HISTORY AND BOTTOM SEDIMENTS
OF STANWELL-FLETCHER LAKE,
SOMERSET ISLAND, N.W.T.

A thesis

Presented to the

Department of Geology

University of Ottawa

In partial fulfillment

of the requirements for the Degree

Master of Science

in Geology

by

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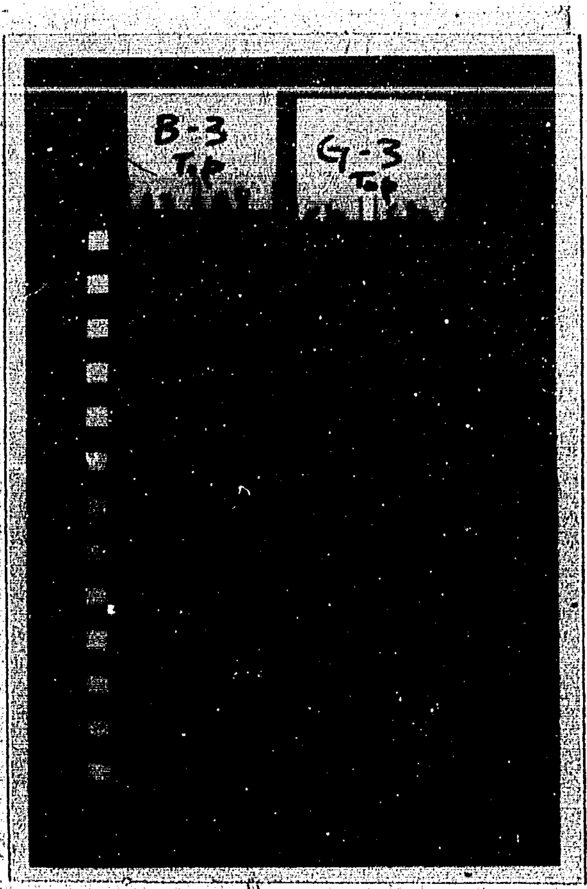
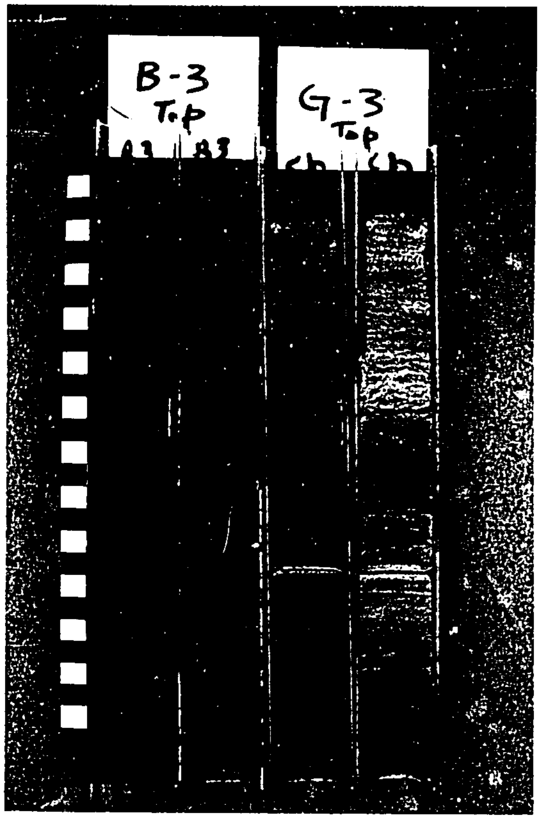


Core samples taken from Stanwell-Fletcher Lake

(scale in centimeters)



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ABSTRACT

Stanwell-Fletcher Lake lies in a post-Cretaceous graben on the east side of the Boothia Arch, Somerset Island, Northwest Territories. The lake site was formed by glacial excavation of a down-faulted block of relatively soft Cretaceous (?) rocks, and the history of the area can be traced through three stages as post-Pleistocene uplift progressed; marine, estuarine, and the present lacustrine stage. The last stage is believed to have commenced approximately 5,000 years ago.

Since that time, the saline water formerly occupying the lake site has been completely replaced by fresh water, largely through circulation during the estuarine stage. The lack of chemical stratification and the isothermal nature of the lake indicate efficient circulation and hence oxygenation of the water in spite of the year-round ice-cover.

In general the bottom sediments of Stanwell-Fletcher Lake are unlaminated, fine-grained deposits oxidized to a reddish-brown colour at the surface. Poor sorting and positive skewness are the rule even in the seasonally ice-free, wind-agitated margins. Silt and mud predominate in the central portions of the lake, whereas the marginal areas are generally sandy. The distinctness of these two groupings of sediments is attributed to differing modes of transport and deposition, namely, bottom traction and seasonal deposition of the sand as opposed to slow, year-round settling out of the mud. Surface organic carbon averages 2.3%, and total carbonates less than 1%. The appearance downward in the cores of apparently detrital dolomite and <u>in situ</u> foraminiferal tests is accompanied by an increase in mean grain size. The

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higher energy estuarine phase is believed to have been operative at that time.

The cold climate retards chemical weathering and limits the duration of sediment transport by streams. The rate of sedimentation in the lake is therefore low and sorting is poor because the ice-cover minimizes winnowing by wave activity. Chemical and biological processes in the water are inhibited by the low temperatures with the result that autochthonous sediments such as organic matter and precipitated carbonates (marls) are insignificant in the deposits. As chemical breakdown of clay-producing minerals is minimal, the clay minerals present were mechanically derived from source rocks in the area.

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CHAPTER 1

INTRODUCTION

The field work described here was carried out as part of the University of Ottawa's Arctic Expedition programme on Somerset Island during the summer of 1965. Field work lasted from mid-May to mid-July. Attention was drawn to Stanwell-Fletcher Lake in particular because of unpublished reports, that it was quite deep and probably meromictic, that is, having a permanently unmixed layer of relict sea-water trapped along the bottom. Also, the fact that the expedition was based on Somerset Island made access to the lake and its study very convenient.

THE PURPOSE OF THE STUDY

The prime purpose of the project is to study the effect of an arctic climate on sedimentation in a modern lacustrine environment. In particular, the aim is to investigate anomalous features in the limnology and sedimentation of Stanwell-Fletcher Lake. Such a study entails a thorough appraisal of the more critical sedimentological factors of the unconsolidated bottom deposits, as well as certain physical characteristics of the medium of deposition, the lake water itself.

The study is justified in view of the paucity of literature on the subject of arctic limnology, and the non-availability of any published work on the modern sediments of arctic lakes, that is, lakes in the areas of less than 40°F average July temperature

(Frey, 1963) (Table 1). It is also recognized that a full knowledge of the arctic lake environment is of prime importance to an understanding of the geology and paleoecology of the Pleistocene epoch, when such conditions were much more widespread.

PREVIOUS WORK

The amount of work published on the limnology and sedimentation of temperate and tropical lakes is impressive. This is to be expected considering their importance to inhabited areas in relation to fisheries, water supplies, and recreation. However, the literature on subarctic lakes (lakes in the subarctic climatic zone between the temperate and arctic zones) is much smaller.

Most of the limnological background for this study was obtained from Hutchinson (1957). Besides a comprehensive review of the literature, especially on temperate, tropical, and subarctic lakes, Hutchinson classifies lakes in general into 3 categories:

a. Dimictic, in which circulation takes place twice a year,

b. Warm monomictic, implying winter circulation above 4°C,

c. Cold monomictic, implying summer circulation below 4°C.

He comments on the relative rarity of cold monomictic types the category into which Stanwell-Fletcher Lake falls, and also on the lack of information on their thermal cycles. It is recognized that thermal conditions must be very different from those of the dimictic types due to the continuous solar radiation which affects cold monomictic lakes in summer.

Frey (1963) has also compiled a valuable review of the major limnological research carried out in North America. It includes a chapter on Greenland and the Arctic of North America.

Much work is presently being done on subarctic lakes but the literature on arctic lakes is scant, and is mostly of a biological nature. A summary of the work most relevant to this study is given below.

Livingstone (in Frey, 1963) described and reviewed work on the biological limnology of selected lakes in Alaska, the Yukon, the Northwest Territories, and Greenland. In an earlier publication with Bryan and Leahy (1958), he suggested that the effect of an arctic environment on lakes is principally through physiographic processes affecting origin, sedimentation, and drainage.

Hobbie (1961) described Lake Schrader in Alaska, in which stable stratification was erratic, occurring in 1958 and not in 1959.

Angino, Armitage, and Tash (1964) studied the limnology of Lake Bonney, Antarctica and found that it was meromictic (having a permanently unmixed layer of water along the bottom).

They concluded that the warmer layer of saline water at the bottom was trapped sea water.

The limnology of Greenshield Lake, a glacier-fed lake on Baffin Island, was studied by Quigley (1956). He noted an anomalous layer of cold water along the bottom below a depth of 400 feet, although in shallower water the lake is isothermal. Settling pans placed at various distances from the glacier showed that only sediment settling near the melting glacier was laminated.

Hattersley-Smith and Serson (1964) described a meromictic lake on northern Ellesmere Island. In this case an anomalously warm and relatively saline layer of water occurred along the bottom. No definite explanation was given for this phenomenon.

Deane (1958) conducted both limnological and sedimentological studies of Lake Hazen, northern Ellesmere Island, but unfortunately because of his death, only preliminary reports have been published.

ACKNOWLEDGEMENTS

The help and co-operation of a number of persons and agencies is gratefully acknowledged by the writer. Most of the sampling equipment was supplied by F. G. Barber of the Marine Sciences Division of the Department of Mines and Technical Surveys. In this department thanks are also due to Eric Field, Dr. Jan Terasmae, and Dr. Bruce Craig of the Geological Survey Division; and to Dr. R. S. Dean of the Mineral Processing Division, Mines Branch, for technical assistance rendered to the writer. Dr. Kenneth Hooper of the Geology Department at Carleton University kindly assisted the writer in the study of the foraminifera found.

Sincere appreciation is expressed to Dr. B. R. Rust who supervised the work, and to the other members of the staff of the University of Ottawa Geology Department for their encouragment, criticism, and timely advice.

Funds were obtained for the project through the National Research Council, the Defence Research Board, Department of Northern Affairs, and the Geological Survey of Canada.

CHAPTER II

STANWELL-FLETCHER LAKE AND SURROUNDING REGION

GEOGRAPHIC LOCATION AND CLIMATE

Stanwell-Fletcher Lake is located at Latitude 72°45'N and Longitude 94°45'W, some 400 miles north of the Arctic Circle. It is on Somerset Island, one of the islands of the Canadian Arctic Archipelago, in the District of Franklin (see Fig. 1). The lake covers an area of 131 square miles, and is at an altitude of about 25 feet above sea level.

The climate of Somerset Island is typically arctic, with long, cold winters and short, cool summers. Table 1 shows a monthly synopsis of the weather for the 12 month period ending July 31st, 1965 at Resolute Bay, Cornwallis Island, about 100 miles north of Stanwell-Fletcher Lake. These figures were obtained from the records of the Department of Transport, Shown with these figures, in small, bracketed type are readings taken on Somerset Island. Although the latter were limited both in accuracy and in the number of observations taken, they generally agree with the Resolute readings. The average temperature for May is higher on Somerset Island than at Resolute because readings were taken only during the latter part of the month on Somerset Island. These observations indicate that climatic factors do not differ much between these two locations.

From Table 1, certain significant features of the climatic environment of the lake may be noted:

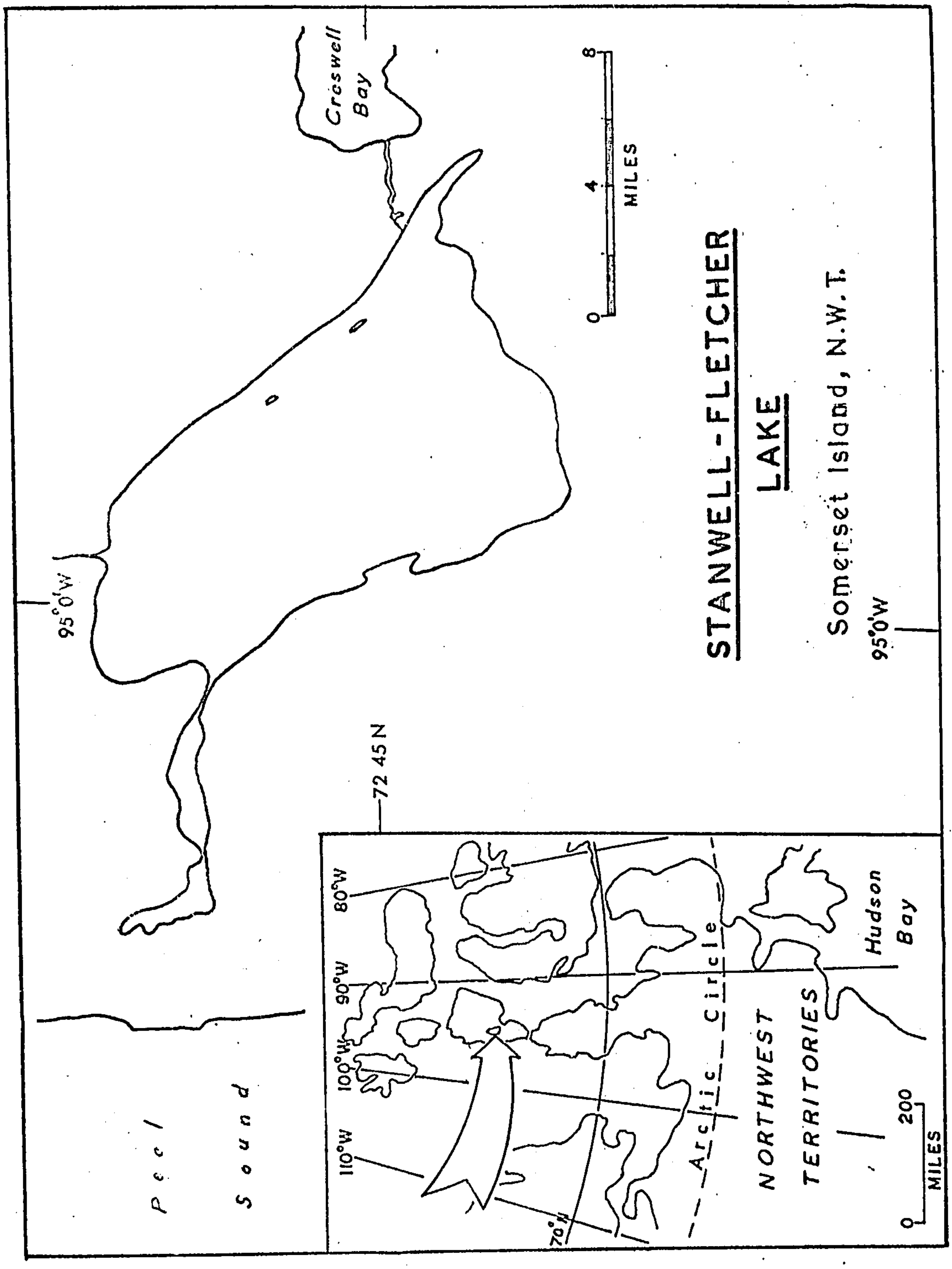

Figure 1: Location map of Stanwell-Fletcher Lake

MONTH	Average Temp. °F			Wind	Cloud	Precipitation (inches)	
	High	Low	Mean	Dir. Vel. mph	%	Type	Total
August 1964	39.6	32.2	35.9	E	90	.28 sn	.94
				14.4		.66 r	
September	28.4	20.8	24.6	NE	86	.26 sn	.30
				15.4		.04 r	
October	4.4	-7.7	-1.7	NNW	52	.18 sn	.18
				10.3		-	
November	-1.5	-11.5	-6.5	ESE	65	.27 sn	.27
				14.5		-	
December	-9.8	-23.5	-16.7	E	45	.40 sn	.40
				19.5		-	
January 1965	-21.0	-31.6	-26.3	NW	38	.07 sn	.07
				17.9		-	
February	-14.9	-30.5	-22.7	NE	48	.12 sn	.12
				19.0		-	
March	-13.7	-27.3	-20.5	SE	35	.22 sn	.22
				13.0		-	
April	-2.3	-16.0	-9.2	NW	48	.31 sn	.31
				14.4		-	
May (19th - 31st)	25.3	13.5	19.4	ESE	71	.26 sn	.26
			(29.0)	18.1	(50)	-	
June (1st - 15th)	31.2	22.9	27.1	NNW	79	.39 sn	1.01
			(28.0)	18.1	(90)	.62 r	
July (3rd - 31st)	41.0	32.7	36.9	W	78	.48 sn	.68
			(37.6)	12.3	(70)	.20 r	

Table 1: Chart showing meteorological data recorded at Resolute Bay, Cornwallis Island; and Somerset Island (small type).

a. The 10 month period of below-freezing average temperatures.

b. The high incidence of extensive cloud cover.

c. The low precipitation (total, Aug. 1964 to July 1965 - 4.45 inches).

The harsh climate permits only the hardiest of plants to grow in the area, such as lichen, arctic willow, and moss. The effect of these factors on the sedimentation and limnology of Stanwell-Fletcher Lake will be examined subsequently.

DRAINAGE

Because of the low precipitation, the influent streams into Stanwell-Fletcher Lake are relatively few and quite small, with the exception of the Stanwell-Fletcher River (Fig. 2). The short period of above-freezing average temperatures permits snow melting and surface run-off only during the summer months. Most of the streams enter the lake from the northern and southern areas of the basin, and the overall drainage is well integrated with a clearly defined water-shed. In the vicinity of the lake the drainage pattern is largely dendritic, although in the areas totally underlain by crystalline rocks, a rectangular, linear pattern develops because of jointing.

Although the drainage is well integrated, the local melting of permafrost in the areas underlain by porous sedimentary deposits allows the formation of small tundra ponds, which occur mostly in the area immediately north of Stanwell-Fletcher Lake.

The perennially frozen substratum prohibits sub-surface drainage, with the result that the surface soil becomes water-logged. Marshes, however, do not develop.

The lake has only one outlet to the sea. This is the Union River, which is 2½ miles long and flows eastward into Creswell Bay across the belt of lowland separating the lake from Creswell Bay.

GEOLOGY AND GEOMORPHOLOGY

The following outline of the regional geology and geomorphology of the Stanwell-Fletcher Lake basin and the geological map (Fig. 2) which accompanies it are based on the following data: personal communication with the members of the expedition working in the various areas; close study of aerial photographs (Department of Mines and Technical Surveys photographs numbers: A16079-152 to 156; A16079-102 to 108; and A16121-25 to-31); and on limited reconnaissance by the writer (himself). Because the area is only sparsely covered by surficial deposits and vegetation, and outcrop is plentiful in most areas, the placing of lithological boundaries is fairly accurate. The geological structures shown, however, are more conjectural, the interpretation depending on aerial photographs, tentative field observations, and the lithological relationships.

