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Chemical Survey of Selected South Dakota Lake Sediments

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CHEMICAL SURVEY OF SELECTED SOUTH DAKOTA LAKE SEDIMENTS

BY

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A thesis submitted
in partial fulfillment of the requirements for the degree
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1973

CHEMICAL SURVEY OF SELECTED SOUTH DAKOTA LAKE SEDIMENTS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

CHEMICAL SURVEY OF THE SEDIMENTS OF SELECTED SOUTH DAKOTA LAKES

Abstract

ALAN ROSS SWANSON

Available phosphorus, organic carbon, and organic nitrogen were measured in bottom sediments of 16 lakes and ponds in northeast South Dakota. These lakes were glaciated, relatively shallow, and productive. Ranges of the surface sediments were: available phosphorus, 2 to 42 ppm; organic carbon, 0.94 to 5.34 percent; and organic nitrogen, 0.29 to 0.79 percent. Ranges of subsurface sediments were: available phosphorus, 2 to 39 ppm; organic carbon, 0.54 to 6.06 percent; organic nitrogen, 0.19 to 0.88 percent. Concentrations in most lakes varied little from top to bottom. Hard-bottomed lakes generally decreased in nutrient concentrations from sediment surface to subsurface. Lower concentrations of carbon and nitrogen appeared to indicate higher rates of deposition of material from the watershed. Sediments from lakes in northeast South Dakota appeared to have lower concentrations of organic carbon and organic nitrogen than sediments from lakes studied in Wisconsin. Levels of organic carbon and organic nitrogen appeared to be related, although this relationship was not reflected by carbon:nitrogen ratios.

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INTRODUCTION

Nutrients generally increase with the depth of sediments down to 2-4 meters and exposure of these sediments may increase fertility of overlying water (Goering, 1972). Brezonik and Lee (1968) attributed 66.7 percent of the nitrogen loss from a lake to sediments and other minor sinks, such as phytoplankton.

Objectives of this study were to measure nutrient concentrations in South Dakota lake sediments and to compare these with concentrations in lake sediments of other geographical areas.

Chemical characteristics of sediments deposited in a lake have been used to infer the conditions under which the sediments were deposited. Relatively high levels of organic carbon and organic nitrogen can be expected in sediments deposited under conditions of little soil erosion from the watershed. Soil erosion dilutes the levels of organic carbon and organic nitrogen by adding inert matter and mineral matter to sediments.

Chemical composition of sediment cores have been used as an indication of the historical record of Wisconsin lakes in conjuction with pollen analysis (Bortleson, 1971). Pollen remains indicated the type of vegetation on the watershed at the time sediments were deposited. Ragweed pollen indicated agricultural use of the watershed. Sediments in euthropic lakes had organic nitrogen levels of 0.6 to 1.0 percent and organic carbon levels of 5.2 to 21.0 percent. Organic carbon levels in a mesotrophic-eutrophic lake ranged from 23.3 to 28.8 percent. An oligotrophic lake had organic carbon levels of 28.2 to 31.7 percent.

Konrad et al. (1970), found total nitrogen of 1.63 to 1.79 percent at the surface, and 1.27 to 1.94 percent in subsurface sediments of a Wisconsin oligotrophic lake. In another oligotrophic lake, total nitrogen was 1.52 percent at the surface while subsurface nitrogen was 1.21 to 1.45 percent. In a mesotrophic body of water, total nitrogen was 1.58 percent at the surface and 1.50 to 2.00 percent in the subsurface sediments.

STUDY AREA

The Coteau des Prairies is a plateau irregularly covered with glacial drift. Morainic deposits of the Wisconsin ice age formed a rough surface which gently slopes to the south and is drained by the Big Sioux River. Elevations range from 1,600 to 2,000 feet above sea level. The Coteau is covered by Chernozem soil developed in a cool, moist climate. Precipitation averages 20 to 22 inches per year, with an average temperature of 43 to 45 F. The average lake evaporation rate is 30 to 34 inches per year. The conditions favor accumulation of organic matter and retard its destruction. Soils of the Coteau differ from adjoining soils to the west in having a higher content of organic matter and total nitrogen in the surface horizons (Westin, et al. 1959).

The Coteau lakes are all third-order temperate lakes as defined by Welch (1952), with temperatures about the same from top to bottom and mixed by wind except during the period of ice cover (Schmidt, 1957). Lake size ranges from a few acres to 7,800 acres.

Lakes in which the substrate was sampled were Poinsett, Dry, Albert, John, Norden, and the Poinsett outlet in Hamlin County; Hendricks in Brookings County; Roy and Clear in Marshall County; Enemy Swim, Pickerel, Blue Dog, and Amsden Dam in Day County; Abbey and LaBolt Pond in Grant County; and Cochrane in Deuel County. These lakes represented a cross section of the lakes of the Coteau.

Lakes Roy, Clear, Enemy Swim, Pickerel, Abbey, Cochrane, and Amsden had maximum depths of 25 to 35 feet. Other lakes varied from 5 to 18 feet in maximum depth.

METHODS

A Phleger sampler and a modified piston corer were used to sample bottom sediments. The Phleger sampler (Standard Methods, 1971) is a gravity corer, and when allowed to fall through the water, penetrates the sediment to a maximum depth of 2 feet. A core 1.5 inches in diameter is obtained. In this study, it was possible to obtain 6-inch cores in most cases. Plastic acetate liners were removed with sediment intact. The liners were stoppered until sediments could be extruded at the laboratory, wrapped in freezer paper or aluminum foil, and frozen until analysis.

Samples were taken from the deepest portions of the lakes. Lakes that were larger or somewhat irregular in shape were sampled in more than one location. Enemy Swin was sampled in the middle and east end, Pickerel Lake was sampled in the middle and south end, Cochrane was sampled in the east and west ends, Roy Lake was sampled at two mid-lake sites, and Dry Lake was sampled in the middle and north end.

The piston corer, modified from the description of Vallentyne (1954), was operated by pushing a rod into the sediments from the surface. It proved satisfactory in four lakes with soft bottoms. Further description of its use will be found in Appendix A. Sediments were extruded in the field, and handled like the Phleger cores.

Organic nitrogen was analyzed by the Kjeldahl method. One and two grams of soil were used, and extra water was added to the flasks to prevent bumping during the distillation step. A dichromate-sulfuric acid digestion method modified from Jackson (1958) was used to determine organic carbon. A standard curve was established by plotting data obtained by digesting the carbon in known amounts of sucrose. Loss on ignition was determined for some of the samples using a crucible and Bunsen burner. Available phosphorus was determined by an adaptation of the Bray and Kurtz No. 1 method (1945). Analyses for phosphorus were done by the Soil Testing Laboratory at South Dakota State University, Brookings.

Percent organic carbon and percent organic nitrogen were used to calculate the organic carbon:organic nitrogen ratio. The same values multiplied together were used to arrive at an organic sediment index (OSI) (Ballinger and McKee, 1971). OSI is considered to be a measure of the oxygen demand and nutrient resource of the sediment.

RESULTS

Available Phosphorus

Available phosphorus levels fluctuated widely and erratically in sediments from all lakes except Enemy Swim, LaBolt, Pickerel, and Albert. Phosphorus levels varied from 1-3 ppm in these four lakes (Figures 1-6). Phosphorus concentrations varied from 2-42 ppm in cores from the other lakes.

Organic Nitrogen

Most of the cores exhibited little variation in organic nitrogen from top to bottom. Organic nitrogen in lakes Albert, Roy, Dry, Cochrane, and Amsden decreased from top to bottom (Figures 6-10). Cores were relatively shallow in lakes Albert, Roy, Amsden, and Dry due to the sampler's ineffectiveness in penetrating their firm sediments.

Sediments from Clear Lake exhibited a decrease in organic nitrogen concentration from the surface to a depth of 7 inches with a higher reading at the 4-inch level (Figure 10). Soft-bottomed lakes, such as Enemy Swim, Pickerel, and LaBolt, exhibited little variation in organic nitrogen concentration with sediment depth (Figures 1-5). Sediments from the middle of Lake Pickerel showed an increase in organic nitrogen concentration at 15 and 20 inches below the surface (Figure 4). The cores from these three lakes were notably different from each other. Cores from Enemy Swim Lake averaged 0.82 and 0.63 percent organic nitrogen; cores from Lake Pickerel, 0.50 and 0.60; while the core from LaBolt Pond averaged just under 0.35 percent from top to bottom of the core.

Organic Carbon:Organic Nitrogen Ratios

No distinct trends were detected in organic carbon:organic nitrogen ratios. The C:N ratio in sediments from lakes Pickerel and Roy increased from top to bottom, while the Cochrane sediments increased down to the 20-inch level (Figures 7 and 8). Ratios from Lake Poinsett also increased from top to bottom (Figure 6). One of the Dry Lake cores exhibited a decrease in C:N ratio from surface to the 10-inch level (Figure 9).

