Working Papers

No.6

ACID LAKES IN THE GALLOWAY UPLANDS, SOUTH WEST SCOTLAND : CATCHMENTS, WATER QUALITY AND SEDIMENT CHARACTERISTICS.

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DECEMBER 1983

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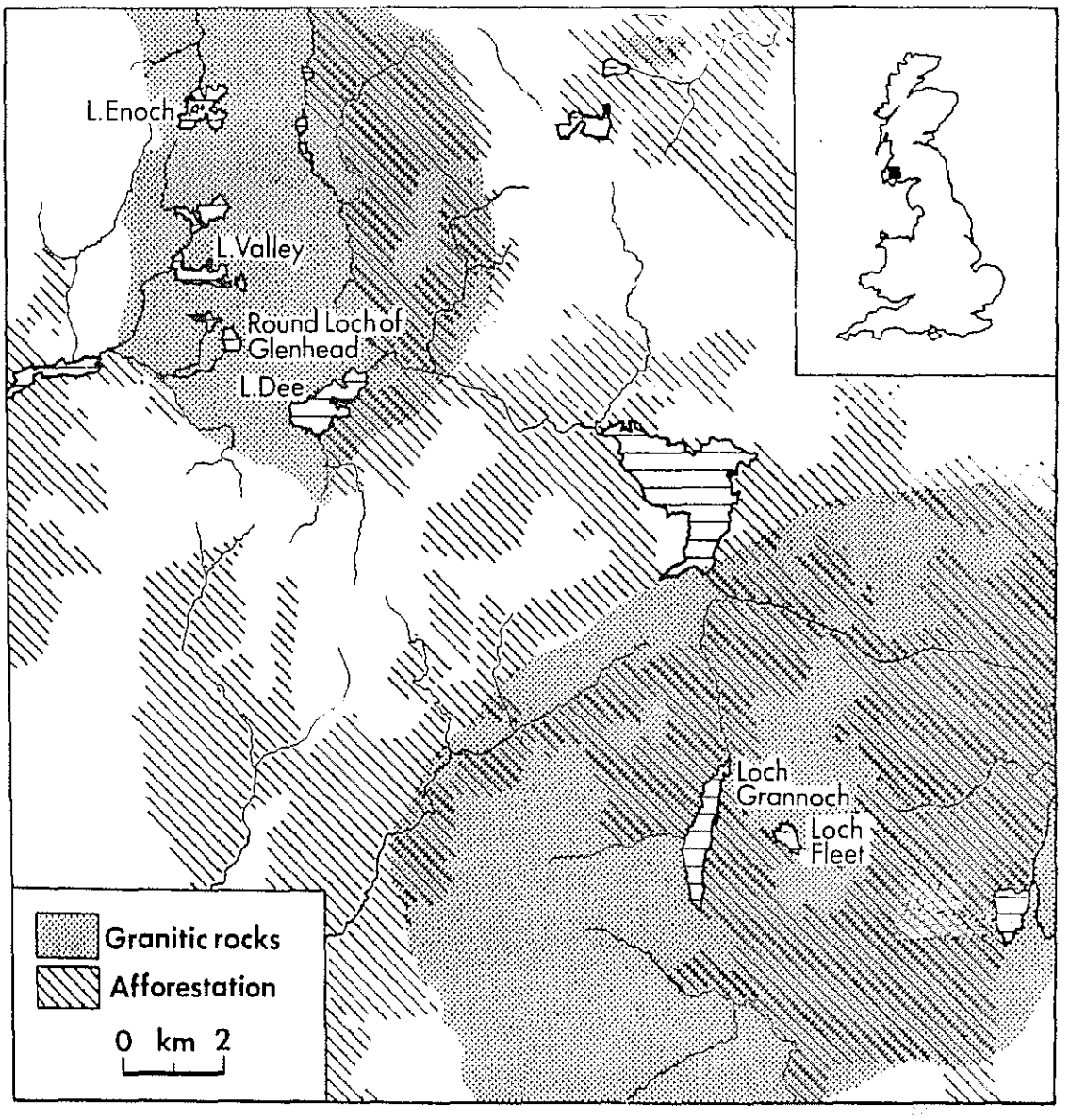
CONTENTS



The study area showing sample sites.

