittent. Clearly the drainage net is not complete. In an area such as the Central Nahanni it is often difficult at times to decide the extent of streams.

Even with the limited data available it is apparent from the map that the drainage pattern in Central Nahanni Park is extremely complex and has undergone considerable alteration. The development of this nearly classic case of deranged drainage is due largely to the effects of glacial activity. In particular, the drainage pattern west of the South Nahanni-Flat confluence has been subject to extensive glacial modification. A sequence of events accounting for the development of the present drainage pattern has been suggested by Ford (1975) and was discussed in Chapter I in connection with the glacial activity in all of area D. As indicated earlier the scenario involves a complex process of valley divide breaching, glacial blockage of valleys, ice blocked ponding of meltwaters and reversal of flow directions for many of the streams and rivers.

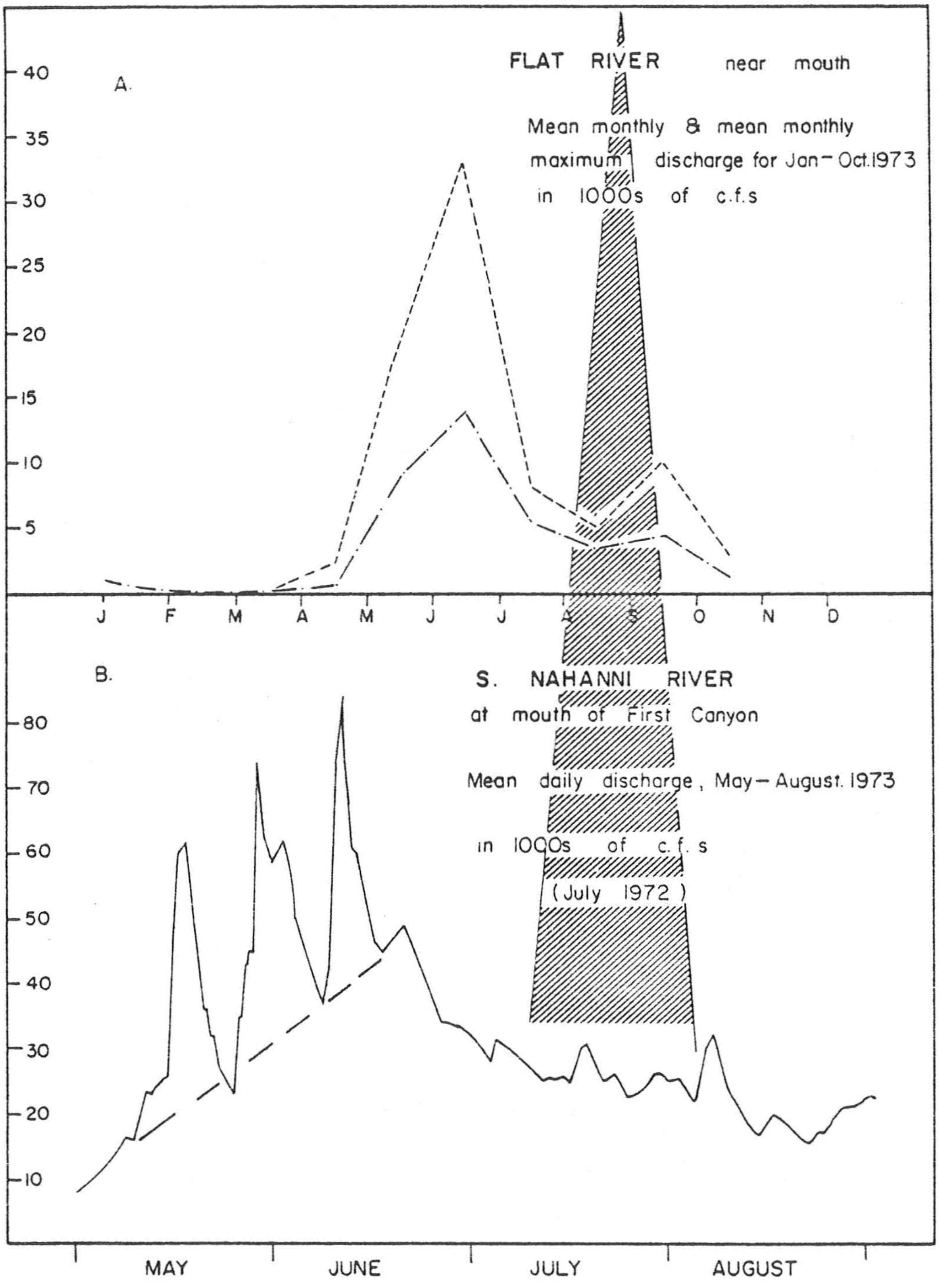
Concerning the present character of the rivers information is limited. Only a small amount of stream-gauging data are available. Stream gauging stations have been installed only quite recently at two sites in the study area. One gauge site is above Virginia Falls, and the second is on the Flat River just above the Flat-South Nahanni confluence. In addition, data are available from a third gauge site outside the study area at the entrance to First Canyon on the South Nahanni River. The record from these sites is short and not of good quality. Nevertheless, the gauging data do indicate a somewhat typical flow regime for such an area with low discharge in winter, peak flows during June, and fairly high discharge levels in July, August, and September (see Figure 17a). As is also fairly common in such regions, there is a tendency towards fairly extreme events with rapid changes in river level and, at times, quite high water levels (see Figure 17b).

Because of the diversity and distinctiveness of the fluvial "environments" present in the Central Nahanni the fluvial and glaciofluvial features present may be best discussed in terms of their occurrence in the different sections of the South Nahanni and Flat Rivers. For the purposes of the present discussion that portion of the South Nahanni within the study area may be divided into several sections: (a) the South Nahanni above Virginia Falls; (b) the Gorge below Virginia Falls; (c) the South Nahanni from



(after Ford, 1975)

Figure 17(a). Mean monthly discharge for Flat and South Nahanni Rivers (1961-1969).



(after Ford,1975)

Figure 17(b). Mean daily discharge for Flat and South Nahanni Rivers (Summer 1973).

the end of the Virginia Falls Gorge to the South Nahanni-Flat confluence. Similarly, the Flat River may be divided into several sections: (a) the stretch from above Seaplane Lake to McLeod Creek (technically outside the park but included here for completeness); (b) a stretch from McLeod Creek to a point seven miles inside the Park; (c) the section of river extending from seven miles inside the Park to a point eight miles above the South Nahanni-Flat confluence; (d) a fourth section of the Flat covering the remaining distance to the confluence. Each of these will be discussed.

The section of the South Nahanni above Virginia Falls, part of the "upper river", extends for some ten miles. The gradient in this portion of the river is gentle varying between 4 and 7 ft./mile (0.7-1.3 m/km). Initially the river meanders across a fairly broad floodplain bordered by quite steep-walled valley sides, but as the river approaches the falls meandering ceases, the floodplain narrows, and the river reverts to a less sinuous pattern becoming straighter as it approaches the Falls.

Along the south side of the river and extending back to the valley side is an extensive terrace of grey laminated silts. Standing 150-200 ft. (46-61 m) above river level, it has been clearly exposed by river entrenchment. Since no bedrock is exposed in the river valley it is not possible to determine the depth to which the silt extends. Moreover, the lack of any valley bedrock exposures in this entire section of the river makes it difficult to determine the depth of fill present in the valley. It would appear however, that the valley floor in this section does consist of lacustrine deposits probably overlying glacial till.

Virginia Falls, the dividing line between this and the next section of the river, is itself an extremely intriguing geomorphic feature (see Plates 7 and 8). Two sketches of the Falls are shown in Figure 18a. Of particular interest here is the thinning out of the silt deposits in the area as the bedrock in the area of the Gorge rises.* A second feature in the area of the Falls is the apparent presence of a buried gorge (see Figure 18b). From some exposures in the small valley cut in the wall below the Falls it appears that, at least partially, the gorge is filled by glacial debris.

The character of the River changes radically below Virginia Falls. In this section the river flows in a narrow, fairly straight, confining gorge and down an increased gradient and is extremely turbulent with numerous sections of standing waves. The Gorge itself is quite spectacular. Approximately three miles in length with nearly vertical 300-400 ft. (90-120 m) walls of a deep orange-yellow colour it

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*For a more detailed discussion of the Falls the reader is referred to Ford (1975) in which much of data collected on the site during the 1973 field season is discussed at length.

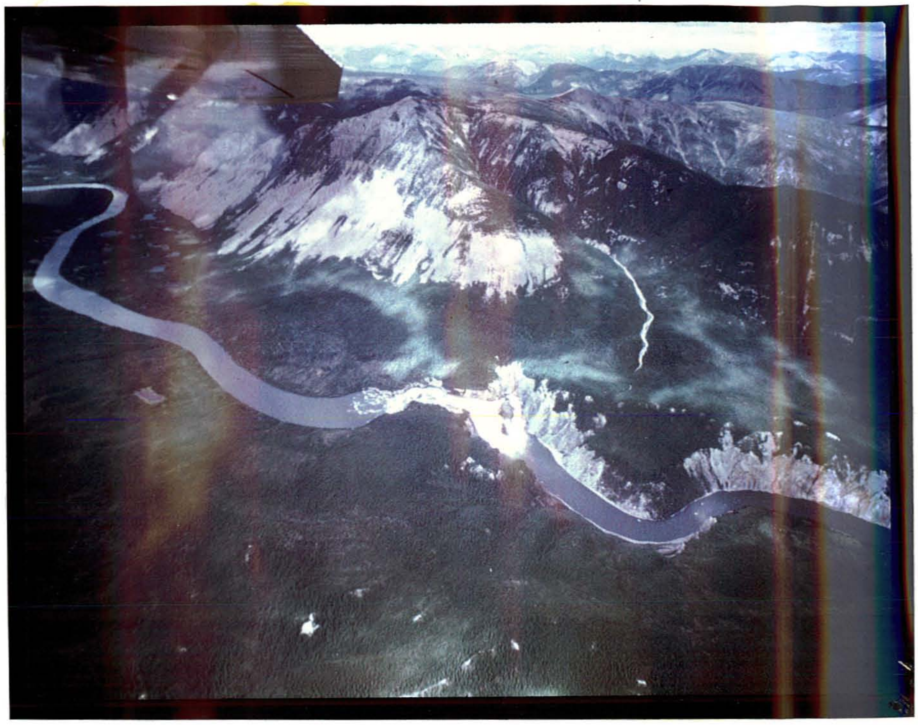


Plate 7. Area of South Nahanni in vicinity of Virginia Falls.

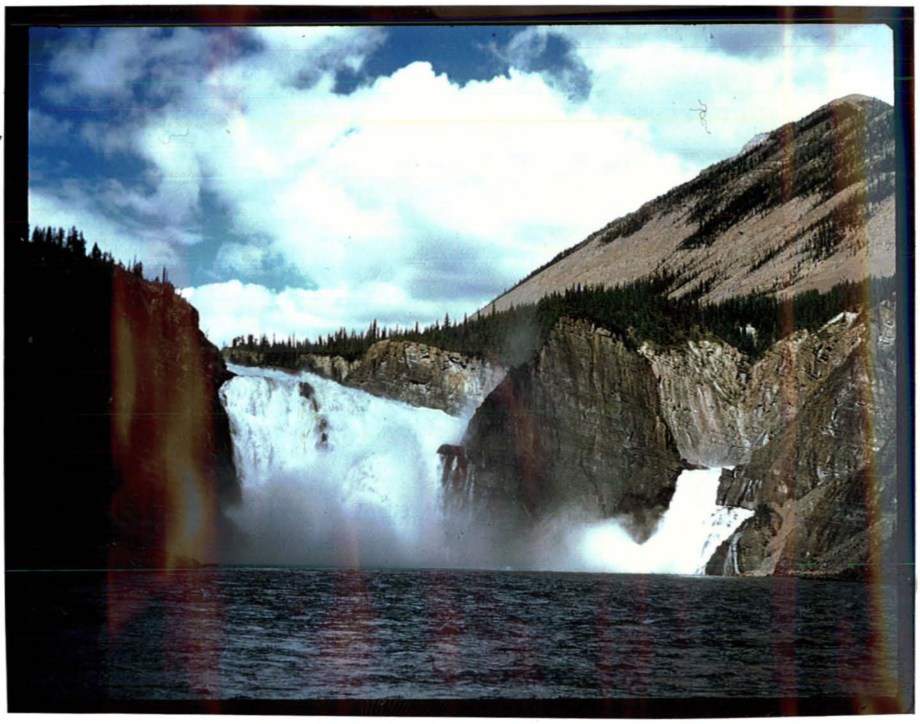


Plate 8. View of Virginia Falls.

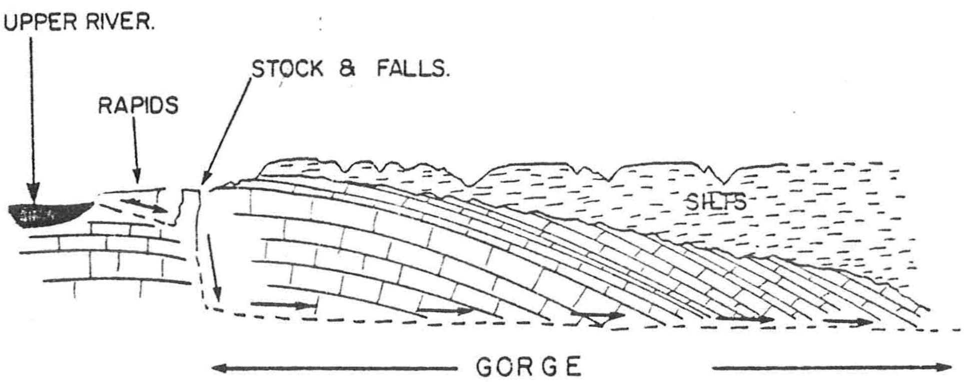
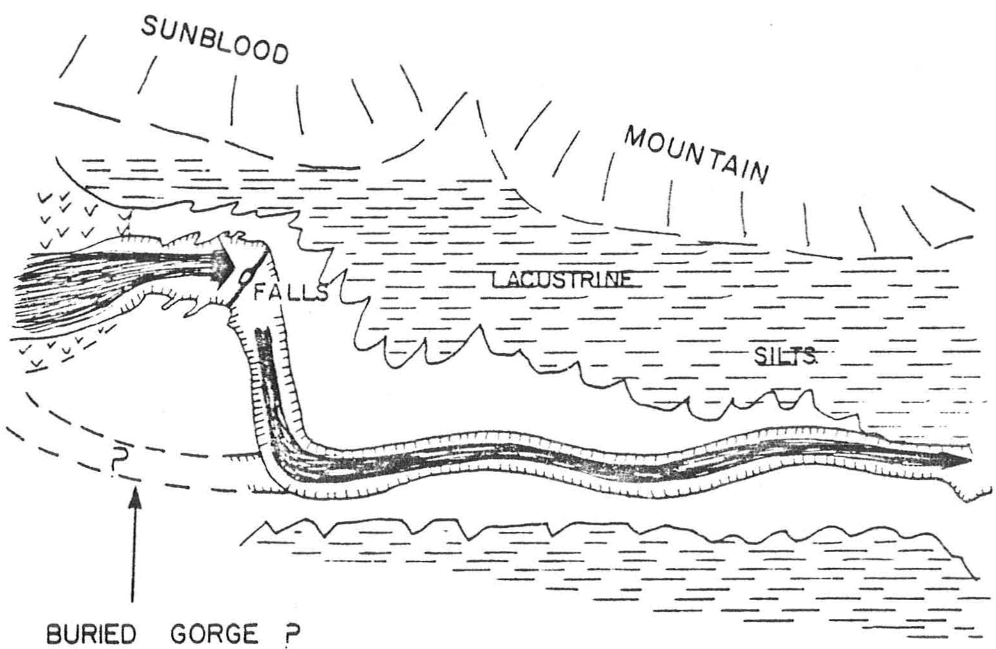


Figure 18(a). Cross-section of Virginia Falls.



(after Ford,1975)

Figure 18(b). Plan view of Virginia Falls area.

appears to be the product of waterfall recession (technically, "nickpoint recession").

The Gorge terminates at the point where Marengo Creek joins the main channel and the third section of the South Nahanni begins. Both the river and the confining valley walls broaden out at this point but the character of the river does not revert to that of the Upper River. Although some stretches, especially the area immediately downriver of the canyon terminus do appear sinuous, the relative narrowness of the valley, the increased gradient, and the structural control of the channel routing prevent any extensive degree of meandering from occurring. Instead, down to the entrance of Third Canyon, the river either flows turbulently in a single channel between confining walls formed by bedrock benches or forms a braiding channel covering nearly the entire width of the valley floor. There is very little floodplain indeed.

Bedrock benches form a distinct feature of this section of the river. They are present intermittently and where they form the banks of the river they provide dramatic evidence of the power of the river. The tops of the benches, varying from 25-80 ft. (7.6-24.3 m) above river level, terminate in vertical cliffs to the water's edge. Often these cliffs show contorted folding and distortion. The River has succeeded in cutting a simple vertical channel down through such varying structure (see Plate 9).

The lacustrine silt terraces first seen above the Falls are also present throughout this entire stretch of river. In fact, the terraces and their accompanying bluffs grow in prominence until at the confluence of the Nahanni and Flat they form bluffs 400-500 ft. (120-150 m) high rising directly from river level, up against the mountain sides (see Plate 10). The lacustrine terraces are also clearly present in two major tributary streams, Marengo and Wrigley Creeks. Along both sides of Marengo Creek they form distinctive bluffs. They are even more prominent in Wrigley Creek where two distinct terrace levels are present; one about 150 ft. (46 m) and a second 250 ft. (76 m) above the level of the present river.

Another feature deserving comment is the "whirlpool" located about 7 miles (11 km) downstream of the Falls. It occurs at a point where the river flows due South then makes a sharp 90^{o} turn to the East, creating a whirlpool reminiscent of that present in the Niagara Gorge. It was not possible in the limited time available to conduct even a limited reconnaisance of the geolocial and structural setting surrounding this feature.

About 7 miles (11 km) below the whirlpool the river widens out as the two major trunk streams of the Park, the Flat and South Nahanni join. The confluence is quite large, occupying several square miles and covering nearly the

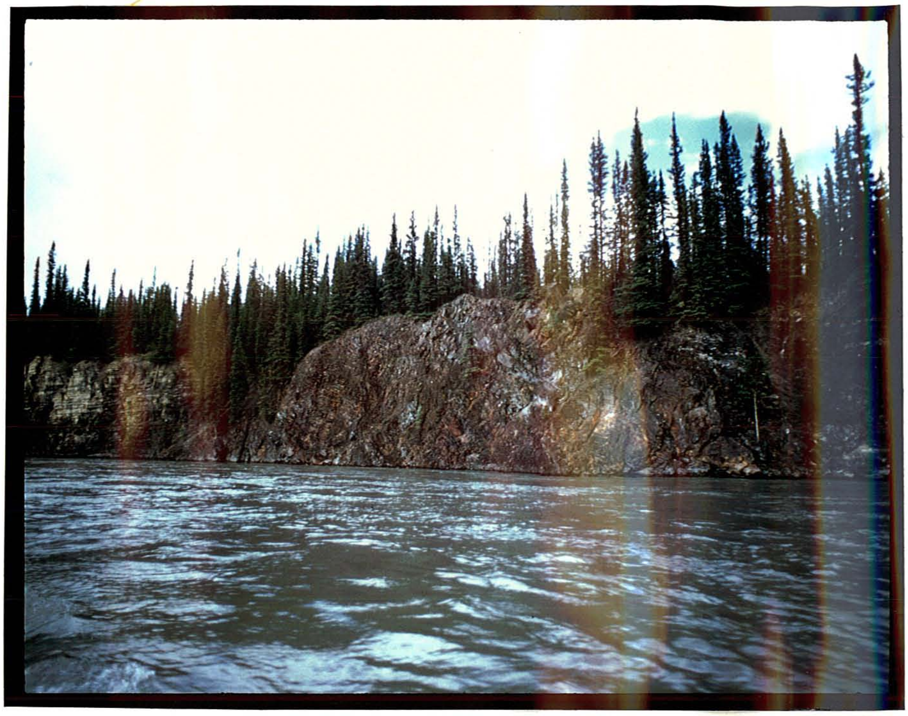


Plate 9. South Nahanni dissecting bedrock benches.

Plate 10. Silt deposits at confluence of Flat and South Nahanni.

entire valley floor. It provides a study in contrasting fluvial regimens (see Plate 11). The south Nahanni immediately above the point where the two rivers join is a braiding channel network with several major anabranches. Its gradient is 10-12 ft./mile (1.8-2.3 m/km). At the junction the South Nahanni is not more than 5 ft. (1.5 m) deep at its deepest and the average depth is about 2.5 ft. (0.76 m). The Flat River at the confluence is quite different. It has one well-defined channel with a valley wall on either side. The gradient immediately above the mixing point is only 8-9 feet/mile (1.5-1.7 m/km). Although no exact depth was determined, it is clear that the channel is much deeper than that of the South Nahanni. In fact, to all appearances, at the confluence it is the South Nahanni which is the lesser of the two streams.

The Flat River is also distinctive in other ways. As previously indicated its course may be divided into several sections.

The first section extends from well above Seaplane Lake to McCleod Creek. The river flows within a classic U-shaped valley possessing a broad floor. It is very similar to the upper valley of the South Nahanni. The river, having a gradient of 10-12 feet/mile (1.0-2.3 m/km), is sinuous with meandering occurring at several points.

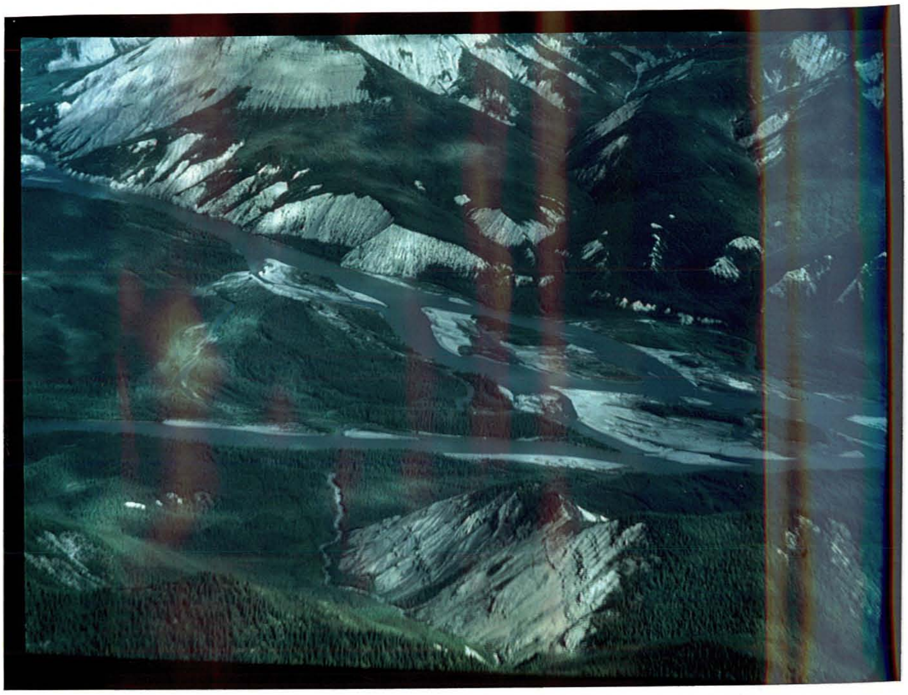


Plate 11. Confluence of Flat and South Nahanni.

Plate 12. Flat River above the Irvine-Flat confluence.

Starting at McCleod Creek and continuing to a point 7 miles (11 km) inside the Park, the nature of the river changes drastically. In this second section its gradient increases to 25-30 feet/mile (4.7-5.7 m/km) and the channel, while sinuous, no longer is free to meander across the valley floor. Instead, it is entrenching down through what appears to be glacial debris. The result is a narrow channel with steep banks 100-200 ft. (30-60 m) in height on both sides. The channel at several points is very shallow and clogged by boulders (see Plate 12).

The third, and most extensive section of the river extends for some 50 miles (80 km) to a point 8 miles (13 km) above the South Nahanni-Flat confluence. The average gradient in this section is 12 feet/mile (2.3 m/km). In this stretch of river its habit is intermediate between meandering and braiding, with braiding become dominant in the latter 15 miles. Of particular interest is the extreme shallowness of many parts of the river. There are stretches where the <u>maximum</u> depth was less than 8 in. (20 cm) in late July, 1973. This fact, in conjunction with earlier described "flashiness" of the rivers in the Park and the width of the valley creates a situation in which the channel is highly mobile.

The sinuous and mobile nature of the channel, in addition to the navigation problems it may generate, also tends to emphasize quite dramatically the complex terracing and benching present. As the river wanders back and forth across the valley floor it undercuts both silt and bedrock benches present along the entire length of this part of Flat creating impressive exposures of bluffs and bedrock cliffs, some of which rise 200 ft. (60 m) vertically from the river. Thus, upon rounding a bend one may find the river undercutting a shale bench with 100-200 ft. (30-60 m) vertical walls and around the next bend may well encounter a steep bluff of silty lake sediments being actively undermined. Moreover, benches and terraces are also present well back from the river having been exposed by earlier fluvial action when the channel stood at higher levels in the valley. The overall result is the most spectacular series of terraces in the Park.

The lacustrine terraces shown on the map first appear well above where the Flat and Irvine join and at a point just downriver from the beginning of the third section of the river. Their presence is indicated by two series of bluffs rising from the river channel. The first bluff is approximately 80 ft. (24 m) in height and the second, 100 ft. (30 m) in height, rests atop and slightly back from the first. Several hundred feet above the level of the terraces, at about the 2,500 ft. (760 m) contour level, there also appears to be a bedrock (probably shale) bench. The exact location of the bench is often obscured by massive slumping of debris from the mountain sides higher up. The same is true of much of the lacustrine terraces and their accompanying bluffs. Sufficient exposures do remain however, both here and down river, to discern the general pattern of such features.

It is at the confluence of the Flat River and Irvine Creek that one becomes aware of the extent and complex nature of the terracing and benching. Irvine Creek, an underfit meandering stream flowing in a broad U-shaped valley, joins the Flat at nearly a right angle. Successive stages of down cutting by both streams have left several levels of terraces on both sides of the main and tributary valley, thereby creating a step-like topography. Preliminary examination indicates the presence of four terraces, two of silt and two of shale, rising several hundred feet above river level. These terraces, cut at different levels by the entrenching river, will be discussed in greater detail in the next section.

Present also at the confluence of the Flat and Irvine is the remnant of a massive delta (see Plate 13) which apparently formed when Irvine Creek poured into the ancient lake that deposited the terraced lacustrine silts. Subsequent river activity has cut down through the delta

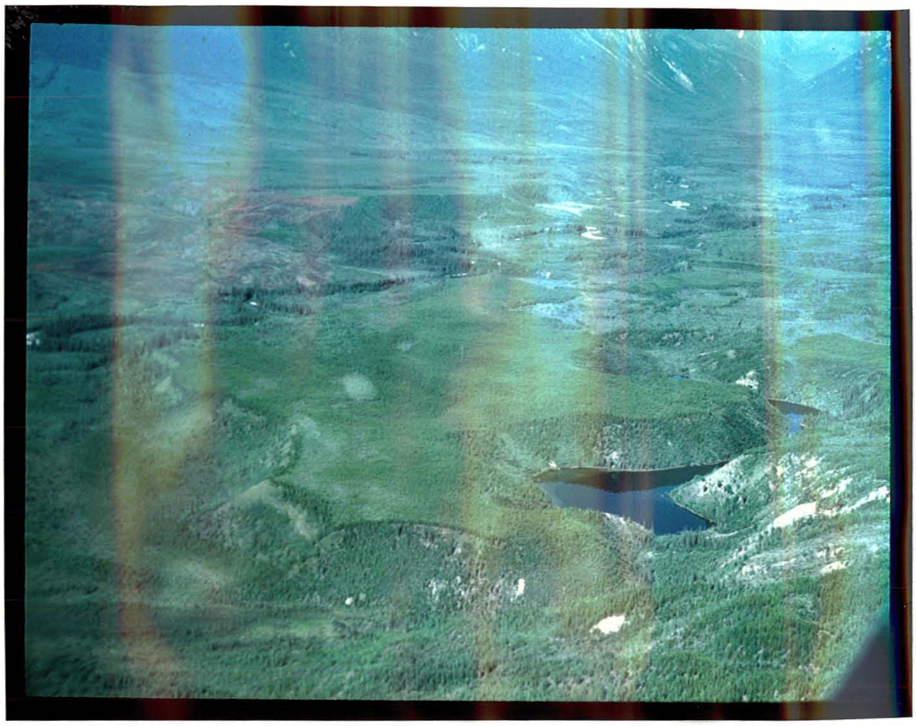


Plate 13. Large paleo-delta at the mouth of Irvine Creek.

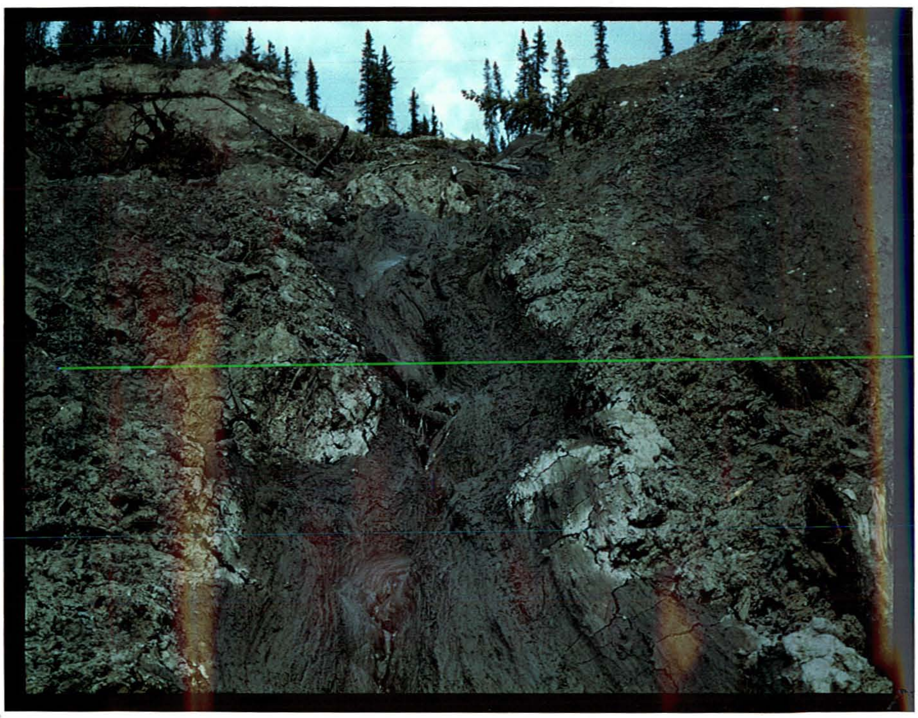


Plate 14. Mud flowing down a silt terrace face.

thereby producing a magnificent section 200 ft. (60 m) high showing its internal structure. This exposure is readily seen from the Flat and can be reached by a 10 minute walk along the east side of Irvine Creek.

Down river from the Flat-Irvine confluence the terracing and benching persists, although the various levels are no longer as distinct. It is in the stretch of river between Irvine Creek and Caribou River that the most intense undercutting of the terraces and benches appears to be occurring. There are some rather unusual features. At several points tributary streams feed into small lakes perched atop the silt terraces. The lakes in turn drain over the surface and down the face of the silt bluffs into the main river channel. But because of the fine silt and clay present in the bluffs, the water from the perched lakes or ponds sometimes produces mud-flows down the bluff faces instead of producing small stream flows. There is, for example, a 200 ft. (60 m) silt terrace along the east side of the river which has periodic mudflows. When observed in 1973 there was a surge of material from the top of the terrace every minute or so. It rushed down a runway, across a 300 ft. (90 m) sloping shore and into the River (see Plate 14). The exact cause of the periodicity is unknown and certainly warrants further study.

This part of the Flat also contains an impressive series of Hoodoos along the east side of the valley. Ex-tending from 300 ft. (90 m) to over 1,000 ft. (300 m) above the River they have been formed in limestone bedrock for a distance of over a mile (see Plate 15).

Just downriver of the hoodoos is the confluence of the Caribou and Flat rivers. The Caribou, a tributary steam, initially was located in a fairly broad glaciated valley but the river has succeeded in cutting down through limestone bedrock floor to create a narrow canyon 150-200 ft. (46-61 m) in depth. This narrow canyon begins outside of the Park and extends to within 3 miles (5 km) of the confluence with the Flat. The Caribou then broadens out occupying nearly all of the valley floor with an extremely shallow braiding channel with an intricate pattern of anabranches. It is here, at the meeting point of the Caribou and Flat, that one finds the most complex sequence of terracing and benching in the entire Central Nahanni and in fact in the entire Park.

In all there appears to be five distinct levels of terracing and benching present. Four consist of lacustrine silt and a fifth is shale. Detailed discussion of these deposits will also be deferred until Chapter IV.

Downstream of the Caribou-Flat confluence the lacustrine terraces and their accompanying bluffs continue. At a point twelve miles below the confluence however, they undergo an abrupt change. Whereas previously the bluffs have had a dominantly dark grey-black colour the sediment suddenly alters to a bright yellow hue. This bright yellow colour, characteristic also of the silts below Virginia Falls and all the lacustrine material down to the entrance of Third Canyon, continues right down the Flat to the South Nahanni Flat confluence.

A fourth section of the Flat extends from about eight miles above the confluence down to where the two trunk streams join. In this section the valley narrows so that the river's course is restricted between high bedrock walls. The gradient of the river drops to 7-9 feet/mile (1.3-1.7 m/km) and the river channel both narrows and deepens. Despite the narrowness of the valley and the steep side slopes remnant terraces and their accompanying bluffs still survive. Some extend continuously from near river level to terrace surfaces perched 400-500 ft. (120-150 m) above river level. Bedrock benches of shale and limestone also persist, some at river level and others much higher up the valley sides.

Another class of glaciofluvial features, not directly related to the present river, but present throughout the Central Nahanni area is that of ice marginal meltwater channels (see Plate 16). They range in elevation from several hundred to over 1,000 ft. (300 m) above the present level of the river. As indicated on the geomorphic map, some are present along the South Nahanni Valley above Virginia Falls. Several in the area just west of the river are at approximately 2,500 ft. (760 m) feet elevation

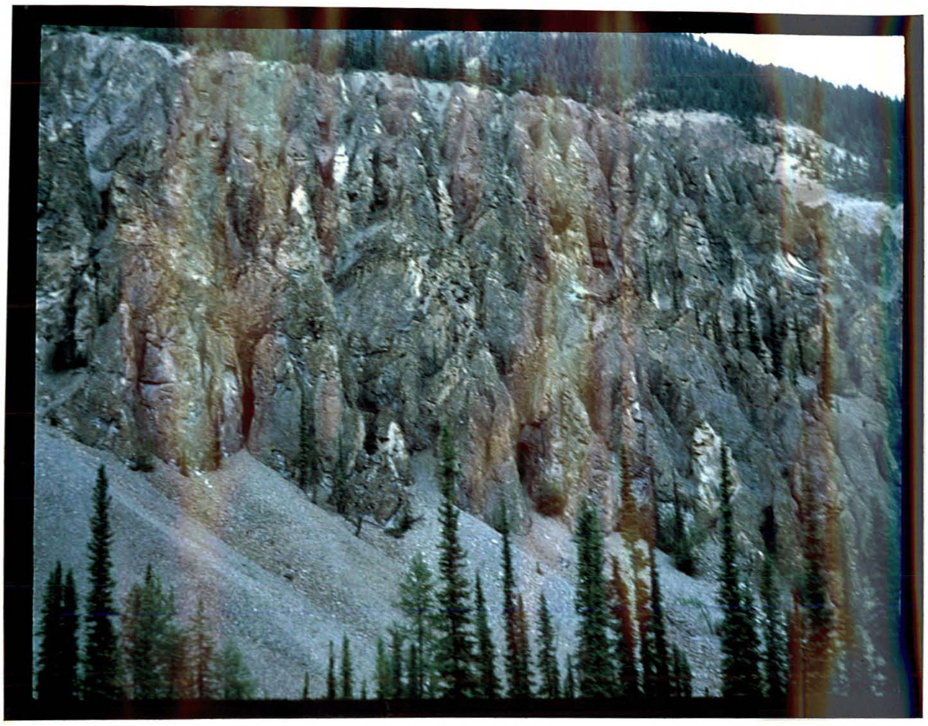


Plate 15. Hoodoos along Flat River.

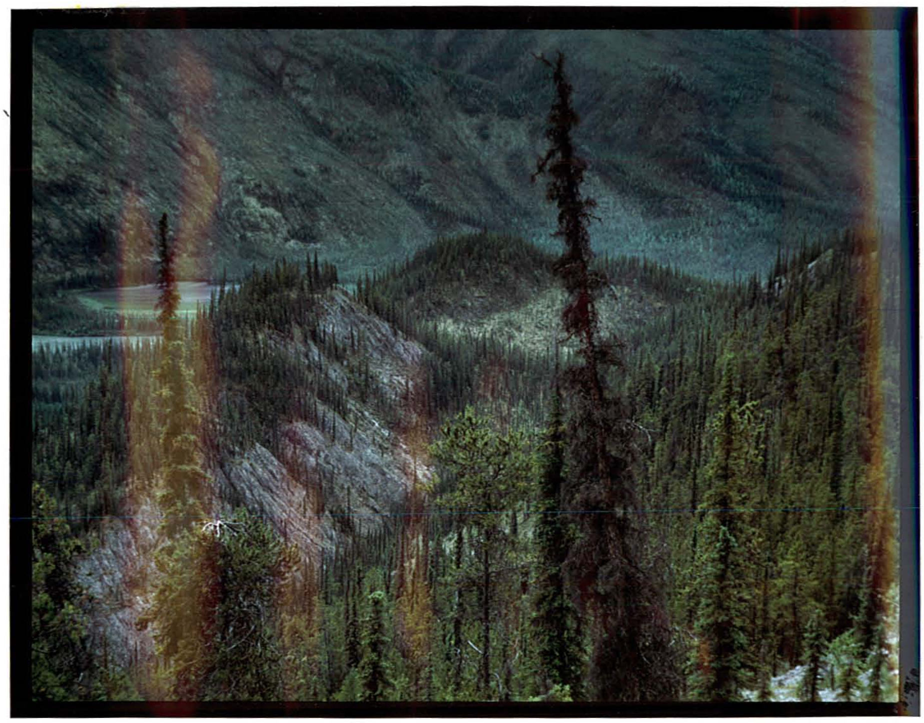


Plate 16. Ice marginal flow channels along the Flat River.

while one is located at 2,300 ft. (700 m) elevation. They are cut into dominantly limestone and dolomite formations.

It is in the Flat River Valley that such features are most extensive. Although cut into gentler slopes and generally into the more erodable shales the ice-marginal channels in this part of the study area tend to be more numerous and much more extensive. One located along the north side of the valley just below the Irvine-Flat confluence is over 6 miles (9 km) in extent. This location also exhibits the most complex series of meltwater channels as well. In total four distinctly different channels located one above the other up the valley side are present. They are 350 ft. (106 m), 450 ft. (137 m), 750 ft. (230 m) and 800 ft. (244 m) above the present river level and clearly indicate a complex fluvio-glacial history.

Finally, mention should be made of the many deltas found over the entire study area. They vary greatly in size, shape and nature of constituent material but all attest to the quite active erosional processes at work.

3. GLACIAL FEATURES

Although the Central portion of Nahanni Park possesses some of the most distinct glaciofluvial features in the entire park the glacial features present are much less prominent. The lower elevation of much of the area and intense mass wasting processes have eliminated any evidence of distinct trimlines which might have been present in the area. Two types of features are present; morainic debris and breached divides. Morainic material apparently fills, at least partially, the buried gorge at Virginia Falls and is also present in the area above the Irvine-Flat confluence. Breached divides, shown with a red symbol, may be found throughout the study area although there is a considerable concentration in the area between the Flat and South Nahanni west of Direction Mountain.

4. PERIGLACIAL FEATURES

As was the case with the glacial features, the Central Nahanni does not abound with a large variety of peri glacial features but two are present in abundance. The first is slumping of material from the melting out of permafrost and permafrost lenses (see Plate 17). This is best seen at various points along the river's edge. The second feature, solifluction, appears to be occurring on a massive scale (see Plate 18). Whole valley sides have become mobilized. Solifluction has been indicated by a brown shading.

These then are the major geomorphic features found in the study area. Although the map must be considered as only preliminary in nature, it does provide an indication of the general character of the Central Nahanni.

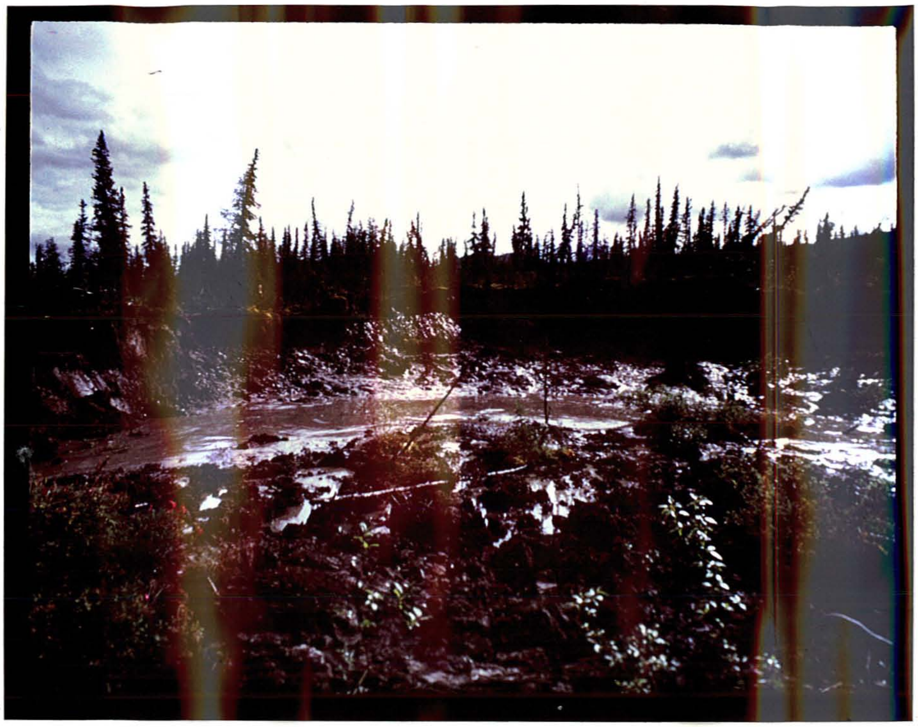


Plate 17. Example of permafrost lens melting out.

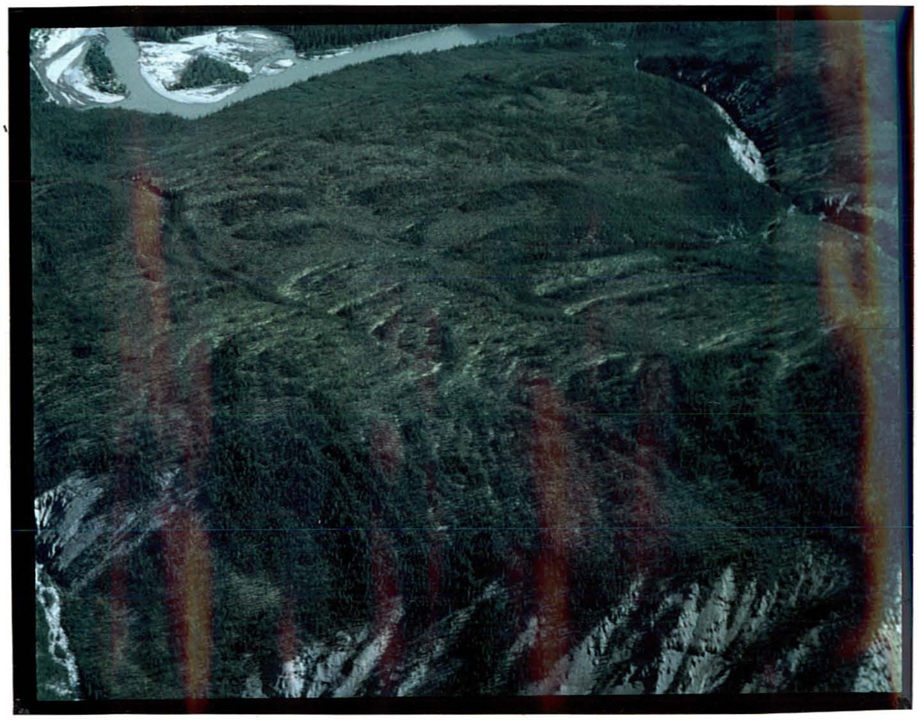


Plate 18. Mass wasting in area above Irvine-Flat confluence.

CHAPTER IV

THE LACUSTRINE DEPOSITS OF THE AREA

Lacustrine deposits are found throughout the major valleys in the Central Nahanni Park area. A considerable amount of time in the field was spent collecting samples, measuring sections and determining the limits of these deposits. Although this could only be done at a reconnaisance level because of the size of the study area and time constraints, it was possible to collect some useful information which, when correlated with the air photo mapping, gives a preliminary indication of the nature, extent, and significance of these deposits.

