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Light Attenuation in the Mixed-Layer
of Lakes in the Experimental Lakes Area,
1969–1990 Data

by

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Abstract

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Light attenuation in the mixed-layer of lakes in the Experimental Lakes Area, 1969–1990 data. *Can. Data Rep. Fish. Aquat. Sci.* 850: iv + 59 p.

Light attenuation as a function of depth has been measured in 52 ELA lakes for periods as long as 22 years (1969 to 1990; 3507 light attenuation depth profiles). The attenuation coefficient (defined as slope of the line describing the logarithm of light plotted as a function of depth) was calculated for data points in the mixed-layer (epilimnion) of each depth profile. These coefficients are plotted as functions of time; one lake is shown per graph, and common axes are used for all graphs to facilitate comparisons. The result is a concise summary of a massive database, showing the quantity of data available for each lake, how transparency differs among lakes, and how transparency varies within each lake over time in response to whole-lake manipulation experiments and/or natural variability.

Key words: limnology; light attenuation; light extinction; transparency; long-term trends; physical limnology; natural variability; long-term monitoring

Résumé

FEE, E.J., E.U. SCHINDLER, J.A. SHEARER, E.R. DEBRUYN, AND D.R. DECLERCQ. 1991.

Light attenuation in the mixed-layer of lakes in the Experimental Lakes Area, 1969–1990 data. *Can. Data Rep. Fish. Aquat. Sci.* 850: iv + 59 p.

L'atténuation de la lumière en fonction de la profondeur a été mesurée dans 52 lacs de la RLE pendant des périodes atteignant 22 ans (de 1969 à 1990; 3507 profils d'atténuation de la lumière en fonction de la profondeur). Le coefficient d'atténuation, défini comme étant la pente de la droite décrivant le logarithme de la lumière en fonction de la profondeur, a été calculé pour des points de la couche de mélange (épilimnion) de chaque profil. Des diagrammes de ces coefficients en fonction du temps sont établis pour chaque lac; les axes sont les mêmes pour tous les graphiques, ce qui facilite les comparaisons. Le résultat est un résumé concis d'une base de données imposante; il indique la quantité de données disponibles pour chaque lac, les écarts de transparence d'un lac à l'autre, les variations temporelles de transparence dans chaque lac à la suite d'expériences de manipulation de l'ensemble du lac et (ou) en raison de la variabilité naturelle.

Mots-clés: limnologie; atténuation de la lumière; extinction de la lumière; transparence; tendances à long terme; limnologie physique; variabilité naturelle; surveillance à long terme

Introduction

This report presents a graphical summary of mixed-layer light attenuation coefficients of lakes at the Experimental Lakes Area (ELA; Johnson and Vallentyne 1971). Between 1969 and 1990 a total of 3507 light attenuation depth profiles were measured in 38 unmanipulated (i.e., reference) and 14 experimentally manipulated lakes. Table 1 presents the general limnological characteristics of these lakes, which range in surface area from 1.7 to 1330 hectares, in maximum depth from 1.8 to 167 meters, and in (watershed area/lake area) ratio from 1.5 to 625; the color of the lakes varies from nearly blue (essentially uncolored) to deep brown (humic).

Light attenuation data have been routinely collected at ELA primarily because this information is required for estimating *in situ* rates of phytoplankton photosynthesis with the method developed at ELA (Shearer et al. 1985, Fee 1990). However, light attenuation is a fundamental physical property of lakes, and these data are potentially relevant to a much broader range of topics, including assessing the effects of year-to-year changes of climatic variables, determining the magnitude of natural variability in different kinds of lakes, assessing the effects of various whole-lake manipulation experiments, aiding in the selection of lakes for future whole-lake experiments, and investigating relationships between transparency and mixing depth. We hope that the concise visual summary presented in this report will facilitate such uses of this unique database.

Studied Lakes

All light attenuation measurements reported here were made during the ice-free season. The frequency of measurement on any specific lake varied from only once on Lakes 99, 161, and 310 to twice weekly in Lake 239 in 1988 and 1989. Because they are subject to more rapid changes in transparency, experimentally manipulated systems were usually monitored more frequently than unmanip-

ulated lakes; Cruikshank (1984, 1986, 1991) presented detailed descriptions of these experiments. Manipulations performed in 1990 that are not described in those reports are:

- Lake 227: eutrophication experiment modified, with phosphorous being added as before, but nitrate additions being discontinued.
- Lake 223: acidification recovery continued, with sulphuric acid being added to maintain the lake at a pH of 5.9 (target pH was 5.8).
- Lake 302S: acidification experiment continued, with sulphuric acid being added to maintain the lake at pH 4.5.
- Lake 302N: acidification experiment continued, with hydrochloric acid being added to achieve a pH of 5.2 (target pH 5.1 to 5.3); sodium nitrate and sodium sulfate were added to achieve target concentrations of $350 \text{ mg}\cdot\text{L}^{-1} \text{NO}_3^-$ and $7.5 \text{ mg}\cdot\text{L}^{-1} \text{SO}_4^{2-}$, respectively.
- Lake 382: cadmium loading experiment continued, 1438 g Cd added.

Methods

Two fundamentally different types of instruments were used to measure light attenuation as a function of depth. In the early years (1969 through 1973), an instrument manufactured by Whitney-Montedoro and containing a cadmium sulfide cell was used; this instrument measured the total *energy* in the 400–700 nm waveband (Reid et al. 1975). In all subsequent years, instruments manufactured by LI-COR and BioSpherical and containing silicon cells were used; these instruments measured the total *number of quanta* in the 400–700 nm waveband.

From 1974 to 1978 a LI-COR 192S sensor (cosine-corrected flat-plate collector) and 185 meter (analog readout) were used (Shearer 1976). In 1979, the 192S sensor was used during May, most of June, and at the end of the

season, and a 193S sensor (spherical sensor) was used between late June and mid-October; output from both sensors was recorded on 185 meters. Shearer and DeClercq (1980) reported that there were no major differences in underwater light attenuation between these two sensors in this year. In 1980, the 192S/185 sensor/meter combination was used for routine measurements, and occasional comparisons were made with two spherical collectors (LI-COR 193S and Biospherical Instruments QSP 200). Shearer and DeBruyn (1981) report which profiles were taken with each instrument; they concluded that all three instruments gave similar light attenuation results. In 1981 and 1982 the 192S/185 sensor/meter combination was again used exclusively. Starting in 1983, the 192S/185 was used interchangeably with a LI-COR 192SB/188 sensor and meter. The 192SB is identical to the 192S apart from having a calibrated connector that permits it to be used with any LI-COR meter, whereas each 192S is calibrated for a specific 185 meter. The 188 differs from the 185 only in that it is a digital instead of an analog meter. After 1987, a LI-1000 Datalogger (digital readout) was frequently used as the meter for the 192SB sensor.

The mixed-layer *vertical attenuation coefficient* (K_d , units m^{-1} ; η'' in the notation of Hutchinson 1957, which contains a useful discussion of how this parameter differs from other light-attenuation parameters) is defined as the slope of the straight line obtained by plotting the logarithm of light intensity (dependent variable) as a function of depth (independent variable). K_d was calculated with a computer program written in Turbo Pascal which displayed the data graphically on the computer screen along with the statistically fit straight line (linear regression) relating these variables; individual data points that deviated obviously from this line were manually identified to the program and were excluded from the calculation of K_d . The values reported here are thus unaffected either by anomalous data points which frequently occur near the air/water interface (wave action

makes it difficult to measure light accurately in this zone), or by nonuniform distributions of phytoplankton below the mixed layer (Fee 1976) which can cause light attenuation there to deviate markedly from the mixed-layer value (Fee, Shearer, DeClercq 1978; Shearer et al. 1987).

Raw data (tables and graphs of light vs. depth) and K_d were previously published for the period 1969–85 (Reid, et al. 1975; Shearer 1976; Shearer and DeClercq 1976, 1977, 1978, 1979, 1980; Shearer and DeBruyn 1981, 1982, 1983, 1987). Copies of some of these reports are no longer available, and there are no plans to produce similar reports for later years. Investigators who wish to work with the data further should contact the senior author, who can supply the complete light vs. depth database as well as a database containing the derived mixed-layer attenuation coefficients on electronic media. Users with access to older reports should note that all previously reported values of K_d were based on all available data in each dataset; because in the present report these datasets were “trimmed” before calculating K_d (in order to obtain values representative only of mixed-layer conditions; see previous paragraph), values reported here may differ from those in older reports.

Results

The mixed-layer attenuation coefficients are presented as graphs in Appendix 1 (one lake per page). Because data were only collected during the ice-free season, the time axis within individual years is expanded; the vertical line marking the start of the year is April 1, and the vertical line marking the end of the year is December 1. Whole-lake manipulations and major forest fires are identified directly on the graphs. Graphs are not presented for several lakes in which very few measurements were made; these results are presented in the following table.

Lake	Date	K_d
099	20 August 1969	0.92
103	10 September 1973	1.95
103	26 September 1973	1.81
103	01 November 1973	1.44
161	20 August 1969	0.19
310	16 September 1969	1.41

Tables 2–4 summarize statistical results by lake and year: Table 2 contains annual means, Table 3 contains coefficients of variation ($100 \times$ standard deviation/mean), and Table 4 contains the total number of measurements.

Discussion

Unmanipulated lakes

Annual means of K_d in unmanipulated lakes varied from around 0.2 in large, ultraoligotrophic lakes (161=Hillock and 228=Teggau) to 2.1 in small, dystrophic (humic) lakes (225 and 661).

Long time-series are available from four unmanipulated lakes (224, 239, 240, and 305). There were two strikingly different patterns of variation of K_d with time in these four lakes: in the first, the trend with time was either not statistically significant (lake 305) or significant but with a very low slope (b) (lake 224: $b = -0.0033 \text{ yr}^{-1}$, $n = 126$, $t = 4.99$); in the second, the trend with time was highly significant and the slopes were appreciable (lake 239: $b = -0.0173 \text{ yr}^{-1}$, $n = 365$, $t = 23.51$; lake 240: $b = -0.0128 \text{ yr}^{-1}$, $n = 145$, $t = 10.82$)¹. It is probably not coincidental that the basins of those lakes in which transparency increased (239 and 240) were extensively burned in 1974 and again in 1980, while the basins of those lakes where transparency remained unchanged (224 and 305) escaped these fires (except for a very small part of the 305 basin). A plausible chain of events linking forest fires with increased transparency is that the flux of dissolved organic carbon (DOC) from the terres-

tial basin to downstream lakes declines after a fire; as DOC concentrations in the lake decline, transparency increases. Confirmation of this theory awaits calculation of DOC loadings to lake 239, but it is well established that DOC concentrations in lakes 239 and 240 decreased in synchrony with transparency increases in these lakes, while during this same period DOC remained unchanged in lakes 224 and 305 (FWI chemistry lab., unpubl.). The notion that forest fires are causally linked with increasing transparency in downstream lakes is further supported by data from lake 383, which is the only other unmanipulated lake in which K_d was measured both before and after a forest fire; just as in lakes 239 and 240, transparency increased in lake 383 in each year following the 1974 fire.

K_d data from lakes 239, 240, 224, and 305 also show that transparency changed gradually (if not exactly linearly) over time in unmanipulated lakes during the 22 year period for which data are available. That is, there are no “jumps” that coincide with the dates when different instruments were used. Taken together with the fact that unmanipulated lakes showed different trends over time, these results support the conclusion that the various instruments used to measure K_d all gave comparable results.

Manipulated lakes

Summer additions of phosphorus and nitrogen to the epilimnia of lakes 227 and 226N caused massive phytoplankton blooms (Fee 1979, Schindler 1988), which caused K_d to be both higher and more variable than in unmanipulated lakes. Curiously, when lakes 303 and 304 were similarly treated, K_d was not as obviously affected.

All lakes that were experimentally acidified (114, 223, 225, 302N, and 302S) increased in transparency (K_d declined); Shearer et al. (1987) concluded that this was a direct consequence of acidification in lake 223, and discuss the problem of differentiating this experimental effect from the trend of decreasing K_d .

¹Trends of K_d with time in 239 and 240 are not independent because lake 239 drains into 240 (it contributes about one-third of the water budget of 240; K. Beaty, pers. comm.).

that occurred simultaneously in some unmanipulated lakes of the region (discussed above).

Other experimental manipulations that had no obvious effect on K_d were: summer additions of only phosphorus to the epilimnion of lake 261; summer additions of nitrogen and carbon to the epilimnion of lake 226S; summer additions of nitrogen and phosphorus to the hypolimnion of lake 302N; winter additions of nitrogen and phosphorus to lake 230; piscivore transfers from lake 222 to lake 221; and cadmium additions to lake 382.

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Table 1. Summary of morphometric characteristics of the lakes in which light attenuation was measured. Watershed areas do not include the area of the lake. Data are from Cleugh and Hauser (1971) and G. McCullough (unpublished). N/A=data not available. *=experimentally manipulated lake; see the figures in Appendix 1 for details.

Lake	Lake Area (A_0 , ha)	Watershed Area (A_d , ha)	A_d/A_0	Maximum Depth (m)
93	7.9	33.1	4.2	10.3
99	6.5	20.5	3.2	7.6
103	2.3	40.7	17.7	4.2
109	14.4	27.6	1.9	10.0
110	5.9	28.1	4.8	13.0
111	9.9	329.1	33.2	30.0
114*	12.1	44.9	3.7	5.0
120	9.3	49.7	5.3	19.0
127	4.7	20.3	4.3	5.2
129	4.5	36.5	8.1	5.4
130	7.6	112.4	14.8	5.7
132	7.2	42.8	5.9	8.4
149	28.0	90.0	3.2	4.2
161	1007.0	1477.0	1.5	117.0
164	15.3	4791.7	313.2	6.6
165	11.4	4663.6	409.1	4.8
221*	8.9	73.1	8.2	5.4
222*	17.5	60.5	3.5	5.4
223*	30.2	245.8	8.1	11.2
224	25.4	86.6	3.4	16.7
225*	5.6	25.4	4.5	1.8
226*	21.8	55.2	2.5	12.2
227*	5.0	44.0	8.8	10.0
228	1330.0	5151.0	3.9	167.0
230*	1.7	6.3	3.7	13.6
239*	56.1	338.9	6.0	30.4
240	44.1	688.9	15.6	13.1
241	1.8	23.2	12.9	12.5
260	32.4	133.6	4.1	14.6
261*	5.6	28.4	5.1	9.6
262	84.2	1144.8	13.6	30.0
265	13.1	178.9	13.7	18.6
302*	23.7	66.3	2.8	13.8
303*	9.9	66.1	6.7	2.5
304*	3.6	5.4	1.5	6.7
305	52.0	246.0	4.7	32.7
310	49.7	489.3	9.8	19.7
373	29.1	53.9	1.9	21.0
374	485.0	1779.0	3.7	30.0
375	23.9	207.1	8.7	26.0
377	27.7	2002.8	72.3	17.5
382*	37.3	160.7	4.3	11.9
383	5.2	40.8	7.8	9.4
384	6.3	57.7	9.2	3.3
442	16.3	168.4	10.3	17.8
622	41.0	378.0	9.2	30.0
623	38.6	612.4	15.9	21.0
629	63.1	N/A	N/A	18.0
661	N/A	N/A	N/A	N/A
938	19.2	12001.8	625.1	6.0

Table 2. Mean vertical attenuation coefficients for each lake (rows) and year (columns).

	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	
093																0.74							
099	0.92																						
103					1.73																		
109															0.39	0.38	0.43	0.42	0.36	0.40	0.41		
110															0.49	0.45	0.55	0.53					
111															0.49								
114	0.80		0.91			0.66	0.60			0.96	0.76	0.71	0.73	0.71	0.65	0.58	0.67	0.67	0.46	0.56			
120	0.56		0.60	0.59		0.66																	
127										0.55													
129			1.33	1.77						1.22													
130										0.58													
132										0.56													
149																			0.69	0.67	0.70	0.62	
161	0.19																						
164																			0.98	0.88	0.86	0.91	
165																			0.87	1.15	1.11	1.19	
221							1.06											1.62	1.19	1.07	1.14	1.01	
222								1.01			1.00	1.15	1.33	1.12	1.04	1.60	1.20	1.01	1.11	1.10			
223						0.48	0.43	0.43	0.33	0.38	0.35	0.32	0.35	0.45	0.34	0.34	0.52	0.36	0.34	0.33	0.33	0.29	
224							0.30	0.27	0.25	0.24				0.24	0.25	0.23	0.22	0.28	0.24	0.22	0.21	0.24	0.22
225																	1.85	2.13	1.90	1.38			
226N		0.52		0.76	1.00	0.81	0.73	0.80	0.98	0.86	0.83	0.61	0.68	0.66	0.62	0.76	0.67	0.59	0.59	0.59	0.59		
226S					0.60	0.63	0.62	0.62	0.70	0.63	0.59	0.68	0.62	0.67	0.64	0.60	0.72	0.66	0.61	0.57	0.62	0.61	
227	1.34	1.23	1.18	1.95	1.63	1.49	1.09	0.97	1.16	1.33	1.97	2.04	1.38	2.00	1.39	1.44	1.55	1.41	1.99	1.38	1.54	1.43	
228			0.20	0.18																			
230	1.02		0.89	1.07			0.86	0.96															
239	0.83	0.85	0.89	0.76	0.82	0.78	0.76	0.71	0.69	0.76	0.78	0.68	0.66	0.64	0.59	0.49	0.66	0.59	0.55	0.53	0.58	0.46	
240	0.77	0.76	0.71	0.67		0.69	0.66		0.64							0.57	0.52	0.66	0.64	0.49	0.48	0.51	0.43
241	2.03		1.57																				
260																		0.56	0.53				
261			0.86	1.10	1.04	1.08	1.05	1.03	0.99														
262																			0.43				
265			0.55																				
302N	0.41		0.64	0.61	0.61	0.66	0.69	0.67		0.60		0.57	0.52	0.68	0.62	0.57	0.70	0.59	0.56	0.49	0.47	0.45	
302S				0.59	0.58	0.59	0.52	0.51		0.47		0.58	0.48	0.48	0.43	0.44	0.51	0.48	0.44	0.40	0.39	0.47	
303	0.98	0.88	0.79			0.80	1.15	1.17					0.90			1.40	1.30	0.67					
304	0.99	1.33	1.41	1.41	1.08	0.92	1.06	1.17	1.16			1.04		1.16		0.95	1.21	1.03	0.92	0.96	0.95		
305	0.33		0.35			0.35								0.37	0.30	0.31	0.39	0.37					
310	1.41																						
373																0.28	0.27	0.31	0.34	0.27	0.30	0.31	0.29
374																0.34	0.32		0.36	0.34	0.24	0.36	
375																0.45		0.47	0.37	0.37	0.41	0.43	
377																		0.44	0.40	0.49	0.45		
382							0.56	0.61	0.59	0.53		0.64	0.56	0.53	0.77	0.63	0.52	0.54	0.60	0.45			
382B									0.91	0.91	0.83		0.92	0.69	0.73								
383					0.98	0.81			0.74	0.74													
384									0.80														
442																		0.39	0.42	0.49	0.47		
622															0.51								
623															0.47	0.43	0.50						
629															0.55	0.50							
661											2.14												
938																		0.49	0.56	0.42	0.43		

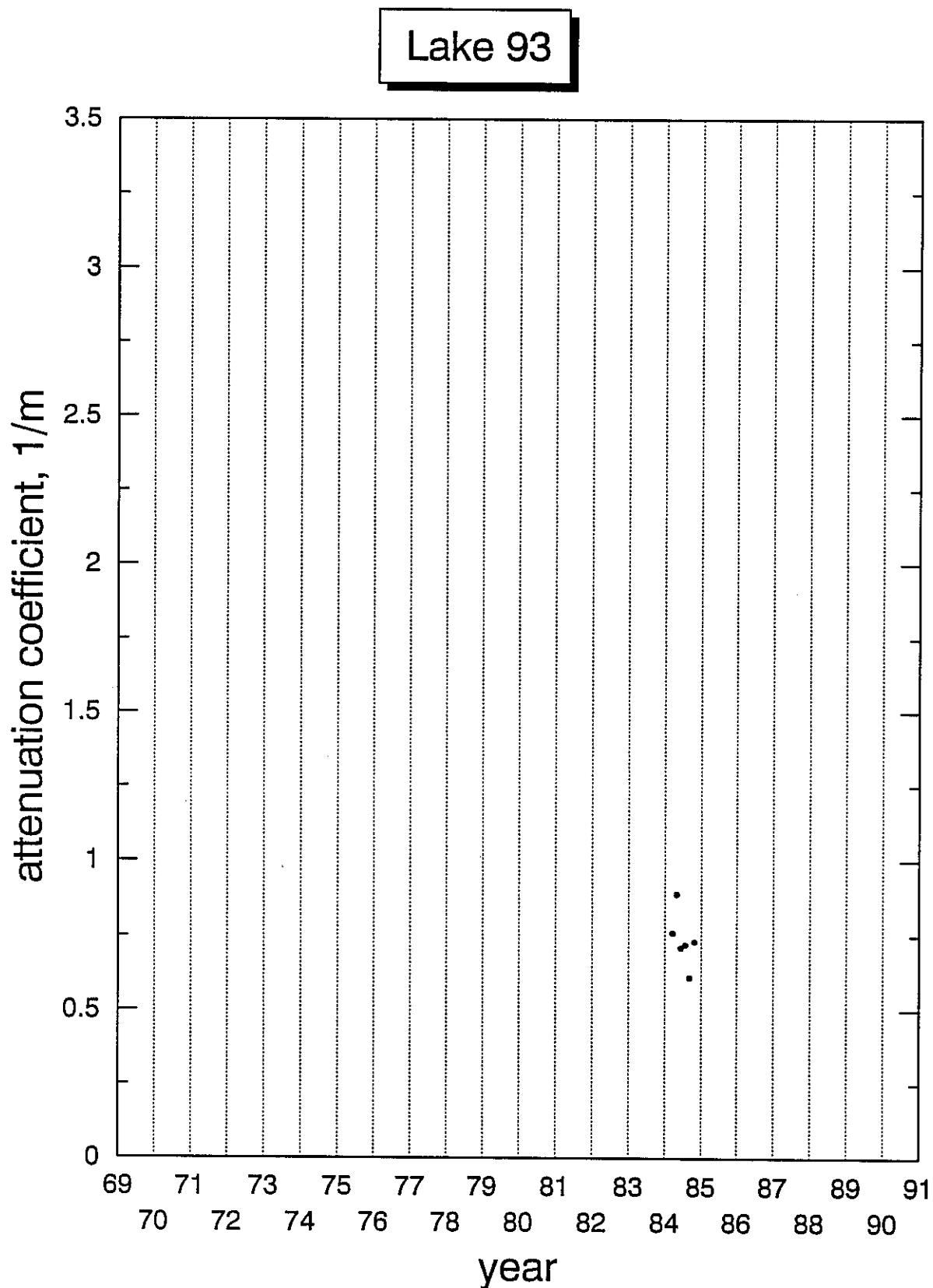
Table 3. Coefficients of variation ($100 \times$ standard deviation/mean) of vertical attenuation coefficients for each lake (rows) and year (columns).