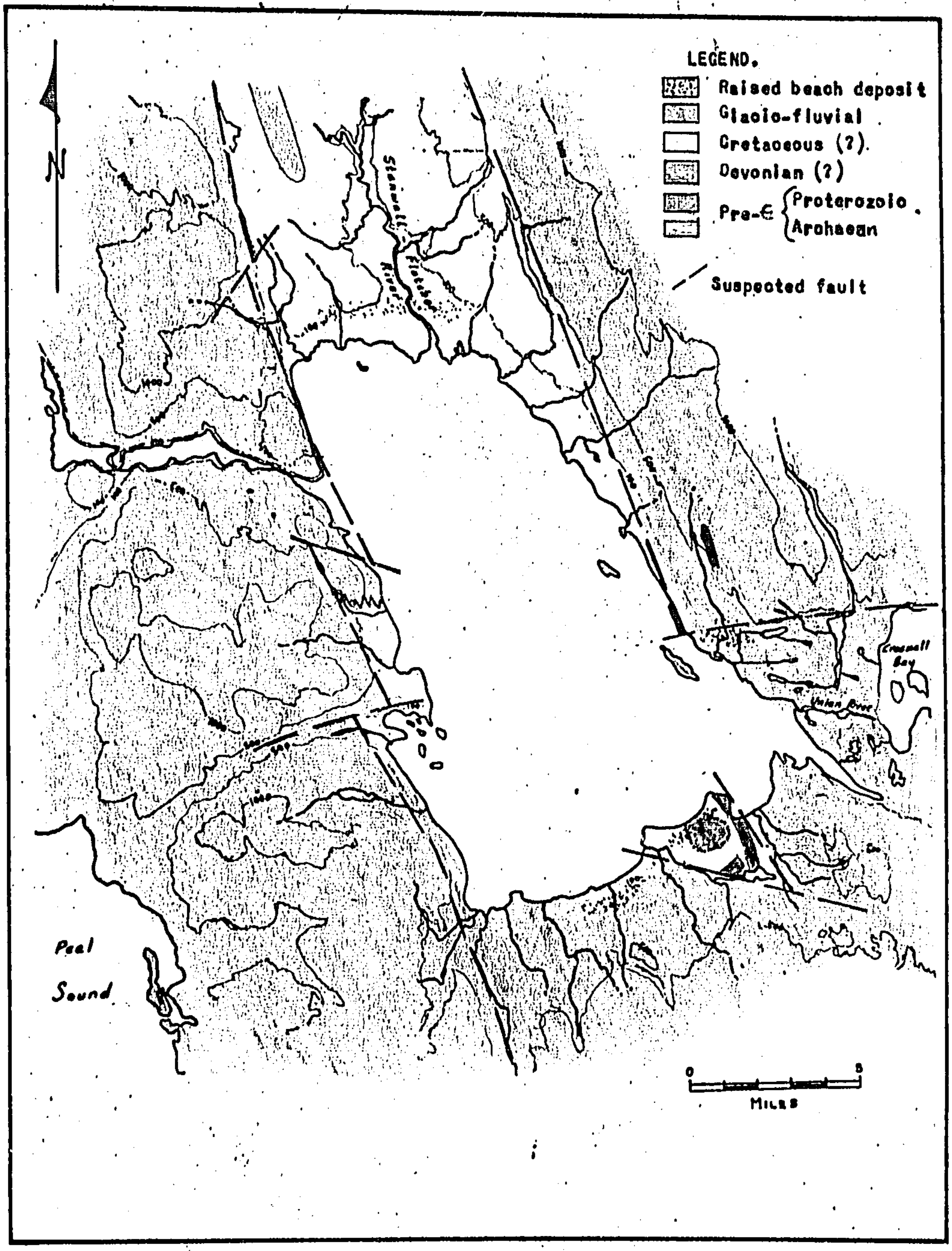

Figure 2: Geological map of the Stanwell-Fletcher Lake basin.

Distribution of Rock Types

Stanwell-Fletcher Lake is situated near the eastern margin of the Boothia Arch, a northward extension of the Canadian Shield, and adjacent to tilted Palaeozoic rocks (Fig. 2). The Precambrian rocks of the arch surround the lake except to the north where Cretaceous (?) sandstones outcrop. These rocks also outcrop on the west shore of the lake. To the south is a small area (coloured brown on Fig. 2) of interbedded, unconsolidated sands and silts. These are interpreted as glaciofluvial deposits, probably of the kame type, showing cross-bedding and channel scour. Current direction studies on cross-lamination dips indicate that flow was toward the north. To the east of these beds is a band of dolarenite, believed to be of the Proterozoic (?) Hunting Formation. This rock type also outcrops near the east shore of the lake as an outlier in the crystalline basement rocks. Also outcropping in the "wedge" to the south is a small section of reddish sandstone and shale. (coloured green in Fig. 2) lithologically similar to the Devonian Peel Sound Formation.

The rocks underlying most of the area immediately adjacent to the shore of Stanwell-Fletcher Lake are masked by delta deposits and the weathering products of raised marine beaches. These beach deposits are discontinuous in lateral extent around the lake, and reach an elevation of over 100 feet to the east of the lake.

Petrology

As the petrology of the surrounding rocks is very important, particularly in determining the provenance history of the lake sediments, the pertinent characteristics of the former should be noted.

The Precambrian basement rocks are Archaean in age, and comprise gneisses and granites. These are cut by several large gabbroic intrusives. The spatial relationships of these types within the Stanwell-Fletcher Lake area is not clear. However, from limited information, the approximate composition of these rocks may be stated as follows:

a. Quartz ranges from abundant in the granites to very low in some of the gneisses. Practically all quartz crystals show undulose extinction.

b. The feldspars are variable in abundance and type.

c. The mafic minerals are almost equally divided between amphiboles and clinopyroxenes, with lesser biotite.

d. Accessory minerals include ubiquitous magnetite, sphene, garnet, epidote, and zircon.

(Personal communication, J. Giguere)

The Cretaceous (?) rocks are composed mostly of friable, buff-coloured quartz sandstone with a thin, poorly-exposed underlying shale succession. Although very mature in composition (more than 90% quartz), and very well sorted, (average graphic standard deviation- 0.38ϕ), the grains comprising the sandstones are almost entirely angular. Besides quartz, there are varying amounts of garnet, perthite, and zircon. Adundant goethite and hematite occur as grains and also as secondary veins (personal communication, B. R. Rust). The shales are entirely composed of nearly equal proportions of kaolinite and illitic clays*. Also present in these rocks are carbonized plant fragments, spores, and derived vertebrate fragments (Personal communication, U. Mayr, D. L. Dineley).

Raised marine beaches

Raised marine beaches are the other major source of sediment for the lake and are predominantly composed of sand-sized quartz grains. Although most of the grains are angular, there is a significant amount of rounded ones, in contrast to the Cretaceous (?) sandstones from which they were apparently derived. The fossils found in these deposits are mostly marine bivalves, gastropods, echinoid fragments, and ostracods. Foraminifera are rare or absent. Plant remains and spores are also found.

The other geologic entities, e.g., the small outcrops of Devonian (?) and Proterozoic rocks, are of little direct importance and their contributions will be mentioned only where relevant.

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* R. S. Dean, personal communication

Structural geology

Linear topographical features are abundant within the Precambrian outcrop. Some are due to differential erosion along faults, but others are probably controlled by joints or foliation. They trend mostly northwest to southeast but there are some transverse to that direction (Fig. 2). No precise information is available as to the attitude of the suspected faults or to the displacement along them, but field relationships suggest that the west side of the Cretaceous (?) block was downthrown relative to the Precambrian. It is likely that the eastern margin of the Cretaceous (?) outcrop is a similar fault, so that the lake lies in a graben, partly filled by Cretaceous (?) rocks. Owing to the lack of a marginal coarse facies, the displacement of the Cretaceous (?) itself by faults, and paleocurrent data (personal communication, B. R. Rust), it is believed that faulting took place subsequent to deposition of the Cretaceous (?) rocks.

Geomorphology

Two factors appear to have influenced the topography: the nature of the bedrock, and glaciation. The basement rocks mostly form highlands whereas the area underlain by sedimentary deposits is in most cases low-lying and subdued. This is especially noticeable along the west shore of the lake where a fault-line scarp separates the Cretaceous (?) lowland from basement rocks and rises to 600 feet in elevation.

The effects of glaciation are manifested mostly in the flat, regular highlands showing "roches moutonnées" to the east, and kames to the south of the lake. The lake bottom profile also suggests glacial scour.

The preservation of a considerable area of upland surface indicates that rapid erosion is limited to the steep, narrow valleys where youthful streams are engaged in downcutting during summer. This may be a result of the significant isostatic uplift of the area since Pleistocene times. This statement is borne out by the presence of many strandline and beach deposits now exposed at elevations of up to 150 feet above sea level in the vicinity of the lake. In most cases, these features take the form of obscure, shell-littered terraces.

Post-Pleistocene isostatic uplift has been an important factor in the recent history of the area. Uplift occurred as a result of the melting of the Pleistocene ice sheet and directly caused the transformation of the Stanwell-Fletcher Lake area from a marine bay to an isolated lake basin, cut off from Creswell Bay by a low lying, 2 mile wide area of land, over which the Union river flows (Fig. 2).

To try to establish the time of occurrence of this marine retreat, radiometric age determinations using pelecypod shells collected from raised beach deposits of differing elevations in various parts of Somerset Island were compiled (Table 2).

Table 2

Radiometric age determinations in the vicinity of Stanwell-Fletcher Lake

Location	Elevation (ft.)	Age (yrs. b.p.)★
* Aston Bay, north Somerset Island	390-400	9380-180
* Lang River, east Somerset Island	418	9180-170
** Four Rivers Bay, immed. west of Stanwell-Fletcher L.	100	7150-350
*** Peel Sound, immed. west of Stanwell-Fletcher Lake	71	6000
*** Stanwell-Fletcher River	152	7750-140
*** East shore, Stanwell-Fletcher Lake	85	7890-140

From these results it is possible to plot an altitude/time chart (Fig. 3). This gives some idea of the rate of uplift in the area, and thus indirectly sheds light on the age of the lake. The only determination from the raised beaches at Stanwell-Fletcher Lake must be disregarded because it is anomalously high and most likely does not represent the strand-line deposits at that elevation.

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* Dyck and Fyles, 1964

** Olson and Broecker, 1961

*** B. Craig, personal communication

★ before present

It can be seen that the rate of uplift was not uniform but was rapid at first and then decreased with time. However, the approximate age of the lake might well be deduced from the altitude/time curve. In order for a marine or quasi-marine influence to be active in the area now occupied by Stanwell-Fletcher Lake, the land would have to be at least 35 ft. lower than it is at present. This figure comprises 25 ft.,which is given as the present elevation of the lake above sea-level (see topographic map sheet 58B, District of Franklin); in addition to a minimum of 10 ft. to allow for down-cutting by the Union River since uplift isolated the lake from the sea. Above 35 ft. below the present land elevation, the marine influence would have been effectively ruled out and the lacustrine influence would dominate. Thus, using the altitude/time curve it is seen that a point 35 ft. above the present sea-level corresponds to an age of 4,100 years before present. This represents a minimum age for the lake, and depending on the figure chosen for the amount of down-cutting, it could be brought as high as 5,000 years before present.

PHYSICAL LIMNOLOGY

The samples used were collected through the ice of Stanwell-Fletcher Lake after being located on a grid system, the base line of which passes through two islands near the east shore of the lake. Grid lines were laid off at right angles to the base line, generally three stations apart. Stations were located at one mile intervals (Fig. 4). General limnological information is shown on Table 3.

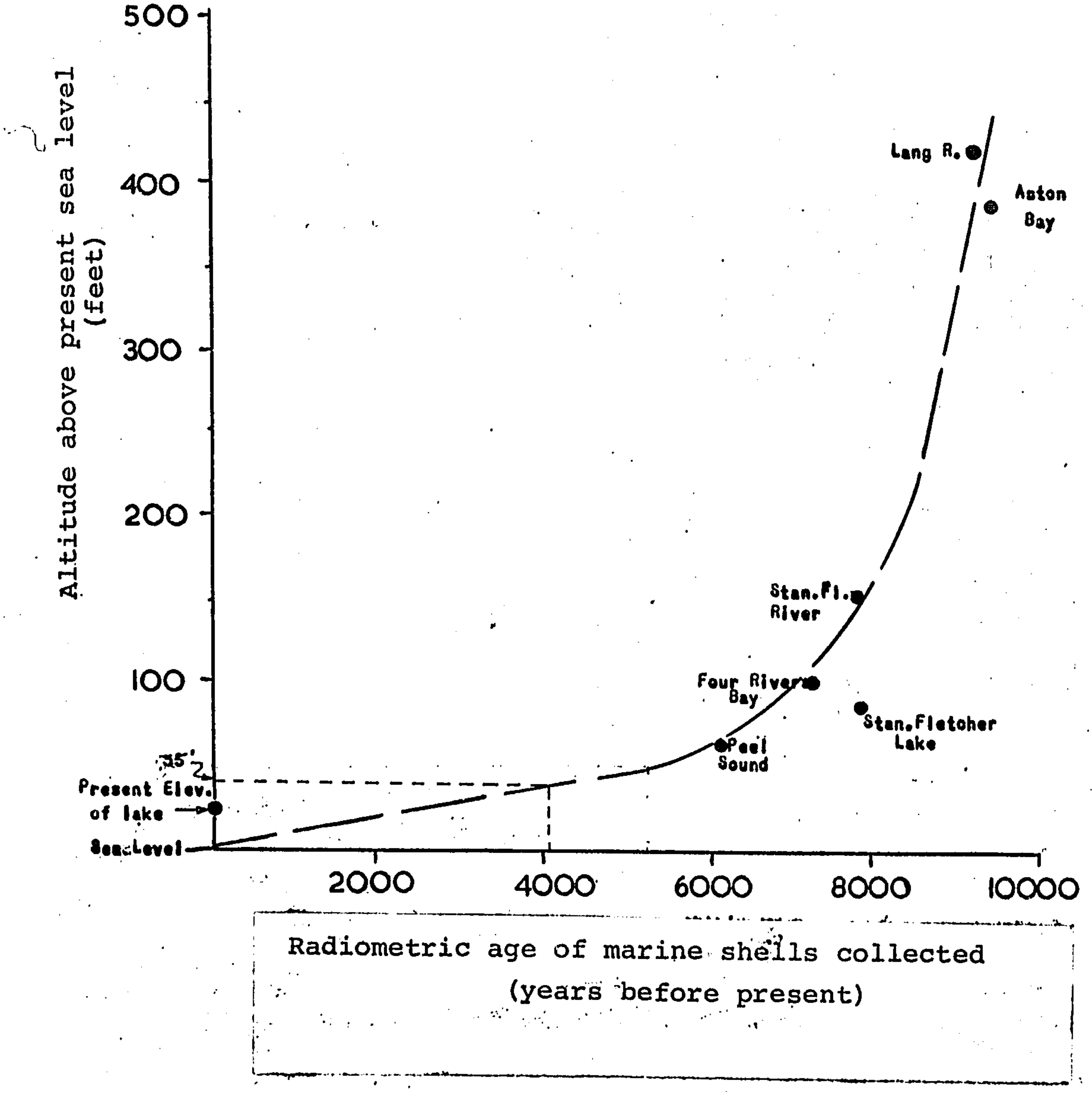

Figure 3: Altitude / time curve plotted from data collected from various parts of Somerset Island.

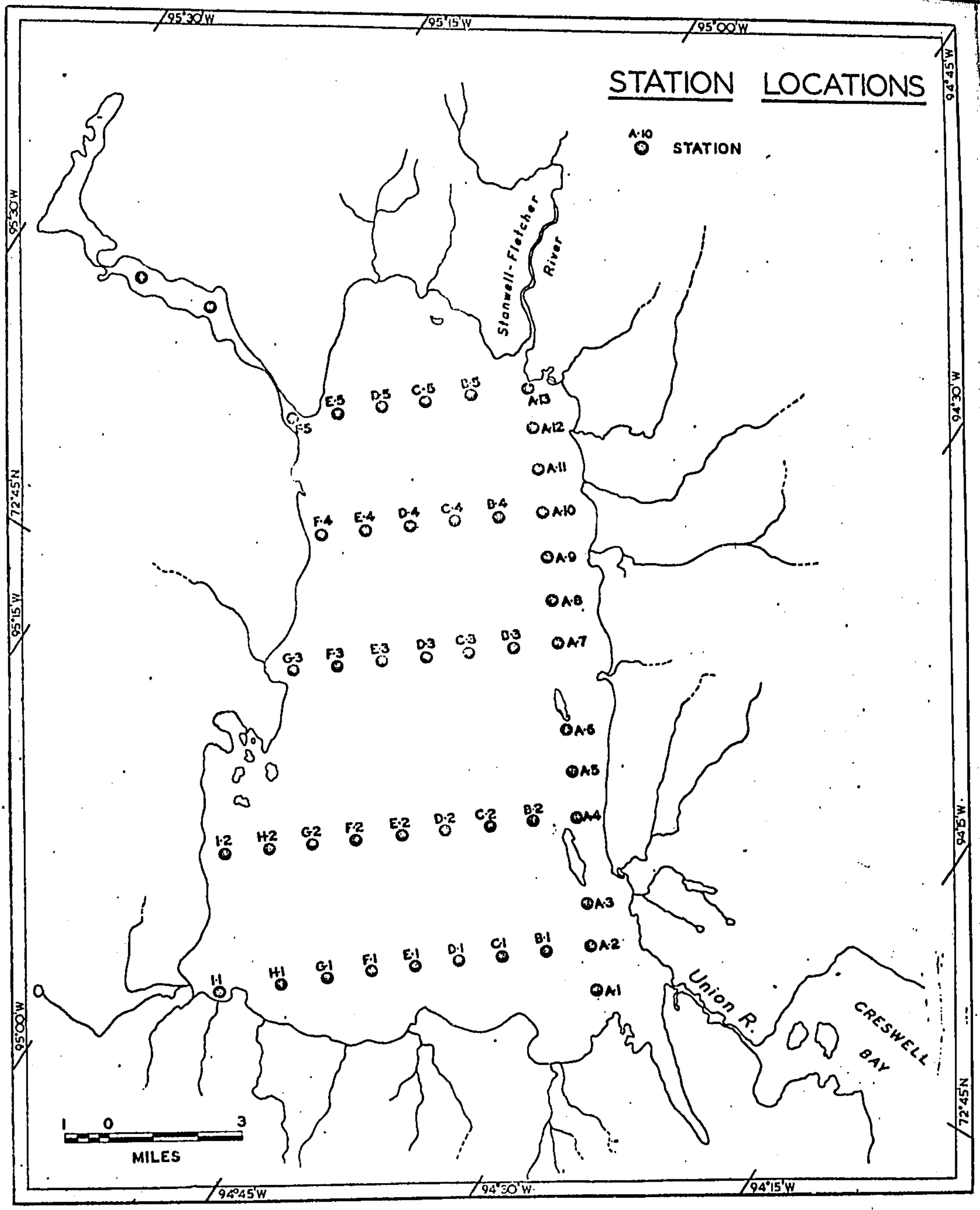

Figure 4: Station locations on Stanwell-Fletcher Lake.

Apparatus and Procedure

The base and grid lines were laid down by means of sight rods. Distances were measured by cyclometer, which was towed behind a snow vehicle[*]. At each station, a hole 20cm in diameter was drilled through the ice with a M-32 power drill. A winch[**] was then set up and a bathythermograph and Knudsen sampling bottle with reversing thermometers were lowered to the bottom. Depth readings were obtained from the winch cable meter and the bathythermograph (an attempt was made to measure depth by a FS-2 portable seismograph, but this was not successful). The apparatus was then raised about 1m and a messenger sent down to trip the Knudsen sampling bottle and reverse the thermometers. After 5 minutes on the bottom, the apparatus was brought up, the bathythermograph slide extracted and labelled, the water sample placed in a clean, rubber-stoppered glass bottle and labelled and the reversing thermometers read and recorded. A Phleger gravity corer was then lowered to within 5m of the bottom and allowed to free-fall from that height. On raising the corer, the sample was held by a retainer in the plastic core liner. The liner containing the core was then capped at both ends, labelled and stored. The

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[*] Snow Cruiser loaned by Outboard Marine Corporation (Canada) Ltd.

[**] Designed by Mr. H. Serson, D.R.B.

last operation was the lowering of the cell of the portable salinometer to record temperature, salinity, and conductivity at 10m intervals. This instrument was presumed reliable until malfunction developed in mid-June and its use was discontinued.

Ice conditions

In view of the low average temperatures for the area and the high incidence of extensive cloud cover (see Table 1), it is not surprising that according to all available information, Stanwell-Fletcher Lake is at least partly ice-covered all year round. In 1965, the ice-cover started to deteriorate visibly around June 15th when the influent rivers were swollen with melt-water. This water, for the most part, at first flowed out over the ice, melted the overlying firn, and seeped down through cracks, producing a very rough, though water-free, surface. Later on, when the shore near the river mouths became ice-free, no further change occurred except slow wastage from the sides of the ~~new-~~then-candled ice. Ice thickness showed little change, from an average of 2.5m in May to 2.0m in July. In August, when the field season ended, only about 5% of the lake surface was ice-free, almost entirely along the north and east shores.