Organic Sediment Index (OSI)

Lake Cochrane sediments exhibited a decrease (4.06 to 2.78, and 4.43 to 2.98) in OSI from the surface to the 20-inch depth, then increased again to 3.20 and 3.74 at the 24- and 26-inch depths, respectively. The OSI in mid-Pickerel sediments increased from 2.27 to 3.32 over the first 20 inches then decreased to 2.04 at the 34-inch depth (Figure 4). Sediments from lakes Albert, Amsden, and Dry decreased in OSI from top to bottom (Figures 6, 9 and 10). Cores from LaBolt, Poinsett, and Amsden, in addition to one of the Roy cores, all showed low OSI readings throughout. Most of the calculations totaled less than 1.0 (Figures 5, 6 and 10). Dry Lake sediments showed OSI values greater than 2.0 at the surface, which decreased through the length of the 10-inch cores (Figure 9). OSI of sediment cores from lakes Enemy Swim, south Pickerel, LaBolt, and Poinsett varied little throughout their length (Figures 1,2,3,5 and 6).

Loss on Ignition

The loss on ignition corresponds roughly to organic content

(Juday, Birge, and Meloche, 1941). When large amounts of calcium carbonate are present, there is also a loss of carbon dioxide during ignition. A relationship between loss on ignition and percent organic carbon is illustrated in Figure 4. Loss on ignition expressed as a percentage is approximately double the percent organic carbon in most cases. Loss on ignition would appear to have its greatest value in instances where a quick estimate of relative levels of organic content was desired from different areas or different sediment levels of the same lake, or from lakes with apparently similar bottom sediments.

Organic Carbon

Patterns of organic carbon distribution followed those of organic nitrogen (Figures 1-10). Organic carbon was highest in sediments from lakes Enemy Swim, Pickerel, and Cochrane, ranging from 3.65 to 6.06 percent, with one low reading from mid-Pickerel of 2.12 percent. A 34-inch core from mid-Pickerel increased in organic carbon from 3.92 at the surface to 4.96 percent at the 20-inch depth. It then decreased to 3.92 percent at the 34-inch level.

Organic carbon concentrations in Lake Poinsett sediments were nearly constant (Figure 6), with all findings being close to 1 percent. The LaBolt sediments were also relatively constant, ranging from 2.3 to 2.9 percent. Cores from lakes Albert and Dry showed decreases from surface to the bottom sediments (Figures 6 and 9). The Amsden core, with a surface and 4-inch reading, showed a decrease from 2.74 to 1.90. Carbon concentration in the Clear Lake sediments increased from surface to the 4-inch depth (4.2 to 4.6 percent), then decreased between the 4- and 7-inch depth (4.6 to 3.3 percent).