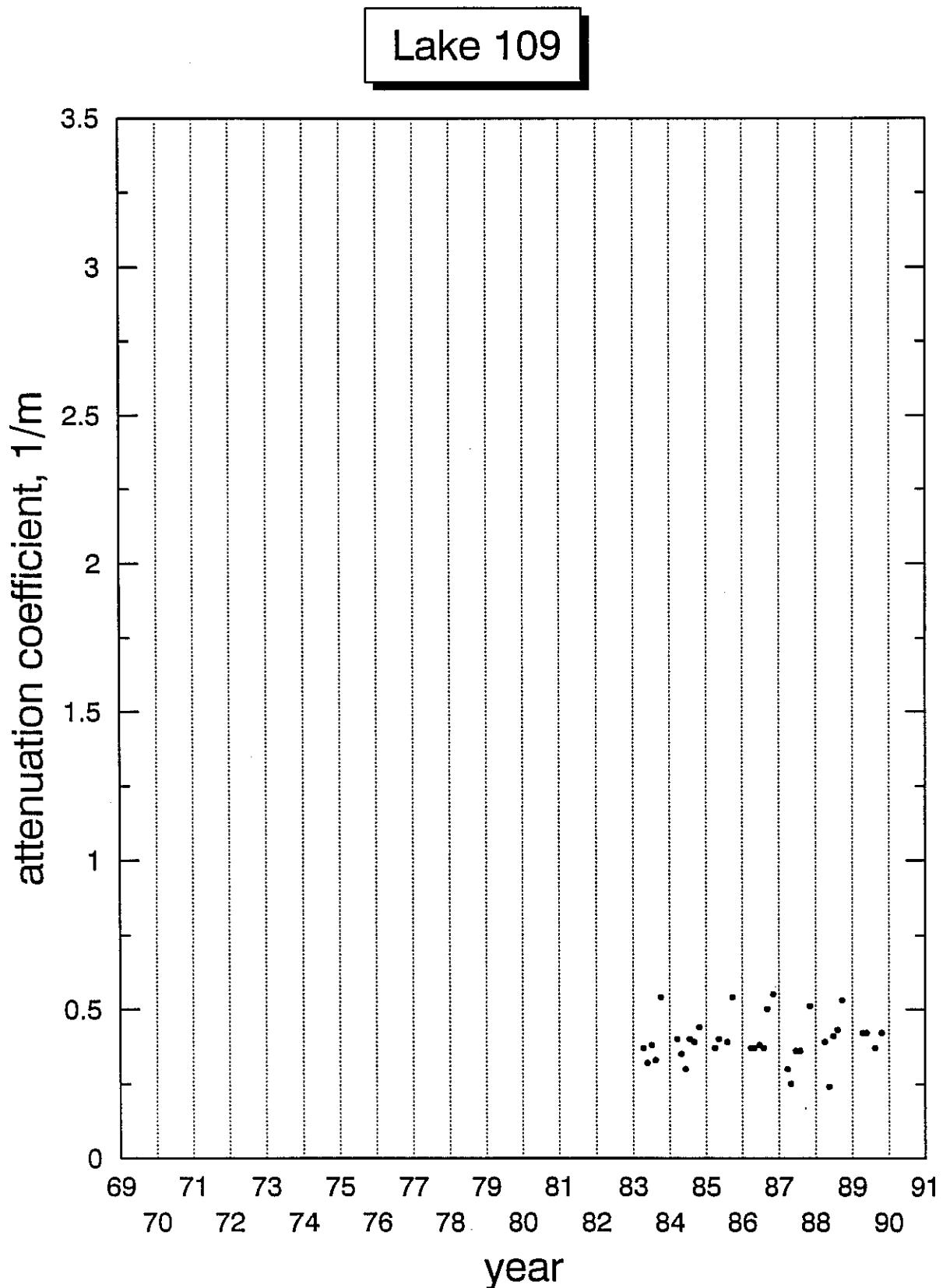
	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
093																	12					
099																						
103																						
109																23	13	18	19	27	26	6
110																20	12	4	12			
111																		10				
114			21			18	17			27	23	18	16	11	9	23	22	28	22	22		
120			5	18		9																
127											12											
129			3	43							9											
130											16											
132											5											
149																			19	25	32	20
161																						
164																			6	21	19	18
165																			49	18	22	19
221									17									15	4	8	18	10
222								22				19	9	13	10	12	20	20	6	16	8	31
223						11	15	13	17	19	32	25	23	26	14	43	12	18	22	25	21	18
224						10	17	13	14					12	10	9	19	14	27	14	16	8
225																	17	9	10	12		
226N			12		35	35	23	15	19	43	19	19	11	12	17	17	10	10	12	10	23	13
226S					23	16	15	12	17	14	24	11	11	11	18	14	10	12	12	18	18	18
227	37	18	18	35	44	19	22	12	24	22	24	18	19	39	31	30	13	13	30	16	33	43
228			19																			
230	12		10	22			13	17														
239	9	10	11	10	15	10	7	8	11	14	15	8	16	9	9	8	10	12	18	15	13	12
240	18	25	12	26		7	9		10							9	22	16	18	15	14	7
241	16		39																			
260																		18	8			
261			30	28	17	17	9	10	10													
262																			22			
265			16																			
302N			12	19	24	21	14	15		17		22	15	14	11	14	19	18	18	24	26	30
302S				20	20	11	12	13		8		33	14	9	16	16	18	20	29	31	27	25
303	51	26	23			21	22	24							20		64	21	31			
304	18	18	15	42	17	15	18	21	17			8		13		30	12	16	13	12	17	
305	14		15			12								5	13	5	13	19				
310																						
373																18	14	12	6	16	14	20
374																11	14		12	13	17	17
375																11		5	6	11	15	10
377																		10	24	20	12	
382										8	10	13	13		2	8	11	9	11	11	16	8
382B										21	21	13		12	11	13						
383						6	11			11	15											
384										12												
442																		16	15	23	19	
622																11						
623																12	8	9				
629																15	10					
661															19							
938																		28	13	19	19	

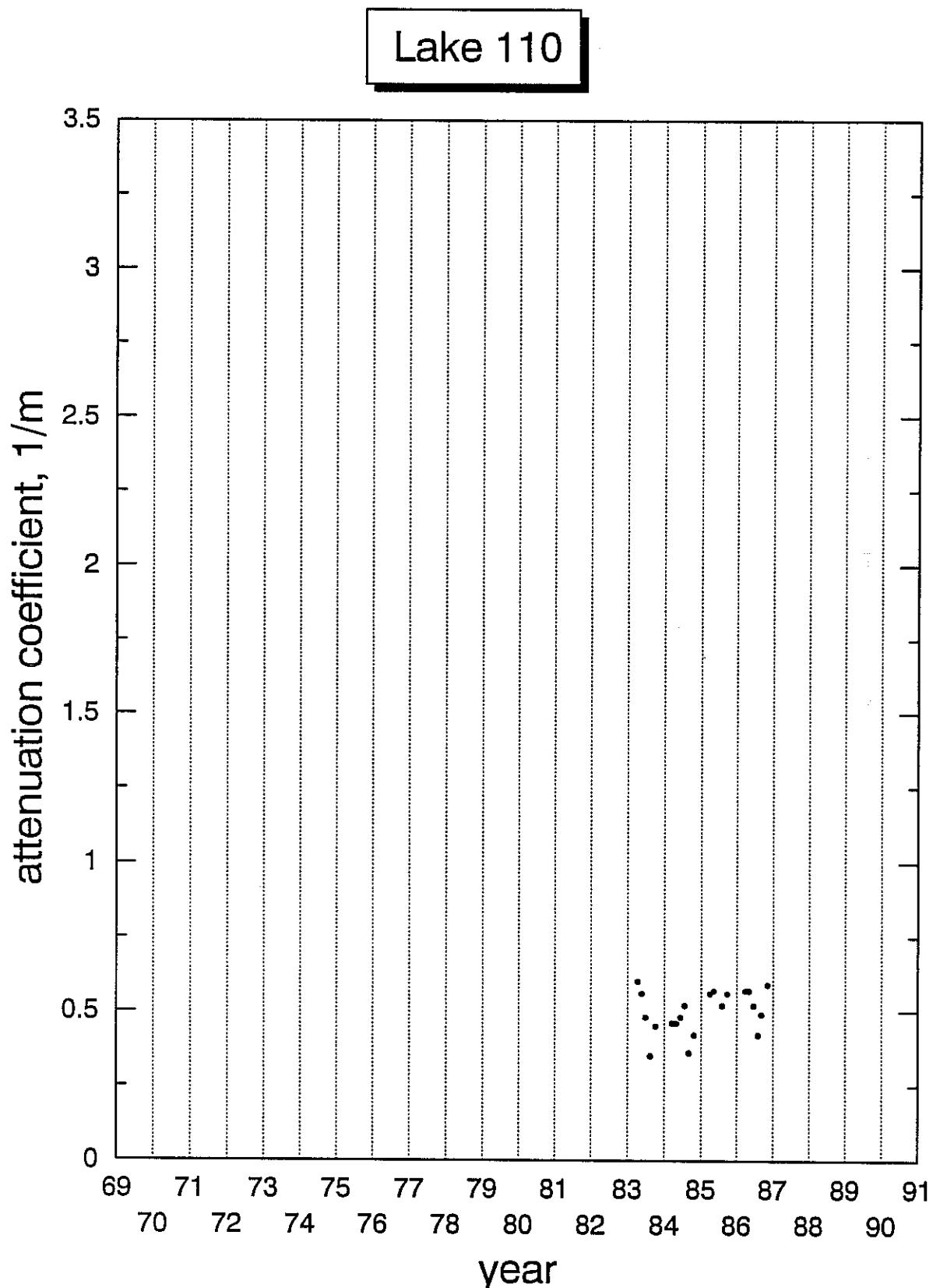
Table 4. Total number of light profiles measured in each lake (rows) and year (columns).

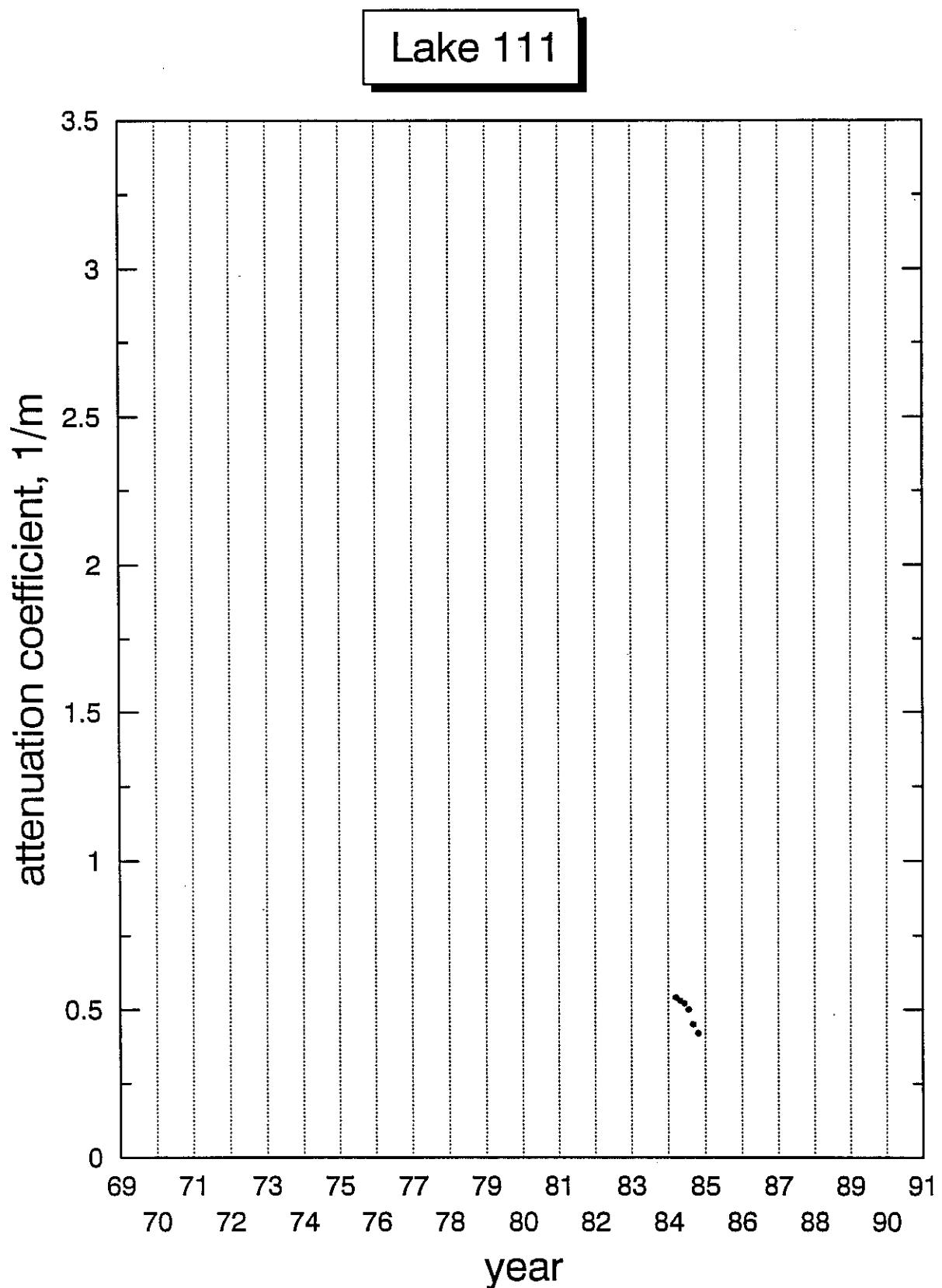
	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	
093																6							
099	1																						
103					3																		
109																5	6	4	6	5	5	4	
110																5	6	4	6				
111																6							
114	1		4			11	15			9	13	13	12	12	11	14	12	14	11	6			
120	1		5	7		10				8													
127										8													
129		3	7							8													
130										8													
132										9													
149																		4	8	5	11		
161	1																						
164																		5	10	4	11		
165																		5	10	6	11		
221							6										5	2	10	6	6	12	
222							6			6	9	7	6	6	6	7	7	7	6	6	12		
223					11	13	12	13	9	14	13	15	14	13	16	14	12	13	12	9	12		
224					11	11	13	9			13	7	8	8	8	8	7	7	6	6	12		
225																4	5	5	19				
226N		4		30	13	15	22	13	17	12	12	13	7	7	7	8	9	7	6	5	12		
226S				28	13	15	23	13	14	13	13	14	8	7	6	8	9	7	6	6	11		
227	5	23	14	15	30	12	14	15	13	10	13	14	14	14	16	13	14	15	13	13	10	12	
228		3	1																				
230	2		6	7		20	11																
239	7	16	6	8	28	12	11	15	10	10	17	18	15	14	14	14	14	13	16	51	34	22	
240	3	17	6	7		13	15		9							9	7	8	5	6	11	18	11
241	2		6																				
260																	3	6					
261			6	7	13	13	14	13	7														
262																		5					
265		5																					
302N	1		4	13	14	15	13	17		11		9	12	13	15	16	15	14	13	12	11	11	
302S				11	14	14	13	18		11		10	12	15	15	15	14	14	13	12	11	11	
303	2	8	8		7	15	12							6		5	7	5					
304	3	9	16	14	13	10	15	14	7		4		6		6	7	6	7	4	4			
305	7		5		12									7	6	7	6	8					
310	1																						
373																6	6	5	6	9	11	7	11
374																5	6	5	5	3	5		
375																5		5	4	4	4	11	
377																		4	9	8	11		
382							7	10	12	6		6	6	6	6	6	7	7	8	10	12		
382B								9	12	7		6	6	6									
383					14	17			9	12													
384									8														
442																		4	11	6	11		
622																5							
623																5	6	5					
629																5	6						
661												6											
938																		4	9	8	11		

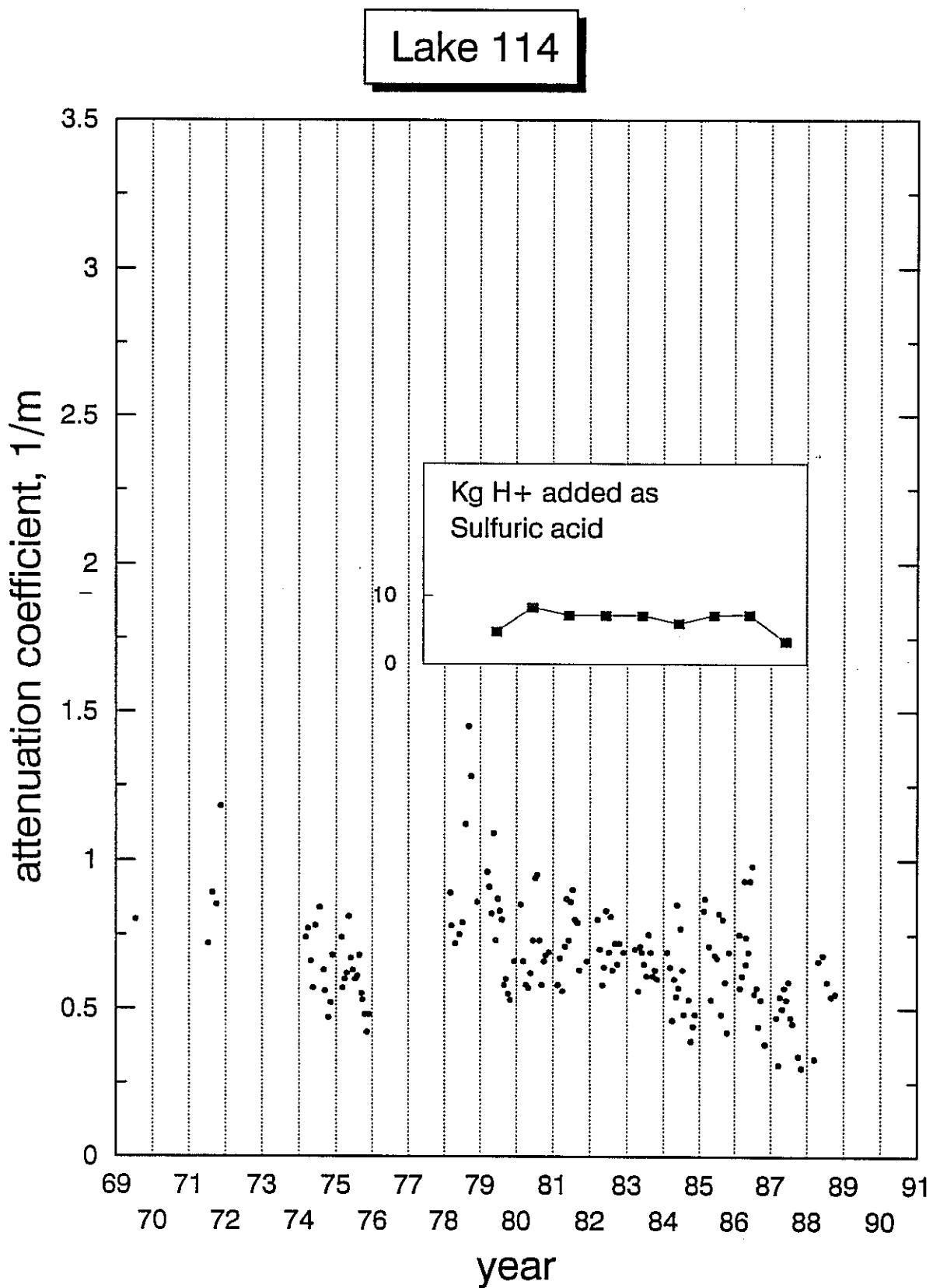
Appendix 1. Graphic presentation of mixed layer extinction coefficients for 49 ELA lakes sampled between 1969 and 1990. Because data were collected only during the ice-free season, the time axis within each year is expanded: the vertical line marking the start of the year is April 1, and the vertical line marking the end of the year is December 1. In order to facilitate intercomparisons between lakes, all data are graphed on a single set of scales, regardless of the quantity or range of information available for any particular lake. Whole-lake manipulations are indicated directly on the graphs; this facilitates interpretation of causal linkages between these manipulations and changes in transparency.