1. A BRIEF OVERVIEW

The presence of lacustrine deposits in the South Nahanni area was not documented in the literature prior to our field study of 1973. This is not entirely surprising for, aside from the remoteness of much of the area, the presence of the silts would not be readily detectable with conventional aerial photography. Two factors account for this: first, many of the lacustrine deposits are heavily vegetated making recognition difficult; and second, the lake silts are often overlain by a layer of fluvial and glaciofluvial stratified and unstratified deposits. In addition, as the geomorphic map indicates, the area also contains many shale and limestone benches and terraces which, in conventional aerial photography would appear the same as the silts (especially since they also often have till or drift covering). Even on the ground it is often very difficult to determine whether a terrace is silt or bedrock because many of the bedrock benches are covered with overlying material which has washed down unto the face covering the outcropping bedrock with a thin mantle of debris. Such debris also covers some of the silt terrace exposures.

In general, the lacustrine deposits tend to be present in quite thick units; some are 400-500 ft. (120-150 m) in thickness (base unseen), although 150-200 ft. (45-60 m) would probably be a more representative figure. Most deposits rise directly up from the valley floor and in some cases they are perched atop bedrock benches which themselves rise up from river level. Quite a few of the silt deposits are perched up against the side walls of the valleys while others form broad terraces which gradually merge with the valley sides.

2. THE NATURE AND EXTENT OF THE LACUSTRINE DEPOSITS

Although there are numerous exposures along the valleys of the main trunk streams, time did not permit detailed examination of a large number of the interesting sites. Figure 19 indicates the location of exposures which could be examined as well as the sites at which sediment samples were collected. The discussion of the visited exposures as well as the general disposition of the deposits will commence with the deposits in the Flat River Valley above the Flat-Irvine confluence, proceed down the Flat to the South Nahanni Flat confluence and then approach that confluence from above Virginia Falls following the course of the South Nahanni.

Interestingly, at the parks western boundary there does not appear to be any evidence of lacustrine silts. Instead kame and kettle topography at approximately 2,500 ft. (760 m) elevation a.s.l. on the northwest side of the Flat valley and some isolated patches of lacustrine deposits at 1,800 and 2,000 ft. (550-600 m) a.s.l. appear. The valley of the Irvine above the Irvine-Flat confluence contains even less evidence of lacustrine deposits. If any were previously present they have been lost to solifluction taking place on a massive scale.

It is at the confluence of the Irvine and Flat that the deposits become quite prominent. Figure 20 is a map of the confluence at a 1:50,000 scale. Figure 21 is a cross-section of the valley showing the differing levels.

Preliminary examination suggests the presence of four distinct terrace or bench levels. The lowest level

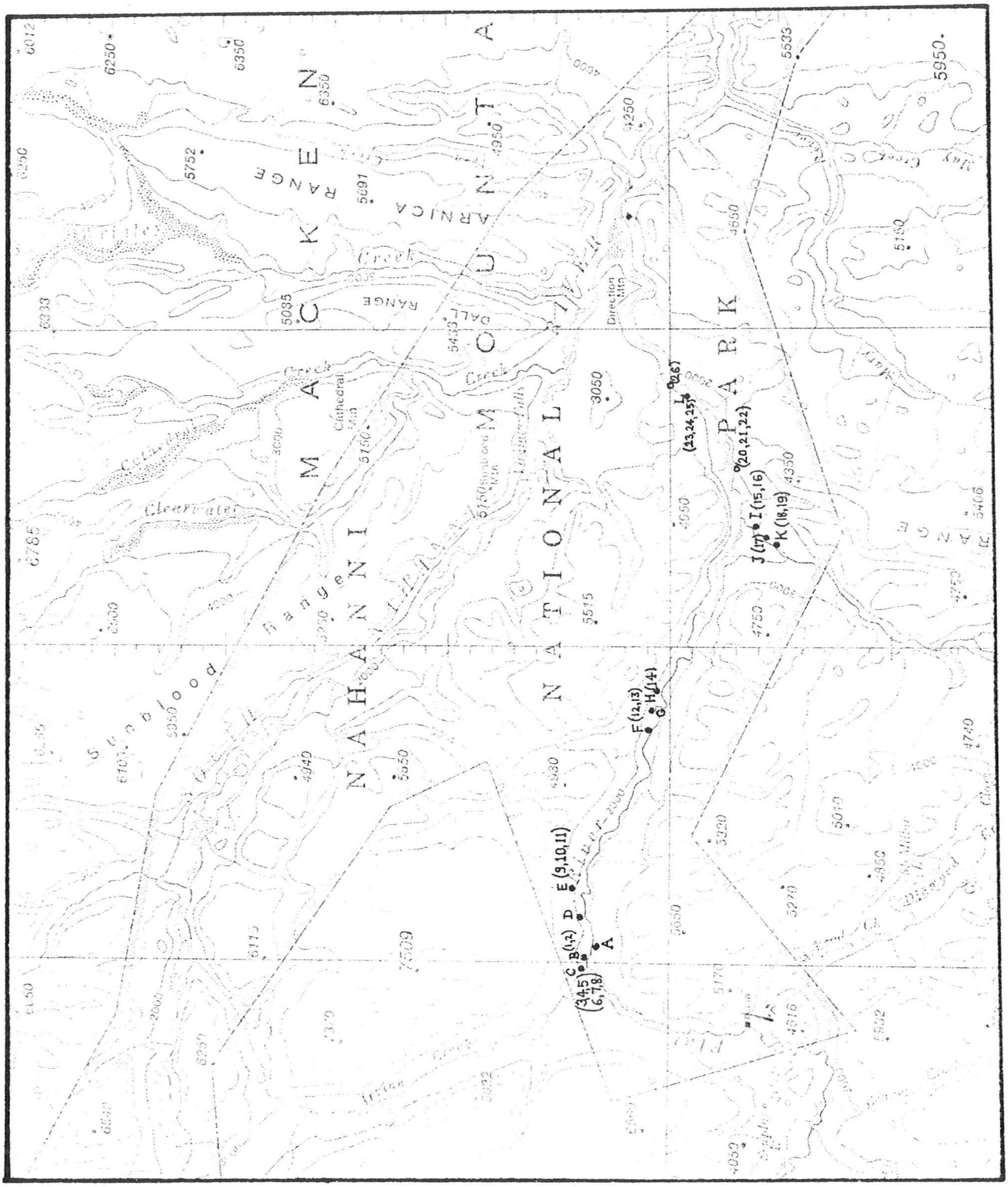


Figure 19. Location of sections examined and sample of collection sites.

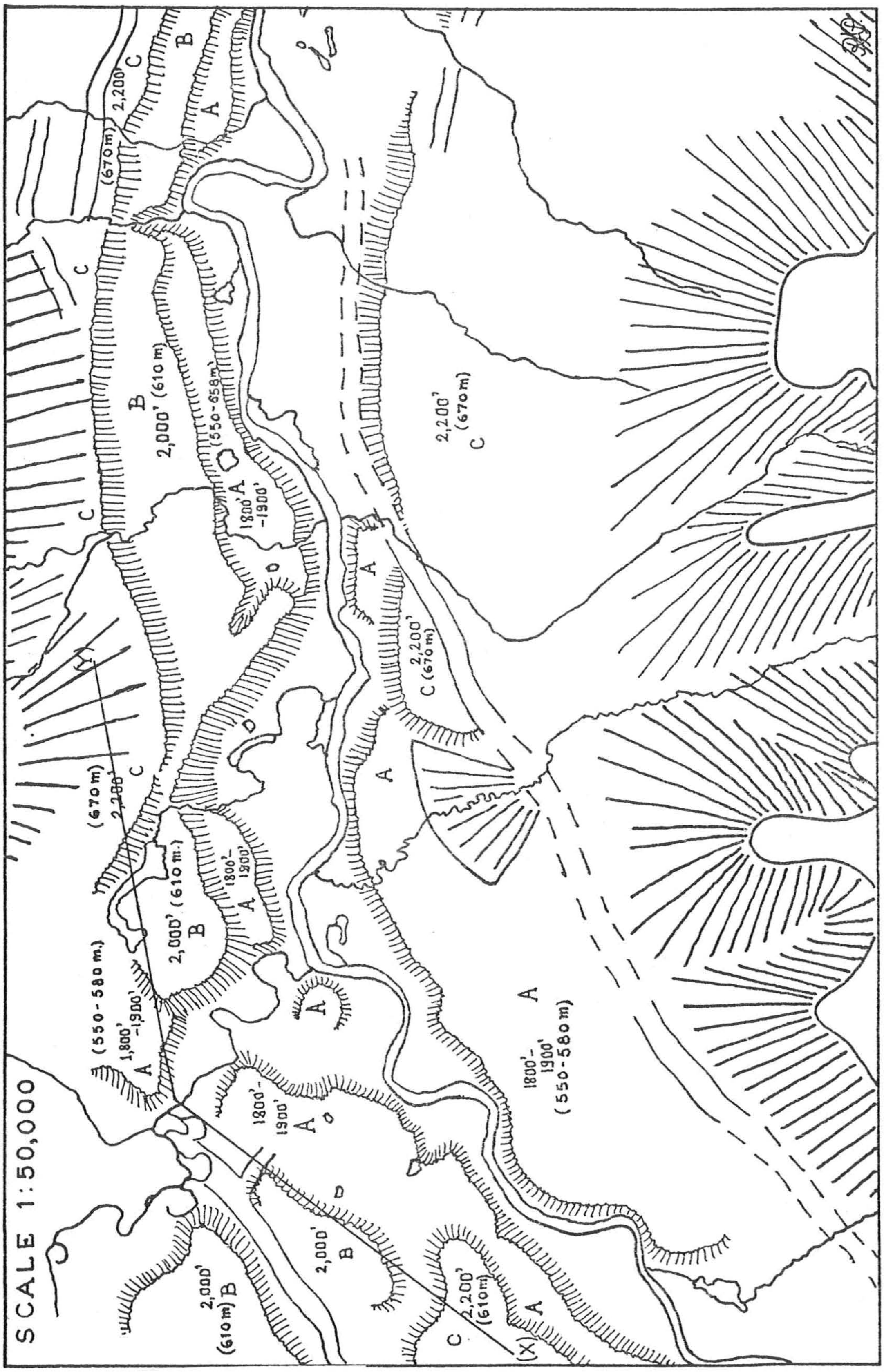


Figure 20. Terraces at Flat-Irvine confluence.

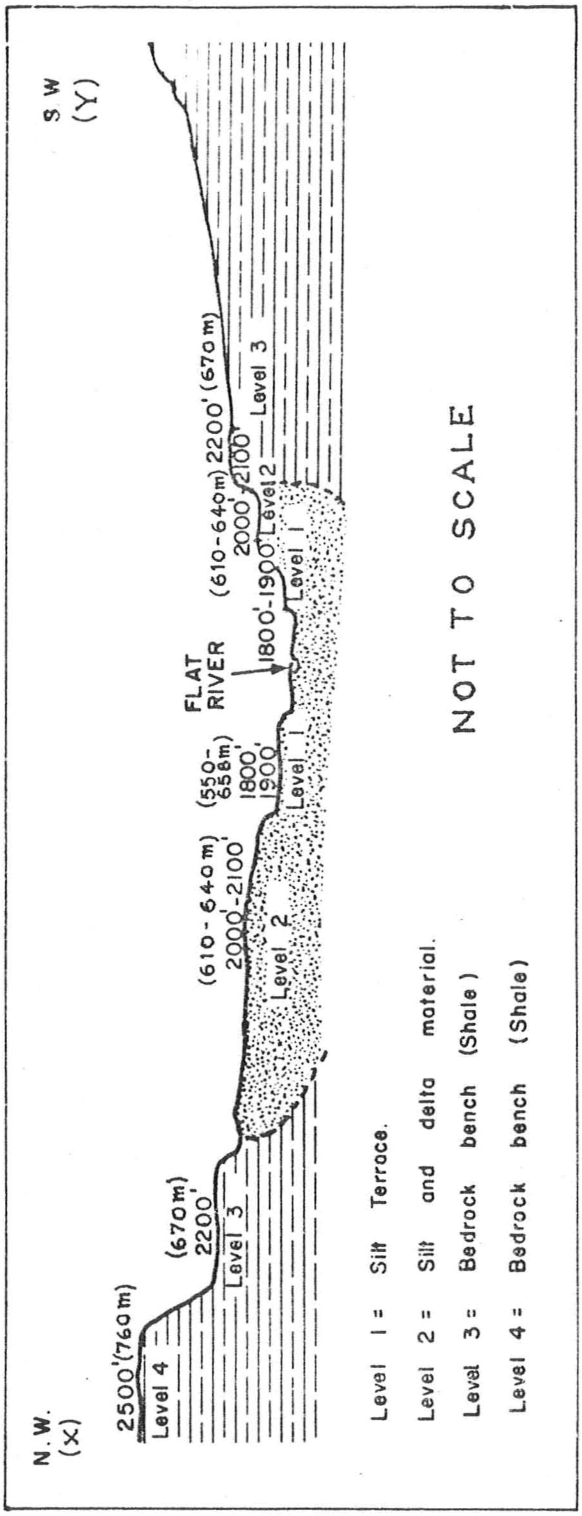


Figure 21. Cross-section of the Flat-Irvine confluence showing the different terrace levels. The location of the cross-section is indicated on Figure 20.

consists of several silt terraces at 1,800-1,900 ft. (550-580 m) a.s.l., with bluffs ranging from 50-75 ft. (15-23 m) in height. The bluffs rise from river level and often form the stream bank. The second level, at 2,000-2,100 ft. (610-640 m) a.s.l., contains both lacustrine and deltaic features and has bluffs ranging from 100-150 ft. (30-46 m) in height. Also found at level 2 on both sides of the river are benches of shale. Both the terraces and benches of levels 1 and 2 are clearly visible from the river although the distinction between bedrock terraces and silt terraces, as indicated earlier, is very difficult to determine at times.

The third and fourth levels consist of shale benches located a considerable height above the river and usually some distance back from the channel. The benches at level 3 are at an elevation of approximately 2,200 ft. (670 m) while those at level 4 reach 2,500 ft. (760 m) elevation. Neither of these two benches is readily seen from the river.

Three sections of the deposits at the confluence were examined in detail. Section A is located on the south bank of the Flat immediately downsteam from the confluence at a point where the river is actively undercutting the bank. It consists of three units. The first, of some 25 ft. (7.6 m) in height, rises directly from the river (see

Figure 22 on page following) and its total thickness could therefore not be determined. It consists of black silty material containing laminations. Immediately above it is found some 25 ft. (7.6 m) of black silty material which contains clear evidence of cross-bedding. Overlying the cross-bedded silt is a 25 ft. (7.6 m) layer consisting of stratified boulders, cobbles, and pebbles. This material is held in a fine grained matrix which appears to be dominantly silt sized. The upper portion tends to have a greater concentration of boulders and larger materials. The contact between the upper and middle units is abrupt.

Section B is across and sightly upstream from the location of the previous section (Figure 19). As at section A the basal unit consists of a dark silt some 50 ft. (15.2 m) thick with a 25 ft. (7.6 m) thick overlying unit of stratified boulders, cobbles, and pebbles in a brown silty matrix. The cross-bedding, however, present in the middle 25 ft. (7.6 m) of section A was much less prominent in section B. At this location two sediment samples (#1 and #2) were collected. A sketch of the section is shown in Figure 23. Approximately 300 ft. (90 m) upstream another section similar to section B in character was also examined. It is interesting to note that the tops of all three sections were within 1^{o} of being at exactly the same elevation.

The third section examined at the confluence and the most complex of the three appears to be part of a large

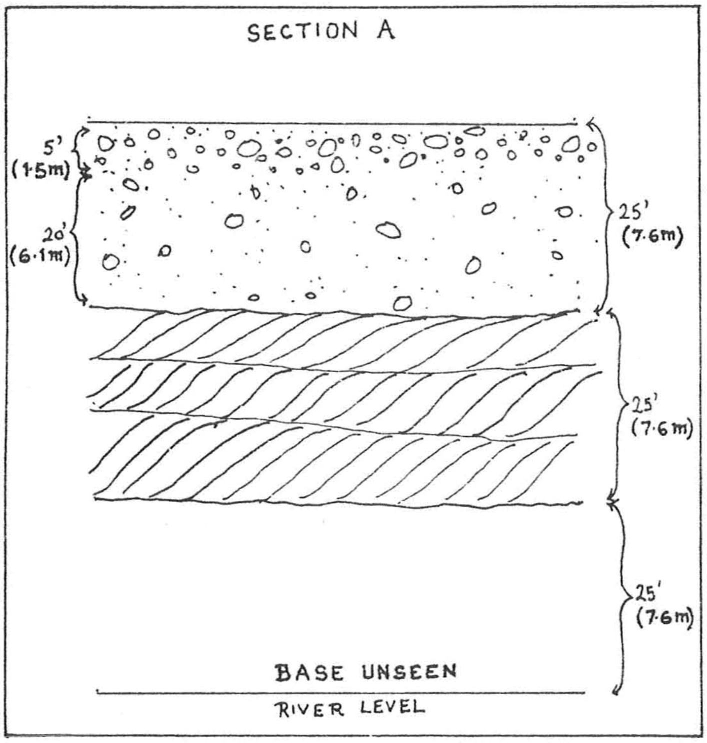


Figure 22.

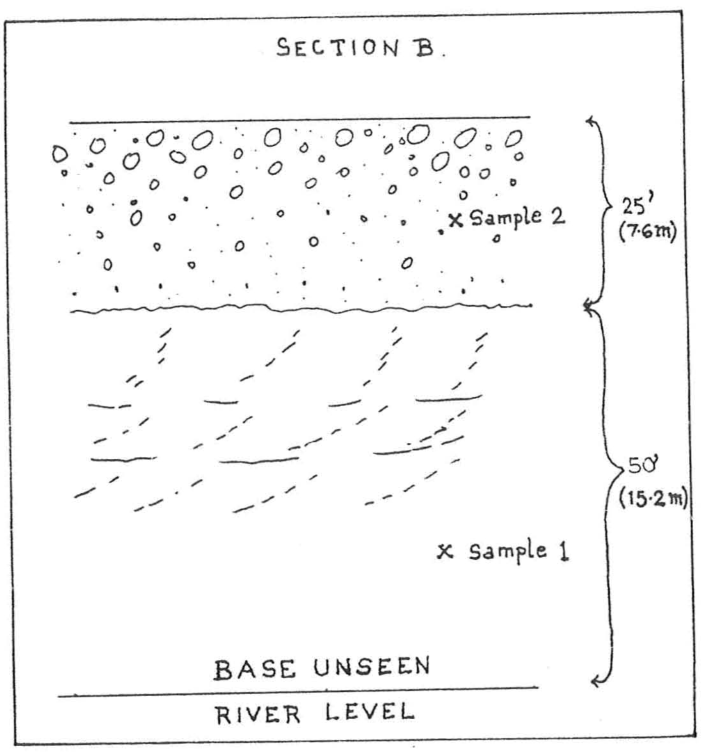


Figure 23.

paleo-delta (Plate 19). Its location is indicated in Figure 19 as section C. Figure 24 is a cross-section of the feature. There are 6 units present with a total thickness of 125 ft. (38 m). The basal unit 15 ft. (4.6 m) thick (base unseen), consists of cobbles and pebbles cemented together. The entire unit is cemented. It is overlain by 26 ft. (7.9 m) of coarse and fine cross-bedded sands containing a large lens of fine yellow sand. Above the cross-bedded sands are 2 units of coarse sands of 12 ft. (3.7 m) and 5 ft. (1.5 m) thickness with a distinct contact between them. The upper unit in this section is 50-60 ft. (15-18 m) thick and consists of yellow silts and clays. Samples #3 - #8 were obtained from this section.

It should be noted that no overlying layers of boulders, cobbles and pebbles were present as was the case with sections A and B. Finally the elevation of the top of this terrace, at the 2,000 ft. (610 m) level puts it approximately 100 ft. (30 m) above the level of sections A and B. The total depth of the delta materials could not be determined.

Below the confluence of the Irvine and Flat silt terraces and bedrock benches persist. The silt terraces maintain two levels, one at approximately 1,800-1,850 ft. (550-560 m) a.s.l. and a second at 1,900 ft. (580 m) a.s.l. The bedrock benches in this portion of the river also have

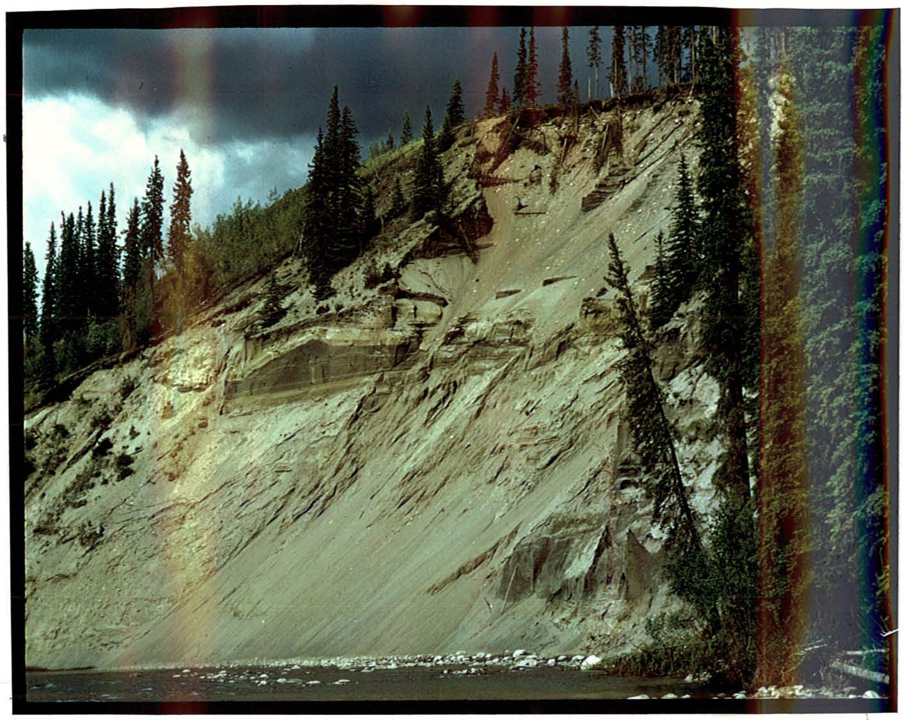


Plate 19. Paleo-delta section at confluence of Irvine and Flat Rivers.

Plate 20. Shale bench along the Flat River.

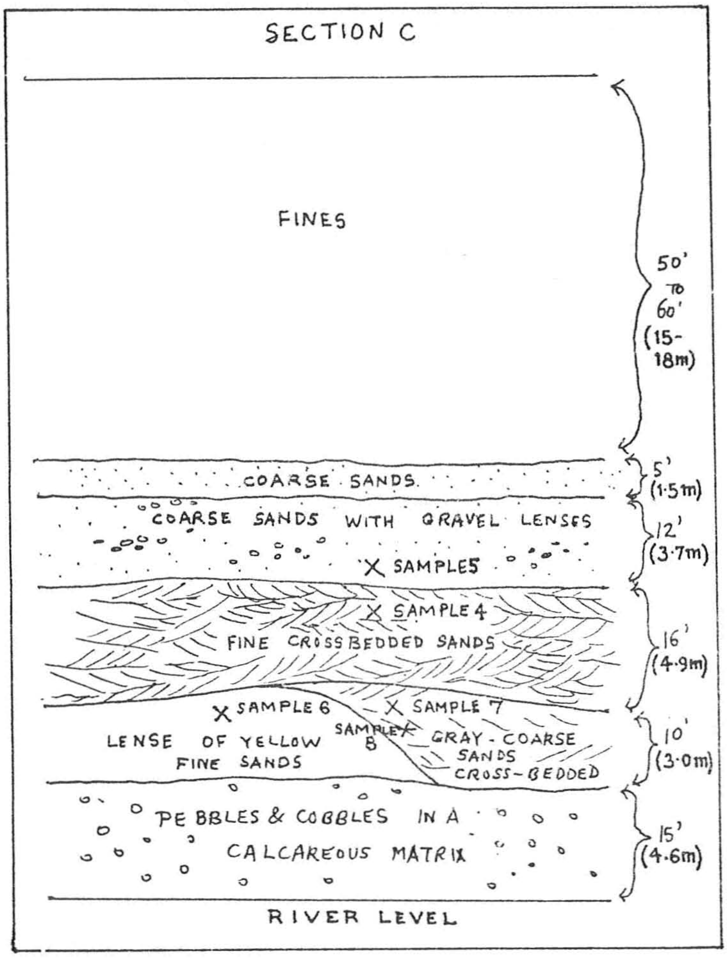


Figure 24.

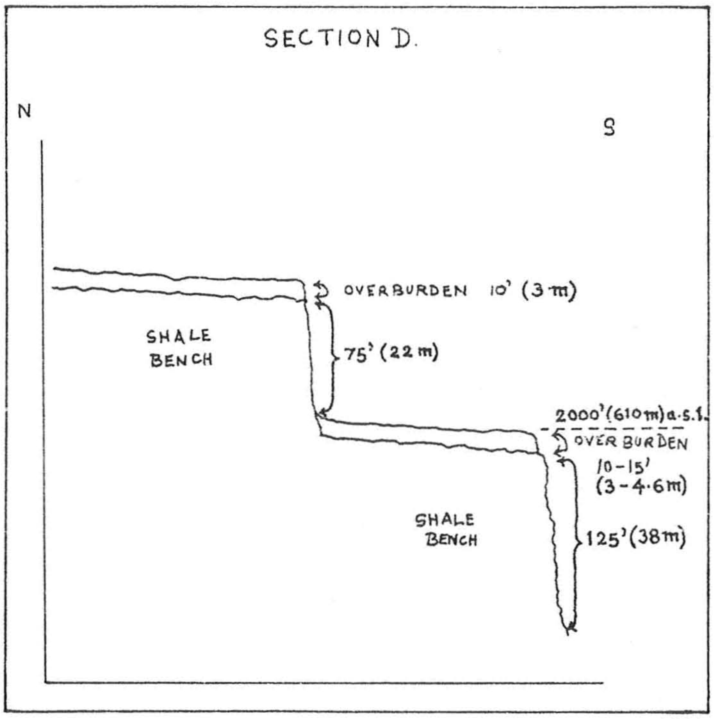


Figure 25.

two levels. A case in point is section D (Figure 25 and Plate 20). This is located 0.5 miles (0.8 km) back from the water's edge on the north side of the river and approximately 6 miles (10 km) downstream from the Flat-Irvine confluence. It consists of two shale benches. The lowest is some 125 ft. (38 m) in height and is overlain by some 10-15 ft. (3.0-4.5 m) of what appears to be glacial till. A short distance back from this bench rises a second bench of shale some 75 ft. (22 m) in height which is also overlain by 10 ft. (3 m) of unstratified boulders, pebbles and cobbles in a fine brown matrix, also suggestive of a glacial till. The lower of these benches lies at the same level as the top of the paleo-delta (i.e. at approximately 2,000 ft. (610 m) a.s.l.).

The lacustrine deposits along the Flat, downstream of section D, are of varied character.

Section E, (Figure 26) located approximately 2.5 miles (4.0 km) downsteam of section D, consists of a massive unit of fine silt approximately 150 ft. (46 m) in height rising directly from the river with an overlying unit of 20 ft. (6 m) of a light coloured silty matrix holding cobbles and pebbles of all sizes. No stratification is in evidence in the upper unit. Interestingly, the dark silt in the lower unit contains unstratified pebbles and cobbles scattered throughout. Fine laminations are also present in the lower

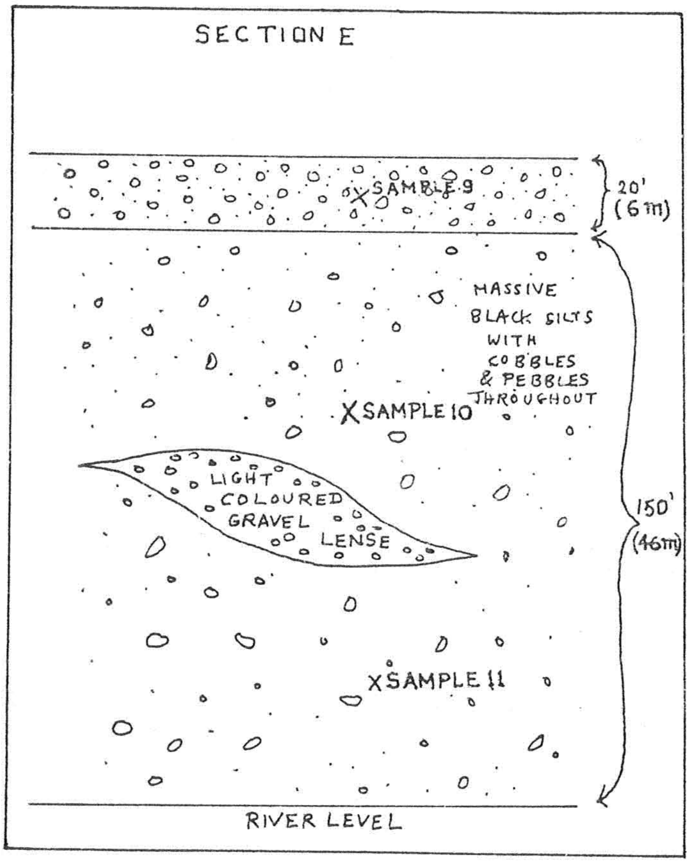


Figure 26.

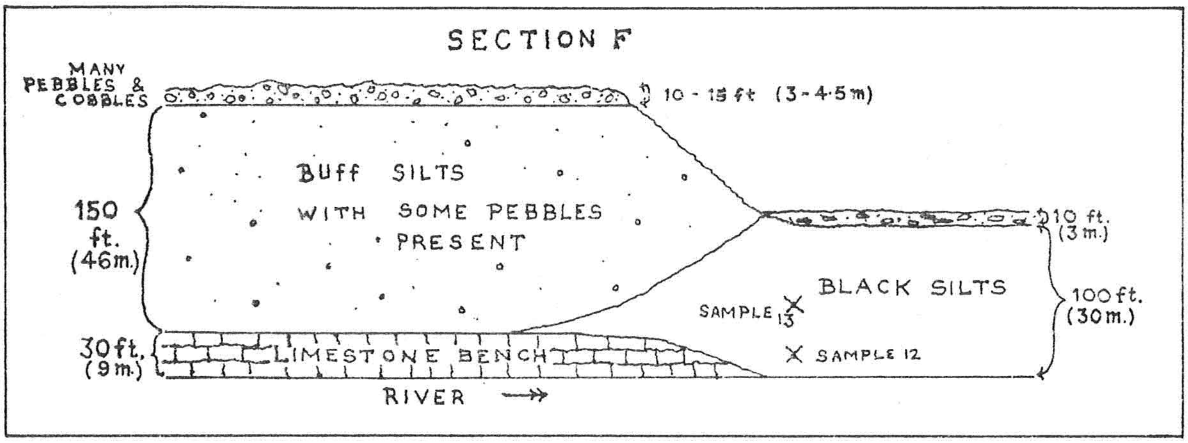


Figure 27.

unit. In addition, a large gravel lens with a fine grained light coloured matrix is also present some 30 ft. (9 m) above water level in the dark silts. Samples #9, #10 and #11 were collected from this site.

Section F (Figure 27) is located approximately 10 miles (16 km) downstream of section E. The basal unit consists of 30 ft. (9 m) of flat lying limestone which is lost below river level as one moves downstream. It is overlain in its upstream portion by 150 ft. (46 m) of buff coloured silts with some pebbles scattered throughout. Overlying the silt is 10-15 ft. (3-4.5 m) of unstratified material containing many cobbles and pebbles in a light coloured silty matrix. The downstream portion of the section consists of 100 ft. (30 m) of black silt (base unseen) with an overlying unit of 10 ft. (3 m) of stratified cobbles and pebbles in a silty matrix.

Moving downstream the height of the deposits increases such that at section G, 1 mile (1.6 km) downstream of section F, the top of the terrace is some 260 ft. (80 m) above river level. As is indicated in Figure 28 three units may be distinguished: an upper unit 10-15 ft. (3-4.5 m) thick made up of a light brown matrix of silty material with pebbles and cobbles throughout; a second unit of 200 ft. (60 m) of dark massive silts; and a lower unit of at least 40-50 ft. (12-15 m) in thickness of flat lying limestone.

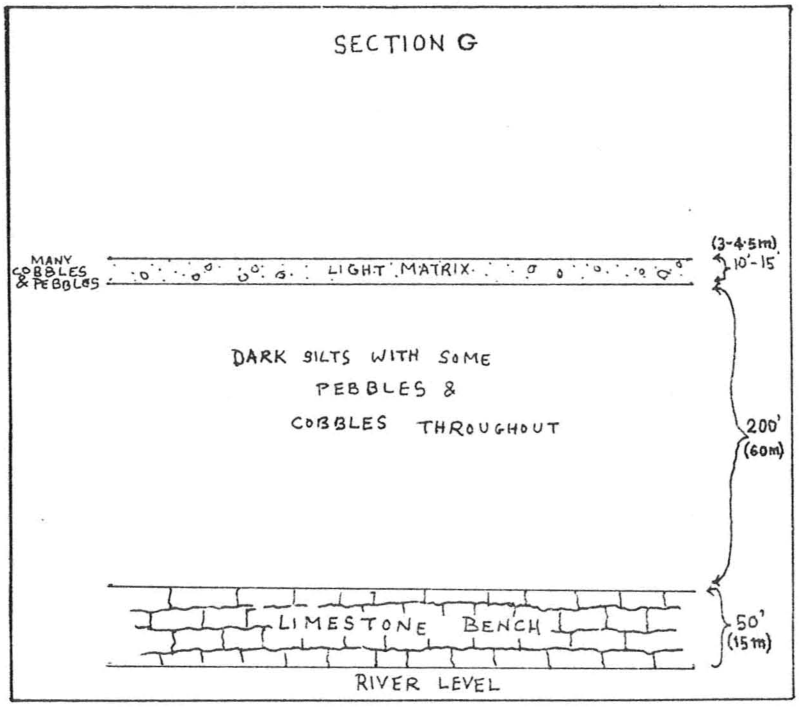


Figure 28.

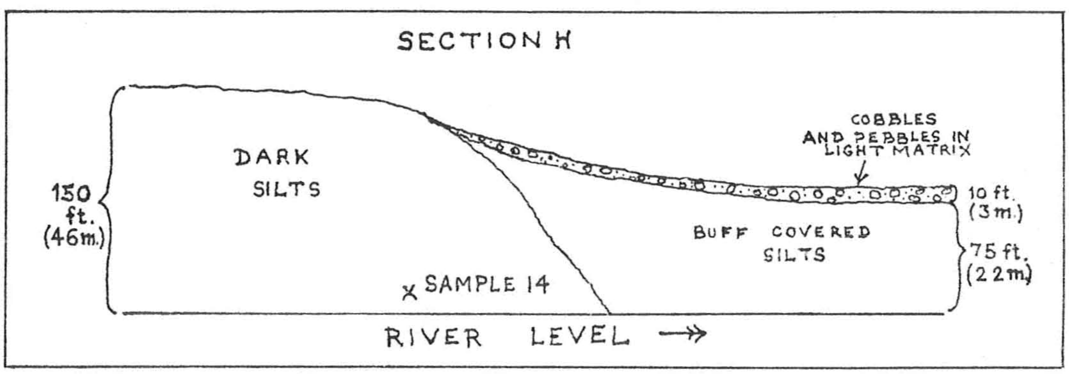


Figure 29.

The next section, section H (Figure 29), is located 1 mile (1.6 km) further downstream. It consists of 150 ft. (46 m) of dark silts (base unseen) without any pebbles or cobbles present. No overlying material was visible. Immediately downstream of the dark silt unit a different unit appears. It consists of buff coloured silts overlain by a 10 ft. (3 m) unit containing unstratified cobbles and pebbles in a buff coloured silty matrix. The transition between the dark and buff silts is quite evident with the buff silts overriding the dark silts (Plate 21), but the exact nature of the contact could not be determined because of the slumping down of the yellow over the darker silts. Sample #14 was obtained from the dark silt unit.

The Flat-Caribou confluence contains the most complex terracing in the study area, and, in fact, in the entire park. Figure 30 shows the terrace levels in some detail on a 1:50,000 scale. Figure 31 is a cross-section from location X to Y of the terraces. Also shown in both the above figures is a tentative correlation between the different terraces and their approximate elevation above sea level. There appear to be five distinct levels of terracing and benching present. Level 1, at 1,500 ft. (460 m) a.s.l. is a lacustrine silt terrace which has a bluff 75-100 ft. (23-30 m) height which forms the river bank at several locations. Levels 2, 3 and 4 also consist

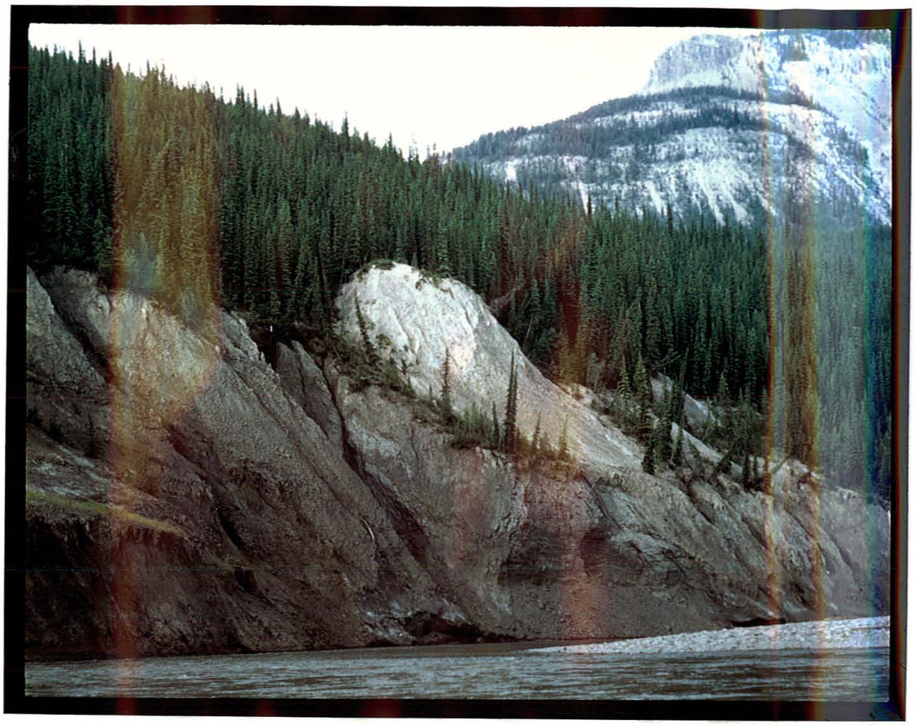


Plate 21. Contact of dark and buff silts at section H.

Plate 22. Deposits of dark silt at Caribou-Flat confluence.

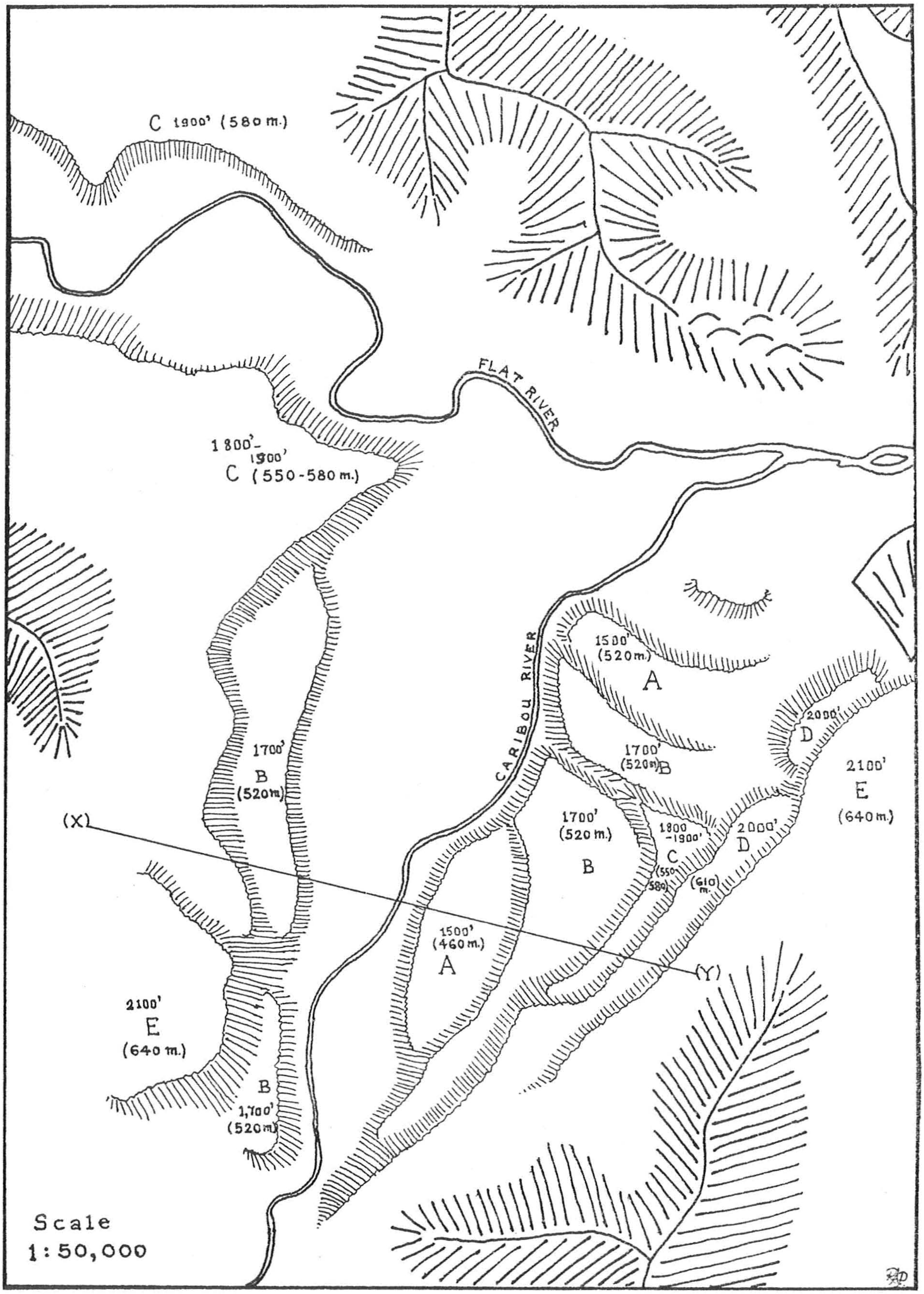


Figure 30. Terraces at the Flat-Irvine confluence.

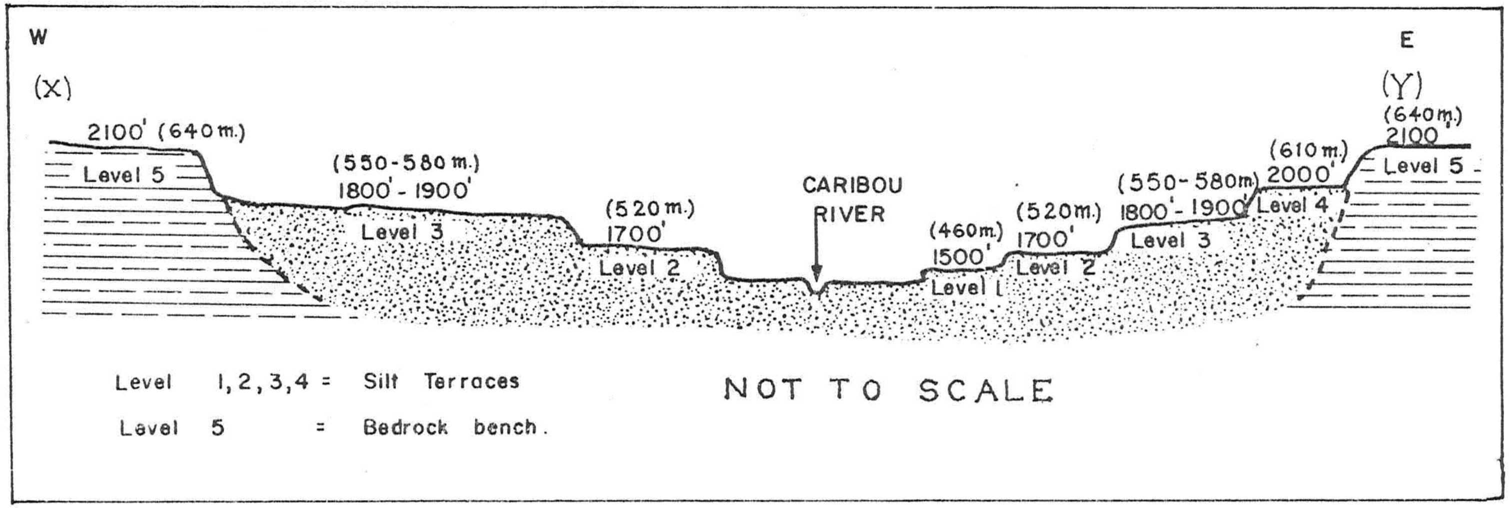


Figure 31. Cross-section of terraces at Flat-Caribou confluence.

of lacustrine silt, at 1,700 ft. (520 m), 1,800-1,900 ft. (550-580 m) and 2,000 ft. (610 m) a.s.l. respectively and with bluffs of varying heights. Finally, at 2,100 ft. (640 m) a.s.l. is a fifth level which appears to be of bedrock, probably shale, (see Figure 31).

