CHAPTER 4

Geology of the Main Valley Lakes

4.1 PREVIOUS WORK

The earliest publications concerned with the geology of the Okanagan Valley are those of Dawson (1878, 1879) and Daly (1912). More recent work on bedrock geology has been reported in Cairns (1932, 1937, 1949); Jones (1959); Hyndman (1968); and on the maps (annotated) GSC (1940); (1960 and 1961).

Surficial geology and Pleistocene history has been discussed in Flint (1935 a,b), Meyer and Yenne (1940), Mathews (1944), Nasmith (1962), Wright and Frey, (1965); Armstrong *et al,* (1965), and Fulton (1965, 1969, and 1971). The works of Nasmith (op. *cit),* and Fulton (op. *cit)*provide the most complete discussions of the Pleistocene history of the area.

Soil types of the Okanagan Valley have been discussed by Woodridge (1940) and Kelly and Spilsbury (1949). Hansen (1955) published valuable work on pollen geochronologies in peat deposits from southern B.C., and his work provides a background for present Okanagan Valley pollen studies.

Volcanic explosion ash bands have been used with success in geologic studies in the B.C.-Washington border area. Information on these ash bands has been published in Rigg and Gould (1957), Wilcox (1965), and Westgate, *et al* (1970). Publications on ash band chronology have been reviewed by Fulton (1971).

Geomorphological aspects of the Okanagan area have been discussed in Reinecke (1959), Holland (1964), and Tipper (1971).

4.2 RESULTS

The Okanagan Valley is a structural trench overlying a system of subparallel, linked faults that separate the late Paleozoic or early Mesozoic Monashee group of metamorphic rocks of differing lithology, but of similar age. This trench is partially filled by several hundred feet of unconsolidated material. The thickness of this unconsolidated material varies, but typical minimum thickness under the centers of the lakes are presented in Table 4.1. The trench is apparently continuous under the Okanagan River between Skaha and Okanagan Lakes as well as under Vernon Creek between Wood and Kalamalka Lakes.

It is likely that the unconsolidated material in the trench was deposited in association with the earlier glaciations of the Pleistocene Epoch. The nature of the deposits is uncertain from seismic records alone, but it seems probable that during the Pleistocene, the Valley was the site of deposition resulting from glacial outwash, direct glaciation and Lacustrine fluvial sedimentation. During deglaciation, a number of terraces were formed as the lowering of post-glacial lake levels was repeatedly arrested. A previously undiscovered terrace 50 feet below the present lake level appears to be a remnant of a low stand of Okanagan and Skaha Lakes.

The prominent silt and clay cliffs that border Skaha Lake and southern Okanagan Lake were formed during this period of glacial downwashing and degradation (Flint, 1935). Fulton (1969) has estimated that the deglaciation of the interior plateau of British Columbia was well advanced by 9,750 B.P. (Before Present), and by 8,900 B.P. all ice was melted and glacial lakes had been drained. From this time to the present day, the main valley lakes of the Okanagan have been in existence. Data from these studies do not allow a direct calculation of the total accumulation of recent lake sediment, but if one uses a sedimentation rate of 1 mm. of compacted sediment per year, this would yield an accumulation of 8.9 meters of sediment in 8,900 years.

Bathymetric charts have been constructed from soundings gathered as part of the geological study (Maps 3 to 10). Wood Lake is the smallest of the main valley lakes and consists of a single shallow basin, with a maximum depth of 100 feet (34 meters). Kalamalka Lake contains two distinct basins separated by a ridge in the unconsolidated material filling the structural trench (Map 9). The most unusual feature of Kalamalka Lake is the presence of flat terraces of $CaCO_3$ in the littoral zone that are found chiefly at the southern end of the lake. These terraces are formed by the precipitation of $CaCO_3$ during the summer from the water of the epilimnion. The bottom of Okanagan Lake is characterized by irregular undulations that presumably reflect glacial modifications in the Valley from the last ice age. A large drumlinoid structure exists under 200 feet (61 meters) of water off Squally Point and a point 700 feet (213 meters) deep was discovered south of Trepanier (Map 7). Skaha Lake is comprised of two distinct basins that are separated by a bedrock sill at a depth of about 80 feet (24 meters - Map 5). Osoyoos Lake is in fact three lakes with sand deposits dividing them (Map 3). The northern-most of these "lakes" has three distinct basins and attains a maximum depth in excess of 200 feet (61 meters). The central and southern basins are not as deep, and are partially shielded from significant input of terrigenous sediments by the northern-most basin.