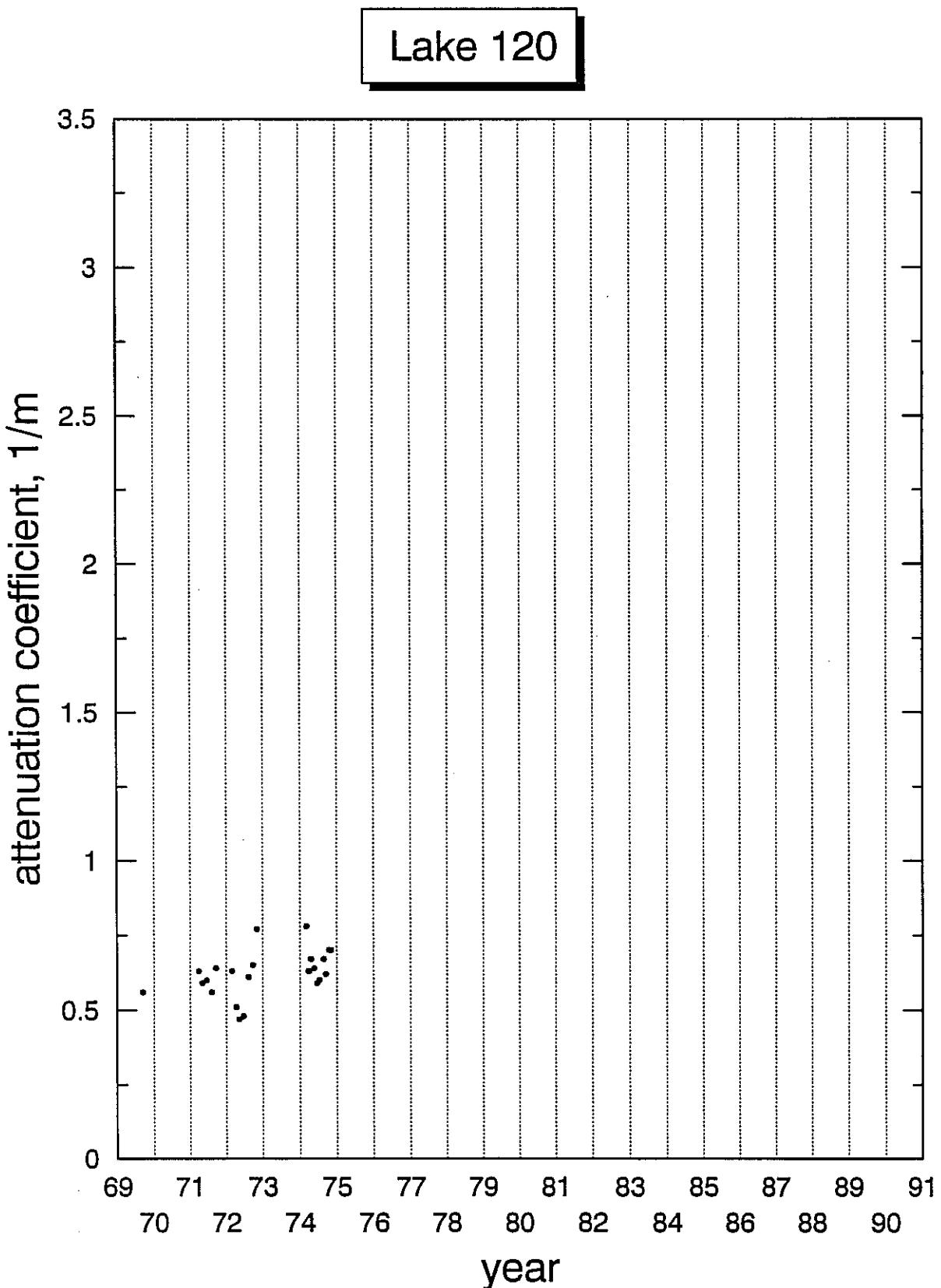


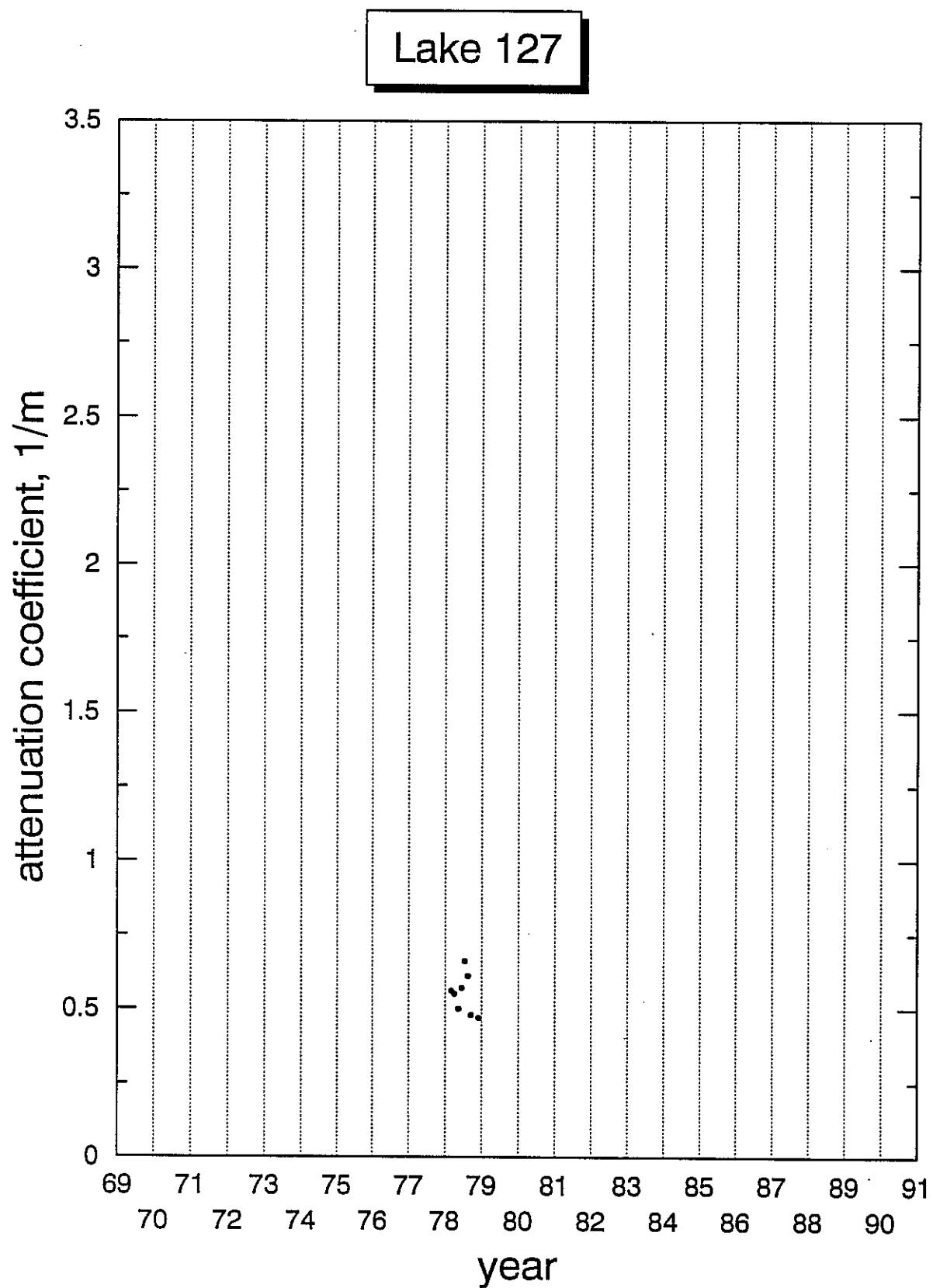


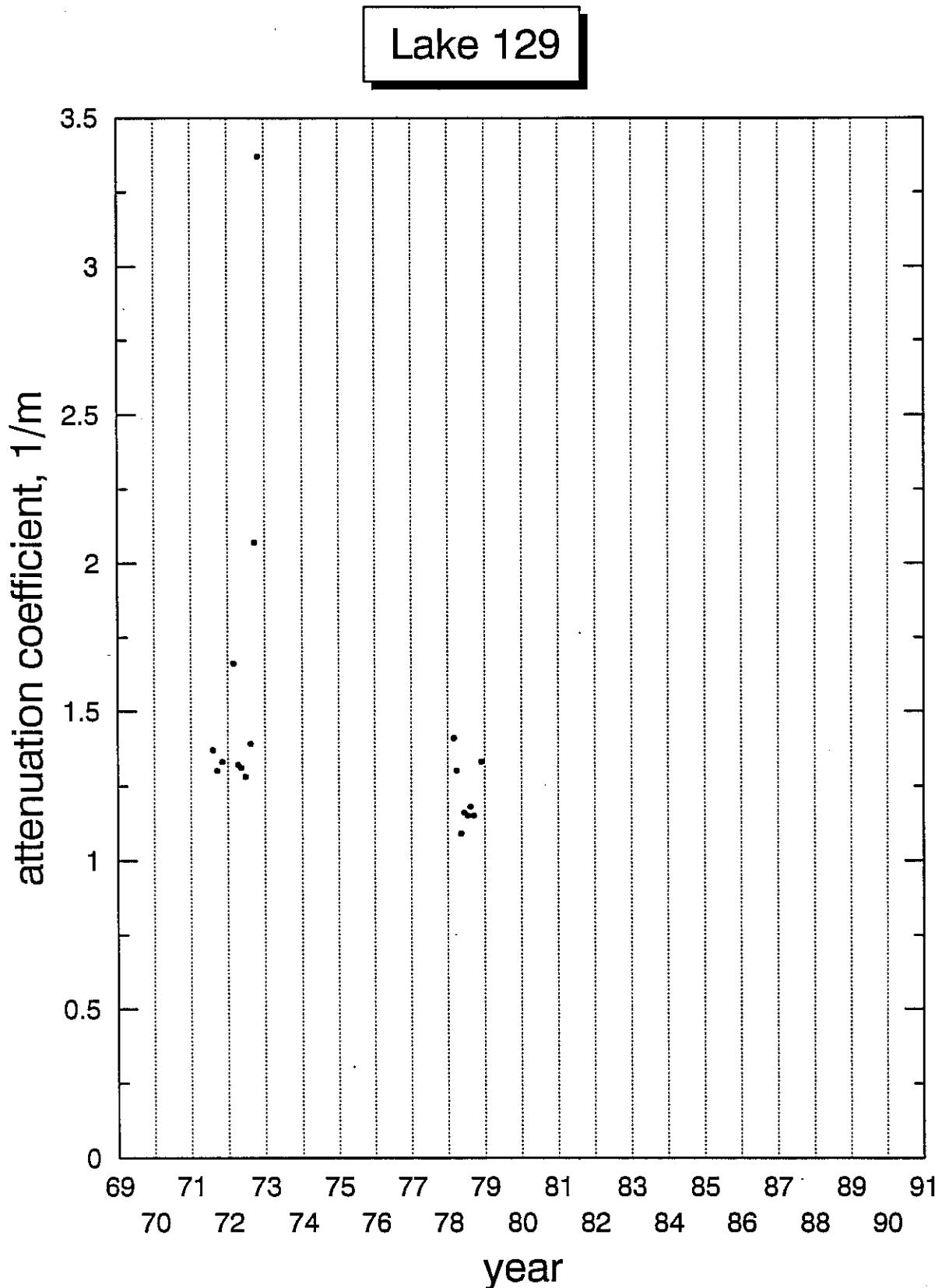


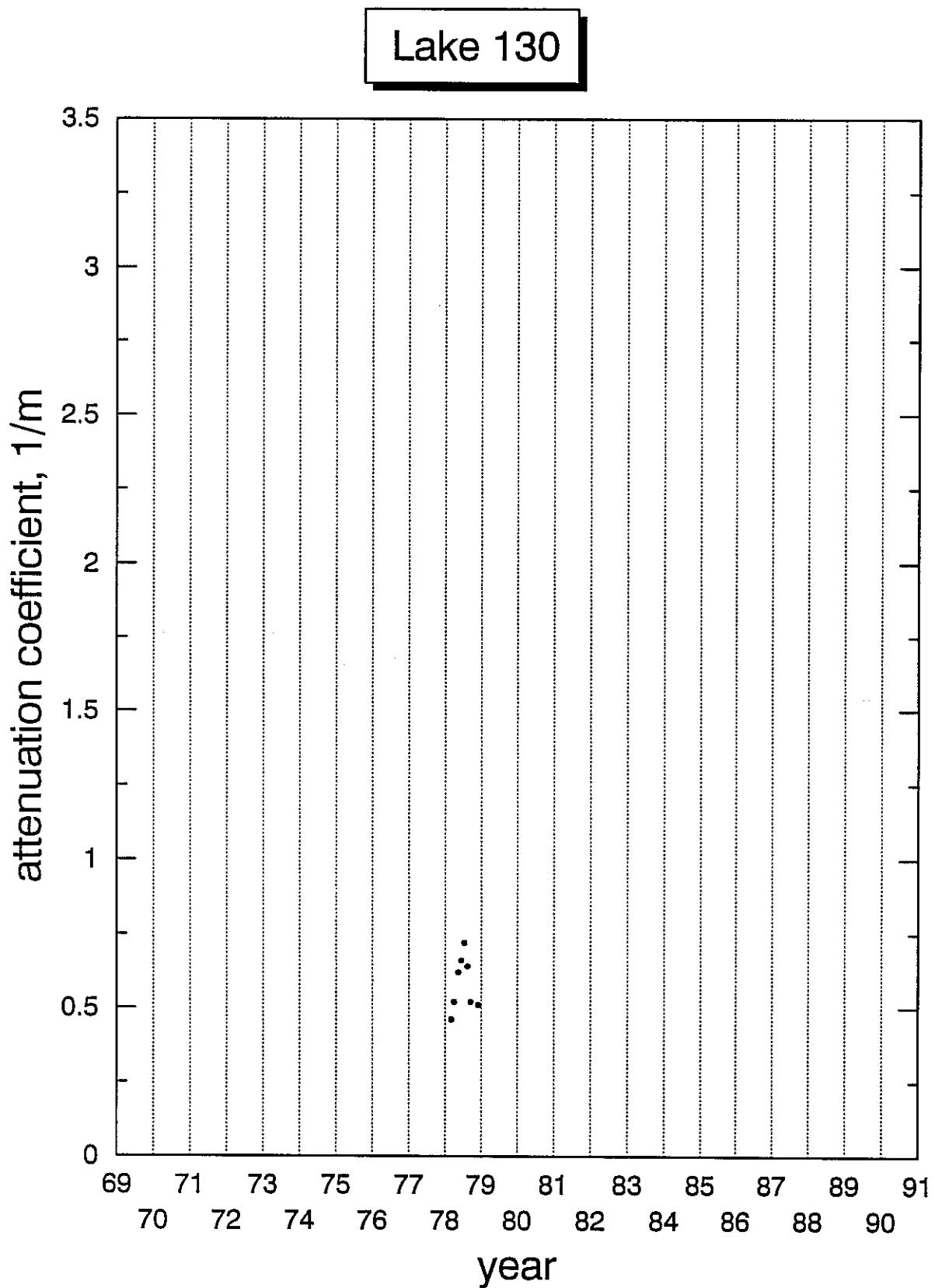


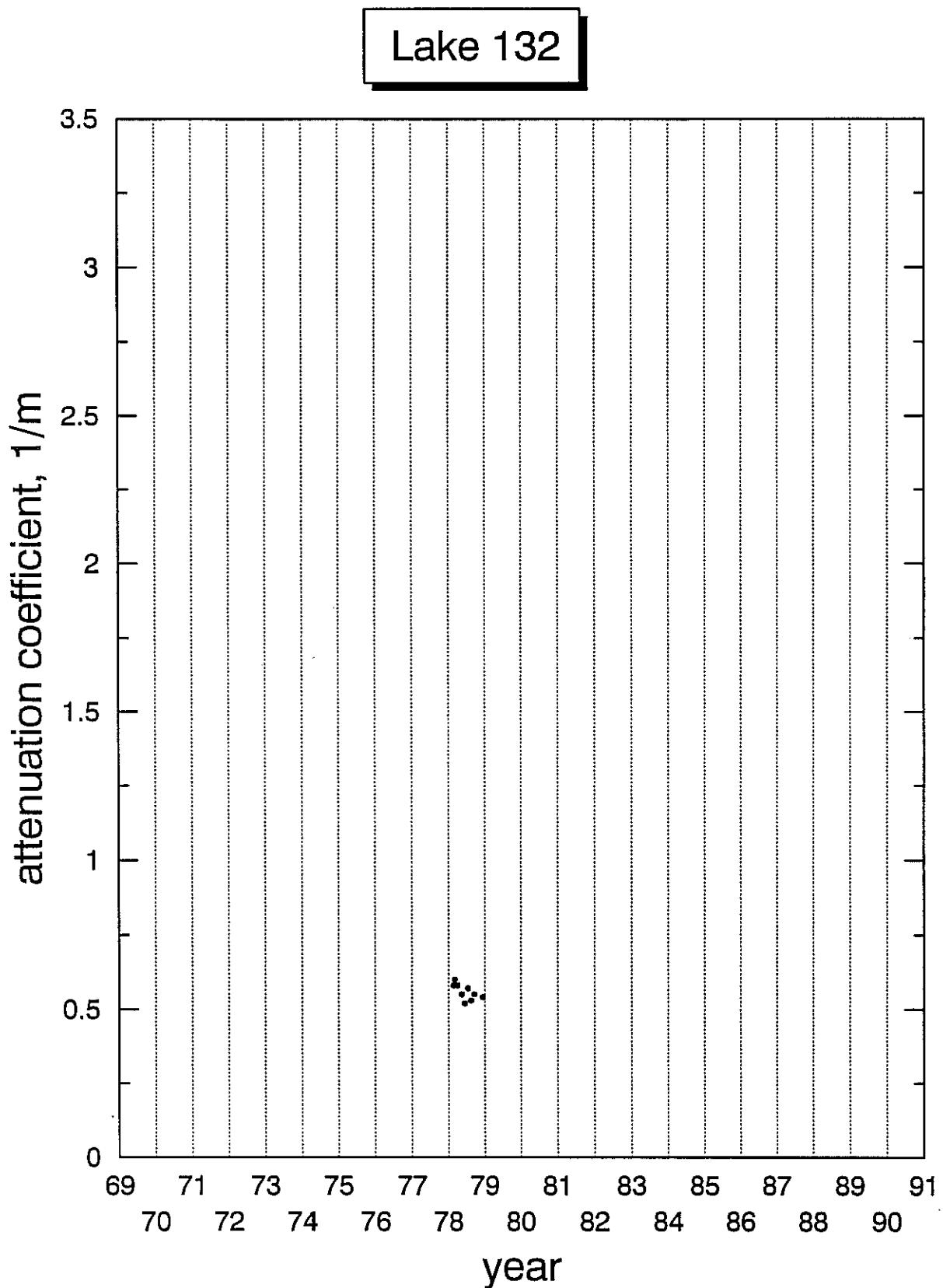


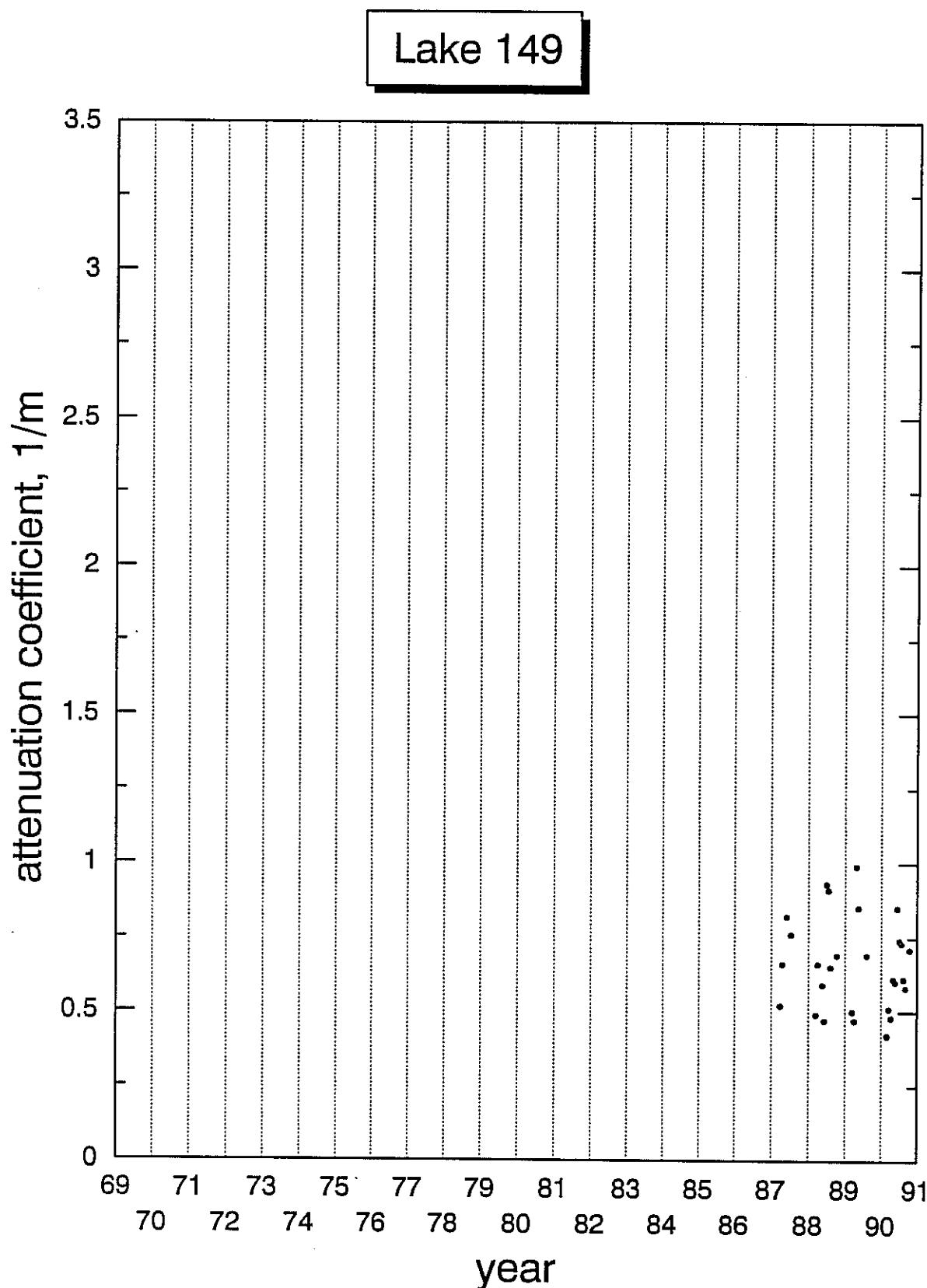


