A STUDY ON THE DECOMPOSITION IN LAKE BOTTOM SEDIMENTS IN THE ORDOVICIAN AND POST-ORDOVICIAN OF ONTARIO

by

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A. INTRODUCTION.

This thesis deals with a part of a more extensive project by which the relationship between the biological productivity, and the rate of mineralization of organic detritus in lakes is being studied. The present investigation is concerned, only, with the intensity of the decomposition in the lake bottom sediments.

It is known that organic material in lakes is produced, primarily, by phytoplankton which, in turn, supply all other organisms in the lake with organic matter. The biological productivity of a lake, therefore, is determined mainly by the rate of growth of the phytoplankton. This growth is dependent, to a great extent, on the availability of the mineral nutrients dissolved in the lake water, which are assimilated by phytoplankton and incorporated into organic substances. These mineral nutrients can again be made available for new generations of phytoplankton only by the decomposition of the organisms and their waste products. This results in the liberation of valuable minerals which were part of the complex organic substances forming the living matter of the organisms. Therefore, the faster and more complete this decomposition, the quicker the elements are returned to the nutrient cycle. Since the availability of nutrients in the water is one of the decisive factors which determine the biological productivity, we expect to find a relationship between the rate and intensity of decomposition of organic detritus and the biological productivity of the lake.

The decomposition of the organic material of the dead organisms continues as their remains descend from the productive layer to the

lake bottom, and may be carried on there. However, it is known from field and laboratory observations that most intensive organic decomposition, which is carried out by bacteria, takes place in aerobic conditions. Organic detritus on the surface of many lake bottoms, though, is exposed to aerobic conditions for only a short period of time. Much detritus is often laid down during periods of thermal stratification when anaerobic conditions in the hypolimnion may prevail. Furthermore, the surface layer of the sediment is continuously being covered by new material, favouring anaerobic conditions detrimental to further decomposition of the organic substance in the underlying layer. Any products of decomposition in this layer are not likely to be returned to the lake water.

It seems, therefore, that the more thorough and the faster the decomposition of the organic detritus, while still in the water and before it is incorporated in the bottom sediment, the smaller the amount of nutrients that will be immobilized in the lake bottom sediment. As some of these elements (e.g. phosphorus, nitrogen) are in such short supply in lake waters that they often become limiting factors in productivity, it is believed that a relationship may exist, as stated previously, between the rate of liberation of these elements and the biological productivity of the lake.

The problem was approached on a regional basis to help get a clear picture of the relationship between these factors. As it is most likely that the chemical composition of the ground water supplying the lakes could be one of the prime factors indirectly determining the rate of decomposition, the investigation was carried out in lakes of geologically comparable regions.

The main purpose of this research was to determine the degree of decomposition of the organic matter in the lake bottom sediments. Therefore, quantitative chemical analyses were made of those intermediate compounds which are characteristic for certain phases of mineralization of organic substances produced in lakes. Our analyses included total carbon, bitumen, proto-bitumen, fats, pectin, soluble proteins, carbohydrates, hemicellulose, cellulose, lignin and humic acids. In addition, quantitative analyses were made on nitrogen and phosphorus.

Although considerable work has been done on the chemistry of marine and lake sediments, no reports on the analyses of the intermediate products of decomposition could be found in the literature. Such analyses, however, were done on Moors (8).

Sverdrup (10) found that the most important source of organic material in the ocean is phyto-plankton. Carbon and nitrogen determinations on lake waters have been made by many workers such as Juday, Birge and Meloche (6) and Wiseman (20). Investigations in the effects of bacteria in decomposition have been carried on by Waksman and Vartiovaara (17); Hock (4); Waksman, Hotchkiss, Carey and Hardman (16) and Zobell (21).

It was found by Waksman (15) that on land, organic constituents of plant residues such as sugars, cellulose and hemicellulose decompose rapidly, while lignin decomposes slowly. Proteins may increase in total concentration as a result of synthesis by micro-organisms. It was assumed that similar conditions would prevail in the sea. Abundance of organic matter was determined by loss on ignition which is rather inaccurate due to losses by carbonates and silicates.

Waksman also used oxygen consumption as a measure of decomposition (18).

He mentioned that Winberg and Ivanova found that from May to November, the amount of oxygen liberated was greater than the amount consumed. Therefore, decomposition is less in this period.

Methods used for determination of lignin in wood are described by Brauns (3). Klason (1908) used 64% - 72% sulfuric acid for the hydrolysis of ca rbohydrates and the isolation of lignin. Brauns discusses the a dvantages of pretreatment on lignin determinations by the use of organic solvents, hot water and delute acids.

Hutchinson and Wollock (5) used cold, 72% sulfuric acid for the determination of apparent lignin, which was the organic material insolubb in the acid. The true lignin was calculated by subtracting the protein equivalent of the nitrogen in the apparent lignin. No pretreatment method was mentioned in these determinations.

Steiner and Meloche (9) used the sulfuric acid method in the study of lacustrine materia ls. They found that for lake muds, 30% - 48% of the total organic matter is lignin. They also found that the cellulose and hemicellulose content of the mud decreased with depth.

Twenhofel (14) determined the organic content of gyttja as from 41.22% - 69.52%. The lignin content of this organic matter was from 15.34% - 30.95%. The top cores showed the lowest lignin content, as the sediments of this lake indicated that the bacterial activity ceased after the sediments were buried. The orga nic content in this case was found by ignition.

Twenhofel (14) observed that oozes contained high organic matter and were very black. This organic matter was largely eliminated through diagenetic processes, brought about by micro-organisms. The calcareous sediments were transformed into light-gray to white marls with little or

no evidence of organic origin.

Allgeier, Peterson, Juday (2) found the organic matter in lake deposits to be about 1/3 protein, 2/3 non-nitrogenous. It was highly resistant to decomposition.

It seems, therefore, that a lthough much work has been done on lake muds, that the analyses have not, as yet, been carried out in any great detail with respect to the intermediate organic compounds of decomposition.

B. MATERIALS.

Bottom samples were taken from thirty lakes in the Ordovician and Post-Ordovician regions of Ontario during the summers of 1951 and 1952. The results of the analyses of samples from ten lakes are presented in this thesis. For the location of the ten lakes, see the accompanying map (Fig.1).

Many factors were considered when choosing the lakes to be sampled. Any lake which, according to available information, had been dredged, were polluted, or had evidence of heavy silting were avoided. Their accessibility was also a prime factor in their selection.

One sampling site was chosen for each lake. Sampling was done in a place away from the inlet of the lake and far enough from the shore to be free of shoreline disturbances. Thus, the effort was made to obtain samples from the sediments having a natural, undisturbed deposition.

In order to compensate for local variations in each lake, it would be necessary to take numerous samples at several sampling stations in the one lake. However, the regional nature of the problem here presented required sampling of several widely spread lakes. The sampling and analysis of cores from more than one station in each lake would not have been feasible within the period of time available for this work.

C. LOCATION OF LAKES AND DESCRIPTION

The geographical location of the lakes reported on in this thesis is shown in table I. The latitude and longitude numbers in this table refer to the topographical maps published by the Geographical Section, General Staff, Department of National Defence, Ottawa.

Table II shows the water temperatures and pH of the surface water taken colorimetrically at the time the cores were sampled.