Approximately 150 surface sediment and core samples from the Okanagan main valley lakes were analyzed for particle size distribution. The mean particle size analysis of the surface sediments of the main valley lakes are presented in Table 4.2. The highest silt content was noted in Wood Lake, while the highest clay content was observed in the deep water sediments of Okanagan Lake. The sediment of Skaha and Osoyoos Lakes had very similar particle size distributions. The terraces of Kalamalka Lake contained close to 16% sand and 57% silt.

TABLE 4.1

MINIMUM THICKNESS OF UNCONSOLIDATED MATERIAL UNDER THE CENTERS OF THE MAIN VALLEY OKANAGAN LAKES

SKAHA	North of Kaleden	1200 feet
OKANAGAN	Penticton to Squally Point	1500 feet
	Squally Point to Westbank	1600 feet
	Kelowna Area	1200 feet
	Wilson's Landing - Okanagan Center	1200 feet
	Okanagan Center - Vernon	1200-2000 feet
	Armstrong Arm	1300 feet +
WOOD		400 feet +
KALAMALKA		300-400 feet

TABLE 4.2

SEDIMENT-SIZE DISTRIBUTION IN MAIN VALLEY OKANAGAN LAKES

LAKE[a]	PERCENT SAND (< 63u)	PERCENT SILT (4 - 63u)	PERCENT CLAY (< 4u)
WOOD	3.31	61.73	34.96
KALAMALKA	2.46	43.65	53.89
Terraces	15.96	57.14	26.90
OKANAGAN	---	50.00	50.00
SKAHA	0.52	58.49	40.99
OSOYOOS			
North Basin	4.42	54.68	40.90
South Basin	4.62	53.46	41.92

[a] deep-water surface sediment

Sedimentation rates for the main valley lakes were calculated by pollen studies conducted by Anderson (1972). He concluded that ranching, and other man-induced disturbances of the natural flora of the Okanagan Valley dates back to around 1860 as large ranches were established to supply beef and horses to miners attracted to the Caribou gold rush. His pollen diagrams indicate a depletion of grass pollen in the near-surface sediments of most lakes examined. For the purposes of this study, a measure of 100 years is assumed for the basis of calculating man's influence on the pollen distribution in cores from the valley lakes. The mean annual sedimentation rate in each of the main valley lakes is presented in Table 4.3.

TABLE 4.3

DEPTH TO MAN'S INFLUENCE AND NET ACCUMULATION RATE OF SEDIMENT IN EACH OF THE OKANAGAN MAIN VALLEY LAKES[1]

LAKE	DEPTH TO MAN'S INFLUENCE (cm)	RATE OF SEDIMENTATION (mm)	AVERAGE SURFACE SEDIMENT SPECIFIC GRAVITY	AVERAGE WATER CONTENT (PERCENT)	AVERAGE ANNUAL NET ACCUMULATION OVER 100 YEARS (kg)
WOOD	20	2.0	1.20	90.0	2.23×10^6
KALAMALKA	29	2.9	1.10	87.0	1.07×10^7
OKANAGAN	10	1.0	1.14	83.5	6.39×10^7
SKAHA	21	2.1	1.25	77.0	1.15×10^7
OSOYOOS.	28	2.8	1.20	78.0	1.11×10^7

1. St. John (1972)
2. Values for Osoyoos Lake based on a core taken in the south basin only.

Paleolimnological studies of the distribution of algal microfossils (diatoms) were carried out on cores from all the main valley lakes except Vaseux. Total counts of diatoms per microscope field correlated to sediment depth are presented for Wood, Kalamalka, Okanagan and Osoyoos Lakes in Figure 4.1.