Bottom Topography

It was originally intended to make numerous depth measurements with a portable seismograph, but due to lack of success with this instrument, depth readings had to be restricted to

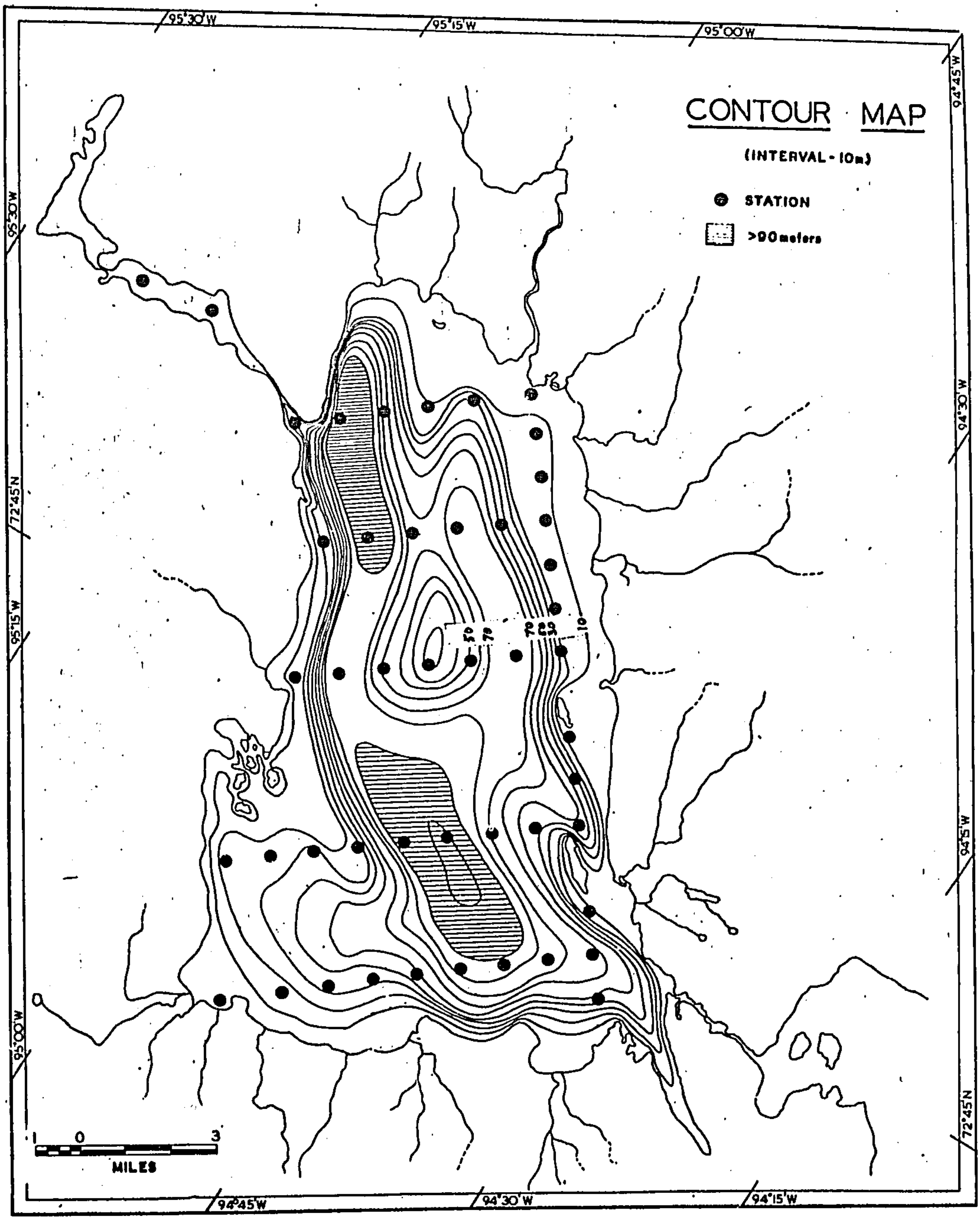

Figure 5: Bottom topography of Stanwell-Fletcher Lake.

the sampling stations - 1 mile apart(Table 3). However, a reasonably accurate presentation of the bottom topography of the lake was obtained and several features should be noted (Fig. 5).

The deepest part of the lake (deeper than 70m) is a sinuous trough, U-shaped in section, which branches around a raised feature in the center of the lake. The deeper arm of the trough (80 - 100m) occurs near to, and roughly parallel to the west shore, with a steep shoreward slope on the west side. The two branches of the trough are separated by a fairly high underwater ridge. The deep area curves toward the Union River and Creswell Bay to the southeast. In the southwest corner and also along the northeast shore of Stanwell-Fletcher Lake, the contours indicate a marked shelf above a depth of 20m.

Salinity

Salinity was investigated because it was suspected that the lake might be meromictic, i.e. having a layer of denser saline water along the bottom. Readings were taken with a portable salinometer at 10m depth intervals at all stations. The salinity readings varied from 0 to 0.1 parts per thousand (‰). This figure approaches the lower accuracy limit of the instrument so it serves more as an indicator of the range of salinity in the lake rather than as an absolute measure. No significant vertical or lateral variation was noted.

In addition, water samples collected from the bottom of the lake were analysed at the Industrial Waters Section of the Department of Mines and Technical Surveys (Table 4). There was insufficient water to carry out all the tests on each sample, so

Sample Number	Depth (meters)	Specif. Conduct.	Dissolved Salts (ppm)				
			Na	Ca	Mg	Cl	Hard.
A-6	10.4	93.0	5.1				
A-7	22.4	88.6	4.8				
G-1	37.8	85.9	4.6				
E-3	59.2	84.7	4.6				
F-3	82.9	83.4	4.5				
D-2	103.7	84.0	4.7				
A-11	11.7	88.1	4.7				
A-4	20.0	85.8	4.7				
F-1	36.8	85.9	5.1				
A-2	60.1	83.9	4.8				
D-1	87.7	84.3	4.7				
C-1	88.1	84.9	4.7				
Composite Sample	16.1			7.5	3.2	7.6	31.8
Comp. Sample	48.5			7.4	2.9	7.4	30.3
Comp. Sample	90.6			7.1	2.9	7.5	29.8

Table 5: Water chemistry of Stanwell-Fletcher Lake.

in the analyses requiring a greater volume, composite aliquots based on the sampling depth were used. H.M. Woodroffe[*] reported:

> "... the variation in specific conductance (mineral content) and sodium at the various depths and sample locations is insignificant ... within sampling and experimental error."

about the composite samples:

> "These composites show little significant differences in total hardness, calcium, magnesium, and chloride content. There is perhaps a slight drop in total hardness with depth but all waters are classed as very soft."

The above data completely negate the belief that the lake is meromictic. Also, the lack of chemical stratification or restricted bottom conditions imply efficient circulation of the bottom waters.

Thermal data

The thermal data collected consist of bottom temperatures measured by reversing thermometers and temperature/depth curves obtained from a bathythermograph. The reversing thermometer readings (Table 3) on the bottom and bathythermograph traces for all the stations are seen in Fig. 6, 6a. The conclusions drawn are as follows:

a. Below a depth of 20 m there appears to be a direct linear relationship between bottom temperature and depth, taking the lake as a whole. Nevertheless the bottom temperature varies very little, i.e. about 1.3 to 1.5°C (Table 3).

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[*] Chief, Mineral Processing Division

Table 3: Physical information at Stanwell-Fletcher Lake stations.

...cation		Date Occupied	Ice Thick. (m)	Total Depth (meters)	Bottom Salinity (‰)	Bottom Temp. (oC)
.W	Lat.N					
0'	72°42'	18th.May	2.75	49.4		1.34
3'	72°43'	19th.	2.9	60.1		1.40
5'	72°45'	20th.	3.2	16.2		1.26
8'	72°47'	20th.	2.9	47.0		1.30
0'	72°49'	21st.	3.05	33.6		1.38
2'	72°50'	21st.	2.6	10.4		1.04
5'	72°51'	23rd.	2.75	22.4		1.34
5'	72°42'	24th.	2.75	73.6		1.48
8'	72°42'	26th.	2.75	88.1		1.46
'	72°41'	26th.	2.9	87.7		1.49
2'	72°41'	27th.	2.75	47.1		1.37
'	72°40'	28th.	2.9	36.8		1.43
'	72°40'	28th.	3.05	37.8		1.38
'	72°39'	29th.	2.9	15.7		1.39
'	72°39'	29th.	2.45	[illegible].8		-
'	72°46'	30th.	3.2	42.2		1.38
'	72°45'	4th.June	2.9	69.3		1.47
'	72°44'	4th.	2.75	103.7		1.53
'	72°43'	5th.	3.05	90.4		1.48
'	72°42'	5th.	2.9	24.4		1.04
'	72°41'	6th.	2.9	36.9		1.30
'	72°40'	6th.	2.45	22.1		1.16
'	72°39'	7th.	2.75	20.7		1.36
'	[illegible]	[illegible]	[illegible]	[illegible]		1.44
'	72°50'	9th.	2.9	[illegible]		1.41

Stn. No.	Location		Date Occupied	Ice Thick	Total Depth (m)	Bottom Salin'y	Bottom Temp.
	Long.	Lat.					
D-3	94°53'	72°49'	11 June	2.75	25.8		1.40
E-3	94°55'	72°48'	11th.	2.75	59.2		1.41
F-3	94°57'	72°47'	11th.	2.6	82.9		1.47
G-3	94°59'	72°46'	12th.	2.6	18.0		1.34
A-8	94°47'	72°53'	12th.	2.75	18.7		1.38
A-9	94°49'	72°54'	12th.	2.75	16.3		1.34
A-10	94°51'	72°55'	12th.	3.05	12.8		1.28
B-4	94°53'	72°55'	15th.	3.2	48.4		1.39
C-4	94°56'	72°54'	15th.	2.75	78.5		1.50
D-4	94°58'	72°53'	16th.	2.6	62.4		1.43
E-4	95°00'	72°52'	16th.	2.75	90.6		1.52
F-4	95°02'	72°51'	16th.	2.75	24.4		1.39
A-11	94°53'	72°56'	19th.	2.75	11.7		1.32
A-12	94°55'	72°58'	19th.	2.9	13.0		1.29
B-5	94°59'	72°58'	1st.July	2.45	32.5		1.54
C-5	94°01'	72°57'	1st.	2.3	11.7		1.53
D-5	94°03'	72°56'	1st.	2.3	61.7		1.47
E-5	94°06'	72°55'	2nd.	2.15	97.7		1.58
F-5	94°08'	72°54'	3rd.	2.75	25.8		1.53
A-13	94°57'	72°59'	19 June	-	0.8		-

b. The only surface temperatures recorded were under the ice using the bathythermograph (Fig. 6a) and were all at or near 0°C. The ice-free margins are expected to have a higher temperature, but due to the limited extent of open water, the average surface temperature is presumed to remain below 4°C.

c. The temperature/depth curves for any one station traced by the bathythermograph show that below 10m the lake water is almost completely isothermal. The temperature variation below this depth is less than 0.2°C (Fig. 6).

It can be seen that Stanwell-Fletcher Lake falls into the cold monomictic category of Hutchinson (1957) in which summer circulation is short or absent with the possible exception of warm summers when the lake may become ice-free and summer warming might occur and produce overturn. However, there is no evidence that the lake ever becomes totally ice-free. Therefore, it conforms more closely to the type described by Ruttner (1940) as follows:

> "In the Arctic there is another type ..... (which) .. is frozen throughout almost the entire year and does not reach a stable condition of direct stratification by warming in the short period it is ice-free. The state of these lakes thus varies between winter stagnation and total circulation."

It appears that the major agent of circulation would be the warmer, denser water from the influent streams and from the ice-free, wind-agitated sides flowing along the bottom and displacing the colder less dense water in the deep areas. The fact that the wind action is restricted to the ice-free northeast shore may affect circulation in the rest of the lake through the development of internal seiche waves, caused by oscillation of the lake's

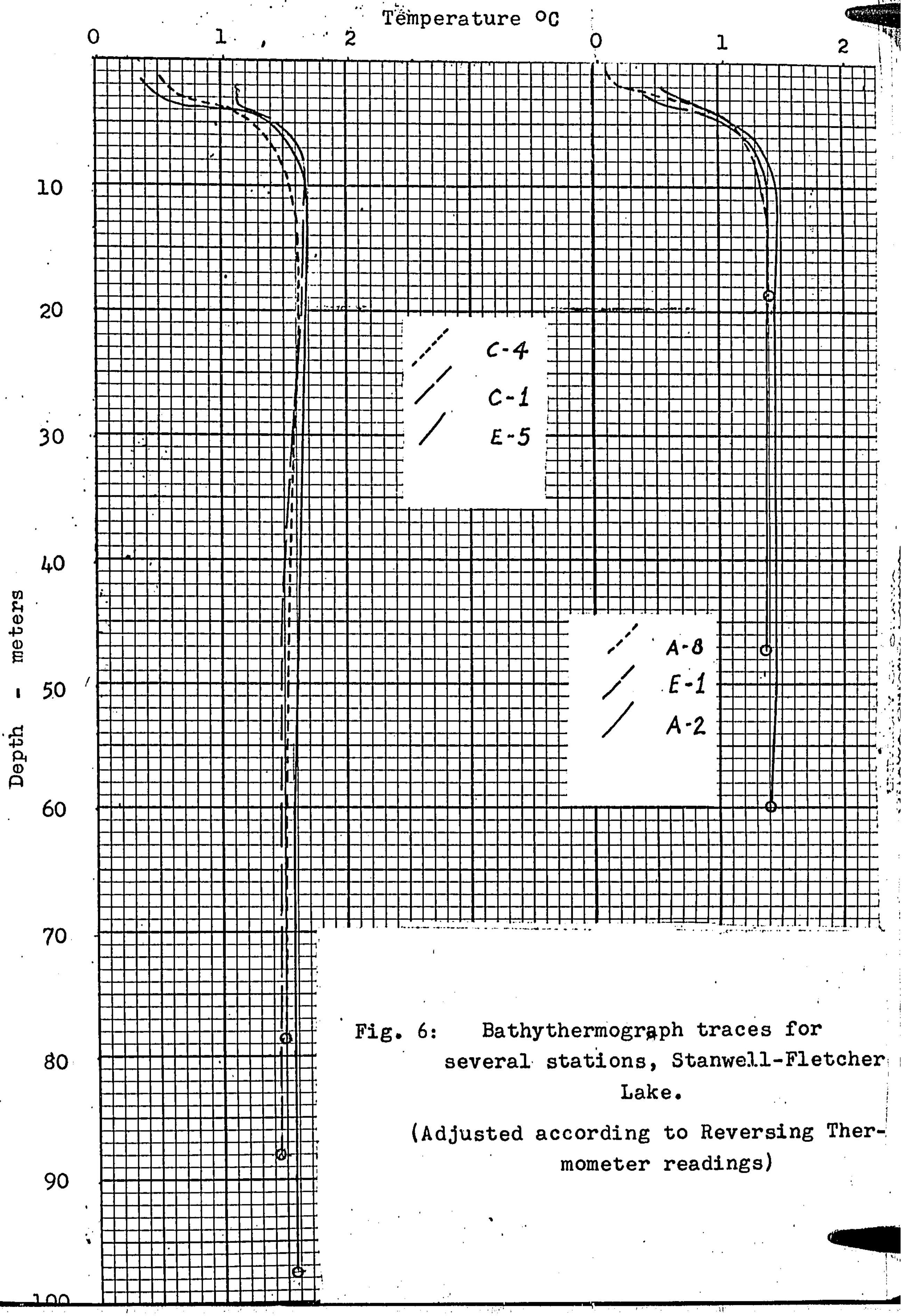


Fig. 6: Bathythermograph traces for several stations, Stanwell-Fletcher Lake.

(Adjusted according to Reversing Thermometer readings)

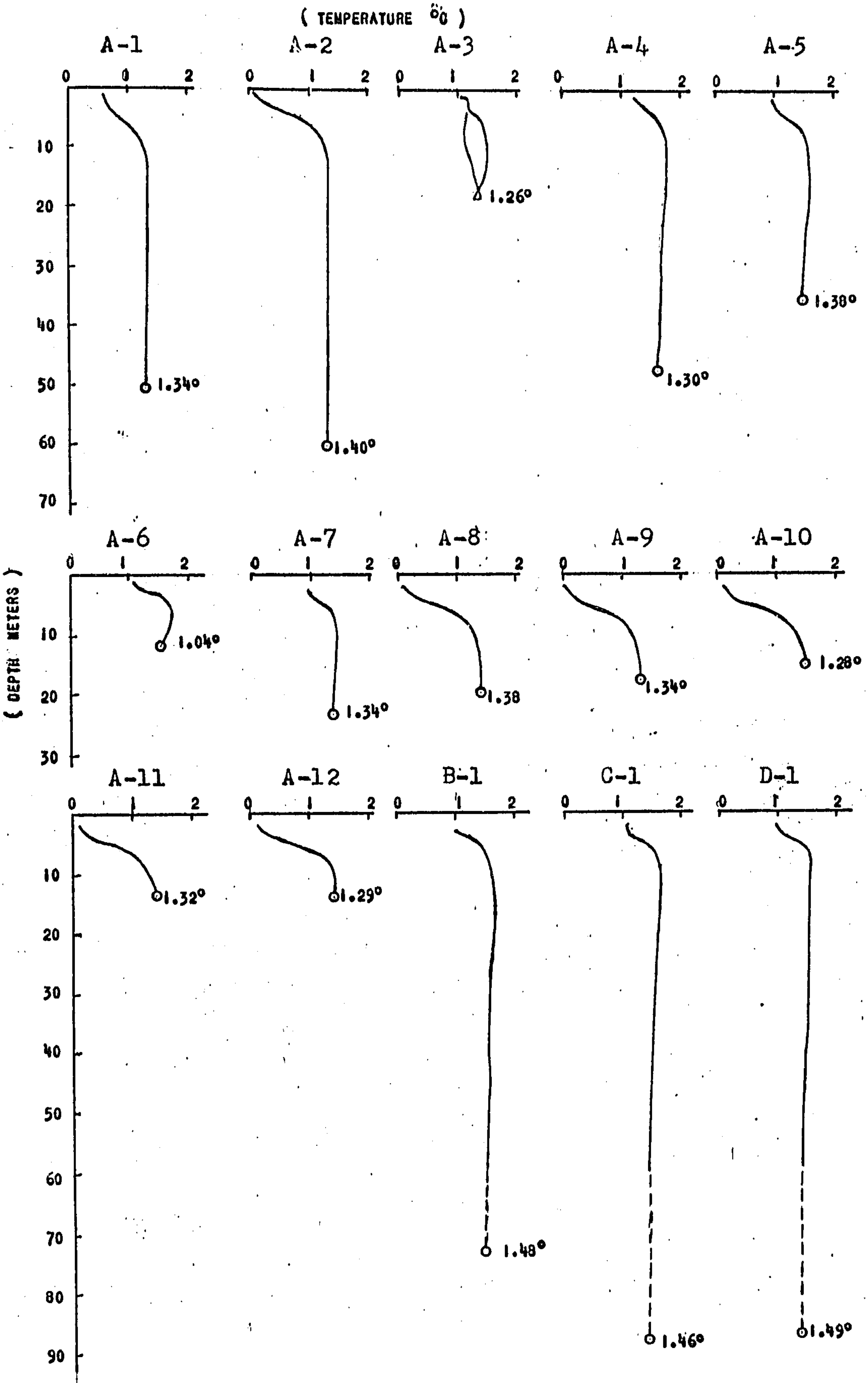


Figure 6a: Bathythermograph traces for remaining stations, Stanwell-Fletcher Lake, with reversing thermometer readings at bottom.