The above associations must be considered as tentative. The intense slumping and solifluction in much of the Central Nahanni often obscures if not entirely eradicates features. Although the terraces in this location appear exceptionally distinct there is still room for considerable confusion. Level 3 for example, varies from 1,800-1,900 ft. (550-580 m) a.s.l. It may well represent not one but two or more low terraces which, because of mass movement, are no longer readily distinguishable.

Several sections were measured along the confluence area of which three are particularily noteworthy.

Section I (Figure 32) is located just above the confluence. It consists of a basal unit of 150 ft. (46 m) of black silt (base unseen) which is quickly lost to view upstream and an overlying unit of buff silts 50 ft. (15 m) in thickness which continues upstream for a short distance before being lost to view. The contact between the two units is distinct. Sample #15 was obtained from the black silt unit and sample #16 from the buff unit.

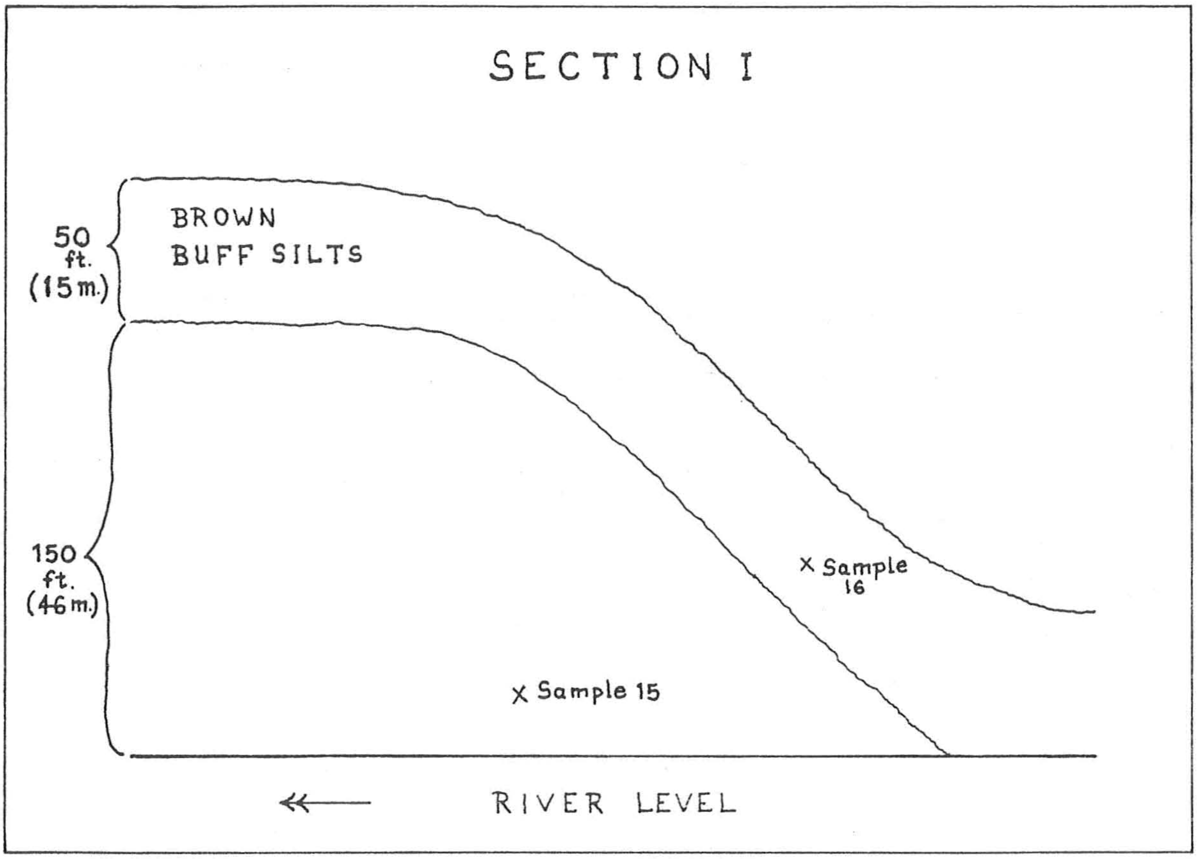

SECTION I
50 ft. (15 m.)
BROWN BUFF SILTS
150 ft. (46 m.)
x Sample 16
x Sample 15
RIVER LEVEL

Figure 32.

Section J (Plate 22) is located on the southeast bank of the Caribou approximately 0.5 miles (0.8 km) above the confluence. It consists of four units (Figure 33). The lowermost and largest is made up of 180 ft. (55 m) of black silt with laminations present. A definite upward coarsening sequence is present in the unit. The lower part is quite fine grained but about 30 ft. (9 m) above the base coarse material appears and at the 90 ft. (27 m) level cross-bedded sands appear. This unit is overlain by 5 ft. (1.5 m) of stratified gravels followed by 5 ft. (1.5 m) of pebbles and cobbles in a fine dark silty matrix. Finally, the top unit consists of 10 ft. (3 m) of stratified gravels in a brown, fine-grained matrix.

Section K is located just 0.5 miles (0.8 km) upstream from the previous site. It consists of a massive deposit of fine dark silty-clay (Figure 34) overlain by a cover of boulders, cobbles, and pebbles in a fine brown matrix. Layering is clearly present in the black silts and is of a rather large scale (Plate 23). No pebbles of any kind are to be found in the lower unit. Samples #17, #18 and #19 were collected from this area.

The silt terraces present at the confluence continue downstream for some distance. 1 mile (1.6 km) downstream is an exposure with 200 ft. (60 m) unit (base unseen) of dark silts with an overlying 20 ft. (6 m) of fine brown material. Samples #20, #21 and #22 were

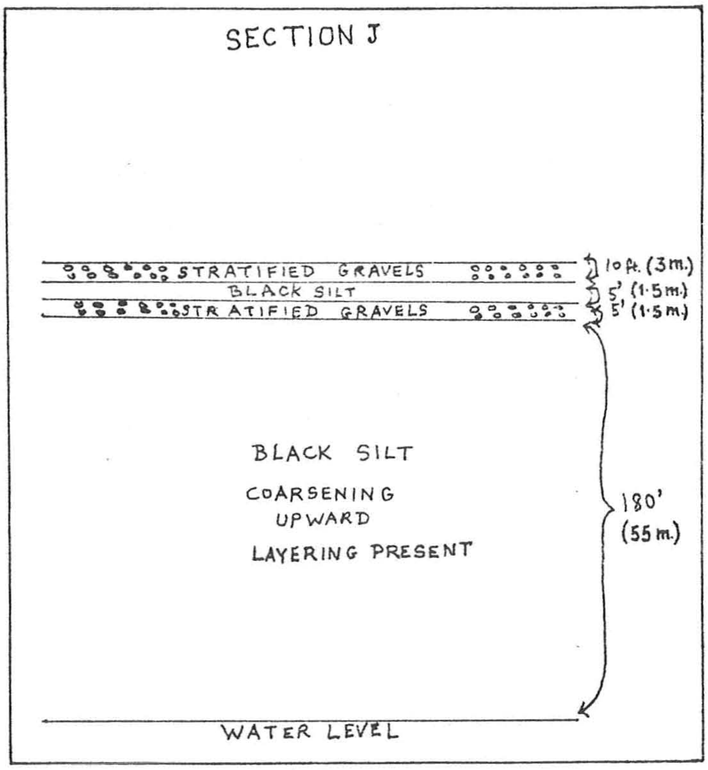


Figure 33.

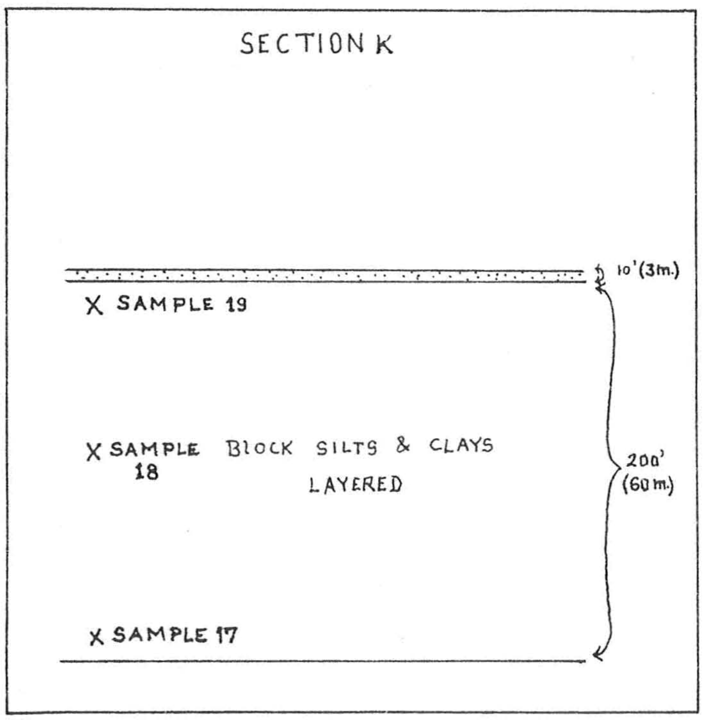


Figure 34.

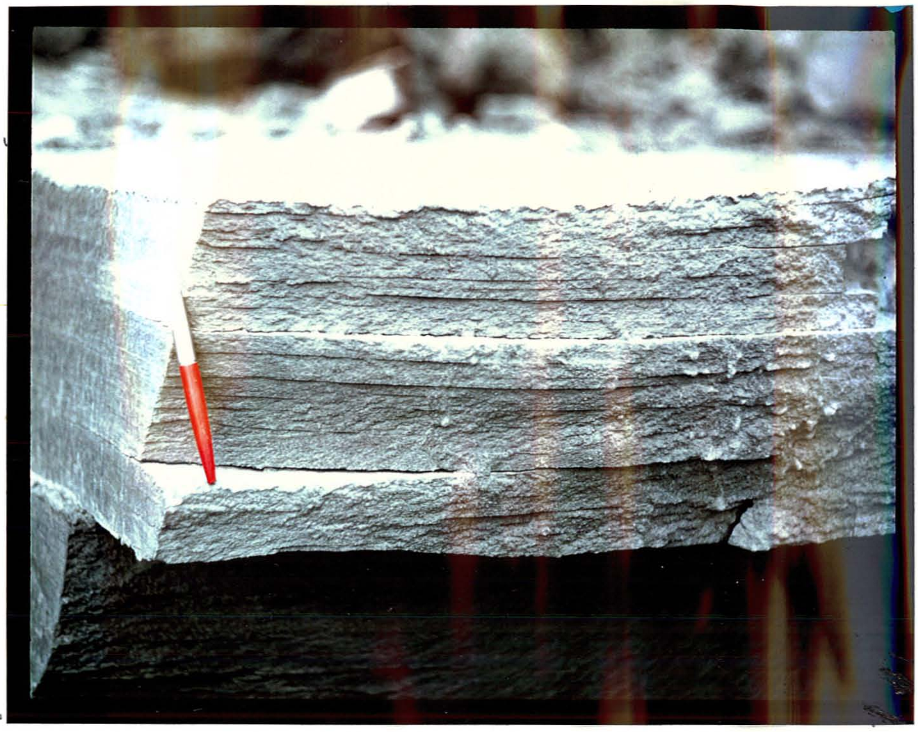


Plate 23. Laminations in dark silts at section K.

Plate 24. Transition of dark to buff silts at section L.

taken from this section. The dark silts are laminated much in the same manner as those where section K was measured. The top of these deposits is at 1,700 ft. (520 m) a.s.l., the same level as the top of sections J and K. Extending above these deposits and along the entire south side of the river in this area are bedrock benches at the 2,000-2,100 ft. (610-640 m) level. The north side to the river below the confluence continues to maintain the silt deposits for a considerable distance downstream. On the south side however, below the site where samples #20, #21 and #22 were collected, the deposits can no longer be distinguished. This may well be the result of the combined effects of fluvial erosion and mass wasting.

As one approaches section L the lacustrine deposits on the north bank of the river become more prominent. At the section (Figure 35) a major change occurs. The dark silts, some 200 ft. (60 m) in thickness in the area and resting directly on the limestone bedrock, give way laterally to much lighter yellow coloured silts of comparable thickness also resting directly on the bedrock (Plate 24). The transition can be clearly seen (Plate 25). Above the silts bedrock benching is again present. Samples #23, #24 and #25 were obtained here. Sample #26 was collected at a point 2 miles (3 km) downstream.

Approaching the confluence of the Flat and South Nahanni Rivers the now yellow silts persist as perched

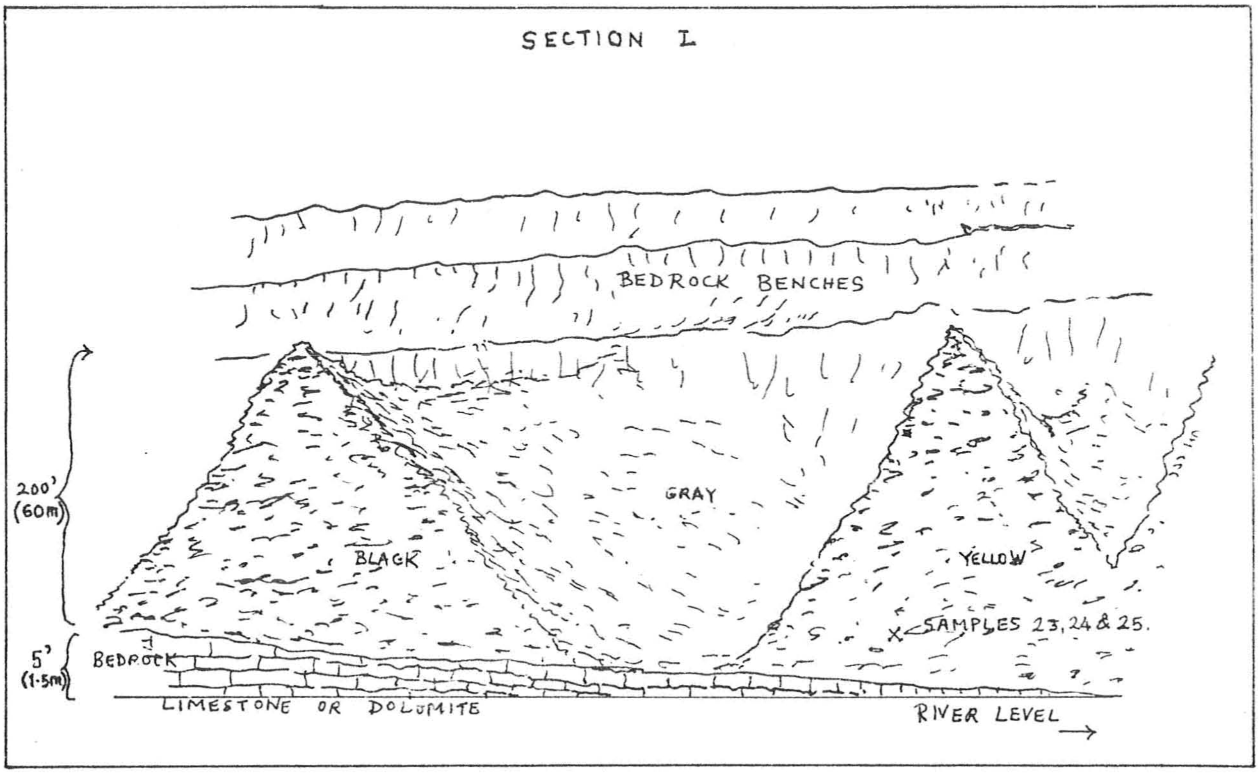

SECTION I
BEDROCK BENCHES
200' (60m)
GRAY
BLACK
YELLOW
SAMPLES 23, 24 & 25.
5' (1.5m)
BEDROCK
LIMESTONE OR DOLOMITE
RIVER LEVEL

Figure 35.

Plate 25. Close-up of contact of buff silts and bedrock.

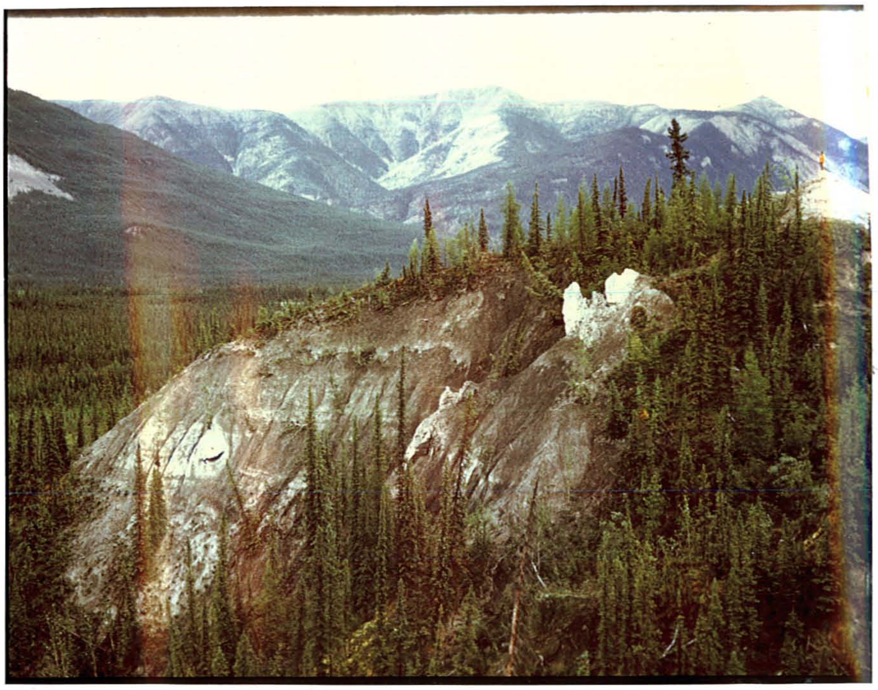


Plate 26. Dark silt deposits above Virginia Falls.

deposits up the valley walls. Above them, some 600-650 ft. (180-200 m) above river level, run bedrock benches.

The area above Virginia Falls also possesses lacustrine materials. These deposits, found dominantly along the southern side of the river and extending back up against the valley sides, are dark in colour and appear similar to the dark silts along the Flat (Plate 26). Evidence of the silts persists below Virginia Falls in the form of exposures above and back from the canyon walls. These deposits, at 2,000 ft. (610 m) a.s.l., are bright yellow in colour.

Although evidence of the silts is lost below the confluence of Marengo Creek and the Nahanni, they reappear in the area of Clearwater Creek. Deposits 300-400 ft. (90-120 m) in thickness are present at the Clearwater confluence with the South Nahanni. Even stronger evidence of lacustrine deposits are found in the area of Wrigley Creek. Here two distinct terraces are present; a lower level found in the area above the South Nahanni-Wrigley confluence which is at the 1,700 ft. (520 m) a.s.l. level, and an upper terrace which reaches the 2,000 ft. (610 m) a.s.l. level. The colour of the upper deposits is bright yellow; that of the lower level could not be determined.

At the confluence of the Flat and South Nahanni the most massive lacustrine deposits in the park are located (Plate 27). The best exposures are found along the north side of the South Nahanni. They consist of 500 ft. (150m) of yellow silts reaching from the edge of the floodplain near river level up to an elevation of 2,000 ft. (610 m) a.s.l. While no samples could be collected in this area because of time constraints it does appear that the silts extending from below Virginia Falls down to the confluence are from the same unit. The material is of uniform colour and texture throughout. No overlying units could be seen in any of the exposed sections. Moreover, these deposits appear similar to those deposits extending up the Flat from the confluence.

Figures 36A and B constitute an attempt to correlate the different levels. There appears to be two fairly persistent levels to the terraces; the more extensive is at 2,000 ft. (610 m) a.s.l. while the second, at 1,700 ft. (520 m) is less prominent.

The extent and source areas of the silt deposits is indicated in Figure 36C. The massive buff silt unit extends from below Virginia Falls down to the Nahanni-Flat confluence and up the Flat beyond Direction Mountain. It continues up the Flat at least as far as the Flat-Irvine confluence. The dark silt unit extends to within 11 miles (17 km) of the Nahanni-Flat confluence. There is also the dark silt unit present above Virginia Falls which

Plate 27. Buff silt deposits at South Nahanni-
Flat confluence.

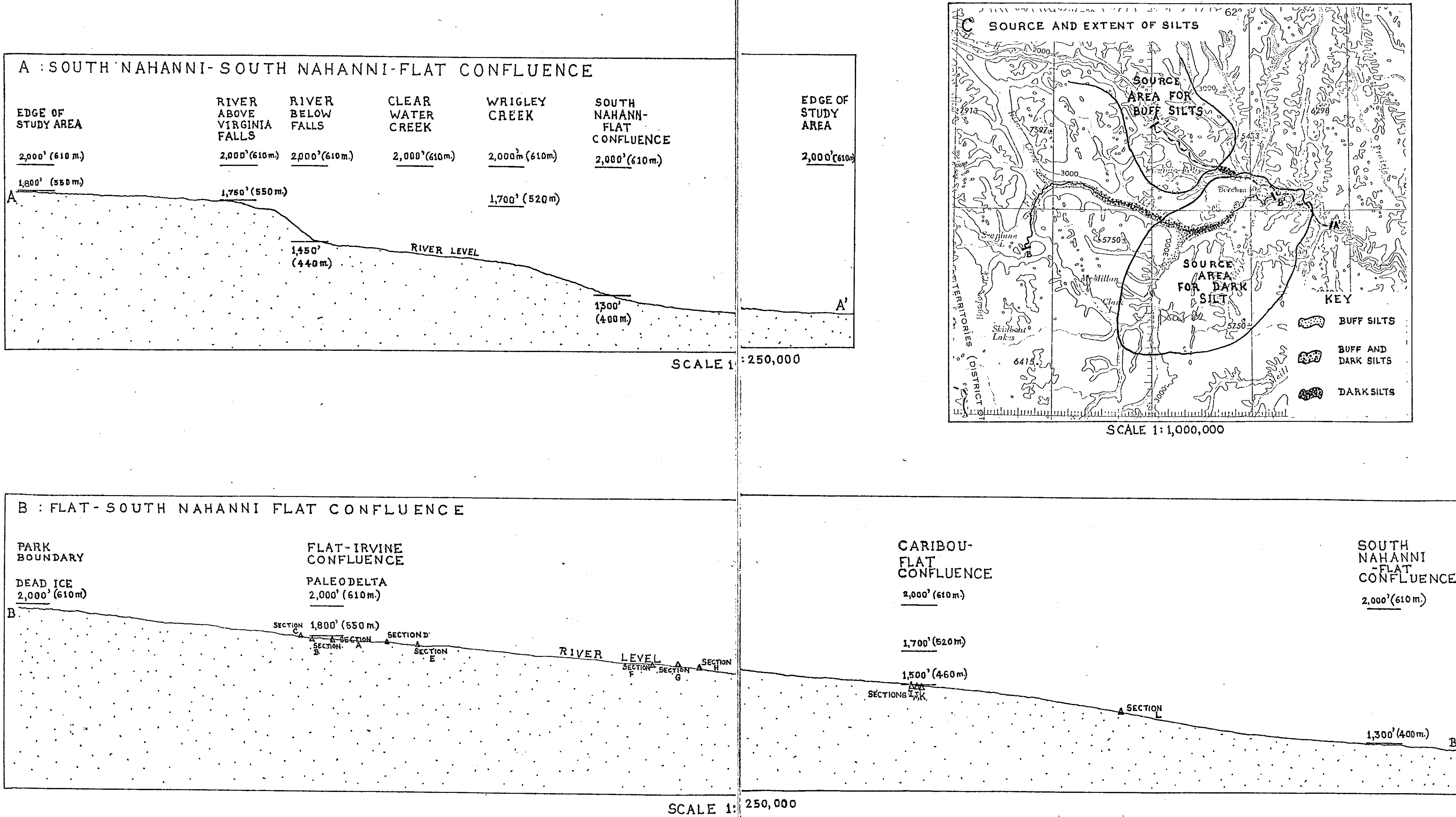


Fig.36(a) Correlation of terrace levels for South Nahanni River valley

(b) Correlation of terrace levels for Flat River valley

(c) Source and extent of silt depsoits

may be tentatively correlated with the dark silt unit of the Flat River valley. No dark silt exposures were seen from below Virginia Falls to the confluence or on the Flat River directly above the Nahanni-Flat confluence. The till unit is the least extensive of the three. It is confined to the Flat River valley from above the Flat-Irvine confluence to a point immediately below the Flat-Caribou confluence. Its presence was not detected in the South Nahanni River valley.

3. ANALYSIS AND INTERPRETATION OF THE DEPOSITS

Grain size analysis of all the sediment samples collected was conducted using dry and wet sieving at one half phi intervals down to 4 phi and pipette analysis at 1 phi intervals down to 12 phi. The methods employed followed procedures outlined by Folk (1974). The results are summarized in Table 3 and the cumulative curves and histograms for all the samples have been included in Appendix I.

Although considerable care was taken in conducting the sediment analysis the results must be regarded with caution. The number of samples is not large and there is a good possibility that some of the samples may have been contaminated by material washed down the exposure from the overlying unit or the fines may have been winnowed out of some samples.

Table 3. Results of Grain Size Analysis

Sample	Source	Location in Unit	Description	Mean (phi)	Standard Deviation (phi)	Skew-ness	Kurt-osis
1	Section C	middle	deltaic (medium sand)	1.0	0.95	-.05	1.65
2	Section C	middle	fluvial-stratified	-2.4	2.25	.02	1.26
3	Section D	middle	deltaic (coarse sand)	-0.8	0.75	.60	.90
4	Section D	upper	deltaic (medium sand)	1.6	0.45	.78	2.12
5	Section D	lower	deltaic (medium sand)	0.7	1.20	.25	1.62
6	Section D	upper	deltaic (fine sand-silt)	3.5	1.90	.33	1.41
7	Section D	upper	deltaic (fine sand)	2.0	0.45	-.11	3.83
8	Section D	middle	deltaic (fine sand)	3.2	0.75	.27	1.50
9	Section E	middle	till	1.1	4.90	.24	.71
10	Section E	middle	lacustrine (silt)	6.3	1.90	0	1.00
11	Section E	lower	lacustrine (silt)	5.1	1.80	.02	.97
12	Section F	lower	lacustrine (fine sand-silt)	4.0	2.25	.33	1.05

Sample	Source	Location in Unit	Description	Mean (phi)	Standard Deviation (phi)	Skew-ness	Kurt-osis
13	Section F	middle	lacustrine (silt)	7.7	2.50	-.24	.93
14	Section H	lower	lacustrine (silt)	6.4	2.75	-.02	.72
15	Section I	lower	lacustrine (silt)	4.6	1.85	.51	1.26
16	Section I	lower	lacustrine (fine sand-silt)	3.4	0.35	-.14	2.17
17	Section K	lower	lacustrine (fine sand-silt)	3.4	0.30	-.67	3.67
18	Section K	middle	lacustrine (fine sand-silt)	3.1	1.20	.17	1.53
19	Section K	upper	lacustrine (silt)	6.3	2.45	-.02	.95
20)	Section below	lower	lacustrine (silt)	5.4	1.90	.38	.95
21)	Flat-Caribou	middle	lacustrine (silt)	6.4	2.10	.24	1.03
22)	confluence	upper	lacustrine (silt)	7.0	2.15	-.05	1.00
23	Section L	middle	lacustrine (silt)	7.2	2.30	.13	1.02
24	Section L	middle	lacustrine (silt)	5.6	1.60	.25	1.03
25	Section L	lower	lacustrine (fine sand-silt)	3.9	1.65	.19	1.01
26	Downstream of Section L	upper	lacustrine (silt)	6.0	1.50	.40	1.14

Despite the difficulties cited above, difficulties which are reflected in the variability of the data, some preliminary distinctions and observations may be made. Of particular interest are the results for samples #2, #9, #20, #21, #22, #15 and #16.

Sample #2 (Figure 37) demonstrates the character of the stratified deposits overlying several of the silt sections between the Irvine-Flat confluence and the Caribou-Flat confluence. The mean value of -2.4 phi and the standard deviation of 2.25 phi is typical of glaciofluvial deposits.

The results of the analysis of sample #9 (Figure 38) are in sharp contrast with those of sample #2. The trimodal and platykurtic nature of the distribution, the strong fine skewness, and the high standard deviation of 4.90 phi are typical of a glacial till. Unfortunately, although similar till and stratified deposits appear to overlie several sections, these were the only samples of these deposits which could be obtained due to the inaccessibility of the upper units.

The results of grain size analysis in conjunction with the presence of dropstones, fine laminations, and cross-bedding in some sections clearly demonstrates a lacustrine origin for the massive silt deposits of both the buff and dark units (Table 3).

Cumulative Curve and Histogram

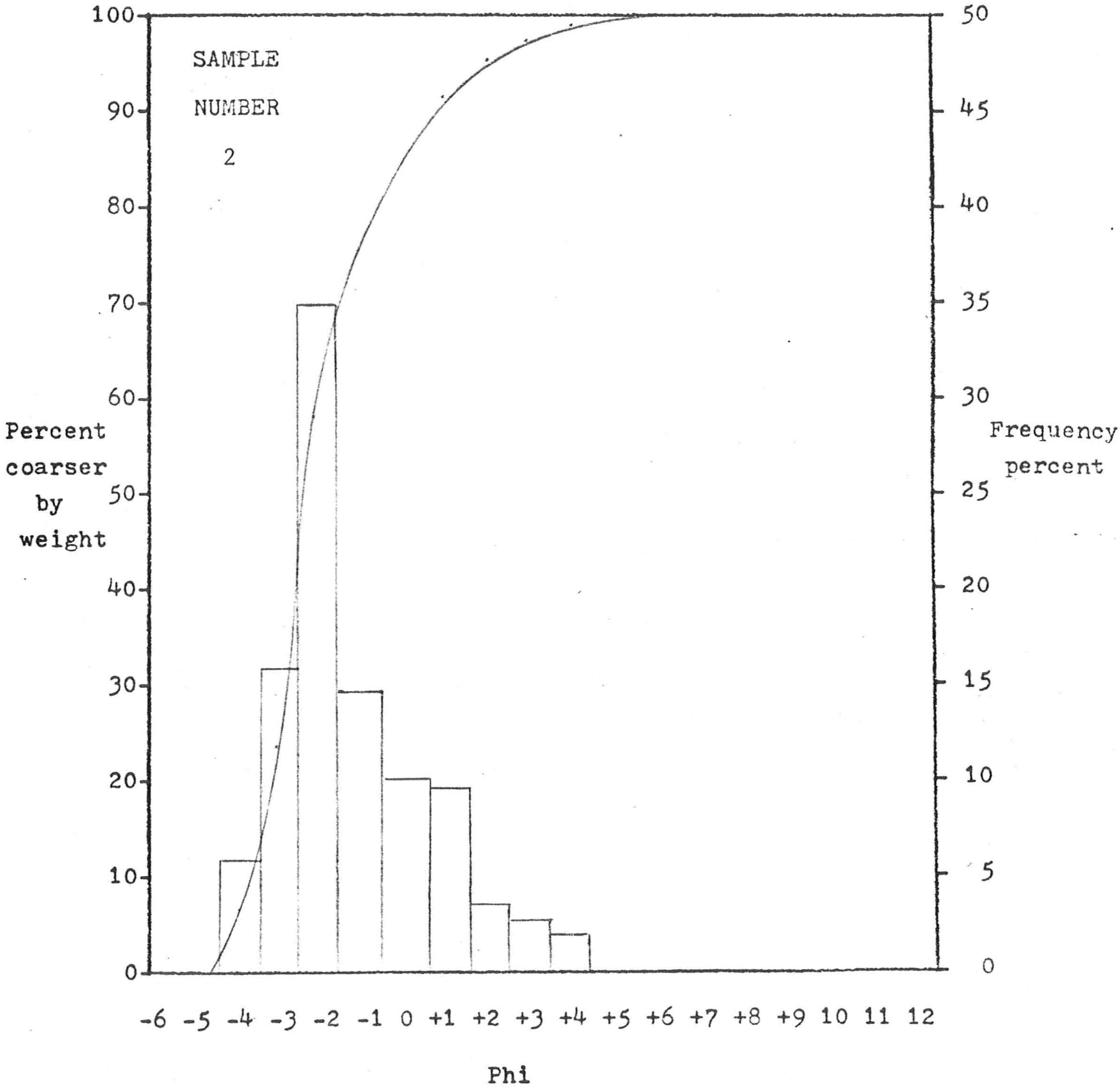


Figure 37.

Cumulative Curve and Histogram

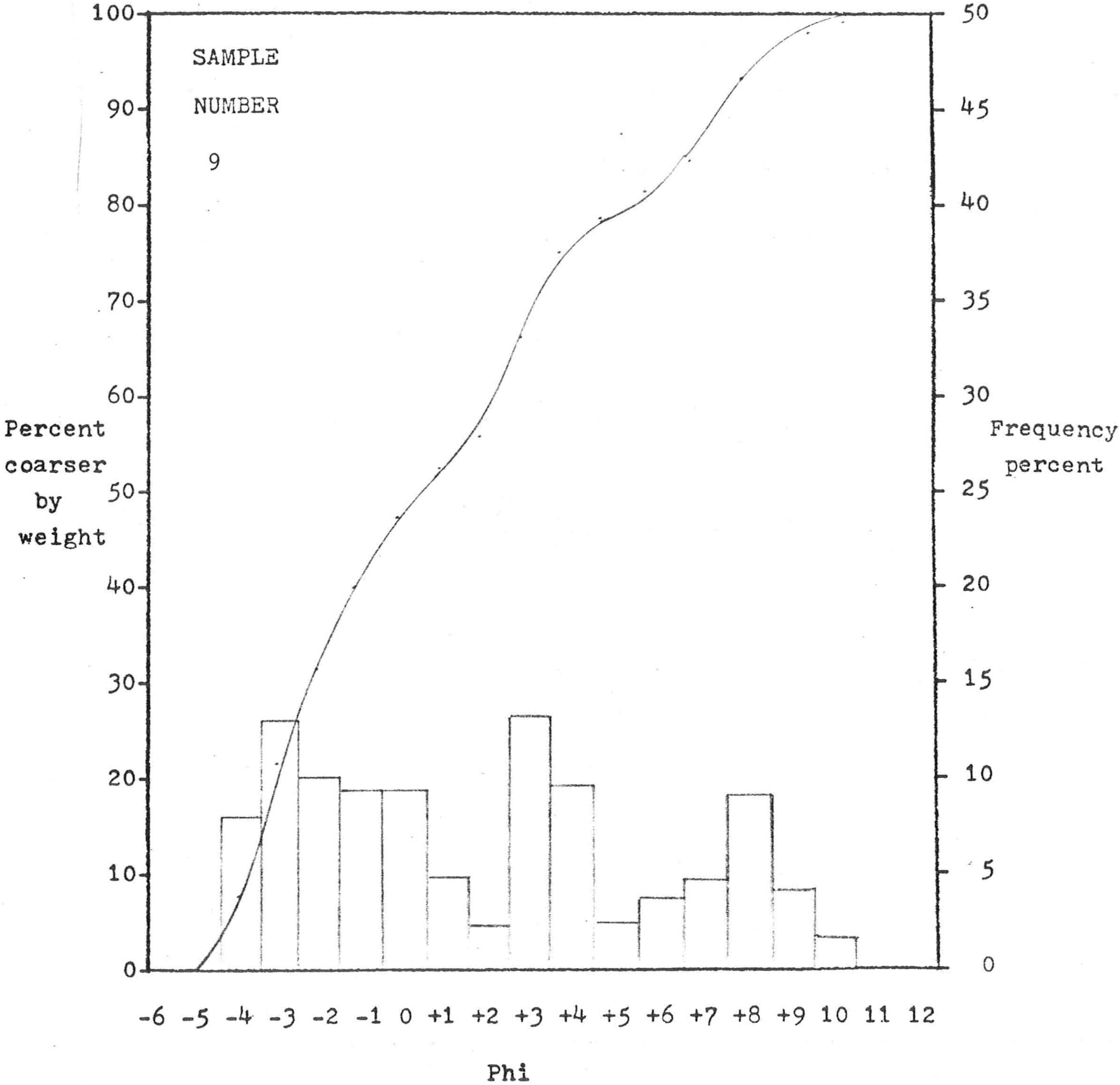


Figure 38.

A second feature of the silt deposits evident in the grain size data is a general tendency for a fining upwards sequence in both the buff silts and the dark silts. The cumulative curves and histograms for samples #20, #21 and #22 (Figures 39, 40, 41) demonstrate this. A similar sequence occurs in the buff silts with the mean of sample #25 being 3.9 phi while that of sample #24 is 5.6 phi and sample #26 is 6.0 phi. It should be noted however that sample #23, while located lower in the unit than sample #26 is of smaller mean size. This may be the result of contamination from higher in the unit or the product of slumping by material higher in the unit.

Finally, the analysis of sample #15 (Figure 42) and sample #16 (Figure 43) are also of special interest since they come respectively from a dark silt unit and a buff unit which are in direct contact. Although the mean grain size of both is similar, the yellow silt deposit (sample #16) appears somewhat better sorted than the dark silts (sample #15) in this area.

Statistical differentiation between the dark and yellow silt deposits is difficult on the basis of the limited samples obtained. The lack of samples of buff deposits in particular hampers such a comparison. Unfortunately, time constraints precluded further sample collection during the field season. A more extensive sampling would appear warranted.

Cumulative Curve and Histogram

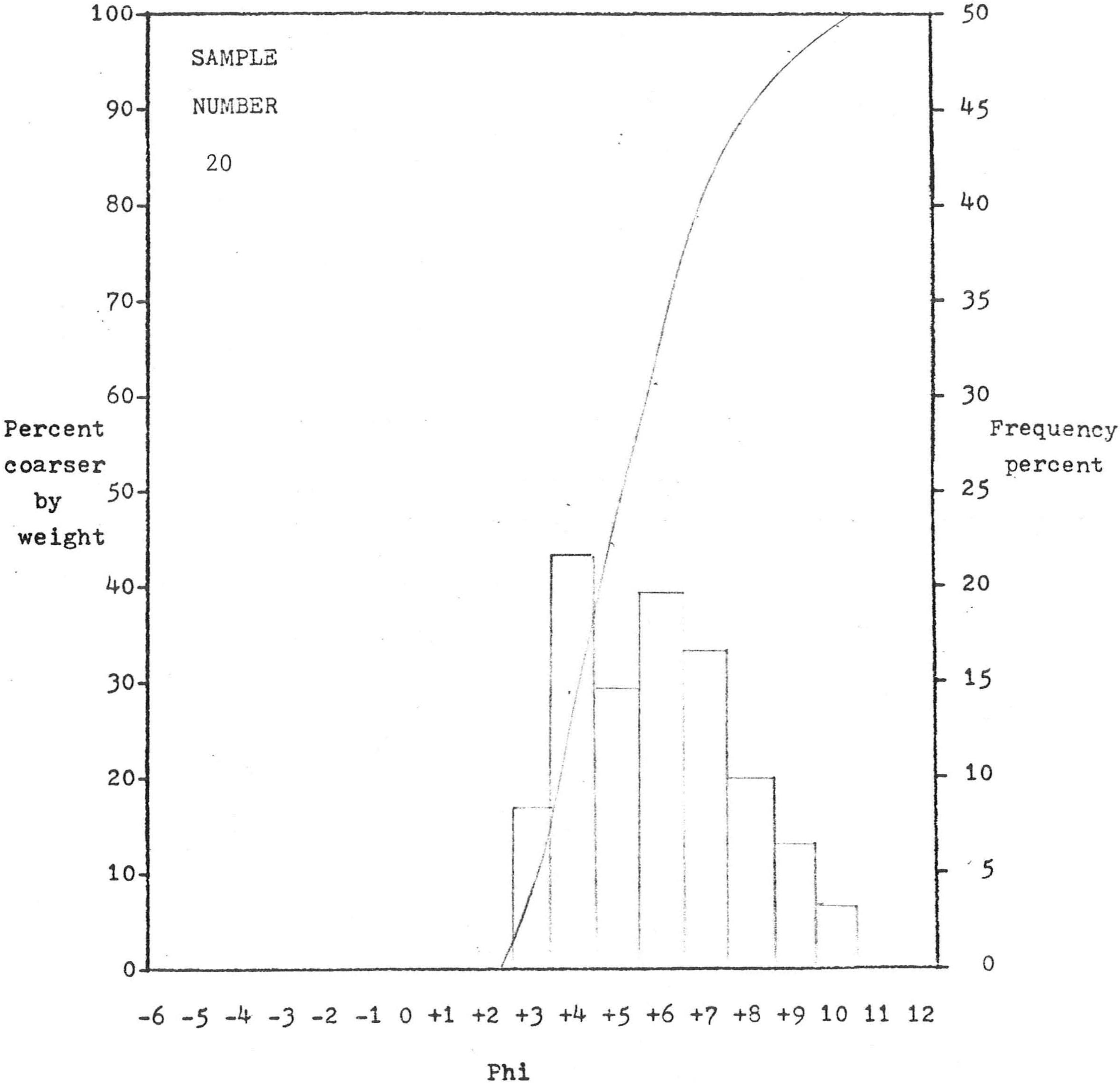


Figure 39

Cumulative Curve and Histogram

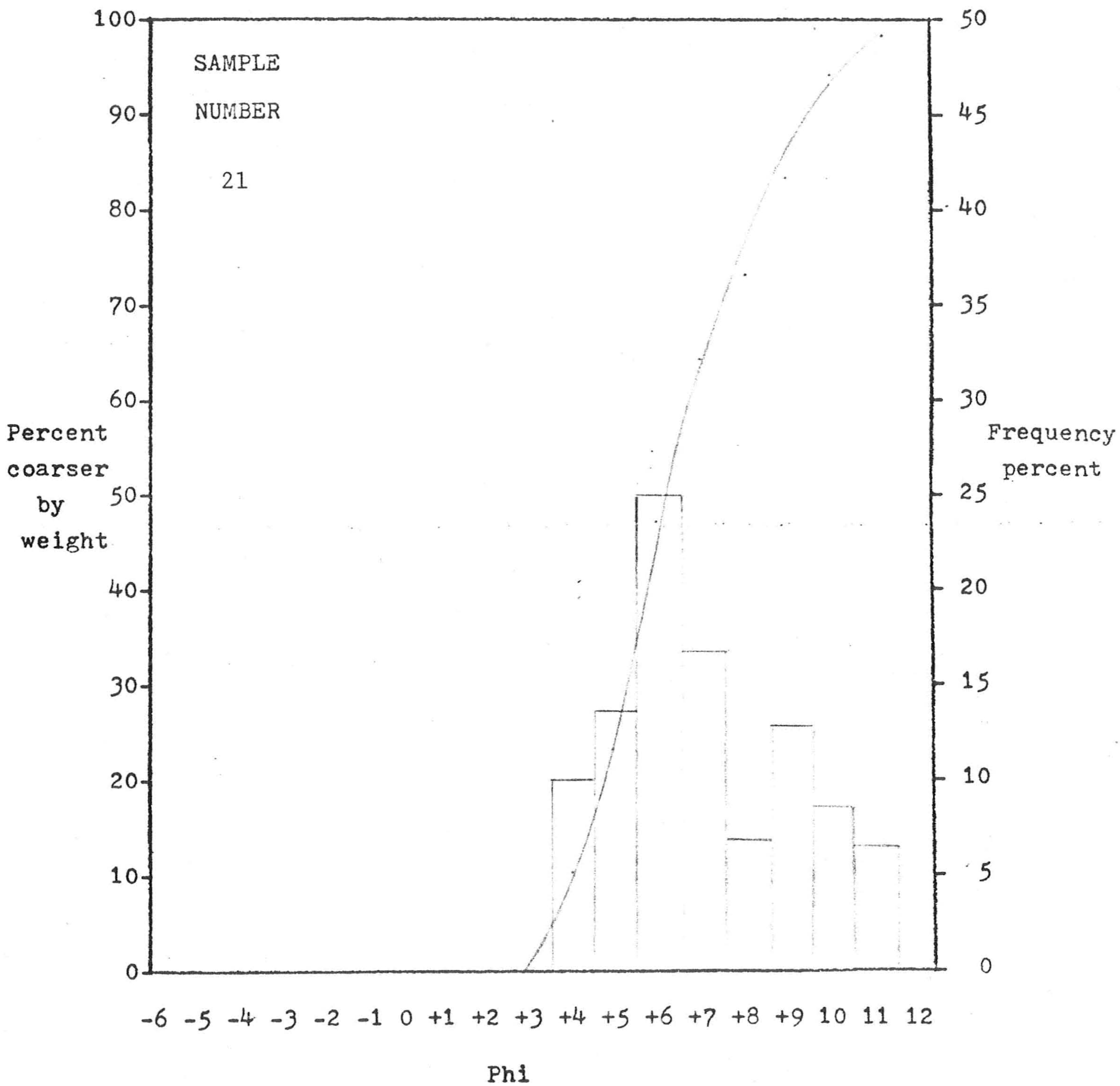


Figure 40.