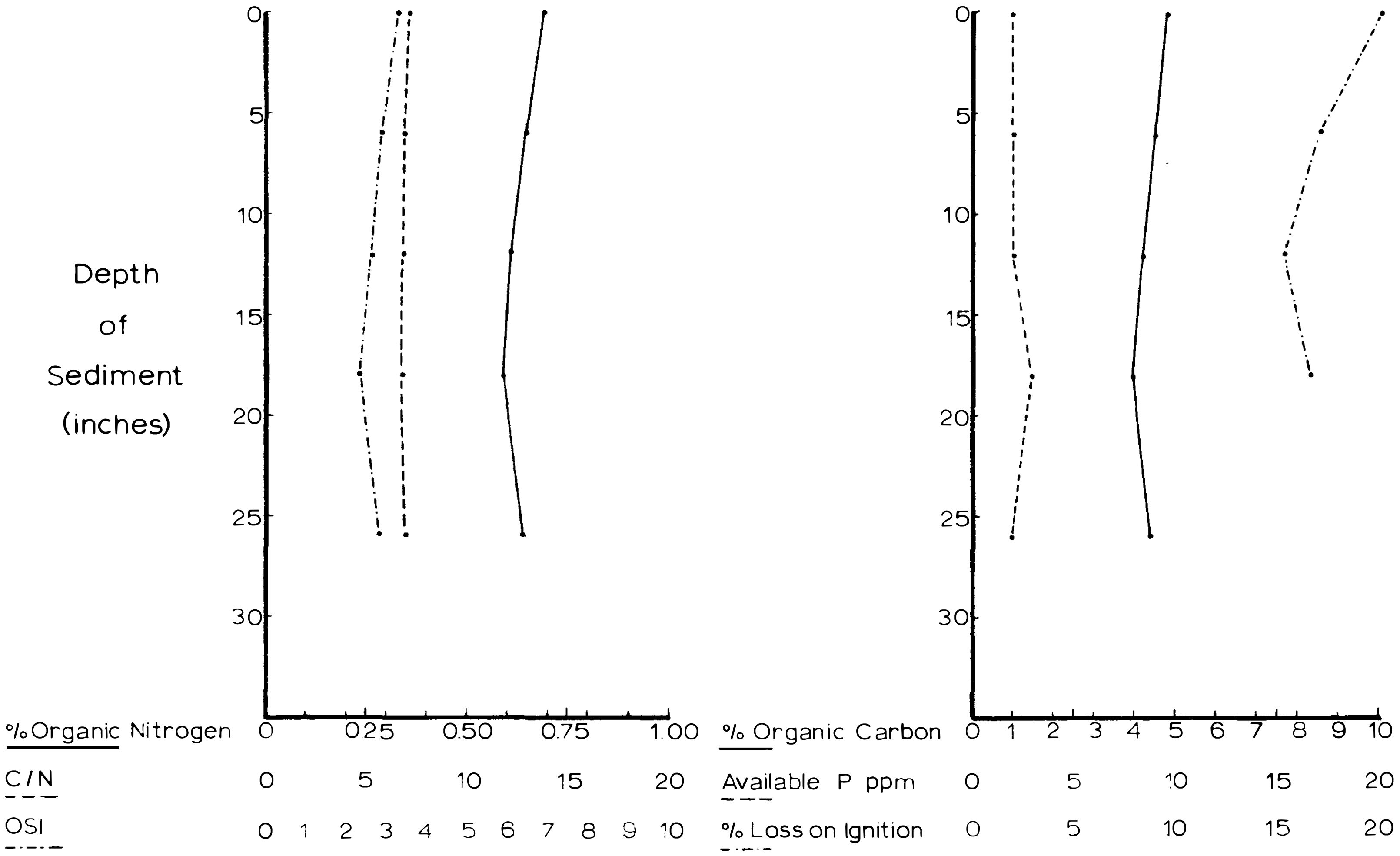

FIGURE 1. CHEMICAL STRATIGRAPHY OF ENEMY SWIM LAKE (EAST BAY STATION). SPRING, 1972

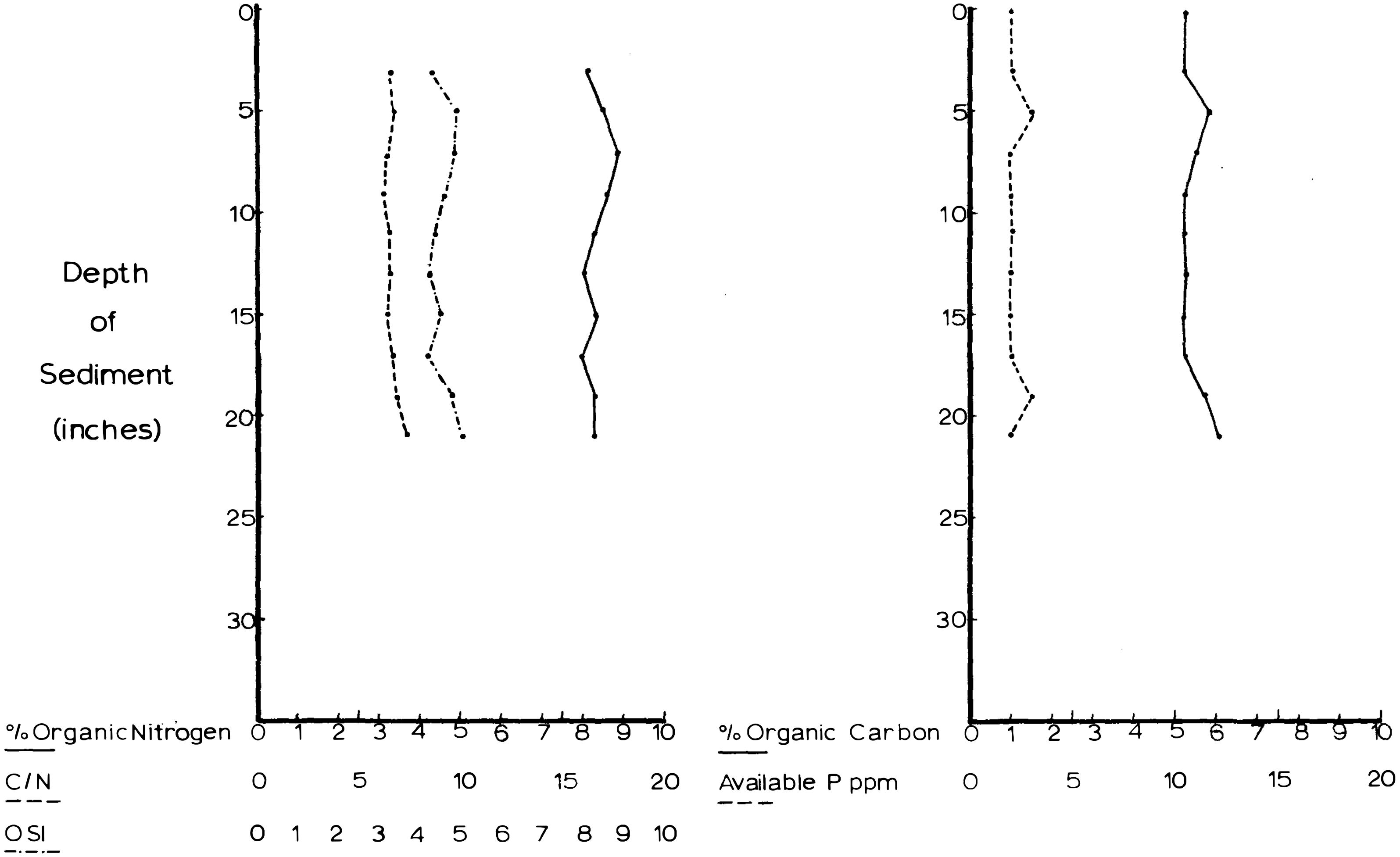

FIGURE 2. CHEMICAL STRATIGRAPHY OF ENEMY SWIM LAKE (MIDDLE STATION). SPRING, 1972.

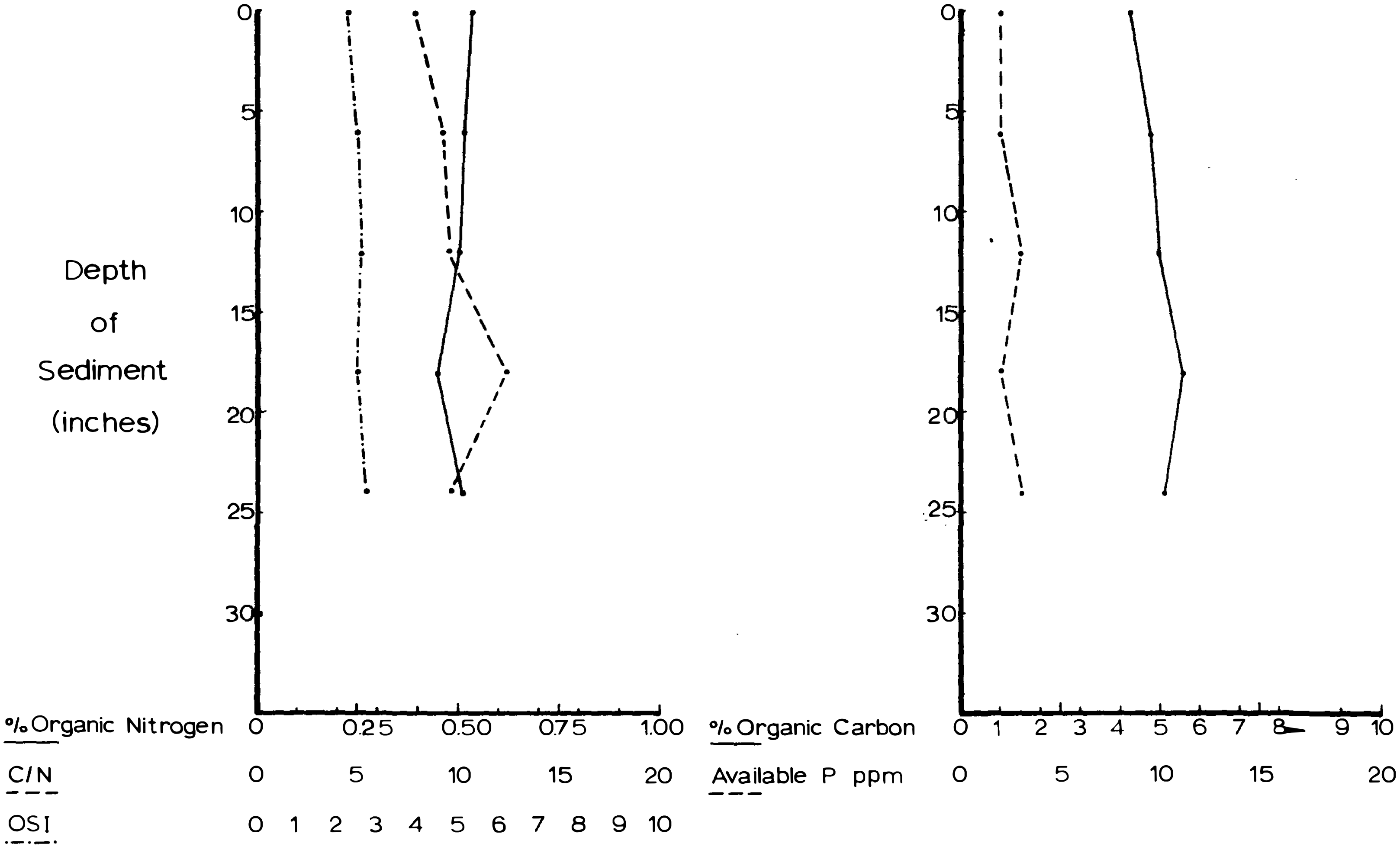

FIGURE 3. CHEMICAL STRATIGRAPHY OF PICKEREL LAKE (SOUTH STATION). SPRING, 1972.

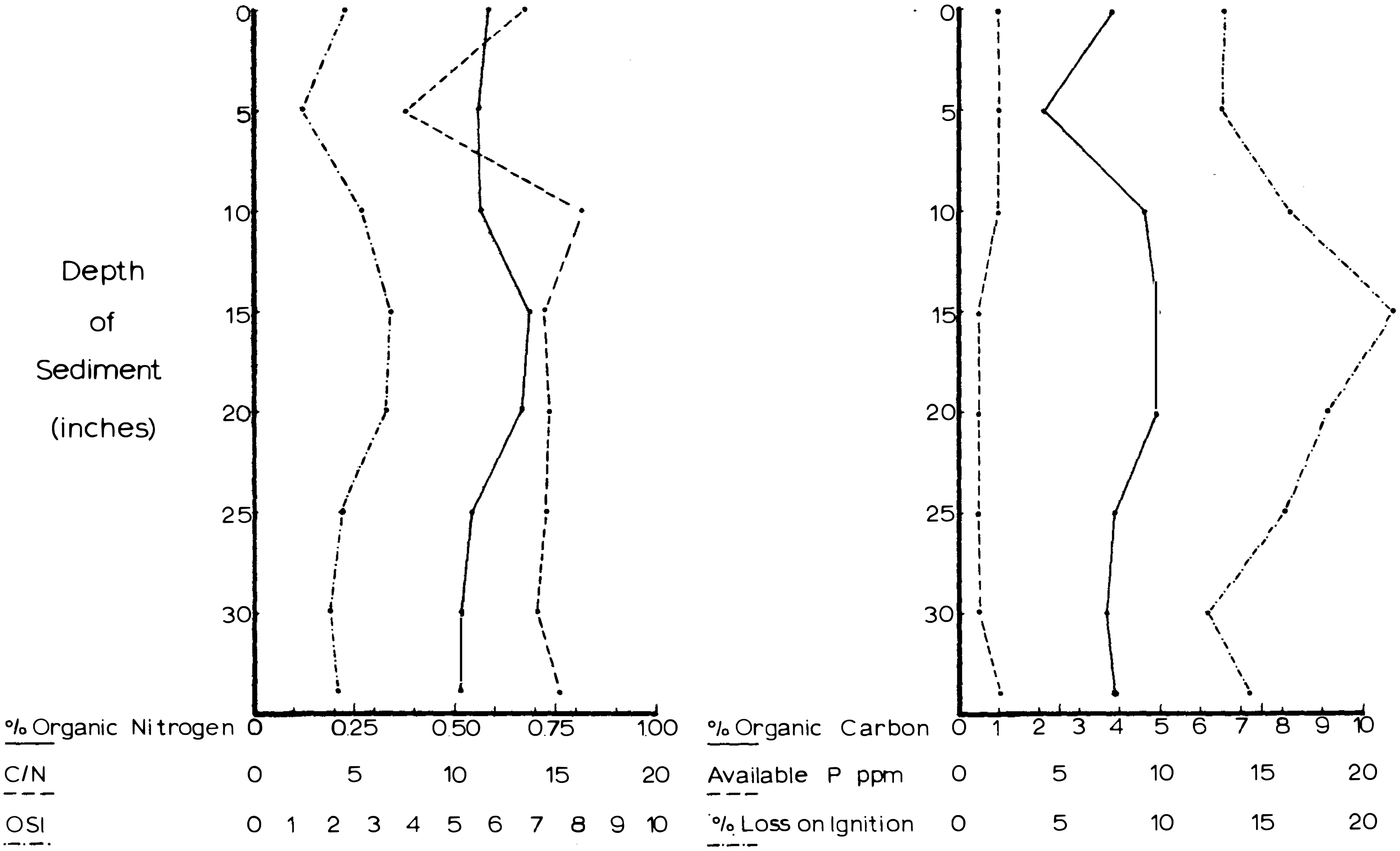

FIGURE 4. CHEMICAL STRATIGRAPHY OF PICKEREL LAKE (MIDDLE STATION). SPRING, 1972.