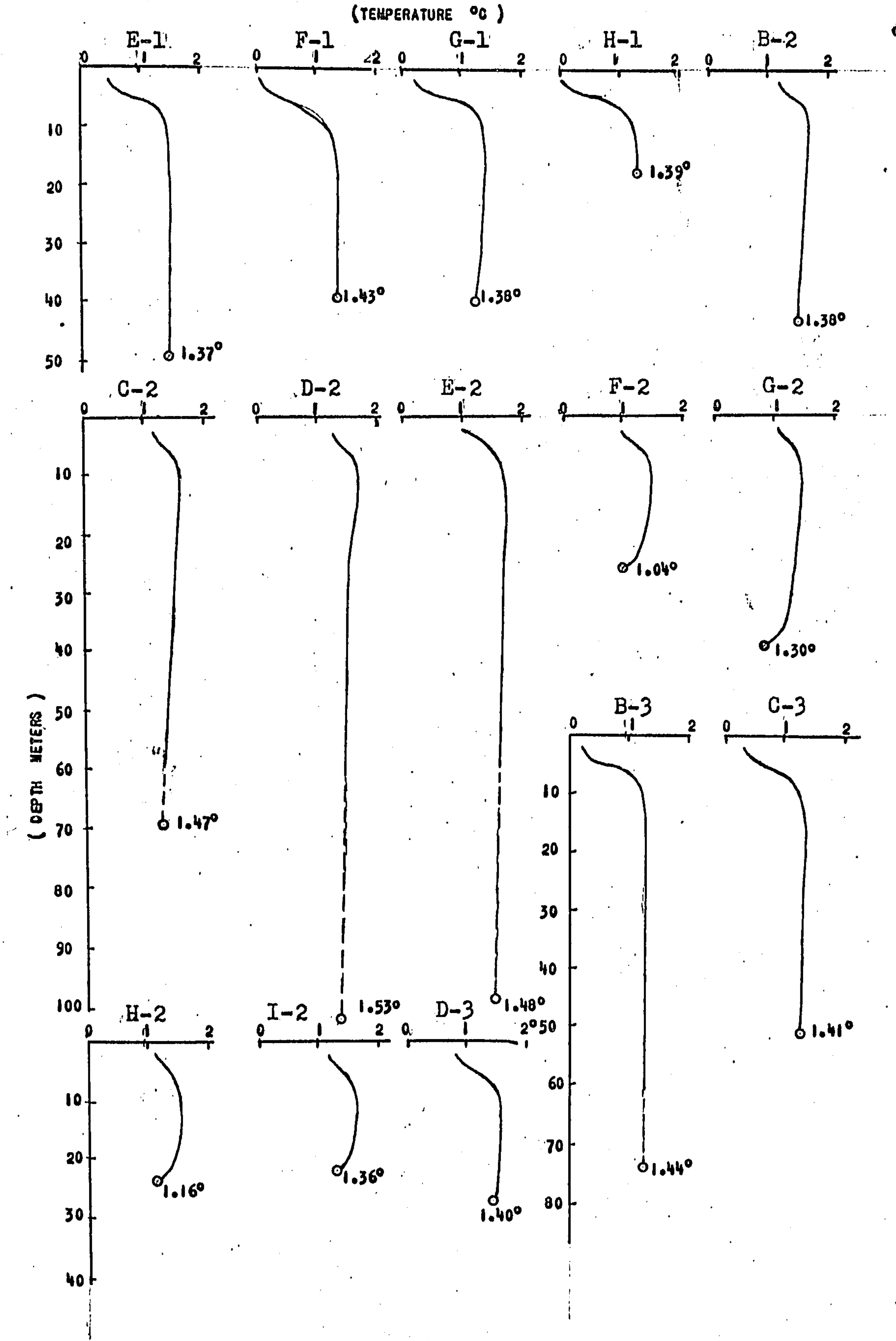


Figure 6a: (continued)

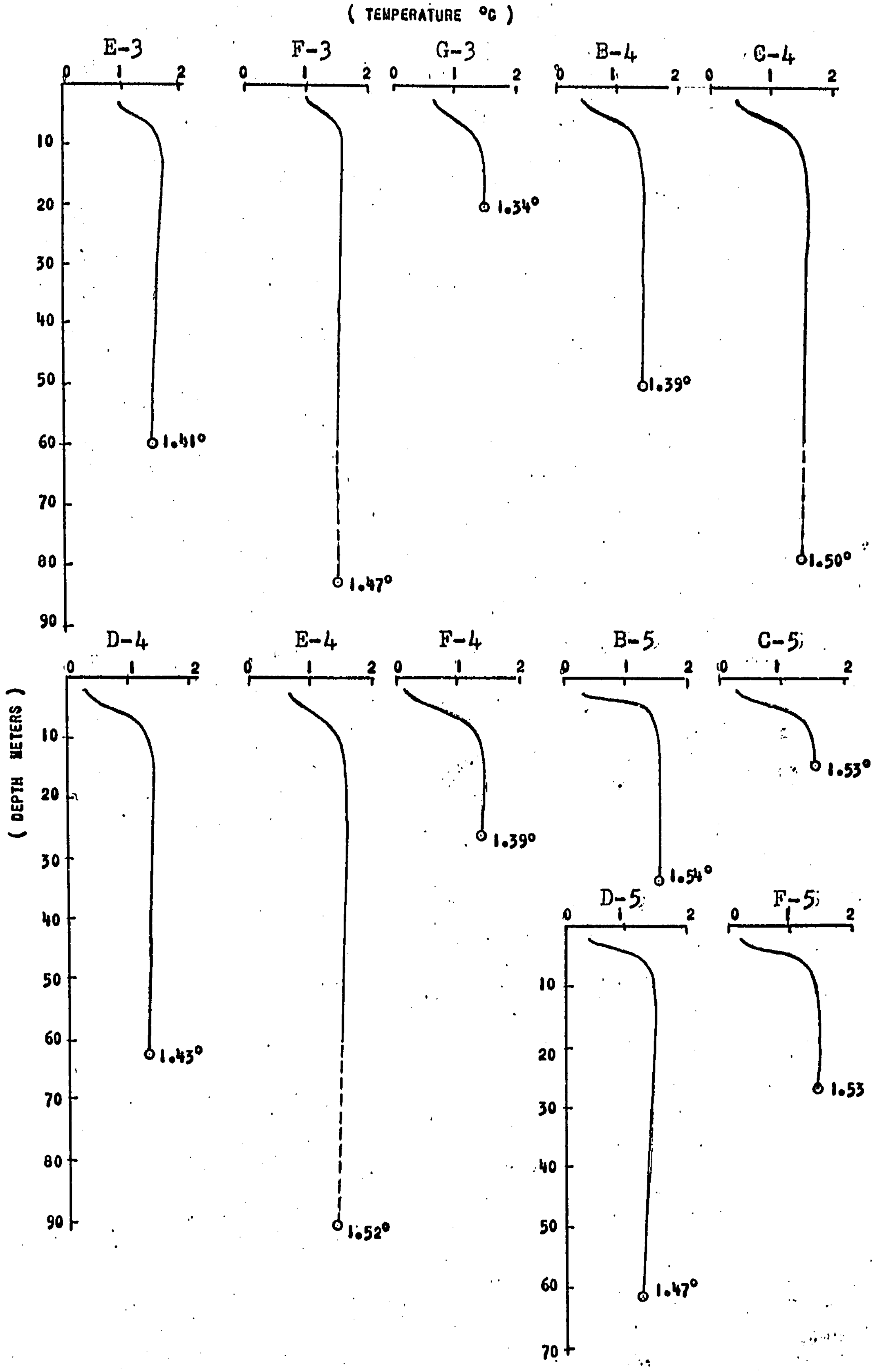


Figure 6a: (continued)

surface due to uneven pressure (Hutchinson, 1957). However, in spite of the ice cover, complete circulation can probably be achieved without difficulty due to the virtual lack of any density stratification in the water. Fig. 7 illustrates the relationship between water temperature and density, and it is seen that density differences within the range of the temperatures encountered are minimal.

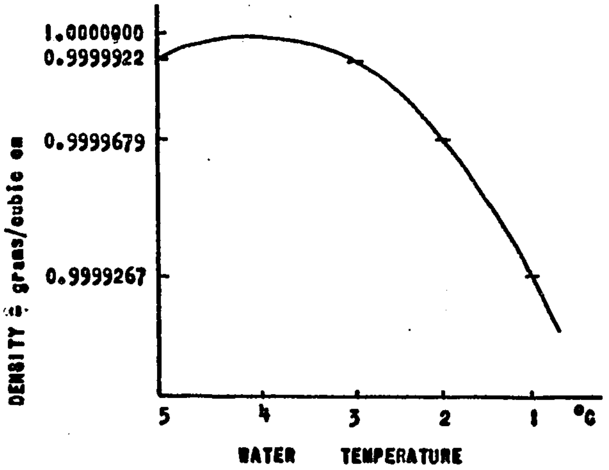


Figure 7: **Thermal characteristics of water at low temperatures. (Plotted from data in Deane, 1960)**

A calculation of the heat budget of Stanwell-Fletcher Lake has not been attempted because of the limited data. However, insofar as the biologic productivity in the lake is concerned, it must be noted that the presence of very pure and soft water at the bottom of the lake (even in the stagnating winter periods as represented by the observations in May) seems to preclude the possibility of intense biologic activity. The only animals noted were Arctic Char in the ice-free portion of the lake in July. The biologic aspect will be investigated more closely in the section on bottom sediments.

SUMMARY

The following is a summary and synthesis of the data in hand.

The events leading to the origin of the Stanwell-Fletcher Lake basin were initiated by the post-Cretaceous development of a graben-like structure in the area. This resulted in the presence at the lake basin site of a basement low, in which a downthrown block of Cretaceous (?) rocks was preserved.

However, the major agent in the formation of Stanwell-Fletcher Lake proper was the action of the glaciers which covered Somerset Island in Pleistocene times. It is believed that the lake basin was formed as a result of glacial scour, primarily of the portion underlain by the soft Cretaceous (?) rocks. The restriction of the lake to the outcrop area of these rocks, and the U-shaped profile of the lake bottom supports this contention. The raised feature in the center of the lake is believed to be an inlier of the more resistant basement rocks, probably a continuation of the basement outcrop feature that extends southwards in the northern portion of the area (Fig. 2). The difference in resistance to glacial scour is also evidenced by the deepening of the lake to approximately 350 feet below the elevation of the "sill" separating the lake from Creswell Bay. Ice movement was hindered by the up-faulted basement rocks to the west.

When the Wisconsin Laurentide ice sheet melted, 7,270 - 11,340 years ago (McCulloch and Taylor, 1965), the ice retreated toward the south, and marine invasion took place in the areas vacated. In the southern part of Somerset Island, the marine deposits of this stage occur up to 520 feet above present sea level. Subsequent isostatic rise of the land slowly eliminated the marine influence in the Stanwell-Fletcher Lake area, as evidenced by the progressively lower marine deposits.

What happened next is not so easily determined. From about 4,000 years (page 18) before present to the present time, the major change in the lake basin has been the replacement of saline by fresh water. The present lacustrine state must have succeeded the marine only after a transitionary, intermediate period of embayed or estuarine conditions with free connection with the sea over a progressively shallowing sill (Pickard 1964, page 180). When this sill became a barrier, the salinity in the lake thus formed must have been much higher than that at present. Two alternative mechanisms can be advanced to explain the transformation of the lake from saline to its present fresh condition:

a. Flushing, through the displacement of the saline bottom water by sediment-laden and therefore denser river water.

b. Dissipation and dilution of the saline water in the lake through efficient circulation.

Although the latter seems more credible, with the information available, any further commitment would be purely speculation. A more complete re-construction of the history and development of the lake is presented in Chapter IV.

CHAPTER III

THE LAKE BOTTOM SEDIMENTS

INTRODUCTION

Examination of the sediments was carried out on cores, or on bulk samples if cores were not available (for collecting procedure see page 21). Length of cores, colour, sedimentary structures and approximate grain size were noted in the field. Although some three months elapsed between the collection and the analysis of the samples, there were no apparent gross changes except for minor shrinkage. Textural analysis was carried out on the surface portions of all cores. However, in view of the limited time mechanical, chemical, palaeontological and palynological analyses were undertaken only on samples selected for their suitability for the analysis concerned. The details of these will be outlined more fully in subsequent sections.

It is unfortunate that for the most part the cores taken by the Phleger corer were rather short, ranging from 5 to 50cm in length.

PHYSICAL DESCRIPTION OF CORES

Photographs of selected typical cores taken from the bottom of Stanwell-Fletcher Lake (Plates 1 and 2) show that in general the sediments lack dramatic structural features. However, significant comment can be made on the basis of their colour and the structural features shown. In cases where a bracketted suffix or other qualifiers is omitted, surface position is assumed.

Colour

The colour of the surface layers varies very little from core to core.

It can be classified as moderate brown ($5YR^4/4$) to moderate yellowish brown ($10YR^5/4$) according to the Rock Colour Chart distributed by the National Research Council and the Geological Society of America. In the vertical sense, however, colour variation is considerable. The bottom parts of almost all the cores are olive gray ($5Y^4/1$, $5Y^5/2$), to dark gray. In some, the dark gray areas appear as irregular patches. No colour chart was available at the time of sampling but the dark portions appeared to become lighter with time. The boundary between the gray and brown sediment is generally gradational, but in some cases is quite abrupt and occurs at a depth of from 5 to 20cm. (Plates 1,2).

Also noteworthy and occurring in several cores is a thin layer (not more than 1cm in thickness) near the top of the cores, of nodular, rusty orange ($5YR^5/6$) material, suggesting limonite coating.

Discussion

The phenomenon of dark grayish sediment underlying brown material has been described by Carsola (1954) in samples from the shelf of the North Polar Sea. He explained this as being due to the oxidation state of the iron in the sediment: the brown indicating the effect of oxidizing conditions, and the darker portions due to reduction brought on by burial,

Bøggild (1904) ascribed a similar case in the North Polar Sea to the reverse effect: gray, ferrous sediment deposited and afterwards oxidized to brown ferric in the uppermost portions due to a slow rate of sedimentation. Predominantly gray cores are thus obtained if the rate of sedimentation was sufficiently high for little oxidation to take place, either during settling or on the bottom. In the Stanwell-Fletcher Lake material, this latter explanation is unlikely, mainly because the lack of relatively coarser material or corresponding sedimentary structures in the gray portions indicates slow deposition.

Bøggild also described the precipitation of limonite on pebbles on the bottom of the sea by bacteria probably aided by organic matter. This seems to be a likely explanation of the nodular, thin limonite layers noted in the Stanwell-Fletcher Lake cores. These layers, which show a wide distribution and regular position in the cores might correspond to a period of very slow sedimentation in the lake.

From the colour of the bottom sediments one can conclude that oxidizing conditions have affected sedimentation everywhere in the lake for a considerable time before the present. This ties in well with the evidence of the water analysis (page 26), in which well-circulated, oxygen rich water with very low dissolved solid content is the rule. This coupled with the convincing evidence of very slow settling of the fine particles leaves no doubt that the iron in the sediments was in an oxidized state when deposited, due to long time settling out. The vertical colour variation is thus seen to be due to reducing conditions existing at depth below the mud-water interface. This is also supported by the fact that after splitting and exposure to the air, these dark portions rapidly became brownish in colour. This vertical variation in colour will be also reviewed in relation to the organic matter content in later chapters.

Structures

The structures noted in the cores from Stanwell-Fletcher Lake may be described under the following headings:

Anomalous Inclined Bedding Surfaces

This feature was apparent in several cores, notably H-1, B-5, E-2 and A-1 (Plates 1, 2). Inclination of bedding surfaces up to 25° from the horizontal occurs. Initial dip is unlikely as other bedding surfaces in the same cores are close to horizontal. The most spectacular is H-1 in which an inclined, grayish layer of sand overlies finer, brown sand-silty material. It seems likely that this and most of the others are due to local scour by bottom currents.

Other cores show inclined, irregular as opposed to inclined, planar bedding surfaces (see B-3, Plate 2). This can only be ascribed to loading and/or small scale slumping. The rather gentle slopes of the lake bottom, the low rates of sedimentation, and the lack of coarser sediments in the deeper areas rule out large scale slumping.

Lamination

Contrary to the fairly common belief that lake sediments in a glacial regime are laminated, the sediments of Stanwell-Fletcher Lake are for the most part devoid of this feature. Only a few of the sandy cores from the shallow margins of the lake show anything that can be described as regular lamination. In these, the laminae are mostly vague and are visible only in dried cores and thin sections. Cores B-5, H-1, and G-3 illustrate this feature best (Plates 1, 2).

The bottom sediments of Garibaldi Lake, a glacial lake in the Rocky Mountains, also lack visible varves. Mathews (1956) attributed this to several factors:

a. A low rate of sedimentation.

b. A lag of years rather than months between the introduction of much of the suspended sediments and their deposition on the lake floor.

c. The obliteration of any thin and inconspicuous varves by small scale slumping on the steeper slopes.

Several features in the physiology of Stanwell-Fletcher Lake suggest that similar reasons may be presented to explain the lack of varves there. First, the relative scarcity of large streams and the restriction on their load capacity by the short run-off period preclude a high sedimentation rate. Deane (1960) gave a figure of 2-3 weeks for the period of maximum load in streams on Ellesmere Island. After this time the amount of sediment carried is only a fraction of that at the maximum period. Thus, due to the considerable size and depth of the lake, seasonal variation in sedimentation rate and hence, lamination, would be minimal, and would be apparent only in the coarser marginal sediments where shallow water promotes relatively rapid settling.

Second, the extreme chemical purity of the lake water and its good circulation would make flocculation insignificant and settling out of the finer particles, which comprise the bulk of the sediments, a very slow process, probably entailing a period of years.

Third, some structural features already mentioned in the cores point to the presence of small-scale slumping. Of these three processes, the first two are more likely to be major factors.

Ice-rafted Material

Fragments attributed to transportation by floating ice have been found in five cores: F-5, A-4, B-3, A-1, and A-10. Core F-5 (Plate 1) is a typical example. They range in size from 0.25 to 2.5cm, and are found, with the exception of B-3, in the peripheral sediments of the lake. These pebbles and granules are generally more rounded than the sediments in which they occur.

The rock type represented is usually granite or gneiss, except in A-4 where a large (± 2cm) rusty sandstone pebble is found.

MECHANICAL ANALYSIS

After splitting, photographing, and description, the upper layers of all cores were subjected to mechanical analysis. Cores from six widely separated locations were selected for analysis of vertical textural variation.

The sample was weighed dry, and then was wet-sieved through the 4Ø ($^1/16$mm, 250 mesh) Tyler sieve. This process separated the sand from the silt-clay fractions as defined by the Wentworth-Udden scale. The sand fraction was then dried, weighed, and sieved. The portion finer than 4Ø was analyzed by the Pipette method (Folk, 1961). The results were graphically presented on frequency charts, from which prime statistical parameters of the cumulative frequency distributions were obtained. The parameters determined are mean grain size, sorting coefficient (Phi Standard Deviation), and skewness of the distribution (Table 5). The relationship between the various mechanical features of the sediments were illustrated by diagrams, charts and plots.

(Surface) Grain Size Distribution

The surface sediments of Stanwell-Fletcher Lake are relatively fine

Station	Core Length (cm)	Colour	Mean Ø Diam.	Ø Stand. Dev.	Skewness	%Sand	% Silt	%Clay	% Org. Carbon	% Carbonate
A-1	51.5	5YR 4/4	6.93	2.7	+0.185	10.5	55.4	34.1	2.60	
A-2	34.0	"	7.07	2.8	+0.25	11.4	52.7	35.9	2.97	
A-3	No	Core	-	-	-	-	-	-	-	
A-4	34.0	5YR 4/4	5.8	2.8	+0.14	31.9	45.1	23.0	1.05	
A-5	11.0	"	5.3	2.9	+0.24	38.2	43.1	18.7	1.65	
A-6	Bulk	5YR 3/4	3.5	0.72	+0.035	77.5	19.5	3.0	0.88	
A-7	13.0	5YR 4/4	3.6	1.95	+0.18	65.7	27.8	6.5	1.06	0
A-8	42.0	5YR 5/6	4.5	1.95	+0.41	53.4	36.8	9.8	1.72	
A-9	Bulk	10YR 4/2	3.8	1.5	+0.33	66.5	32.2	1.3	1.33	
A-10	14.5	10YR 5/4	4.5	2.1	+0.52	50.7	36.1	13.2	1.17	
A-11	10.2	5YR 4/4	3.5	1.15	0.0	71.9	24.9	3.2	1.61	
A-12	27.7	10YR 5/4	4.5	2.1	+0.29	52.5	40.9	6.6	1.03	
B-1	39.5	5YR 4/4	7.5	2.5	+0.04	7.45	51.6	40.9	3.46	
C-1	35.9	"	7.6	2.75	-0.07	7.45	45.6	46.9	2.82	1.2
D-1	31.0	"	7.7	2.55	+0.04	6.75	47.3	45.9	3.62	
E-1	46.5	10YR 5/4	7.3	2.8	+0.07	9.5	53.5	37.0	2.33	
F-1	35.0	"	6.97	2.55	+0.08	10.8	52.7	36.5	2.70	
G-1	33.0	"	6.37	2.85	+0.175	18.4	50.7	30.9	1.30	
H-1	21.5	"	3.55	1.55	+0.23	70.0	26.5	3.5	1.01	
B-2	13.2	5YR 4/4	6.97	3.2	+0.22	15.6	50.4	34.0	3.49	
C-2	46.0	10YR 5/4	8.03	2.7	-0.04	4.0	44.9	51.1	3.48	
D-2	32.2	5YR 4/4	8.0	2.5	0.0	2.0	47.8	50.2	3.66	

Table 5: Physical and chemical data for sediments of Stanwell-Fletcher Lake.