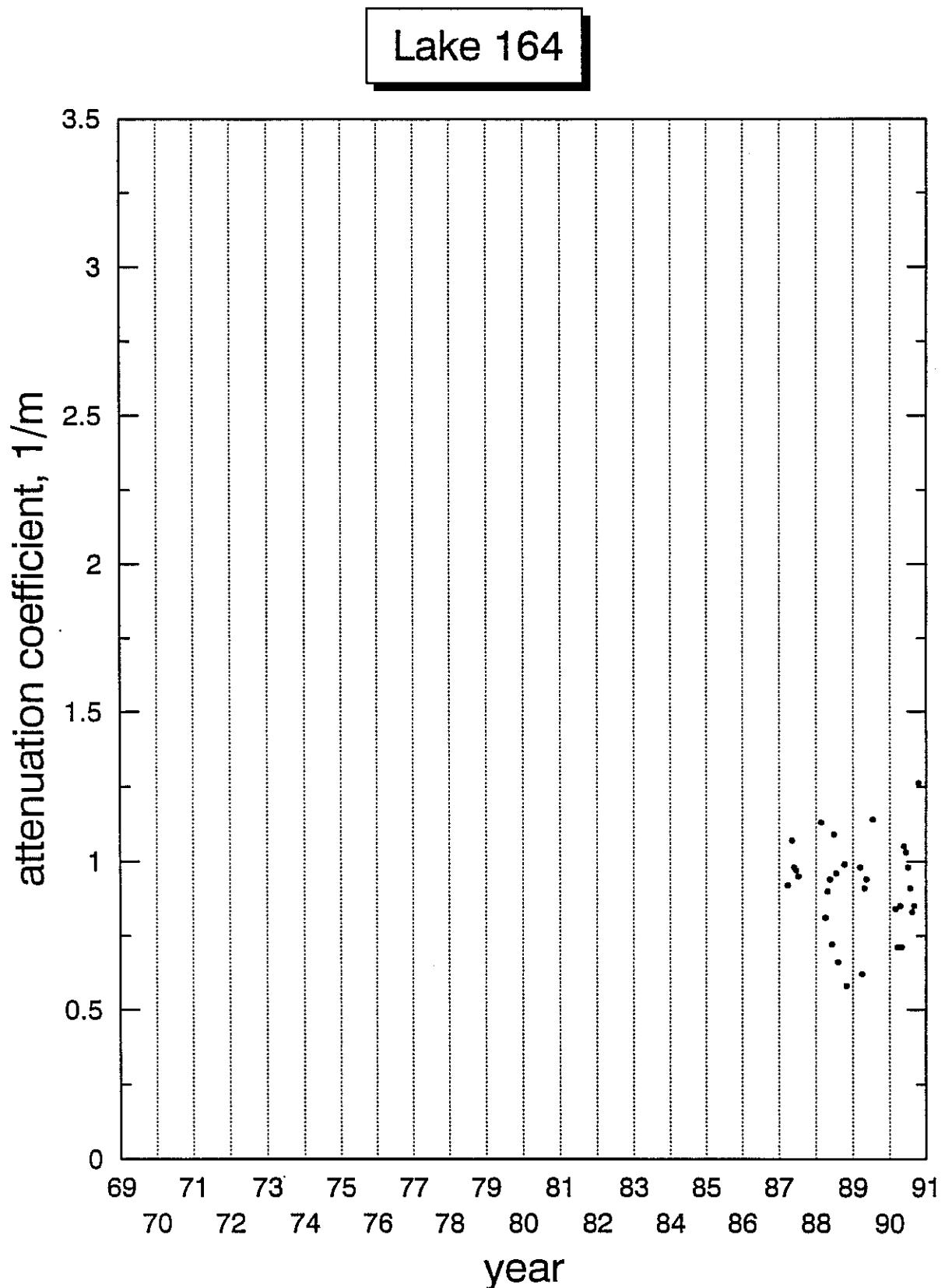


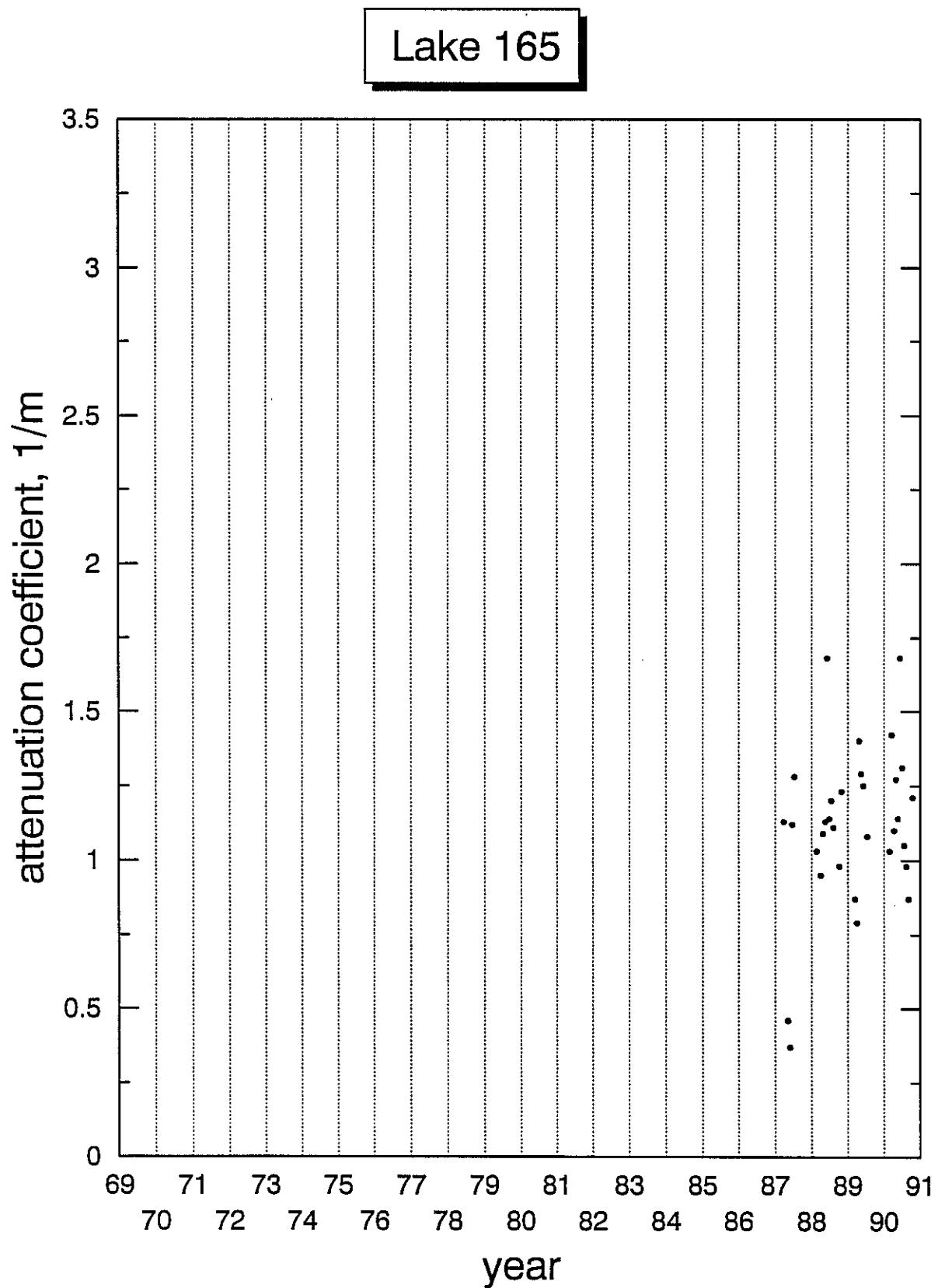


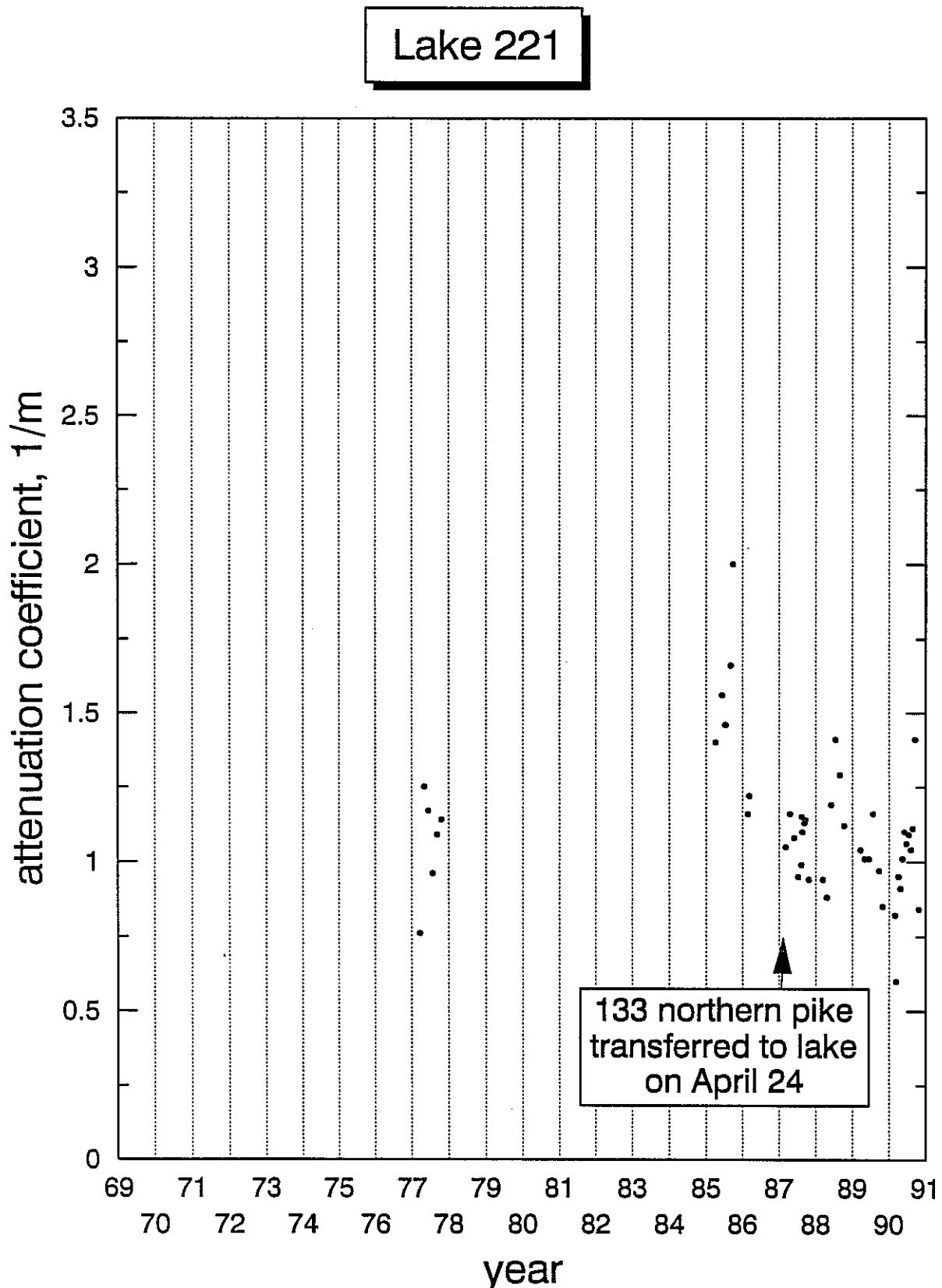


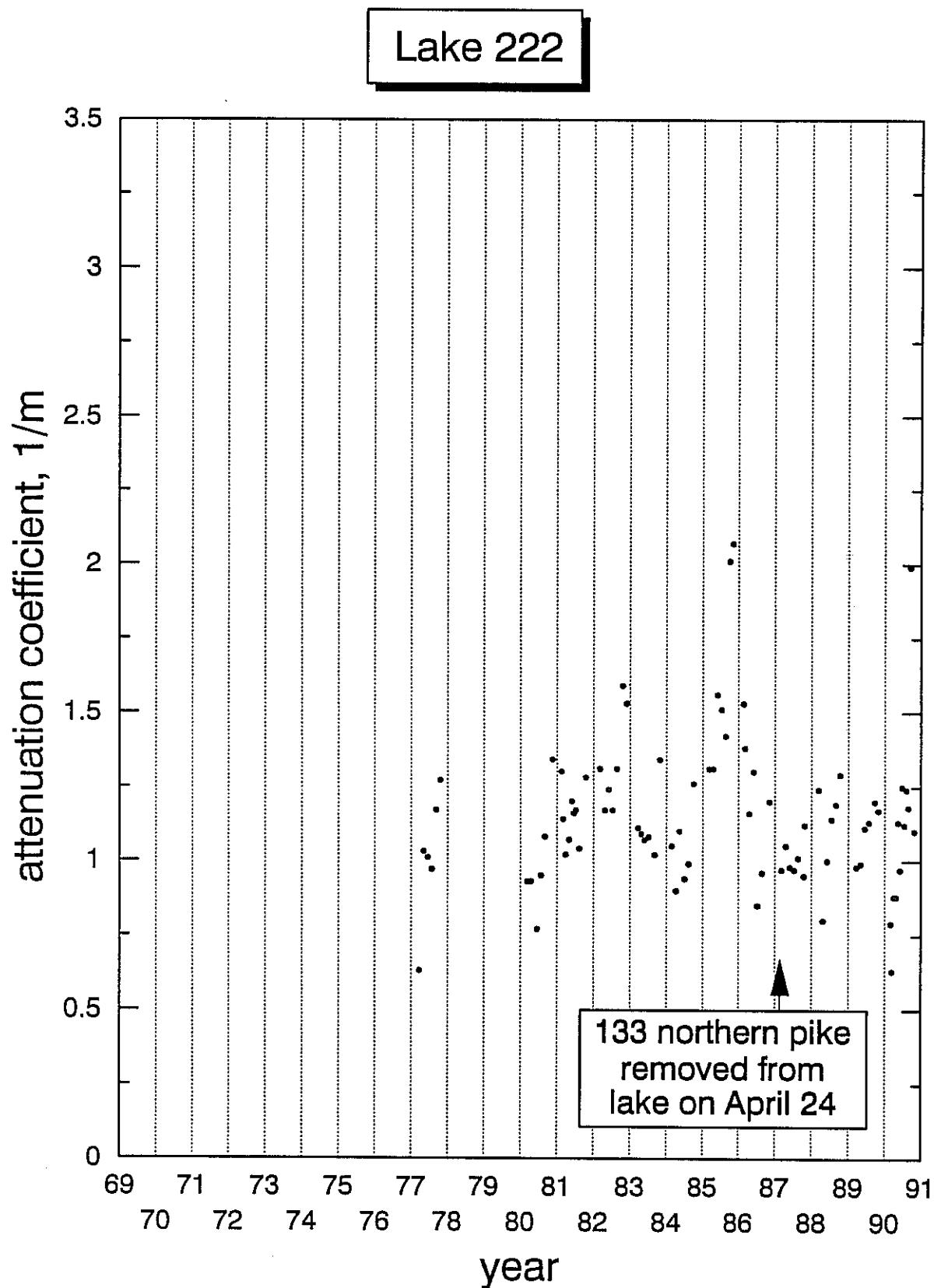


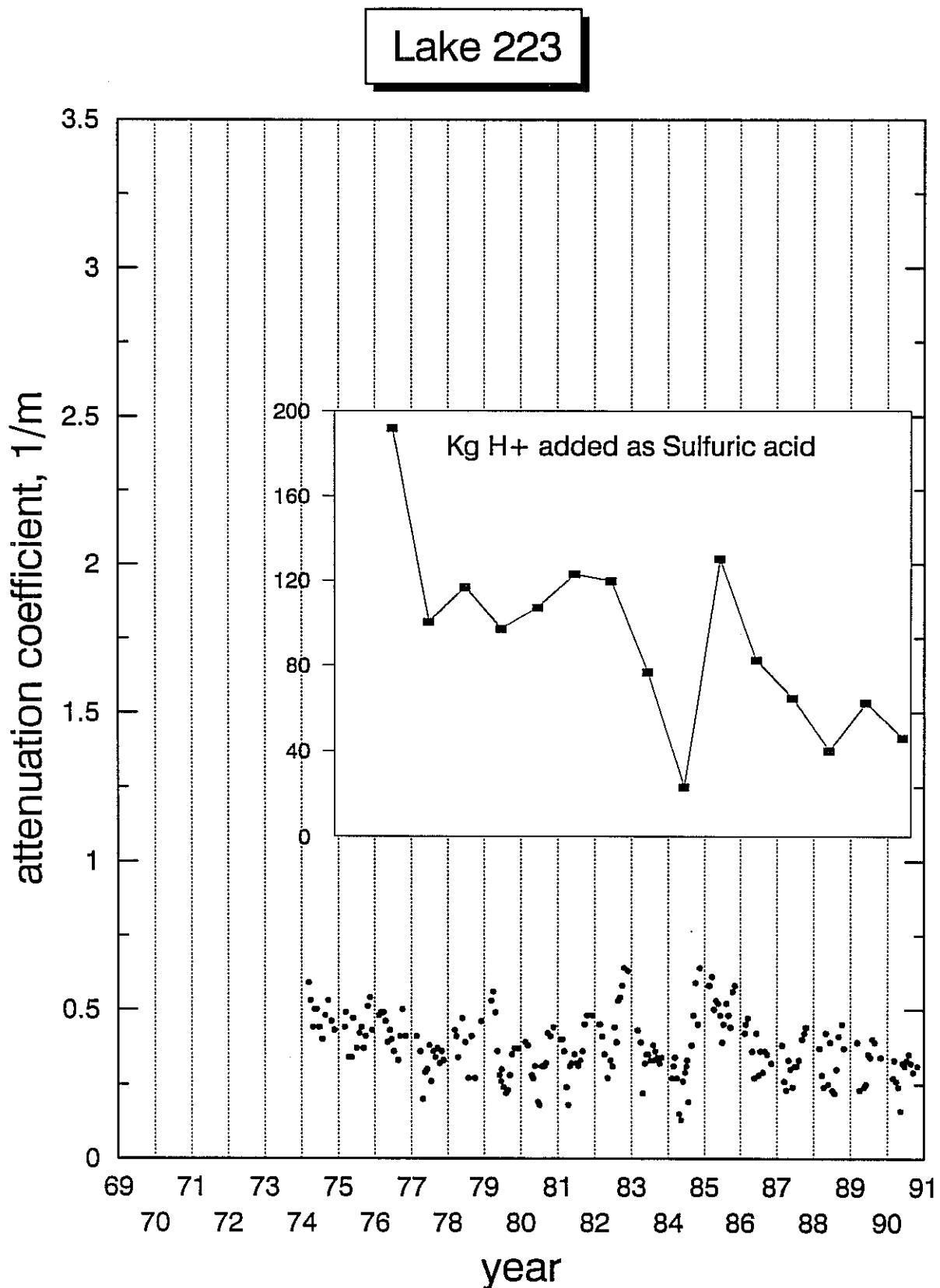