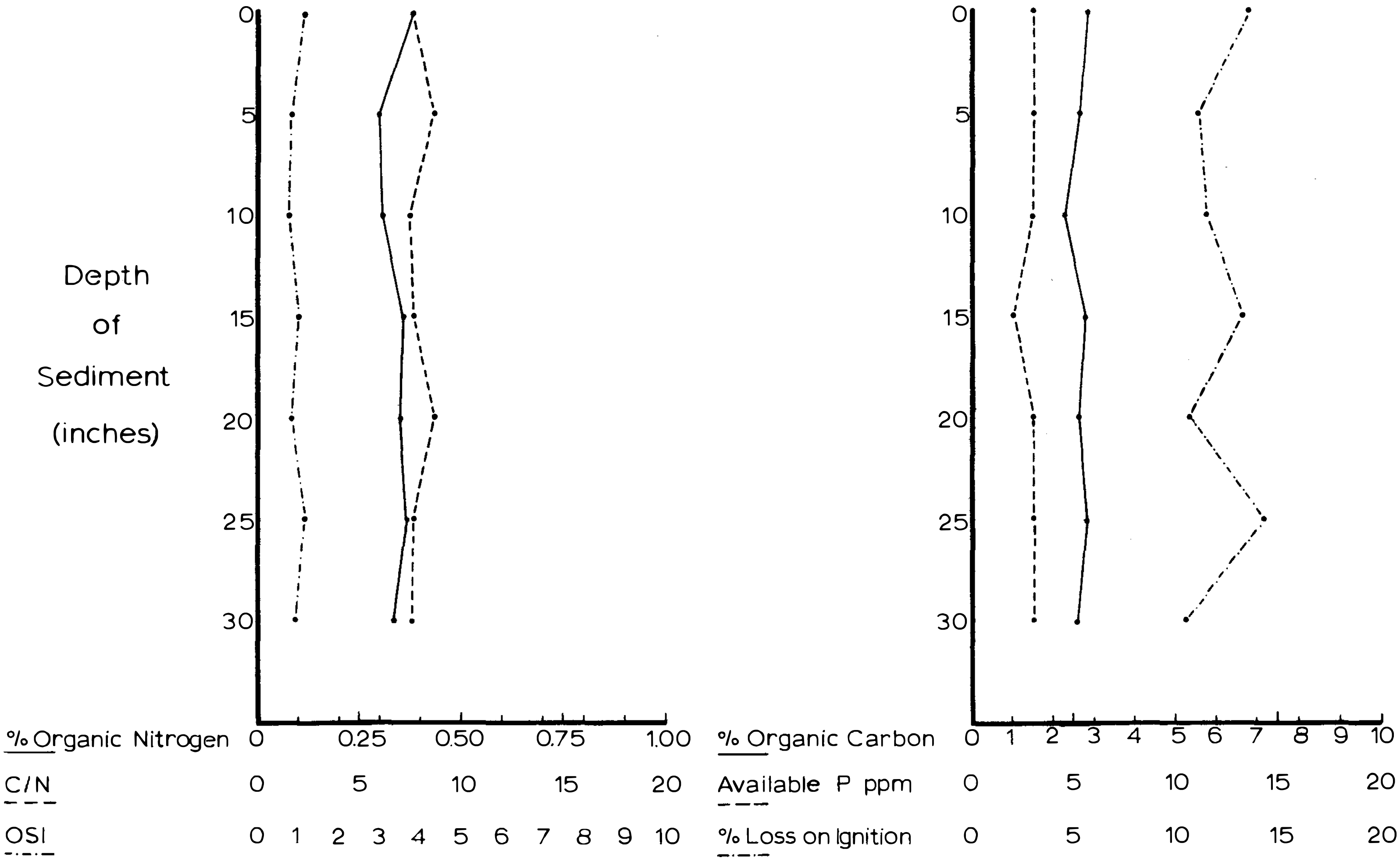

FIGURE 5. CHEMICAL STRATIGRAPHY OF LABOLT POND. SPRING, 1972.

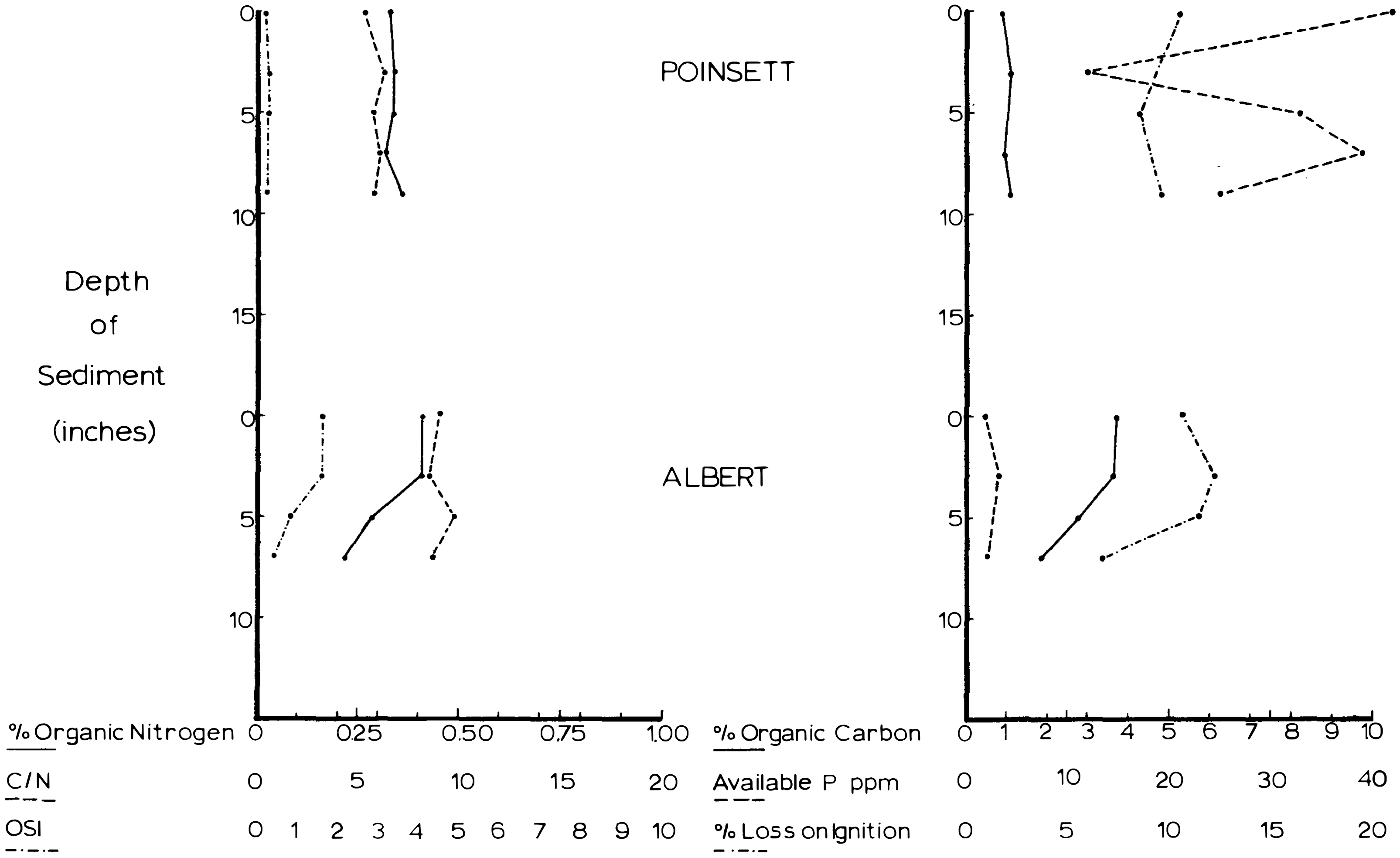

FIGURE 6. CHEMICAL STRATIGRAPHY OF LAKES POINSETT AND ALBERT. SPRING, 1972.