INTRODUCTION

Reports of diminishing salmonid fisheries and increasing acidity of lakes and streams in S.W. Scotland have attributed the cause to low pH precipitation (Wright & Henriksen 1980) and afforestation effects (Harriman & Morrison 1982).

In 1981 we initiated a project with CEGB funding to examine the history of lakewater acidity in both afforested and unafforested catchments in the Galloway uplands (see frontispiece). Analysis of diatom remains in lake sediments is used to reconstruct lake pH change over the past 150 years at each site. Sediment chronology is provided by lead-210 dating (Appleby & Oldfield 1978). Contemporary limnological data on water quality and diatom communities has been collected over an annual cycle (1981-82) to aid evaluation of the sedimentary data.

This working paper presents the non-diatom data collected since 1980 (June 1983) and is divided into four sections:

(1) Description of the lakes and their catchments

(2) Water quality data

(3) Collection of sediment cores and routine measurements of sediment characteristics

(4) Lead-210 analysis and sediment dating methods.

Methods and results of the diatom analysis of the sediment cores will be presented in a later paper.

SECTION 1 - THE LAKES AND THEIR CATCHMENTS

Six sample lakes were selected for study, all are located in catchments draining granite rocks with varying degrees of blanket peat and drift cover. Three of the sites, Round Loch of Glenhead (RLGH), Loch Enoch (LEN) and Loch Valley (LVAL), have unafforested catchments; the other three, Loch Dee (LDEE), Loch Grannoch (LGR) and Loch Fleet (LFL) have been partly afforested with coniferous trees (Fig. 1.2 - 1.7). Areas of lakes, unafforested and afforested catchments were calculated by digitising topographic information and estimated using the computer program POLYAREA (see Table 1.1).

In addition to the data in Table 1.1 the Loch Grannoch catchment was afforested in three phases, 7.9 hectares in c. 1900, 510.8 ha in 1962/4 and 376.4 ha in 1977/78. The unafforested portion of the Loch Dee catchment contains an area of 213.9 ha which was added in 1930-35 by stream diversion associated with the Loch Ken Hydro-Electrical Power Scheme. The Loch Valley catchment contains three other lochs not sampled in this study, they are Loch Neldricken 32.9 ha, Loch Narroch 3.5 ha and Loch Arron 2.6 ha. Computer drawn maps of the catchments are given in Figs. 1.1 to 1.6.

We have relatively little information on the land-use history. The catchments have been probably largely devoid of forest since at least Bronze Age times (Birks 1972). At present buildings, now uninhabited, are only found in the Grannoch and Dee catchments. Apart from afforestation, evidence of human land-use activity within the other catchment is confined to sheep grazing, which has probably been carried out since the 12th century. Smith (1813) notes that moor burning and sheep grazing have been long-established practices in the Galloway hills.

Rosenquist (1979) argues that a decline in transhumance and upland grazing pressure has led to runoff acidification in Norway by causing raw

TABLE 1.1 LAKE AND CATCHMENT DATA FOR THE SIX SAMPLE SITES

	Lake Area	Altitude	Maximum Depth	Afforested Area	Unafforested Area	Date of First Planting
	(ha)	(m)	(m)	(ha)	(ha)	
Round Loch of Glenhead	12.6	299	13.5	-	95.1	-
Loch Enoch	50.1	493	36.0	-	185.7	-
Loch Valley	34.7	320	16.5	-	640.1	-
Loch Dee	100.0	225	c. 14.0	291.7	1190.9	1973
Loch Grannoch	114.3	210	21.1	895.1	391.9	1962
Loch Fleet	17.3	344	19.5	19.2	87.8	1963

humus to accumulate in soils. Sheep (and goat) stock numbers over the last century and a half have also declined in the Galloway region - particularly in the parish of Minningaff where the study lakes are situated (Table 1.2).

These figures clearly show the effect of (i) Forestry Commission acquisition of land for afforestation and (ii) the consequent decline in sheep stocks. The sheep stock decline does not, of course, mean that grazing intensity has diminished on the remaining unafforested areas. Indeed, sheep over-grazing appears to be a major problem on south facing slopes near the Round Loch of Glenhead where peat erosion is now occurring.