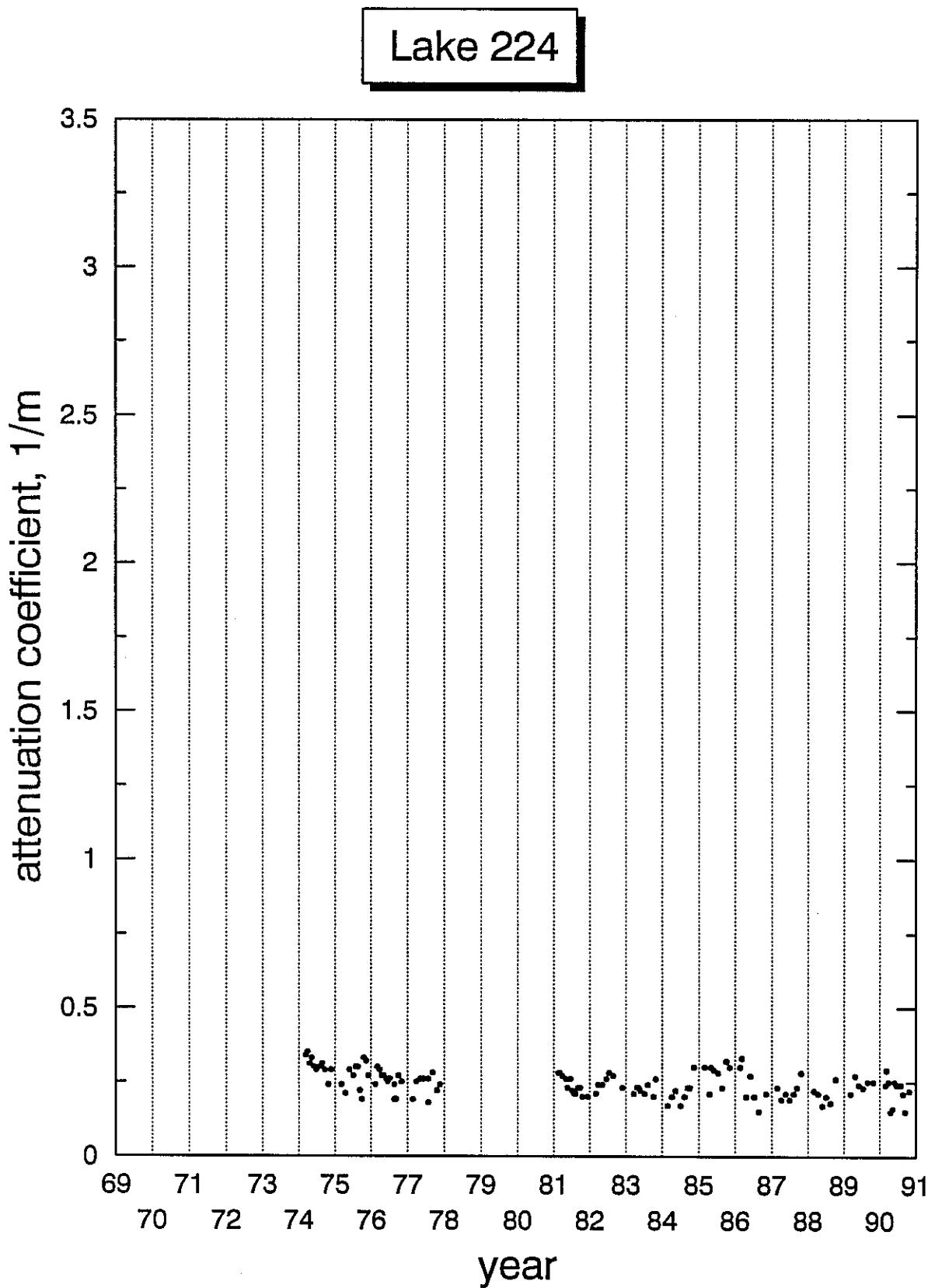


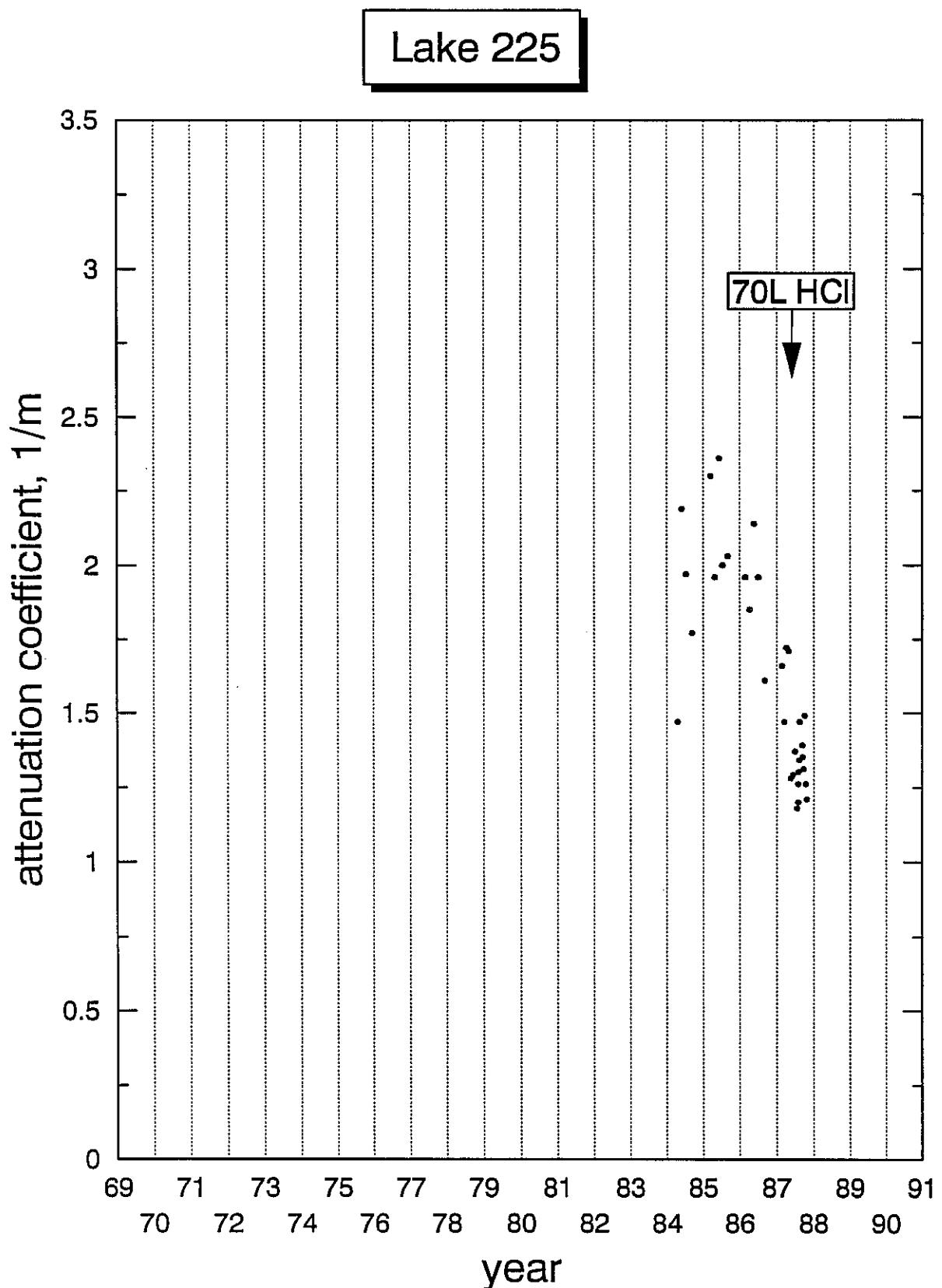


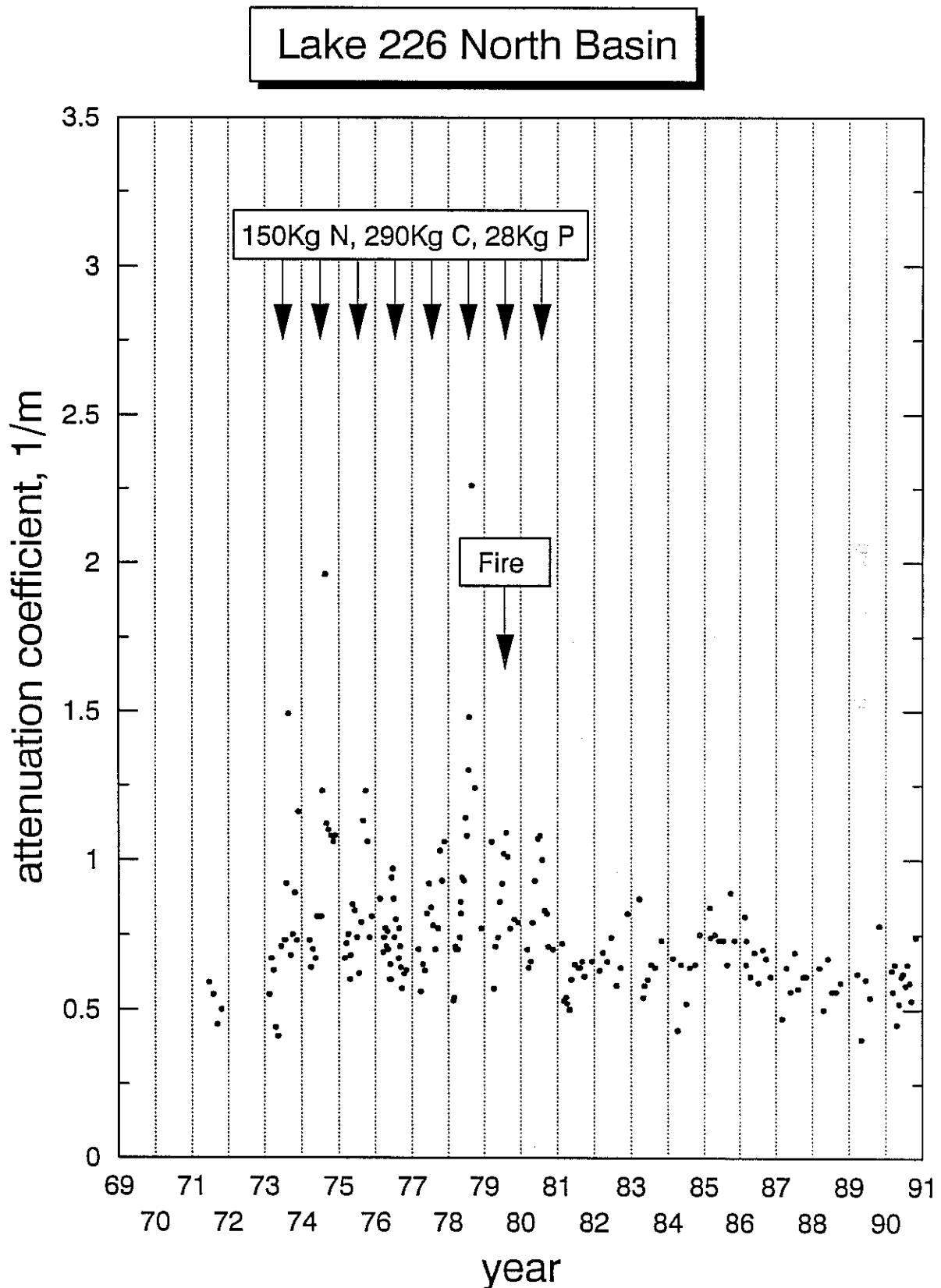


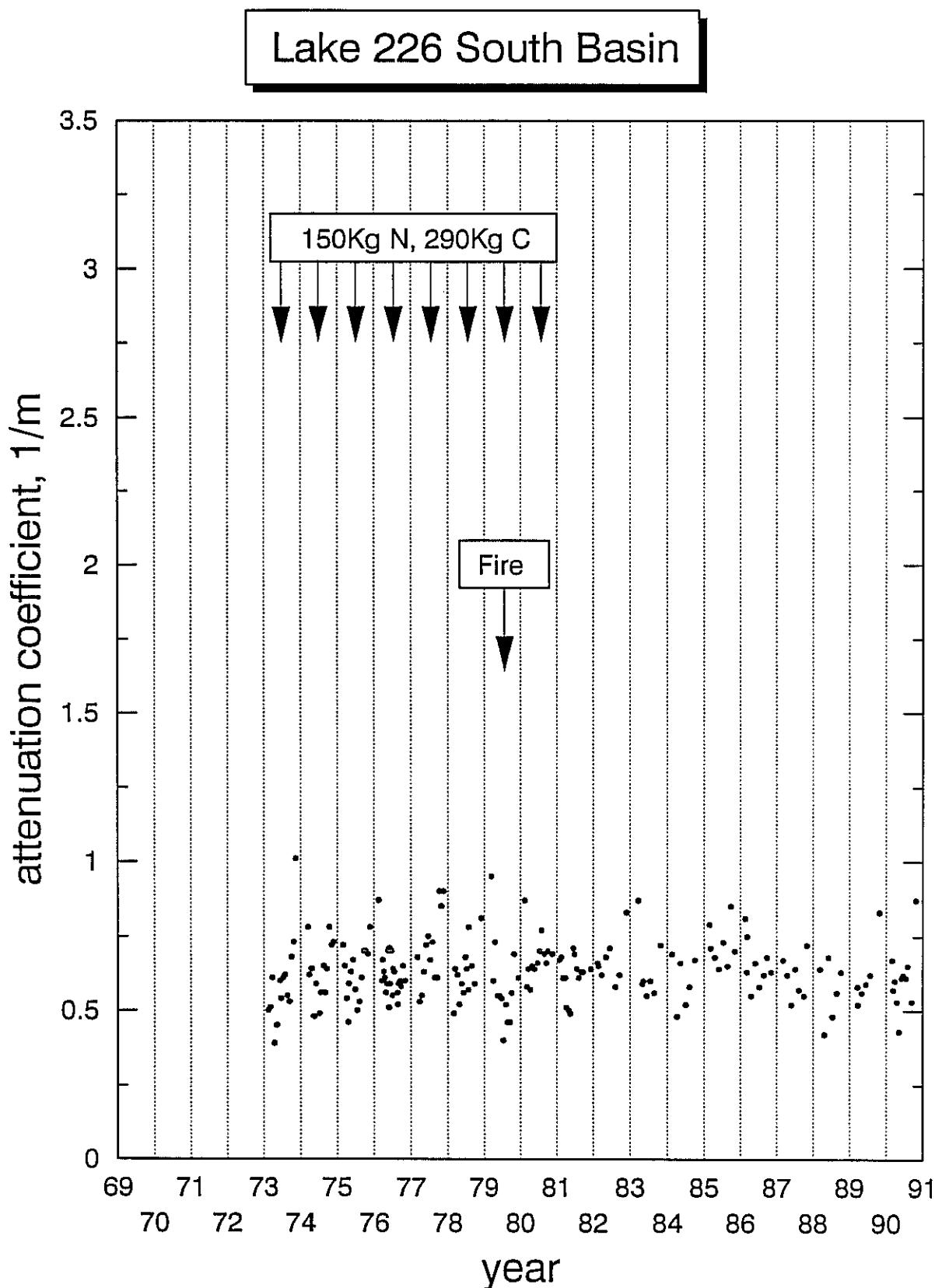


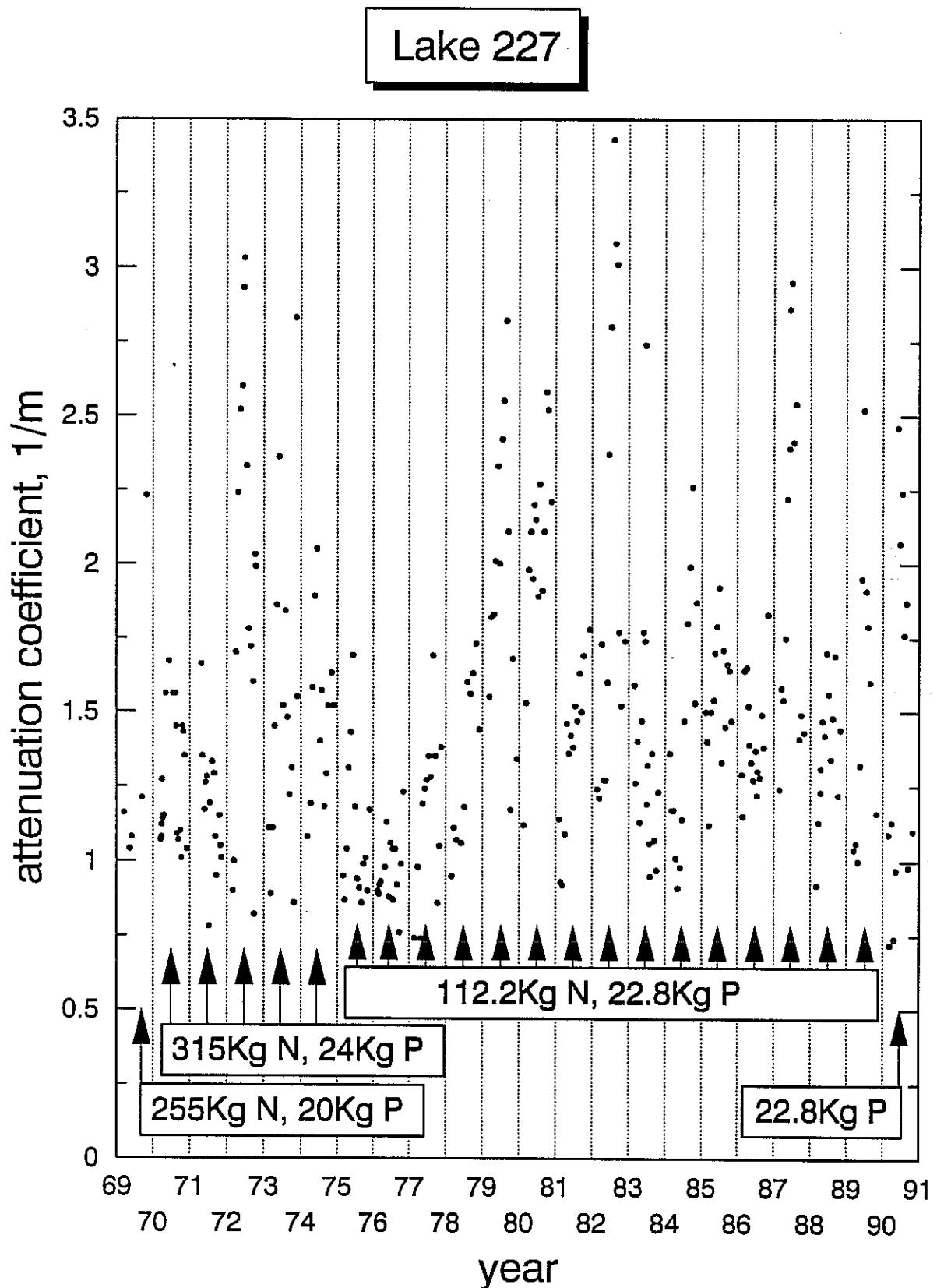


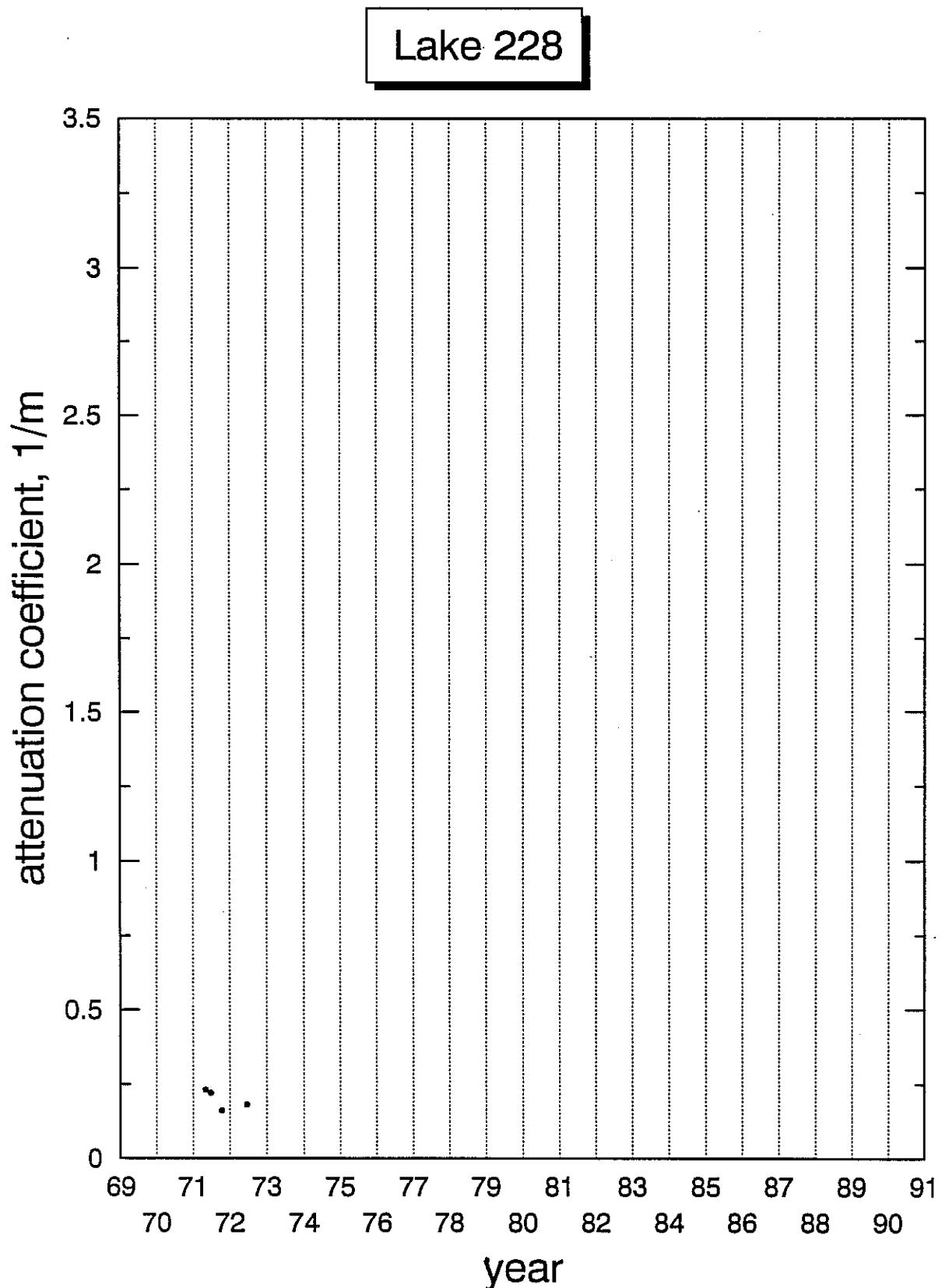