TABLE I

LOCATION AND DEPTH OF LAKES STUDIED

NAME OF LAKE	LOCATION OF LAKE				WATER DEPTH AT SAMPLING STATION IN METERS
	SHEET NUMBER	LATITUDE	LONGITUDE	COUNTY	
Jordan Harbour	30 $\frac{M}{3}$	43°12'N	79°22'W	Lincoln	2.00
Wilcox	30 $\frac{M}{14}$	43°57'N	79°26'W	York	7.00
Constance	31 $\frac{G}{5}$(w)	45°25'N	75°79'W	Carleton	2.75
Mississippi	31 $\frac{F}{1}$	45°05'N	76°10'W	Lanark	5.00
Taylor	31 $\frac{F}{1}$	45°09'N	78°21'W	Lanark	3.50
Chemung	31 $\frac{D}{8}$	44°24'N	78°23'W	Peterborough	3.00
Rice	31 $\frac{D}{1}$	44°06'N	78°19'W	Northumberland	2.75
Boat	41 $\frac{A}{11}$	44°43'N	81°14'W	Bruce	0.50
Silver	41 $\frac{A}{3}$	44°06'N	81°25'W	Bruce	5.00
Puslinch	40 $\frac{P}{8}$	43°25'N	80°16'W	Wellington	2.00

TABLE II

WATER TEMPERATURES AND pH OF LAKE WATER AT TIME OF SAMPLING

NAME OF LAKES	WATERDEPTH IN METERS	WATER TEMPERATURES (°C)	pH
Jordan Harbour	0	19.0	8.4
Wilcox	0	-	8.5
Constance	0.0	23.6	8.8
	0.5	23.8	-
	1.0	22.4	-
	1.5	22.3	-
	2.0	22.2	-
	2.5	21.8	-
	3.0	21.6	-
Mississippi	0.0	21.0	8.2
	0.5	21.0	-
	1.0	21.0	-
	1.5	21.0	-
	2.0	21.0	-
Taylor	0	20.0	8.4
Chemung	0.0	20.0	8.6
	1.0	20.0	-
	2.0	19.9	-
	3.0	19.8	-

TABLE II (continued)

NAME OF LAKES	WATERDEPTH IN METERS	WATER TEMPERATURES (°C)	pH
Rice	0	-	8.6
Boat	0	26.2	8.6
Silver	0	-	8.6
Puslinch	0.0	20.4	7.2
	1.0	20.5	-
	2.0	19.9	-
	3.0	18.9	-
	3.5	17.8	-

D. SAMPLING METHODS.

The sediments were sampled with Lundqvist and Hiller samplers.

The Lundqvist sampler was used for surface samples as it prevented any compression of the sediment and could retain thin, liquid samples unlike the Hiller sampler.

The Hiller sampler was used to sample the sediment at fifty centimeter intervals from the surface of the sediment to the maximum depth at which it was possible to sample. The sampler was modified by making the bore detachable. This allowed for quick removal of the outer sleeve and easy cleaning of the apparatus.

While still in the core, the sediments were examined as to colour, texture, relative amount of macroscopic detritus and fossils. Based on these physical characteristics, the distinct strata were measured and removed individually from the cores, preserved with chloroform and stored in jars. Checks were made on the presence of H_2S in each of the samples.

The pH of surface water was determined colorimetrically. Water temperatures were recorded with a reversing thermometer and a bathythermograph.

An aeroplane wing tank was used as a float to stabilize the boat from which the core samples were taken. This tank was fastened to the boat by long rods and lowered in the water on the side of the boat where the samples were taken.

Each sample of sediment, when returned to the laboratory, was examined for fossil mollusks, which were identified by Dr. H. Van der Schalie, University Museum, University of Michigan. Glycerine jelly mounts were made from each sample for the study of the microscopic characteristics.

The remainder of the sediment was dried, ground and used for the chemical analyses reported on in this thesis.

E. CHEMICAL METHODS

I. DRYING METHODS

Put moist sediment on blotting paper and leave it to dry in the air until all excess moisture is gone.

Put sediment in a weighed drying dish and weigh it again.

Dry sediment to constant weight at 105°C.

From these data, calculate the water loss of the sediments.

For further chemical analyses, grind the sediment to a fine texture and again dry to constant weight.

All mollusk fossils were not removed but considered as part of the sediment.

II. CHEMICAL ANALYSES

a. Total carbon

Total carbon determinations were done according to the method outlined by Waksman (19).

(1) Apparatus

A Graham condenser was joined by means of a reducing adapter to the middle neck of a three-necked flask. One neck of the flask contained a separatory funnel for the introduction of the oxidizing solution and the remaining neck of the flask contained a tube connected to two absorption bulbs. Air was drawn into the system through these bulbs. The upper part of the condenser was connected to a U-tube containing pumice saturated with silver sulphate, separated by glass helices from the other side having pumice saturated with concentrated sulphuric acid. Joined to the U-tube was glass tubing which reached to the bottom of a three necked

absorption flask. The centre neck of the flask was connected to the vacuum line through a glass tube filled with helices. The third neck was stoppered.

All ground glass joints connected to the flask containing the oxidizing solution and those to the condenser were sealed with phosphoric acid saturated with phosphorus pentoxide. The remaining joints were sealed with a silicone high-vacuum grease.

(2) Method

Place in the absorption flask 40 millilitres of 0.5N sodium hydroxide.

In the large flask put about 100 milligrams of dried sediment.

Introduce the oxidizing solution through the separatory funnel. It consisted of 85 grams of chromic anhydride in 100 millilitres of water, made up to 250 millilitres with 85% phosphoric acid.

Apply a slight vacuum and add 40 millilitres of a solution containing equal parts phosphoric and sulphuric acids.

Heat the flask and take the digestion time as 80 minutes after the mixture begins to boil. The fumes are drawn through the condenser into the U-tube where the chlorine is absorbed by the silver sulphate and the sulphite by the sulphuric acid. The carbon dioxide gas is absorbed by the 0.5N sodium hydroxide.

Remove absorption flask at the end of the digestion time.

Wash down the flask with carbon dioxide free water.

Precipitate the carbon dioxide as barium carbonate with 10 millilitres of 2N barium chloride.

Titrate excess alkali with 0.5N hydrochloric acid using phenolphthalein as an indicator.

(3) Calculation of total carbon

1 millilitre 0.5N sodium hydroxide = 3 milligrams of carbon.

(number of millilitres of sodium hydroxide added - number of millilitres of 0.5N hydrochloric acid used) x 3 = number of milligrams of carbon.

b. Organic products of decomposition

The determinations for lignin and the related compounds of decomposition were carried out according to the method given by Souci ( ).

1. Determination of ash

Weigh about 2 grams of dried sediment into a weighed silica crucible and incinerate it for 1 hour in a muffle furnace at 660°C.

Calculate the weight of the ash in percentage of the dried sediment (A).

2. Substances soluble in benzene-alcohol solution (bitumen, protobitumen and fats).

(1) Method

Weigh about 10 grams of dried sediment into an asbestos thimble (E).

Extract sediment in a soxhlet until the returning solvent is colourless. The solvent used was of equal parts benzene and absolute alcohol.

Transfer the liquid containing benzene-alcohol soluble substances to a weighed silica crucible.

Dry material in the silica crucible to constant weight at 105°C.(R)

Determine the ash content of the benzene-alcohol soluble substances (A).

3. Calculation

$$B = \frac{100.\ (R-A_1)}{E}$$

B - material soluble in benzene-alcohol in percentage of the dried sediment.

R - amount, in grams, of benzene-alcohol soluble substances.

A_1 - weight in grams of inorganic material soluble in benzene-alcohol.

E - weight in grams of dried sediment used for the extration.

3. Substances soluble in hot water (pectins, soluble carbohydrates, proteins and minerals)

(1) Method

Dry residue from benzene-alcohol extraction to constant weight at 105°C.

Weigh out about 4 grams of this residue (R_1).

Add weighed material quantitatively to a one litre florence flask.

Add 300 millilitres of distilled water to the florence flask.

Attach a Liebig condenser to flask and reflux for 3 hours.

Filter mixture through a fritted glass crucible and wash for a short time with hot water.

Take an aliquot of the filtrate and dry in oven at 105°C. Determine the ash content of the aliquot (A_2).

Dry residue in crucible to constant weight in the oven at 105°C(R_2).

(2) Calculation

$$P = \frac{100.\ (\ R_1 - (R_2+A_2)\ ).}{M}$$

P - amount of material hydrolyzed by hot water in percentage of the dry sediment.

R_1 - weighed amount of residue from benzene-alcohol extraction.

R_2 - material in grams insoluble in hot water.

A_2

A_2 - $\frac{R_1 - R_2}{\text{amount ashed}}$ x ash weight - expressed in grams.

M - $\frac{100.R_1}{100-(B+100.A_1)}$ - expressed in percent.