TABLE 1.2 SHEEP POPULATION AND ROUGH PASTURE IN THE PARISH OF MINNINGAFF
(As supplied by the Scottish Records Office, Edinburgh)

	Sheep and Lambs (Totals)	Rough Pasture (acres)
1980	19,412	11,119
1976	18,045	15,828
1966	26,464	57,271
1956	32,874	73,868
1946	43,903	86,322
1936	41,216	79,004
1926	43,336	79,611
1916	41,422	71,098
1896	57,867	77,960
1886	53,542	-
1877	49,944	-
1866	32,651	-

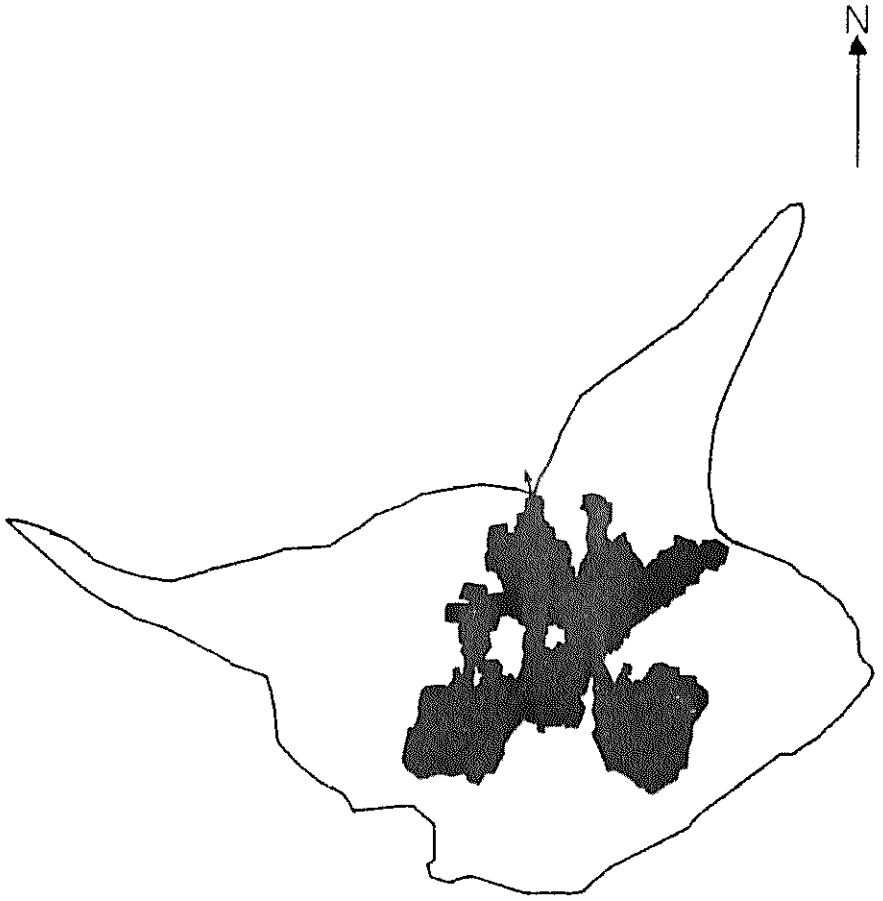


Fig.1.2. Loch Enoch Catchment.