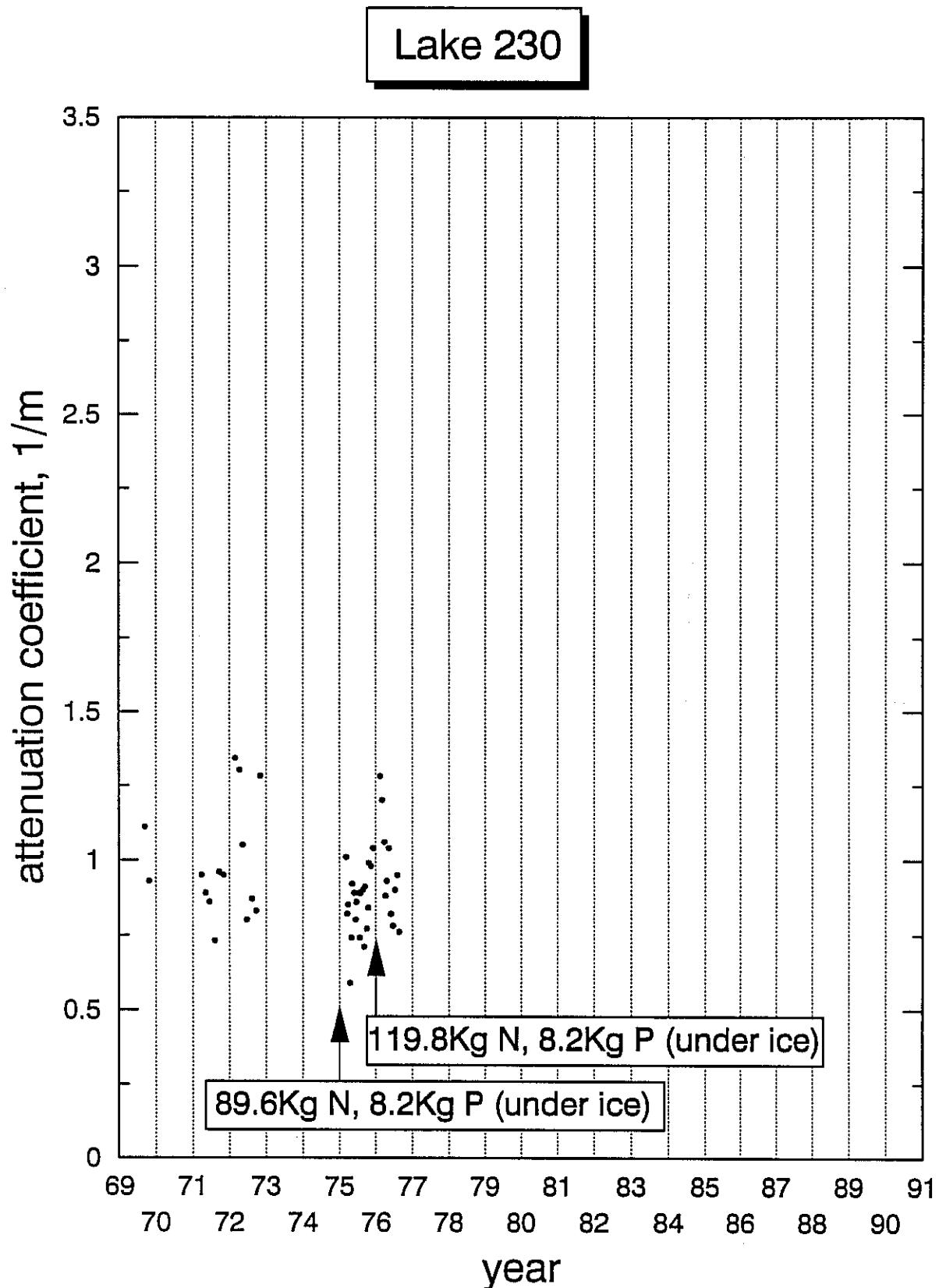


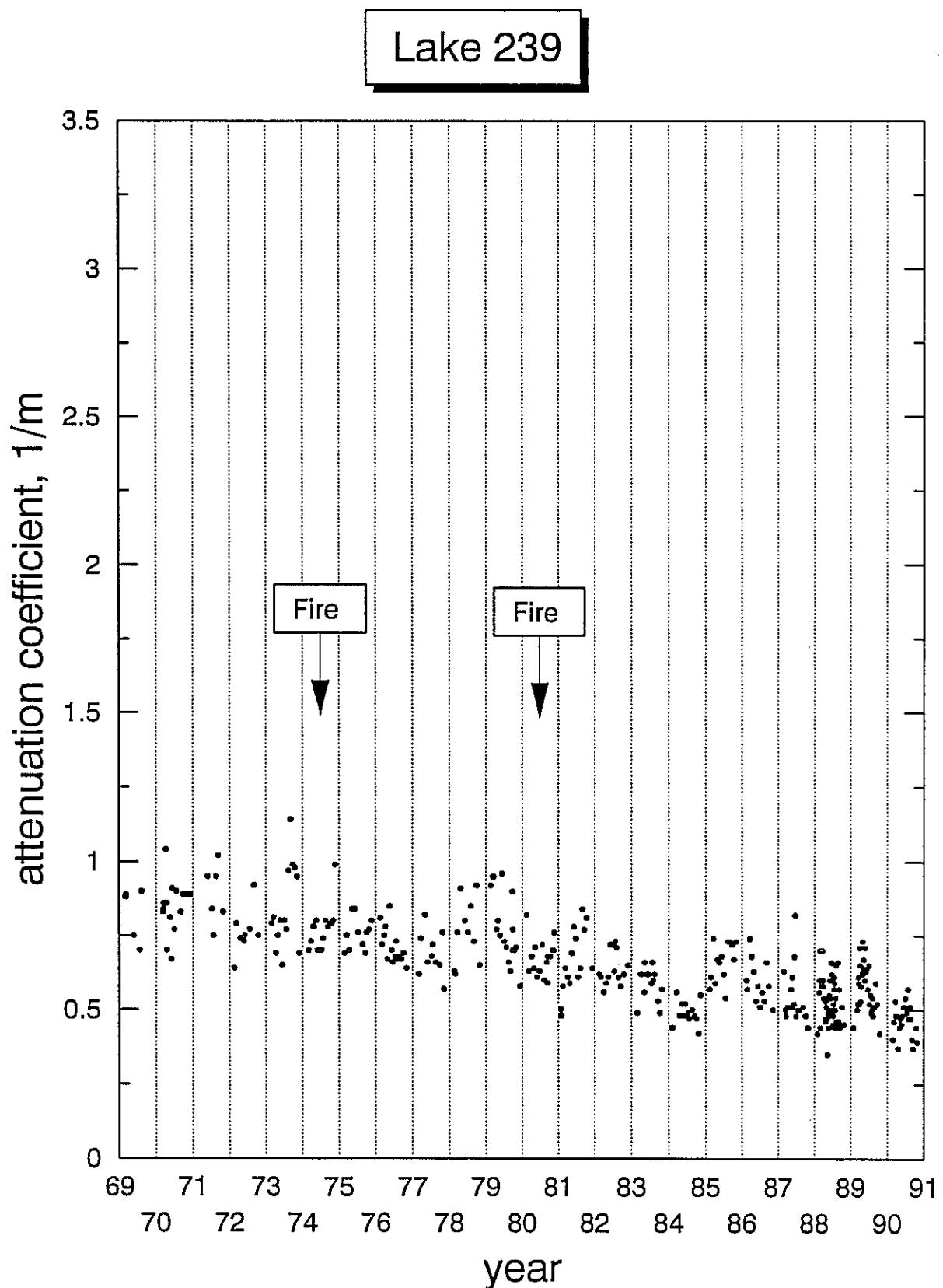


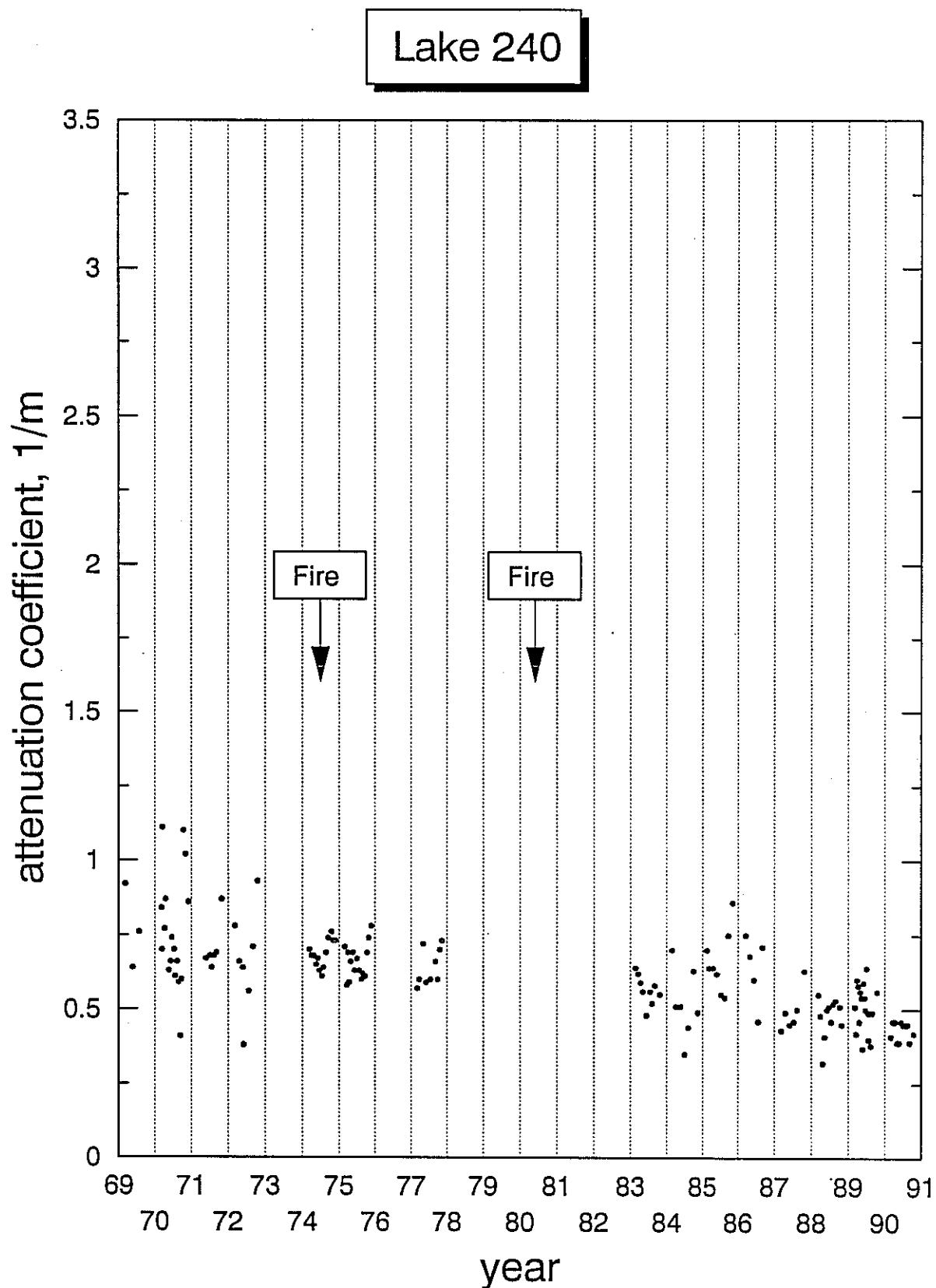


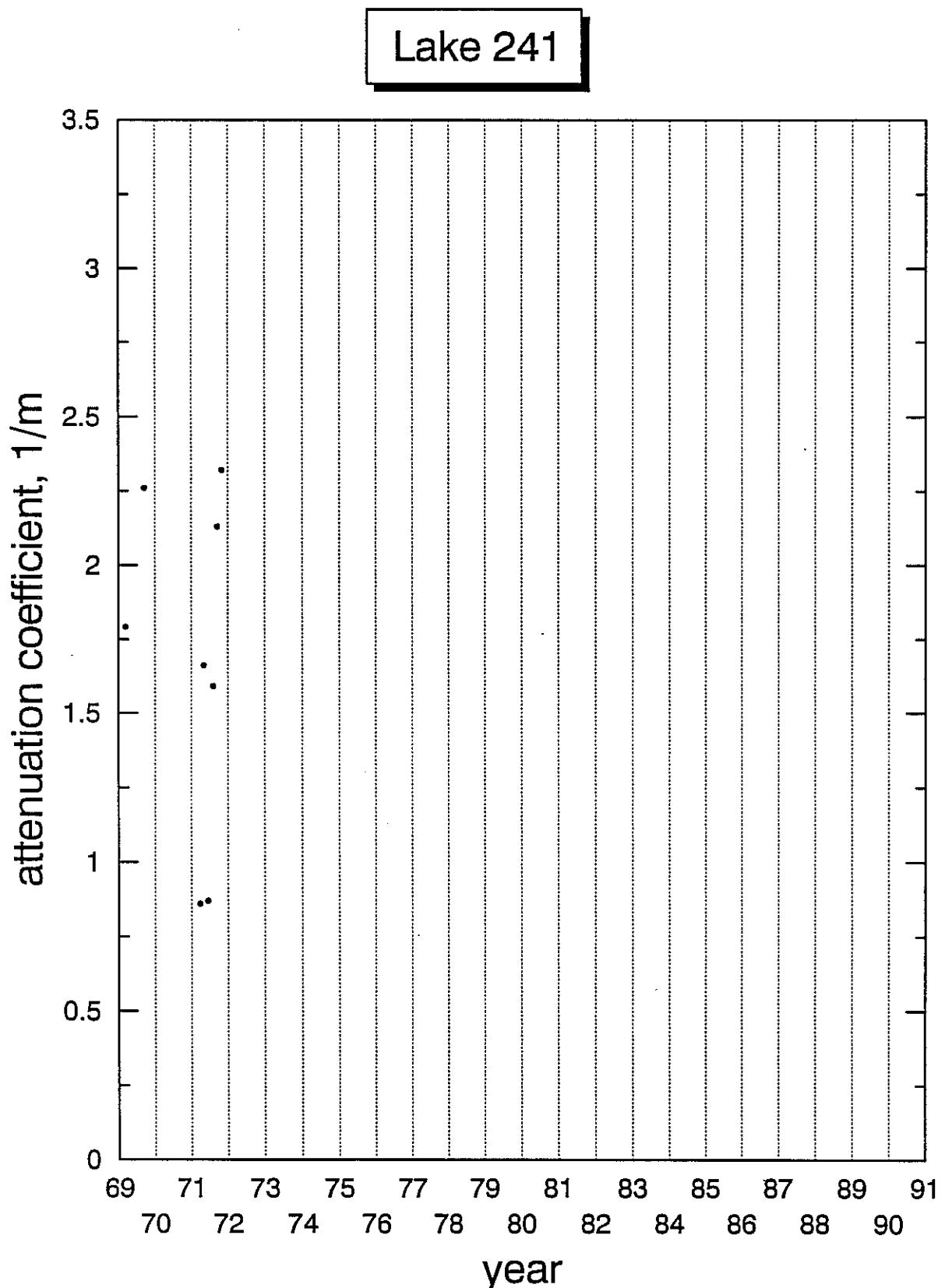


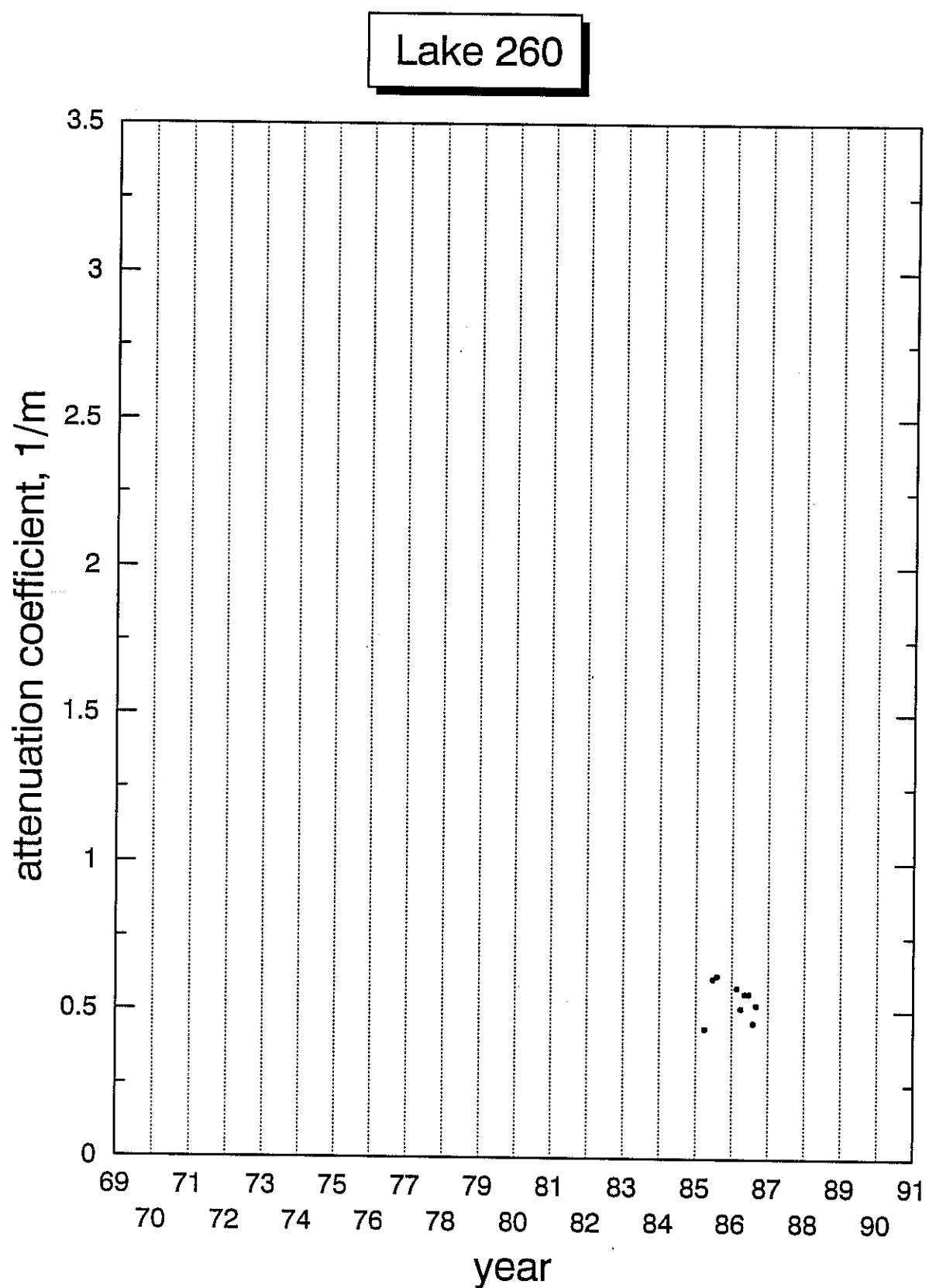