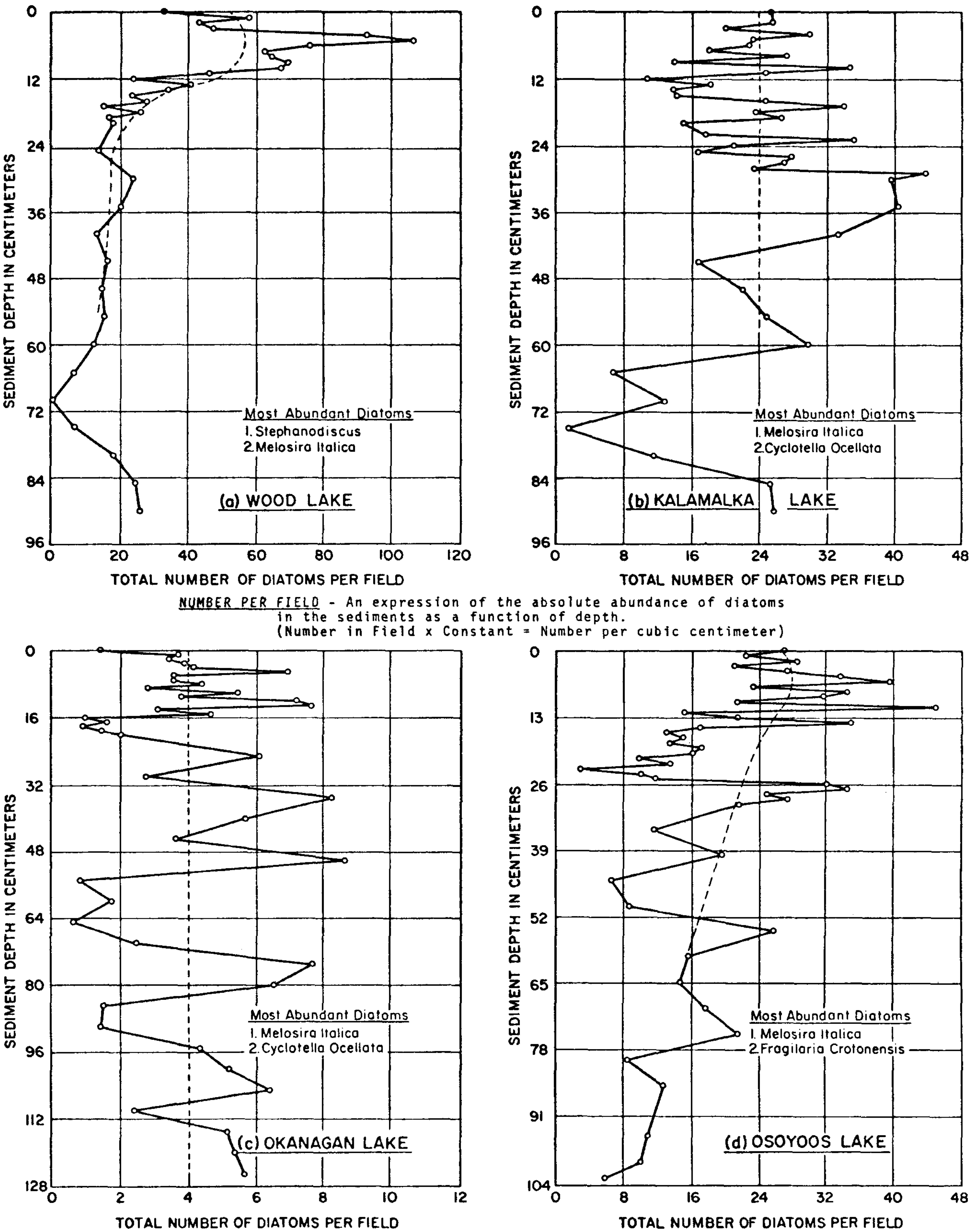
Skaha Lake cores were analysed in a different manner and cannot be directly compared with other lake data. However, spot checks using the same techniques indicate a pattern of diatom abundance very similar to that of Okanagan Lake:

Depth in Sediment (centimeters)	Diatoms per Field	
	Skaha	Okanagan
1-2	5.6	3.8
5-6*	2.0	3.2
9-10	5.8	7.0
14-15	5.1	5.0
19-20	6.7	2.0
50-51	8.0	8.5

*Major silt lense - 1949 flood

The similarity of Skaha and Okanagan values might be expected due to their close positions in the chain and the fact that Skaha Lake is rinsed almost annually with Okanagan Lake water.

The entire artificially enriched period for Skaha Lake would only involve the top 2-3 cm. of sediment, thus it is unlikely that any highly revealing data would be presented in the limited comparisons made. The generally lower values for diatoms in the upper sediments might be indicative of a shift to a dominance of blue-green algae (indicators of more eutrophic conditions) during July and August.



ABUNDANCE OF DIATOMS IN LAKE SEDIMENTS AS A FUNCTION OF DEPTH FOR WOOD, KALAMALKA, OKANAGAN AND OSOYOOS LAKES.

Figure 4.1

The other lake values presented in Figure 4.1 reveals some interesting trends. Kalamalka and Okanagan Lakes, despite considerable variation which is probably due to annual in-lake differences, i.e. very dry year or very wet year, vacillate around a fairly constant mid-point throughout the length of core studied. Mean values of 4 per field and 24 per field for Okanagan and Skaha Lakes respectively are not significantly altered throughout the core length, an indication of little if any advancement toward a more eutrophic state. Osoyoos Lake shows a gradual increase in diatom numbers over a long period of time, indicating a generally steady advance toward eutrophy. Lower numbers of diatoms near the surface could be indicative of a lake shift to the blue-green algae dominance with more enriched conditions or a lack of compaction in the near-surface sediments. The data from Wood Lake is most revealing with regard to understanding its eutrophication. At a depth of 18-20 cm. the lake rapidly increases in diatom production and then falls again, an indication of a predominance of blue-green algae in recent years. This is an excellent example of a lake turning eutrophic in a short period of time.

The mean concentrations of major elements found in the surficial sediments of the main valley lakes are presented in Table 4.4. The more salient points in this table are discussed below:

1) Wood Lake

Calcium content is closely associated with inorganic carbon content, due to association as calcite. $CaCO_3$ content is increased in the upper sediment layer, probably due to increased carbon loading in more recent times and the mineralization of this carbon to carbonate.

2) Kalamalka Lake

The dominant process in the sedimentary cycle of Kalamalka Lake is the precipitation of calcium carbonate. $CaCO_3$ concentrations of 95% have been recorded in sediments from the terraces at the south end of the lake. The terrace sediments represent the greatest concentration of this material however, thus calcium content decreases with increasing depth.

3) Okanagan Lake

Calcium concentrations in Okanagan Lake sediments is strongly linked to inorganic carbon content, probably linked as calcite. The importance of the carbonate cycle in this lake is unknown.

4) Skaha Lake

Calcium in the sediments of Skaha Lake appear to be essentially unrelated to inorganic carbon. This is at variance with the situation in Wood, Kalamalka and Okanagan Lakes. Instead, calcium content appears to be partitioned between silicon and phosphorus.