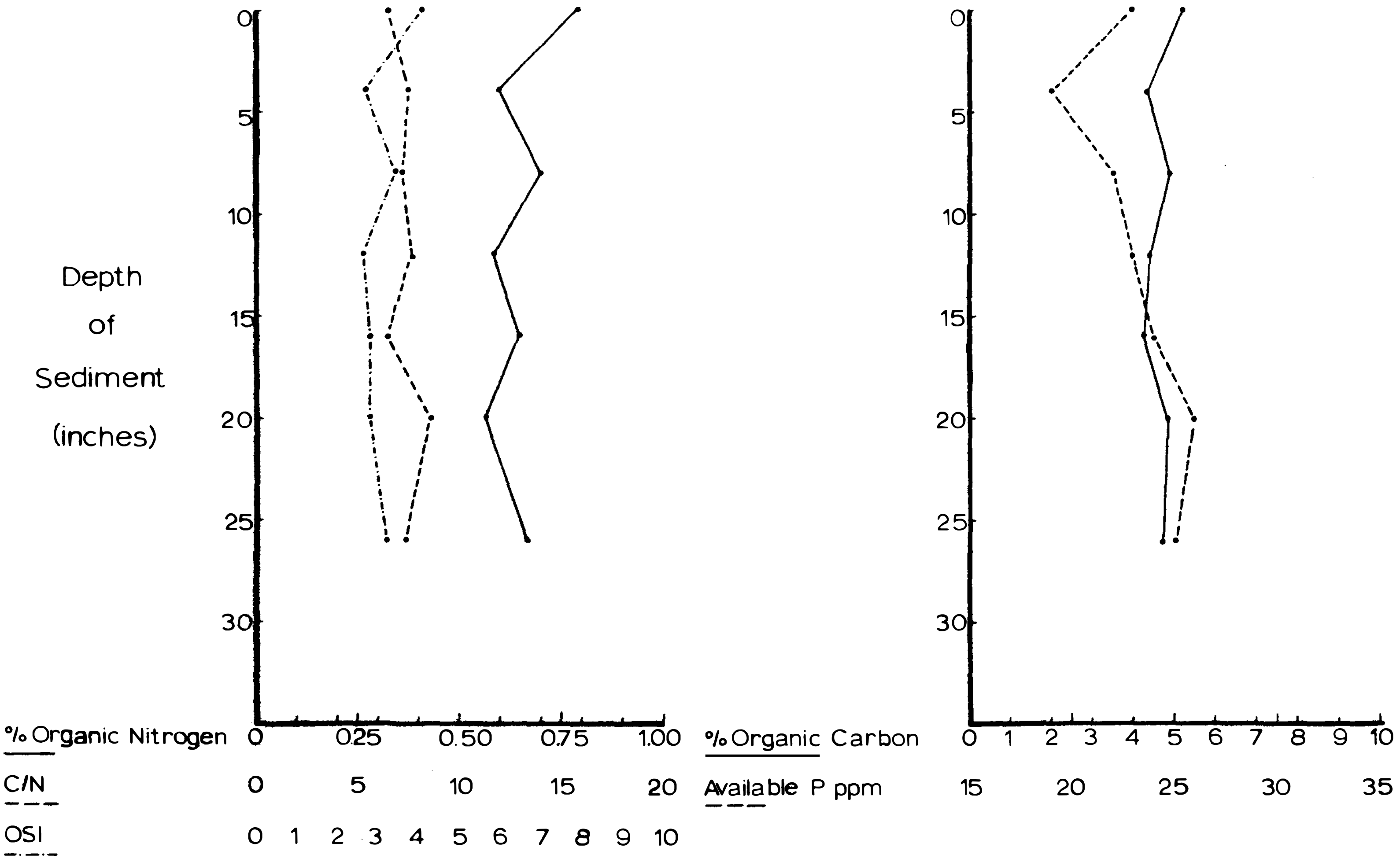

FIGURE 7. CHEMICAL STRATIGRAPHY OF LAKE COCHRANE (EAST STATION). SPRING, 1972.

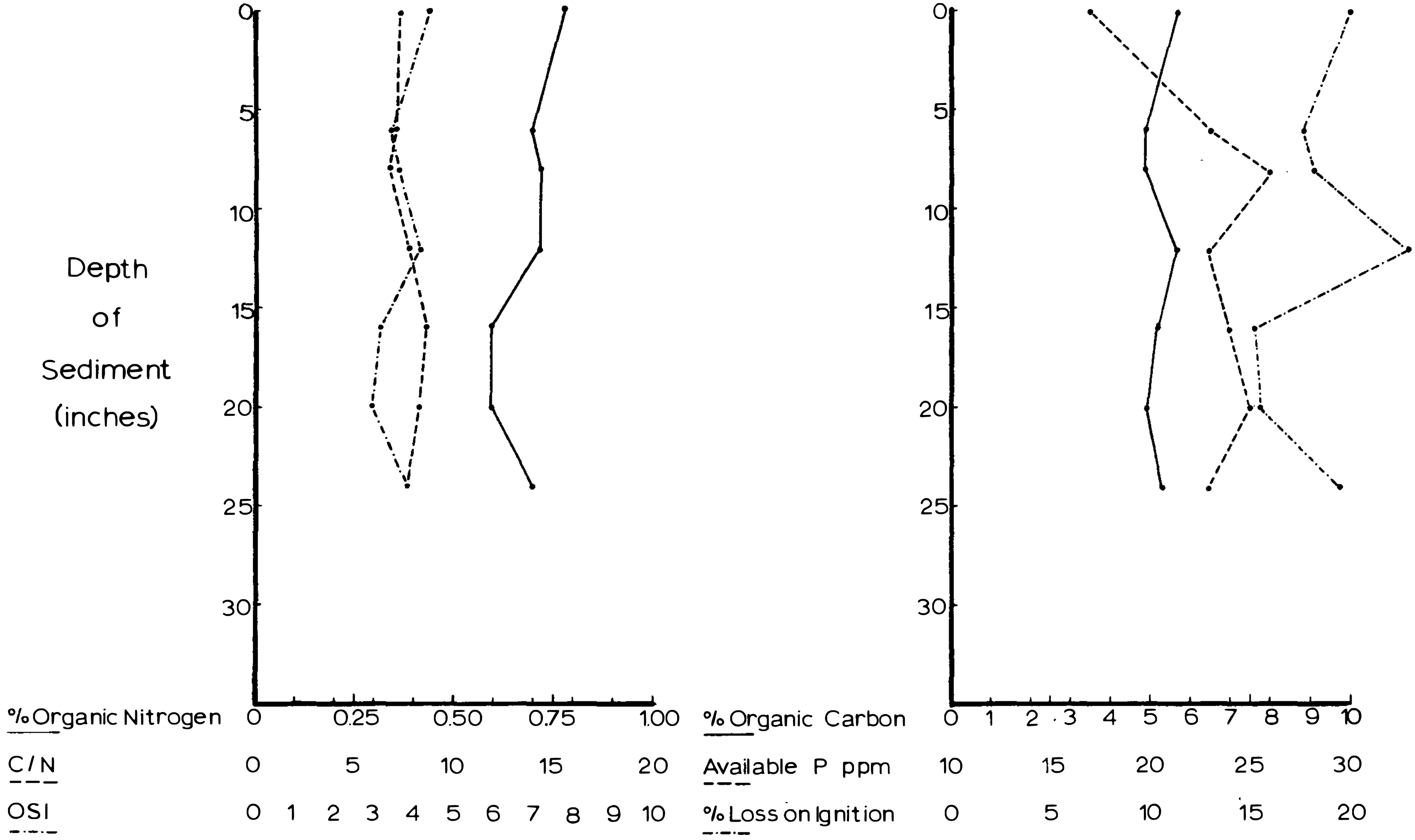

FIGURE 8. CHEMICAL STRATIGRAPHY OF LAKE COCHRANE (WEST STATION). SPRING, 1972.