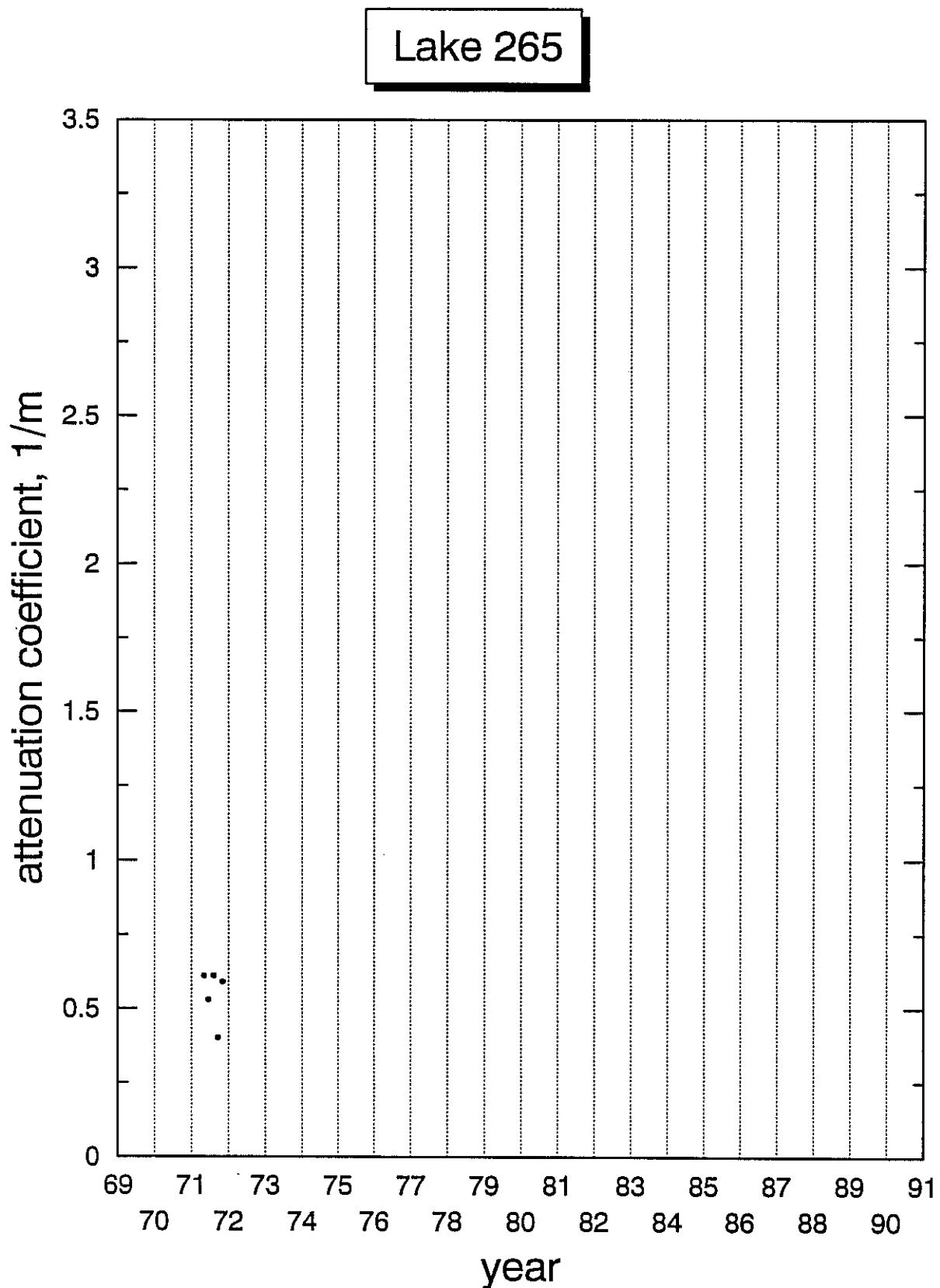


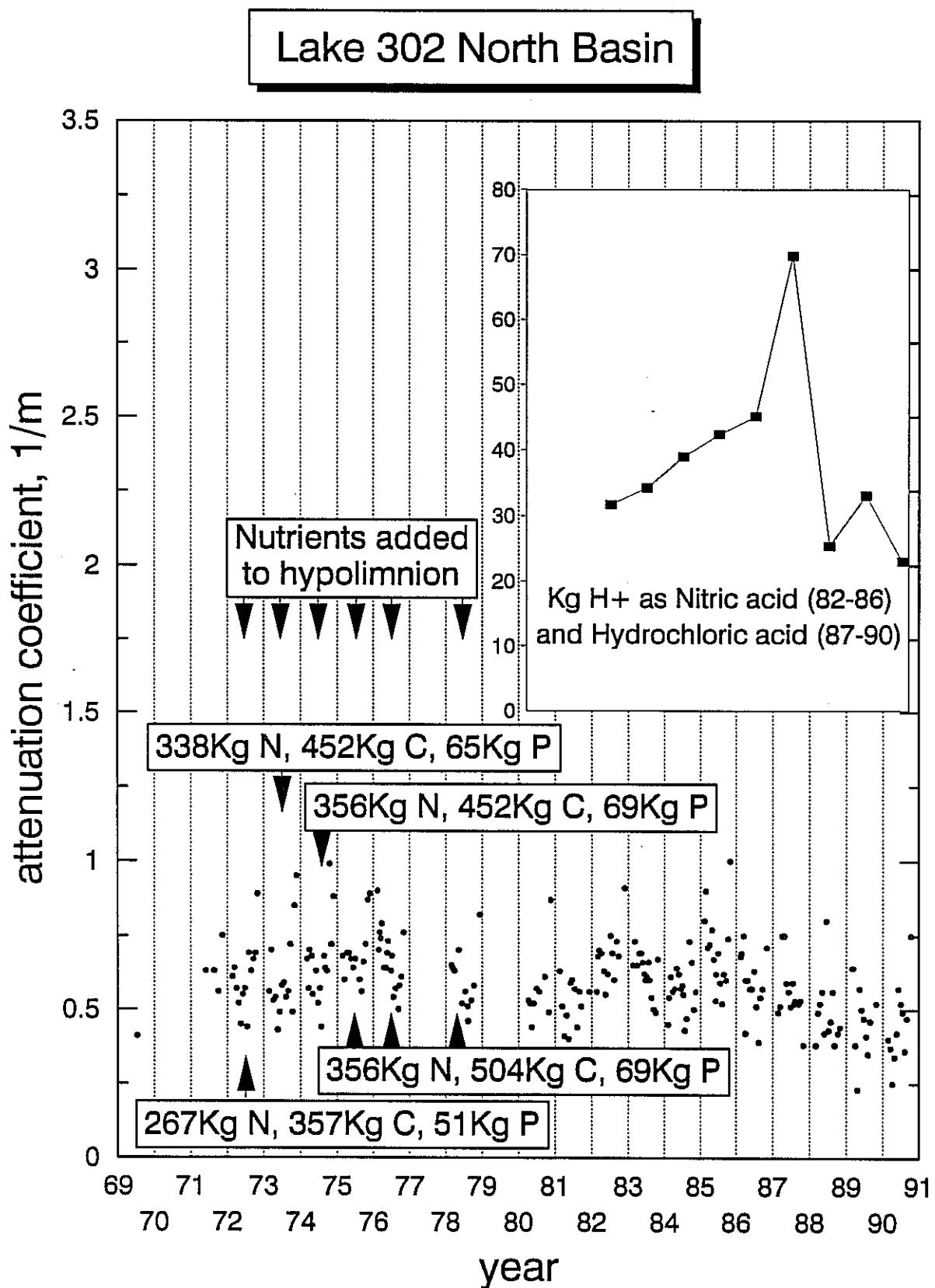


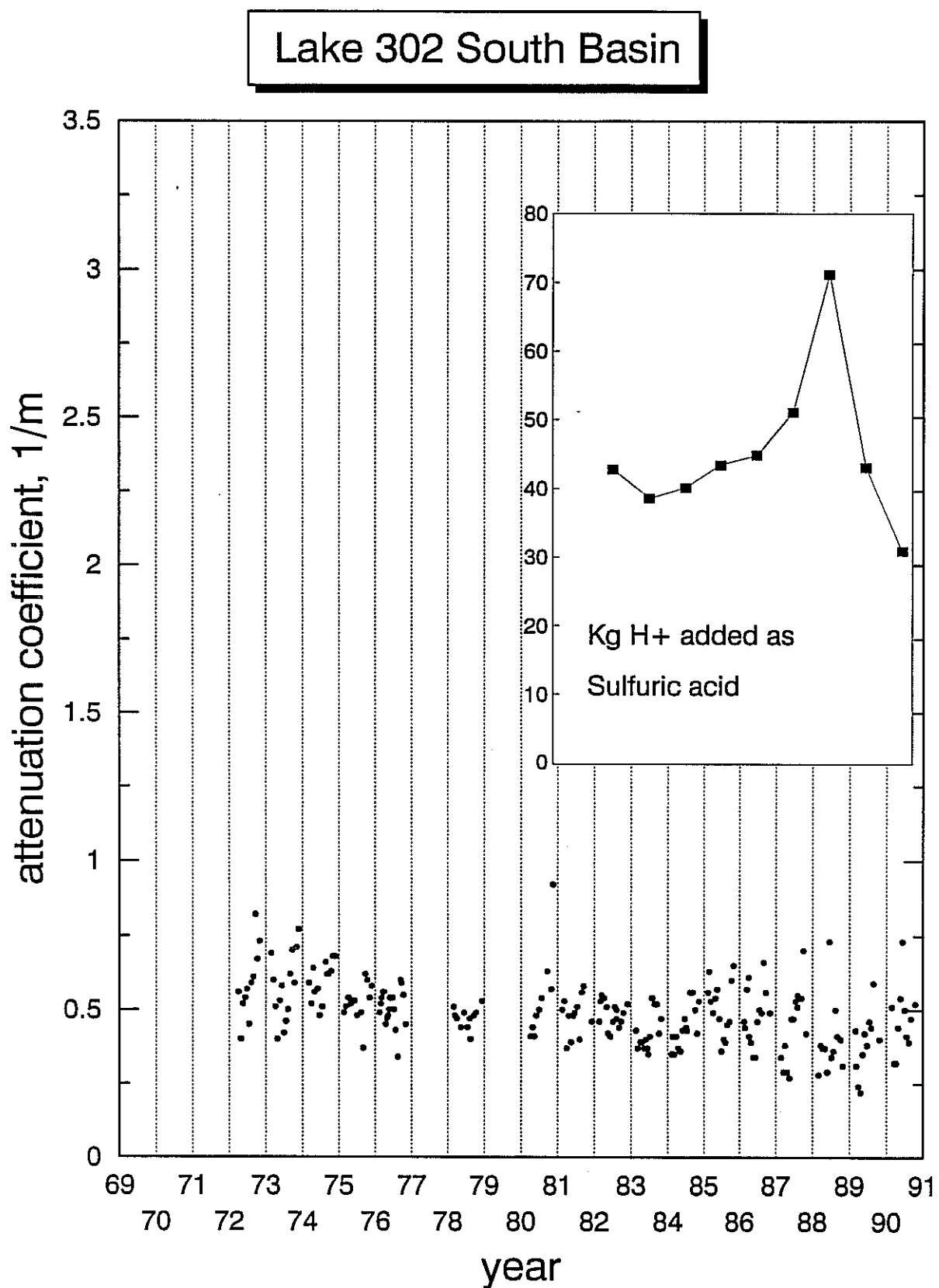


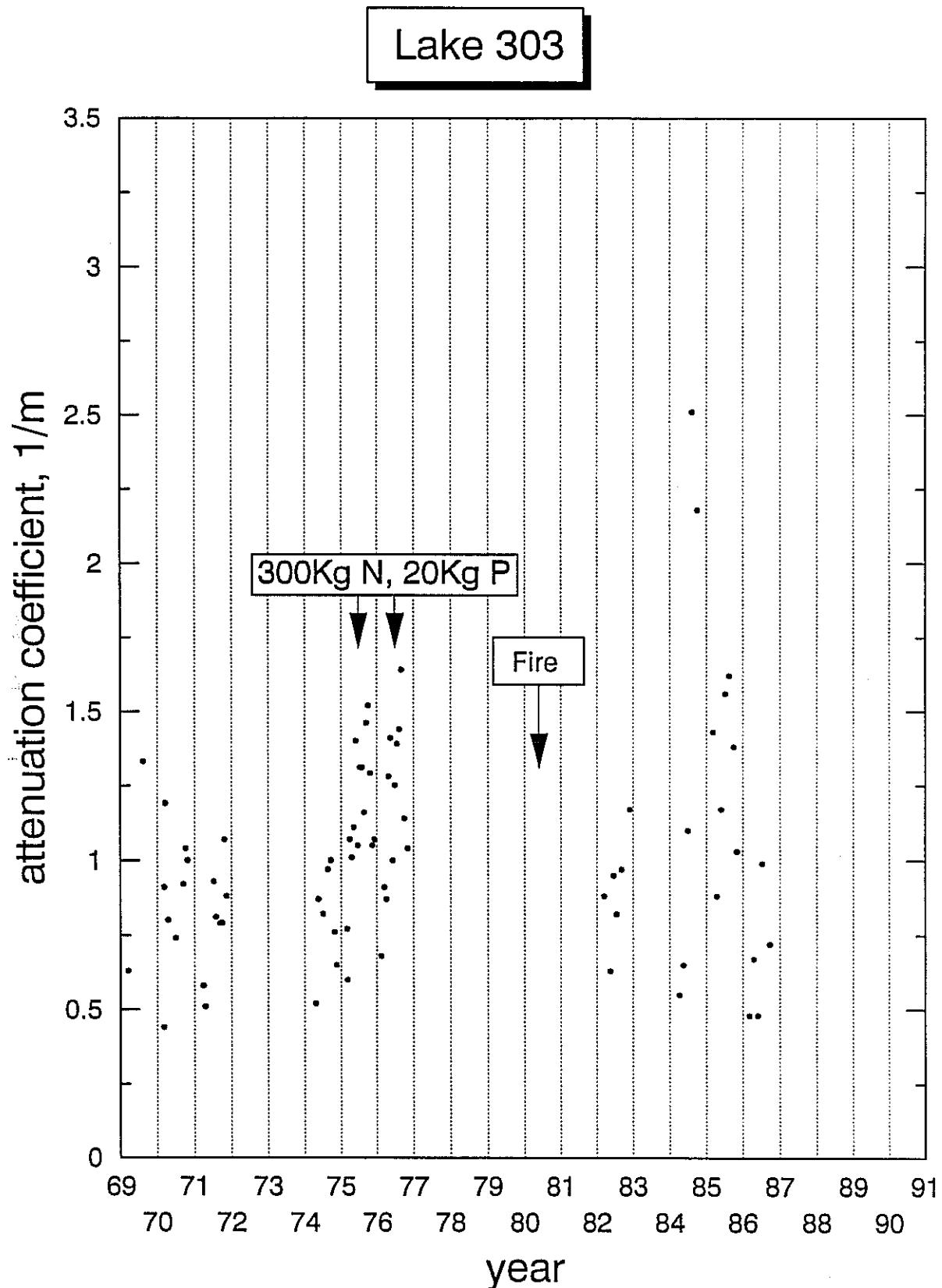


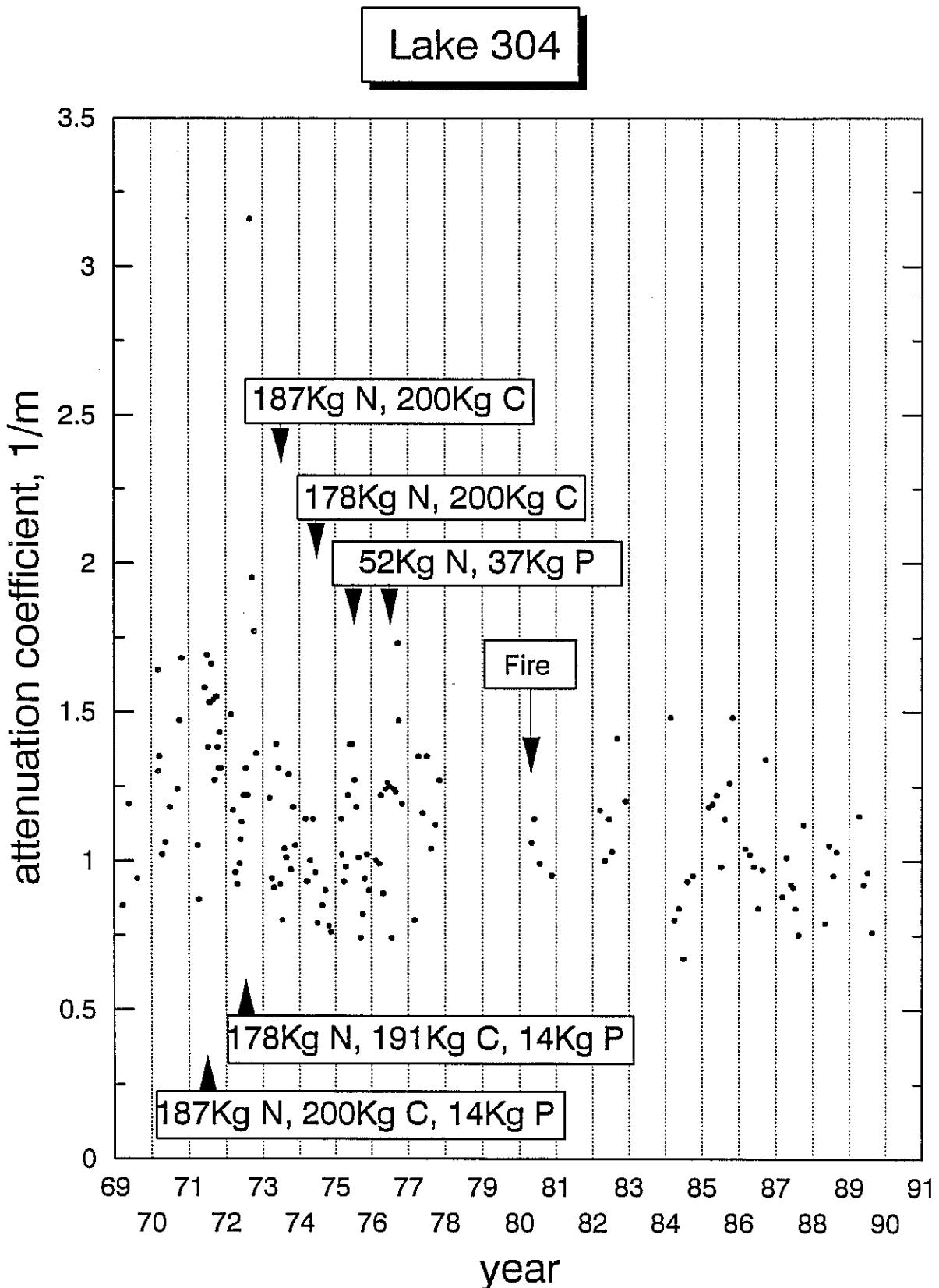


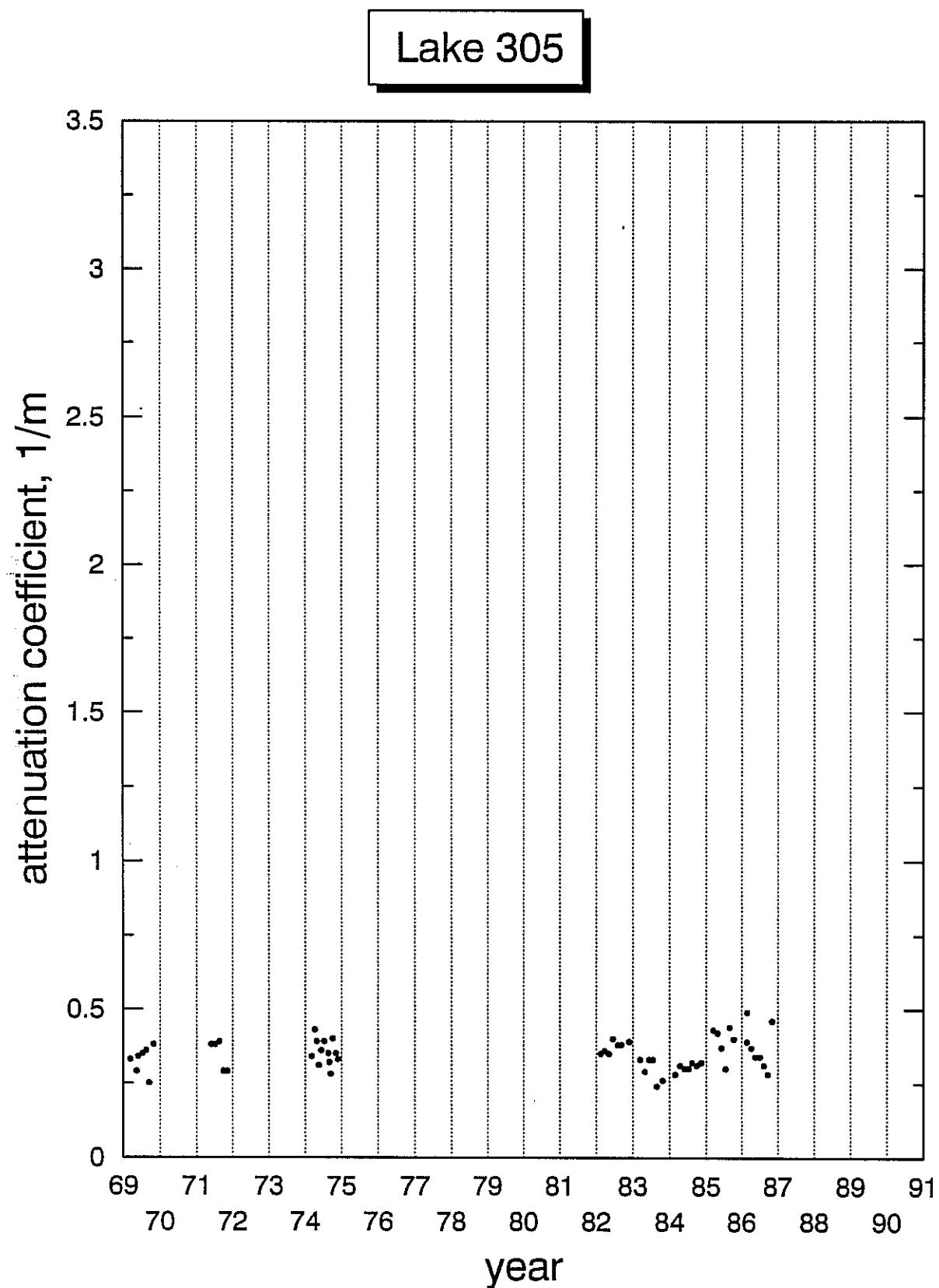