5) Osoyoos Lake

Variances of sodium, potassium and aluminum are largely accounted for by a

TABLE 4.4

MEAN CONCENTRATIONS OF MAJOR ELEMENTS IN SURFACE SEDIMENT SAMPLES FROM OKANAGAN MAIN VALLEY LAKES

LAKE	TOTAL*									ACID EXTRACTABLE*				
	CaO	Na_2O	Fe_2O_3	MgO	MnO	SiO_2	K_2O	S	Al_2O_3	Fe	Mn	K	Ca	Mg
WOOD														
Mean	7.2	1.5	5.0	1.7	0.18	61.4	1.8	0.95	8.1	2.7	0.12	0.19	3.7	0.67
Standard Deviation	3.2	1.0	2.1	.44	.11	5.5	.72	.71	2.5	1.37	0.06	0.09	2.8	0.30
KALAMALKA														
Mean	26.7	.93	2.5	1.6	.17	44.7	1.2	--	4.8	1.32	0.08	0.16	--	0.63
Standard Deviation	17.1	.64	1.6	.74	.17	18.9	.75	--	2.9	0.95	0.10	0.13	--	0.22
OKANAGAN														
Mean	3.1	1.6	6.1	2.7	.20	61.8	2.5	.21	10.9	3.17	0.12	0.29	0.75	0.77
Standard Deviation	2.5	.43	1.6	.78	.17	4.4	.31	.25	1.1	1.04	0.12	0.17	0.16	0.31
SKAHA														
Mean	2.4	2.1	4.2	1.7	.12	67.8	2.6	.20	10.7	2.28	0.07	0.21	--	0.55
Standard Deviation	.58	.31	1.2	.31	.074	3.8	.18	.14	.72	0.70	0.05	0.09	--	0.19
OSOYOOS														
Mean	3.0	1.8	5.2	2.3	.18	64.3	2.4	.65	10.3	2.53	0.10	0.25	0.68	0.78
Standard Deviation	.94	.32	1.6	.61	.20	4.1	.13	1.7	.91	1.02	0.12	0.11	1.11	0.30

*All values as Percent

single variance vector, while the bulk of the calcium variance and part of the aluminum variance is accounted for by an independent variance vector. It seems probable that these distinctions reflect the mixing of at least two silicate mineral populations.

The results of surface sediment analyses for carbon are presented in Table 4.5. Percent inorganic, organic and total carbon is also presented in Figure 4.2. The highest organic carbon contents occurred in Wood Lake and the north arm of Okanagan Lake, (Table 4.5). The highest inorganic carbon content occurs in the terraces of Kalamalka Lake which are primarily composed of $CaCO_3$.

On the basis of carbon content of sediments over time, some insight into the trophic history of the main valley lakes can be gained (Figure 4.2). The lakes can be divided into three groups on the basis of carbon content:

1) Osoyoos, Wood and Okanagan Lakes that have manifested a significant increase in carbon accumulation over the past 100 years;
2) Skaha Lake that has registered a sharp increase in organic carbon accumulation over the past 25 years, but little change before that;
3) Kalamalka Lake, that has shown an increase in CO_3 accumulation over the past 10 to 15 years.

From the above it is apparent that Osoyoos, Okanagan and Wood Lakes have been subjected to some considerable increase in rate of change (as indicated by carbon accumulation) over the same period of time as man's development in an intensive agricultural community. In fact these lakes drain the areas of most intense rural agricultural activity.

The lake most affected by urban development is Skaha Lake, by virtue of being immediately downstream of the Penticton Sewage Treatment Plant. It is likely that sewage discharge over the last 25 years has contributed substantially to the rapid increase in sediment carbon accumulations. The same parallel can be drawn between carbon accumulation in the Vernon Arm of Okanagan Lake and sewage outfalls of the Vernon area. The unique carbonate cycle of Kalamalka Lake has thus far effectively prevented any noticable increase in organic carbon accumulation in the sediments.