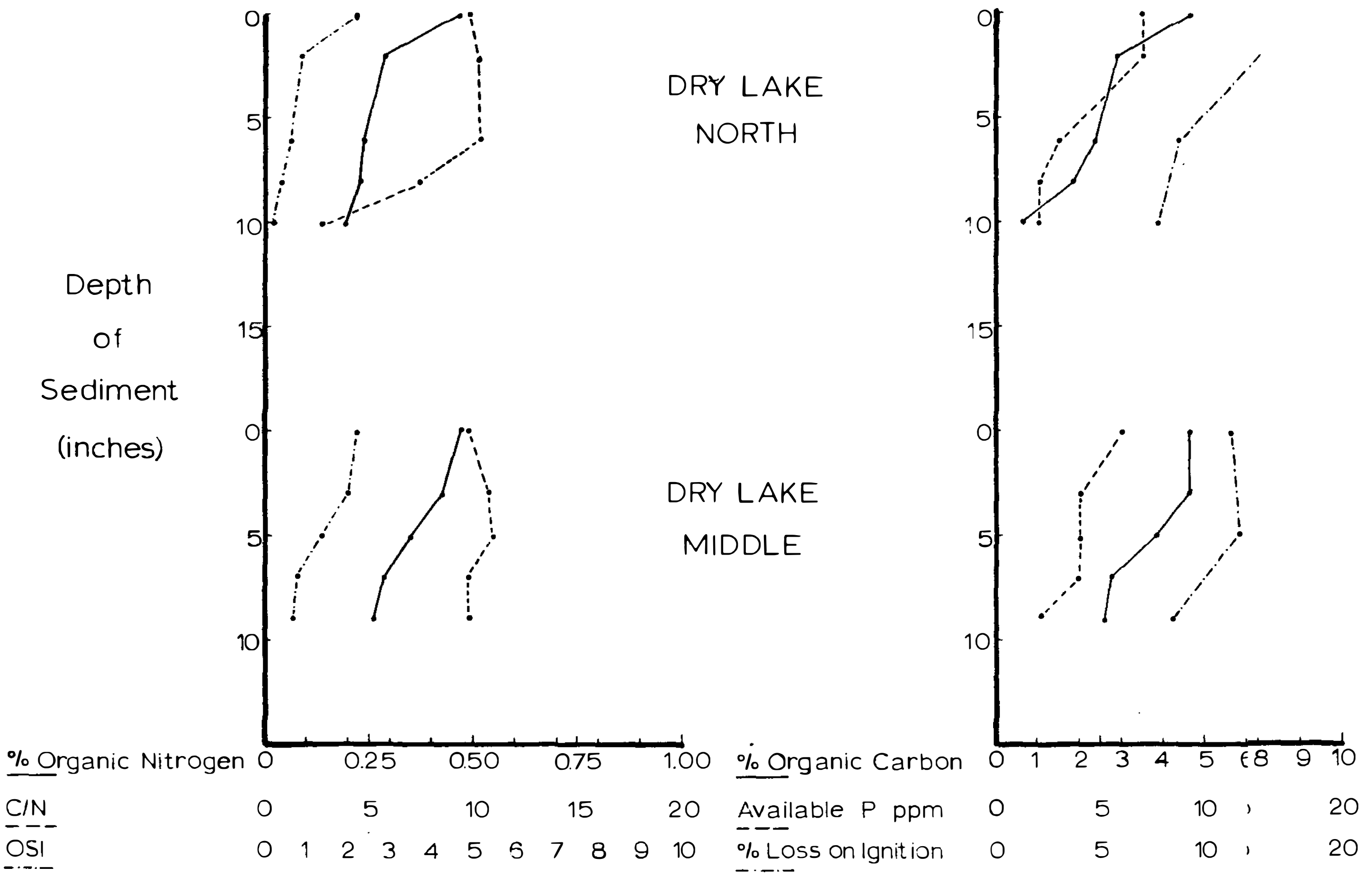

FIGURE 9. CHEMICAL STRATIGRAPHY OF DRY LAKE (NORTH AND MIDDLE STA.). SPRING, 1972.

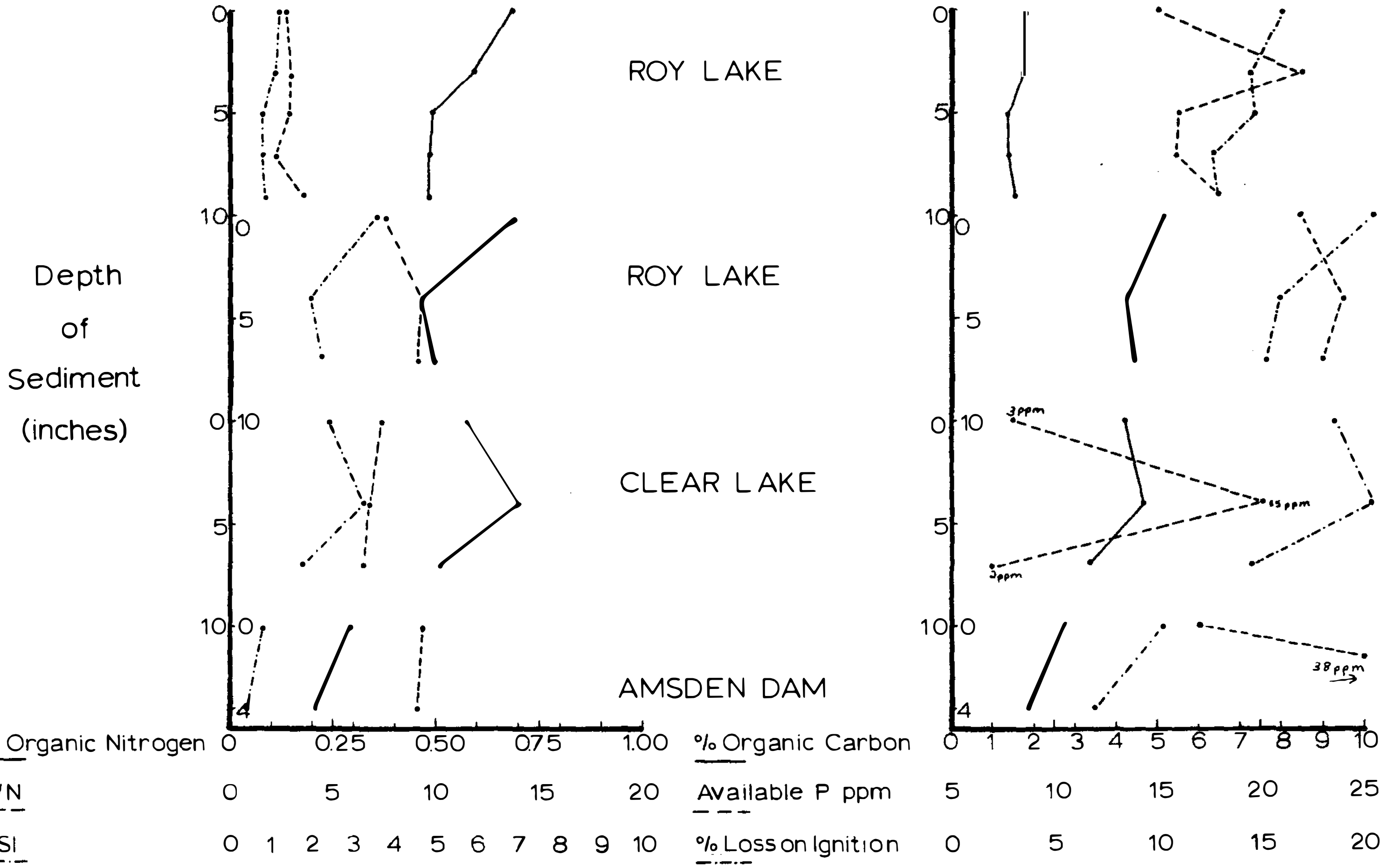

FIGURE 10. CHEMICAL STRATIGRAPHY OF ROY LAKE, CLEAR LAKE, AND AMSDEN DAM. SPRING, 1972.

DISCUSSION and CONCLUSIONS

Available Phosphorus

Analyses of sediment core samples from lakes Enemy Swim, Cochrane, and Dry indicate a possible direct relationship between available phosphorus and organic carbon concentration (Figures 2, 7 and 9). This was not shown in other sediments sampled, and, considering evidence of other investigators (Mortimer, 1969; Bortleson, 1971), I conclude that available phosphorus in sediment alone is unreliable as a record of nutritional enrichment.

Mortimer (1969) stated that phosphorus in the sediment profile of a lake does not serve as a direct record of eutrophication, refuting the earlier assumption that as a lake undergoes eutrophication, the levels of phosphorus in the sediment laid down will increase. Further evidence of this was presented by Livingstone and Boykin (1962) from Linsley Pond. They found that a high phosphorus-binding capacity was correlated with a high mineral content of sediments, and not with the concentration of phosphorus in the lake at the time of deposition. Since watershed material is higher in mineral content than is plankton fallout, high phosphorus levels in the sediments could indicate erosion of the watershed. Mackereth (1966) used sodium and potassium concentrations as indicators of watershed erosion, concentrations of which increased with the amount of watershed erosion. Similarly, bodies of water receiving allochthonous sediments would be expected to have higher levels of phosphorus. This would depend on other factors affecting phosphorus solubility being the same.

Bortleson (1971) found that an increase in inorganic sedimentation was evidenced by an increase of several elements, including phosphorus, in the upper sediments. He found that the postcultural deposition rate of phosphorus was five to eight times that of precultural deposition rates.