Station	Core Length (cm)	Colour	Mean Ø Diam.	Stand. Ø Dev.	Skewness	%Sand	% Silt	%Clay	% Org. Carbon	% Carbonate
E-2	32.7	5YR 4/4	7.6	2.4	-0.04	6.0	48.9	45.1	3.10	
F-2	No	Core.	-	-	-	-	-	-	-	
G-2	33.0	10YR 5/4	7.9	2.4	+0.04	4.6	47.4	48.0	2.58	
H-2	10.5	10YR 4/2	5.93	3.2	-0.03	31.7	41.5	26.8	1.48	
I-2	28.0	5YR 4/4	6.63	2.5	+0.04	15.5	54.4	30.1	1.38	
B-3	27.5	"	7.7	2.3	0.0	4.8	49.5	45.7	3.30	
C-3	45.0	"	7.7	2.6	+0.15	4.8	54.2	41.0	3.02	
D-3	No	Core.	-	-	-	-	-	-	-	
E-3	55.0	5YR 4/4	8.2	2.8	+0.02	2.6	45.2	52.2	4.30	1.5
F-3	23.0	"	7.3	2.35	+0.08	6.6	52.1	41.3	2.78	
G-3	27.0	10YR5/4	4.33	1.7	0.0	43.1	55.3	1.6	0.70	
B-4	32.0	5YR 4/4	6.87	3.0	-0.07	17.1	48.0	34.9	2.56	
C-4	23.5	"	7.93	2.75	+0.13	4.5	48.5	47.0	3.04	
D-4	26.5	10YR 5/4	7.57	2.5	+0.04	6.9	49.7	43.4	2.94	1.0
E-4	35.5	"	7.3	2.4	-0.04	6.3	53.8	39.9	2.86	
F-4	Bulk	5YR 4/4	3.93	1.45	+0.45	70.4	29.0	0.6	0.61	
B-5	37.0	10YR 4/2	6.5	2.15	+0.19	10.6	69.8	19.6	2.20	
C-5	No	Core.	-	-	-	-	-	-	-	
D-5	25.5	10YR 5/4	7.7	2.55	-0.08	6.7	46.9	46.4	2.18	2.5
E-5	9.0	5YR 4/4	7.83	2.35	-0.08	2.5	48.0	49.5	3.00	
F-5	26.0	10YR 5/4	6.47	2.9	+0.24	17.4	53.6	29.0	1.50	
D-4(bott)		10YR 4/2	4.67	3.25	+0.12	48.2	34.7	17.1	1.68	23.1

Table 5: (continued)

Station	Core Length(cm)	Colour	Mean ∅ Diam.	Stand. ∅ Dev.	Skewness	% Sand	% Silt	% Clay	% Org. Carbon	% Carbonate
A-1(bott)		5Y 4/1	5.67	2.2	+0.23	21.0	61.8	17.2		18.8
E-3 "		5GY 4/1	6.2	2.8	+0.18	19.2	64.3	16.5		26.9
B-2 "		10YR 4/2	5.5	2.1	+0.48	28.0	56.8	15.2		
I-2 "		5Y 4/1	5.4	2.9	+0.24	36.6	43.6	19.8		
A-4 "		10YR 4/2	4.4	1.35	+0.65	53.2	40.2	6.6		
E-1 "									1.59	
D-2 "									3.57	
F-5 "									3.24	
B-4 "									2.29	

Table 5; (continued)

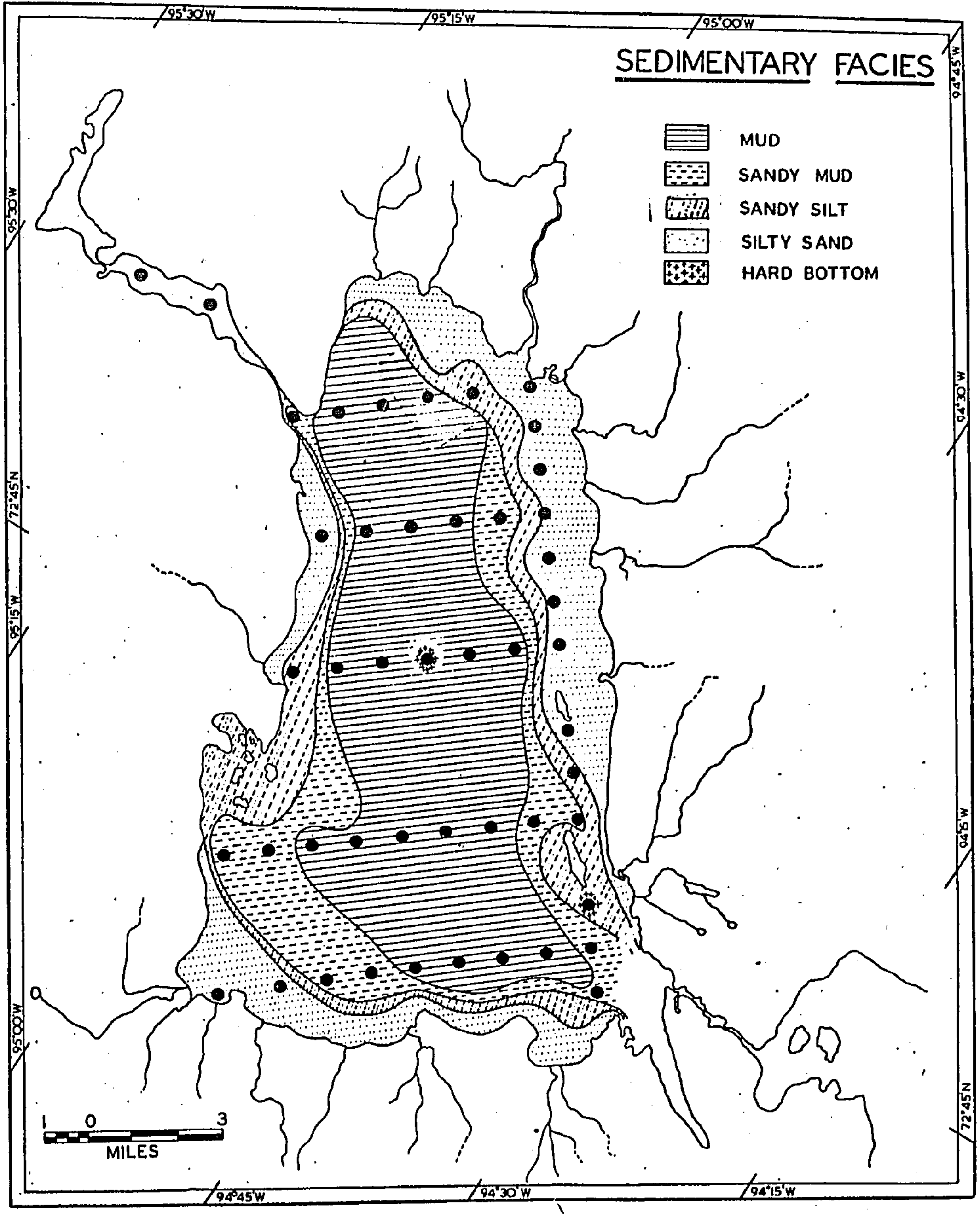


Figure 8: Surface sedimentary facies in Stanwell-Fletcher Lake.

grained, ranging in mean diameter from 0.9 to 0.004mm (or 4 microns). The finest sediments are located in the deep areas of the lake, whereas the coarsest material is laid down in the shallows skirting the shore. (Fig. 8). It is clear that the prime controlling factors in this distribution are water depth and distance from shore. Along the margin of the lake, especially in the delta areas, the main means of sediment dispersal is bottom traction due to currents generated by both entering streams and by wind action over the ice free water. In the depths, however, the sheltered, low current energy regime allows sedimentation by settling only, with insignificant sand fractions. Fig. 9 shows a plot of the surface samples in terms of their three components: sand, silt and clay. The two distinct areas enclosed effectively show the contrast between the sediments in these two energy environments in the lake.

The sediments of the lake may be classified and named on the basis of their grain-size properties (Fig. 9). The divisions of the diagram were taken from Folk, 1961.

Sorting

The measure of sorting chosen for this study was the Graphic Standard Deviation (σ, Folk, 1961). The samples were found to be generally poorly sorted with σ ranging from 0.76 (moderately sorted) to 3.2 (very poorly sorted) (Table 5). The best sorted sediment is silty sand (zS on Fig. 9). and is confined to the margins of the lake. The most poorly sorted sediment is sandy mud (sM). The mud areas (M) are intermediate and are consistently poorly sorted (Fig. 10). This generally poor sorting is not surprising in view of the low energy currents operative in a lake that is ice-covered all year round, but one would

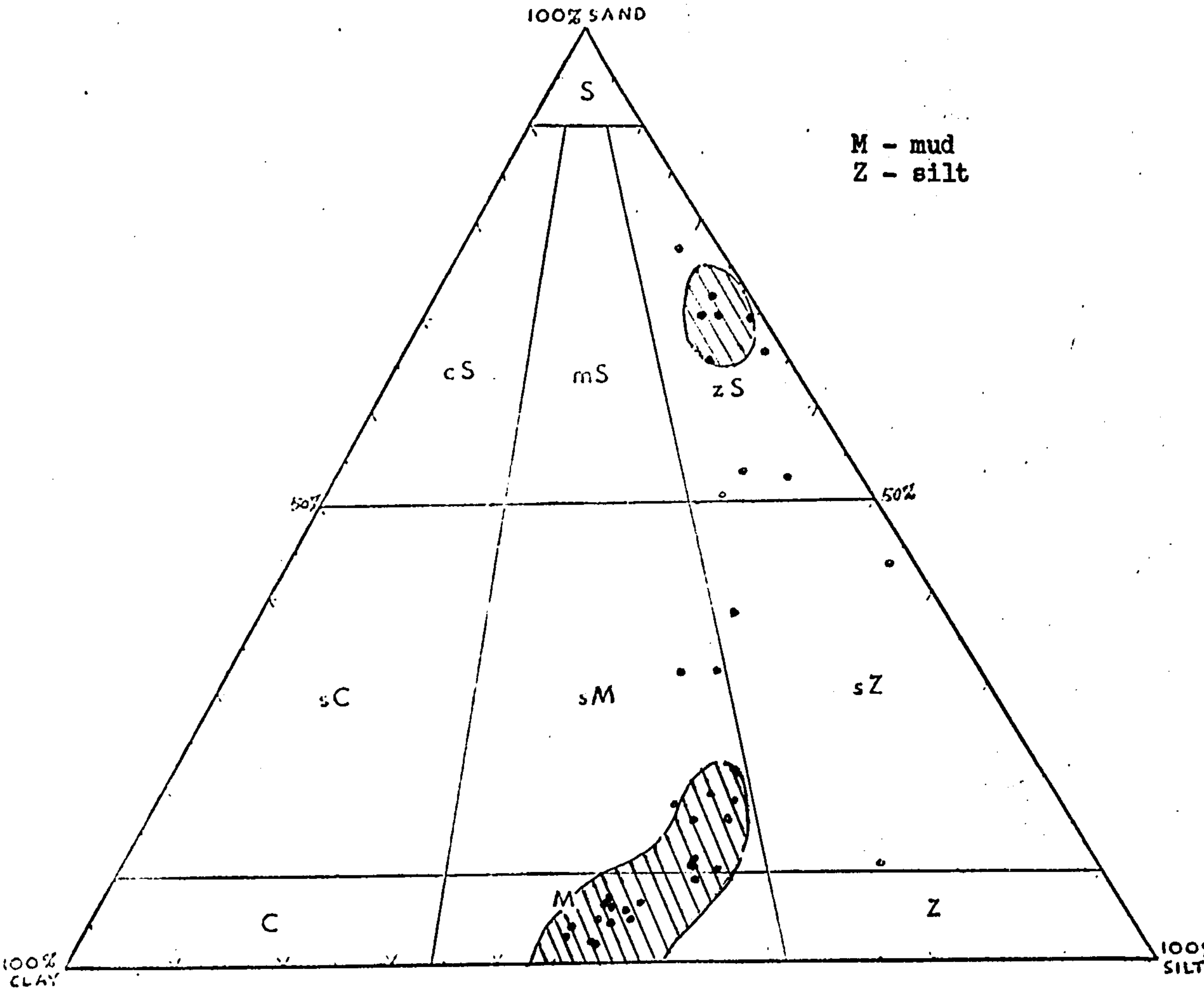


Figure 9: Size composition and classification of surface sediments, Stanwell-Fletcher Lake.
(Divisions after Folk, 1961)

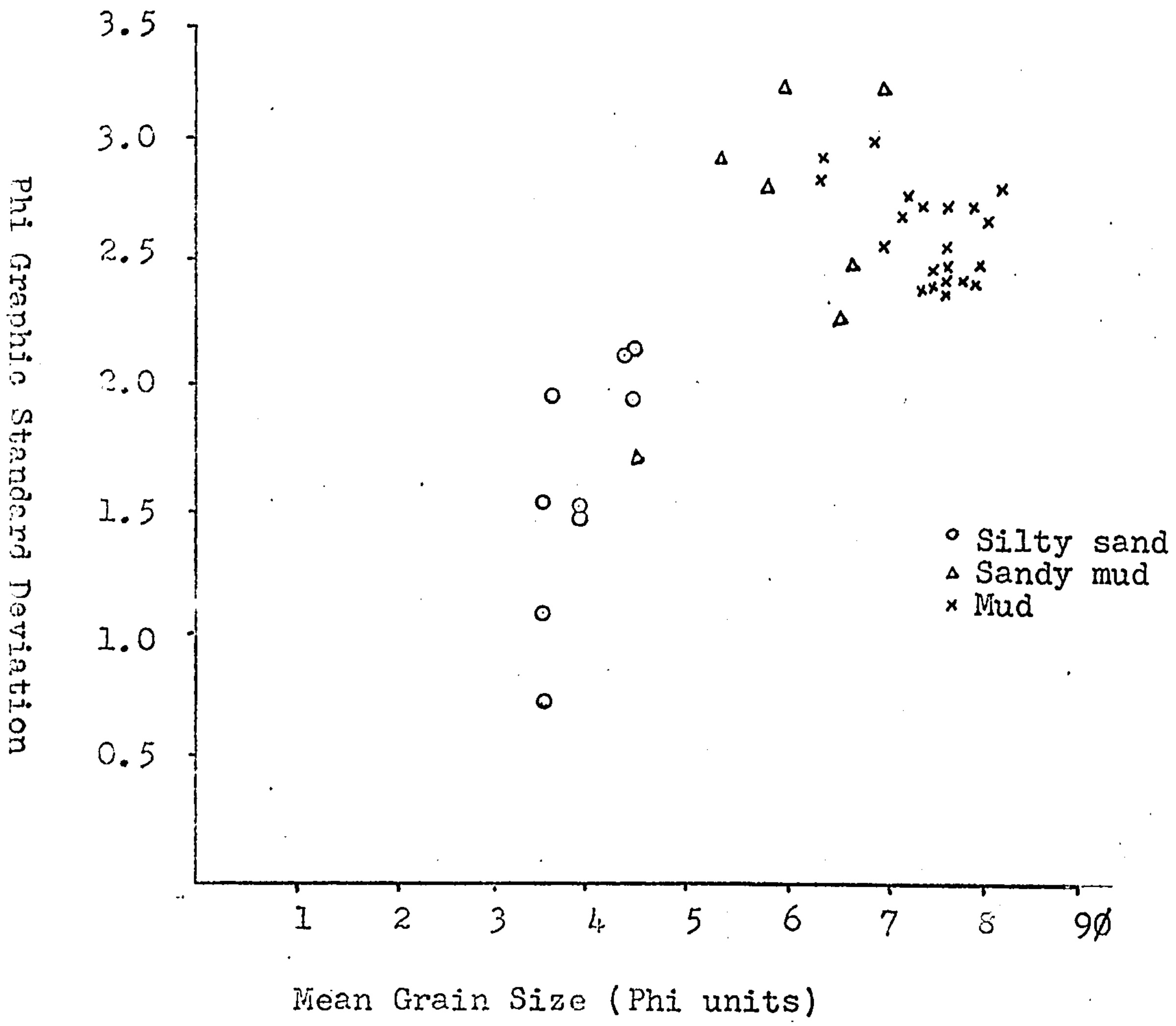


Figure 10: **Relationship between sorting and mean grain size in the surface sediments of Stanwell-Fletcher Lake.**

expect the samples taken near the deltas of the entering rivers to be better sorted. The most likely explanation for this is the lack of reworking and winnowing of the sediment on the deltas by waves and currents due to the long period of ice cover.

Skewness

The measure of the skewness or asymmetry of the distribution used was the Graphic Skewness initiated by Inman (1952). The formula is:

$$\frac{\phi_{16} \quad \phi_{84} - 2\phi_{50}}{(\phi_{84} - \phi_{16})}$$

The surface sediments in Stanwell-Fletcher Lake are mostly positively skewed, i.e., they have an excess of fine material (Table 5). This also suggests the interaction of two modes of deposition: bottom traction of the sand as well as settling from suspension of the fine material.

Vertical Variation of Parameters

The results of the mechanical analysis of the cores studied for vertical variation in six cores is also shown on Table 5. Several features are noteworthy. They are:

a. The downward increase in grain size.
b. The downward increase in positive skewness.
c. The roughly similar sorting of the sample throughout the length of the core.

Discussion of Grain Size Distribution and Sorting

The *a priori* knowledge of the present environment of deposition in Stanwell-Fletcher Lake is borne out and substantiated by the evidence of the cores. The study of the vertical textural variation also indicates that the environment has undergone certain changes in the time represented in the cores.

The very fine mean grain size of the sediment in most parts of the lake indicates that the media of transportation are of very limited competence. No coarse water-deposited material was found. Therefore with the exception of the margins of the lake where material is transported by streams, probably with the help of wind-generated currents, the lake is presently characterized by a low energy current regime. That this was not always the case is shown in the general downward increase in grain size in all six of the cores studied (Table 5). This feature appears to be directly related to a corresponding increase in the percentage of the sand fraction. The increased competency of the environment at the time of deposition of these parts of the cores indicates that a more energetic current regime was then operative.