$\frac{}{E}$

4. Substances hydrolyzable with dilute acids (hemicellulose, proteins and small amounts of cellulose)

(1) Method

Weigh the material insoluble in hot water.

Transfer weighed material quantitatively into a one litre florence flask.

Reflux material for 3 hours with 300 millilitres of 2% hydrochloric acid.

Filter mixture through a fritted glass crucible and wash with hot water until free of acids.

Dry residue of material insoluble in dilute acids to constant weight (R_3).

Take 0.6 grams of R_3 and determine the ash content (A_3).

(2) Calculation

$$H = 100 \left(\frac{R_2 - R_3 + A_2 + A_3}{M} + \frac{A_1}{E}\right) - A$$

H - material hydrolyzed by dilute acids expressed in percent of the dry sediment.

R_3 - $\frac{R_2}{\text{amount of } R_2 \text{ used in extraction}}$ x residue from dilute acid extraction expressed in grams.

A_3 - $\frac{R_3}{\text{amount ashed}}$ x ash weight - expressed in grams.

A - $\frac{\text{ash weight}}{\text{amount of original sediment ashed}} \times 100$ - expressed in percent of original sediment.

5. Substances hydrolyzable with strong sulphuric acid (celluloses, humic acids, lignin, and small amounts of proteins

(1) Method

Weigh out amount of material insoluble in dilute acids (E_1)

Mix weighed material with 20 millilitres of 72 - 80% sulphuric acid. Leave mixture standing, at room temperature, for 2½ hours, with frequent stirring.

Wash mixture quantitatively into a one litre florence flask and reflux for 5 hours.

Filter mixture as previously described and dry the residue (R_4) to constant weight.

Do an ash determination (A_4) on R_4.

(2) Calculation

$$Z = \frac{100.R_3 \left(E_1 - R_4 - \frac{A_3 \cdot E_1}{R_3} + A_4\right)}{M.E_1}$$

Z - amount of material soluble in strong acid in percent of dry sediment.

E_1 - weighed amount of R_3 expressed in grams.

R_4 - material insoluble in strong acid expressed in grams.

A_4 - $\frac{R_4}{\text{amount of } R_4 \text{ ashed}} \times$ ash weight - expressed in grams.

In all determinations of section b, losses due to volatile substances were disregarded.

c. Nitrogen

The nitrogen determinations were done using the original Kjeldahl method. The catalyst used was 0.3 gram - 0.5 gram of three parts cupric sulphate and one part potassium sulphate.

d. Phosphorus

The determinations of phosphonus were done according to the Deniges Colorimetric Method for Phosphorus and Arsenic modified by Truog and Meyer (11).

(1) Method

Fuse 50 milligrams of dry ash with 0.500 grams of sodium carbonate in a platinum crucible.

Allow material to harden to a cake in the crucible and then transfer it to an evaporating dish with water.

Rinse the platinum crucible with a few drops of concentrated hydrochloric acid and wash into the dish.

Cover the evaporating dish with a watch glass and add 3 millilitres of concentrated hydrochloric acid under the cover.

When effervescence has stopped, remove the watch glass making sure that the cake has completely disintegrated and evaporate to dryness over steam.

Heat evaporating dishes on a steam bath for one hour.

Add 2 millilitres of concentrated hydrochloric acid and bring it into contact with all the solids by means of the stirring rod.

Add 10 - 20 millilitres of water and heat for about 10 minutes on the steam bath to dissolve all the soluble constituents.

Filter material to remove silica and wash thoroughly with 1:100 hydrochloric acid.

Discard residue and heat filtrate to boiling.

Precipitate aluminium, iron and phosphorus by adding concentrated ammonium hydroxide dropwise. Add no more than is necessary.

Filter and wash with 1 percent ammonium chloride and discard filtrate.

Dissolve the residue from the filter with 2 millilitres of 10N sulphuric acid and wash through with about 20 millilitres of water.

Remove iron and aluminium from the solution by passing it through a cation exchanger and collect it in a 100 millilitre volumetric flask.

Wash with two 20 millilitre portions of water each containing 1 millilitre of 10 N sulphuric acid.

Continue washing the column with distilled water until the volumetric flask contains 90 - 95 millilitres.

Add 4 millilitres of 2.5 percent ammonium molybdate and mix thoroughly. This mixing is important.

Add 10 drops of stannous chloride (25 grams in 1 litre of 10 percent hydrochloric acid).

Allow the solution to stand for 10 minutes after mixing to develop the color.

Add 5 more drops of stannous chloride, mix and read density on spectrophotometer immediately.

Read the concentration of phosphorus in parts per million from the calibration curve.

Express the phosphorus as a percentage of the original dry sediment.

F. RESULTS OF ANALYSES

In table III, the results of total carbon, total nitrogen, total phosphorus and water content are represented as percentages of the dry material.

In table IV are tabulated the amounts of bitumen, pectin, hemicellulose and cellulose likewise as percentages of the dry material.

Table V shows the nitrogen and phosphorus contents of some of the samples.

Figures 2 - 11 represent, in graphic form, the percentages of bitumen, pectin, hemicellulose and cellulose of the sediments analysed.

TABLE III

TOTAL CARBON, TOTAL NITROGEN, TOTAL PHOSPHORUS AND WATER CONTENT OF THE BOTTOM SEDIMENTS OF TEN LAKES OF THE ORDOVICIAN AND POST-ORDOVICIAN OF ONTARIO

NAME OF LAKE	SAMPLE NUMBER	DEPTH OF STRATUM FROM SURFACE OF SEDIMENT IN CENTIMETERS	THICKNESS OF STRATUM IN CENTIMETERS	PERCENTAGE OF DRY WEIGHT				
				WATER CONTENT	TOTAL CARBON	TOTAL PHOSPHORUS	TOTAL NITROGEN	PRESENCE OF H_2S
Jordan Harbour	B 3.0	0.0	20.0	85.06	7.15	0.124	0.64	-
	B 6.0(1)	0.0	0.3	28.57	-	0.015	-	-
	B 6.2	0.3	1.8	9.37	6.37	0.155	0.66	-
	B 6.3	2.1	3.0	26.31	5.15	-	0.86	-
	B 6.4	5.1	15.0	73.16	4.50	0.088	0.83	-
	B 4.0	10.0	12.0	44.21	3.74	0.077	0.64	-
	B 3.1	20.0	30.0	47.82	4.69	0.093	0.56	-
	B 4.1	22.0	36.0	34.25	5.98	0.081	0.60	-
	B 8.0	100.0	35.0	-	5.32	0.099	0.43	-
	B 8.1	135.0	15.0	88.63	4.93	0.112	0.75	-
	B 7.0	150.0	20.0	25.00	6.91	0.102	1.13	-
	B 7.1	170.0	20.0	44.77	-	0.017	-	-
	B 7.2	180.0	10.0	-	6.32	0.079	1.15	-
Wilcox	B 81.0	0.0	30.0	85.43	10.15	0.077	0.28	-
	B 81.1	0.0	20.0	141.99	13.28	0.063	0.40	-
	B 82.0	50.0	50.0	225.00	14.58	0.049	0.49	-
	B 85.0	200.0	40.0	166.16	11.37	0.054	0.48	-
	B 85.1	240.0	10.0	144.18	14.01	0.061	0.45	-

TABLE III (continued)