Cumulative Curve and Histogram

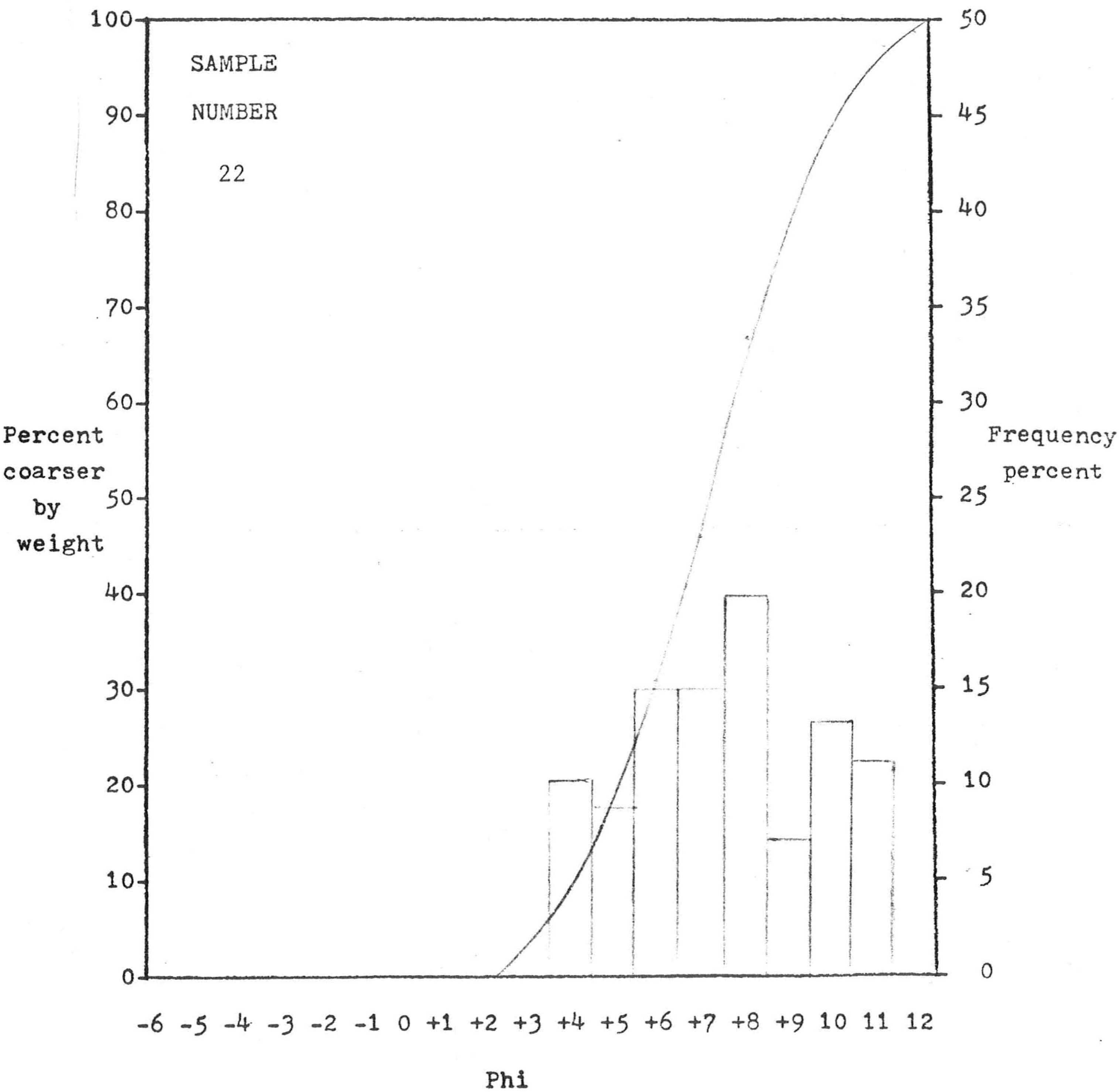


Figure 41.

Cumulative Curve and Histogram

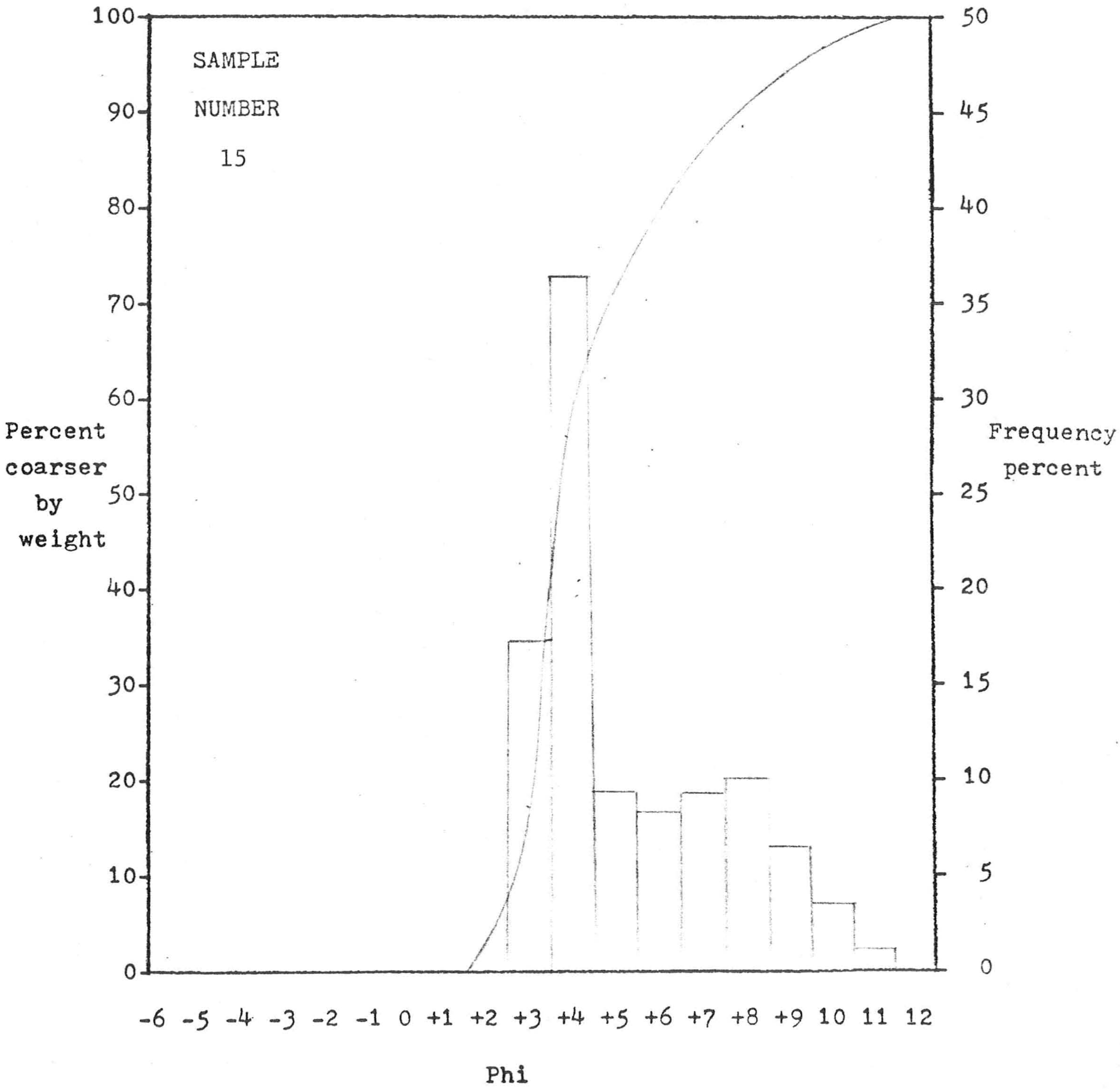


Figure 42.

Cumulative Curve and Histogram

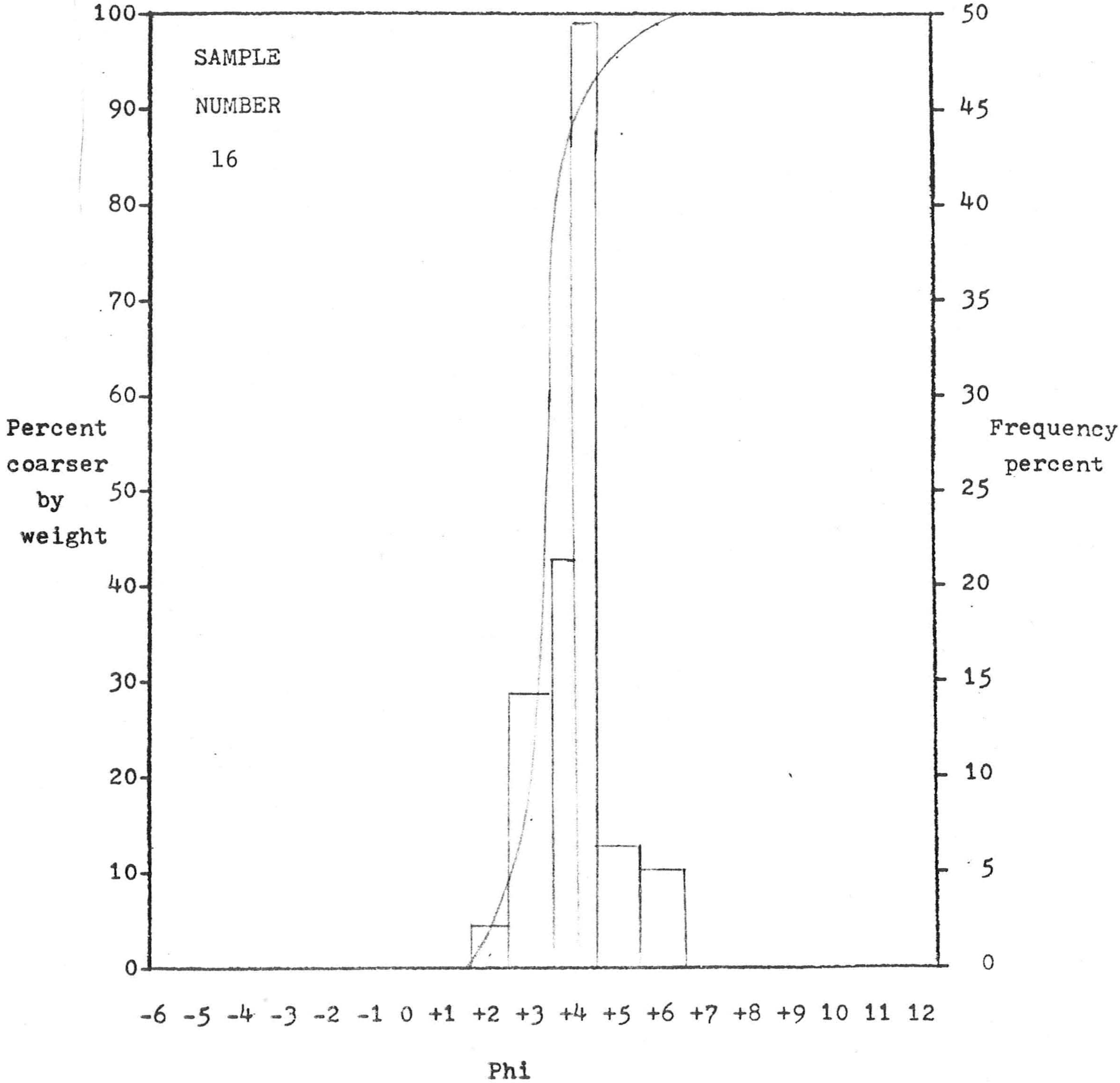


Figure 43.

In addition, the presence of laminations in both the buff and dark silt units, while supporting the interpretation of the deposits as being lacustrine, must be regarded with caution when viewed as a possible means of establishing sedimentation rates or as a means of establishing an age for the lake. Although glacio-fluvial and glacio-lacustrine sediments have been widely discussed in the literature,* the mechanics of deposition, varve formation, and the significance of turbidity currents in such environments is not well understood. As a consequence one must exercise caution in any assessment such deposits, particularly in attempting to date deposits on the basis of unit thickness or band counts.

4. SIGNIFICANCE OF DEPOSITS

The field assessment of the stratified glacio-fluvial sediments and till deposits, and the lacustrine interpretation of the massive fine sand and silt deposits is supported by the results of the grain size analysis. The significance of such deposits from a glacial history viewpoint however, merits further consideration; particularly in view of the fact that some exposures of the lacustrine deposits appear to be overlain by the till.

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*A rather comprehensive summary is provided by Jopling (1975).

It is clear from the geomorphic map (Figure 16) and from the evidence of erratics in the study area that the plateau area between the South Nahanni and Flat River was subject to a major glaciation.

The broad u-shaped nature of the Flat River from the park boundary to a point 45 miles (75 km) above Direction Mountain and the large meltwater channels below the Flat-Irvine confluence also indicates the occurrence of an intense valley glaciation followed by a long period of stagnation. The valley glaciation is younger in age than the plateau glaciation. The narrowing down of the Flat valley above the confluence suggests that the valley glaciation did not reach the Flat Nahanni confluence. The lacustrine silts must date from after this intense but not extensive valley glaciation.

Of considerable significance is the fact that in three examined exposures we find buff silts overlying or overriding the dark with distinct contacts present at two exposures. Moreover, the rapid transition from the lower dark silt unit to the overriding buff unit cannot be readily accounted for on the basis of groundwater or chemical effects. The change is too rapid and far too frequent. The only reasonable conclusion appears to be that the dark silts and the buff silts are the result of two different lakes.

The dark silt, clearly the older deposit, was laid down in an ancient proglacial lake, herein named Lake Caribou. Because the dark silt deposits of this lake rest directly upon the bedrock it is inferred their emplacement began shortly after the retreat of the major valley glacier which filled the Flat and may have been contemporary with a valley glacier which extended down the South Nahanni. The development of the lake is inferred to be the result of ice blockage of the South Nahanni by Laurentide ice outside the study area and in all likelihood, beyond the First Canyon area near the entrance of the park. It would also appear that the lake was at or above 2,000 ft. (610 m) a.s.l., the maximum elevation of the deposits.

The draining of the lake after the retreat of the blocking ice appears to have been followed by a period of river entrenchment which saw the removal of most of the dark silts of Lake Caribou. Only remnant terraces were left close to the valley sides.

This downcutting phase must have been of considerable duration since it reached levels at least as low as the present river. This is indicated at section L where buff silts lie directly upon the bedrock demonstrating that the valley floor must have been downcut to this level before the buff silt unit was emplaced!

In the period following the draining and downcutting of the deposits of Lake Nahanni no major valley glaciation would appear to have occurred. Such an event would have entirely removed the lake's deposits. A minor advance in the area is possible but no evidence supporting the occurrence of such an event has been found.

The long period of downcutting was followed by the development of a second lake, Lake Nahanni. The massive buff silt deposits of this lake reach over 2,000 ft. (610 m) a.s.l. indicating that the lake stood at or above this level. Again ice-blockage by Laurentide ice outside the study area and in all likelihood in the vicinity of the park entrance is inferred as the cause of the impounding. The appearance of the contact between the dark and buff silt units suggests that the dark silt terraces with their steep exposure faces were quickly submerged in a rapidly rising lake. The lake then began to fill with the buff sediment to at least 2,000 ft. (610 m) a.s.l. Following the retreat of the impounding ice the lake drained and river entrenchment was initiated. It has continued down to the present. The persistent terracing at 1,700 ft. (520 m) a.s.l. suggests a still stand of some duration following the initiation of downcutting.

Finally, the presence of the till overlying the two lacustrine deposits suggests a valley glacier advance at least part way down the Flat River valley. The absence of till below the Flat-Caribou confluence and in the South Nahanni valley within the study area suggests that the advance was confined to the valley of the Flat River in the Central Nahanni. This view is supported by evidence from outside the study area which indicates that the major ice sources within the region lie to the south-west of the study area and hence in closer proximity to the Flat River area.

The relative chronology outlined above is summarized in Table 4.

The question of the absolute age of the deposits is more difficult. The length of time required for the river to downcut through upwards of 500 ft. (150 m) of sediment must be considerable. Moreover, the downcutting through the silts of Lake Nahanni is considered to be contemporaneous with the cutting of the Second Virginia Falls Gorge (Ford, 1976) and the time required for cutting back this gorge the 1,800 ft. (990 m) from the buried gorge through resistant limestone bedrock would be considerable (Ford, personal communication).

On the basis of the above it seems reasonable to postulate a considerable age for the Lake Caribou.

Table 4. Relative Chronology for Glacial Events in Central Nahanni

	Event	Age
1.	Continued dissection of silts by entrenching river.	Most recent
2.	Minor valley glaciation extending only part way down the Flat to the area of the Flat-Caribou confluence.	
3.	Long period of downcutting following drainage of Lake Nahanni. This period of downcutting was of sufficient length to allow intense dissection and the removal of the bulk of the lacustrine deposits of Lake Nahanni as well as the excavation of the second Virginia Falls.	
4.	Formation of Lake Nahanni as a result of impounding by Laurentide ice outside the Central Nahanni. Extensive buff silts deposited.	
5.	Long period of downcutting following drainage of Lake Caribou. River entrenching through deposits of lake.	
6.	Creation of Lake Caribou shortly after valley glaciation. The lake was probably produced by impounding Laurentide ice. It deposited extensive dark silt deposits.	
7.	Valley glaciation down Flat River Valley to a point directly upstream of Direction Mountain. A valley glaciation of the South Nahanni Valley may have been contemporary with this.	
8.	Old major plateau glaciation of upland and Plateau areas.	Oldest

Similarly, the time required for river entrenchment through the silts of Lake Nahanni to below present river level, the massive dissection and the substantial removal of the deposits must also have required a considerable period of time. It would appear then that the time span between the existence of the Lake Caribou and Lake Nahanni is large.

Finally, the absence of "fresh" glacial features and the extent of mass wasting processes suggests that the till deposits are not of neoglacial age.

More will be said regarding this problem of the absolute age of the deposits in the next chapter.

CHAPTER V

CORRELATION OF RESULTS FROM THE CENTRAL NAHANNI WITH THE REGIONAL VIEW

1. THE PROBLEM OF CORRELATION

Correlating glacial events in an area as large as the Yukon - Western District of Mackenzie is a difficult undertaking. The problem is further complicated by the fragmentary nature of the data available and the paucity of absolute dates of deposits. Finally the interaction of climate and physiography in the region may have greatly affected the course of glacial history. It is this latter point which will be dealt with first, by discussion of the significance of current climatic data for the glacial processes in the region.

2. CLIMATIC DATA AND ITS SIGNIFICANCE FOR THE GLACIAL HISTORY OF THE REGION

The precipitation and, in particular, the snowfall values, have already been discussed. Figures 44 and 45 (upon which Figure 2 is based) provide a better perspective of the overwhelming role of shadowing and screening effects. Figures 46 and 47 which indicate respectively the date on

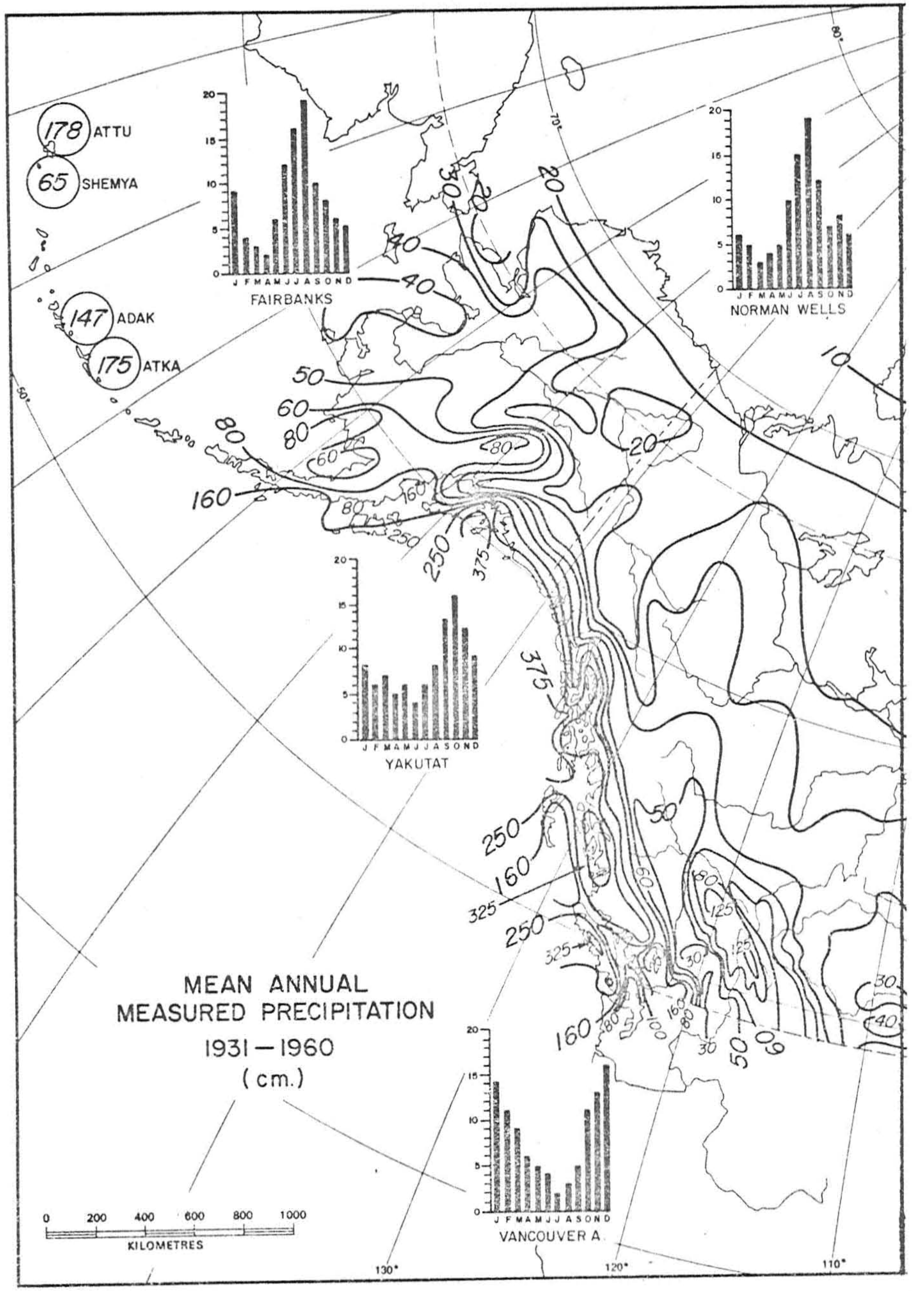

Figure 45.

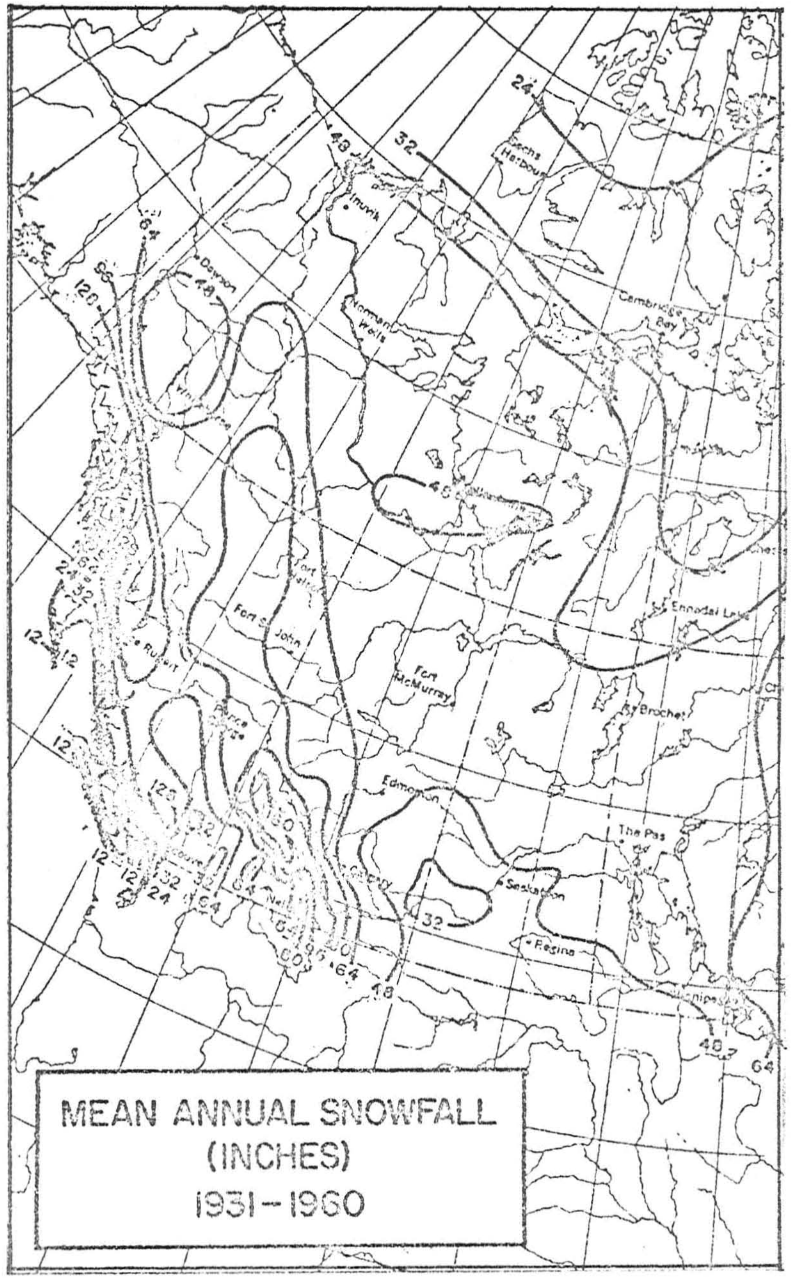

Figure 44.

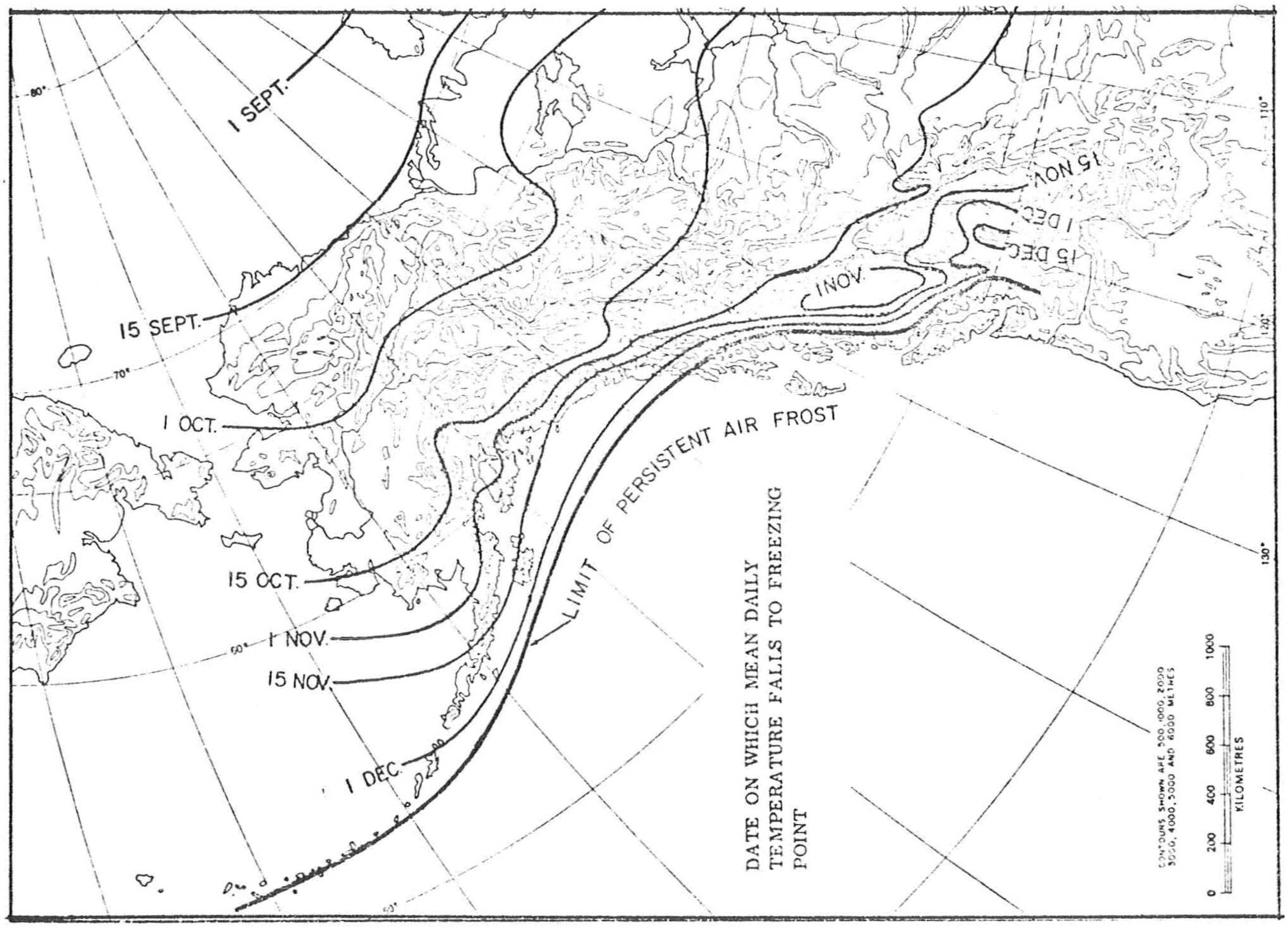

Figure 46.

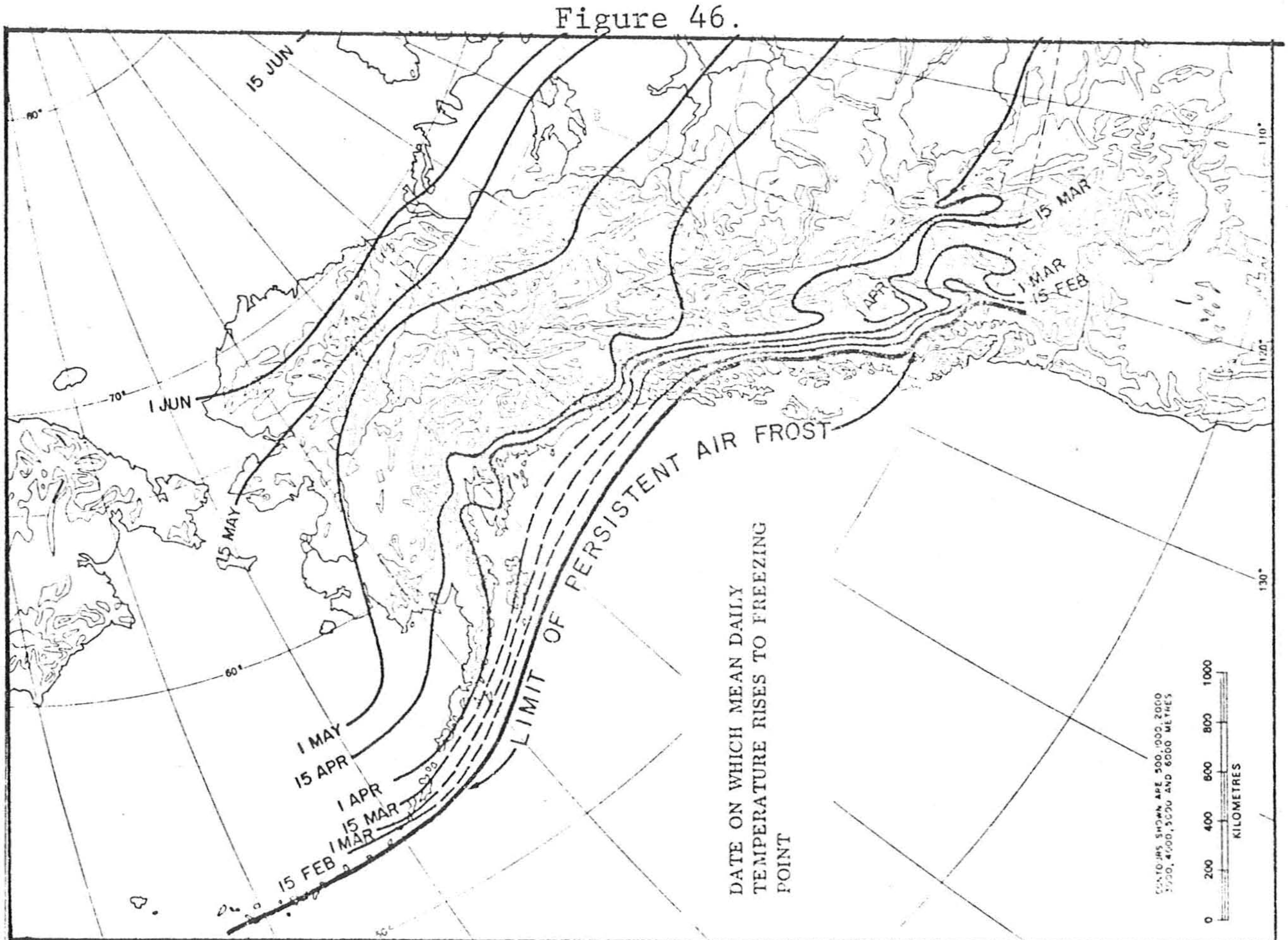

Figure 47.

which the mean daily temperature rose to the freezing point and the date on which the mean daily temperature fell to the freezing point provide further evidence of the significance of the maritime influences and the primary and secondary screening processes which dominate the climate of the region.*

It is in the wind systems and the shifting of the climatic fronts that the critical climatic control of glacial processes appears to be vested. Figures 48, 49, 50 and 51 indicate the resultant streamlines, wind roses, and frontal locations for the months of January, April, July and October respectively. The significance of these figures and in particular the shifting of the mean frontal locations is typified by the situation at Norman Wells. In January, when the mean location of the Arctic Front was

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*The above data have been derived by a tabulation of the climatic data found in the Climatic Station Data Catalogue-Yukon and Northwest Territories, CLI 3-70, Dept. of Transport, Met. Branch, May 1, 1970. The catalogue contains a record of all stations, types of measurements, and lengths of record, for the entire region.

For such a vast area there have been very few climatic stations in operation. Of the stations operating most have been limited to only taking basic measurements. Moreover, the records are largely incomplete, often of short duration, and of necessity come from sites which often have been situated with little regard to their true "representativeness". In the entire region only eight sites have continuous records from 1930 to the present. Only thirteen more have partial records of at least ten continuous years' duration. Thus the current data on the climate of the region must be approached with caution.

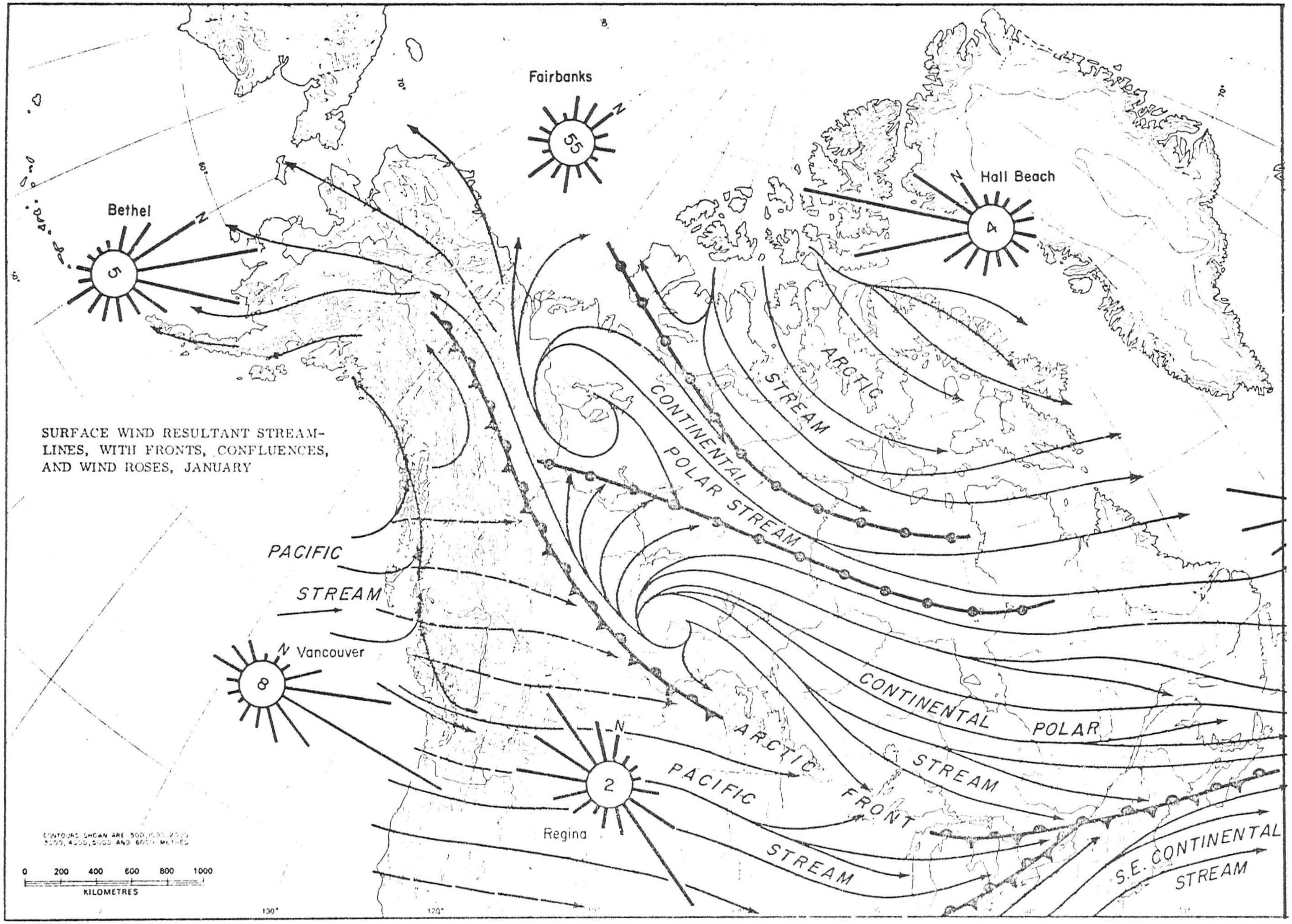

Figure 48. January air mass data.

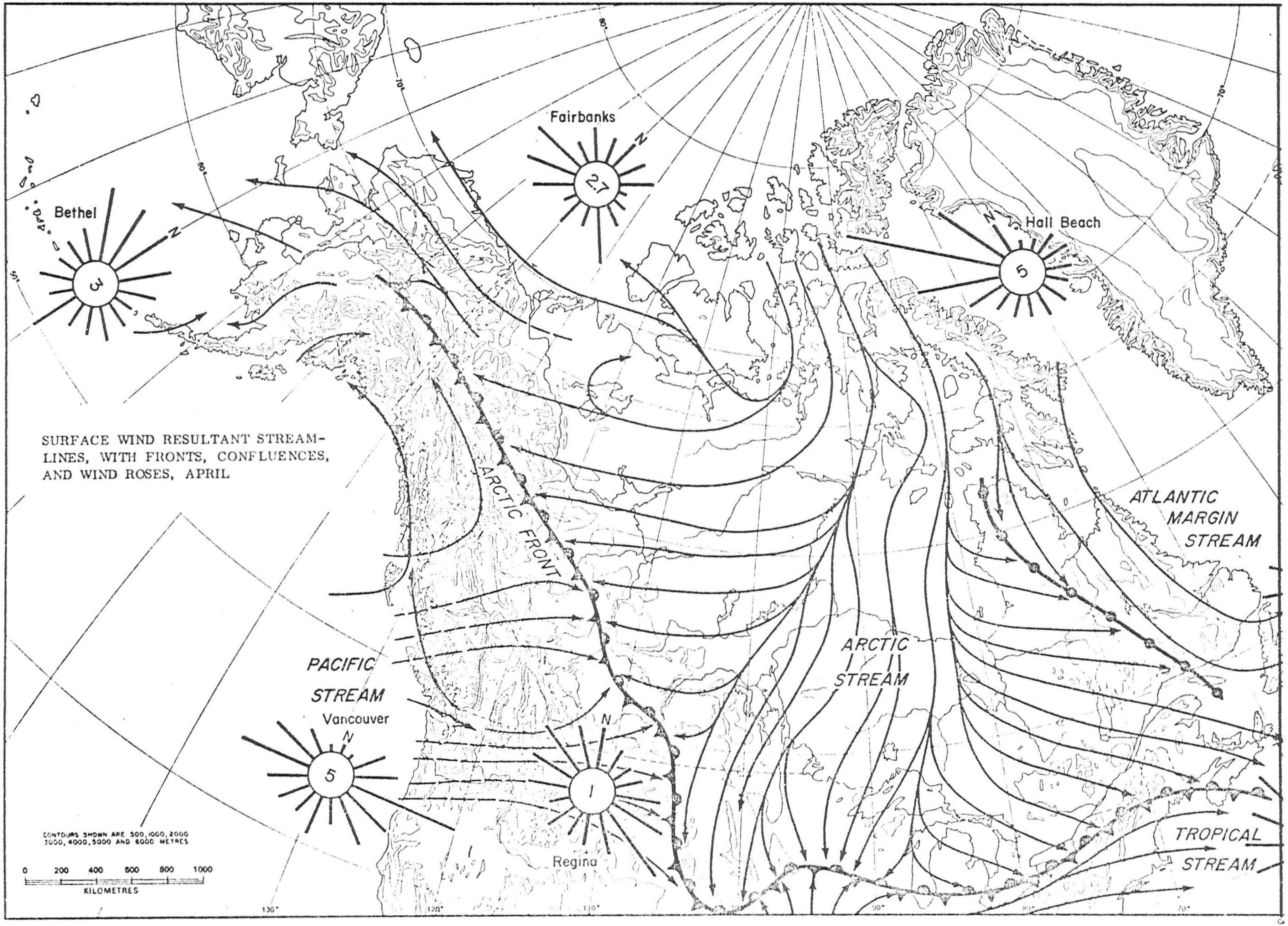

Figure 49. April air mass data.

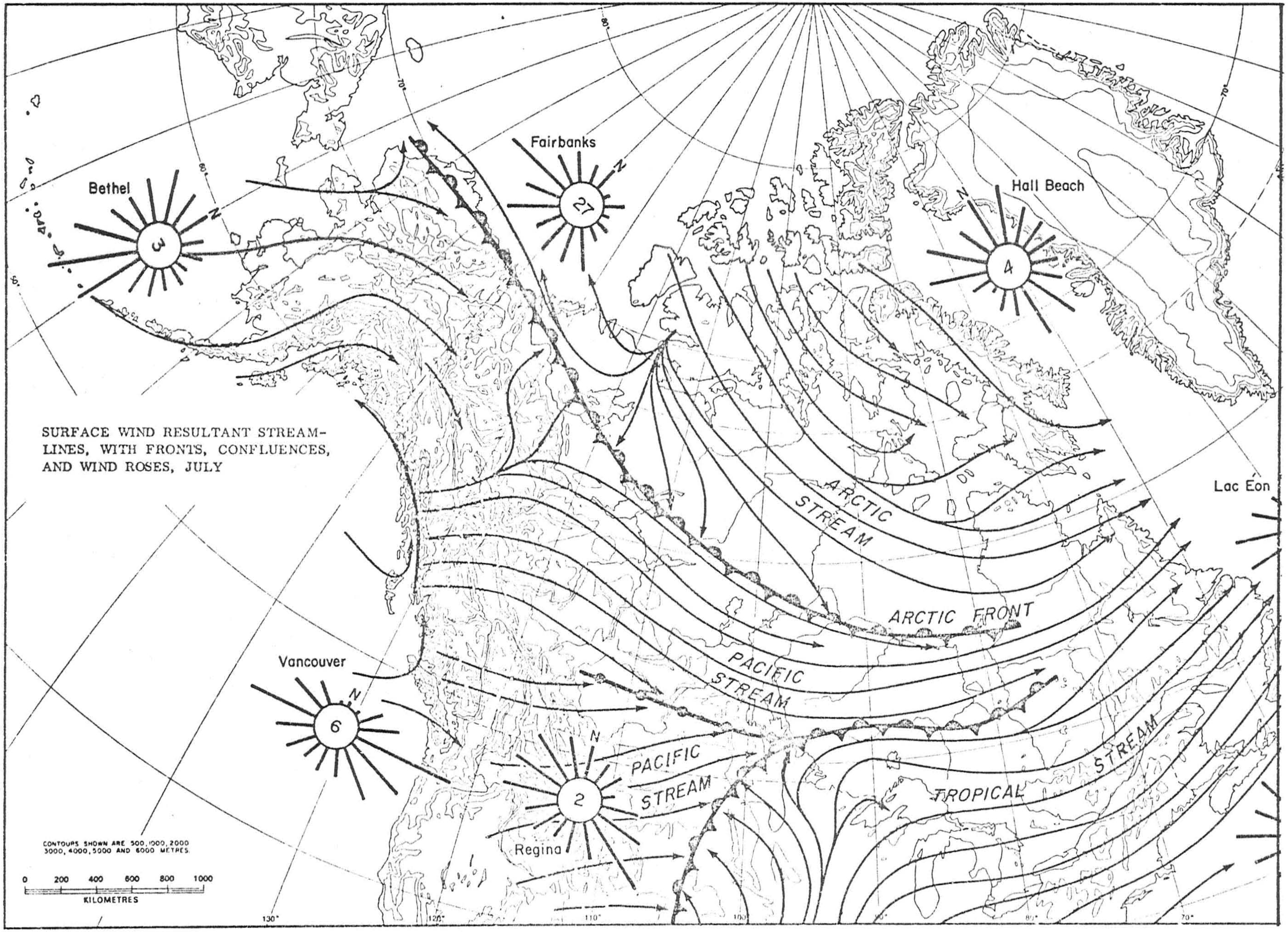

Figure 50. July air mass data.