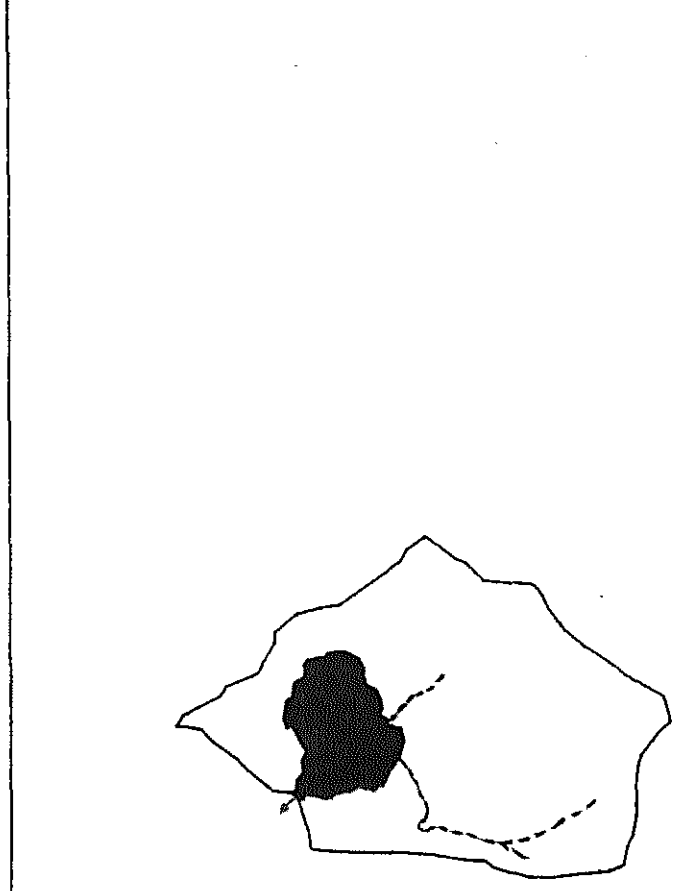
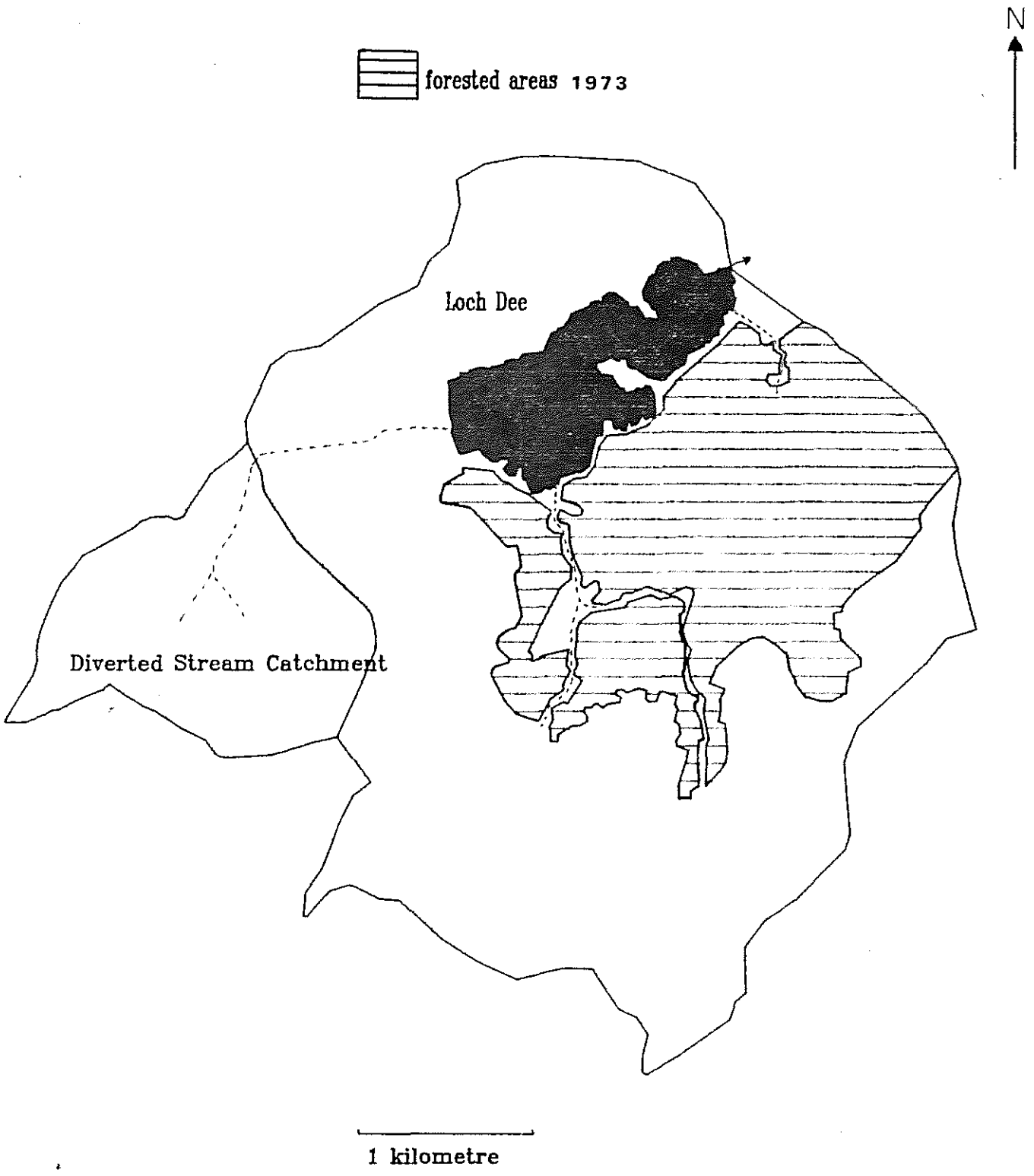


Fig.1.1. Round Loch of Glenhead Catchment.