NAME OF LAKE	SAMPLE NUMBER	DEPTH OF STRATUM FROM SURFACE OF SEDIMENT IN CENTIMETERS	THICKNESS OF STRATUM IN CENTIMETERS	PERCENTAGE OF DRY WEIGHT				PRESENCE OF H_2S
				WATER CONTENT	TOTAL CARBON	TOTAL PHOSPHORUS	TOTAL NITROGEN	
Constance	B 115(1)	0.0	50.0	-	7.71	0.123	0.94	-
	B 104	0.0	50.0	-	45.49	0.145	1.70	-
	B 105	50.0	50.0	165.82	59.86	0.106	1.65	-
	B 108	200.0	50.0	303.77	56.86	0.080	1.15	-
	B 111	350.0	50.0	3.90	16.55	0.098	1.65	-
	B 112	400.0	50.0	4.59	36.52	0.092	1.65	-
	B 113	450.0	50.0	-	5.16	0.116	1.35	-
Mississippi	B 120(1)	0.0	3.0	-	10.13	0.109	-	-
	B 117	0.0	25.0	533.33	20.30	0.065	1.29	-
	B 117.1	25.0	25.0	297.40	13.98	0.066	0.79	-
	B 118	50.0	45.0	205.88	12.73	0.045	0.51	-
	B 119	100.0	50.0	-	4.99	0.098	0.04	-
Taylor	B 140(1)	0.0	10.0	-	-	0.114	3.43	-
	B 131	0.0	50.0	1544.52	31.02	0.049	1.82	+
	B 132	50.0	50.0	5206.25	25.96	0.050	1.84	+
	B 133	100.0	50.0	80.00	24.48	0.043	2.43	+
	B 134	150.0	20.0	1096.96	24.02	0.054	2.27	+
	B 134.1	170.0	30.0	3207.14	24.44	0.066	1.53	+
	B 135	200.0	30.0	2929.03	23.05	0.025	1.80	+
	B 135.1	230.0	20.0	1263.63	32.36	-	2.48	-
	B 136	250.0	18.0	694.66	31.71	-	2.99	-
	B 136.1	268.0	22.0	1321.15	38.56	0.051	3.24	-

TABLE III (continued)

NAME OF LAKE	SAMPLE NUMBER	DEPTH OF STRATUM FROM SURFACE OF SEDIMENT IN CENTIMETERS	THICKNESS OF STRATUM IN CENTIMETERS	PERCENTAGE OF DRY WEIGHT				PRESENCE OF H_2S
				WATER CONTENT	TOTAL CARBON	TOTAL PHOSPHORUS	TOTAL NITROGEN	
Taylor (cont)	B 136.2	290.0	10.0	912.50	21.81	0.105	0.87	-
	B 137.0	300.0	25.0	1377.35	28.98	0.066	2.39	-
	B 137.1	325.0	25.0	532.74	37.74	0.078	1.95	+
	B 138.0	350.0	50.0	-	28.72	0.093	2.23	-
Chemung	B 165	0.0	5.0	246.66	11.47	0.052	0.54	-
	B 165.1	5.0	5.0	32.90	17.60	0.021	0.59	+
	B 166.0	50.0	50.0	346.93	10.00	0.027	0.61	+
	B 170	250.0	50.0	185.03	20.30	0.012	0.40	-
	B 173	400.0	50.0	182.09	14.25	0.388	0.32	-
Rice	B 176	0.0	20.0	853.84	16.48	0.076	2.81	-
	B 176.1	20.0	15.0	547.61	21.61	0.112	-	-
	B 176.2	35.0	15.0	79.60	5.23	0.052	1.56	-
	B 182	250.0	50.0	109.43	14.05	0.038	0.50	-
	B 186	450.0	20.0	77.32	15.69	0.031	-	+
	B 186.1	470.0	30.0	105.80	11.59	0.031	-	+
Boat	B 215	0.0	20.0	77.24	7.00	0.032	0.68	-
	B 215.1	20.0	20.0	40.77	6.23	0.051	0.08	-
	B 215.2	40.0	10.0	208.47	10.52	0.030	0.73	-
	B 217.1	100.0	25.0	12.14	5.25	0.055	0.31	-

TABLE III (continued)

NAME OF LAKE	SAMPLE NUMBER	DEPTH OF STRATUM FROM SURFACE OF SEDIMENT IN CENTIMETERS	THICKNESS OF STRATUM IN CENTIMETERS	PERCENTAGE OF DRY WEIGHT				PRESENCE OF H_2S
				WATER CONTENT	TOTAL CARBON	TOTAL PHOSPHORUS	TOTAL NITROGEN	
Silver	B 228	0.0	50.0	495.33	12.22	0.202	2.01	-
	B 232	200.0	20.0	231.81	10.28	0.095	0.41	-
	B 232.1	220.0	30.0	149.80	14.87	0.051	0.26	-
Puslinch	B 235	0.0	50.0	253.75	11.33	0.020	3.65	-
	B 239	200.0	50.0	184.04	28.61	0.049	2.15	-
	B 243	400.0	40.0	1098.69	27.20	0.052	2.67	-
	B 243.1	440.0	10.0	114.60	8.03	0.224	0.21	-

(1) - samples collected with Lundquist sampler
other samples were collected with the Hiller sampler

TABLE IV

BITUMEN, PECTINS, HEMICELLULOSES, CELLULOSE, IN THE BOTTOM SEDIMENTS OF TEN LAKES OF THE ORDOVICIAN AND POST-ORDOVICIAN OF ONTARIO

NAME OF LAKE	SAMPLE NUMBER	PERCENTAGE OF DRY WEIGHT			
		BITUMEN	PECTINS	HEMICELLULOSES	CELLULOSE
Jordan Harbour	B 3.0	0.309	3.819	0.077	0.331
	B 6.0	0.727	3.570	32.261	0.376
	B 6.4	0.059	3.514	0.006	0.036
	B 4.0	0.043	4.016	0.164	0.063
	B 3.1	0.354	2.125	0.005	0.266
	B 4.1	0.048	1.974	0.091	0.026
	B 8.0	0.087	3.868	0.161	0.204
	B 8.1	0.045	3.982	0.873	0.648
	B 7.0	0.216	3.668	4.155	0.091
	B 7.1	0.330	8.729	0.014	2.057
	B 7.2	0.059	0.602	46.399	4.641
Wilcox	B 81.0	0.024	11.616	0.240	0.274
	B 81.1	0.108	0.932	9.964	0.330
	B 82.0	0.029	4.244	0.013	0.195
	B 85.0	0.063	4.679	25.228	1.272
Constance	B 104.0	0.357	0.996	13.057	1.134
	B 105.0	0.215	3.677	7.515	0.103
	B 108.0	0.322	2.834	8.069	1.417
	B 111.0	0.739	17.906	8.950	1.256
	B 112.0	0.071	2.414	10.767	0.777
	B 113.0	0.052	2.359	2.234	1.239

TABLE IV (continued)

NAME OF LAKE	SAMPLE NUMBER	PERCENTAGE OF DRY WEIGHT			
		BITUMEN	PECTINS	HEMICELLULOSES	CELLULOSE
Mississippi	B 120.0	0.186	10.882	6.600	0.966
	B 117.1	0.042	6.459	14.200	1.056
	B 118.0	0.101	4.480	10.010	0.919
	B 119.0	0.004	0.213	3.080	0.137
Taylor	B 131	0.712	8.494	22.363	4.047
	B 132	0.936	16.499	21.544	-
	B 133	0.494	8.256	22.170	0.003
	B 134	0.820	16.654	9.858	3.782
	B 134.1	0.568	0.975	34.014	-
	B 135	0.606	13.630	8.291	2.493
	B 135.1	1.426	24.381	22.228	1.540
	B 136.1	1.361	34.147	24.135	2.202
	B 137	0.777	32.773	17.766	4.227
	B 137.1	0.468	23.267	13.100	1.129
	B 138	0.721	14.611	14.107	9.345
Chemung	B 165.1	0.011	1.798	6.695	0.779
	B 166	0.188	6.023	17.629	0.128
	B 170	0.022	1.261	1.485	0.850
	B 173	0.048	3.879	0.234	0.041
Rice	B 176.2	0.001	11.815	5.584	0.621
	B 182	0.118	1.531	3.951	0.103
	B 186	0.135	3.664	13.316	-
	B 186.1				

TABLE IV (continued)

NAME OF LAKE	SAMPLE NUMBER	PERCENTAGE OF DRY WEIGHT			
		BITUMEN	PECTINS	HEMICELLULOSES	CELLULOSE
Boat	B 215	0.140	5.336	3.828	0.019
	B 215.1	0.004	0.941	0.001	0.032
	B 217.1	0.011	1.930	0.316	3.973
Silver	B 232.1	0.063	0.389	2.870	0.968
Puslinch	B 239	0.677	1.378	29.949	9.506
	B 243	0.192	8.172	20.999	1.729
	B 243.1	0.066	1.797	3.327	0.821