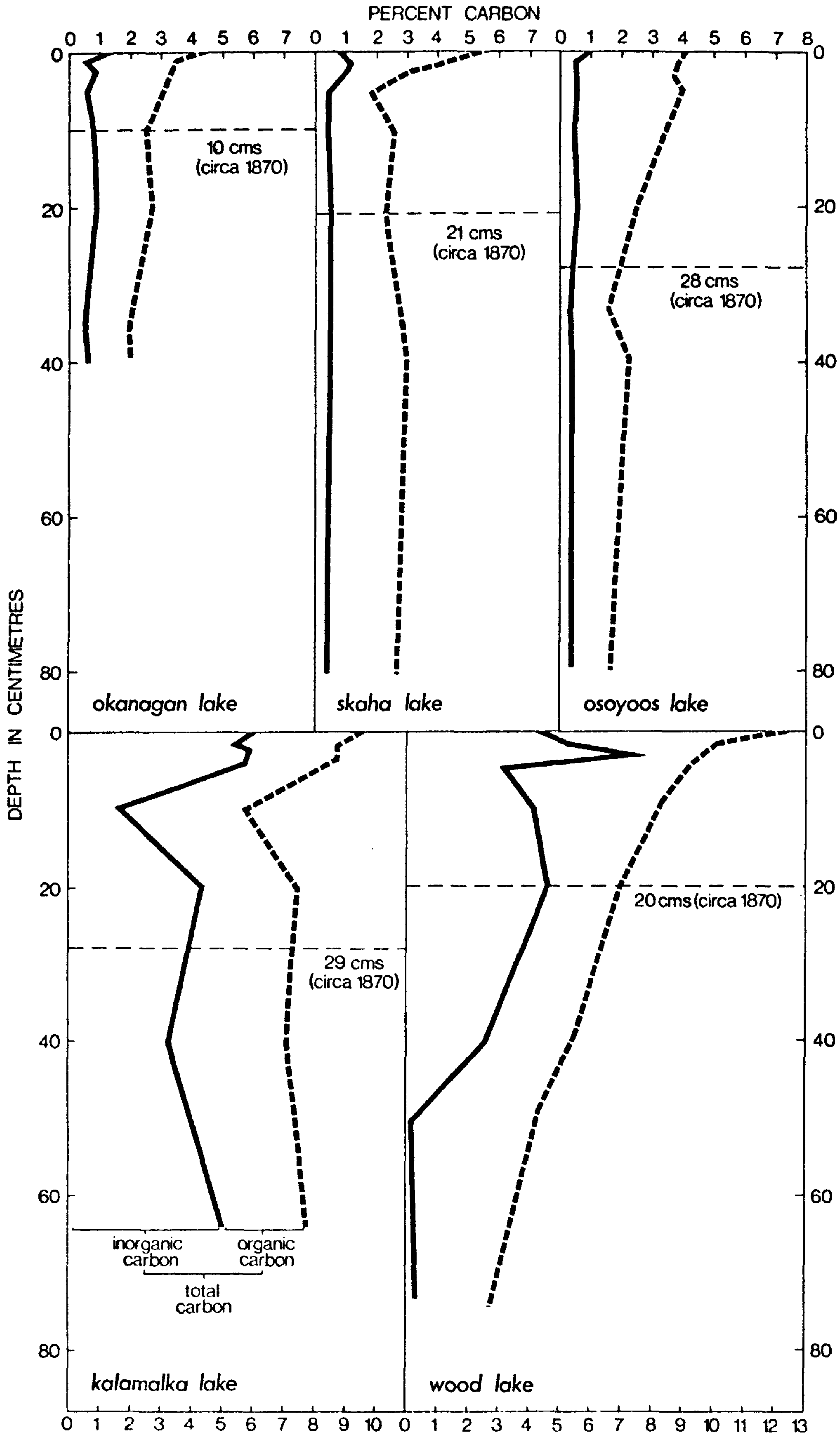
The acid-soluble phosphorus content of the surface sediments has been calculated for each of the main valley lakes (Table 4.6). These data have made it possible to estimate the mean annual phosphorus accumulation to the sediments. Statistical analysis and selective extraction on the sediments from Skaha Lake suggest that hydroxyapitite (or related phases) may be undergoing a rapid inorganic removal from the biologically available state in this lake, thus limiting to a degree, the productive capacities.