Figure 51. October air mass data.

located approximately 300 km. (approximately 175 miles) to the west of Norman Wells, the mean January precipitation was only 6 cm. (2.4 in.). In April, when the mean location of the Arctic Front was even farther west (approximately 400 km.) (250 miles), Norman Wells received only 4 cm. (1.6 in.) of precipitation. In July, however, when the Front had moved back so that its mean location was 180 km. (approximately 110 miles) east of Norman Wells and the area was exposed to the Pacific Stream, the precipitation jumped to a mean value of 15 cm. (8.9 in.). Finally in October, when the mean location was almost directly over Norman Wells, mean monthly precipitation was 7 cm. (2.8 in.).

From the above case it is clear that the location of the Arctic Front is decisive in determining the amount of precipitation which will be received at any location in the region. The Pacific Stream, apparently no matter what the degree of screening exercised by the Coastal and Interior Ranges, is still capable of bringing increased precipitation to virtually any point in the entire region. The limiting factor controlling precipitation, once the effect of topographic screening has been taken into account, is the mean location of the Arctic Front: the point at which the Arctic and Continental Polar Streams block the advance of the Pacific Stream.

The fact that not only the screening effect of topography but also the location of the Arctic Front is critical in determining the amount of precipitation an area will receive is of considerable significance for the glacial history of the region. It is generally recognized that the effective response time of the Laurentide ice would be considerably greater than that of the Cordilleran ice sheets. The argument upon which this is based is simple enough: once glaciation has begun the Cordilleran ice sheets and valley glaciers only had to emerge from the mountain chains and would then move out across the region. The Laurentide ice, having to traverse much greater distances, would not reach the region until later in the glaciation. So far so good! But what has not always been clearly recognized, and what is suggested by the above evidence, is that once the Laurentide ice enters or even approaches the region it will effectively begin to starve the Cordilleran and alpine glaciers of the precipitation they require to continue to advance. This process of starvation would occur because the presence of a large mass of ice would tend to push the Arctic Front further west. The further west the Arctic Front migrated the less precipitation the interior valley glaciers and Cordilleran ice sheets would receive. The tendency would be for more of the precipitation to be deposited in the Coastal Ranges and the windward glaciers flowing westward to the Pacific. Thus, the advance of the Laurentide ice into the region would, at the minimum, tend to cause a stand-still in the advance of the Cordilleran and valley glaciers, and at best might indirectly force them to retreat.*

It must be emphasized however, that the suggestion that a Laurentide advance could cause a Cordilleran or valley glacial advance to stop or even retreat by forcing the Arctic Front to move westward and thereby cutting off the supply of precipitation to the Cordilleran or alpine glaciers is only tentative. As was indicated at the beginning of this section the climatic data upon which this assessment is based are quite meagre and the general principle upon which it is founded requires more analysis and supporting evidence.

3. AN ATTEMPT AT CORRELATION

At this point an effort will be made to synthesize the information from the previous four chapters. The analysis which follows must be viewed as provisional. Many of the correlations indicated have not been verified

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*It is interesting to note that this pattern of the migration of the centre of gravity of a Cordilleran ice mass westward towards the oceanic source of precipitation as time elapses during a glacial period is the converse of that proposed by Flint (1957) for the Scandinavian ice sheet, fuelled by the warmer North Atlantic Drift.

by absolute dating, and the possible asynchroneity of glacial events suggested in the previous section further compounds the problem; hence, the correlations must regarded as tentative.

Table 5* constitutes an attempt at correlation of the major sequences outlined in the paper. In addition, chronological and stratigraphic sequences from Alaska and the general sequence for mid-continental North America are presented. Indicated as well is the general locality of the site upon which each of the chronologies is based. In the following discussion the glacial history of the region will be considered in terms of:

(A) The late Wisconsin and Neoglacial;

(B) The early Wisconsin;

(C) The pre-Wisconsin.

(A) THE LATE WISCONSIN AND THE NEOGLACIAL

The late Wisconsin, not surprisingly, appears to be the best understood major advance in all four major areas of the region. In area A, Muller's (1967), Denton and Stuivers' (1969) Kluane, Bostock's (1966) McConnell, and Vernon and Hughes' "last" could well be contemporary. Hughes application of the McConnell advance to much of the Yukon, barring minor problems, appears reasonably sound. In area B the late Laurentide of Hughes (1972)

*Table 5 located in pocket at back.

and the "last" (Hughes, 1972) glaciation both appear to correlate with the McConnell advance. In area C the late Laurentide of Craig (1965) and Rutter (1974) also appear to correlate with the McConnell. In area D, the Jackfish Glaciation apparently correlates with the McConnell as well (Ford, 1976). In the Central Nahanni the minor valley glacial advance along the Flat River valley may also be tentatively correlated with the McConnell.

Evidence for neoglaciation has been described in detail for area A by Muller (1967) and Denton and Stuivers (1969). Similarly authors in the other areas have discussed the evidence for neoglaciation. The extremely localized nature of the evidence for many sites however, makes correlation difficult. Such correlations will depend greatly upon more detailed chronologies supported by absolute dating. No evidence of neoglaciation was found in the Central Nahanni area.

(B) THE EARLY WISCONSIN

Evidence of a region-wide early Wisconsin glaciation is quite extensive but inconclusive. In area A, Muller's (1967) Nisling, Denton and Stuivers' (1969) Ice Field, Bostock's (1966) Reid, and Vernon and Hughes' (1966) "intermediate" glaciation may all be ascribed to an early Wisconsin advance. In sector B most writers (Prest, 1972), (Hughes, 1972), consider the area to have been subject to an early Wisconsin Laurentide advance. Hughes (1972) "intermediate" Cordilleran advance may have been correlative with this advance. The Reid, moreover, in area A, might well correlate with these advances.

In area C, evidence from several sections, numerous radiocarbon dates, and evidence from the flanks of the mountain ranges has led to the suggestion (Rutter, 1974), (Craig, 1965) of two Laurentide advances in the area. Moreover, Hughes' (1972) and Federovich's (1974) work provides evidence of two Laurentide advances followed by two large glacial lakes in area B. No evidence is present of any earlier Laurentide advance.

Terasmae (1959) has ascribed a Sangamon age to material from a section at Reindeer Depot. Overlying this material are deposits indicating two major Laurentide advances. The other sections from several locations in areas B and C tend to support such a view. If it is accepted that two major advances occurred after the Sangamon and it is known with certainty that the younger is late Wisconsin in age than it would appear that an early Wisconsin advance did occur in area C.

Area D appears somewhat of an anomaly with regards to an early Wisconsin advance. Rutter (1974), as we saw earlier, has traced the limit of late Laurentide advance into the northern portion of area D. The limit approaches 5,000 ft. (1,500 m) a.s.l. in elevation. An older, more extensive glaciation, he refers to would appear to be at the same height (5,000 ft. (1,500 m) a.s.l.). If Terasmae is correct, the older and more extensive glaciation would be early Wisconsin. In the light of this it should be expected that early Wisconsin ice might well have deposited some of the erratics on top of the Nahanni Plateau! However, Ford (1974) and (1976), working in the central portion of the region, argues that no early Wisconsin glaciation occurred.

The evidence from within the study area is inconclusive. Lake Nahanni and the second Virginia Falls are clearly of considerable age. Whether the time from the early Wisconsin to the present was sufficient for the excavation of the massive deposits of Lake Nahanni and the cutting of the gorge of the new falls through very resistant limestone is problematic. At this time all that may be said on the basis of evidence within the Central Nahanni is that Lake Nahanni is of at <u>least</u> early Wisconsin age. However, Ford (1976) provides evidence from outside the Central Nahanni suggesting that the lake is pre-Wisconsin.

With respect to the incorporation of area D within the broad regional view there would appear to be three alternatives. The first involves treating area D as a special case. The barrier mountains, it might be argued, blocked most of the ice and hence lowered the ice surface before it reached the flanks of the Mackenzie Mountains.

The second alternative involves the acceptance of Terasmae's suggestion of a Sangamon age for the Reindeer deposits and hence the occurrence of an early Wisconsin glaciation which did penetrate area D. This would imply that Lake Nahanni is early Wisconsin in age.

The second alternative is to put aside Terasmae's Sangamon age for the Reindeer Depot deposits. Moreover, this involves the postulate that the deposits beyond the late Wisconsin Laurentide advance limits are not early Wisconsin but pre-Wisconsin in age. This would mean that all the more extensive deposits are pre-Wisconsin and that no early Wisconsin Laurentide advance occurred in either areas C or D. In such a situation Lake Nahanni would be considered pre-Wisconsin in age.

Consideration of the above is imperative. If Ford's chronology is correct then the entire interpretation of the early Wisconsin period may well require adjustment. If there was a major early Wisconsin Laurentide advance then the chronology for area D will require some revision.

(C) THE PRE-WISCONSIN

As Table 5 indicates, evidence of pre-Wisconsin glaciation within the Yukon - Western District of Mackenzie Region is extremely limited. Several authors working within the region have suggested major glaciations pre-dating the early Wisconsin: Bostock's (1966) Nansen and Klaza; Denton and Stuivers' (1969) Shakwak Glaciation; Vernon and Hughes' (1966) "older" glaciation; and Hughes' (1969), (1972) Pre-Reid and "old" glaciations are all considered as pre-Wisconsin. But they all lack absolute chronologies to support them. Only the presence of a till under lava in area A (Prest, 1972) and the use of uranium dating by Ford (1973) in area D have provided absolute dates to verify the occurrence of pre-Wisconsin glaciations within the region.

In the case of the till under the lava the dating of the lava clearly indicates that a pre-Wisconsin glaciation occurred in the area but can provide no indication of precisely when. Ford's work (1972), (1975), (1976) in area D however, not only indicates the presence of pre-Wisconsin glaciation in the area but also suggests the actual times of occurrence. The use of uranium dating of stalagmite and stalactite deposits enables him to suggest that a major Cordilleran glaciation greater than 350,000 B.P., and tentatively correlated with the Illinoian, as well as a major Laurentide and a second Cordilleran glaciation, correlated with the Kansen have occurred in area D.

In addition, considerable support for earlier region-wide glaciations is provided by the work outside the region, particularly in Alaska (see Figure 37). Denton and Armstrong's (1969) White River study is of special interest. Besides a till deposited during the late Wisconsin they have found three other tills at least two of which are greater than 47,000 B.P. Moreover, below the four tills they have found at least twelve tillites, one of which has been dated at 3.7 m.y. and at least two date from between 8.8 and 2.7 m.y. In all they have found evidence for at least sixteen major glacial advances during the last ten million years.

As is clear in Figure 37 correlation of Ford's chronology with those of Bostock (1966), Denton and Stuivers' (1969), Vernon and Hughes (1966), and Hughes' (1969), (1972), although clearly speculative, is possible. In such a scheme the Nansen would correspond to the First Canyon Glaciation, while the Klaza would be correlated with the Flat River and Clausen Glaciations. The Shakwak Glaciation, and Vernon and Hughes (1966) "older", Hughes (1969), (1972) Pre-Reid and "old" glaciations, although they would clearly be considered to be pre-Wisconsin, could not be ascribed to any one glaciation.

The evidence from within the study area indicates a major plateau glaciation which correlates with the First Canyon Glaciation. The major valley glaciation, younger in age than the plateau glaciation, would appear to be the Flat River Glaciation. If this is the case then Lake Caribou, which is clearly pre-Wisconsin in age, cannot be older than the Flat River Glaciation. If Lake Nahanni is also pre-Wisconsin as Ford (1976) suggested then both lakes are from this period. Moreover, there must have been a considerable time span between the existence of the two lakes.

Closer study of, and correlation with the Alaskan chronologies, particularly Denton and Armstrong's White River work (1969), with information from within the region, especially Ford's work, should prove fruitful.

CONCLUSIONS

The complex nature of glacial history in the Yukon - Western District of Mackenzie, in conjunction with the extremely limited amount of data in general and ground truth in particular, has severely limited our understanding of many of the features and the sequence of glacial events in the region. In this thesis an effort has been made to: (a) bring together and correlate information in the literature and; (b) study one specific area and map its geomorphic features in an effort to provide at least a general indication of the major events in the glacial history of the region. While broad generalizations are inherently dangerous the following conclusions, applicable to the problem of regional glacial history, do appear to be reasonably well substantiated by the present evidence:

(1) There is scattered evidence for a neoglaciation.

(2) There is extensive evidence of a late Wisconsin glaciation within much of the region.

(3) There is good evidence for at least two Laurentide advances in the eastern part of the region. One of these was clearly late Wisconsin in age.

(4) There is some evidence in the western and northern parts of the region for an early Wisconsin advance but no clear evidence in the south-eastern portion (area D).

(5) There is evidence for at least two major pre-Wisconsin glaciations in the region.

Within the study area of Central Nahanni Park certain conclusions also appear possible:

(1) There does not appear to be any evidence of neo-glaciation.

(2) The existence of Lake Nahanni, initially suggested on the basis of field work in 1973 may be considered confirmed. The lake, an ancient proglacial lake at <u>least</u> early Wisconsin and quite possibly pre-Wisconsin in age was at or above 2,000 ft. (610 m) a.s.l. and was sufficiently long-lived to deposit upwards of 500 ft. (150 m) of buff coloured silts and was of sufficient depth to leave scattered evidence of varving.

(3) The existence of a second and older proglacial lake, herein named Lake Caribou is indicated. This lake, of pre-Wisconsin age was at <u>least</u> as extensive as Lake Nahanni. It deposited great quantities of dark grey silts and was deep enough to deposit varve and rhythmite sequences.

(4) There is a considerable span of time between the occurrence of the two lakes.

(5) There is evidence of two pre-Wisconsin glaciations in the study area as indicated by the Flat River

valley glaciation and the occurrence of even an earlier plateau glaciation.

In addition to the above sets of conclusions three aspects of the glacial history of the region would appear to merit special consideration. The first might best be described as the "water problem". While almost all glaciated areas have undergone severe drainage alteration as a consequence of glacial activity, the Yukon - Western District of Mackenzie is somewhat exceptional in this regard. The presence of three potential ice sources acting in such a highly varied terrain has not only played havoc with the drainage patterns but also has made the question of meltwater routing a prime consideration in any study. Perhaps as much as 50-60% of the entire region was at some time covered by a glacial or proglacial lake. Moreover, as Prest has pointed out (personal communication), the problem of meltwater routes is central to the problem of ascertaining ice front locations.

The problem is further compounded by the question of the climatic alteration within the region produced by the advance of Laurentide ice from the east. The possibility that advancing Laurentide ice may have induced the starvation of the Cordilleran ice would appear to merit further study.

Finally, and perhaps most intriguing of all, is the possibility that not merely two but perhaps even more pre-Wisconsin glaciations have affected the area and that these glaciations may be capable of being accurately dated. Ford's uranium dating in the Nahanni and radiocarbon and palynological studies in other areas of the region, in conjunction with Alaskan studies such as Denton and Stuiver's and the marine transgression studies, might conceivably form the basis for the development of a glacial chronology reaching back farther than any in Canada and perhaps North America.

Aside from its intrinsic value, then, the study of the glacial history of the Yukon - Western District of Mackenzie and, in particular, areas such as the Central Nahanni Park area, could potentially provide accurate dating of major glacial events which affected not only northwestern Canada but all of North America. Needless to say, much work will be necessary if that potential is to be realized. Towards that end pollen analysis and efforts to obtain carbon-14 dates on the material extracted from the Central Nahanni lake silts is currently being undertaken.

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APPENDIX I

RESULTS OF GRAIN SIZE ANALYSIS

Contained in this appendix are the cumulative curves and histograms for the sediment samples. It should be noted that the curves and histograms for samples #2, #9, #15, #16, #20, #21, #22, which are presented in the text are not included here. The results from all the remaining samples however, have been included.

Cumulative Curve and Histogram

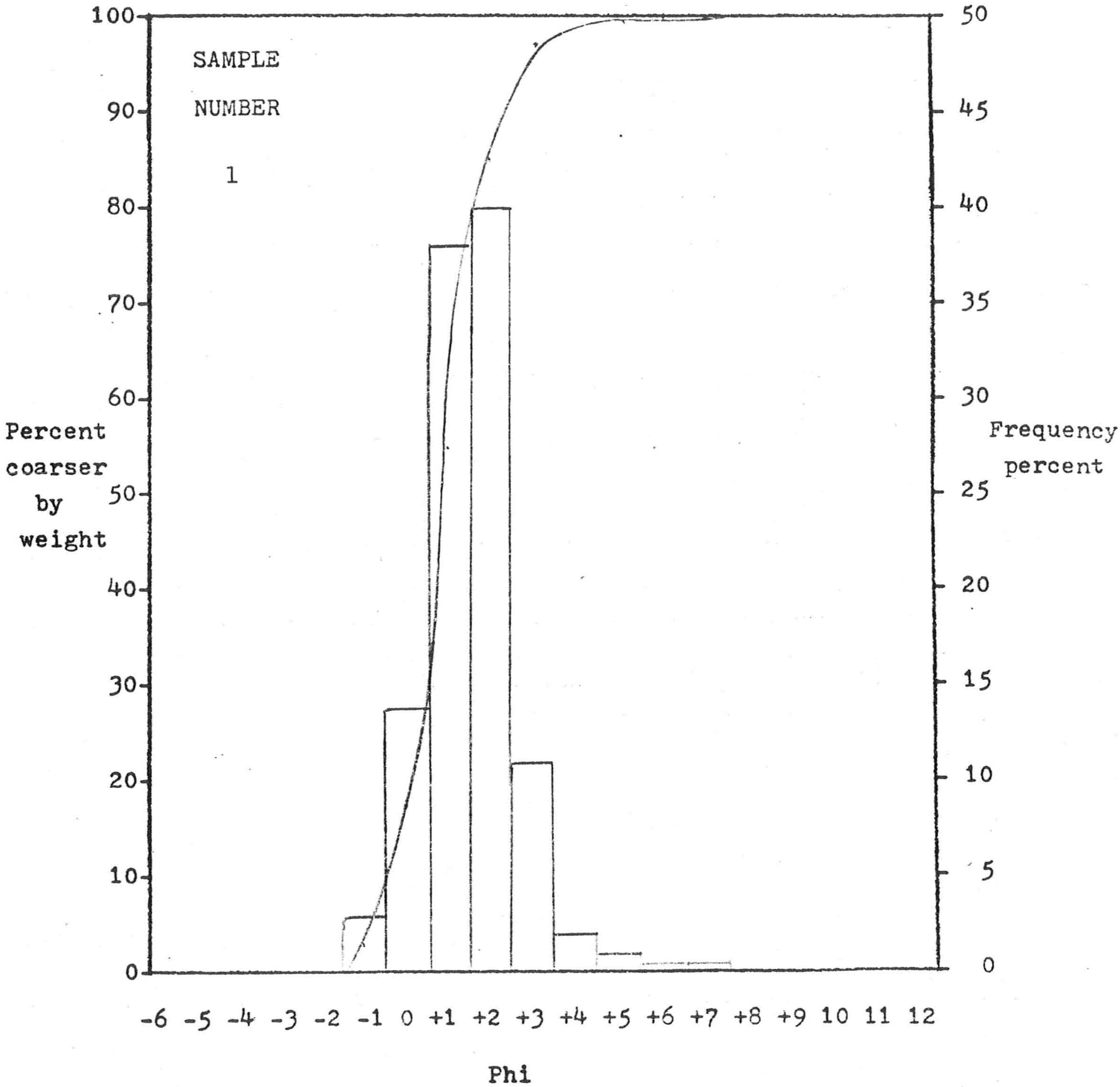

Figure 52.

Cumulative Curve and Histogram

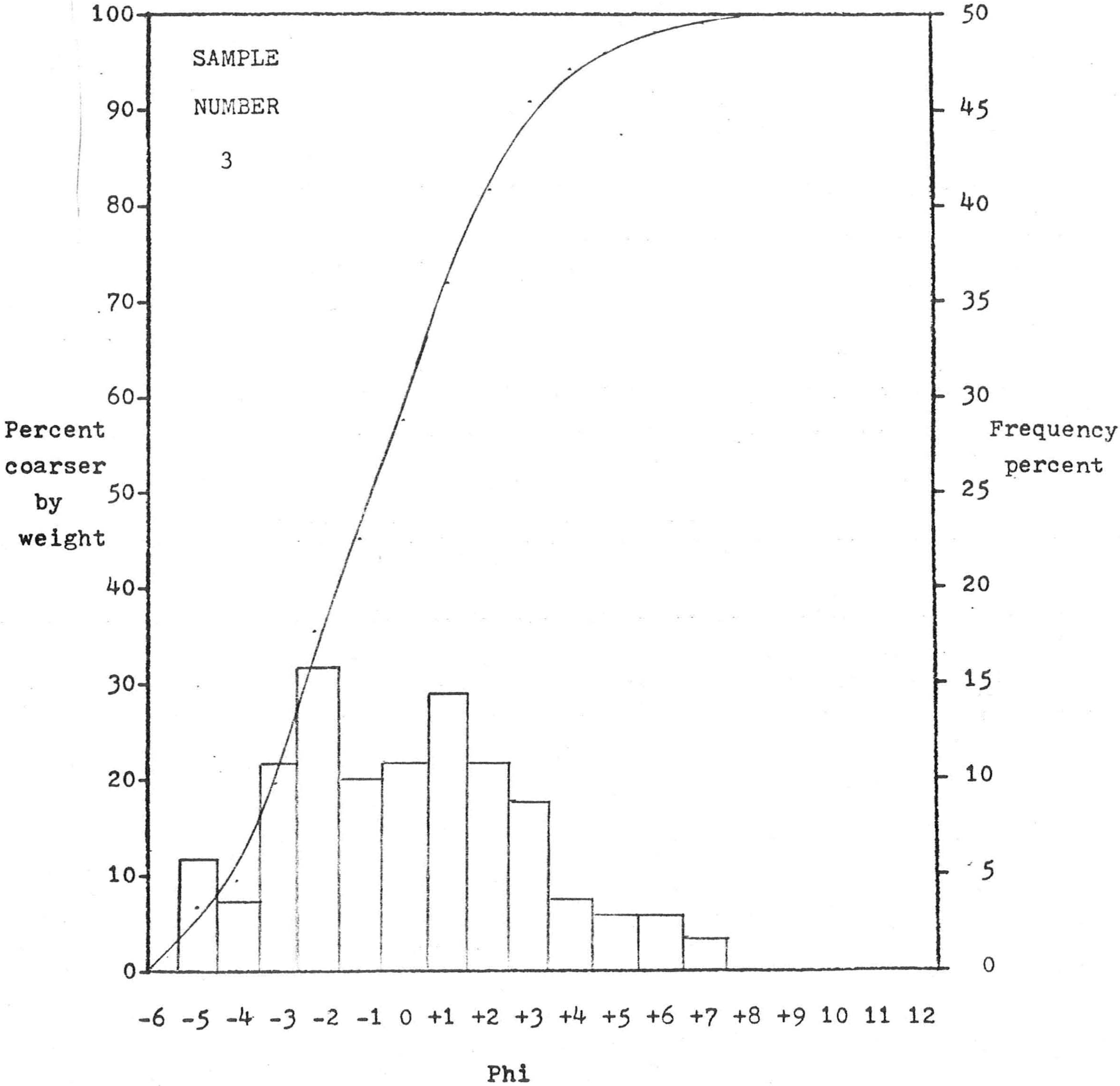

Figure 53.

Cumulative Curve and Histogram

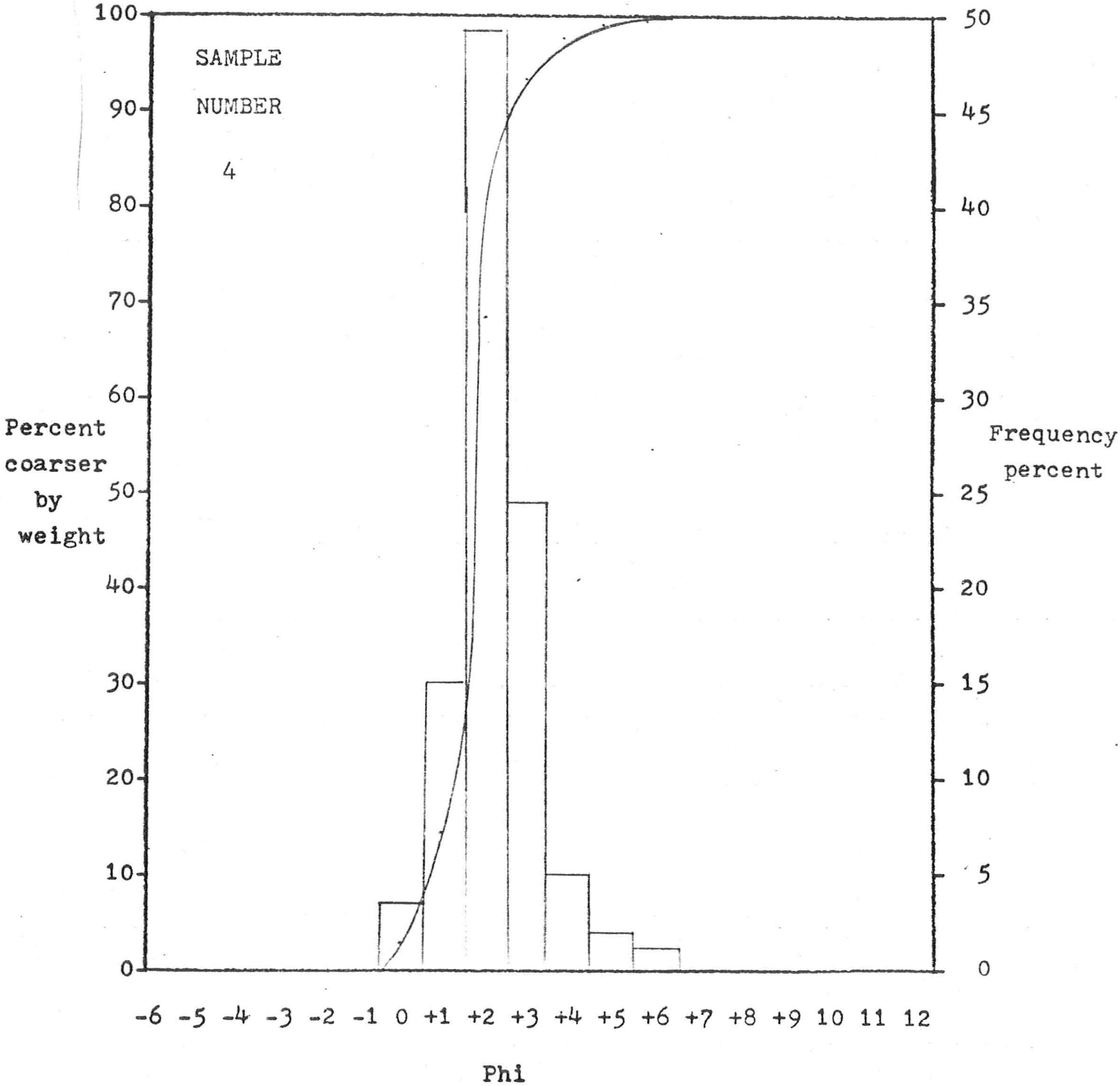

Figure 54.

Cumulative Curve and Histogram

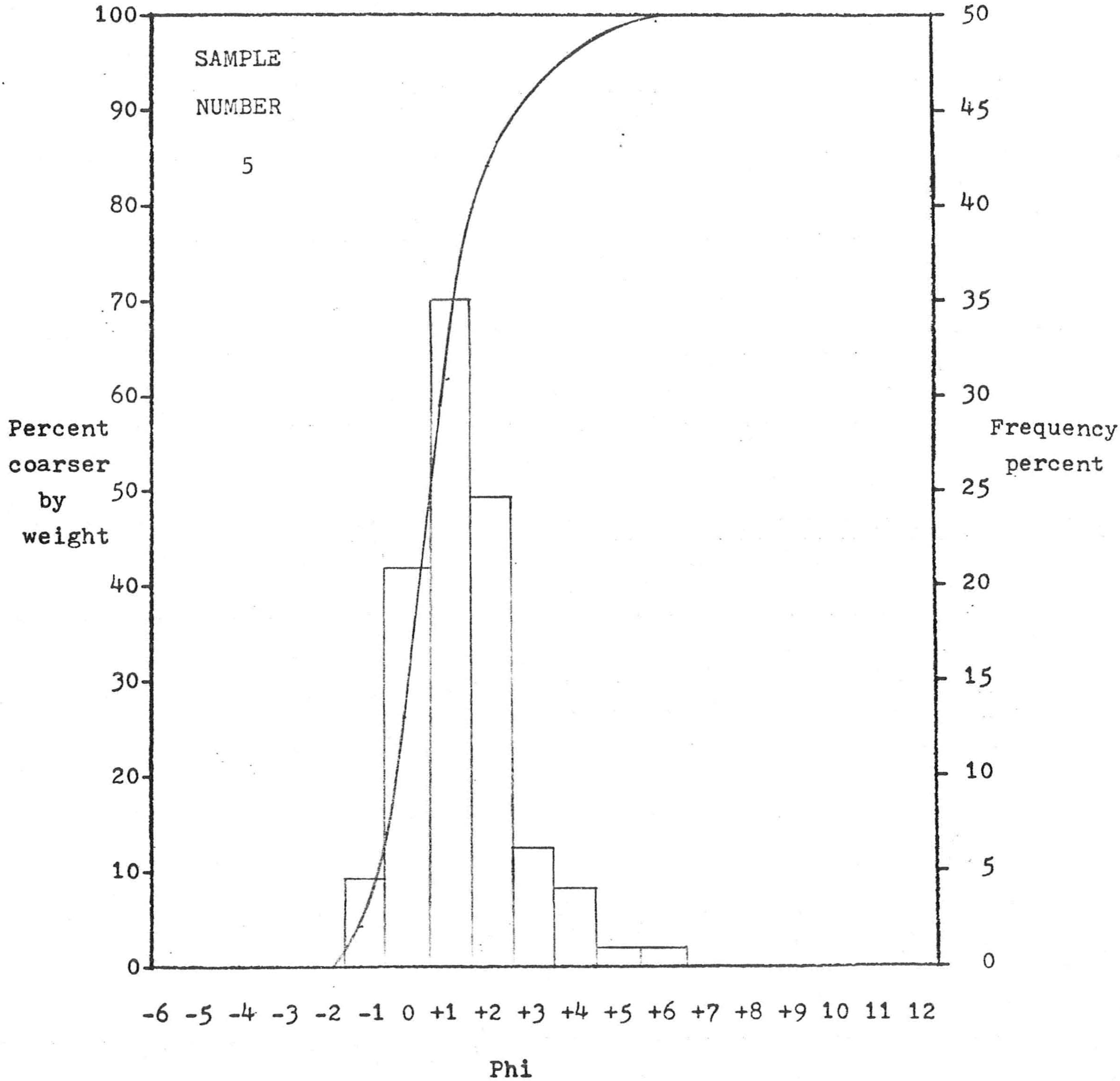

Figure 55.

Cumulative Curve and Histogram

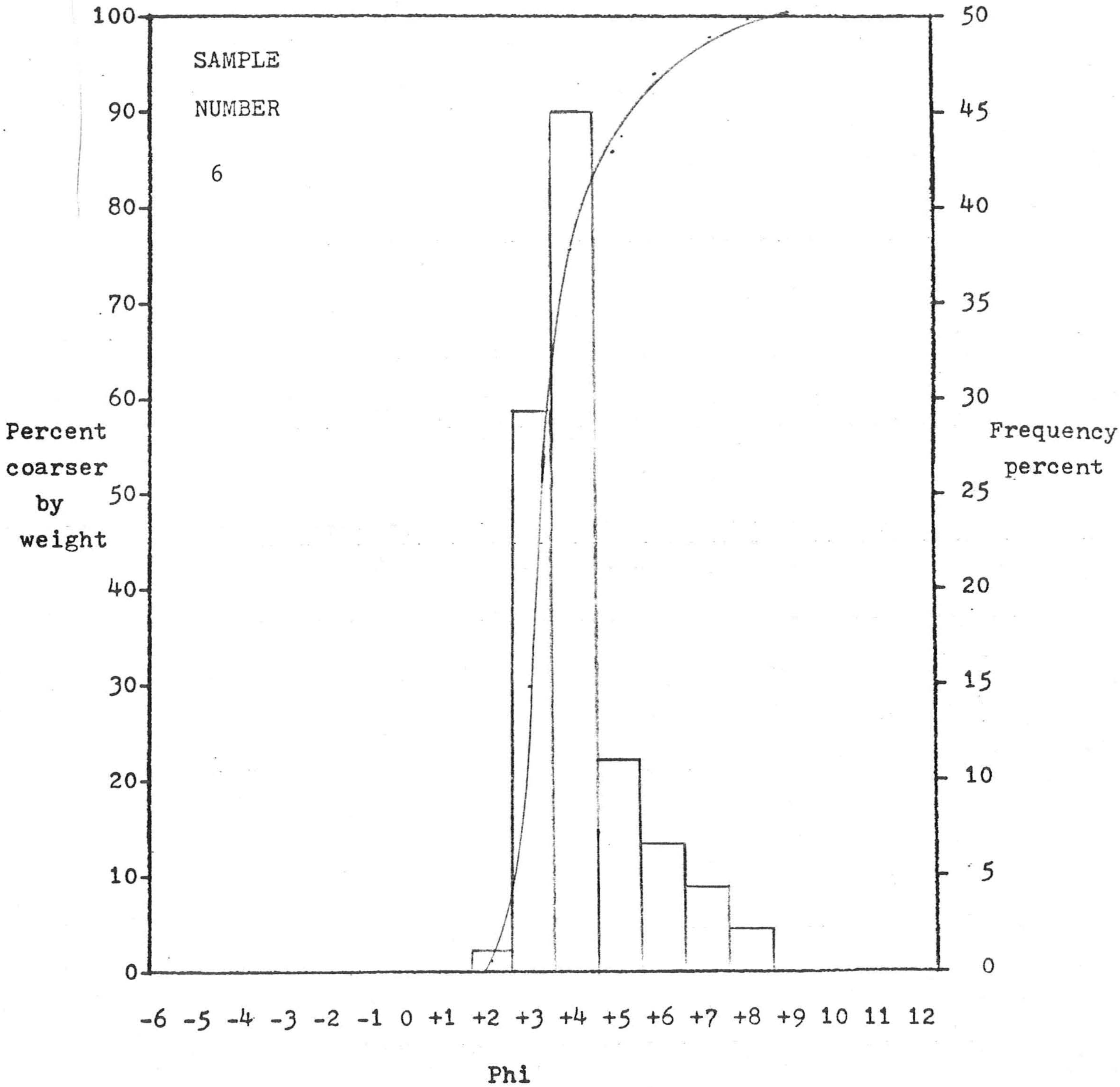

Figure 56.

Cumulative Curve and Histogram

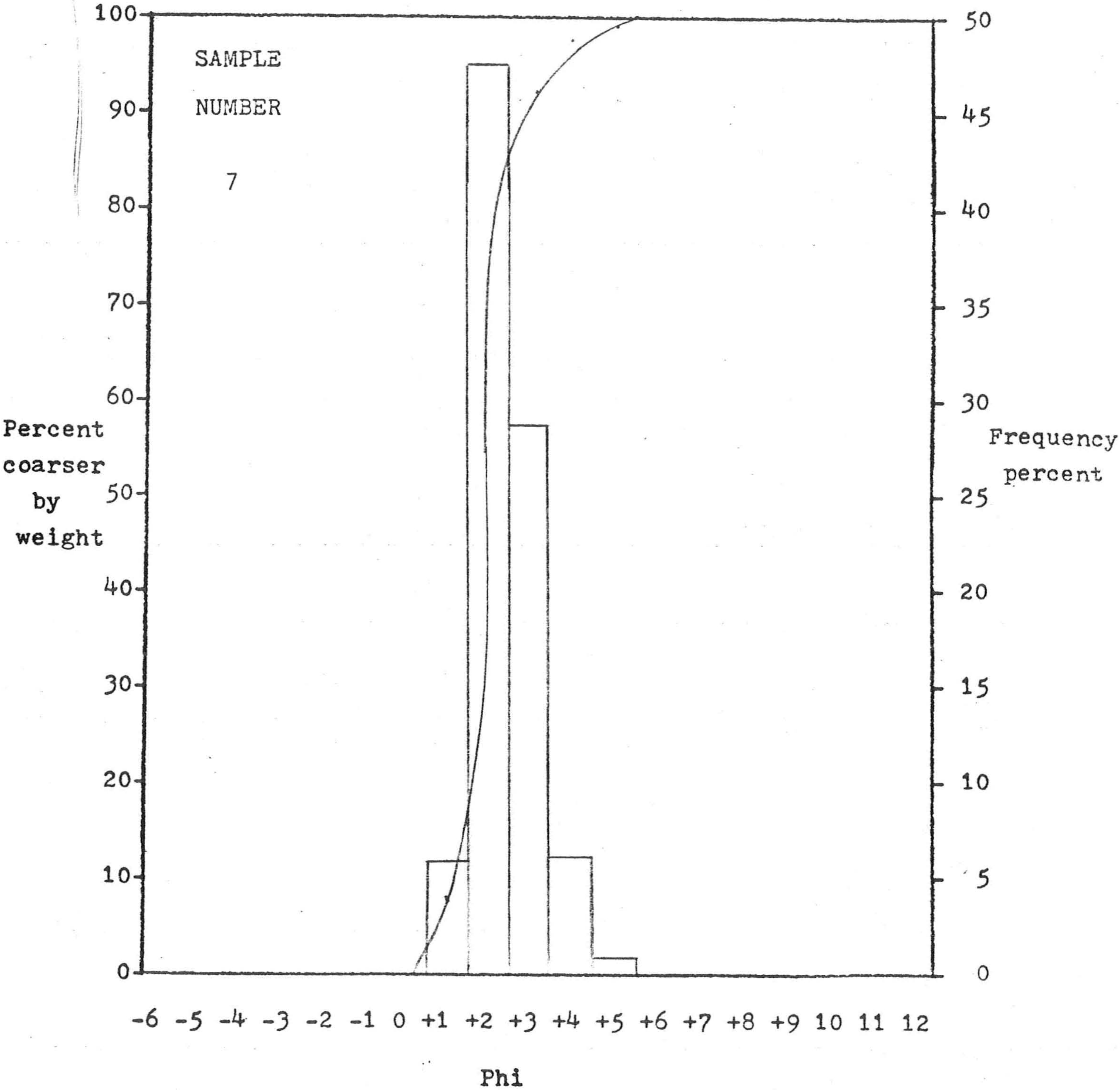

Figure 57.

Cumulative Curve and Histogram

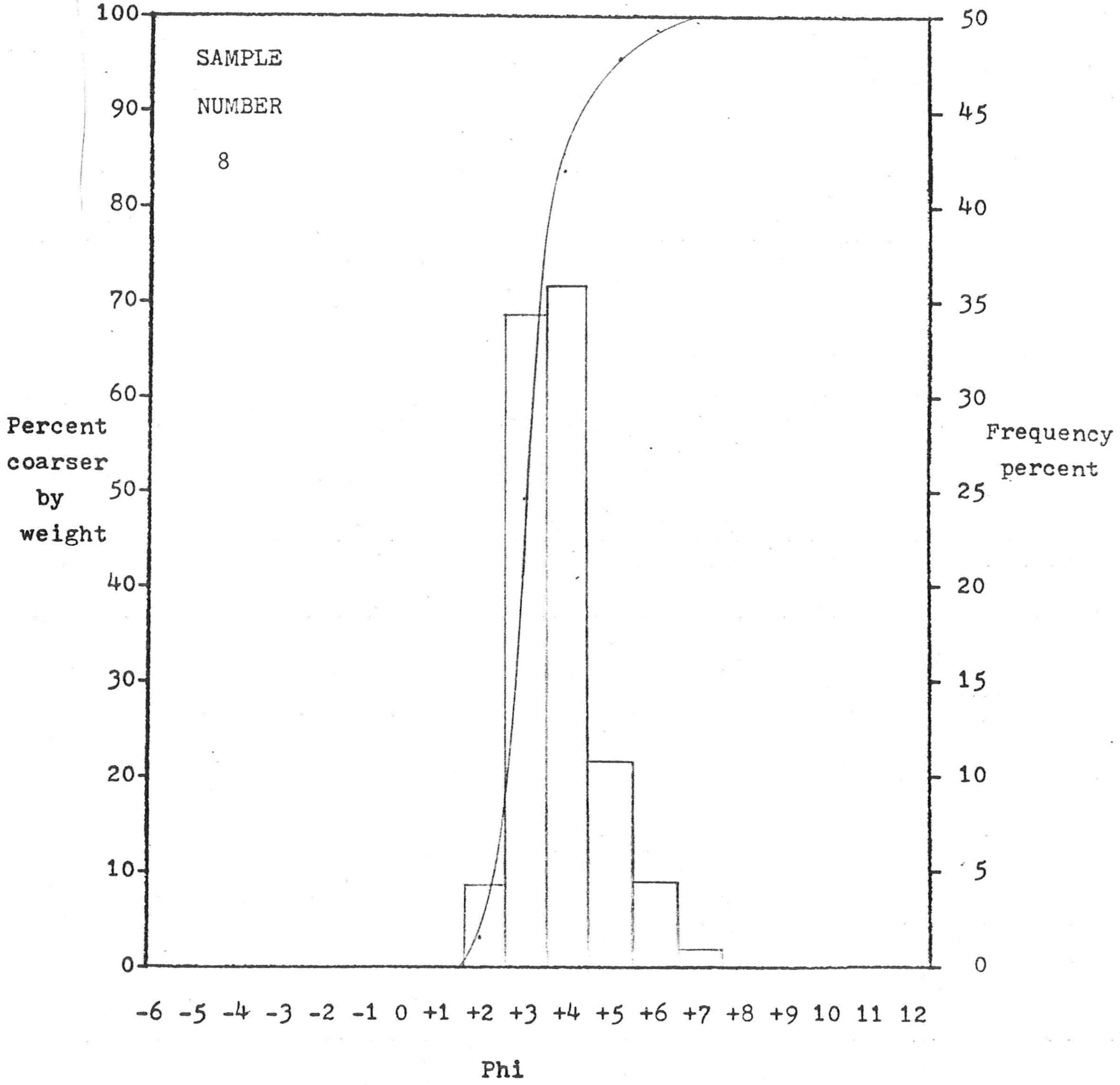

Figure 58.

Cumulative Curve and Histogram

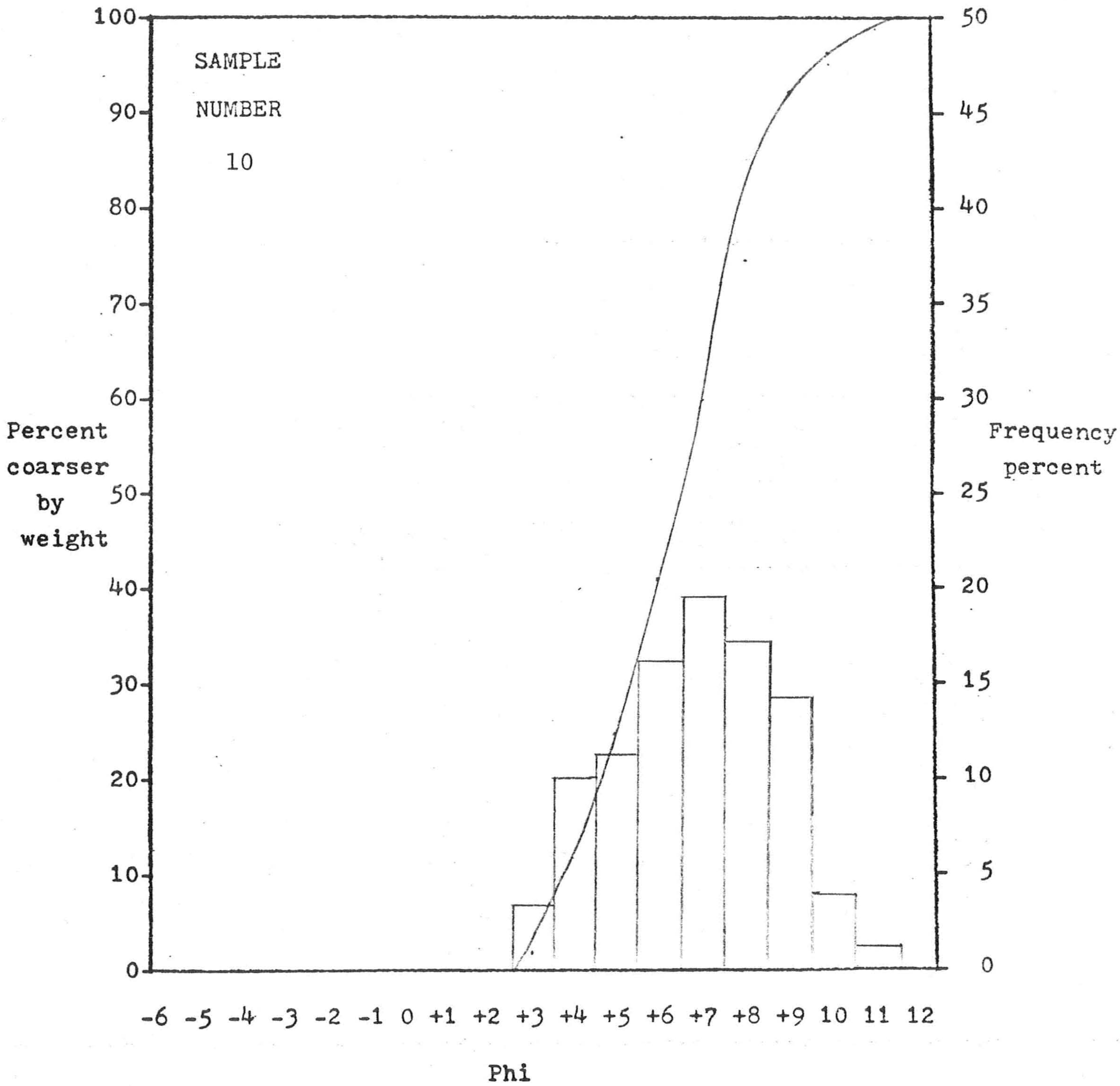

Figure 59.