TABLE V

NITROGEN AND PHOSPHORUS IN THE ORGANIC FRACTIONS OF A NUMBER OF SAMPLES

NAME OF LAKE	SAMPLE NUMBER	PERCENTAGE OF DRY WEIGHT			
		NITROGEN IN HOT WATER FILTRATE (1)	NITROGEN IN HCl FILTRATE (2)	PHOSPHORUS IN HCl RESIDUE (3)	PHOSPHORUS IN H_2SO_4 RESIDUE (4)
Jordan Harbour	B 3.0	-	0.017	-	0.010
	B 6.0	0.145	0.501	0.001	0.0003
	B 6.4	-	0.049	0.040	-
	B 4.0	-	0.010	0.014	0.026
	B 3.1	-	0.085	0.022	0.041
	B 4.1	-	0.011	0.014	0.007
	B 8.0	-	0.086	-	0.019
	B 8.1	-	0.072	0.009	-
	B 7.0	-	0.089	0.013	0.041
	B 7.1	-	0.274	0.010	0.015
	B 7.2	-	0.073	0.012	0.008
Wilcox	B 81	-	0.036	0.031	0.007
	B 81.1	-	0.089	0.007	0.008
Constance	B 104	0.543	0.295	0.012	0.006
	B 105	-	0.142	0.015	0.006
	B 108	0.075	0.059	0.004	0.001
	B 111	0.686	0.189	0.008	0.009
	B 112	-	0.089	0.007	0.013
	B 113	0.147	0.132	0.020	0.014
Mississippi	B 117.1	-	0.184	0.009	0.006

TABLE V (continued)

NAME OF LAKE	SAMPLE NUMBER	PERCENTAGE OF DRY WEIGHT			
		NITROGEN IN HOT WATER FILTRATE (1)	NITROGEN IN HCl FILTRATE (2)	PHOSPHORUS IN HCl RESIDUE (3)	PHOSPHORUS IN H_2SO_4 RESIDUE (4)
Taylor	B 131	0.222	0.502	0.002	0.0007
Chemung	B 165.1	-	0.055	0.018	0.003
Rice	B 176.2	-	0.086	0.007	0.007
	B 186.0	-	0.075	0.0006	-
Boat	B 215	-	-	0.007	0.009
	B 215.1	-	0.021	0.014	0.030
Silver	B 232.1	-	0.038	-	-
Puslinch	B 239	0.701	0.531	-	-

(1) This filtrate contains, besides pectins, small amounts of nitrogenous compounds, mainly water soluble proteins.
(2) The filtrate contains, besides hemicelluloses, small amounts of nitrogenous compounds, mainly proteins of higher stability.
(3) Phosphorus content of substances not hydrolyzable by 2% HCl (cellulose, proteins, lignin and intermediate products of decomposition).
(4) Phosphorus content of substances not hydrolyzable by 72% H_2SO_4.

G. DISCUSSION OF RESULTS

Potonie (7) designates the carbonaceous substances and oxidizable compounds of native carbon in lake sediments as caustobioliths. These caustobioliths, especially sapropelites, are mainly built up by products of decay from aquatic organisms such as plankton. Decay of these caustobioliths does not take place completely, so amounts of these substances accumulate on the lake bottom as organogenic sediments (sapropel, sapropelites). One use of total carbon determinations is to give information on the amount of decay which took place. The varying amounts of carbon may also indicate varying levels of productivity in the lake.

Phosphorus in bottom sediments has its origin partly from organic substances of decaying aquatic organisms and from colloidal and chemical precipitation, closely related with oxidation-reduction potentials of the mud-water interphase. Since phosphorus is a critical nutrient element in lakes, it is important to find out where and in what form it is found in different lakes. From the data available, phosphorus variations are very small and no sequence in its distribution can be found, as yet.

Nitrogen may be present in abundance in sediments as a result of the presence of proteins of bacterial origin. This is often typical in deeper strata. In two lakes analyzed this is found to be true. In Jordan Harbour, the total nitrogen content increased from 0.64% at the surface of the sediment to 1.15% at 180 centimeters from the surface. In Wilcox lake, the total nitrogen ranged from 0.28% at the surface of the sediment to 0.45% at 240 centimeters from the surface. From our nitrogen determinations, we may, in time, be able to establish the amounts of proteins in

the sediment.

Bitumen (waxes, resins) is highly resistant to decomposition. Since it is particularly high in organic matter of aquatic origin (e.g. plankton) it may be possible to find out differences in origin of sediments in older strata.

In nature, pectins are decomposed first, then hemicellulose and finally cellulose. Since hemicellulose predominates in Sphagnum, which does not form cellulose, old sediments enriched by hemicellulose may indicate a Sphagnum bog origin. Relative amounts of these substances give information on the progress of decomposition and its thoroughness.

Two lakes showing the greatest percentages of organic matter were: (1) Taylor lake with total carbon ranging from 21.81% - 97.65%; total nitrogen from 0.87% - 3.43%; bitumen from 0.469% - 1.426%; pectin from 0.975% - 39.148%; hemicellulose from 8.291% - 34.014%; and cellulose from 0.003% - 9.3452%. Puslinch lake with total cabon from 8.03% - 28.61%; total nitrogen from 0.21% - 3.65%; bitumen from 0.066% - 0.677%; pectin from 1.378% - 8.172%; hemicellulose from 3.327% - 29.949%; cellulose from 0.821% - 9.506%. The large amount of organic material in the sediments of these two lakes is due to the fact that the sedimentation rate was much greater than the decomposition rate, thus allowing for a large accumulation of material on the lake bottoms. Although at this stage of the investigation no conclusions can be drawn, it would seem that the supply of nutrients in these particular lakes did not depend on the rate of decomposition of the bottom sediments.

Boat lake had total carbon ranging from 5.25% - 10.52%; total nitrogen from 0.08% - 0.73%; bitumen from 0.004% - 0.140%; pectin from

0.942% - 5.336%; hemicellulose from 0.001% - 3.828%; cellulose from 0.019% - 3.974%. In comparison with the other lakes, the organic matter in the sediment of this lake is rather thoroughly decomposed. This is a eutrophic lake which is gradually filling up. The maximum water depth was one meter.

No conclusions can be drawn as to the relationship between the biological productivity of the lakes studied and the intensity of decomposition of the organic matter in the bottom sediment, until more data are available on a larger number of lakes in different geological regions. Accurate productivity measurements must be made to establish such relationship.