TABLE 4.5

MEAN CARBON CONTENT OF SURFACE SEDIMENTS AND MEAN CARBON ACCUMULATION RATES FOR OKANAGAN MAIN VALLEY LAKES

LAKE	ORGANIC CARBON (%)	INORGANIC CARBON (%)	MEAN (OVER 100 YRS) ANNUAL ACCUMULATION IN LAKE IN kg OF ORGANIC C	MEAN (OVER 100 YRS) ANNUAL ACCUMULATION IN LAKE IN kg OF INORGANIC C
WOOD			9.8×10^4	1.13×10^5
All Samples	3.91	1.63		
Basin Muds	5.19	2.41		
KALAMALKA			*———	———
All Samples	3.08	5.83		
Basin Muds	3.32	4.20		
Terraces	2.10	10.23		
OKANAGAN			1.75×10^6	5.00×10^5
All Samples	2.31	0.44		
Basin Muds	2.07	0.30		
Armstrong Arm	2.62	1.14		
Vernon Arm	4.67	0.37		
SKAHA			3.15×10^5	7.12×10^4
All Samples	1.59	0.19		
All (north basin)	1.48	0.21		
All (south basin)	2.07	0.12		
Basin muds (north)	3.46	0.19		
Basin muds (south)	2.05	0.24		
OSOYOOS			3.18×10^6	5.77×10^4
All Samples	2.49	0.42		
All (north basin)	2.23	0.34		
All (central basin)	3.41	0.64		
All (south basin)	2.26	0.40		
Basin muds (north)	2.61	0.35		
Basin muds (central)	4.65	0.44		
Basin muds (south)	3.24	0.32		

* The carbon sedimentation budget for Kalamalka Lake is being subjected to further study. The simple calculations used for this table are insufficient to provide an accurate figure for this lake.



PROFILES OF CARBON CONTENT OF CORES FROM THE OKANAGAN MAIN VALLEY LAKES. Figure 4.2

TABLE 4.6

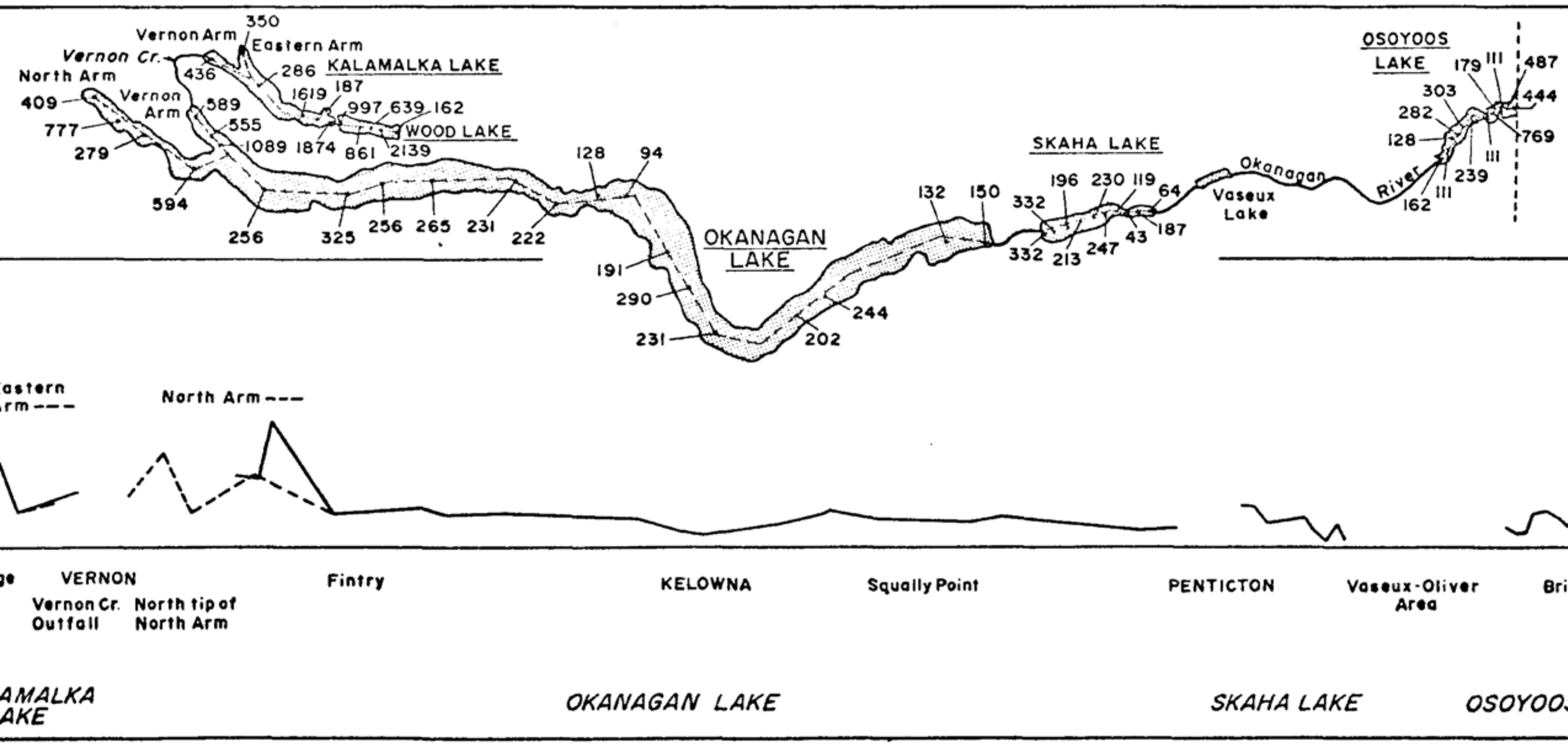
ACID EXTRACTABLE INORGANIC PHOSPHORUS IN SEDIMENTS FROM THE OKANAGAN MAIN VALLEY LAKES