Cumulative Curve and Histogram

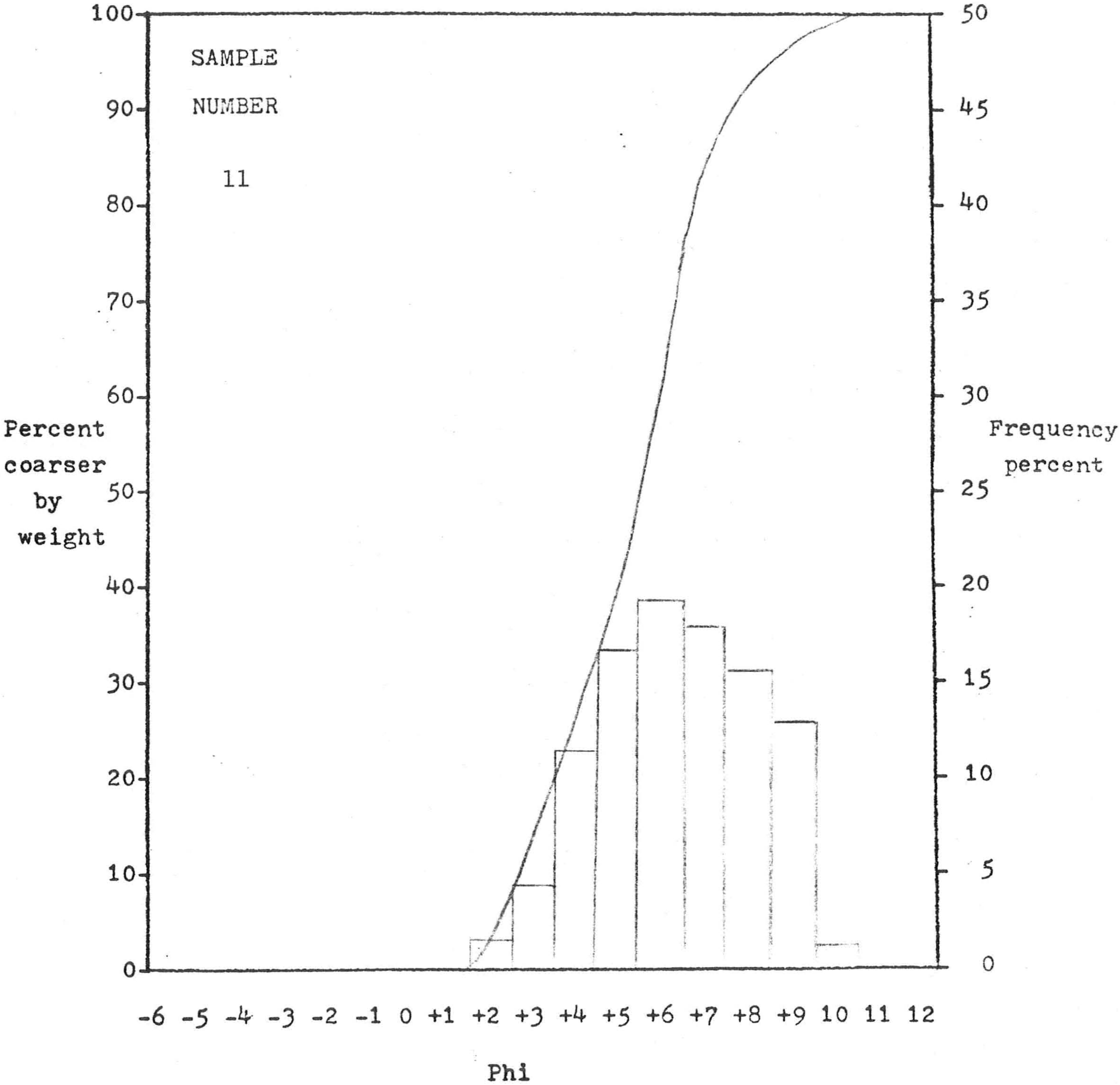

Figure 60.

Cumulative Curve and Histogram

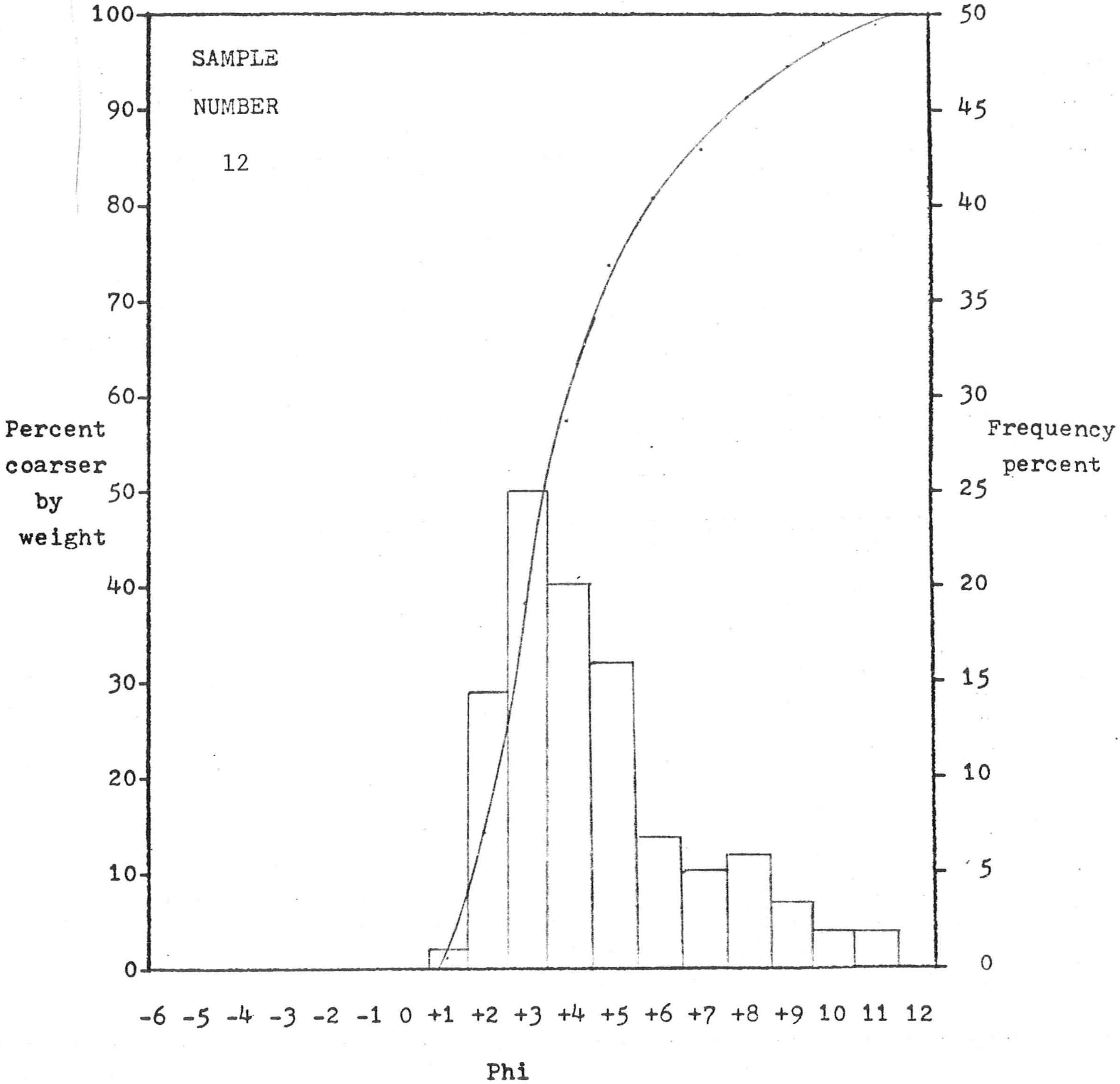

Figure 61.

Cumulative Curve and Histogram

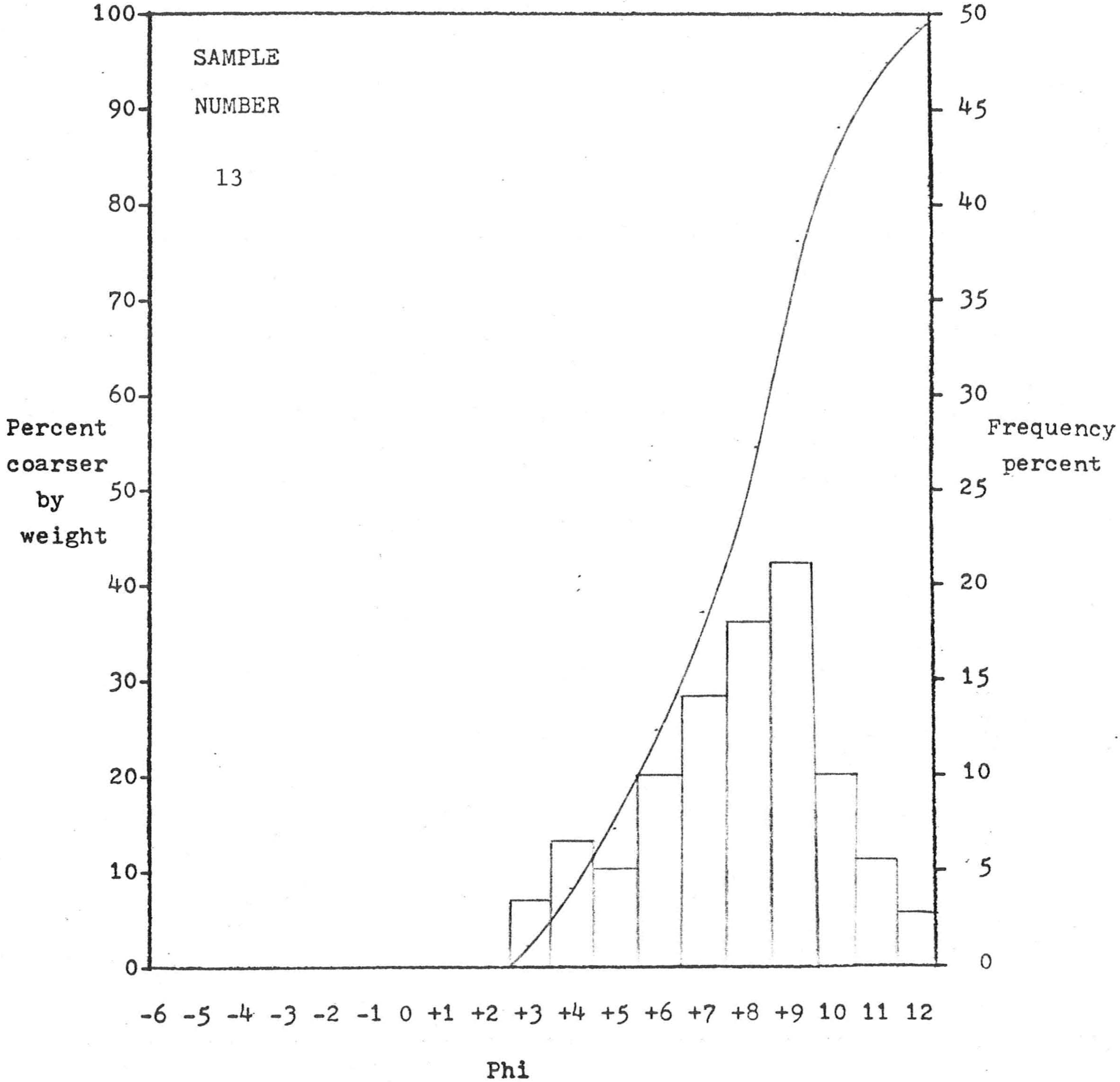

Figure 62.

Cumulative Curve and Histogram

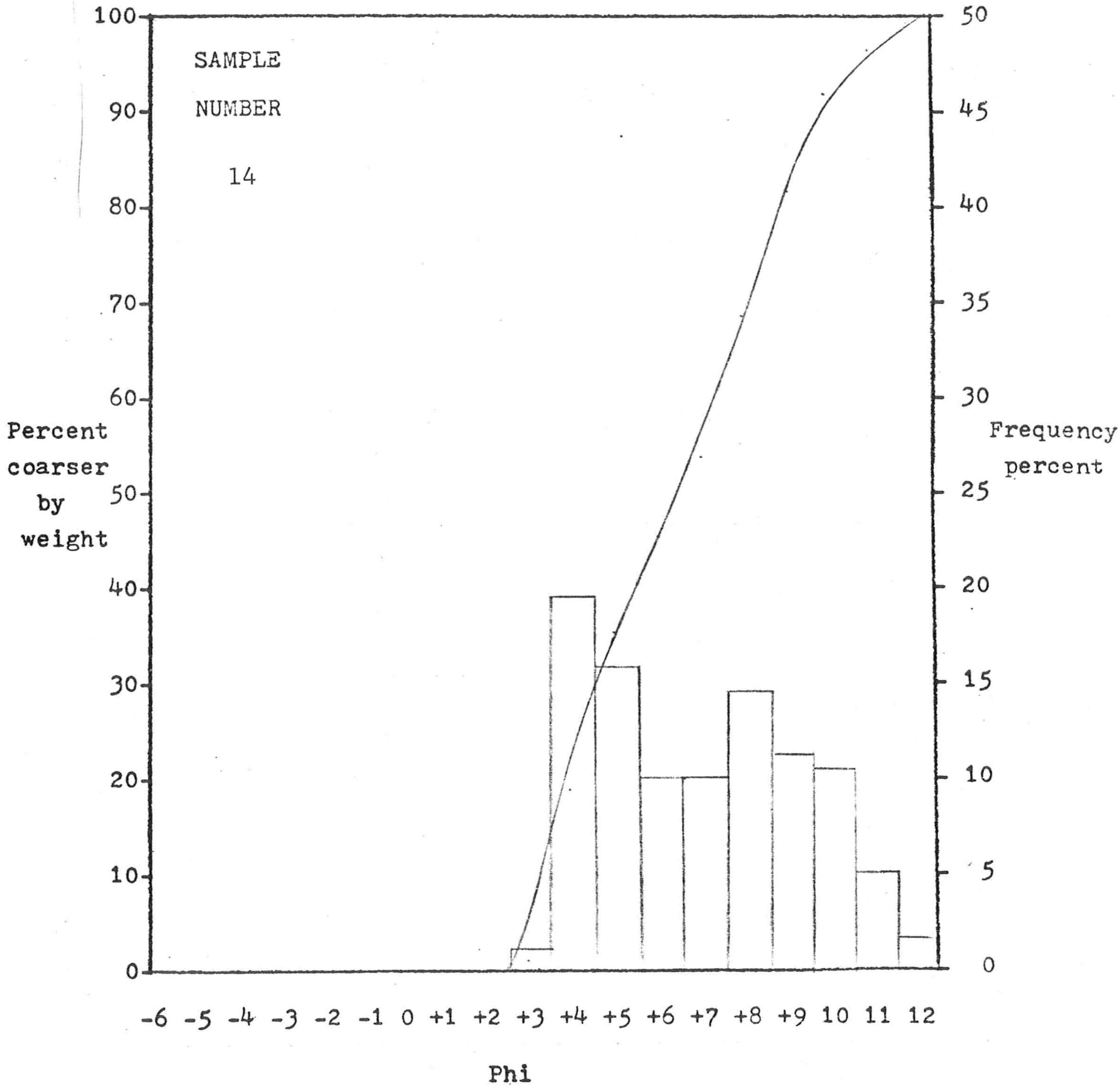

Figure 63.

Cumulative Curve and Histogram

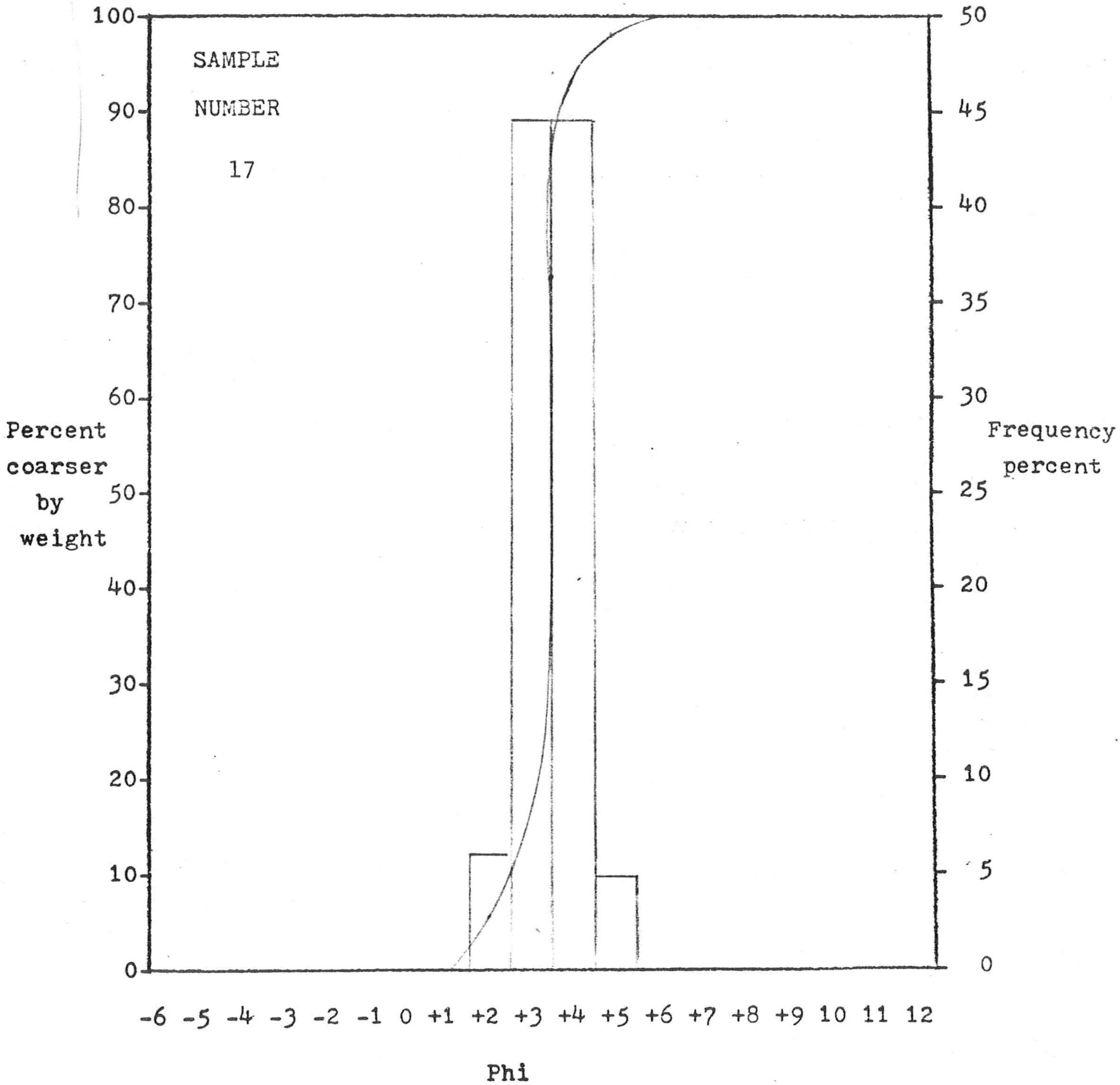

Figure 64.

Cumulative Curve and Histogram

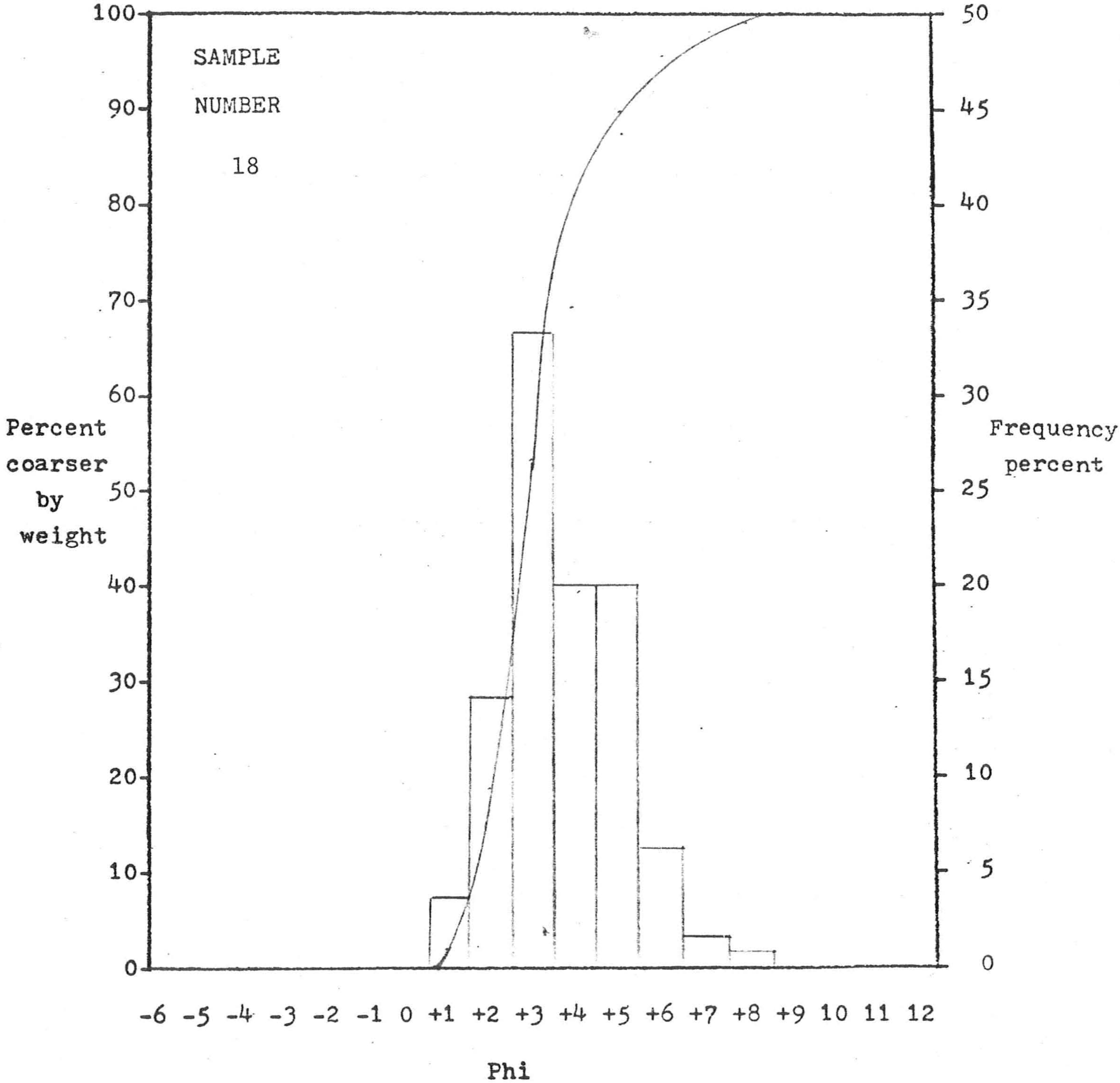

Figure 65.

Cumulative Curve and Histogram

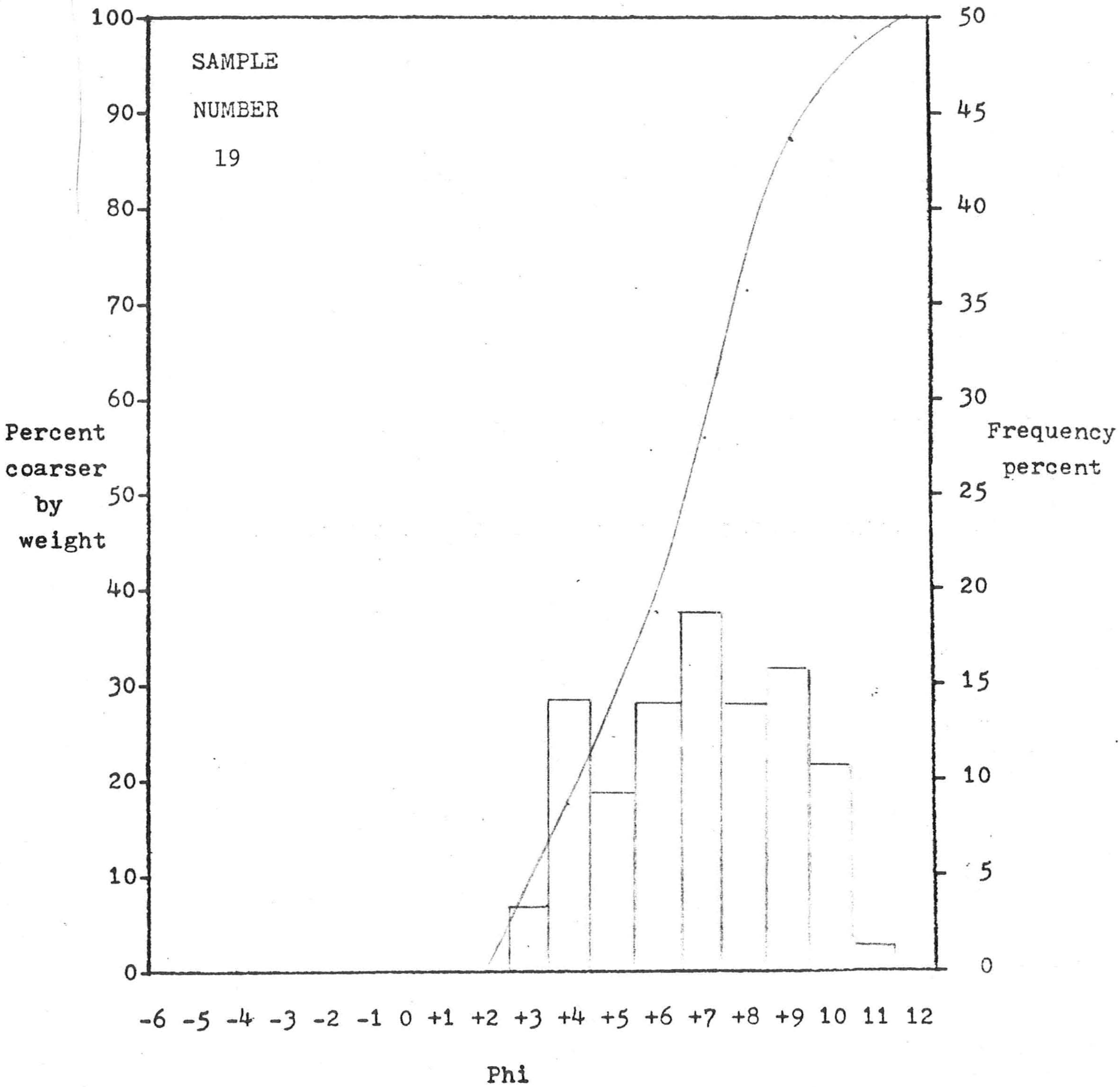

Figure 66.

Cumulative Curve and Histogram

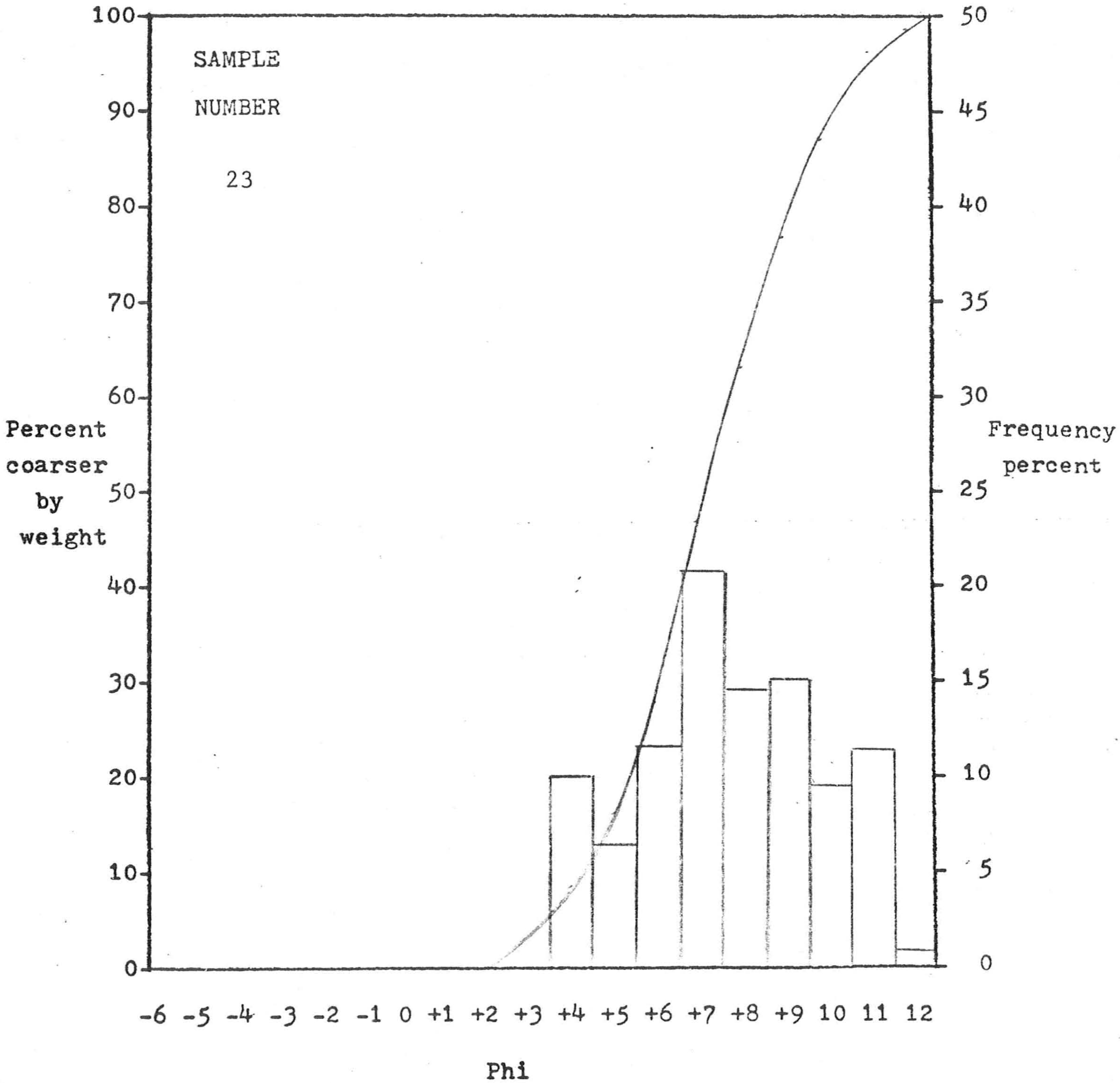

Figure 67.

Cumulative Curve and Histogram

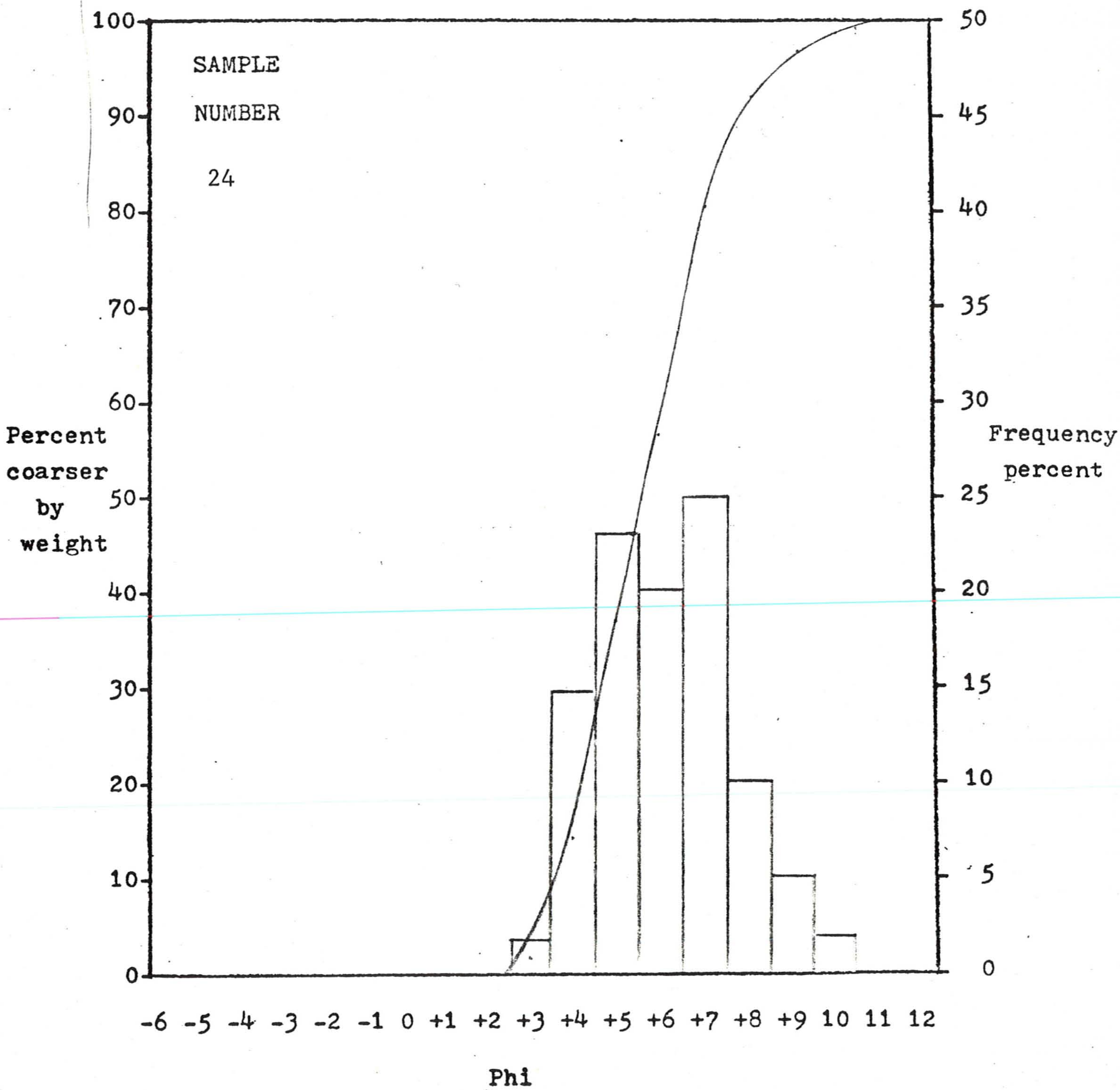

Figure 68.

Cumulative Curve and Histogram

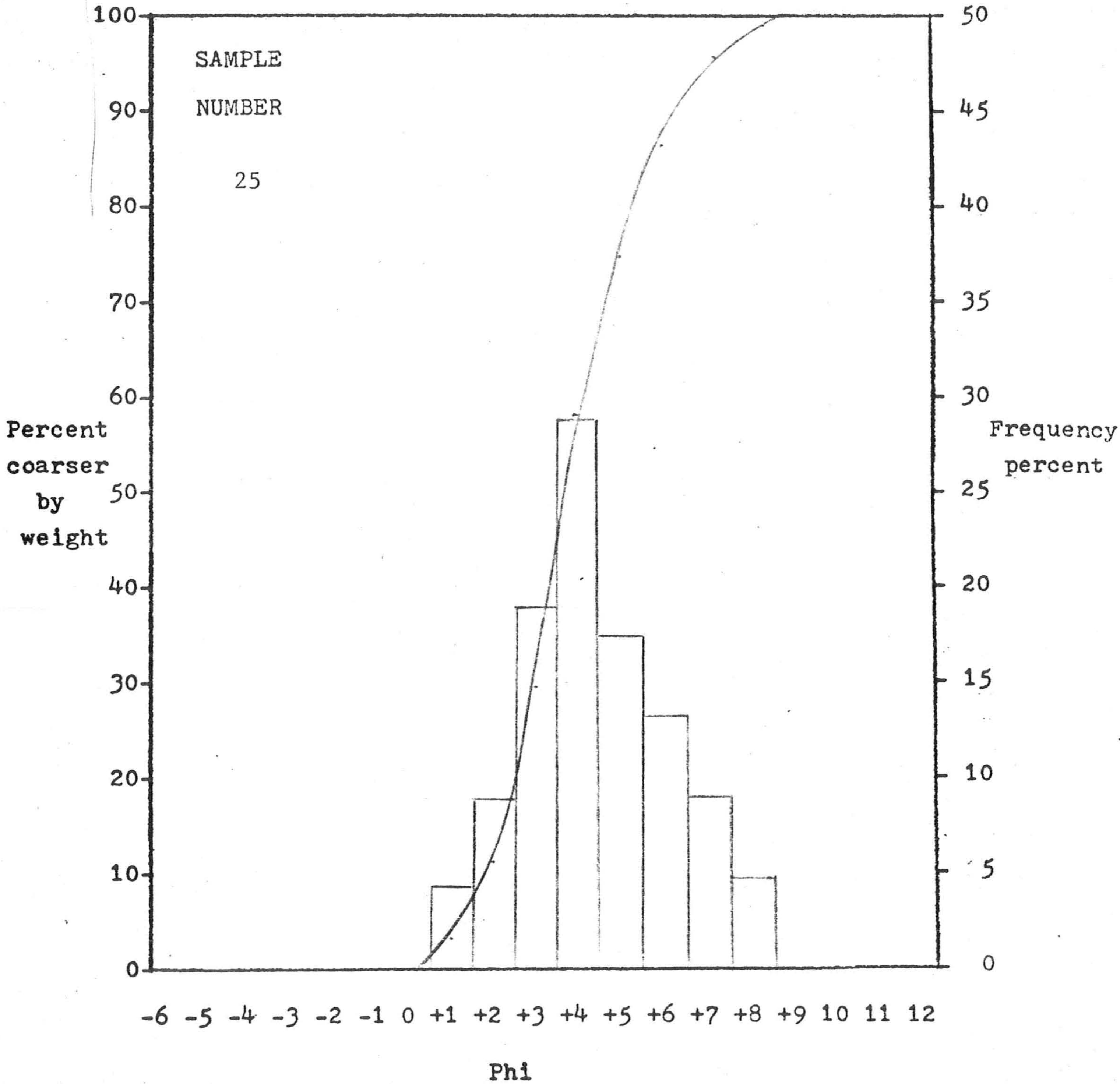

Figure 69.

Cumulative Curve and Histogram

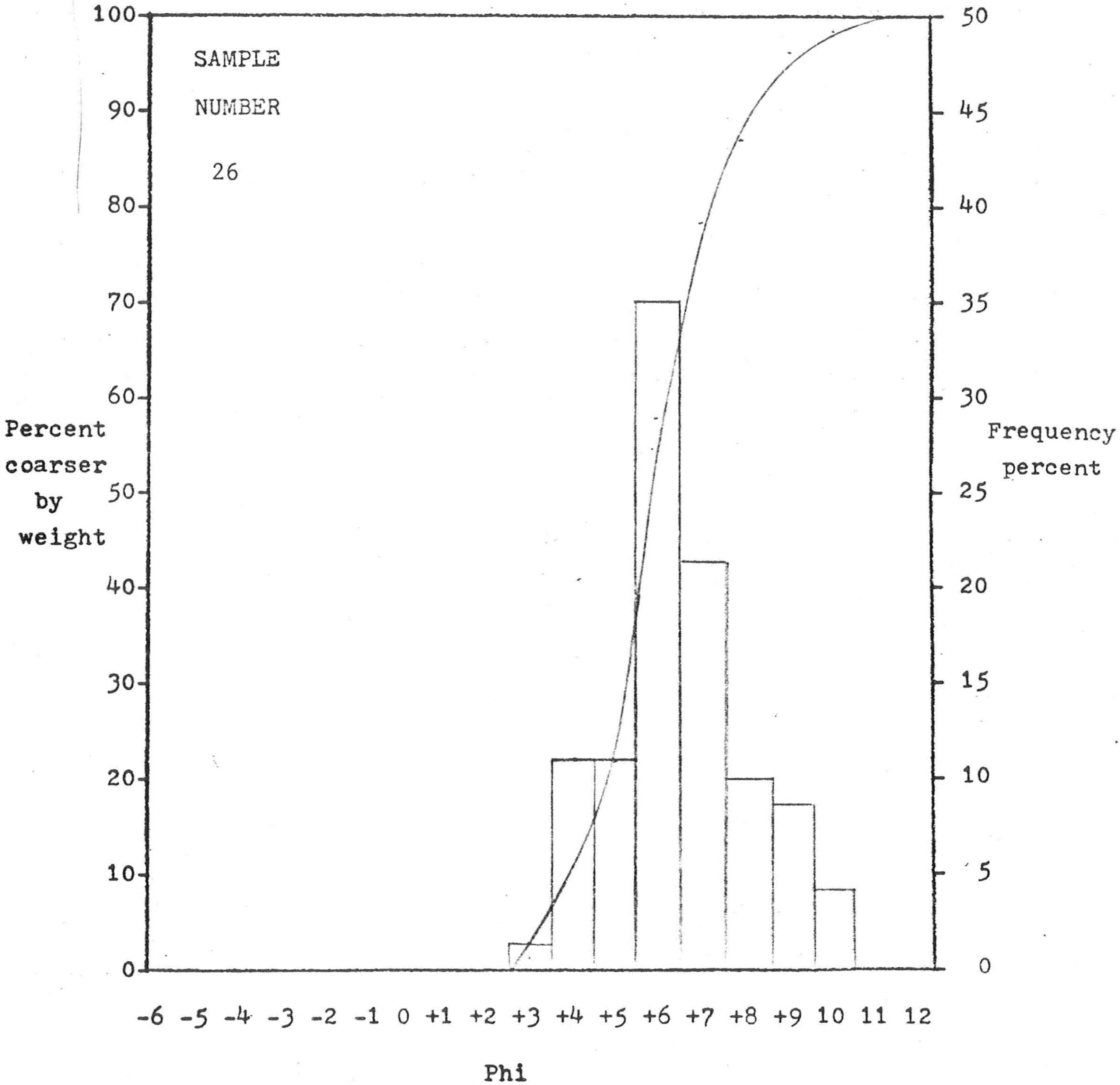

Figure 70.

APPENDIX II

RADIOCARBON DATES IN THE REGION

Collected here is a listing of published radiocarbon dates for the region.* The only exclusion has been certain dates less than 4,000 B.P. which, while archaeologically useful, do not appear significant from a glacial history viewpoint.

The dates are ordered first by laboratory with the laboratories being listed in alphabetical order and then secondly, within each laboratory's list by number (lowest to highest) and hence approximately earliest to most recently published. This method appears to provide the most rapid access. Moreover, the location, age of sample, and other pertinent information is provided after each identifying number.

*From differing issues of Radiocarbon, Am. J. Sci.(supplement).

GSC I

GSC-10. Kellett River, Banks Island **6940 ± 110**

Peat 2-ft below the ground in the wall of a gully 4 mi N of Kellett River, Banks Island, District of Franklin (71° 56′ N Lat, 123° 13′ W Long). Sample is from the upper part of an 8-ft sec. of pond and bog sediments in a shallow depression in the upland adjoining the river valley. Coll. 1960 by J. G. Fyles. *Comment*: on the basis of this date and of I(GSC)-197 (9820 ± 220, Isotopes II), from base of peat section at the same locality, peat has accumulated at ca. 2 ft/1000 yr.

GSC I

GSC-12. Northern Banks Island **5730 ± 100**

Organic silt from a depth of 8 ft in the wall of a gully 8 mi W of Castel Bay and 8 mi S of N coast of Banks Island, District of Franklin (74° 16′ N Lat, 123° 05′ W Long). Sample from near the base of peaty colluvium, ca. 10-ft thick, flooring a small valley cut into an extensive gravel outwash, alt ca. 200 ft. Coll. 1960 by J. G. Fyles. *Comment*: although definite evidence of recent marine submergence has not been found in this part of Banks Island, the gravel terrace may possibly relate to a shoreline at alt 150 to 200 ft. The date relates to a later time, subsequent to dissection of the terrace. NaOH-leach was omitted from sample pretreatment.