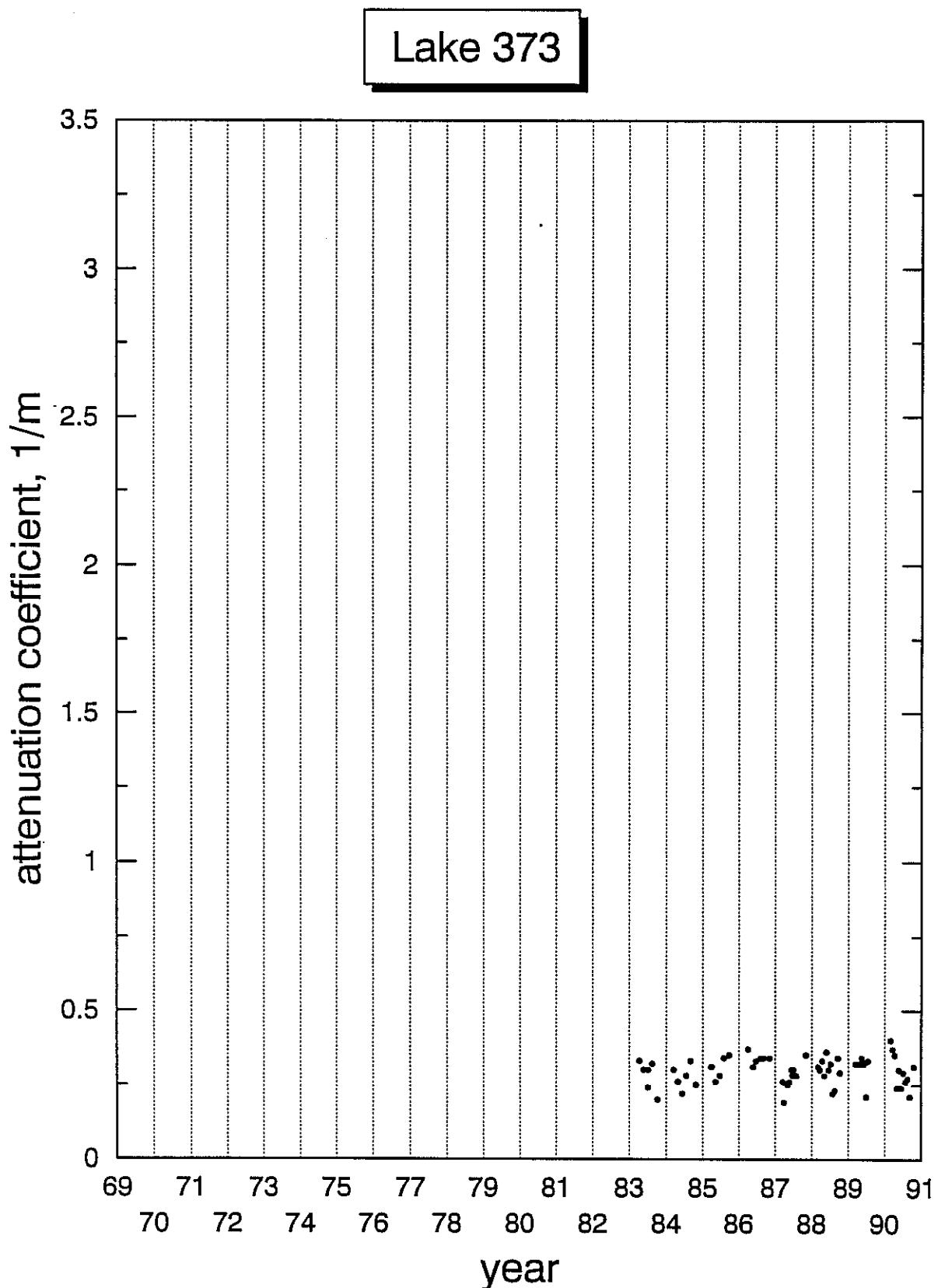


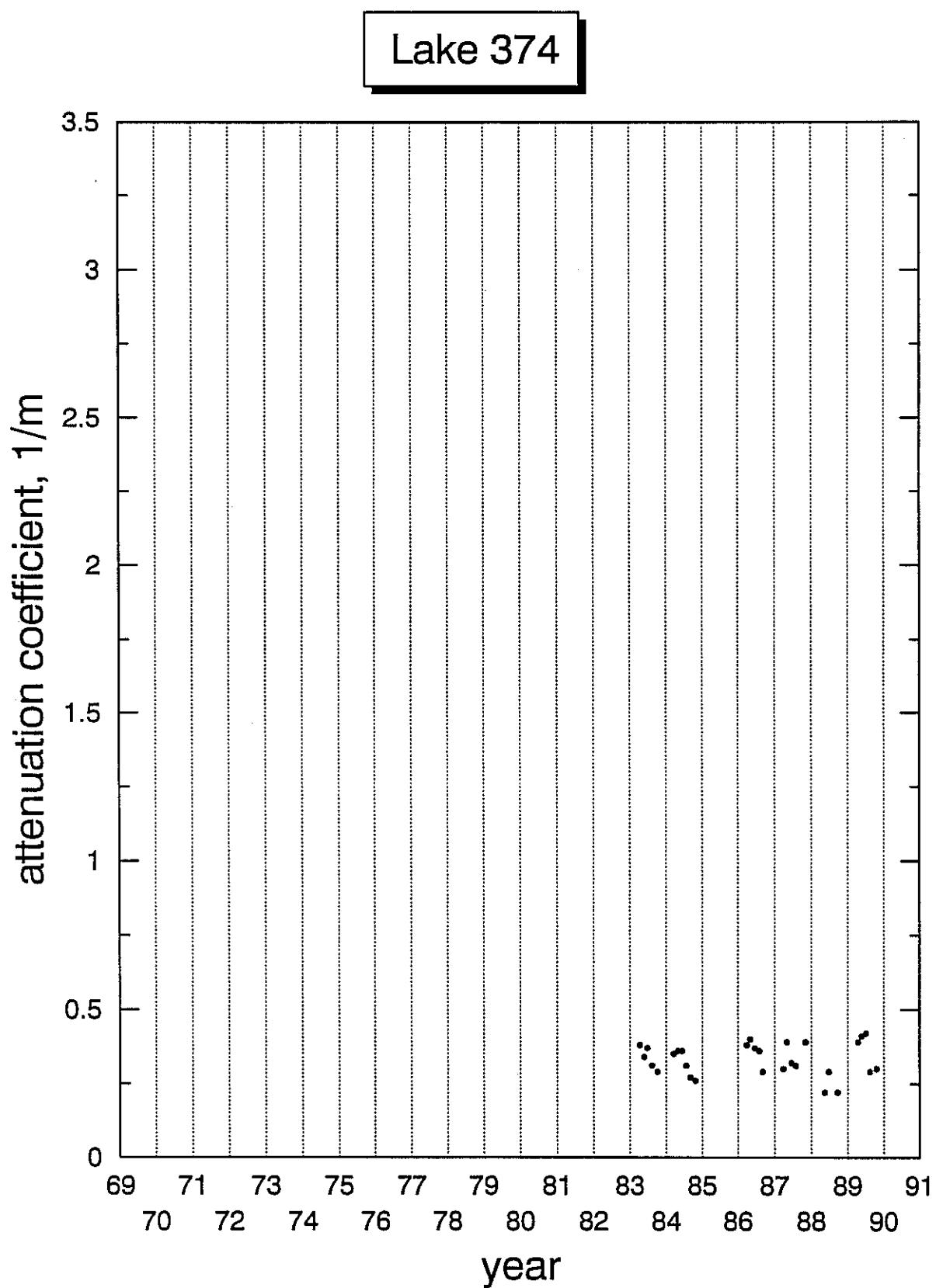


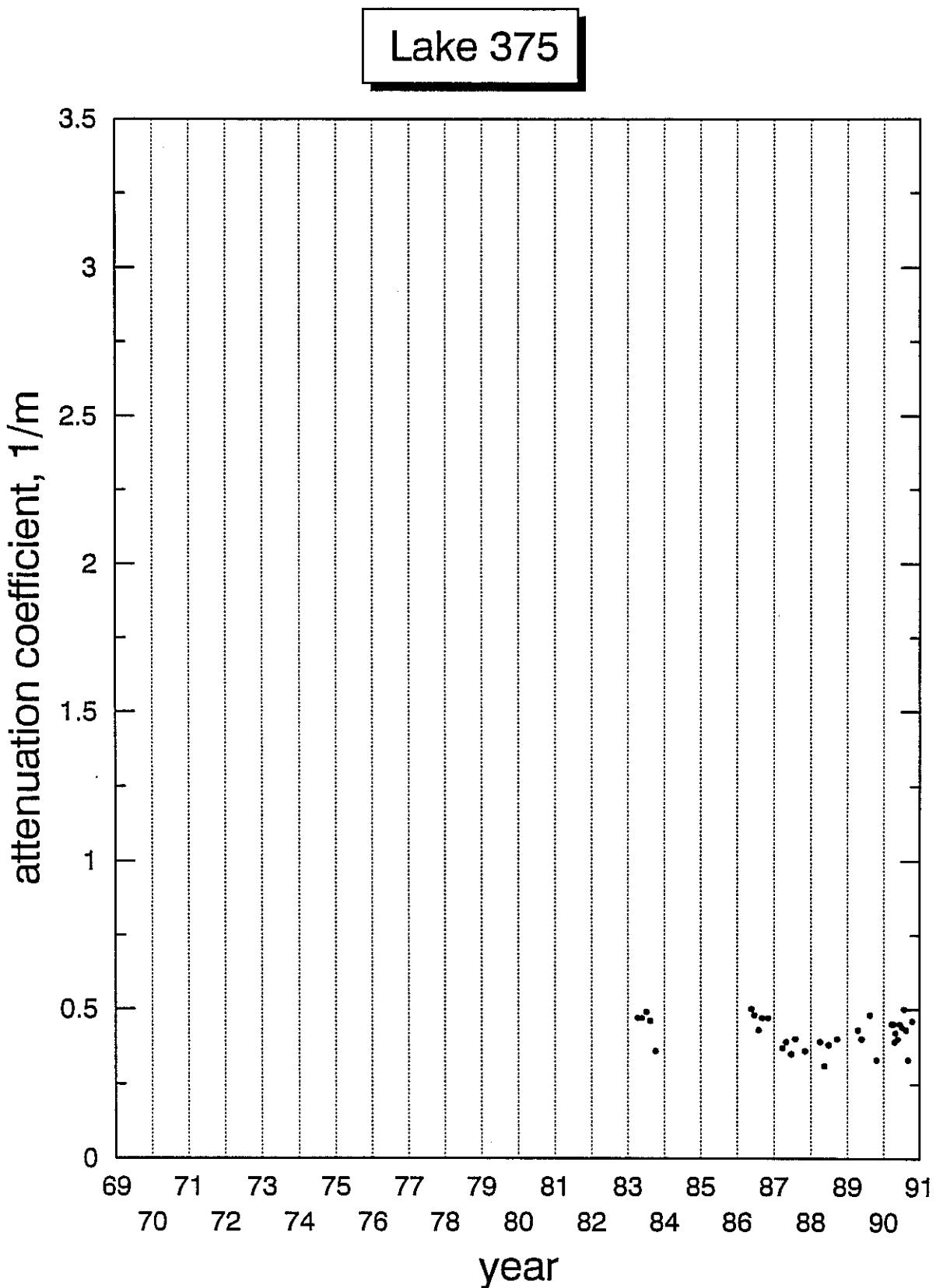


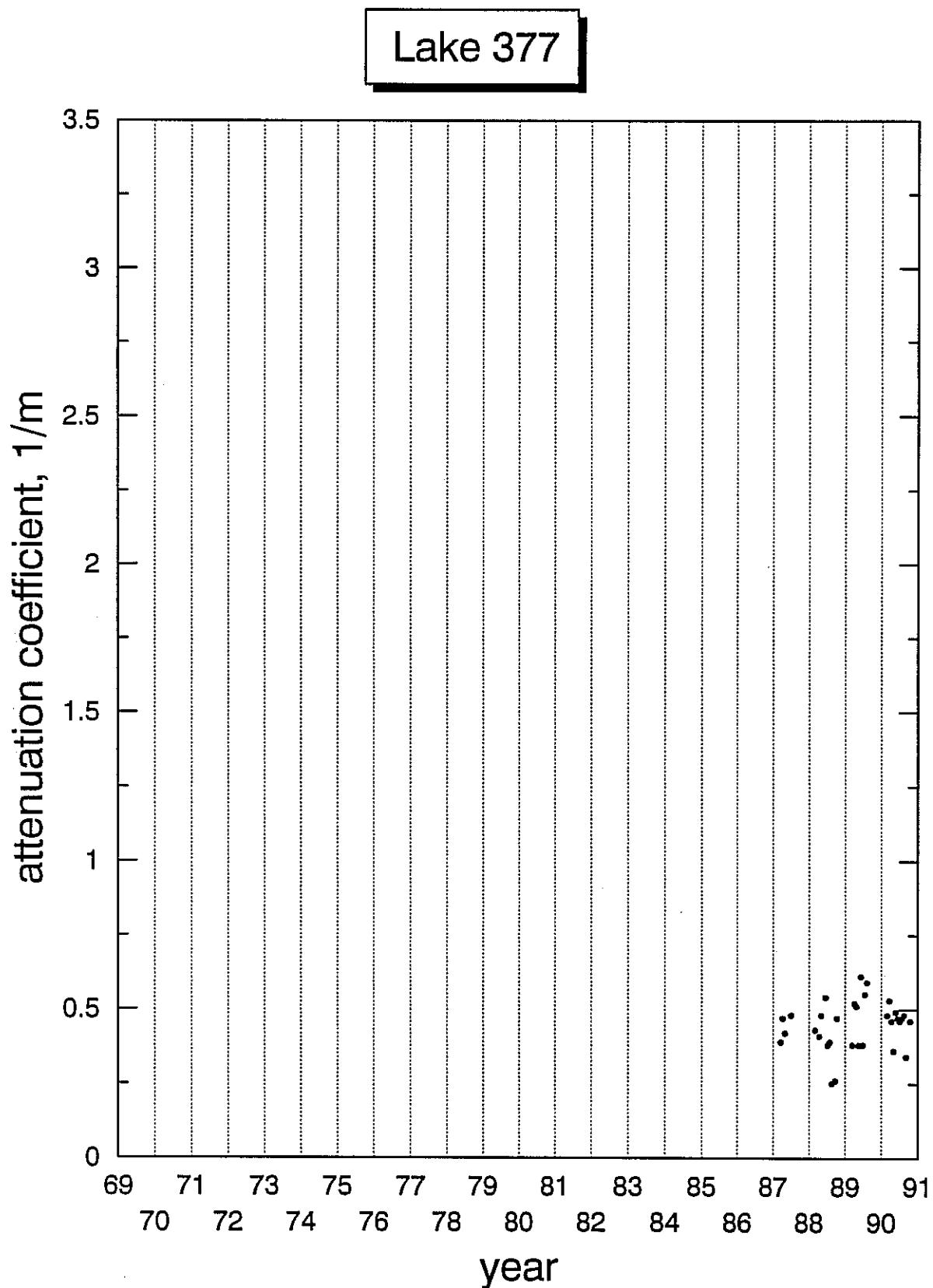


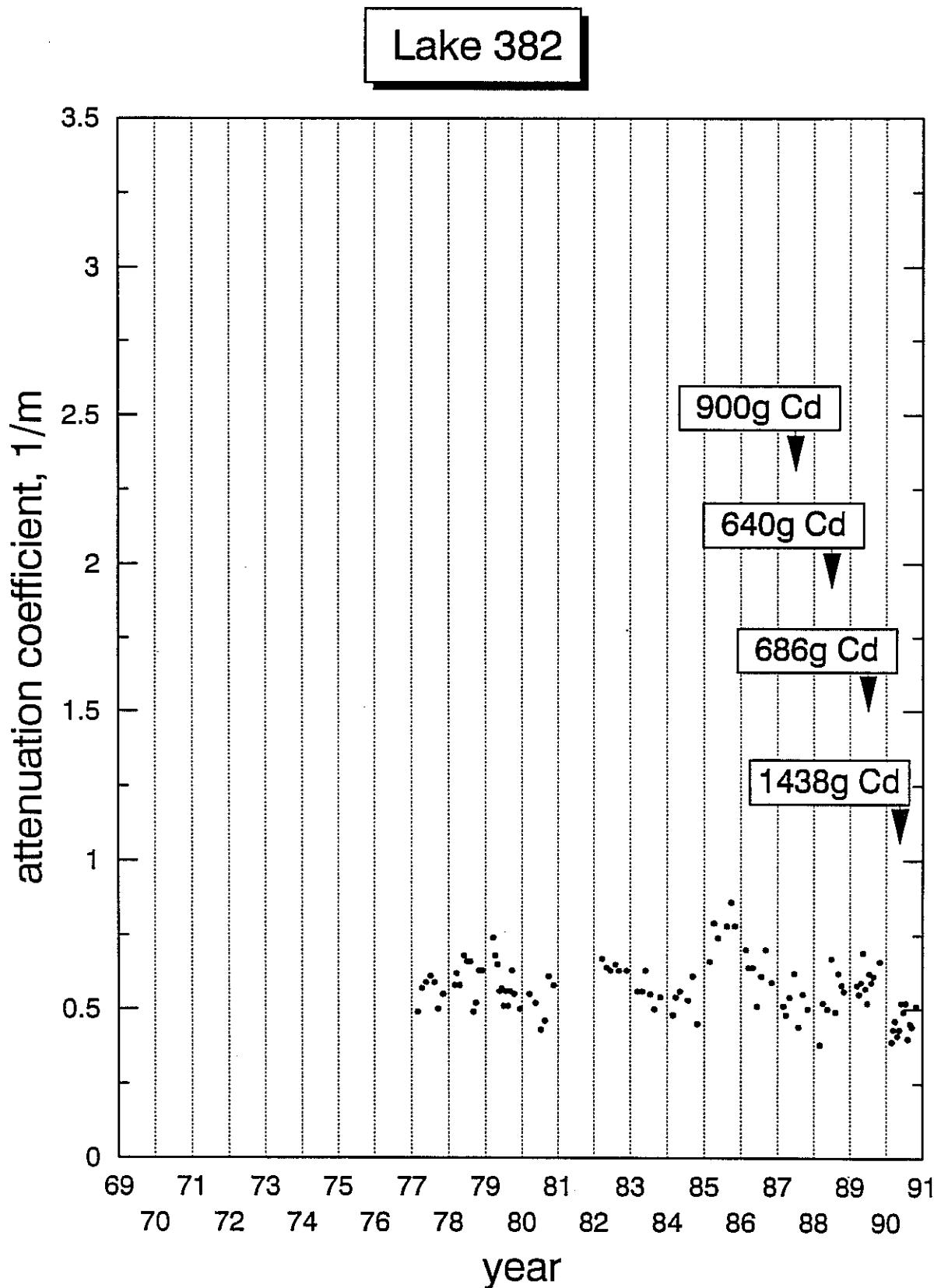












Lake 382 Bay