LAKE	HCl-P (ppm)	MEAN ANNUAL HCl-P ACCUMULATION IN EACH LAKE (kg). (Mean HCl-P content of surface basin muds used for calculation)
WOOD		1.64×10^{3}
All Samples	786	
Basin Muds	735	
KALAMALKA		* ________
All Samples	406	
Basin Muds	607	
Terraces	44	
OKANAGAN		7.67×10^{4}
All Samples	1069	
Basin Muds	1200	
Armstrong (north basin)	931	
Armstrong (central basin)	955	
Armstrong (south basin)	1027	
SKAHA		1.15×10^{4}
All Samples	864	
Basin Muds	1000	
OSOYOOS		1.18×10^{4}
All (north basin)	1056	
All (central basin)	657	
All (south basin)	781	
Basin muds (north	1070	
Basin Muds (central)	876	
Basin Muds (south)	851	

* The phosphorus sedimentation budget for Kalamalka Lake is being subjected to further study. The simple calculations used for this table are insufficient to provide an accurate figure for this lake.

Mercury content of the sediments of the Okanagan main valley lakes have been determined. Surficial sediments of Wood Lake have the highest mercury content (Figure 4.3). Most of this mercury occurs as a sulphide and indications are that methylation, and hence its entry into the food chain, is unlikely to occur. The mercury content of Kalamalka Lake is also high, and presents a potential danger if it enters the food chain. The mercury content in the sediments of roost of Okanagan, Skaha and Osoyoos Lakes was considerably lower than values noted in Wood and Kalamalka Lakes.

In conclusion, the sedimentary evidence of long term (one century) water quality degradation in Wood, Okanagan and Osoyoos Lakes - the lakes draining the watersheds most affected by agricultural activity - suggests that various agricultural practices have affected their water quality. In addition to the carbon evidence, the surface distribution of mercury in the Vernon Creek drainage, the Armstrong Arm of Okanagan Lake and in Osoyoos Lake, provides strong circumstantial evidence that rural practices may have resulted in the accumulation of this toxic element in the lake environment. Skaha Lake appears to have undergone rather sudden changes in water quality, contemporaneous with the initiation of sewage input from Penticton some 25 years past. This resulted in an increased accumulation rate for organic carbon. The carbonate cycle in Kalamalka Lake may have "protected" this lake from significant water quality degradation since man settled in the Okanagan Valley some 120 years ago.



PROFILE OF MERCURY CONTENT OF SEDIMENTS IN THE OKANAGAN LAKES SYSTEM ALONG THE DEEPEST PART OF EACH LAKE. MERCURY IN PARTS PER BILLION.