This feature should also be reflected to some degree in the sorting of the sediments. The difference between the sorting of the top and that of the bottom of the cores, however, is not consistent. As is shown on the histograms (Fig. 11), the distribution of the size grades is very broadly based and in a significant number of instances, mostly in the mud areas of the lake, it is bimodal. Pettijohn (1957) put forward several explanations for bimodal distributions in sediments but none apply to this particular setting. The occurrence of the peaks in the fine sand-coarser silt (4-5 ϕ) and fine silt-coarse clay (7-8 ϕ) areas suggests the interaction of two modes of deposition: limited bottom traction by wind-generated currents in addition to gravity

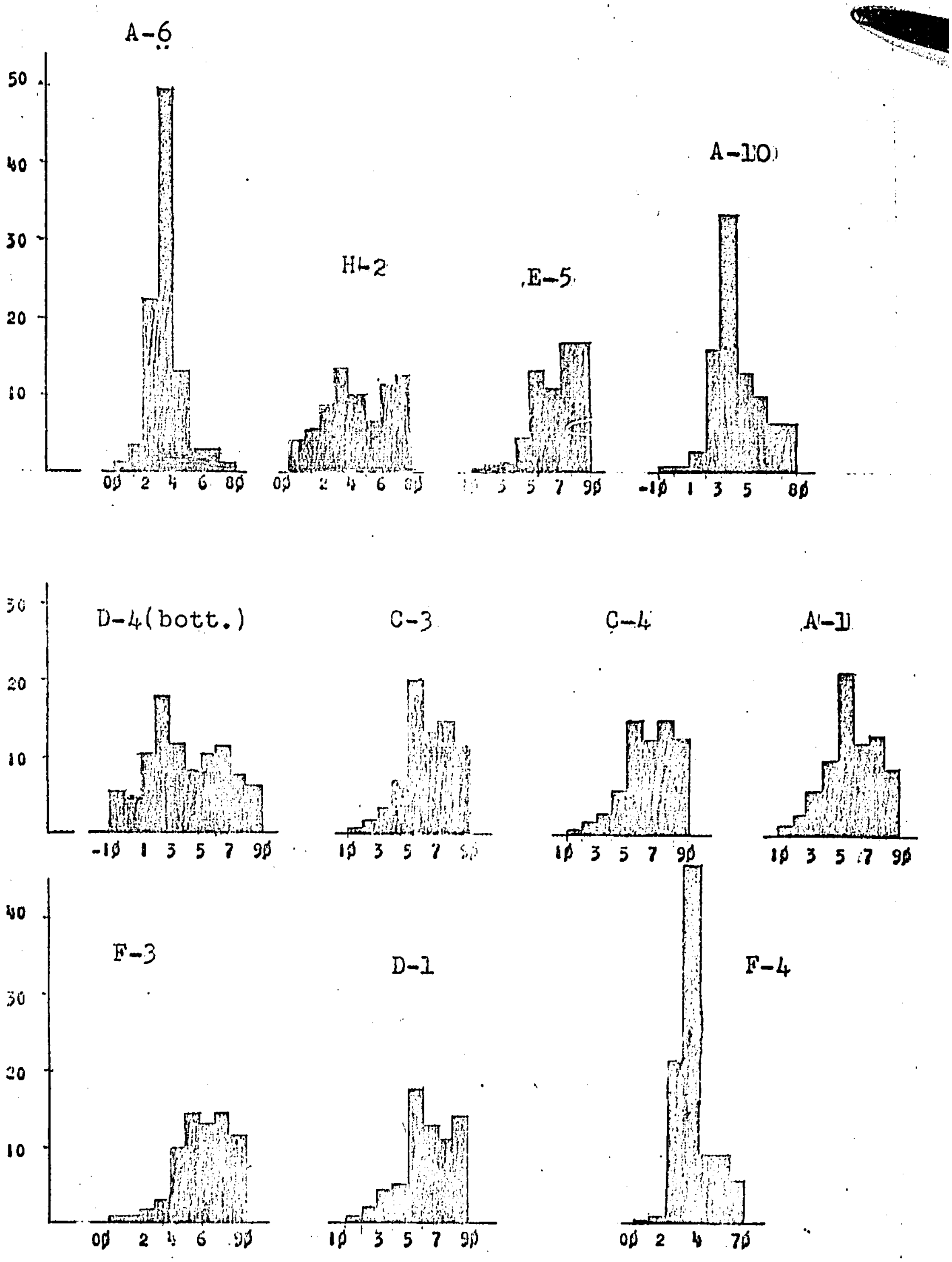


Figure 11: Histograms of grain-size distribution of selected cores from Stanwell-Fletcher Lake.

settling of suspended material. These two mechanisms would take place independently. However, during the period when the lake is ice-covered, gravity settling of finer material would dominate.

In the case of the bottom of the cores, it is suggested that although the currents were strong enough to deposit coarser material in places where only fine material is laid down at present, they must have been periodic and either non-oscillatory or of too short a duration for winnowing and sorting to be effective. Most of the time slow settling of suspended material deposited fine sediment and produced a poorly sorted deposit.

Duane (1964) suggested a relationship between positive skewness and lack of winnowing of the sediment, and thus postulated a mode of differentiating between some depositional environments. Where winnowing is inefficient, the fines are not washed away and positive skewness results. Therefore, the same reasons outlined in the above paragraph to explain the poor sorting may also account for the positive skewness in the Stanwell-Fletcher Lake sediments. If the currents were non-oscillatory or of short duration, little winnowing would take place.

MINERALOGICAL AND CHEMICAL ANALYSIS

Mineralogy of the sand-sized fraction

Mineralogical analysis and grain counts were carried out on the sand fraction of selected samples, i.e., those with a sufficiently high percentage of sand. Care was taken to get a wide distribution of localities.

As mentioned previously, almost all the samples taken are poorly sorted with wide ranges in grain size. This makes accurate quantitative determination of the mineral composition of the entire samples very difficult. Optical methods may be used for analyzing the sand fraction, but for the silt and clays, X-ray Diffraction and Differential Thermal Analysis are the only feasible methods. In this section it must suffice to give a qualitative and in some cases, a quantitative account of the mineralogy of the sand-sized fraction of the samples chosen (Table 6).

Mineralogical analysis was carried out by:

a. Thin sections of several cores for preliminary identification;

b. Heavy liquid separation of the sieved sand portion and calculation of weight percentages of light and and heavy fractions.

c. Point counting of 200 grains under a binocular microscope and determining qualitative and semiquantitative occurrence of individual minerals (Table 6).

Quartz is very abundant in the sand fraction of all the samples tested, comprising up to 94%. The feldspar (almost entirely potash feldspar) is fresh and unweathered and ranges from 5 to 12%. The heavy mineral content of the surface samples is never very great (up to 3.5%) and is composed of garnet, hornblende, biotite, both specular and finely-divided hematite, magnetite, and very minor tourmaline, rutile, and zircon (Table 6). Graphite, chlorite, and vermiculite appear as insignificant components of the "light" fraction. Rock fragments are rare in the water-deposited sediments and never exceed 2%.

The variation of mineralogy with depth is striking in one sense. Although the high percentage of quartz varies little and so to a lesser degree does that of the feldspar, the heavy mineral suite is completely

MINERALS	A-1	A-4	A-8	A-12	I-2	G-3	H-1	F-4	A-4 bott.	A-8 b.	I-2 b.
LIGHTS	96.5	98.8	97.6	98.1	98.9	99.3	98.2	99.5	97.8	93.9	95.9
Quartz	88	90	87	89	83	94	86	92	87	79	80
Felds.	6	7	10	8	12	5	11	7	7	14	15
Graph., Organic	2.5	1.8	0.6	1.1	3.9	0.3	1.2	0.5	3.8	0.9	0.9
HEAVYS	3.5	1.2	2.4	1.9	1.1	0.7	1.8	0.5	2.2	6.1	4.1
Garnet	3	0.5	1.5	1	C	P	P	P	P	R	R
Hornbl.	P	C	P	P	P	P	P	P	R	P	P
Hemat.	P	P	P	P	P	P	R	C	A	R	A
Biotite	P	P	R	P	P	P	P	P	P	P	P
Magnet.	R	P	P	R	P	P	P	P	P	R	P
Dolo.	A	A	A	A	A	A	A	A	2	6	4
% of total sample	5	16	20	30	5	21	38	23	10	46	27

P : 5-20% of heavy mineral fraction
C : 20-50% of heavy mineral fraction
R : < 5% of heavy mineral fraction
A : absent in 200 grains

Table 6: Semiquantitative mineralogical composition of sand-sized fraction, Stanwell-Fletcher Lake.

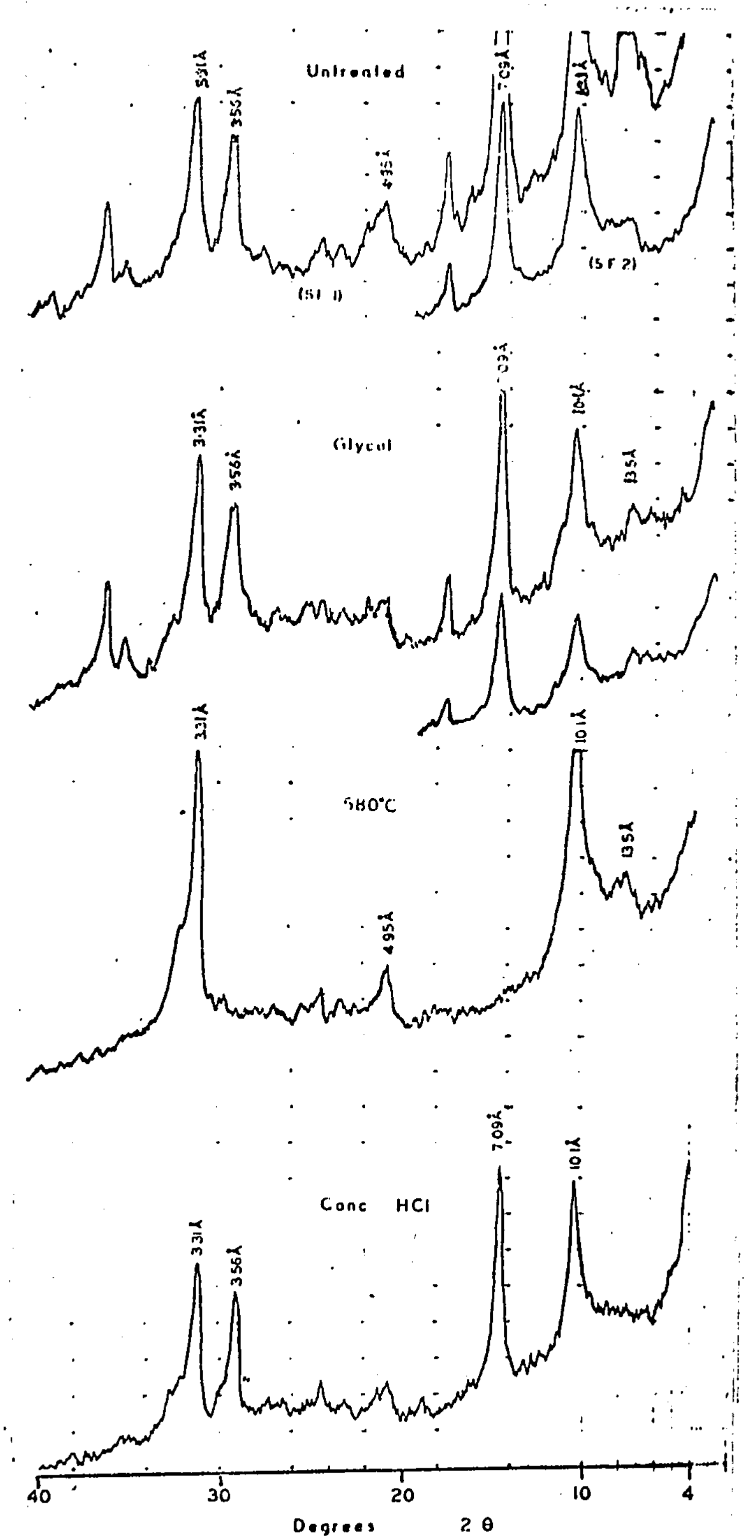
different. The results of the analysis of cores A-4 (bottom), A-8 (bottom), and I-2 (bottom) show that the heavy mineral fraction is greatly increased by the dominant entrance of dolomite into the suite. It comprises up to 90% of the heavy minerals and up to 6% of the whole sand fraction. The dolomite occurs mostly as equidimensional, subangular grains, some of which clearly show the characteristic rhombohedral cleavage. On the basis of the form of these grains, it is concluded that they are detrital as opposed to authigenic. This contention is supported by the proximity of an outcrop of the Hunting Formation dolomite (Fig. 2).

Mineralogy of the clay and silt fraction

The methods used to determine the minerals present in the clay and silt-sized fraction of selected cores were: X-ray Diffraction and Differential Thermal Analysis. Although X-ray analysis was carried out on a number of samples using the facilities of the University of Ottawa, their accuracy was questioned owing to the use of incorrect radiation. The results described here are for samples processed by the Mineral Sciences and Mineral Processing Divisions of the Department of Mines and Technical Surveys.

X-ray Diffraction

Separate samples of silt and clay sized material were obtained from cores F-1 and A-1 (bottom). The diffractograms of the clays (Fig. 12,13) and the Guinier photographs taken were diagnosed by Dr. R. S. Dean and the minerals contained are:



S.F. - Scale factor
Å - Angstrom unit

Figure 12: X-ray diffractograms for sample A-1 (bottom). (clay sized fraction)

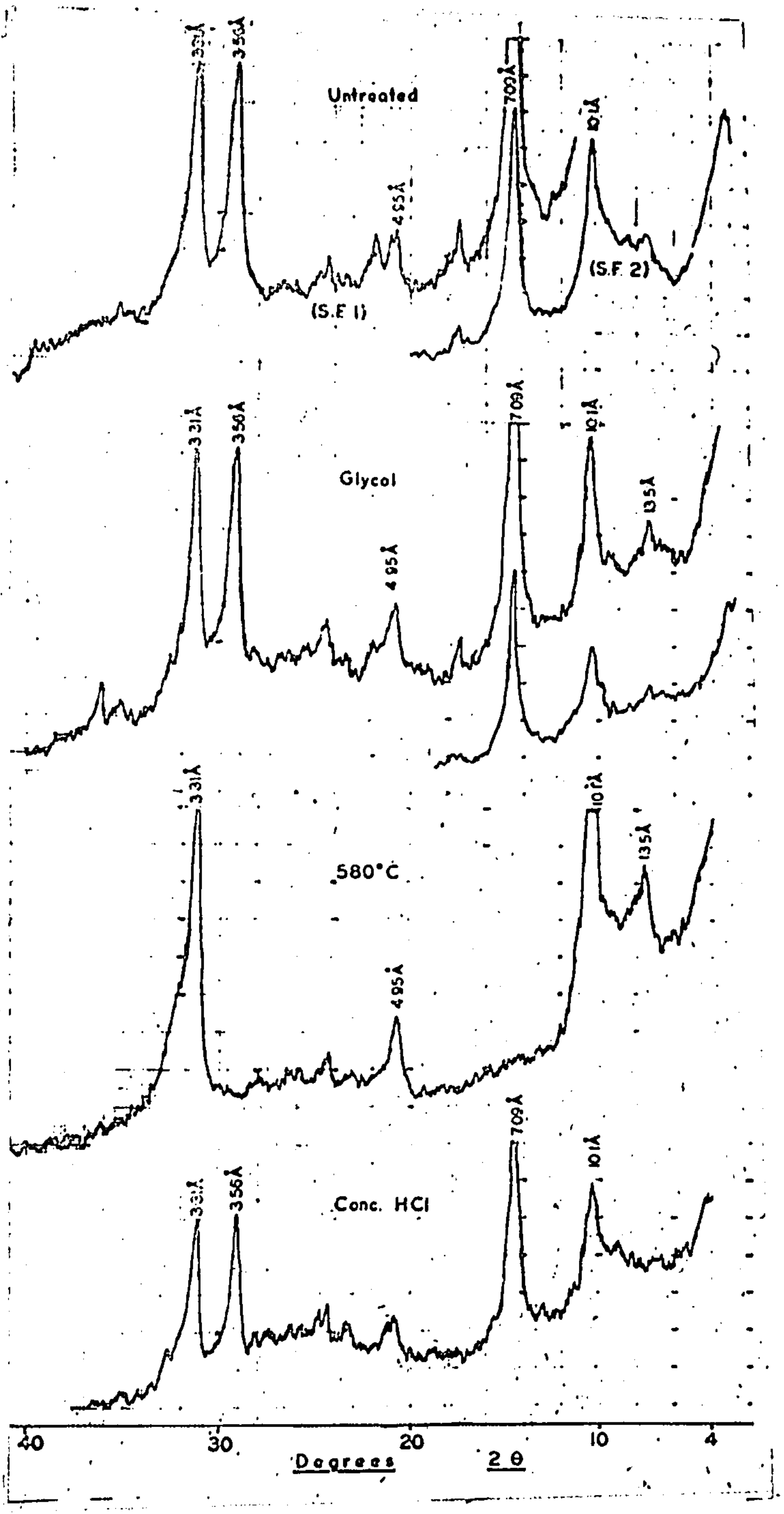


Figure 13: X-ray diffractograms for sample F-1.

F-1 - Kaolinite (7.09, 3.56 Å units): very abundant in the clay fraction and fairly well crystallized.

Illite (10.1, 4.95, 3.31Å): abundant in the clay fraction.

Mixed-layer clay mineral (13.5Å): common in the clay fraction. Appears to be a combination of chlorite with lesser proportions of expandable layers of undetermined type.

Quartz: very abundant in the silt fraction, fairly common in the clay.

K-feldspar: common in silt, fairly common in the clay.

A-1 (bottom) - The clay fraction is similar to that of F-1. However, dolomite is listed as very abundant in the silt fraction and fairly common in the clay; quartz is the same as above; K-feldspar is rare; and there is a trace of pyrite[*] in the clay fraction.

Differential Thermal Analysis

This procedure was carried out chiefly as a check on the X-ray work. Two runs were made. The first (on sample C-1), which was done to determine the presence of illite, disclosed that:

> ".... in addition to the clay mineral illite which forms the bulk of the sample as received, and a small amount of quartz, the sample contained a quantity of organic matter ... and some other unknown substances."[**]

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[*] This ties in with the evidence for reducing conditions existing downward in the cores (see page 39). On the other hand, the possibility of detrital origin cannot be ignored.

[**] Analysis performed by Richard Lake, Mineral Sciences Division, Department Mines and Technical Surveys.

Quantitative Determination of Boron

An attempt was made to evaluate the variation in paleosalinity downward in the cores by boron determination.[***] According to Fredrickson and Reynolds (1959), the relative proportion of the element boron taken into the structure of the illite present is directly proportionate to the salinity at the time of deposition of the sediment. The results obtained were inconclusive.

Chemistry of the sediments

Total Carbonates

The apparatus used for this analysis was the Chittick apparatus (Dreimanis, 1962). The proportions of calcite and dolomite were determined by measurement of the CO_2 evolved on addition of dilute HCl. The sample was prepared by passing it through a 250 mesh (40) Tyler sieve and weighing out the aliquot to be tested (normally 1.7g).

Tests were run on the top portions of 4 scattered cores. These all showed consistently very low carbonate content (Table 4) and it was concluded that the areal variation was insignificant. After this, 6 widely distributed cores were analysed for vertical variation of total carbonate content. The results in this case were more significant, showing a marked increase with depth in the core (Fig. 14). Dolomite is by far the dominant carbonate mineral and is present in considerable amounts (up to more than 40%) of the sample tested in one case, F-1 (lower parts). It should be borne in mind that the percentages listed are for the aliquot

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[***] Analysis done by Technical Research Laboratories, Toronto.