GSC I

GSC-16. Eskimo Lakes, Northwest Territories **7400 ± 200**

Wood from 6 in. above base of bog deposit, 7.5-ft thick, exposed in bank of a channel between "fingers" of the Eskimo Lakes, E of the mouth of Mackenzie River, District of Mackenzie (69° 12′ N Lat, 132° 27′ W Long). The deposit overlies organic-rich lake-bottom sand in a tundra area. The sample site, at alt ca. 5 ft, has stood above sealevel at least during accumulation of the deposit. Coll. 1960 by J. Ross Mackay; subm. by Geog. Branch, Dept of Mines and Tech. Surveys, Ottawa. *Comment*: on the basis of this date, peat has accumulated at ca. 1 ft/1000 yr. subject to the assumptions noted above for GSC-25. Sample received no chemical pretreatment.

GSC I

GSC-25. Inuvik, Northwest Territories **8200 ± 300**

Wood from base of bog deposit, 12-ft thick, exposed on shore of Twin Lakes, 0.3 mi NW of Inuvik, District of Mackenzie (68° 21′ 50″ N Lat, 133° 41′ 10″ W Long). Sample site, at alt ca. 20 ft, has stood above sealevel at least during accumulation of the bog deposit. Coll. 1960 by J. Ross Mackay, Univ. of British Columbia; subm. by Geog. Branch, Dept. of Mines and Tech. Surveys, Ottawa. *Comment*: on the basis of this date, peat has accumulated at ca. 1.5 ft/1000 yr. assuming that the exposed peat face represents the true thickness of the deposit, and that accumulation at the top of the section has not been retarded appreciably adjacent to the encroaching bank. The site is approximately at the tree line.

GSC I

GSC-29. Inuvik, Northwest Territories **>39,000**

Wood from sand and gravel, containing much ground ice, ca. 36 ft below the original surface, in gravel pit ca. 1 mi E of Inuvik, District of Mackenzie (68° 21′ 20″ N Lat, 133° 41′ 10″ W Long). Site lies within the area of a delta-kame complex at the mouth of an abandoned channel apparently eroded by a W-flowing stream during the last deglaciation of the region. Coll. 1960 by J. Ross Mackay, Univ. of British Columbia; subm. by the Geog. Branch, Dept. Mines and Tech. Surveys, Ottawa, Canada. *Comment:* sample was dated to gain information about the age of retreat of the last (late Pleistocene, probably classical Wisconsin) ice sheet from the area. In view of the infinite date, the wood is now thought to be older than the delta. Sample was counted once at a reduced pressure of 125 cm and once mixed with 23.0% of coal gas. Net corrected counting rates: −0.049 ± .041 counts/min and +0.066 ± .031 counts/min respectively. The negative value may be misleading since no background count at similarly reduced pressure was carried out. Ignoring the negative count would give an age of >37,000 yr instead of the quoted value of >39,000 yr.

GSC II

GSC-34. Nicholson Peninsula **>35,230**

Wood collected 20 ft below top of 120-ft sea cliff at N end of Nichol[illegible] Peninsula, Dist. of Mackenzie, Northwest Territories (69° 53′ N Lat, 128° [illegible] W Long). Sample from deformed sand containing numerous flattened logs [illegible] to 5 in. in diam. Shells of *Yoldia arctica* (id. by F. J. E. Wagner) are prese[illegible] in underlying clay, and fragments of mammoth (?) tusk apparently wash[illegible] out of the cliff are present on the beach. The wood-bearing strata are believ[illegible] to have been deformed by glacial ice thrust (Mackay, 1956) and therefore [illegible] be older than the last glacial invasion of the region. Coll. 1960 by J. R[illegible] Mackay, Univ. of British Columbia; subm. by the Geog. Br., Dept. of Mi[illegible] and Tech. Surveys, Ottawa, Canada.

GSC – [illegible]

GSC-50. North Fork Pass, Yukon **7510 ± 100**

Gyttja from lowermost 2 in. of a bog deposit occupying a depression in an arcuate terminal moraine in North Fork Pass at head of North Klondike River, Ogilvie Mountains, Yukon Territory (64° 34′ N Lat, 138° 15′ W Long). Sample collected with a ship's auger 5 ft below ground. The moraine marks the limit of the restricted latest advance of valley glaciers in the region, separated from an earlier more extensive glaciation by a considerable interval of erosion. Coll. 1961 by O. L. Hughes. *Comment:* date is minimum for the late advance of valley glaciers and admits, but does not demand, correlation of this advance with Riley Creek glaciation of Nenana Valley, Alaska, considered by Wahrhaftig (1958, p. 18) to have reached a maximum ca. 11,000 yr ago on the basis of W-49 (10,560 ± 200, USGS I). NaOH-leach was omitted from pretreatment of sample. Date based on one weekend count only.

GSC II

GSC-51. Mackenzie River Delta **6900 ± 1[illegible]**
4950 B.C.

Wood from depth 123.5 ft in bore-hole MD2, Natl. Res. Council perm[illegible] frost borings 5 mi SW of Inuvik, Dist. of Mackenzie, Northwest Territo[illegible] (68° 18′ N Lat, 133° 50′ W Long), on the delta plain of Mackenzie River. T[illegible] borings encountered (top to bottom) 100 ft of thinly stratified sandy silt [illegible] layers of woody plant material throughout, 60 ft of sand with plant lay[illegible] (dated sample), spaced at irregular intervals throughout, and 65 ft of [illegible] clay with no visible organic remains and with stones in the lowermost [illegible] feet. Microorganisms from various woody layers represent fresh water rat[illegible] than marine conditions. Coll. 1961 by G. [illegible] Dept. of [illegible] Natl. Res. Council, Ottawa, Canada. *Comment:* [illegible] sand and silt began to accumulate [illegible] after retreat of the last (classical Wisconsin?) [illegible] site, which is close to [illegible] limit. NaOH-leach was [illegible]

[illegible]

GSC II

Hunker Creek series, Yukon

Wood from frozen silty peat in a fresh cut-bank exposure in right bank Hunker Creek, at the mouth of Last Chance Creek, Klondike Dist., Yukon (6[illegible] 01′ N Lat, 139° 06′ W Long). Samples were collected from a 20-ft bed woody, silty peat underlain by 6 ft of silt containing plant detritus down to [illegible] creek. Sand and gravel seams occur in the base of the peat unit. Coll. 1961 [illegible] Jaan Terasmae and O. L. Hughes.

GSC-57. Hunker Creek — 8660 ± 1[illegible] / 6710 B.C.

Wood from woody silty peat unit at depth 16 ft. Pollen is poorly preserved: vegetation was similar to the present Boreal forest.

GSC II

Hart Lake marl series, Yukon

GSC-67. Carbonate fraction — **12,900 ± 150** / **10,950 B.C.**

GSC-67-2. Organic residue — **12,120 ± 140** / **10,170 B.C.**

Marl from ca. 6 ft below original surface, exposed on the face of a frost-heaved block in an area of palsa mounds, NW end of Hart Lake, Yukon (64° 37′ N Lat, 135° 10′ W Long). The marl is overlain by 2 to 12 in. of peat. Hart Lake, in which the marl was deposited, is impounded by a moraine ridge at its NW end. The age is minimum for retreat of a valley glacier from the moraine. Coll. 1961, by Peter Vernon; subm. by O. L. Hughes. *Comment* (O.L.H.): the age is compatible with approximate correlation of the moraine with late Wisconsin moraines of the region, but does not rule out correlation with considerably older moraines of the same region. Carbonate rocks are abundant in the area; the greater apparent age of the inorganic fraction may be attributed to hard water effect.

GSC II

GSC-73. Hunker Creek — **9520 ± 130** / **7570 B.C.**

Wood from base of woody silty peat unit at a depth of 20 ft. *General comment* (O.L.H.): the change from uniform silt (lower part of this section) to woody silty peat containing sand and gravel seams (upper part of this section) represents a significant change in sedimentation. The age of GSC-73, immediately above this break, is almost identical with the 9510 ± 220 yr age (I(GSC)-196, Isotopes II) obtained for organic silt underlain by silty gravel with mammal bones, and capped by woody peat, from Fant and Norbeck placer pit 1.5 mi upstream on Hunker Creek. Silt in the lowermost 6 ft of the present section is tentatively correlated with silt that lies beneath the bone-bearing gravel at Fant and Norbeck placer pit, and that has yielded wood dated at >35,000, (I(GSC)-131, Isotopes II).

GSC III

C. Northern Canada, General

GSC-88. Hunker Creek (silt), Yukon — **30,800 ± 1600 / −1400** / **28,850 B.C.**

Fine plant detritus from frozen silt beneath a 20-ft bed of woody, silty peat in right bank of Hunker Creek at mouth of Last Chance Creek, Klondike Dist., Yukon (64° 01′ N Lat, 139° 06′ W Long), 2 ft above creek level and 4 ft below top of silt. Coll. 1961 by J. Terasmae and O. L. Hughes. *Comment*: wood from base of peat at depth 20 ft dates 9520 ± 130 (GSC-73; GSC II). Dates confirm existence of a major stratigraphic break between silt and overlying peat. Silt is tentatively correlated (O.L.H.) with similar material, 1.5 mi upstream along Hunker Creek, beneath a bone-bearing gravel that yielded wood dated >35,000 (I(GSC)-131, Isotopes II). NaOH-leach was omitted

GSC II

GSC-97. Peel River, Yukon 8780 ± 165 6830 B.C.

Wood from 6.5 ft below surface in the backwall of a flow slide, S bank of Peel River 3.5 mi downstream from mouth of Wind River, Bonnet Plume Basin, Yukon (65° 52′ N Lat. 135° 08′ W Long). Peel River at this point is intrenched through 230 ft of Pleistocene and 135 ft of Tertiary sediments. The Pleistocene stratigraphy, typical of that exposed along lower Wind and Bonnet Plume Rivers, and Peel River between the mouths of the former, consists from the bottom up of gravel, glacio-lacustrine clay, till, and glacio-lacustrine clay capped by woody silt and peat. Coll. 1962 by O. L. Hughes. *Comment:* the age of the sample, from near the base of woody silt and peat at the top of the section, is minimum for drainage of a glacial lake which discharged northward via Eagle River during retreat of a lobe of Laurentide ice which earlier had pushed westward at least to 136° 20′ W Long. Drainage may have occurred considerably before burial of the wood. Date based on one weekend count on

GSC III

GSC-121. Porcupine River, Yukon 10,740 ± 180 8790 B.C.

Peat 4 ft below ground on upper part of S bank of Porcupine River, Yukon (67° 28′ N Lat. 139° 54′ W Long), from base of marly peat with fresh-water shells overlying silty clay which overlies a thick section of silt with minor sand and gravel. Coll. 1962 by O. L. Hughes. *Comment* (O.L.H.): silty clay beneath peat possibly accumulated in a lake when meltwater from Laurentide Ice Sheet discharged into Porcupine Basin through McDougall Pass and/or through headwaters of Eagle River, perhaps as recently as late Wisconsin. NaOH-leach omitted from sample pretreatment.

GSC III

GSC-120. Rat River, Northwest Territories >37

Wood, in part beaver-chewed, from W side of Rat River, W of Mack River, Northwest Territories (67° 39.5′ N Lat. 135° 28′ W Long): coll base of 40-ft section of silt with organic layers, which overlies till over No till was seen above silt in poorly exposed upper part of section, but ev from surrounding area suggests that Laurentide ice covered the site a tended several mi W in (classical?) Wisconsin time. Coll. 1962 by Hughes.

GSC-147. Rat River, Northwest Territories 9970 ± 8020 B

Wood (twigs) 12 ft below ground on back wall of flow slide on of Rat River, W of Mackenzie River, Northwest Terirtories (67° 43.5′ 135° 50.5′ W Long). Sample from organic silt 0.4 ft thick beneath cla and peat, and resting on 1 ft of clay over sand. The dated layer may originated in pond or floodplain antedating modern valley of Rat River 1962 by O. L. Hughes. Sample mixed with dead gas for counting.

GSC III

GSC-128. 'Gill' Lake, Yukon 12,550 ± 180 10,600 B.C.

Silty gyttja from NW side of 'Gill' Lake, Yukon (65° 28′ N Lat. 139° 42′ W Long), coll. with SIPRE coring drill at depth 91 to 93 in. near base of permanently frozen bog in a depression in terminal moraine of a former valley glacier. Coll. 1962 by O. L. Hughes. *Comment* (O.L.H.): date is compatible with view that the moraine relates to a glacial advance distinctly older than the latest advance in the Ogilvie Mtn area (Vernon and Hughes, in press). Minimum date for the latter is GSC-50: 7510 ± 190 (GSC-I) for basal peat on a moraine at North Fork Pass, Yukon. Sample pretreatment did not include usual NaOH-leach.

GSC III

King Point series, Yukon

Peat and wood from deposits exposed on rapidly eroding sea cliff E of King Point, Arctic coast, Yukon (69°04.5′ N Lat, 137° 50′ W Long). C 1962 by O. L. Hughes.

GSC-151. King Point, beneath till >38.2

Wood and peaty fragments coll. 2 ft above base of sea cliff 3.5 mi E end of King Point spit. Sample from organic silt grading up into stony with marine shells (thickness 10 to 18 ft) overlain in succession by till 30 ft), sand and silt (8 to 15 ft), and surface peat (up to 3 ft). The till senting last glaciation of site, apparently terminates in vicinity of a mo ca. 4 mi W, which is assumed to mark maximum (classical?) Wisconsin of Laurentide Ice Sheet.

GSC-159. King Point, above till 9510
7560 B.

Peat 18 ft below ground level 0.2 mi W of GSC-151, from 2 in. pe in silt 4 ft above till in stratigraphic section similar to that at GSC-151. S treated with cold (rather than hot) NaOH.

GSC V

GSC-151-2. King Point, Yukon >51.100

Wood and peaty fragments coll. 2 ft above base of sea cliff 3.5 mi E of E end of King Point Spit, Yukon Territory (69° 04.5′ N Lat, 137° 50′ W Long). Sample from organic silt grading up into stony clay with marine shells (thickness 10 to 18 ft) overlain in succession by till (20 to 30 ft), sand and silt (8 to 15 ft), and surface peat (up to 3 ft). The till representing last glaciation of the site, apparently terminates in vicinity of a moraine ca. 4 mi W which is assumed to mark maximum (classical) Wisconsin stand of Laurentide ice sheet. Coll. 1962 by O. L. Hughes. *Comment:* date is based on one 6-day count in 5-L counter at atm and supersedes earlier date of >38,200 for same sample (GSC-151 GSC III). Pretreatment included *cold* NaOH-leach.

GSC V

(Ohio Wesleyan U). Dates on twigs from earlier sample are L-221A (lignin): 25,850 ± 500, L-221A (cellulose): 25,900 ± 300 (Lamont V); GSC-11: 26,000 ± 600 (GSC I).

C. Northern Canada

GSC-181. Snake River, Yukon >31,000

Wood near base of organic silt 10 ft thick, overlying 10 ft of boulder gravel and overlain by 55 ft of gravel; sequence lies on bedrock terrace ca. 150 ft high on W side of Snake River, Yukon Territory (65° 41′ N Lat, 133° 26′ W Long). Coll. 1962 by O. L. Hughes. *Comment* (O.L.H.): locality is in unglaciated terrain N of inferred late Wisconsinan limit of montane glaciers and W of inferred late Wisconsinan limit of Laurentide ice; overlying gravel may correlate in part at least with Wisconsinan montane glaciation.

GSC IV

GSC-192. Miner River, Yukon 6670 ± 140
4720 B.C.

Basal peat from bog near headwaters of Miner River, Northern Ogilvie Mountains, Yukon Territory (65° 20′ N Lat, 140° 07′ W Long). Bog borders a pond impounded against a bedrock spur by a late Wisconsinan moraine. Coll. 1962 by O. L. Hughes. *Comment* (O.L.H.): age is minimum for widespread late Wisconsinan glaciation in Ogilvie and Mackenzie Mountains. Peat from bog on a distinctly older moraine at nearby 'Gill' Lake is 12,750 ± [illegible] (GSC-128, GSC III), and peat from bog on a moraine at North Fork Pass, considered correlative with moraine at present locality, is 7510 ± [illegible] (GSC-30, GSC I). NaOH-leach omitted from sample pretreatment.

GSC IV

GSC-199. Porcupine River, Yukon, wood >41,300

Wood from S bank Porcupine River, Yukon Territory (67° 28′ N Lat, 139° 51′ W Long), 25 ft below top of silt, sand, and gravel 111 ft thick, overlain by 20 ft of gray silt and clay and 4 ft of peat. Coll. 1962 by O. L. Hughes. *Comment* (O.L.H.): locality is not glaciated, but gray silt and clay is believed to have been deposited during one of two glacial stages when meltwater discharged into area from E and S. Peat from base of uppermost unit is 10,740 ± 480 yr old (GSC-121, GSC III).

GSC IV

GSC-204. Rat River, Northwest Territories, organic silt >38,300

Organic silt from W side Rat River, W of Mackenzie River, Northwest Territories (67° 39.5′ N Lat, 135° 28′ W Long), from near top of 40-ft section of silt with organic layers which overlies till over gravel. Coll. 1962 by O. L. Hughes. *Comment* (O.L.H.): no till was seen above silt in poorly exposed upper part of section, but evidence from surrounding area suggests that Laurentide ice covered the site and extended several miles W in (classical?) Wisconsinan time. Wood from near base of silt unit is >38,600 yr old (GSC-120, GSC III). NaOH-leach omitted from sample pretreatment.

GSC IV

GSC-222. Nelson Head, Banks Island >41,6

Willow wood 40 ft above sea shore in wave-cut cliff on proximal (SE) ... moraine 3 mi N of Nelson Head, Banks Island, Northwest Territories (...′ N Lat, 122° 12′ W Long), from sand, gravel and silt beneath ca. 15 ... till and glaciofluvial gravel and sand. Moraine dates from last glacial (classical Wisconsin ?). Wood-bearing deposit is interstadial or interglac... Coll. 1960 by J. G. Fyles.

GSC IV

GSC-238. Duck Hawk Bluff, Banks Island >40,6

Peat and willow stems ca. 10 ft below top of shore cliff 125-ft high, on ... coast Banks Island, Northwest Territories, few hundred ft W of Duck Ha... Bluff (71° 58′ N Lat, 125° 45′ W Long), from organic silt beneath colluvi... or till and overlying till over Beaufort Formation. Silt contains sparse pol... including alder, willow, rare spruce, and herbaceous plants (id. J. Terasma... Coll. 1959 by J. G. Fyles. *Comment:* deposits probably are interglacial; possi... correlatives are (I(GSC)-19, I(GSC)-28, >35,000, >38,000 resp., Isoto... I).

GSC IV

GSC-240. Thesinger Bay, Banks Island 10,660 ± 170
8710 B.C.

Plant debris from depth 1.5 ft in 5-ft layer of alluvium overlying ... terrace, SW coast Banks Island, 9 mi N of Masik River (71° 4... N Lat, 12... ...′ W Long). Dated layer yielded pelvis of muskox (*Ovibos moschatus*, ... A. W. F. Banfield, Nat. Mus. Canada). Terrace (alt 35 ft) is NW extremity ... emerged delta (?) of Masik River. Coll. 1960 by J. G. Fyles. *Comment:* terrace probably is same as that covered by alluvium dated 10,600 ± 120, 10 mi to SE (I(GSC)-185, Isotopes II). The following determinations ha... been made:

soluble in NaOH (2 L counter; one 3-day count)	10,640 ± 150
not dissolved in NaOH (2 L counter)	10,550 ± 160
not dissolved in NaOH (5 L counter)	10,660 ± 170

GSC V

GSC-294. Glacier Creek, Yukon 5190 ± 110
3240 B.C.

Basal peat coll. with SIPRE-type ice-coring drill from depth of 6.1 ft in bog between North Klondike River and Dempster Hwy, 1.5 mi S of bridge over Glacier Creek, Yukon Territory (64° 03.6′ N Lat, 138° 32.5′ W Long). Coll. 1961 by O. L. Hughes. *Comment* (O.L.H.): ice advanced S beyond bog site almost to South Klondike River during an "intermediate" glaciation (Vernon and Hughes, in press); this event was approximately correlative with construction of moraine at Chapman Lake and hence older than 13,870 yr (GSC-296, this list). Date is minimal for deglaciation of site. Pretreatment included *cold* NaOH-leach.

GSC V

GSC-293. Blackstone River, Yukon 6650 ± 140
4700 B.C.

Silty peat from 11.4 ft depth in boring made with SIPRE-type ice-coring drill on SW edge of small pond, W of Blackstone River and 5.2 mi N of Chapman Lake, Yukon Territory (64° 56′ N Lat, 138° 26′ W Long). Pond is in subdued moraine beyond limit of and higher than moraine of "intermediate" age in vicinity of Chapman Lake. Coll. 1961 by O. L. Hughes. *Comment* (O.L.H.): moraine is older than that at Chapman Lake, hence older than 13,870 yr (GSC-296, this list). Pretreatment included *cold* NaOH-leach. Date based on one 2-day count.

GSC V

Chapman Lake series, Yukon

Peat and organic silt, coll. with SIPRE-type ice-coring drill from bog on a moraine 0.4 mi E of Chapman Lake, between the lake and Dempster Hwy, Yukon Territory (64° 51.5′ N Lat, 138° 19′ W Long). Moraine marks northern limit of glaciation in Blackstone River valley during an "intermediate" glacial advance (Vernon and Hughes, in press). Ice advanced to ca. 16 mi S of site during last advance recognized in the region. Coll. 1962 by O. L. Hughes.

GSC-296. Chapman Lake, basal organic silt 13,870 ± 180
11,920 B.C.

Basal organic silt in bog at 12.6 to 13.0 ft depth.

GSC-311. Chapman Lake, organic silt 10,900 ± 150
8950 B.C.

Organic silt at 8.05 to 8.45 ft depth, from base of a prominent silt layer within the bog succession.

GSC V

GSC-310. Chapman Lake, peat 9620 ± 150
7670 B.C.

Peat from 5.1 to 5.5 ft depth, above the prominent silt layer. Pollen studies by J. Terasmae indicate significant increases in spruce and alder pollen at ca. this level. Three determinations were made:

untreated fraction	9620 ± 140
soluble in NaOH	9510 ± 150
not dissolved in NaOH	9620 ± 150

General Comment (O.L.H.): GSC-296 (basal organic silt) provides minimum date for deglaciation of site and is compatible with the assumption, based on field evidence, that moraine is comparable in age to that at Gill Lake, Y.T. (GSC-128, 12,550 ± [illegible] GSC III). GSC-311 supports hypothesis that the prominent silt layer is loess derived from the [illegible] Blackstone River at beginning of last glacial advance, as it is compatible with dates of ca. 11,000 yr for Alaskan advances (Vernon and [illegible] in press); GSC-311 and GSC-310 together place this advance [illegible] [illegible] and [illegible] yr ago. NaOH-leach [illegible] in the [illegible]

GSC V

Southern Eskimo Lakes series, Northwest Territories

Peat from partly overgrown bluff, SW Eskimo Lakes (68° 45′ N Lat 133° 16′ W Long). Coll. 1962 by O. L. Hughes.

GSC-329. S Eskimo Lakes, beneath gravel **>50,900**

Peat 62 ft above lake level (sealevel) and ca. 10 ft below top of organic silt overlain by 75 ft glaciofluvial gravel capped by 7 ft peat. Two determinations have been made:

5-L counter (standard procedure)	>42,620
5-L counter (one 3-day count at 4 atm)	>50,900

GSC-371. S Eskimo Lakes, above gravel **7120 ± 140**
5170 B.C.

Basal peat from 7 ft-thick surface peat layer overlying gravel. *General Comment* (O.L.H.): gravel is outwash from a glacial lobe in Sitidgi Lake basin which stood at a well-defined moraine along E and N sides of the lake during a late Wisconsinan stillstand or readvance. GSC-371 is minimal for this event, but probably is considerably younger than the outwash. Other basal peat dates from region are GSC-16, 7400 ± 200 and GSC-25, 8200 ± 300 (GSC I; Mackay and Terasmae, 1963). When collected, GSC-329 was expected to date approximately beginning of outwash deposition, but subsequent study of nearby sections suggests that an unconformity separates organic silt from outwash gravel and that an ice advance occurred after deposition of silt and before deposition of gravel (J. G. Fyles, oral commun., 1965). Pretreatment of GSC-329 included *cold* NaOH-leach; date for GSC-371 based on one 3-day count.

GSC V

GSC-331. Mayo, Yukon **>46,530**

Wood from beneath till, right bank of Stewart River 1.5 mi downstream from Mayo, Yukon Territory (63° 36′ N Lat, 135° 56′ W Long), from same locality as I (GSC)-180, (>35,000, Isotopes II). Exposure had been freshened by erosion to expose thin-bedded silt and fine-grained sand and minor gravel extending 35 to 50 ft above river level and overlain in turn by ca. 10 ft till and up to 50 ft silt and sand. Abundant pieces of wood up to 5 in. diam occur near top of lower silt unit. Coll. 1964 by E. B. Owen. *Comment* (O. L. Hughes): till overlying wood represents last glaciation in region; it is exposed intermittently downstream, and terminates ca. 7 mi downstream at a well-marked moraine. Despite age of sample, last glaciation may have culminated as recently as 10,500 yr ago. Sample dated in 5-L counter at 4 atm. Date based on one 4-day count.

GSC V

GSC-342. Stewart River, Yukon **>38,910**

Wood enclosed in lenticular ash layer beneath 10 to 15 ft silt, organic silt and peat in natural exposure on SE side Stewart River, at mouth of small stream ca. 8.5 mi upstream from mouth of Valley Creek, Yukon Territory (63° 21′ N Lat, 138° 10′ W Long). Coll. 1964 by O. L. Hughes. *Comment* (O.L.H.): as suspected from field relationships, ash is much older than surface or near-surface ash layer of central and western Yukon (Bostock, 1952; Stuiver *et al.*, 1964).

GSC V

10,840 ± 150
8890 B.C.

GSC-365. Twin Buttes, Yukon

Organic silt obtained from perennially frozen palsa bog using SIPRE-type ice-coring drill (Hughes and Terasmae, 1962). Sample was at 7.3 to 7.5 ft depth, immediately above pebbly gritty silt interpreted as bog bottom. Bog is ca. 1 mi N of W butte at Twin Buttes, Talbot Plateau, Yukon Territory (63° 30′ N Lat, 135° 23.5′ W Long), and 2.5 mi SW of (beyond) the limit, as inferred from a well-defined moraine, of late Wisconsinan ice which occupied Stewart River Valley to the N. Coll. 1961 by O. L. Hughes. *Comment* (O.L.H.): date is minimal for deglaciation of locality. NaOH-leach omitted from sample pretreatment. Date based on one 3-day count.

GSC V

4930 ± 140
2980 B.C.

GSC-366. Hart Lake, Yukon

Organic silt and twigs coll. from permanently frozen bog on NW side of moraine ridge impounding Hart Lake, Yukon Territory (64° 37′ N Lat, 135° 10′ W Long), using SIPRE-type ice-coring drill. Sample from 13 ft below surface in palsa mound; bog bottom not reached. Coll. 1964 by O. L. Hughes. *Comment* (O.L.H.): date is minimal for deglaciation of locality, which may have taken place more than 12,000 yr ago (GSC-67, GSC-67-2; GSC II). NaOH-leach omitted from sample pretreatment.

GSC V

6480 ± 140
4480 B.C.

GSC-372. Old Crow River, Yukon

Wood at base of 6 ft surface peat layer overlying 100 ft of sediments, mainly silt and clay, from riverbank exposure, Old Crow River, Yukon Territory (68° 03.5′ N Lat, 139° 50′ W Long). Coll. 1962 by V. N. Rampton. *Comment* (O. L. Hughes): the silt and clay, probably lacustrine in origin, are believed to have been deposited when Old Crow Basin was more or less completely occupied by one or more large lakes. Date is minimal for initiation of present environment of numerous lakes interspersed with bogs. Date based on one 5-day count.

GSC VI

3050 ± 150
1100 B.C.

GSC-397. Horton River, Northwest Territories

Peat from intercalated lacustrine and peat layers exposed in crater of a pingo 50 ft high, 11 mi E of Horton River and 65 mi S of Dernley Bay, Northwest Territories (68° 29′ N Lat, 123° 16′ W Long; Craig, 1960, p. 7), at alt ca. 1650 ft. Coll. 1959 by T. N. Irvine for B. G. Craig. *Comment:* NaOH-leach omitted from sample pretreatment.

GSC VI

5290 ± 140
3340 B.C.

GSC-409. Blackstone River, Yukon (II)

Organic silt from 8.7 ft depth in boring made with SIPRE-type ice corer on SW edge of small pond, W of Blackstone R and 5.2 mi N of Chapman Lake, Yukon Territory (64° 56′ N Lat, 138° 29′ W Long). Pond is in subdued moraine beyond limit of and higher than moraine of "intermediate" age (older than 13,870 ± 180, GSC-296, GSC V) in vicinity of Chapman Lake. Coll. 1964 by O. L. Hughes. *Comment* (O.L.H.): sample from depth 11.1 ft in same boring (GSC-295, [illegible] ± [illegible], GSC V) was younger than expected; this sample, dated as [illegible], is consistent with GSC-295. Organic accumulation at locality began [illegible] after construction of moraine. NaOH-leach omitted from sample pretreatment.

GSC VIII

GSC-411. East Blackstone River, Yukon 5070 ± 130 3120 B.C.

Organic silt from E bank East Blackstone R., ca. 0.5 mi upstream from crossing of Dempster Hwy and river (64° 35.7′ N Lat, 138° 20′ W Long). Sample coll. at downstream end of exposure near base of 19 ft sec. of fluvial sediments, mainly gravel, with peat and organic silt, disconformably overlying glaciolacustrine(?) silt.

GSC V

GSC-412. Liard River, Yukon >40,100

Wood from log in lower part of more than 100-ft section of stratified and crossbedded sand and pebbly sand, overlain by ca. 100 ft of boulder till, in turn overlain by 2 ft grey-brown sand with intercalated thin white ash bed, and capped by reddish soil, humus, and moss. Sample from actively eroding cliff, E side of Liard River, 39.2 mi NW of Upper Liard bridge, Alaska Hwy, Yukon Territory (60° 28′ N Lat, 129° 41′ W Long). Coll. 1952 by W. H. Poole. *Comment* (W.H.P.): preservation of wood suggests Pleistocene rather than pre-Pleistocene age, whereas highly kaolinized state of feldspar in granite pebbles within sand suggests age considerably older than latest ice advance. Feldspar in granite pebbles in till overlying sand is fresh.

GSC VII

GSC-416. Dempster Highway, Yukon (I) 3100 ± 130 1150 B.C.

Basal peat from 4.6 to 4.75 ft depth in boring at margin of small pond, at N fringe of moraine, W side Dempster Hwy at Mile 55.8 (64° 36′ N Lat, 138° 22.5′ W Long). Peat underlain by till(?).

GSC-469. Dempster Highway, Yukon (II) 3180 ± 130 1230 B.C.

Basal peat from 4.15 to 4.3 ft depth in boring, 16 ft E of GSC-416, small pond, W side Dempster Hwy at Mile 55.8 (64° 36′ N Lat, 138° 22.5′ W Long). Peat underlain by till(?) or coarse outwash(?).

GSC VII

GSC-470. North Fork Pass, Yukon (I) 11,250 ± 160 9300 B.C.

Organic silt with twigs (dwarf birch?) from 16 ft depth in boring in peat hummock, NE side of large pond in flat N of moraine loop forming divide in North Fork Pass (64° 35′ N Lat, 138° 17.5′ W Long). 6 ft fibrous peat overlies 10+ ft silty sand, grit, and pebbles with sparse organic material.

GSC-471. North Fork Pass, Yukon (II) 7050 ± 110 5100 B.C.

Organic silt with twigs (dwarf birch?) from 6.6 to 6.8 ft depth in boring in peat hummock 200 ft NW of GSC-470 (64° 35′ N Lat, 138° 17.5′ W Long). 4 ft fibrous peat overlies 2.8+ ft of silt with grit.

General Comment (O.L.H.): minimum age of moraine in North Fork Pass, previously 7510 ± 100 yr (GSC-50, GSC I), extended by GSC-470 to 11,250 ± 160. Date may be older than beginning of loess deposition 10,960 ± 150 yr ago (GSC-311, GSC V) in bog sequence near Chapman Lake, 16 mi N of moraine system, assumed to correlate with last glacial advance. If age difference is real (i.e., not within limits of error of dating method) and if silt deposition was related to glacial advance, difference may be due to one or both of 2 factors: 1) change of East Blackstone R. from normal to braided stream that was source of loess, may have taken place [illegible] time lag may have occurred between change in stream regimen near ice margin and response of stream to change downstream. [illegible]

GSC VII

GSC-472. Gravel Lake, Yukon **10,930 ± 1** **8980 B.C.**

Gyttja from base of 3 m thick organic layer, SE end Gravel La Yukon Territory (63° 45.5′ N Lat, 137° 53.5′ W Long). Water de 1.5 m. Coll. 1965 with Hiller peat sampler by O. L. Hughes. *Comm* (O.L.H.): Gravel Lake lies in Tintina Trench on thick drift fill assumed older than deposits of Reid advance and hence >42,900 yr (GSC-524, this list). Lake is impounded on NE side by large fan at its NW (outlet) end by extensive bog; hence lake may be much your than underlying drift. NaOH-leach omitted from sample pretreatm Sample mixed with dead gas for counting.

GSC XI

Cape Bathurst series

Wood and shells from ca. 3 m-thick marine clay unit underlying ca. 1.5 m silty sand and up to 2.5 m surface peat in shore bluff ca. 5 m high 11 km SE of Cape Bathurst, N.W.T. (70° 31′ N Lat, 127° 48′ W Long). Coll. 1965 by J. G. Fyles.

GSC-478. Cape Bathurst (I) **>32,800**

Shells (*Yoldia arctica*). Because of small sample (8.0 g), HCl-leach omitted from pretreatment. Sample mixed with dead gas for counting. (One 3-day count.)

GSC-545. Cape Bathurst (II) **>41,000**

Wood (*Picea* or *Larix*, prob. *Picea* sp.; id. by R. J. Mott) from alt ca. 1.2 m in marine clay. (One 5-day count.)

General Comment (J.G.F.): marine clay exposed above sea level throughout much of unglaciated Cape Bathurst-Baillie I. region (Fyles, 1966; Rampton, 1971a). Assuming wood is not reworked, GSC-545 indicates clays were deposited >41,000 yr ago.

GSC VI

GSC-495. Macauley Ridge, Yukon **13,660 ± 180** **11,710 B.C.**

Organic silt from NW end of lake, alt ca. 2580 ft, 0.5 mi N of milepost 1192, Alaska Hwy, Yukon Territory (62° 17′ N Lat, 140° 42.5′ W Long). Organic silt overlies laminated silt and sand, and underlies 16 ft of gyttja and loose organic detritus. Coll. 1965 with Davis sampler by V. Rampton. *Comment* (V.R.): date is minimum for ice retreat from moraine representing main-Wisconsin maximum. NaOH-leach omitted from sample pretreatment.

GSC XI

Antifreeze Pond series

Gyttja, mossy peat, and organic silt in cores retrieved from small lake by Livingstone sampler and bordering bog by Sipre corer; 300 m E of Alaska Hwy. M.P. 1198.5 (62° 21′ N Lat, 140° 50′ W Long), alt 700 m. Coll. 1965 (GSC-496) and 1968 by V. N. Rampton.

GSC-496. Antifreeze Pond, 645 cm — >36,000

Organic silt from base of 645 cm peat and silt sequence in bog.

GSC-1230. Antifreeze Pond, 622 to 640 cm — 29,700 ± 700; 27,750 B.C.

Organic silt from 622 to 640 cm interval of cores from lake.

GSC-1193. Antifreeze Pond, 537 to 552 cm — 27,100 ± 390; 25,150 B.C.

Organic silt from 537 to 552 cm interval of cores from lake.

GSC-1257. Antifreeze Pond, 515 to 524 cm — 28,500 ± 440; 26,550 B.C.

Organic silt from 515 to 524 cm interval of core from lake.

GSC-1048. Antifreeze Pond, 512 to 532 cm — 31,500 ± 700; 29,550 B.C.

Organic silt from 512 to 532 cm interval of core from lake.

GSC-1110. Antifreeze Pond, 393 to 403 cm — 13,500 ± 300; 11,550 B.C.

Organic silt from 393 to 403 cm interval of core from lake.

GSC-1042. Antifreeze Pond, 317 to 320 cm — 9980 ± 150; 8030 B.C.

Gytjja from 317 to 320 cm interval of core from lake.

GSC XI

GSC-506. Difficult Creek — 8860 ± 140; 6910 B.C.

Wood (*Salix* sp., id. by R. J. Mott) from base of 0.6 m thick peat in old exposure (ground ice slump) on small lake 1.6 km W of head of Difficult Creek, 2.8 km E of Kugaryuk Creek, Yukon (69° 25′ N Lat, 139° 23′ W Long), alt ca. 50 m, ca. 8.8 km SSW of Arctic coast. Coll. 1965 by J. G. Fyles. *Comment* (J.G.F.): date is minimum for mud-flow debris. (One 4-day count.)

GSC VI.

Northwest Garry Island series

Peat and wood from surface blanket of peat up to 1.7 m thick, and from underlying lacustrine sediments ca. 3 m thick, in coastal exposures on NW Garry I., N.W.T. (69° 30′ 05″ N Lat. 135° 47′ 25″ W Long). Deposits occupy small depressions. Peat surface has high-centered polygons. GSC-513 and -517 coll. 1964 by D. E. Kerfoot, Univ. of British Columbia, Vancouver; now at Brock Univ., St. Catharines, Ontario. GSC-516 and -575 coll. 1965 by D. E. Kerfoot, J. R. Mackay, Univ. of British Columbia, Vancouver, and J. G. Fyles.

GSC-513. Garry Island, peat, 1.5 m — **4140 ± 140; 2190 B.C.**

Peat from 1.5 m depth in 1.7 m-thick peat sec., top at alt 4.9 m. Sample level, alt 3.4 m, just below change in pollen assemblage suggestive of Hypsithermal Interval (J. C. Ritchie, Scarborough College, West Hill, Ontario, pers. commun.). *Comment* (D.E.K.): polygons show no sign of burial, hence not inundated by sea in last 4000 yr (Kerfoot, 1969). NaOH-leach omitted from sample pretreatment.

GSC-517. Garry Island, peat, 1.1 m — **4120 ± 130; 2170 B.C.**

Peat from 1.1 m depth below surface, same site as for GSC-513. Sample, alt 3.8 m, from just above change in pollen sequence which may represent Hypsithermal Interval. *Comment* (J.G.F.): NaOH-leach omitted from sample pretreatment.

GSC-516. Garry Island, peat, 9.4 m — **10,330 ± 150; 8380 B.C.**

Peat from 10 cm-thick bed exposed in cliff sec., top alt 18 m, ca. 0.5 km along shore from GSC-513 and -517. Peat, at alt 9.4 m, overlies gravel above stony clay and is overlain, in succession, by 1.2 m marl and silt, 1.5 to 1.8 m gravel (pebble beach), 0.6 m peat, plus some soliflucted material (cf. Kerfoot, 1969, fig. 6). *Comment* (W.B., jr.): peat is younger than wood from nearby higher-level peat and lacustrine silt deposits on Garry I.: S-278, 11,300 ± 190; S-277, 11,700 ± 250; R., 1968, v. 10, p. 371. NaOH-leach omitted from sample pretreatment. (One 4-

GSC VII

East Blackstone River series, Yukon

Peat and organic silt from boreholes in permanently frozen bog bordering small pond, in moraine where unnamed valley opens from W into valley of East Blackstone R., Yukon Territory (6[illegible]° [illegible]′ N Lat. 138° 21′ W Long). Coll. 1965 with SIPRE-type ice-corer by O.L. Hughes.

GSC-415. East Blackstone River, peat — **6010 ± 150; 4060 B.C.**

Peat from 5.3 to 5.5 ft depth in boring on W side of pond.

GSC-515. East Blackstone River, organic silt — **13,740 ± 190; 11,790 B.C.**

Organic silt from 12.5 to 13 ft depth in boring on E side of pond. *General Comment* (O.L.H.): date GSC-515 is minimum for establishment of vegetation on moraine, mapped as correlative with moraine system in North Fork Pass (Vernon and Hughes, 1966) that is more than 11,250 ± 160 yr old (GSC-170, this list); moraine may correlate more closely with older moraine system near Chapman Lake, ca. 45 mi N, older than 13,870 ± 180 yr (GSC-296, GSC V). NaOH-leach omitted from pretreatment of GSC-515. Date GSC-415 based on one 4-day count.

GSC. [illegible]

L-522A. Mackenzie River, Northwest Territories >42,000

Peat from lower part of a succession of gravels, sands, and silts exposed on E bank of E Branch of the Mackenzie River, 20 mi N of Reindeer Station, Northwest Territories, Canada (68° 52′ N Lat, 134° 30′ W Long). The sediments are believed to have been overridden by glacier ice and are considered by Mackay (1956) to be part of an ancient delta of Mackenzie River.

Terasmae (1959c) studied pollen in apparently correlative peat from a nearby locality and inferred that inclosing sediments are interglacial. A possible finite date for the peat was suggested by a date of 23,000 ± 2000 on nearby driftwood that lay beneath glacial deposits (L-300A, Lamont V). Coll. 1957 by J. R. Mackay; subm. by Geol. Survey of Canada.

GSC VII

GSC-524. Stewart River, Yukon (II) >42,900

Wood from volcanic ash, S side Stewart R., Yukon Territory (63° 30.2′ N Lat, 137° 16′ W Long). Sample from gully 1300 ft downstream of discontinuous exposure. Ash layer 1 to 5 in. thick lies in surface layer of organic silt and peat, overlying gravel, till, and gravel. Coll. 1965 by O. L. Hughes. *Comment* (O.L.H.): upper gravel and till are products of Reid advance (Bostock, 1966); hence date is minimum for that event. Wood from similar ash exposed 43 mi downstream is >38,940 yr old (GSC-342, GSC V). Date based on one 3-day count.

GSC VII

GSC-527. Hunker Creek, Yukon >53,[illegible]

Spruce wood from Fant and Norbeck placer pit, at limit of Hun[illegible] Creek between Too Much Gold and Gold Bottom Creeks, Klon[illegible] District, Yukon Territory (63° 58′ N Lat, 138° 57′ W Long). Taken f[illegible] organic silt overlying auriferous gravel and overlain, successively, by s[illegible] gravel with mammoth, horse, and bison remains, organic silt, and p[illegible] Area has not been glaciated. Coll. 1960 by O. L. Hughes. *Comm[illegible]* (O.L.H.): date is based on one 4-day count in 5-L counter at 4 atm [illegible] supercedes earlier date of >35,000 (I-(GSC)-181, Isotopes II) on s[illegible] sample.

GSC VI

C. Northern Canada, Mainland

Niggerhead Lake series, Yukon

Organic detritus and peat from lake bottoms in Niggerhead Lake region, Yukon Territory. Coll. 1965 with Davis sampler by V. Rampton.

20 *Geological Survey of Canada Radiocarbon Dates VI*

GSC-511. Niggerhead Lakes, Yukon (I) 6200 ± 150
4250 B.C.

Organic detritus from N end of lake, alt ca. 2550 ft, 0.5 mi E of milepost 1190, Alaska Hwy (62° 15.5′ Lat, 139° 11′ W Long). Material overlies gravel and underlies 9 ft of silt and gyttja. Water depth at site 5.3 ft.

GSC XI

GSC-549. Richards Island >40,400

Wood (*Picea* sp.; id. by R. J. Mott) from 143 (?) to 152 (?) m below surface in B.A.-Shell-Imperial Reindeer D-27 oil well ca. 12 km NNE from S tip of Richards I., 1.6 km NW of East Channel, Mackenzie R., N.W.T. (69° 06′ 05″ N Lat, 134° 58′ 54″ W Long). At surface, gravel (esker?) appears to overlie interglacial sand. Coll. 1965 by J. H. Manning, British Am. Oil Ltd., Edmonton; subm. by J. G. Fyles. *Comment* (J.G.F.): date suggests subsurface gravel at S end Richards I. are >40,000 yr old. (One 3-day count.)

GSC XI

GSC-575. Garry Island, twigs, 10.7 m 9730 ± 140
7780 B.C.

Iron-stained twigs and wood fragments from base of gravel, alt 10.7 m, over marl in same sec. as GSC-516. *Comment* (W.B., Jr.): date, with GSC-516, at base of marl and silt unit, indicates time that lacustrine phase existed at site. (One 3-day count).

GSC-562. Northern Garry Island >35,000

Marine pelecypod shells (*Astarte borealis, A. montagui* var. *warhami, Mya truncata*; id. by F. J. E. Wagner, Bedford Inst., Dartmouth, N.S.) from top part of sand deposit, 7.5 to 9 m thick, exposed in cliffed headland on N coast Garry I., N.W.T. (69° 30′ N Lat, 135° 40′ W Long). Coll. 1965 by D. E. Kerfoot. *Comments* (D.E.K. and J.G. Fyles): shells well preserved with periostracum intact, not believed reworked despite absence of hinged specimens. Enclosing sands form marine terrace representing relative sea level 9 to 15 m above present, following withdrawal of last glacier to reach outer Mackenzie Delta area. GSC-630 (>37,000, this list) dates shells from terrace at same level 16 km to SE. (W.B., Jr.): due to computer error, date 1st reported as >42,600; cf. Kerfoot (1969). Sample mixed with dead gas for counting. (One 3-day count).