Phosphorus data collected in this study was not extensive enough to show whether or not phosphorus concentration can be used as an indicator of sedimentation intensity. Total phosphorus, which was not run, would possibly have given clearer indications of any relationship between phosphorus levels and sedimentation intensity. Neither total nor available phosphorus apparently can be used to indicate the quality of overlying water at the time of sediment deposition.

Organic Nitrogen

Based on several of the lakes studied it appears that organic - nitrogen levels in sediments can be used as an indication of the degree of sediment coming in from the watershed and the degree of lake aging. LaBolt Pond decreased from 20 to 11 feet in maximum depth between 1935 and 1971 (Unkenholz, 1971), illustrating a rapid rate of fill-in. The only apparent source of sediment was the large amount of erodible material entering the pond from the watershed. Organic nitrogen in LaBolt sediments was lower than in sediments from lakes Enemy Swim and Pickerel (Figures 1-5). Thus, lower levels of nitrogen apparently indicate higher levels of deposition of allochthonous sediments.

Bortleson (1971) found the distribution ranges of organic nitrogen in sediments from two eutrophic Wisconsin lakes to be lower than the range of organic nitrogen concentration in the sediments of a mesotrophic-oligotrophic lake (0.6 to 1.1 percent as opposed to 1.4 to 1.8 percent).

Differences in levels of organic nitrogen in various lakes can possibly be explained by the findings of Konrad et al. (1970) in Wisconsin. They found that higher loads of erodible material tended to dilute sediments and resulted in a lower total nitrogen content. Keeney et al. (1970) found that more than 98 percent of total nitrogen occurred as organic nitrogen in Wisconsin lake sediments.

Organic Carbon:Organic Nitrogen Ratio

Bortleson (1971) found that average carbon:nitrogen ratios were smaller in two eutrophic lakes than in a mesotrophic-oligotrophic lake. The C:N ratio of plankton is around 5.7 (Emery and Rittenberg, 1952). Thus, in lakes where plankton fallout is the primary course of sediment, a C:N ratio of around 5.7 is to be expected. According to Emery and Rittenberg (1952), when the C:N ratio in such lakes is higher than 5.7, organic material undergoes decomposition releasing nitrogen faster than carbon. Lake Enemy Swim appears to fit this description with C:N ratios of 6.21 to 7.30.

An increasing C:N ratio through the sediments indicates further decomposition of nitrogen-containing compounds with aging. Only Lake Pickerel showed any indication of this phenomenon (Figures 3 and 4).

Arrhenius (1950) indicated that C:N ratios are affected by dilution of organic matter with mineral matter. High dilution will tend to keep organic matter rich in nitrogen, resulting in low C:N ratios. Thus there appears to be dilution in the lower portion of one core from Dry Lake, one core from Lake Poinsett, and one of the cores from Roy Lake (Figures 6, 9 and 10).

In LaBolt Pond, where it is apparent that much of the sediment is from the watershed, C:N ratios throughout the profile ranged from 7.48 to 8.80. This supports the findings of Juday et al. (1941) that C:N ratios are independent of lake types. This same indication of independence was found in examination of the Phleger cores (Table 1), where no apparent relationships were indicated between C:N ratios and the various lakes.

Examination of sediment cores taken with a Phleger sampler gave sediment by mineral matter at the time of deposition of the more recent sediments. Over twice as many sediment cores taken with a Phleger sampler had a lower C:N ratio at the surface than at the subsurface level (Table 1).

Organic Sediment Index (OSI)

The organic sediment index (OSI) is outlined and explained by Ballinger and McKee, (1971:217). ''In terms of pollutional sources and effects, the most important characteristic of bottom deposits is the organic matter. The concentration of organic carbon and organic nitrogen depend on the material originally suspended in the water and govern the extent of oxygen demand and nutrient contribution.''

OSI indicates that nearly all the sediments obtained in this study are characteristic of bottom deposits made up of sewage sludge, decaying vegetation, pulp and paper wastes, and sugar beet wastes.

OSI patterns from lakes Albert and Dry, decreasing from surface to bottom (Figures 6 and 9), were similar to OSI patterns for sediment cores from Lake Sebasticook, Maine, and an impoundment in Tennessee as noted by Ballinger and McKee (1971). Other lakes sampled in this study showed no distinct trends, remaining much the same from top to bottom of the sediment core. Had deeper cores been obtained in this study, perhaps more could be inferred about the quality of sediments deposited under conditions of different water quality and conditions of the watershed.

Organic Carbon

Primary factors affecting concentrations of organic carbon in sediments are autochthonous production of organic carbon, sedimentation of allochthonous organic matter, and varying deposition rates of whole sediment (Bortleson, 1971). Bortleson found that highest levels of organic carbon content occured in precultural sediments and decreased in postcultural sediments, and that changes in the organic carbon profile were inversely proportional to the inorganic sedimentation rate. Mackereth (1965) reported that carbon-level variations were caused either by changing rates in production and deposition of organic matter or changing rate of erosion of mineral matter. Carbon content is unreliable as a criterion for distinguishing the relative importance of these processes.

Lakes Albert and Dry increased in organic carbon from bottom to top, possibly indicating a decrease in the relative intensity of inorganic sedimentation. Emery and Rittenberg (1952) found that organic nitrogen and carbon both decreased with depth of sediment. If the rate of sedimentation is inversely proportional to organic carbon content, lakes Poinsett, Albert, LaBolt, and Amsden have faster rates of sedimentation than other lakes sampled. It would also appear that the East Bay of Enemy Swim has received more sediment than the middle of the lake, and east Cochrane somewhat more than the west end of the lake throughout recent history.

The samples from lakes John and Norden (Table 2) indicate a nearly steady decrese in organic carbon from top to bottom, thus indicating a recent history of decreasing inorganic content. It is difficult to draw definite conclusions, however, from 6 inches of sediment.

Further study should include an attempt to arrive at a factor involving organic nitrogen and/or organic carbon to be used as a comparative value indicating intensity of sedimentation and whether the source is plankton fallout or the washing in of watershed material. By periodic sampling and chemical analysis of surface sediments, it might be possible to monitor the sedimentation of a lake. Such evidence could make easier the implementation of programs dealing with improvement of watershed management practices. Before a lake is dredged, it is also essential to know to what depth sediment must be removed in order to decrease or at lease prevent an increase in nutrient supply.

Table I. Nitrogen, Carbon, Loss on Ignition; Carbon:Nitrogen Ratio, Organic Sediment Index (OSI) of Several Eastern South Dakota Lakes as Sampled with a Phleger Corer.

Location		N (% dry wgt.)	C (%)	Loss on Ignition (%)	C:N	OSI (CxN)
Poinsett (S)	Surface		4.62	12.4		
	6''	0.44	2.88	10.3	6.55	1.27
Poinsett (NE)	Surface	0.41	4.96	14.5	12.01	2.03
	6''	0.08	0.84	4.2	10.50	0.07
Poinsett (E)	Surface	0.07	1.10	7.8	14.86	0.08
	6''	0.06	.45	2.8	7.63	0.03
Dry (N)	Surface	0.63	4.96	13.5	7.87	3.12
	6''	0.50	4.96	13.6	9.92	2.48
	12''	0.17	1.40	6.6	8.24	0.24
Dry (S)	Surface	0.62	4.78	16.0	7.71	2.96
	6''	0.53	4.78	13.7	9.02	2.53
	12''	0.18	1.60	7.1	8.89	0.29
Norden (SE)	Surface		1.44	5.8		
	6 ''		1.56	2.7		
John	Surface	0.64	4.20	11.8	6.56	2.69
	6''	0.22	1.90	8.8	8.64	0.42
Albert (Mid)	Surface	0.54	4.32	12.9	8.00	2.33
	6''	0.46	3.04	9.9	6.61	1.40
Albert (S)	Surface	0.47	3.82	10.2	8.13	1.80
	6''	0.33	2.94	8.4	8.91	0.97
	12''	0.25	2.32	----	9.28	0.58
Poinsett Outlet	Surface	0.24	1.80	5.9	7.50	0.43
	6''	0.12	0.94	4.7	7.83	0.11

Table I. Continued

		N (%)	C (%)	Loss on Ignition	C:N	OSI (CxN)
Abbey	Surface	0.25	2.06	8.7	8.24	0.52
	6''	----	0.84	4.3		
Hendricks	Surface	0.70	5.56	17.5	7.94	3.89
	6''	0.34	3.30	10.6	9.71	1.12
Cochrane	Surface	0.89	5.56	17.1	6.25	4.95
	6''	0.78	5.14	17.1	6.59	4.01
Blue Dog	Surface	0.78	5.34	13.2	6.85	4.15
	6''	0.28	2.64	11.2	9.43	.74
Enemy Swim	Surface	1.20	5.56	17.5	4.63	6.67
	6''	1.01	5.34	18.7	5.29	5.39
Indian Bay (E. Swim)	Surface	0.99	5.80	20.7	5.86	5.74
	6''	0.55	6.60	22.5	12.00	3.63
Pickerel	Surface	0.56	4.06	11.7	7.25	2.27
	6''	0.80	4.96	16.1	6.20	3.97
Clear	Surface	0.66	5.14	14.8	7.79	3.39
	6''	0.57	5.14	16.3	9.02	2.93
Roy	Surface	0.76	4.78	13.4	6.29	3.63
	6''	0.59	3.92	10.8	6.64	2.31
Enemy Swim	Surface	0.81	6.68	24.0	8.25	5.41
	6''	0.79	5.80	21.1	7.34	4.58

Table 2. Organic Carbon and Loss on Ignition at Various Sediment Depths of Lake Norden and Lake John as Sampled with a Phleger Corer.