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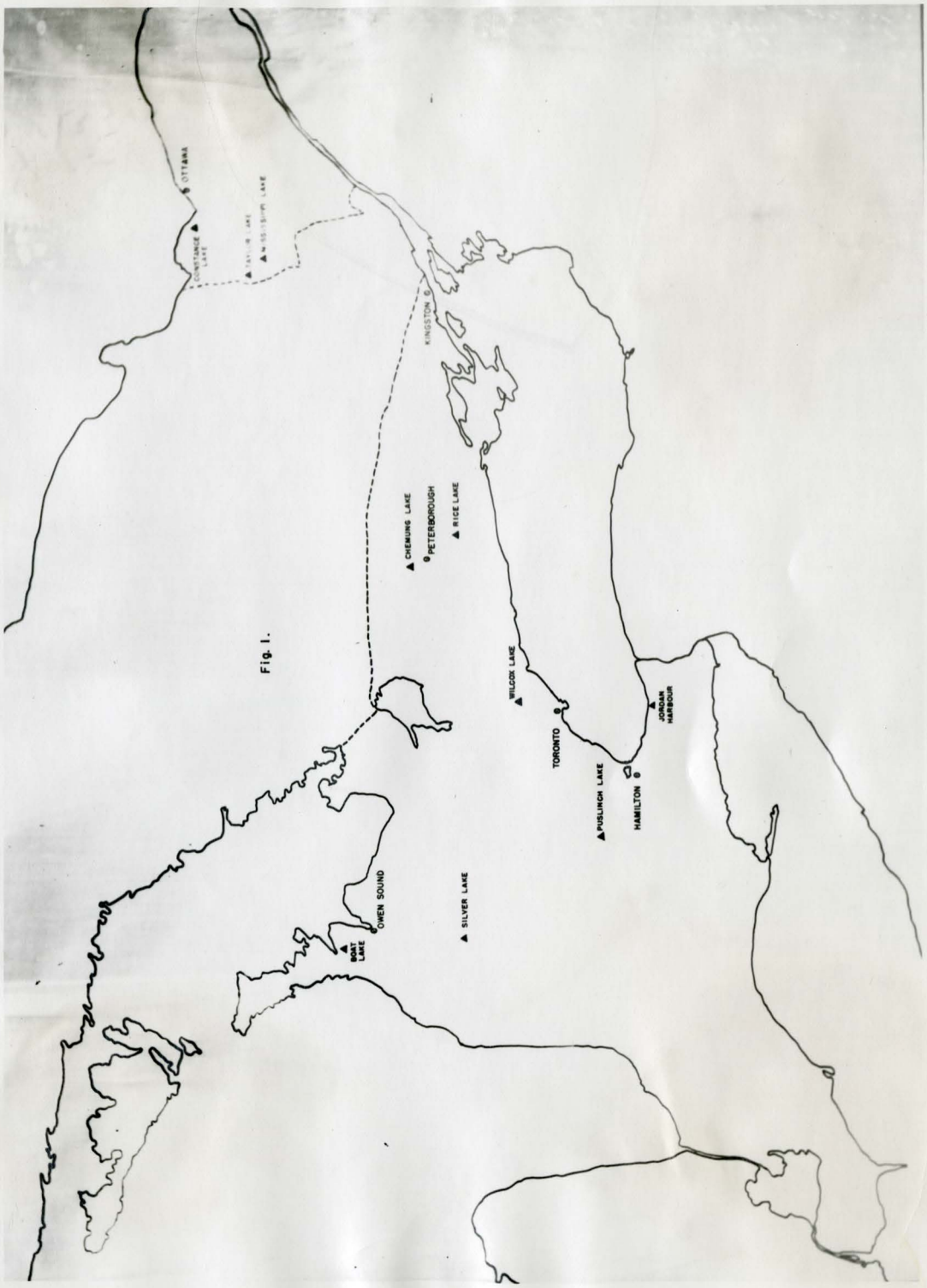
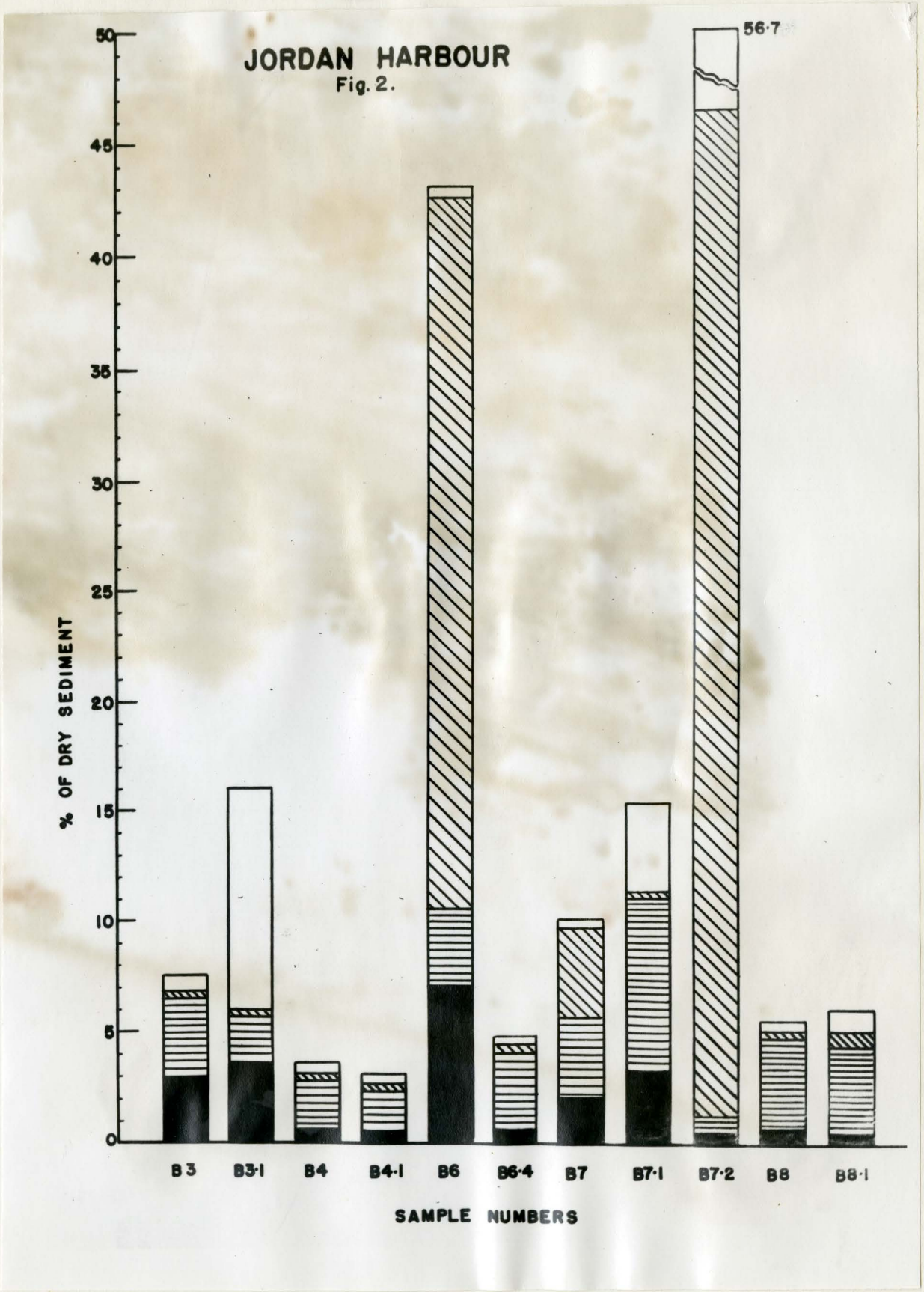