GSC VI

GSC-580. Niggerhead Lakes, Yukon (II) 4550 ± 150
2600 B.C.

Organic detritus from NE end of lake, alt ca. 2550 ft, 5 mi N of Snag Junction, along Snag Road (62° 17.5′ N Lat, 140° 35′ W Long). Material overlies pebbly sand and underlies 3.2 ft of gyttja. Water depth at site 4.6 ft.

GSC-581. Niggerhead Lakes, Yukon (III) 4470 ± 140
2520 B.C.

Peat from sedge mat beside lake, alt ca. 2550 ft, 5 mi N of Snag Junction (62° 17.5′ N Lat, 140° 36′ W Long). Material overlies a pebbly sand and underlies 12 ft of loose sedge peat.

General Comment (V.R.): dates are minimum for ice-block melting and give time for beginning of organic accumulation in depressions in moraininic complex of probable late Wisconsin age. NaOH leach omitted from pretreatment of GSC-544 and GSC-580. GSC-580 mixed with dead gas for counting. Dates for GSC-544 and GSC-581 based on one 3-day count and one 4-day count, respectively.

Gsc II

GSC-586. Snake River, Yukon (II) — 9750 ± 150 / 7800 B.C.

Silty peat from base of 10-ft sec. of alluvial silt, overlying successively gravel, organic silt with wood, boulder gravel, and bedrock of terrace on W side of Snake R., Yukon Territory (65° 19′ N Lat, 133° 26′ W Long). Coll. 1962 by O. L. Hughes. *Comment* (O.L.H.): wood from beneath gravel is >31,000 yr old (GSC-181, GSC IV). Gravel interpreted as outwash of late-Wisconsin valley glaciation in upper Snake R. Outwash deposition ceased prior to 9750 B.P.; river was incised ca. 225 ft after that date. NaOH-leach omitted from sample pretreatment.

Gsc XI

GSC-690. S of Kendall Island — >37,000

Whole shells and fragments (*Astarte borealis*) with waterworn wood fragments, from sand and gravel 6 to 7.5 m above lake, alt ca. sea level, in terrace deposit on unnamed island 16 km S of Kendall I., N.W.T. (69° 21′ N Lat, 135° 22′ W Long). Terrace, surface alt ca. 9 m, is part of extensive terrace, probably estuarine, along W side Richards I. and at same height as equivalent terrace on NE side Garry I. (cf. GSC-562, >35,000, this list). Coll. 1966 by J. G. Fyles. *Comment* (J.G.F.): shells *probably* not reworked, as they are fresh-appearing with periostracum intact on many, although hinged specimens not found. Assoc. wood probably reworked. Terrace interpreted as representing former sea level ca. 9 m higher (relative to land) than present following withdrawal of last glacier ice to reach outer Mackenzie Delta area (cf. Fyles, 1967). Due to computer error date 1st given as >42,000. (One 3-day count.)

G.S.C. VII

GSC-718. Kletsan Creek, Yukon — 5250 ± 130 / 3300 B.C.

Wood from fresh exposure on SE bank, W tributary of Kletsan Creek, Yukon Territory (61° 31′ N Lat, 140° 58′ W Long), from 2 ft below top of unoxidized gravel overlying oxidized(?) till and underlying pebbly silt, volcanic ash, and turf. Coll. 1966 by V. Rampton. *Comment* (V.R.): relationship of gravel to climatic and glacial history of region is presently unclear; however, site is ca. 200 ft above tree line, suggesting conditions formerly more favorable to tree growth (cf. GSC-760, 5950 ± 140, this list, for comments on trees above tree line in S British Columbia). Date based on one 3-day count.

GSC IX

White River series, Yukon

Wood and organic silts from exposures downstream from Alaska Hwy. bridge across White R., Yukon. Coll. 1965, 1966 by V. N. Rampton.

GSC-714. White River, Yukon (I) — 11,690 ± 160; 9050 B.C.

Organic silt from base of bog, W bank of White R., 2.2 mi downstream from Alaska Hwy. bridge (62° 01′ N Lat, 140° 34′ W Long); 1.5 ft organic silt is overlain by 10 ft peat and underlain, successively, by 12 ft gravel and 45 ft till.

GSC-777. White River, Yukon (II) — 7760 ± 170; 5810 B.C.

Wood from base of bog, W bank of White R., 2.3 mi downstream from Alaska Hwy. bridge (62° 01′ N Lat, 140° 34′ W Long). Peat is underlain, successively, by 2 ft till-like material, 47 ft gravel, and 30 ft till.

GSC-552. White River, Yukon (III) — >42,000

Organic silt and silty peat from W bank of White R., 1.3 mi downstream from Alaska Hwy. bridge (62° 00′ N Lat, 140° 34′ W Long). Organic silts are from angular unconformity between till and underlying gravels and sands. Till is capped by gravel and peat.

GSC-732. White River, Yukon (IV) — 48,000 ± 1300; 46,050 B.C.

Wood from mud-flow debris, W bank of White R., 1.2 mi downstream from Alaska Hwy. bridge (62° 00′ N Lat, 140° 34′ W Long). Mud-flow debris is underlain by 10 ft till whose top 5.5 ft is oxidized and overlain by slump composed of gray drift.

GSC-995. White River, Yukon (V) — >41,000

Wood and silty peat from alluvium, W bank of White R., 1.3 mi downstream from Alaska Hwy. bridge (62° 00′ N Lat, 140° 34′ W Long). Alluvium is at river level and is overlain by 100 ft olive gray till containing pods of peat and mud-flow debris in its basal part. Till is capped by gravel and peat.

General Comment (V.N.R.): GSC-714 is minimum for deglaciation. GSC-732 is maximum for time of mud-flow, and minimum for underlying till although possibility of sample contamination cannot be ruled out (Rampton, 1969). NaOH-leach omitted from pretreatment of GSC-552 and GSC-714. Dates for GSC-552 and GSC-732 each based on one 3-day count, the latter in 5-L counter at 4 atm.

GSC-IX

Aishihik Lake series, Yukon

Wood and peat from near Aishihik Lake, Yukon. Coll. 1966 by O. L. Hughes.

GSC-719. Aishihik Lake, peat — 9660 ± 15[illegible]; 7710 B.C.

Peat from frozen pond sediments in depression on S margin of hummocky moraine belt, at NW corner of unnamed pond E of road to radio towers, 3.6 mi N of Aishihik Lake (61° 40.7′ N Lat, 137° 27.[illegible]′ W Long). Discontinuous organic layer (this sample, 0.5 ft thick (in [illegible]) is underlain by blue-gray lacustrine silt and overlain, successively, by 1.3 ft silty clay with abundant mollusks, 3 ft fine sand with mollusks at base and organic stringers at top, 0.5 ft White River Ash, and 0.[illegible] surface organic layer.

GSC-755. Aishihik Lake, wood 7170 ± 14
5220 B.C.

Wood from 5.1 ft below surface in bluff, N shore of Aishihik Lak (61° 37′ N Lat, 137° 29′ W Long). Woody layer 0.2 ft thick is underlai by silty clay that grades downward into distinctly varved glacio-lacustrin sediments and is overlain by 2.1 ft silty clay with molluscs, 1.1 ft silt wit peat stringers, 0.8 ft silty peat with molluscs, 0.2 ft organic soil wit charcoal, 0.6 ft White River Ash, 0.2 ft eolian silt with organic stringe *General Comment* (O.L.H.): GSC-749 is minimum for retreat of ic from position marked by moraine belt. GSC-755 is minimum for drai age of glacial lake that occupied basins of Sekulmun and Aishihik Lak and drained N to Nisling R.; it is compatible with GSC-749. Each dat based on one 3-day count.

Silver Creek series, Yukon

Organic debris including wood, from silt beds in Icefield Outwash II, W side of Silver Creek, Yukon (61° 00′ N Lat, 138° 19′ W Long). Exposures at this locality have been studied in detail by Denton and interpreted by Denton and Stuiver (1967). Coll. 1966 by O. L. Hughes and V. Rampton. Detailed cross sections provided by Denton in advance of publication were used to duplicate as closely as possible samples coll. by Denton that yielded finite "older" dates. Samples were intended to be cross-check with Yale Radiocarbon Lab.

GSC-734. Silver Creek series (I) >35,000

Organic debris including wood in silt layer within gravel of Icefield Outwash II; same as Y-1356 ($37,700\ ^{+1500}_{-1300}$; Denton and Stuiver, 1967). *Comment* (J.A.L. and W.B., Jr.): small sample size used (100 g) necessitated dating in 2-L counter, in which finite ages over 35,000 yr are rarely obtained. NaOH-leach omitted from sample pretreatment. Sample mixed with dead gas for counting.

GSC-769. Silver Creek series (II) 29,600 ± 460
27,650 B.C.

Organic debris including wood in silt layer within gravel of Icefield Outwash II; same as Y-1385 (30,100 ± 600; Denton and Stuiver, 1967). *Comment* (O.L.H.): agreement with Y-1385 is within stated limits of error. Pretreatment included *cold* NaOH-leach. Date based on one 3-day count.

GSC IX

GSC-776. Genere River, Yukon 9360 ± 15
7410 B.C.

Organic silt from base of peat bog overlying 8 ft till and 25 ft gravel, W bank of Genere R., 1.5 mi upstream from mouth of unname small creek, Yukon (61° 42.5′ N Lat, 140° 38′ W Long). Coll. 1966 b V. N. Rampton. *Comment* (V.N.R.): date is minimum for deglaciation of locality. NaOH-leach omitted from sample pretreatment.

GSC IX

GSC-781. West Aishihik River, Yukon 1920 ± 130 / 2980 B.C.

Organic silt from stringer 7 ft below surface in natural exposure in gully, N side West Aishihik R., Yukon (61° 0.25′ N Lat, 137° 07.6′ W Long). Stringer is at irregular contact of gray-brown silt (above) and permanently frozen gray silt (below). Gray silt was deposited in glacial lake during retreat of ice tongue from West Aishihik Valley; gray-brown silt is probably reworked by colluviation and cryoturbation, contact forming base of active layer. Coll. 1966 by O. L. Hughes. *Comment* (O.L.H.): date is minimum for drainage of glacial lake in West Aishihik

Valley. NaOH-leach omitted from sample pretreatment. Sample mixe[d] with dead gas for counting.

GSC IX

St. Clare Creek series, Yukon

Compressed twigs and silty peat from under tills along St. Clar[e] Creek, near Klutlan Glacier, Yukon. Coll. 1966, 1967 by V. N. Rampton.

GSC-799. St. Clare Creek, Yukon (I) >39,00[0]

Compressed twigs and peat overlain, successively, by 45 ft silty til[l] and 10 ft sandy till and overlie 25 ft sandy till on W bank of St. Clar[e] Creek (61° 37′ N Lat, 140° 31′ W Long). Upper portion of underlyin[g] till is oxidized. Exposure is within limits of oldest Neoglacial advance of Klutlan Glacier (cf. GSC-751, 1520 ± 130, this list).

GSC-924. St. Clare Creek, Yukon (II) >41,000

Silty peat from upper part of 3 ft of silty peat on NE bank of St. Clare Creek, 0.2 mi downstream from mouth of Bull Creek (61° 32′ N Lat, 140° 23.5′ W Long). Silty peat is overlain, successively, by 10 ft sand, 6 ft till, and 80 ft alluvium, and overlies 2+ ft of till. Coll. 1966, 1967 by V. N. Rampton.

General Comment (V.N.R.): infinite dates do not permit exact ages of overlying tills to be defined, but underlying till was deposited over 39,000 yr ago. NaOH-leach omitted from pretreatment of GSC-924. Dates for GSC-924 and GSC-799 each based on one 3-day count.

GSC - IX

GSC-567. Kluane Lake, Yukon 340 ± 130 / A.D. 1610

Wood from *in situ* white spruce stump partly imbedded in beac[h] gravel, 6 ft below normal high water level, S side of Christmas B[ay], Kluane Lake, Yukon (61° 05.5′ N Lat, 138° 21′ W Long). [illegible] to 18 in. below gravel surface, then cut off with saw; depth to b[ase of] stump (*i.e.*, original surface level) unknown but probably <5 ft. Oute[r]most 0.5 cm (ca. 20 annual rings) used for dating. Coll. 1967 by J. Lee and R. Kluhert for O. L. Hughes. *Comment* (O.L.H.): [illegible] drowned spruce forest are common in Christmas Bay and [illegible] Kluane Lake; according to Bostock (1952, 1969) trees were drowned [when] Neoglacial advance of Kaskawulsh Glacier dammed a S outlet of Kluan[e] Lake via Slims-Kaskawulsh Valley, and forced discharge through [illegible] NW outlet (cf. Borns and Goldthwait, 1966; Denton and Stuiver, 1966; Porter and Denton, 1967). Date based on one 3-day count.

GSC IX

Wolverine Creek series, Yukon

Organic clay and wood from N bank of Wolverine Creek, 0.3 mi downstream from mouth of Lynx Creek, Yukon (61° 32′ N Lat, 13? 55.5′ W Long). Coll. 1967 by V. N. Rampton.

GSC-919. Wolverine Creek, Yukon (I) >35,000

Organic clay overlies 2.5 ft gravel and 10+ ft till, and underlies 5 ft clay, 45 ft sand, 80 ft gravel, and 30+ ft till.

GSC-962. Wolverine Creek, Yukon (II) >40,000

Wood (compressed twigs) from 20 ft deltaic sand overlying, successively, 25 ft sand, 5 ft clay, 2 ft organic clay, 7.5 ft gravel, and 10 ft till, and underlying 80 ft gravel and 30+ ft till.

General Comment (V.N.R.): dates indicate that sediments (enclosing organic materials) resulting from damming of valley by glacier advance from E (which deposited upper till) were laid down more than 40,000 yr ago, (Rampton, 1969), GSC-962 being considered more reliable than GSC-919. NaOH-leach omitted from pretreatment of GSC-919. Date for GSC-962 based on one 5-day count.

GSC IX

GSC-932. Cache Creek, Yukon 6500 ± 140 4550 B.C.

Peat from lower part of 2.5 ft of silty sand, W bank of White R, 0.5 mi downstream from mouth of Cache Creek, Yukon (61° 45′ N Lat, 140° 56′ W Long). Silty sand overlies, successively, 25 ft gravel, 2.5 ft silt, 15 ft gravel, and 5 ft till, and underlies 5 ft gravel and 32 ft poorly exposed sands, silts, and peat. Coll. 1967 by V. N. Rampton. *Comment* (V.N.R.): date is minimum for deglaciation of region; cf. GSC-71 (11,000 ± 160) and GSC-777 (7760 ± 170; both in this list). NaOH-leach omitted from sample pretreatment.

GSC IX

GSC-959. Niggerhead Mountain, Yukon >38,000

Peat and organic silt from bank at edge of small lake N of Niggerhead Mt. and 1.3 mi W of Alaska Hwy. Mile 1196.5, Yukon (62° 18.5′ N Lat, 140° 50′ W Long). Dated material from near top of 2 ft unit containing ice wedge cast. Unit overlies silt containing peaty layers and is overlain, successively, by peat, gray silt, and turf. Coll. 1967 by V. N. Rampton. *Comment* (V.N.R.): it was hoped to obtain maximum age for formation of ice wedge and deposition of gray silt (loess); date indicates that enclosing and underlying silts were deposited over 38,000 yr ago. NaOH-leach omitted from sample pretreatment. Sample mixed with dead gas for counting. Date based on one 3-day count.

GSC IX

GSC-960. O'Brian Creek, Yukon >38,000

Peat from near base of 54+ ft of organic silt, E bank of White R opposite mouth of O'Brian Creek, Yukon (62° 35′ N Lat, 140° 0.5′ W Long). Silts overlie 29 ft gravel. Coll. 1967 by V. N. Rampton. *Comment* (V.N.R.): date is minimum for deposition of underlying gravel which grade to maximum limit of glaciation on White R. (Rampton, 1969). NaOH-leach omitted from sample pretreatment. Sample mixed with dead gas for counting.

GSC IX

GSC-996. Dempster Highway, Yukon, wood 4630 ± 130
2680 B.C.
$\delta C^{13} = -24.9‰$

Wood from base of 10-ft-thick frozen peat layer in roadside exposure, at Mile 102, Dempster Hwy., Yukon (65° 05′ N Lat, 139° 30′ W Long). Peat overlies outwash from oldest recognized glaciation in Ogilvie Mts. (Vernon and Hughes, 1966). Coll. 1965 by J. T. Gray, McGill Univ., Montreal. *Comment* (J.T.G.): date obtained is too young to establish glacial chronology of area. Peat development at site appears to have been recent phenomenon, dependent upon other factors than time of deglaciation. Date based on one 4-day count.

GSC IX

GSC-1002-2. Bull Creek, Yukon >48,000

Peat from 6 ft organic silts and colluvium on W bank of Bull Creek 5 mi upstream from its mouth, Yukon (61° 30′ N Lat, 140° 15′ W Long). Organic silts and colluvium lie along dipping contact between 150 ft gravel above and 10+ ft till below. Coll. 1967 by V. N. Rampton. Two determinations were made:

GSC-1002 (one 1-day count in 2-L counter) >40,000

GSC-1002-2 (one 3-day count and two 1-day counts in 5-L counter at 4 atm >48,000

Comment (V.N.R.): underlying till was deposited over 48,000 yr ago.

GSC XI

GSC-1030. Castle Bluff 4390 ± 130
2440 B.C.
$\delta C^{13} = -23.4‰$

Wood (*Picea* sp. or *Larix* sp.; id. by R. J. Mott) from near base of 3 m colluvium in 15 m-high sea-cliff exposure of drained thaw pond near Castle Bluff, Wood Bay, N.W.T. (69° 47′ 20″ N Lat, 128° 43′ W Long). Coll. 1966 by J. G. Fyles. *Comment* (J.G.F.): dates tree 16 km beyond present N limit of trees. (One 4-day count.)

GSC XI

GSC-1099. Kelly Lake 8880 ± 150
6930 B.C.

Wood in peat from surface of lake clay and silt 8 km SW of Kelly Lake, 24 km N of Norman Wells, N.W.T. (65° [illegible]′ N Lat, 126° [illegible]′ W Long), at 1 m depth, overlain by marl and clay, exposed by landslide. Coll. 1968 by R. J. Fulton. *Comment* (R.J.F.): wood and peat appear to have accumulated in a thermokarst lake basin formed in glacial-lake silt. Date is minimum for deglaciation, for draining of a glacial lake, and for penetration of glacial lake sediments by permafrost.

GSC XI

Horton River series

GSC-1100. Horton River >41,000

Peat beneath ca. 12 m of till and overlying 2 till units ca. 20 m thick, exposed in 45 m bank along W tributary of Horton R. (69° 13' N Lat, 127° 05' W Long), alt ca. 205 m. Coll. 1968 by R. W. Klassen. *Comment* (R.W.K.): date records non-glacial interval of interstadial or intergla[illegible]al rank preceding at least last glaciation of Smoking Hills Upland; an early or pre-Wisconsin age for lowest till is suggested. NaOH-leach omitted from sample pretreatment. (One 3-day count.)

GSC-576. Horton River >38,100

Wood (*Picea* or *Larix* sp., id. by R. J. Mott) assoc. with peat within interbedded, cross-laminated sand and silt, beneath ca. 18 m clay(?) exposed along W tributary Horton R. (69° 12' N Lat, 127° 05' W Long), alt ca. 205 m. Coll. 1965 by D. Waylett, Imperial Oil, Edmonton; subm. by J. G. Fyles. *Comment* (R.W.K.): wood appears to be from same unit as GSC-1100, ca. 1.6 km to E. Overlying 'clay' probably includes at least one till, suggesting unit records a non-glacial interval of interstadial or interglacial rank (Fulton and Klassen, 1969).

GSC XI

GSC-1139. Erly Lake 10,000 ± 150
8050 B.C.

Peaty moss (*Drepanocladus exannulatus, Calliergon sarmentosum,* and *Scorpidium scorpioides*; id. by M. Kuc) enclosed in sandy silt from top of 29 m high pingo 21 km W of Erly Lake, N.W.T. (6[illegible]° 1[illegible]' N Lat, 122° 38' W Long). Organic material from 2 m thick lake sediment overlying gravelly till. M. Kuc reports (pers. commun.) that bryophytes are assemblage of permanently submerged species. Coll. 1968 by R. J. Fulton. *Comment* (R.J.F.): it was hoped that date would indicate time required for construction of this fresh-appearing pingo; result sheds little light on age of pingo but gives indication of time of deglaciation. (One 3-day count.)

GSC XI

GSC-1172. Tombstone Range 9690 ± [illegible]
7740 B.C.
$\delta C^{13} = -22.7‰$

Organic silt and twigs from 498 to 50[illegible] cm depth in permanently frozen bog sediments in tributary valley to North Klondike R., Tombstone Range, Ogilvie Mts., Yukon (64° 27' N Lat, 138° 27' W Long), alt between 1570 and 1525 m. Boring on [illegible] mound from ca. 1.5 m above surrounding surface to 710 cm depth. No core recovered from solid ice at 508 to ca. 509 cm depth or from unfrozen sediments below. Site is inside local limit of widely recognized McConnell Glaciation of central Yukon (Bostock, 1966; Vernon and Hughes, 1966; Hughes *et al.*, 1969), and beyond limit of recent cirque moraines. Coll. 1968 by J. T. Gray, McGill Univ., Montreal. *Comment* (J.T.G.): date is minimum for retreat of last valley glacier from this upper North Klondike tributary to cirque zone above. Date confirms field evidence [illegible] no readvance over site occurred since McConnell Glaciation (cf. G[illegible]-470, 11,250 ± 160, ca. 16 km to NE; R., 1968, v. 10, p. 231). NaOH-leach omitted from sample pretreatment. Sample mixed with dead gas [illegible] counting

GSC-1214. Peninsula Point — 12,500 ± 180 / 10,550 B.C. / $\delta C^{13} = -25.5‰$

Peat, near base of 1.5 m-thick mud flow colluvium overlying sand, underlying 0.6 m lacustrine silt in wave-dissected pingo at Peninsula Point, ca. 7.6 km SW of Tuktoyaktuk, N.W.T. (69° 21.5' N Lat, 133° 09' W Long). Coll. 1966 by J. G. Fyles; subm. by V. N. Rampton. *Comment* (V.N.R.): dates local melting of permafrost before deposition of mud-flow debris and start of lake phase. NaOH-leach omitted from sample pretreatment. Sample mixed with dead gas for counting.

GSC-1242. Antifreeze Pond, 293 to 298 cm — 8690 ± 160 / 6740 B.C. / $\delta C^{13} = -26.5‰$

Gyttja and mossy peat (*Calliergon trifarium*, *Drepanocladus exannulatus*, and *Scorpidium scorpioides*; id. by M. Kuc) from 293 to 298 cm interval of core from lake. Uncorr. date; 8710 ± 160, used in Rampton (1971b).

GSC-1040. Antifreeze Pond, 250 to 255 cm — 5690 ± 140 / 3740 B.C.

Gyttja from 250 to 255 cm interval of core from lake.

General Comment (V.N.R.): GSC-496 confirms that drift plain upon which Antifreeze Pond lies is result of pre-late Wisconsin glaciation (cf. Rampton, 1969 and GSC-959; >38,000, R., 1970, v. 12, p. 80). Remaining dates relate to late Quaternary vegetational history of region as reconstructed from pollen assemblages (cf. Rampton, 1969, 1971b). Pollen diagram suggests fell-field or sedge-moss tundra, followed by shrub tundra, was present between ca. 31,000 and 27,000 B.P. (GSC-1230, -1198, -1257, and -1048). Sedge-moss tundra was present until ca. 10,000 B.P. (GSC-1042); pollen percentage of aquatics rose at 13,500 B.P. (GSC-1110). Shrub tundra was present between ca. 10,000 and 8700 B.P. (GSC-1242) when it was replaced by spruce woodland, which was replaced by spruce forest at ca. 5700 B.P. (GSC-1040). Organic silt from pollen-analyzed core was supplemented with material from nearby core to provide enough material for GSC-1230 and GSC-1198. GSC-1257 (from supplemental core) was run as a check on GSC-1048 (from analyzed core). Anomalous dates from below 510 cm interval of cores are believed to result from redeposition of materials via slopewash or thermokarst erosion (cf. Rampton, 1971b). NaOH-leach omitted from pretreatment of all samples except GSC-1230 and GSC-1257, both of which had cold NaOH-leach. GSC-1230 and -1110 mixed with dead gas for counting. GSC-496, -1230, and -1042, each based on one 4-day count; GSC-1257 based on one 3-day count.

GSC-1407. Little Scottie Creek — 12,0[illegible] ± [illegible] / [illegible] B.C.

Peat, ca. 75% undeterminable vascular plant remains with (*Drepanocladus fluitans*, *Amblystegium riparium*, and Brachytheciaceae cf. *Eurhynchium* sp.; id. by M. Kuc), 8.5 to 8.7 m depth, retrieved by Winkie diamond drill from frozen sediment adjacent to Alaska Hwy. M.P. 1217.5 in valley of Little Scottie Creek, Yukon ([illegible] N Lat, 140° [illegible] W Long), alt 575 m. [illegible] overlain by 7.8 m [illegible] organic silt under 0.7 m surface [illegible]. Coll. 1966 by V. N. Rampton. *Comment* (V.N.R.): although [illegible] underlain by early Wisconsin outwash (Hughes et al., [illegible]) date [illegible]tes much infilling [illegible] late or post-Wisconsin time. NaOH [illegible] omitted from sample pretreatment. (One [illegible]-day count.)

I(GSC)-19. Banks Island, NW Territories (in silt) . >35,000

Wood coll. half way up a 100-ft cliff on W coast of Banks Island at Worth Point (72° 17′ N Lat, 125° [illegible]′ W Long). Dated wood is representative of small trees and beaver-gnawed sticks, apparently embedded in pond silts resting upon till, which in turn overlies Beaufort formation. A younger till (?) may separate wood-bearing silts from uncompressed surface peat (see I(GSC)-26). Coll. 1959 by J. G. Fyles; subm. 1959. *Comment:* (see I(GSC)-26).

Isotopes I

I(GSC)-26. Banks Island, NW Territories (in uncompressed peat) >38,000

Wood (dwarf willow) from same site as I(GSC)-19 (72° 15′ N Lat, 125° 40′ W Long). Sample coll. from 6-ft bed of uncompressed moss peat at top of the exposure. Peat has yielded pollen of birch, in addition to that of plants now growing in the area. Coll. 1959 by J. G. Fyles; subm. 1959. *Comment:* uncompressed surface peat containing dated wood has accumulated since last glaciation of W part of Banks Island. This radiocarbon age supports the inference (based upon other features of the region) that W Banks Island was not glaciated during "classical" Wisconsin time.

Isotopes Inc. I

I(GSC)-27. Fort Selkirk, Yukon Territory >38,000

Charred wood from steep right bank of Yukon River, 100 ft above river, 3 mi downstream from junction of Yukon and Pelly rivers (62° 47′ N Lat, 137° 27′ W Long). Wood was contained in a 12-in. lens of silt beneath 4 ft of sand and gravel and beneath lava flows of the Selkirk volcanics. Coll. 1959

Isotopes I

I(GSC)-28. Bernard Island, near Banks Island, NW Territories >38,000

Moss peat from shore cliff at SW end of Bernard Island which lies off the mouth of Bernard River on W coast of Banks Island (73° 4[illegible]′ N Lat, 12[illegible]° 2[illegible]′ W Long). Moss peat occurs in lacustrine silts lying beneath till or colluvium and overlying till which in turn rests upon Beaufort formation. Pollen of conifers and tundra vegetation now found in area has been obtained from the moss. Coll. 1959 by J. G. Fyles; subm. 1959. *Comment:* lacustrine or pond silts containing dated moss and other similar deposits on W Banks Island (see I(GSC)-19), appear to record a sparsely forested interglacial period (Craig and Fyles, 1960).

Isotopes I

I(GSC)-30. Prince Albert Sound, Victoria Island, NW Territories 28,600 ± 1500

Tundra plants dug from 200-ft river bank ca. 5 mi N of Prince Albert Sound on Victoria Island (7[illegible]° [illegible]′ N Lat, 116° 35′ W Long). Organic material occurs as a succession of thin-growth layers in a 20-ft section of silt lying within ca. 150 ft of gravel and sand. These [illegible] deposits underlie till and glacial gravel and overlie till. Pollen derived from organic layers belongs entirely to tundra plants. Coll. 1959 by J. G. Fyles; subm. 1959. *Comment:* dated material is believed to record an interglacial interval. Deposits including dated material are of local extent, but [illegible] materials (which so far have yielded no organic remains) [illegible] beneath till throughout large parts of NW Victoria Island and NE coast of Banks Island.

Isotopes II

I(GSC)-180. Mayo, Yukon Territory >35,[illegible]

Spruce wood from right bank of Stewart River 3 mi downstream from Mayo (63° 36′ N Lat, 135° 53′ W Long). Partly exposed log 6 in. diam. ca. 4 ft long, abraded at both ends with cracks filled by calcite. Log was imbedded in till at base of till lens near top of an exposure ca. 100 ft high above river level. Till lens lies on sand and gravel and is overlain by bedded silt. It is judged to be same till as that exposed near top of numerous sections from Mayo, downstream to New Crossing, Stewart River. Coll. 1960 by O. L. Hughes. *Comment:* till is product of latest glaciation of locality. Wood appears to have been transported and may be from a deposit much older than the till in which it was found.

Isotopes II

I(GSC)-181. Hunker Creek Wood, Yukon Territory >35,000

Spruce wood from Fant and Norbeck placer pit, left limit of Hunker Creek between Too Much Gold and Gold Bottom Creeks, Klondike District (63° 58′ N Lat, 138° 57′ W Long). Taken from lenticular body of organic silt, maximum thickness 18 ft, overlying auriferous gravel and overlain, successively, by silty gravel, 2 to 5 ft thick, with abundant remains of mammoth, horse and bison; by organic silt, 3 to 18 ft thick; and by woody, silty peat, 5 to 10 ft thick. Area is unglaciated. Coll. 1960 by O. L. Hughes. *Comment:* as expected, material is very much older than similar material from Hunker Creek. Sample Y-133 (8900 ± 320, Yale II) may be compatible with I(GSC)-196 (9310 ± 220, this date list) which came near the top of the organic silt that overlies the silty bone-bearing gravel.

Isotopes II

I(GSC)-185. Masik River, NW Territories 10,600 ± 3[illegible]0

Peat from base of 20-ft section of interbedded peat and silty colluvium forming the upper part of S bank of Masik River, 6 mi from the river mouth (71° 35′ N Lat, 12[illegible]° 3[illegible]′ W Long), Banks Island. Peat rests on gravel 20 ft above river bed at alt between 50 and 100 ft. Coll. 1960 by J. G. Fyles. *Comment:* gravel beneath the dated peat postdates all glacial features in vicinity but may be outwash of Laurentide Ice Sheet whose margin is known to have stood 25 mi to E during Wisconsin time. Although definite evidence of recent marine submergence has not yet been found in vicinity, a delta-like terrace at alt ca. 40 ft near the mouth of the river may be marine and possibly equivalent to the gravel beneath the dated peat.

Isotopes II

I(GSC)-196. Hunker Creek Silt, Yukon Territory 9310 ± 220

Highly organic, frozen silt from left limit of Hunker Creek (6[illegible]° [illegible]′ N Lat, 138° 57′ W Long). Site is same as that of I(GSC)-181 but sample is from near the top of organic silt that overlies the silty gravel containing vertebrate remains. Coll. 1960 by O. L. Hughes. *Comment:* see I(GSC)-181 (this date list).

U. Sask V

Slave River Delta series, North West Territories

Samples from S end [illegible] modern Slave R. Delta (61° 15′ N Lat, 113° [illegible] W Long), from 10 ft [illegible] high bank near beginning of 1st distributary channel (Jean R.). Coll. [illegible] and subm. by N. J. McMillan, Tenneco Oil and Minerals Ltd., Calgary, Alberta.

S-268. Slave River Delta, peat — **2725 ± 115**, **775 B.C.**

From 4 in. bed in vertical bank of Jean R. 8 ft below ground level.

S-269. Slave River Delta, wood — **2215 ± 95**, **265 B.C.**

Enclosed in stratified silty clay 4 ft below ground level in bank of Slave R. 0.2 mi W (downstream) from S-268. *Comment:* dates help establish sedimentation rate and growth of Slave R. Delta.

U. Sask. V

WIS-275. Colville Lake, N.W.T. — **6790 ± 75**, **4840 B.C.**

Sedge peat, 205 to 210 cm below modern surface, which is basal organic material immediately overlying marl at 210 cm. Dates base of pollen diagram by H. Nichols and provides minimum date for deglaciation. Peat monolith cut from exposed peat face at Colville Lake, District of MacKenzie, N.W.T. (67° 06′ N Lat, 125° 47′ W Long). Coll. 1967 by J. A. Larsen, Univ. of Wisconsin; subm. by H. Nichols and R. A. Bryson.

U. Sask. V

Garry Island series, North West Territories

Wood samples from 3.5 m section of peat and from underlying lake silt above ice-thrust Pleistocene sediments at elev. 30 m above sea level on Garry Island, North West Territories (69° 51′ N Lat, 135° 47′ W Long). Face of peat was cleaned off to permafrost and wood obtained from frozen ground. Coll. 1964 and subm. by D. E. Kerfoot and J. R. Mackay, Univ. of British Columbia, Vancouver.

S-276. Wood 1.9 m depth from peat — **9580 ± 150**, **7530 B.C.**

S-278. Wood 2.3 m depth from peat — **11,300 ± 190**, **9350 B.C.**

S-277. Wood 3.7 m depth from silt — **11,700 ± 250**, **9750 B.C.**

Comment (J.R.M.): as underlying icy beds are nearly vertical, permafrost has been present continuously for at least 11,700 yr. Peat overlain by 0.8 m of soil, moved downslope by solifluction.

Yale IX

Bog series, Yukon Territory, Canada

Peat samples from bog near top of rock knob located at junction of Kaskawulsh and Slims R. Valleys in SW sec. of Yukon, Canada (60° 46′ N Lat, 138° 35′ W Long). Coll. and subm. by H. W. Borns. Age of ash is discussed by Stuiver, Borns, and Denton (1964).

Y-1363. Yukon 1A — **1460 ± 70**, **A.D. 490**

First 1.3 cm of peat above 2.5 cm thick layer of volcanic ash.

Y-1364. Yukon 1B — **1390 ± 70**, **A.D. 560**

First 1.3 cm of peat below same ash.

Yale IX

Y-1483. Kaskawulsh Glacier, Yukon — **9780 ± 80**, **7830 B.C.**

Grass buried *in situ* at base of sec. of Kluane loess 1.5 m in thickness. Sample site is same as Y-1435. Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1966).

Yale IX

Y-1385. Silver Creek, Yukon — **30,100 ± 600**, **28,150 B.C.**

Thin organic layer *in situ* in Icefield outwash body overlain by Kluane till and underlain by Icefield till and deposits of Shakwak glaciation. Sample site is in exposure on W bank of Silver Creek in Shakwak Trough on NE border of St. Elias Mts., Yukon, Canada (61° 09′ N Lat, 138° 19′ W Long). Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1967).

Yale IX

Y-1386. Kluane Lake, Yukon — **12,500 ± 200**, **10,550 B.C.**

Basal material from body of organic sediment 3.7 m thick, which fills kettle hole in Kluane ice-contact stratified drift. Sample site is located close to SE shore of Kluane Lake in Shakwak Trough on NE border of St. Elias Mts., Yukon, Canada (61° 03′ N Lat, 138° 21′ W Long). Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1966, 1967).

~~[illegible]~~ Yale IX

Y-1387. Yukon Territory, Canada — **3330 ± 100**, **1380 B.C.**

Woody material from base of peat bog at peat lacustrine silt interface at junction of Kaskawulsh and Slims R. Valleys (60° 48′ N Lat, 138° 3? W Long), St. Elias Mts., Yukon, Canada. Date is minimum for retreat for last major Pleistocene advance, at that point, prior to advance of Neoglaciation. Coll. and subm. by H. W. Borns. For details, see Borns and Goldthwait (1966).

Radiocarbon II

I(GSC)-197. Kellet River, NW Territories **9023 ± 229**

Peat, 8 ft below surface at base of pond deposits, overlying gravel, shale and sandstone, excavated in a gully 1 mi N of Kellet River, Banks Island (71° 56′ N Lat, 123° 17′ W Long). Pond sediments occupy a shallow depression in the upland. Coll. 1960 by J. G. Fyles. *Comment:* landscape of this part of Banks Island, with hilltop remnants of glacial deposits surrounded by broad colluvial slopes, has an old appearance when compared with the fresh moraines of the last ("classical" Wisconsin) glaciation ca. 30 mi to E. Nonetheless, the date of the bog-bottom sample lies in the normal postglacial range. A similar sample (I(GSC)-26, >38,000, Isotopes, Inc. I), coll. ca. 50 mi to the W, is much older (see also Craig and Fyles, 1960).

U. Wisconsin VII

Twin Lakes, Inuvik, N.W.T.

Col. of peat, 120 cm deep, overlying gray clay, obtained in 1967 from Twin Lakes, Inuvik, Dist. of Mackenzie, N.W.T., Canada (68° 22' N Lat, 132° 42' W Long). Sec. exhibited apparently horizontally continuous alternating layers of fibrous peat and *Sphagnum* mosses. Previous sample of peat from bottom of this bog (Mackay, 1963) was dated at 8200 ± 300 B.P., GSC-25 (Radiocarbon, 1962, v. 4, p. 20). Coll. 1967 and subm. by J. C. Ritchie, Dalhousie Univ., Halifax, Nova Scotia.

WIS-279. Twin Lakes, Inuvik, N.W.T. — 5120 ± 70; 3470 B.C.

Sphagnum peat from 50 to 60 cm depth.

WIS-291. Twin Lakes, Inuvik, N.W.T. — 5840 ± 65; 3890 B.C.

Fibrous woody peat from 120 to 130 cm depth.

WIS-310. Twin Lakes, Inuvik, N.W.T. — 7220 ± 80; 5270 B.C.

Woody, fibrous sedge peat from 270 to 290 cm below modern surface.

Yale IX

Y-1481. Outpost Creek, Yukon >49,000

Thin organic layer [illegible] in Icefield ice-contact stratified drift body overlain by Kluane till. Sample site is in exposure on W bank of Outpost Creek in Shakwak Trough on NE border of St. Elias Mts., Yukon, Canada (61° 00′ N Lat, 138° 21′ W Long). Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1967).

Yale IX

Y-1486. Silver Creek, Yukon >49,000

Sinuous stringer of peat in base of Icefield till body which overlies drift of Shakwak glaciation and underlies drift of Kluane glaciation. Sample site is in exposure in W bank of Silver Creek in Shakwak Trough on NE border of St. Elias Mts., Yukon, Canada (61° 00′ N Lat, 138° 19′ W Long). Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1967).

Yale IX

Y-1488. Silver Creek, Yukon 33,400 ± 800 / 31,450 B.C.

Thin organic layer *in situ* in Icefield outwash body underlain by Icefield till and overlain by Kluane drift. Sample site is in exposure in W bank of Silver Creek in Shakwak Trough on NE flank of St. Elias Mts., Yukon, Canada (61° 00′ N Lat, 138° 19′ W Long). Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1967).

Yale IX

Y-2310. Fox-Hazard Glacier, Yukon 7890 ± 120 / 5940 B.C.

Basal organic material from peat bed, 1.5 m thick, which overlies Kluane (classical Wisconsin) till and underlies Neoglacial till deposited by Fox-Hazard Glacier system. Although nearby, this peat bed is distinct from one described under Y-2309. Sec. is at outer edge of Neoglacial moraine system fronting Fox-Hazard Glacier system (61° 15′ N Lat, 140° 16′ W Long). Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): date is minimum for underlying Kluane till and maximum for deposition of outermost Neoglacial moraines of Fox-Hazard Glacier system.

Y-2311. Fox-Hazard Glacier, Yukon 6860 ± 120 / 4910 B.C.

Uppermost organic matter from peat bed described under Y-2310. Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): date is minimum for underlying Kluane till and maximum for deposition of overlying outermost Neoglacial moraines of Fox-Hazard Glacier system.

Y-2312. Fox-Hazard Glacier, Yukon 8200 ± 110 / [illegible] B.C.

Basal organic material from peat sec., 2.4 m thick, which directly overlies Kluane (late Wisconsin) till. Sample site is 2000 ft downvalley from outermost Neoglacial moraines, Canada (61° 15′ N Lat, 140° 15′ W Long). Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): date is minimum for last deglaciation of sample site.

Yale IX

White River Valley series

All samples were coll. from White R. valley on N flank of Wrangell and St. Elias Mts., Alaska.

Y-2301. White River, Alaska — **10,900 ± 16[illegible] / 8950 B.C.**

Organic material from base of peat sec. 14.6 m thick, which directly overlies till of Kluane (late Wisconsin) age. Muskeg is exposed in N bank of White R. on N flank of Wrangell and St. Elias Mts., Alaska (61° 4[illegible]' N Lat, 141° 26' W Long) ca. 8 mi downstream from terminus of Russell Glacier. This exposure was 1st described by S. R. Capps (1916, p. 70-75). Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): date is minimum for last deglaciation of sample site.

Y-2302. White River, Alaska — **8020 ± 12[illegible] / 6070 B.C.**

Lowest spruce stump in peat sec. described under Y-2301. Stump 6[illegible] cm above base of deposit. Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): date is minimum for invasion of spruce into White R. valley [illegible] last deglaciation.

Y-2303. White River, Alaska — **1990 ± 80 / 40 B.C.**

Spaghnum moss from immediately below 60 cm layer of white volcanic ash which, in turn, is 2.1 m below top of muskeg sec. described under Y-2301. Most likely, spaghnum moss was killed by ash fall. Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): sample dates deposition [illegible] volcanic ash.

Y-2304. White River, Alaska — **1850 ± 80 / A.D. 100**

Identical to Y-2303, except for location of sample site 9.1 m W [illegible] Y-2303. Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): dates deposition of volcanic ash.

Y-2305. White River, Alaska — **>47,000**

Organic material *in situ* within gravel unit exposed along N Fork Creek in White R. Valley on N flank of Wrangell and St. Elias Mts., Alaska (61° 52' N Lat, 141° 39' W Long). Gravel unit is underlain by till and overlain by lacustrine sediments containing drop stones. Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): date is minimum for last deglaciation of sample site.

Y-2306. White River, Alaska — **11,270 ± 2[illegible] / 9320 B.C.**

Organic matter from base of peat sec., 7.9 m thick, which directly overlies till of Kluane (classical Wisconsin) age. Sec. is exposed in S[illegible] bank of White R. on N flank of Wrangell and St. Elias Mts., Alaska (61° 43' N Lat, 141° 45' W Long) ca 2.7 mi downstream from snout of Russell Glacier. Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): date is minimum for last deglaciation of site.

Y-2307. White River, Alaska — **8280 ± 12[illegible] / 6330 B.C.**

Organic matter from base of peat sec., 3.0 m thick, which directly overlies till of Kluane (classical Wisconsin) age. Sec. is exposed in [illegible] bank of White R. N flank of Wrangell and St. Elias Mts., Alaska ([illegible] 42' N Lat, 141° 46' W Long) ca. 0.2 mi [illegible]stream from terminus of Russell Glacier. Coll. 1967 by G. H. Denton. *Comment* (G.H.D.): date is minimum for last deglaciation of sample site.

Y-2308. White River, Alaska — **>[illegible]**

Organic matter *in situ* within gravel unit underlain by [illegible] till [illegible] overlain by 1 till. These deposits are exposed along Solo Creek in White R. Valley on N flank of Wrangell and St. Elias Mts., Alaska (61° [illegible]' N Lat, 141° 44' W Long). Coll. 1967 [illegible] G. H. Denton. *Comment* (G.H.D.): date is minimum for 2 lower [illegible]

Yale IX

Yukon Territory series

All samples were coll. from NE and N flank of St. Elias Mts., Yukon Territory, Canada.

Y-1355. Silver Creek, Yukon >46,400

Thin organic layer *in situ* in Shakwak outwash body overlain by drift of Icefield and Kluane glaciation. Sample site is in exposure on W bank of Silver Creek in Shakwak Trough on NE border of St. Elias Mts., Yukon, Canada (61° 06′ N Lat, 138° 19′ W Long). Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1967).

Y-1356. Silver Creek, Yukon 37,700 +1500 −1300; 35,750 B.C.

Thin organic layer *in situ* in Icefield outwash body underlain by Icefield till and deposits of Shakwak glaciation, and overlain by deposits of Kluane glaciation. Sample site is in exposure on W bank of Silver Creek in Shakwak Trough on NE border of St. Elias Mts., Yukon, Canada (61° 06′ N Lat, 138° 19′ W Long). Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1967).

Yale IX

Y-1357. Silver Creek, Yukon 7340 ± 150; 5390 B.C.

Thin organic layer *in situ* in Kluane outwash body underlain by Kluane till as well as drift of Icefield and Shakwak glaciations. Sample site is in exposure on W bank of Silver Creek in Shakwak Trough on NE border of St. Elias Mts., Yukon, Canada (61° 06′ N Lat, 138° W Long). Coll. 1964 by G. H. Denton. For exact location and significance of sample, see Denton and Stuiver (1967).