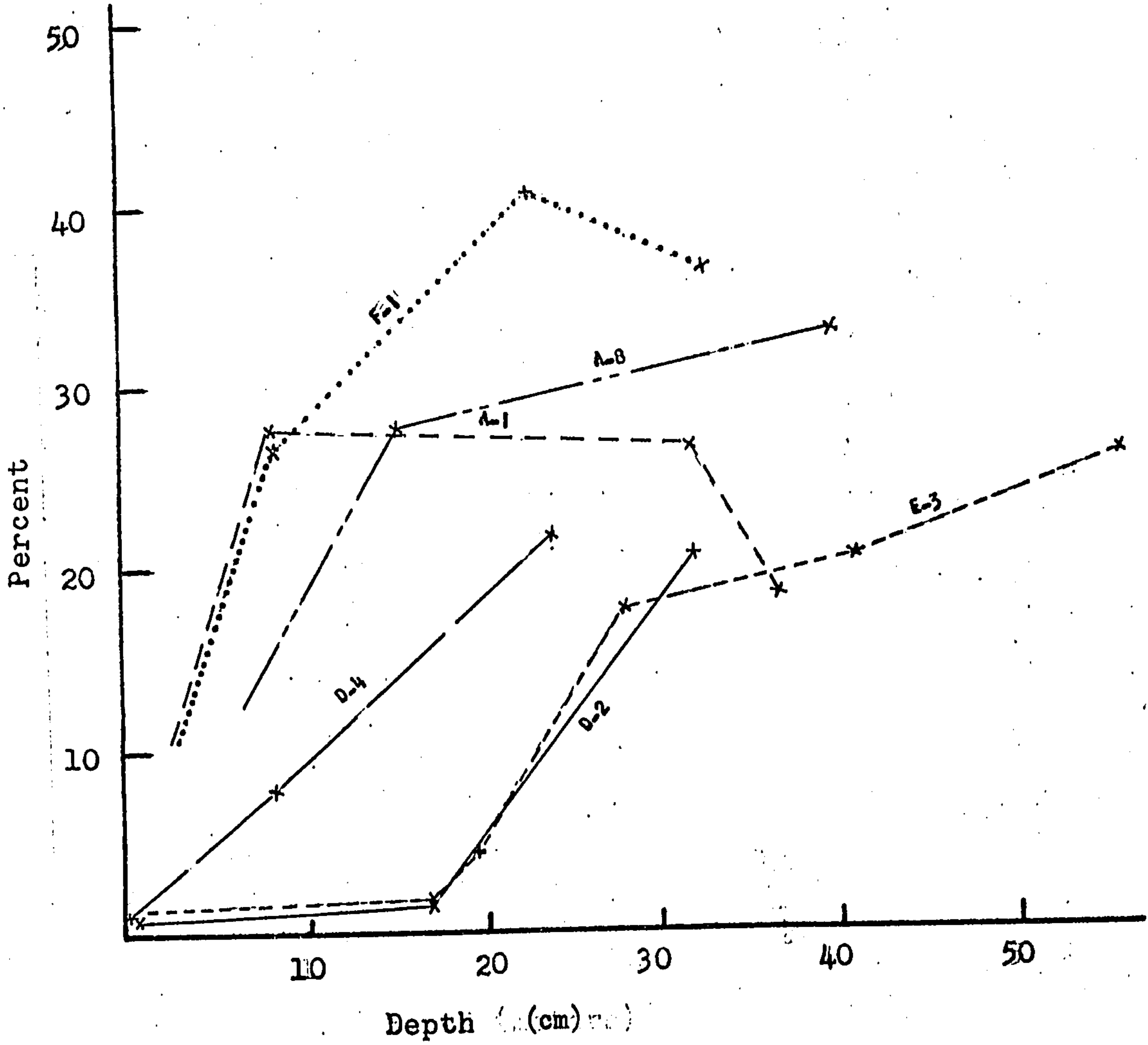

Figure 14: Vertical variation of total carbonate content in six cores.
(fraction < 4 ϕ used)

A-1, A-8, and F-1 extrapolated to 0 cm. depth assuming uniformity with others analyzed, page 56.

tested which included only material smaller than 40 in size, and cannot be extrapolated to apply to the whole sample, which in most cases was largely quartz sand. However, the heavy mineral analysis of the sand fraction and the X-ray Diffraction of the silt from the bottom parts of several cores (page 59) also showed significant dolomite content.

Organic Carbon

Determination of the organic carbon content (oxidizable organic matter) of the samples tested was carried out using a modified version of the Walkley-Black method as outlined in Contribution #169 of the Chemical Division of the Canada Department of Agriculture, Research Branch (1958). In this method the sample (0.5g of material below ½mm in diameter) is oxidized in potassium dichromate with spontaneous heat generated by the addition of concentrated H_2SO_4. The excess dichromate is determined by titration with $FeSO_4$, and multiplication by a constant factor yields the percentage of organic carbon. This method does not measure the carbon present as coal or graphite as they are not readily oxidized. Loss-on-ignition determinations were done on sample C-1 with the following results:

8 hrs. at 250° to 400°C	7.1%
3 additional hours at 700° to 800°C	7.98%
Dichromate	2.82%

Because this wide discrepancy is probably due to loss of water from the clays or to ignition of the coal present, the dichromate results were chosen as more accurate as well as more convenient.

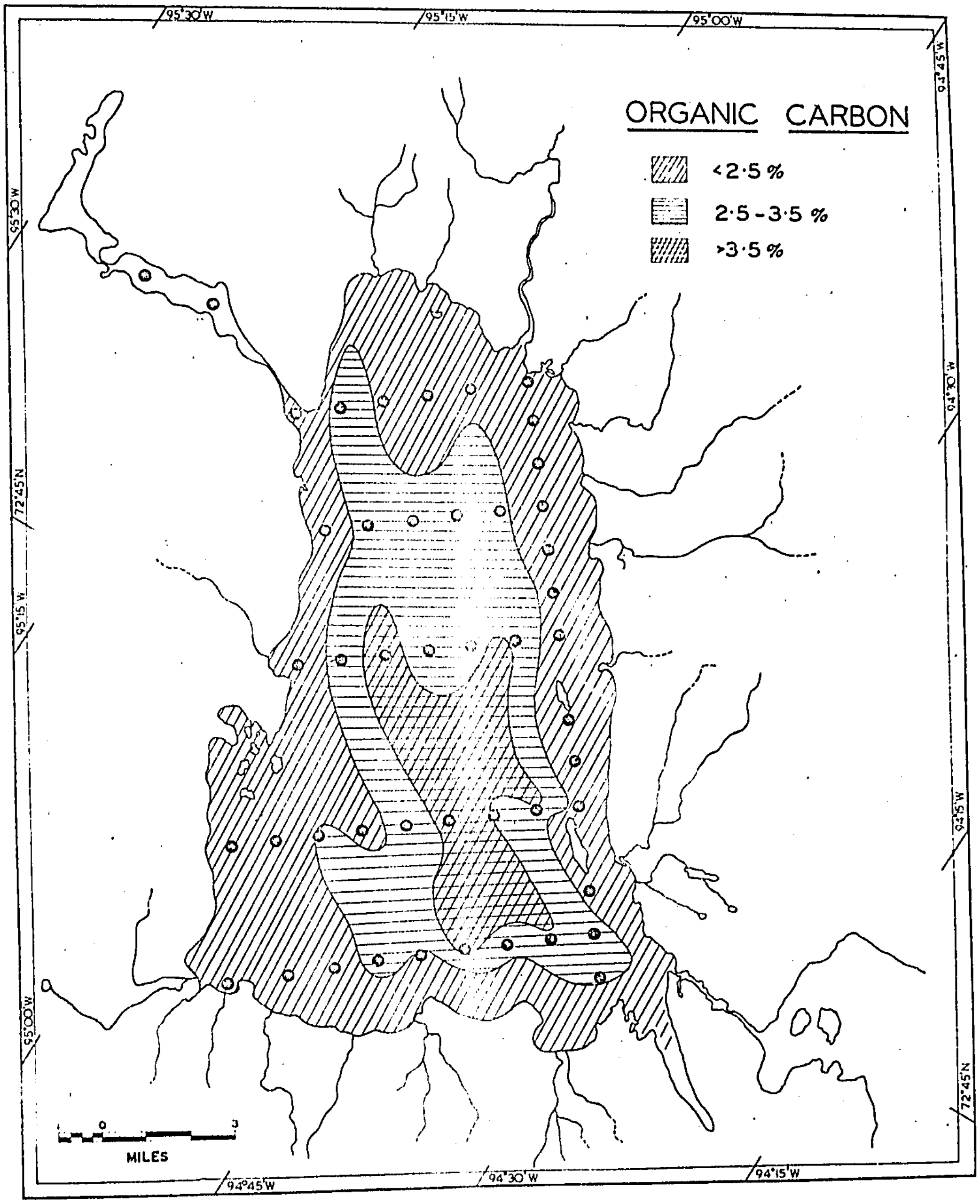

Figure 15: Organic carbon content of surface sediments, Stanwell-Fletcher Lake.

Determinations were carried out on the surface portions of all cores as well as on five for vertical variation (Table 5). The average figure for surface organic carbon content is 2.3%.

To show the relationship between surface organic carbon and geographic position, the carbon values were contoured (Fig. 15). There is apparently a direct relationship between organic carbon and depth of water, and therefore an inverse one with grain size. This is not surprising and is no doubt due to the fact that the light organic matter is usually deposited in the same area as the fine clays.

The vertical variation of organic carbon is on the whole inconclusive. There appears to be a slight decrease in organic carbon downward in all but one of the cores tested (Table 3). This may be due to the increase in mean grain size downward in most of the cores (see page 50).

It was expected that there might be a relationship between organic carbon content and sediment colour and that the lower darker portions of the cores might contain more organic carbon than the lighter portions. The small variation encountered denies this and further supports the postulation that sediment colour is a factor of the oxidation state of the iron present.

PALAEONTOLOGY OF CORES

This portion of the study was concentrated on the occurrence of two types of fossils: foraminifera and plant pollen. No macrofossils deemed indigenous were noted. Fragments of a pelecypod valve were encountered in core A-8 but because of the proximity of this station to the land where these shells are common and also its broken state, it is believed to have been washed into the lake. Cores G-2, B-3, and F-1 were examined by the

Palynological Section of the Geological Survey of Canada for pollen and spores. However, in the slides examined, no pollen or spores were found[*].

Foraminifera were noted in considerable numbers in several thin sections of cores and in mechanical separations to be described later. To all appearances they were deposited in situ as opposed to being transported from the land. They are well-preserved, even the more delicate ones, and very few are worn or broken. Another factor in favour of their indigenous nature is that the foraminifera are restricted to the lower portions of the cores in which they occur. If they were transported from the shore deposits, which are still being eroded, one would expect a more even distribution throughout the length of the core.

Foraminifera were noted in the bottom parts of cores A-12, A-10, A-8 and I-2 only, and of these, A-8, and I-2 were subjected to identification and counting procedures.

The samples were processed as in the following scheme (Hooper, personal communication):

Whole sieved sample $> 4\phi$

Solution 1
(S.G. $>2.65<2.71$)

1. Sinking fraction collected
(calcite and forams
without air)

Floating fraction to Solution 2
(S.G. $<2.56>2.4$)

2. Sinking fraction collected
(quartz and feldspar)

Floating fraction to Solution 3
(S.G. ± 2)

3. Sinking fraction collected
(light minerals)

4. Floating fraction collected
(foraminifera with trapped air)

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[*] Personal communication with staff of Dr. J. Terasmae.

Thus, most of the foraminifera were concentrated in the #4 portion. To avoid biased counts, however, all the portions were checked and if necessary, counted.

The results of the examination are shown in Table 7. The fauna from the Stanwell-Fletcher Lake cores is dominated by calcareous as opposed to arenaceous types. With the exception of a small number of the planktonic Globigerina bulloides, all are benthic in habit. The fauna is characterized by the high incidence of Cassidulinae, Astrononion stellatum, and Elphidium incertum and is comparable to the Hudson Bay fauna described by Leslie (1965).

Leslie proposed foraminiferal depth zones based on the presence of certain species in Hudson Bay. These depth zones are as follows:

Shallow Bay fauna - 26-130m
Intermediate Bay fauna - 50-170m
Deep Bay fauna - 100-230m
Cosmopolitan Bay fauna - 26-230m

The species identified in the cores from Stanwell-Fletcher Lake fall between Leslie's Intermediate and Deep Bay faunas corresponding to a depth range of 50-230m.

However, Green (1960) working on an area to the north of Ellesmere Island, recognized 4 depth zones on the basis of the benthic fauna. They were: Shelf (433-510m), Slope (610-1142m), Apron (1532-2000m), and Abyssal (2250-2760m). Species of Cassidulina as well as Cibicides lobatulus, and Elphidium bartletti characterize the Shelf area. The fauna of the cores from Stanwell-Fletcher Lake shows close relationship to this type, with an expectedly corresponding depth range.

STATION NUMBER	A-8 (bottom) 40 cm. below top of core	A-8 (middle) 15 cm. below top of core	I-2 (bottom) 28 cm. below top of core
FORAMINIFERAL NUMBER *	325	173	107
Cassidulina teretis	29	27	4
C. norcrossi	25	23	45
C. islandica	12	11	27
Cibicides lobatulus	13	12	2
Astrononion stellatum	17	12	7
Elphidium frigidum			x
E. incertum complex	2	10	8
E. bartletti	x		x
Protelphidium orbiculare			1
Lagena semilineata	x	x	x
L. gracillima			x
L. meridionalis		x	x
Fissurina marginata	x	x	x
Virgulina complanata	x	x	2
Reophax curtus	x	x	
Oolina costata	x		
Oolina melo		x	
Laryngosigma hyalascidia	x		
Alveolophragmium crassimargo	x	x	x
Astacolus hyalacrulus	x		
Glandulina laevigata	x		
Ammotium cassis			x
Lamarckina haliotidea		x	x
Patellina corrugata		x	x
Triloculina angularis		x	x
Guttulina pacifica			x
Proteonina atlantica			x
Buccella inusitata		x	x
Bulimina exilis		x	
Dentalina frobisherensis		x	
D. baggi		x	
** Globigerina bulloides		x	x

x - less than 1%

** - The only planktonic species present

* - The number of benthonic foraminifera per gram of sediment

Table 7: Foraminiferal list and percentages of occurrence in two cores from Stanwell-Fletcher Lake.

This fairly large discrepancy between the depth ranges for the above species as given by Leslie and by Green is not explained. Hooper[*] states that this may be due to imprecision in determining the upper and lower limits of species' ranges or, more likely, to the effect of inconsistent depth occurrence of distinctive water layers which are the main controlling factor of depth distribution of foraminifera.

With reference to other ecological factors, Loeblich and Tappan (1953) state that the character of the substratum is the most important. Fewer foraminifera occur in the muddy areas, where oxidation of decaying organic matter cause oxygen shortage. The sandy and gravelly areas offer more protection and places for the organisms to attach themselves. This may account for the lack of specimens in the muddy parts of the lake. Loeblich and Tappan also maintain that temperature has only a regional effect on the distribution of benthic foraminifera because the bottom temperature all over the Arctic and North Atlantic varies very little from place to place.

In the cores studied there were very few planktonic species found. Leslie (1965) observed changes in the number of planktonic species found in Hudson Bay cores. This led him to conclude that a high number of these species denote normal marine saline conditions. Conversely he suggested that a low number of planktonic species of foraminifera indicates an inshore, abnormal marine environment, possibly brackish water. This would agree with what the writer believes to be the paleoecology of the Stanwell-Fletcher Lake area, (see pages35, 36).

Other fossils occurring with less frequency are ostracods, and in one

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[*] Personal communication

core (A-1 bottom) small glass sponge spicules (?). Plant remains are common throughout the cores.

Rate of Sedimentation

In marine sediments, the rate of sedimentation can be calculated using a factor derived from the ratio of living to dead foraminifera present in the surface sample (Bartlett, 1964). In the case of Stanwell-Fletcher Lake no live foraminifera are known to exist so this method can not be applied. However, if the complete thickness of the lake sediments were to be definitely established, this, divided by the time involved in deposition, would give a fair indication of the rate of sedimentation.

In the lake, although foraminifera were found in cores in the sandy shallower areas, one cannot be sure as to whether their vertical position in the core is reliable or whether some of the overlying sediment was truncated by erosion as the water in the lake area subsided. No foraminifera were found in the deep muddy areas of the lake either due to the fact that no foraminifera existed there during the marine and transitional phases (see page 68); or because the cores were too short to penetrate down to these deposits.

On the above information, it would therefore serve little purpose to present a calculated rate of sedimentation. It should be pointed out, however, that several factors indicate a relatively slow rate of deposition existing at the present time. These factors are:

a. The oxidized, reddish-brown bottom sediments (Emery, 1949).

b. The fine mean grain size of the sediments in almost all parts of the lake.

c. The slow rate of subaerial erosion and transportation due to the restrictions of the climate of the area.
d. The lack of slump structures or lamination in the cores.

CHAPTER IV

CONCLUSIONS

THE DEVELOPMENT OF STANWELL-FLETCHER LAKE

The investigation shows that the development of the lake can be traced through three phases from its origin to the present. The lake basin was formed through glacial scour of a downfaulted block of soft, friable Cretaceous (?) sandstone during the later stages of the Wisconsin (Laurentide) glaciation in Pleistocene times.

On melting of the ice the depressed land area was invaded by the sea. The elevation of sea level relative to the land at that time was more than 150 feet above that at present. An idea of what the area must have resembled is seen on Fig. 16A. The conditions existing in the regime would most likely have been of the restricted marine bay type, i.e. having a narrow entrance perhaps partly blocked by low islands or shoals. However, due to the scarcity of the expected planktonic foraminifera and the inconclusive nature of the boron analysis (see page 60), it is believed that the cores are not long enough to contain sediment deposited under these conditions.

The second or estuarine phase was brought on as the land rose, increasing the influence of the sill over which the Union River now flows. On the basis of the present topography, the existing highs in the vicinity must have comprised low islands (Fig. 16B). The outlet to the northwest is believed to have been insignificant in the circulation of the water largely because of its present narrowness. The salinity of the water in the basin must have decreased as the basin became more restricted and fresh water from the land began to assert its influence. Chemical stratification most likely was established and an estuarine circulation

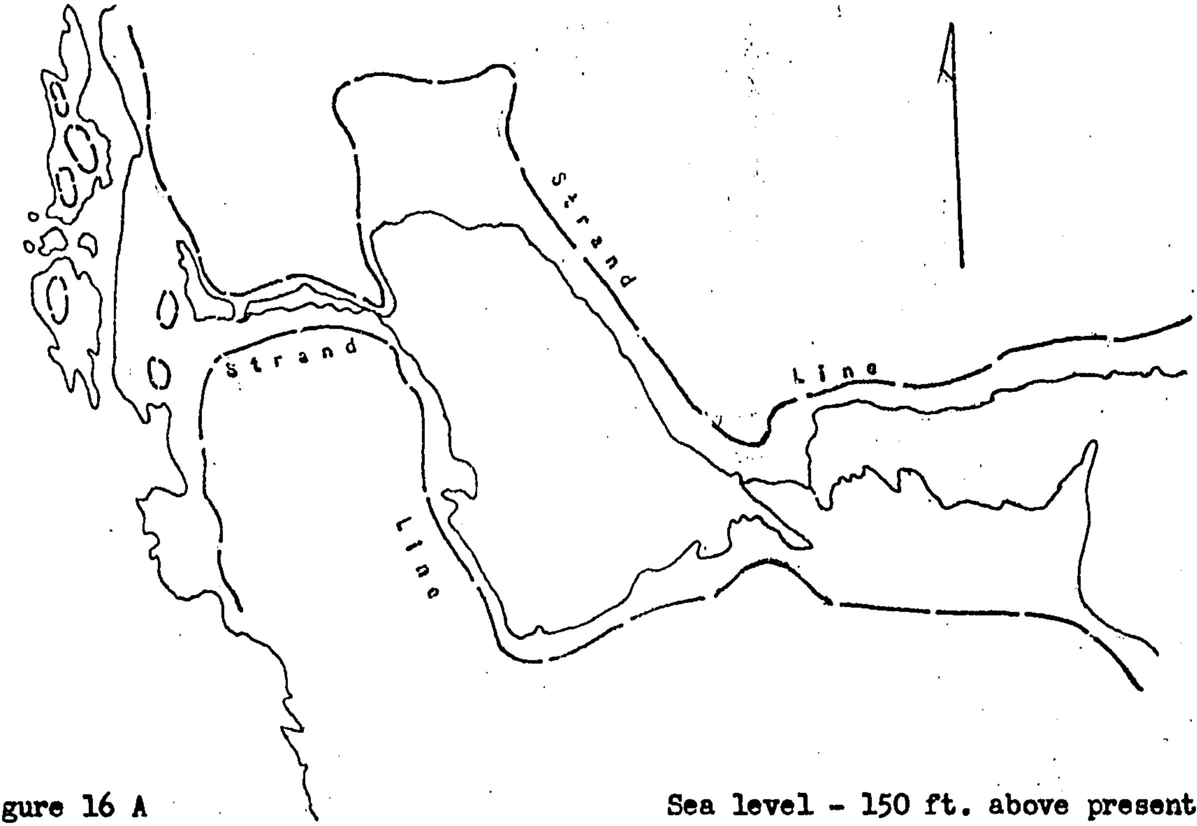


Figure 16 A

Sea level - 150 ft. above present

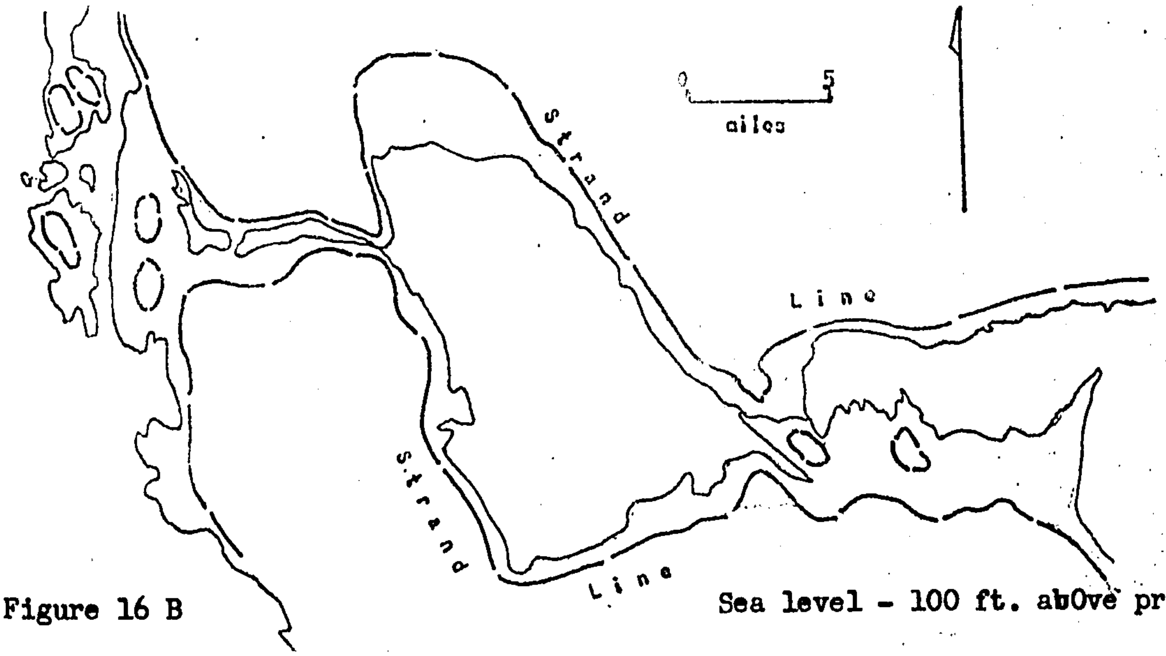


Figure 16 B

Sea level - 100 ft. abOve present

Figures 16 A and B : Assumed paleogeography of the Stanwell-Fletcher Lake area, ensued (see Fig. 17) in which the fresher water flowed out on the surface over the sill, developing currents along the bottom in the opposite direction due to frictional drag (Pickard, 1964).