	Organic Carbon (%)	Loss of Ignition (%)
Lake Norden (SE)		
Surface	1.2	5.4
3-4''	0.2	1.6
6-7''	0.8	3.8
10-11''	0.4	2.9
Lake John (West)		
Surface	2.8	11.5
1 1/2''	2.7	8.9
3 1/2''	2.3	8.7
4''	2.3	9.3
5''	2.1	8.0
6''	1.9	8.1

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Appendix A. Operation of a Modified Piston Core Sampler.

A modified Livingstone piston core sampler as described by Vallentyne (1954) was built in the South Dakota State University engineering shop and used to sample a number of lakes. One half inch galvanized pipe, in 8-foot sections, was attached and used to drive 4 feet of 2-inch diameter stainless steel pipe into the sediments. A small line held a moveable piston at the surface of the sediments while the sampler was driven in using the 1/2-inch drive pipe. In hard bottoms, it was necessary to pound the sampler into the sediment. However, it was still possible to get only a maximum 10-inch core from such bottoms.

Retrieving the sampler was achieved by rocking the boat and wrapping both the line attached to the piston and the line to the outside of the sampler over the edge of the boat, causing the buoyancy of the boat to provide most of the lift. Additional rocking by the operator was sometimes necessary.

Once free of the bottom, an additional loop of rope was placed around the drive pipe to prevent its falling away from the boat. The drive pipe was uncoupled as it was retrieved with the operator standing on both lines while the lengths were uncoupled.

After being retrieved, the rope and drive pipe were removed from the stainless portion. Another piece of pipe was then used to force the piston back down the sampler pipe, extruding the sediment core onto a sheet of aluminum foil. The core was then wrapped, labeled, and taken to the lab where it was frozen until analysis could be completed.

A 16.5-foot fiberglass army-assault boat with a deck built on the front and powered by an 18-hp motor was used in collection of the samples. Its stability was essential and the relative lightness made more lakes accessible. Three anchors were used to hold the boat in position during sampling. One windy days, the two heavy anchors were thrown off the front while a third lighter anchor was pitched and used to pull the boat at an angle to the wind, thus using the wind to hold the boat in a steady position against the anchor lines.

On calm days, one of the heavy anchors was shifted to a rear corner of the boat and the light anchor again pitched and used to pull all anchor lines tight.

Appendix B. Chemical Analysis of Sediments by Lake and Depth of sediment, Spring, 1972.

	% N	% C	% Loss on Ignition	OSI	Available Phosphorus (ppm)	C:N
North Dry Lake						
Surface	0.47	4.62	14.2	2.17	7	9.83
2 inches	0.29	2.94	---	0.85	7	10.13
6	0.24	2.44	8.8	0.59	3	10.17
8	0.23	1.90	---	0.44	2	7.35
10	0.19	0.54	7.8	0.10	2	2.81
Roy Lake						
Surface	0.69	1.74	16.2	1.20	15	2.52
2-4 inches	0.59	1.74	14.5	1.03	22	2.95
4-6	0.49	1.40	14.8	0.69	16	2.86
6-8	0.48	1.46	12.8	0.70	16	2.04
8-10	0.48	1.56	12.9	0.75	18	3.25
Lake Poinsett						
Surface	0.33	0.94	10.7	0.31	42	2.65
2-4 inches	0.34	1.06	---	0.36	12	3.12
4-6	0.34	0.98	8.6	0.33	33	2.88
6-8	0.32	0.98	---	0.31	39	3.06
8-10	0.36	1.06	9.6	0.38	25	2.94
Mid Dry Lake						
Surface	0.47	4.62	11.1	2.17	6	9.83
2-4	0.43	4.62	---	1.99	4	10.74
4-6	0.35	3.86	11.5	1.34	4	10.91
6-8	0.28	2.74	---	0.77	4	9.78
8-10	0.26	2.56	8.4	0.67	2	9.84
Mid Lake Albert						
Surface	0.41	3.70	10.9	1.52	2	9.02
2-4 inches	0.42	3.60	12.1	1.51	3	8.57
4-6	0.28	2.74	11.5	0.77	3	9.79
6-8	0.22	1.90	6.9	0.42	2	8.63

	%.N	% C	% Loss on Ignition	OSI	Available Phosphorus (ppm)	C:N
Mid Enemy Swim						
Surface	---	5.34		---	2	----
2-4 inches	0.82	5.34		4.38	2	6.51
4-6	0.85	5.80		4.93	3	6.82
6-8	0.88	5.56		4.89	2	6.32
8-10	0.86	5.34		4.59	2	6.21
10-12	0.83	5.34		4.43	2	6.43
12-14	0.81	5.34		4.33	2	6.59
14-16	0.83	5.34		4.51	2	6.43
16-18	0.80	5.34		4.27	2	6.79
18-20	0.83	5.80		4.81	3	6.99
20-22	0.83	6.06		5.03	2	7.30
East Enemy Swim						
Surface	0.69	4.88	19.2	3.37	2	7.07
6 inches	0.65	4.54	17.1	2.95	2	6.98
12	0.61	4.24	15.4	2.59	2	6.95
18	0.58	4.00	16.8	2.32	3	6.90
26	0.64	4.46		2.85	2	6.97
South Lake Pickerel						
Surface	0.54	4.32		2.33	2	8.00
6 inches	0.52	4.78		2.49	2	9.19
12	0.51	5.00		2.55	3	9.80
18	0.45	5.56		2.50	2	12.36
24	0.52	r.14		2.67	3	9.88
East Lake Cochrane						
Surface	0.79	5.14		4.06	23	6.50
4 inches	0.60	4.46		2.63	19	7.43
8	0.70	4.96		3.47	22	7.09
12	0.58	4.46		2.59	23	7.69
16	0.65	4.32		2.81	24	6.45
20	0.57	4.88		2.78	26	8.56
26	0.67	4.78		3.20	25	7.13

	% N	% C	% Loss on Ignition	OSI	Available Phosphorus (ppm)	C:N
LaBolt Pond						
10	0.31	2.32	11.7	0.72	3	7.48
15	0.36	2.74	13.3	0.99	2	7.61
20	0.30	2.64	10.8	0.79	3	8.80
25	0.37	2.88	14.3	1.07	3	7.78
30	0.34	2.56	10.6	0.87	3	7.53
Mid Lake Pickerel						
Surface	0.58	3.92	13.1	2.27	2	6.76
5 inches	0.56	2.12	13.1	1.19	2	3.79
10	0.57	4.62	16.4	2.63	2	8.11
15	0.69	4.96	21.5	3.42	1	7.19
20	0.67	4.96	18.2	3.32	1	7.40
25	0.54	3.92	16.1	2.12	1	7.26
30	0.52	3.65	12.5	1.90	1	7.02
34	0.52	3.92	14.4	2.04	2	7.54
Clear Lake						
Surface	0.58	4.20	18.7	2.43	3	7.24
4 inches	0.70	4.62	20.2	3.24	15	6.60
7 inches	0.51	3.30	14.5	1.68	2	6.47
Roy Lake						
Surface	0.69	5.14	20.3	3.55	17	7.45
4 inches	0.46	4.26	16.0	1.96	19	9.26
7 inches	0.49	4.46	15.3	2.19	18	9.10
Amsden Dam						
Surface	0.29	2.74	10.2	0.79	17	9.45
4 inches	0.21	1.90	6.9	0.40	38	9.05

	% N	% C	% Loss on Ignition	OSI	Available Phosphorus (ppm)	C:N
West Lake Cochrane						
Surface	0.78	5.68	20.0	4.43	17	7.28
6 inches	0.70	4.96	17.9	3.47	23	7.09
8	0.72	4.96	18.1	3.57	26	6.89
12	0.72	5.68	22.9	4.09	23	7.89
16	0.60	5.14	15.1	3.08	24	8.57
20	0.60	4.96	15.5	2.98	25	8.27
24	0.70	5.34	19.3	3.74	23	7.63