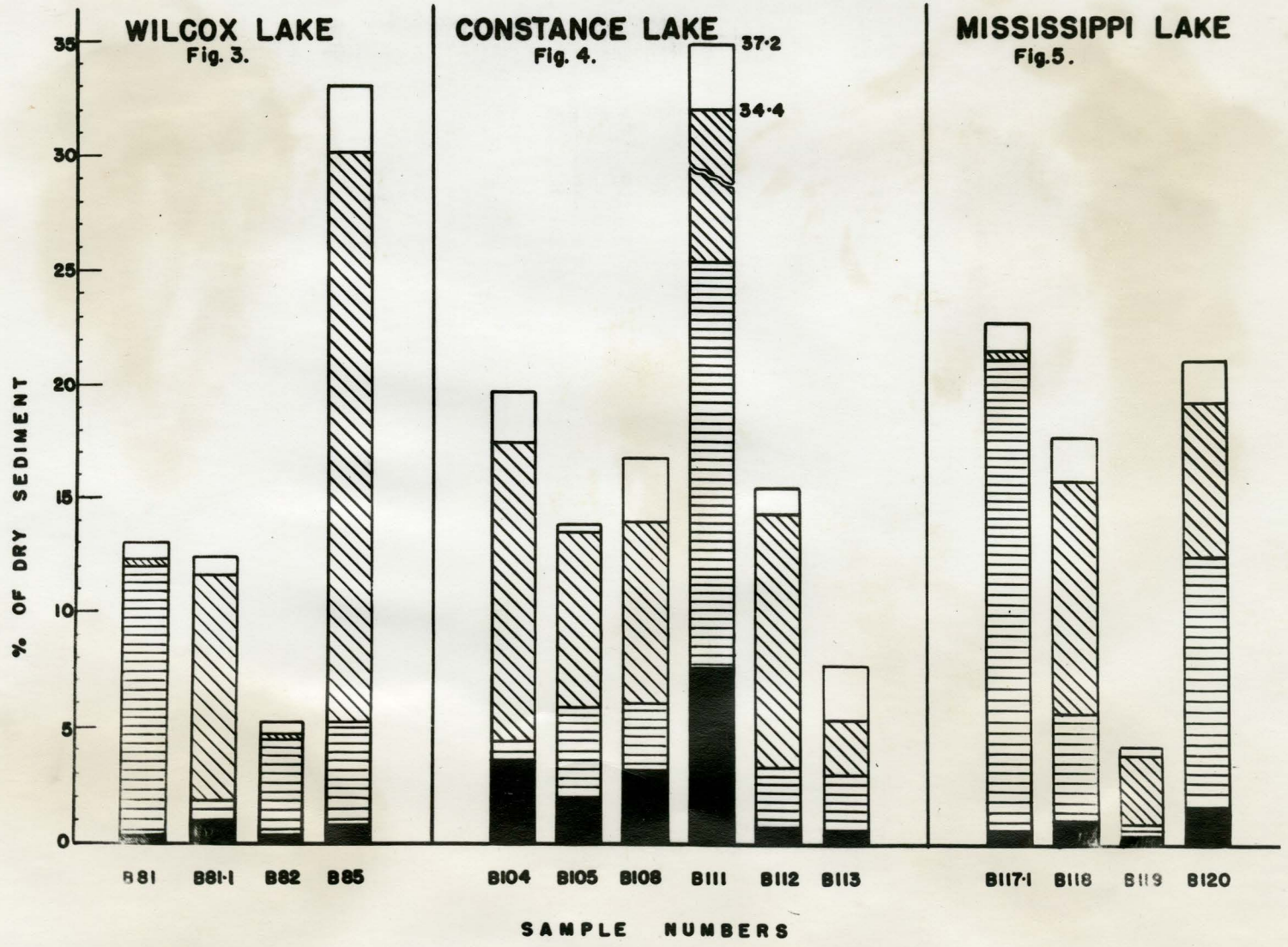
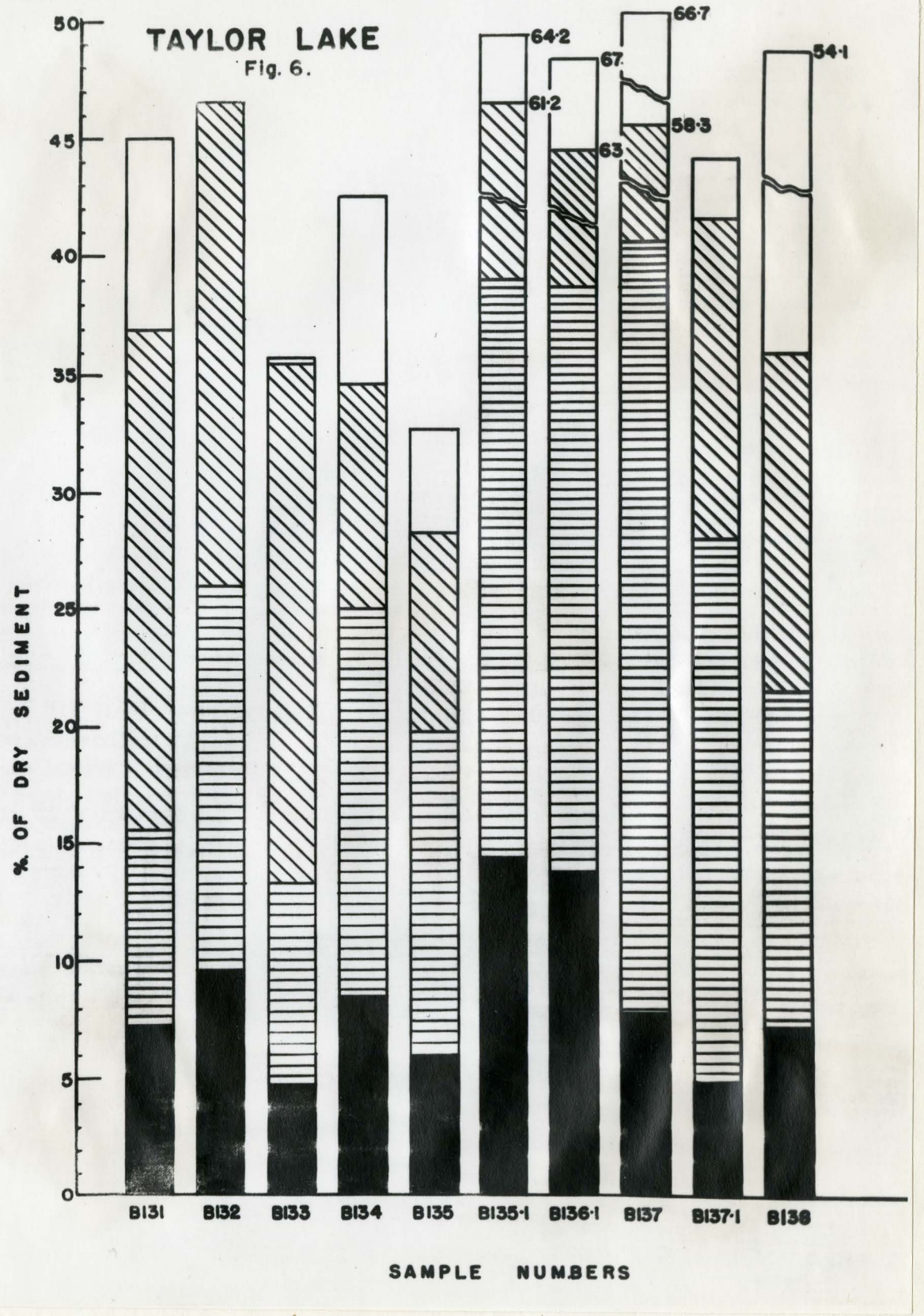
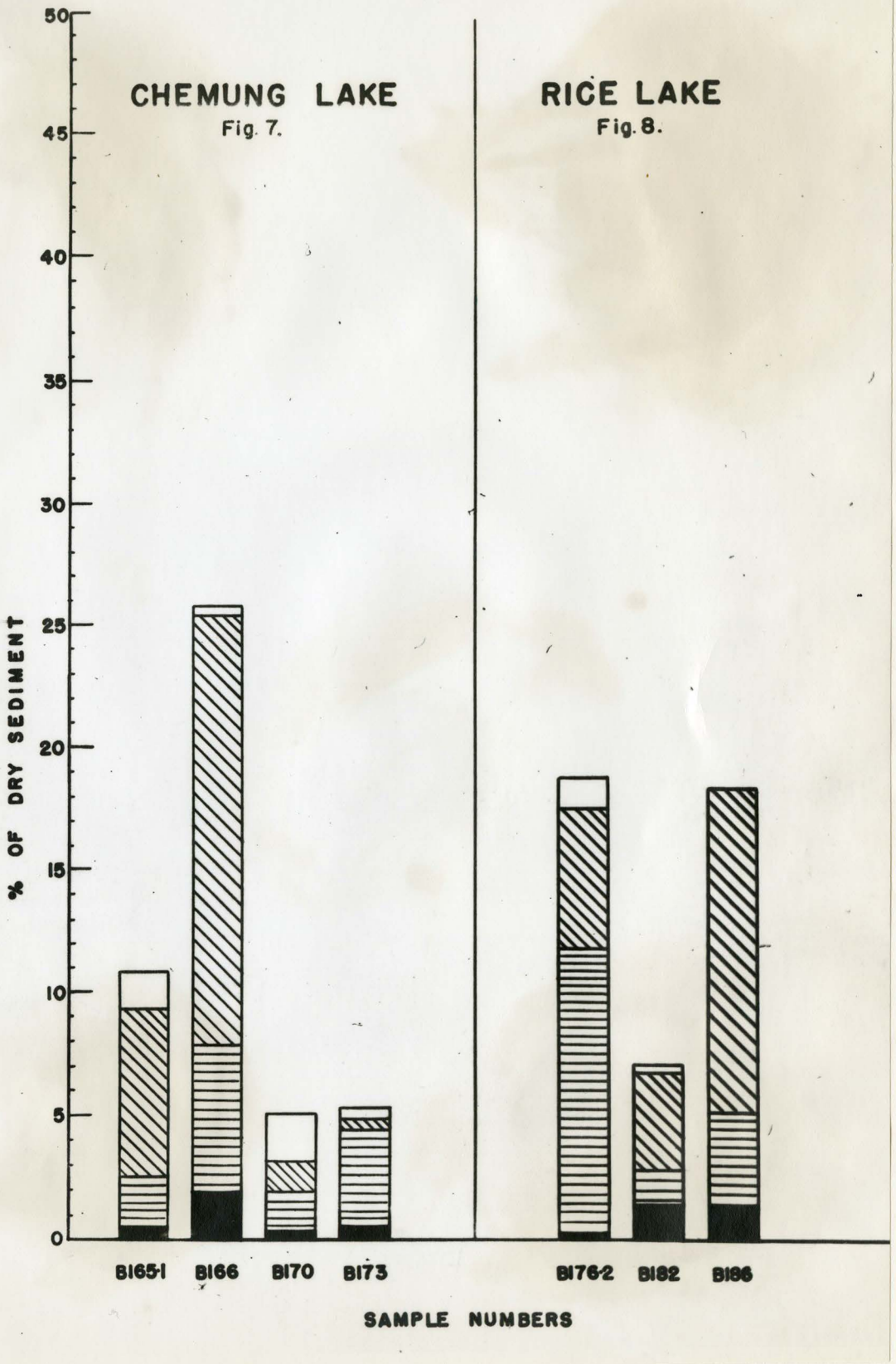