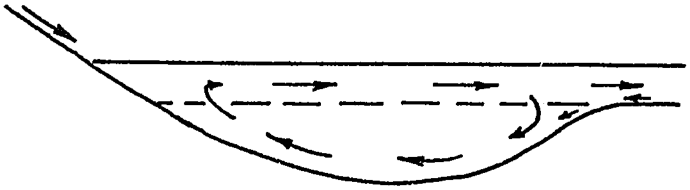


Fig. 17. Assumed estuarine circulation in Stanwell-Fletcher Lake area. (Modified after Reid, 1961, page 143)

This resulted in bottom saline water being brought up to be mixed with the fresh river water and then circulated out over the sill. The bottom currents in narrow-necked estuarine environments are known to be quite strong (Reid, 1961, pages 76, 142-144). Thus fairly rapid deposition and some bottom erosion are thought to have taken place. The dispersion of dolomite grains all over the lake, although dolomite only outcrops in the southeast part of the basin (Fig. 2) supports this postulation. Also some other features such as increase of grain size (page 50), preservation of fossils (Twenhofel, 1964) etc., are present in the sediments which might denote fairly rapid deposition (see pages 39, 56) The foraminiferal fauna at this stage is mostly benthic suggesting that normal marine conditions did not exist and that only in the bottom areas was salinity adequate to allow marine life. It is believed that this phase lasted long enough to flush out most of the saline water left after the marine phase.

As uplift progressed the basin became cut off from the sea due to the exposure above sea level of the land previously forming the sill. The efficient mixing of the water was most likely completed by the agencies on page 36, i.e., flushing out of the salt water, and/or dissipation through efficient circulation. Deposition by bottom currents then became insignificant except around the margins.

THE SEDIMENTARY RECORD

As noted on page 37, the cores were for the most part disappointingly short and sedimentation would have had to be very slow for the complete record (beginning about 8,000 years ago) to be present. From the foraminifera found and the inconclusive nature of the boron analyses (page 60) it is believed that the cores obtained record deposition no earlier than the closing stages of the estuarine phase (about 4,500 years ago, Fig. 3).

Rate of Sedimentation

Although at present the rate of sedimentation is quite low (page 69), several factors point to more rapid deposition during the estuarine phase of the lake's development, as represented by the foraminifera-bearing portions of cores. The good preservation of the fossil shells could be cited as an indication of rapid deposition (Twenhofel, 1942). Also the poor sorting despite a much more energetic current regime could be seen as evidence of fairly rapid deposition.

Thus the rate of sedimentation seems to have decreased markedly with time to its present low value.

Provenance

The provenance of the sediments is best studied through the heavy minerals found. As is seen on Table 6, garnet is present in varying amounts in the surface portions of all cores studied. It appears as very angular grains thus indicating first cycle derivation, most likely from the metamorphic terrains. Other accessory heavy minerals that indicate this source are hornblende, biotite and graphite. In lower parts of the cores, however, the heavy mineral suite changes markedly, with dolomite becoming dominant. This change can be related to the direction and mode of transport prevailing at the time. During the estuarine phase dolomite was derived from the debris of the Hunting dolomite to the south and was probably distributed all over the basin through the action of north-flowing tidal bottom currents. At present the action of bottom currents is minimal whereas that of rivers and streams, most of which flow over metamorphic terrain, account for the ascendancy of garnet.

The contribution of the Cretaceous (?) sandstones is by far the most important and is observed in the high proportion of quartz grains in the sand fraction of all the cores studied, both in the lake sediments and the raised beaches. There is a marked increase in the amount of rounded quartz grains in both the raised beaches and the lake sediments compared to the Cretaceous (?). This increase is probably due to reworking of quartz grains from the Cretaceous (?) rocks.

The presence of illite, kaolinite, and chlorite together shows that sediment is not the result of weathering and erosion of a single rock type. A multiple source is therefore suggested, most probably the fine grained, polymict glacial debris ubiquitous in the area. These deposits originated from the mechanical breakdown of the rocks over which the glacier moved, the end product being thoroughly mixed in the process. Thus, the chlorite was presumably derived from the chlorite-rich metamorphics outcropping in the area, and the kaolinite and illite were derived from the shales of the Cretaceous (?) rocks (see page 14). The chemical breakdown of micas and feldspars to produce illite and kaolinite in conjunction with that of pyroxenes and other mafic minerals to chlorite is unlikely in view of the climatic conditions existing since glacial times. Also the fresh unweathered nature of the mineral grains preclude this mode of origin for the clays.

THE EFFECT OF THE ARCTIC ENVIRONMENT ON SEDIMENTATION

The major factors controlling the processes of sedimentation in Stanwell-Fletcher Lake at the present time are:

a. The physiography of the area
b. The arctic climatic regime
c. The geology of the area

As was stated on page 1 , one of the present purposes is to "study the effect of an arctic climate on sedimentation in a modern lacustrine environment". However, because all the factors listed above together contribute to the type of deposition in Stanwell-Fletcher Lake, the effect of climate alone must be evaluated separately.

The most pertinent characteristic of the arctic environment is the year-round low temperatures resulting in perennially frozen ground to a considerable depth. Other features characteristic of the arctic, but not restricted to it are: the small amount of precipitation and the low productivity of both flora and fauna (Frey and Stahl, 1958).

Because weathering is the first step in the sedimentation cycle, i.e. weathering, transportation, and deposition, the effects of the arctic environment on weathering is of importance. All the characteristics listed in the paragraph above tend to slow down drastically the processes of chemical weathering. The permafrost inhibits the circulation of ground water during the brief surficial thaw and the low surface and soil temperatures coupled with scarcity of vegetation effectively restrict chemical and biological activity at the surface. Thus the soils of the arctic are generally classed as immature and are comprised of mostly bog (or Tundra) soils with zonation only in the well drained areas (Tedrow and Cantlon, 1958). Although the surface areas of both these soil types are moderately to strongly acid (Tedrow et al., 1958), very little leaching takes place. Other chemical processes such as oxidation, carbonation and solution of carbonates are all hindered by the low temperatures (Taber, 1943). Residual chemical weathering products such as the clays therefore tend to be secondary in importance.

On the other hand, mechanical or physical weathering and disintegration is dominant in the arctic because of the permafrost and the effects of the low temperatures (Taber, 1943). Tedrow et al.(1958) attributed the predominantly medium (sic) texture of most arctic soils in which silt is present in large amounts to this factor. They stated:

> "This suggests the possibility that the rocks and minerals have been weathered mainly through physical processes to silt, at which size range they reach a somewhat static state."

They also quoted Sigafoos and Hopkins (1952) to suggest that grain size in arctic soils is largely a function of the grain size of the parent rock.

The effect of the arctic environment on transportation is understandably less discernible than that on weathering. One of the most important factors is the shortness of the season during which run-off occurs (page 41). This feature, added to the effects of overall poor drainage, severely limits the amount of material transported by streams and slope wash (Taber, 1943). Movement of debris downslope by soil creep assumes importance because of the high moisture content of the arctic substratum and the lack of deep-rooted vegetation. Although transportation by wind is operative in some areas, it is of minor importance largely because of the wetness of the substratum.

The three main factors that affect deposition in large arctic lakes, using Stanwell-Fletcher Lake as an example, are:

a. The prolonged ice-cover

b. The lack of seasonal stratification

c. The low water temperature

The ice cover affects deposition in that strong, wind-generated wave action is absent, resulting in a low-energy current regime. Because of this feature, the coarser sediments entering the lake are deposited in the marginal areas only, with mud and silt being deposited in the remainder of the lake. Due to the well circulated water, these fine particles remain suspended for some time and thus seasonally laminated deposits or varves, are not formed. In the cases of lakes into which the volume of water entering is much greater than Stanwell-Fletcher Lake, or in which bottom topography allows significant slumping to occur, some modification of these effects is expected. The low water temperature, aided by the extended periods of ice-cover, accounts for the low biological production in arctic lakes (Frey and Stahl, 1958).

In Stanwell-Fletcher Lake, these factors result in:

a. The low rate of sedimentation and generally poor sorting of the fine, unlaminated sediments especially in the central portions of the lake.

b. The absence of stagnation and oxygen-depletion of the water due to organisms. Thus the water remains very fresh and chemically stable even at the bottom. Oxidizing conditions prevail in the surface sediments.

c. The low amount of organic sedimentation as illustrated by the low organic carbon content of the deposits. Precipitated carbonates (marls) are absent.

The following characteristics are therefore expected to be prominent in the bottom sediments of arctic lakes of similar physiography taking the combined effects of weathering, transportation and deposition into consideration:

a. The bottom sediments are poorly sorted with positive skewness due to a disproportionately high percentage of fine, generally silt-sized material.

b. Seasonal lamination of sediments is rare and if present, is restricted to the marginal areas.

c. The clay fraction of the sediment is minor, except in localities where it composes source rocks in the area.

d. Allochthonous (derived) material constitutes the bulk of the deposits. Autochthonous components, such as marls and organic matter, account for very little of the sediments.

e. Labile minerals, such as feldspars and mafic minerals are largely unweathered.

5. The surface portions of the sediments are brown in colour due to oxidation of iron.

In general, the bottom sediments of Stanwell-Fletcher Lake conform well with the preceding characteristics. Certain features are more closely related to the physiography and history of the area, e.g., the arctic foraminifera and the considerable detrital dolomite found. The presence of clay minerals in significant amounts is anomalous but has been traced to the source rocks around the lake, and is not considered a product of chemical weathering (page 75).

SUGGESTIONS FOR FURTHER WORK

It is unfortunate that more research could not be carried out on the clays due to lack of facilities. This fraction of the sediment should be sensitive to the peculiar climatic conditions existing and further work could usefully be directed to this field. It is also suggested that longer cores be obtained so that more precise evidence as to the origin and history of the lake may be ascertained. Sounding or seismic equipment might be utilized to determine the total sediment depth and thus the overall rate of sedimentation for the lake. Determination of pH and Eh values against depth in the cores would also provide information as to diagenetic processes taking place in the bottom sediments.

PLATES 1 and 2

Selected Stanwell-Fletcher Lake cores

PLATE 1

PLATE 1

PLATE 2

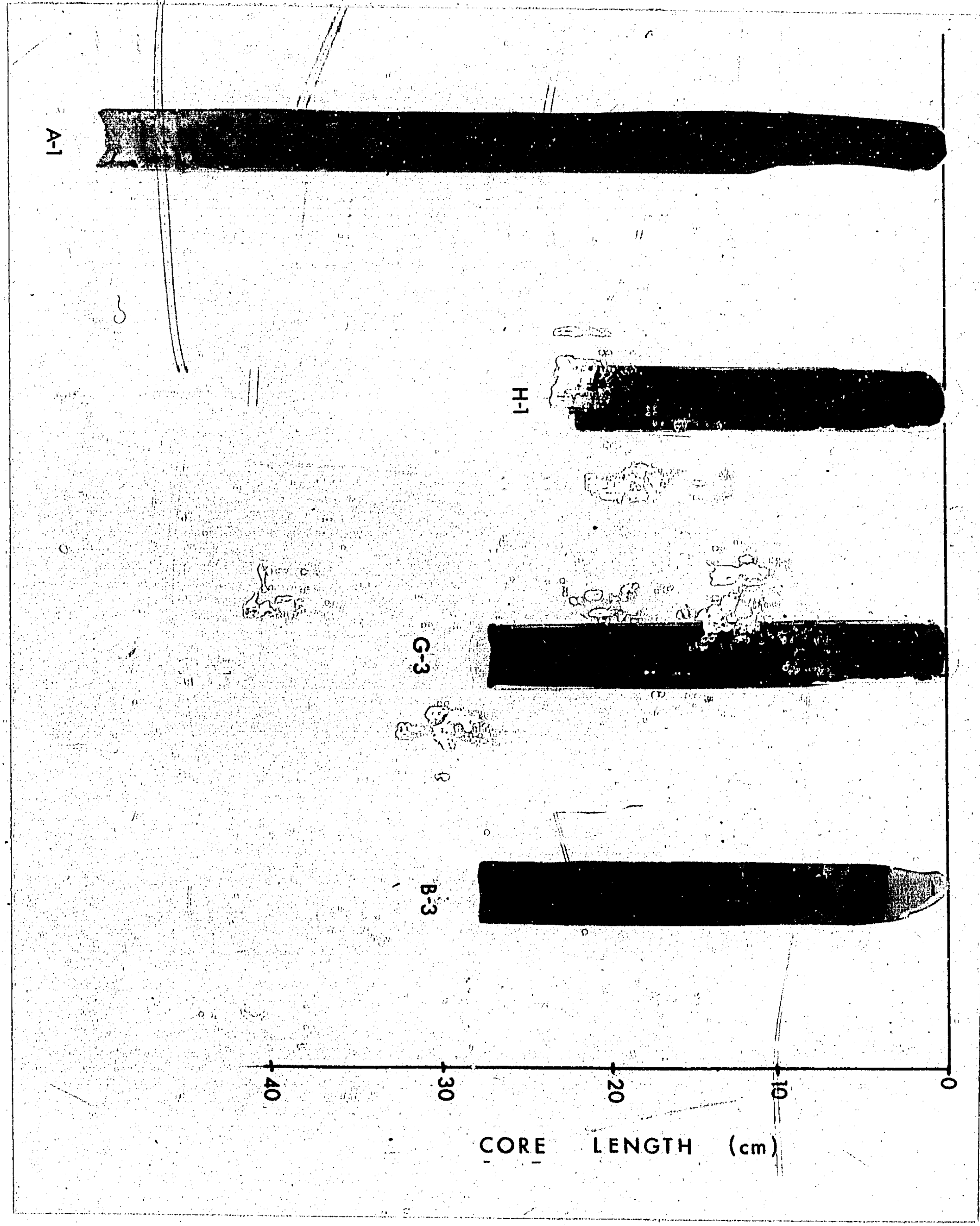
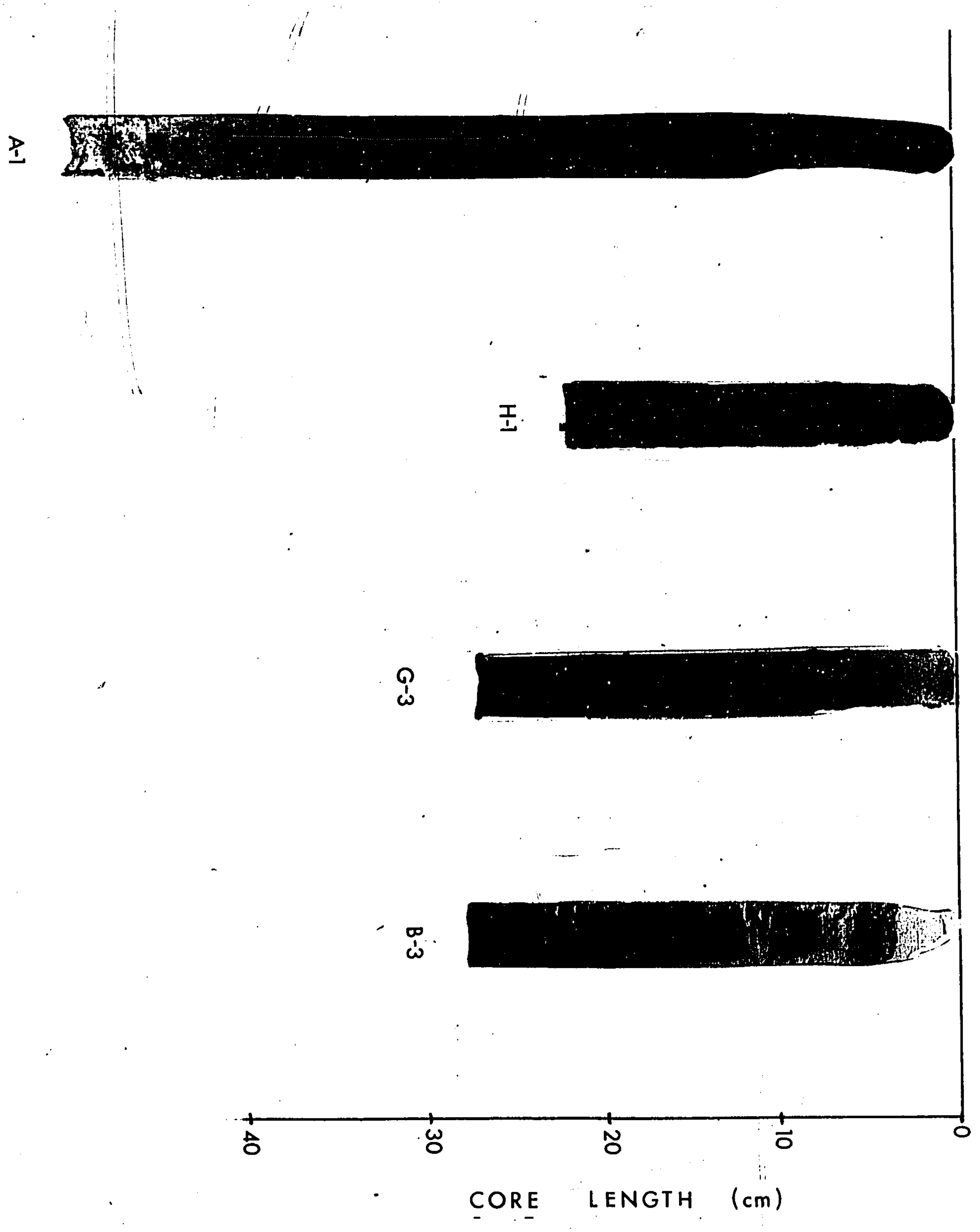


PLATE 2

80c



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