OTTAWA
KINGSTON
CHEMUNG LAKE
PETERBOROUGH
RICE LAKE
WILCOX LAKE
TORONTO
PUSLINCH LAKE
HAMILTON
JORDAN HARBOUR
OWEN SOUND
SILVER LAKE

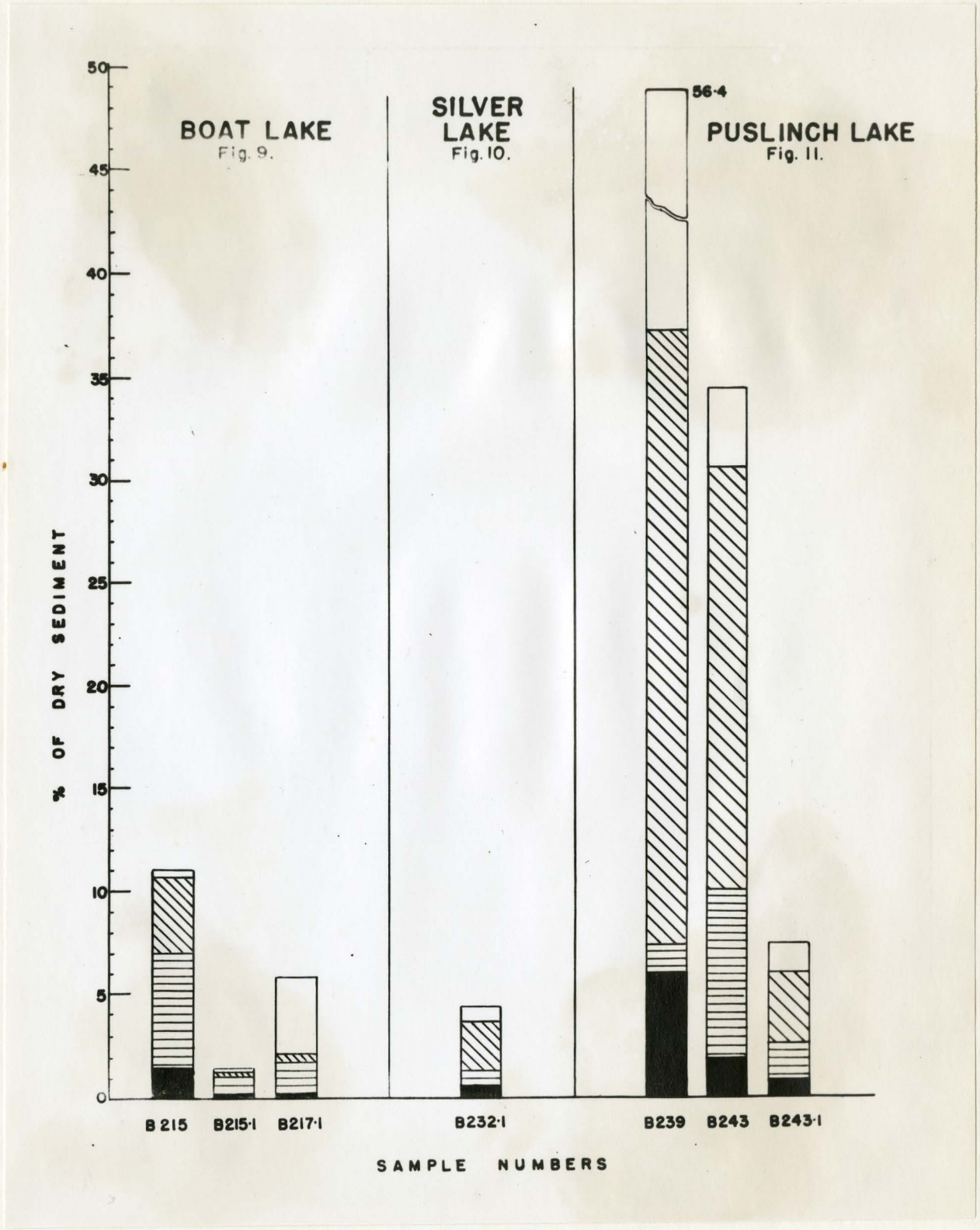
Fig. 1.


JORDAN HARBOUR
Fig. 2.
56·7
50
45
40
35
30
25
20
15
10
5
0
% OF DRY SEDIMENT
B3
B3·1
B4
B4·1
B6
B6·4
B7
B7·1
B7·2
B8
B8·1
SAMPLE NUMBERS


WILCOX LAKE
Fig. 3.
CONSTANCE LAKE
Fig. 4.
MISSISSIPPI LAKE
Fig.5.
37·2
34·4
% OF DRY SEDIMENT
0
5
10
15
20
25
30
35
B81
B81-1
B82
B85
B104
B105
B108
B111
B112
B113
B117-1
B118
B119
B120
SAMPLE NUMBERS


TAYLOR LAKE
Fig. 6.
% OF DRY SEDIMENT
0
5
10
15
20
25
30
35
40
45
50
64·2
61·2
67
63
66·7
58·3
54·1
B131
B132
B133
B134
B135
B135·1
B136·1
B137
B137·1
B138
SAMPLE NUMBERS


CHEMUNG LAKE
Fig. 7.
RICE LAKE
Fig. 8.
% OF DRY SEDIMENT
50
45
40
35
30
25
20
15
10
5
0
B165-1
B166
B170
B173
B176-2
B182
B186
SAMPLE NUMBERS


BOAT LAKE
Fig. 9.
SILVER LAKE
Fig. 10.
PUSLINCH LAKE
Fig. 11.
56·4
% OF DRY SEDIMENT
0
5
10
15
20
25
30
35
40
45
50
B 215
B215·1
B217·1
B232·1
B239
B243
B243·1
SAMPLE NUMBERS

LEGEND FOR FIGURES 2-11

BITUMEN , PROTO BITUMEN, FATS (B)
MULTIPLIED BY 10.

PECTINS, SOLUBLE CARBOHYDRATES. (P)

HEMICELLULOSE , PROTEINS , SMALL AMOUNTS
OF CELLULOSE. (H)

CELLULOSE , HUMIC ACIDS , LIGNIN AND
SMALL AMOUNT OF PROTEINS. (Z)
MULTIPLIED BY 2.