1 kilometre.

Fig.14. Loch Dee Catchment.



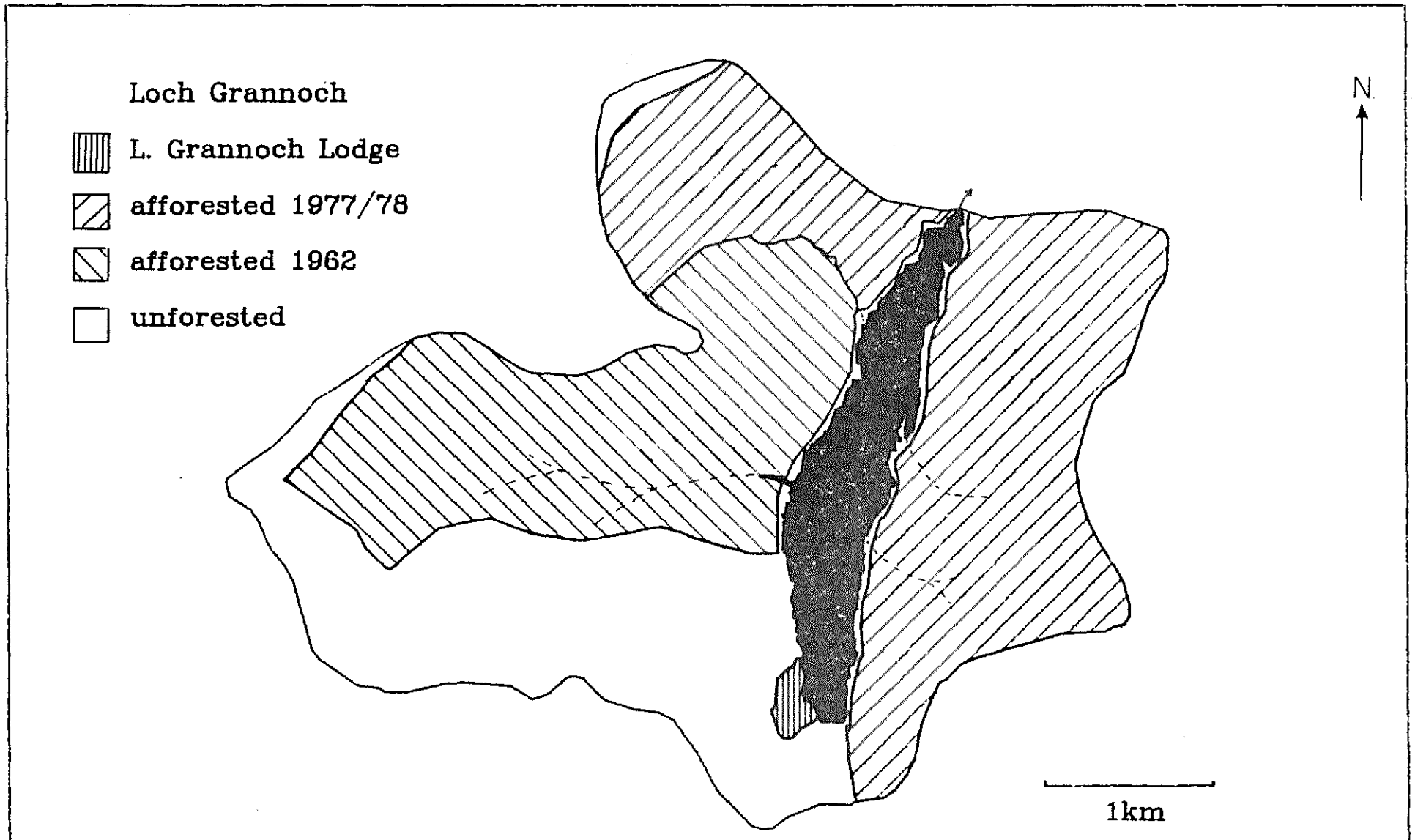


Fig.1.5. Loch Grannoch Catchment.

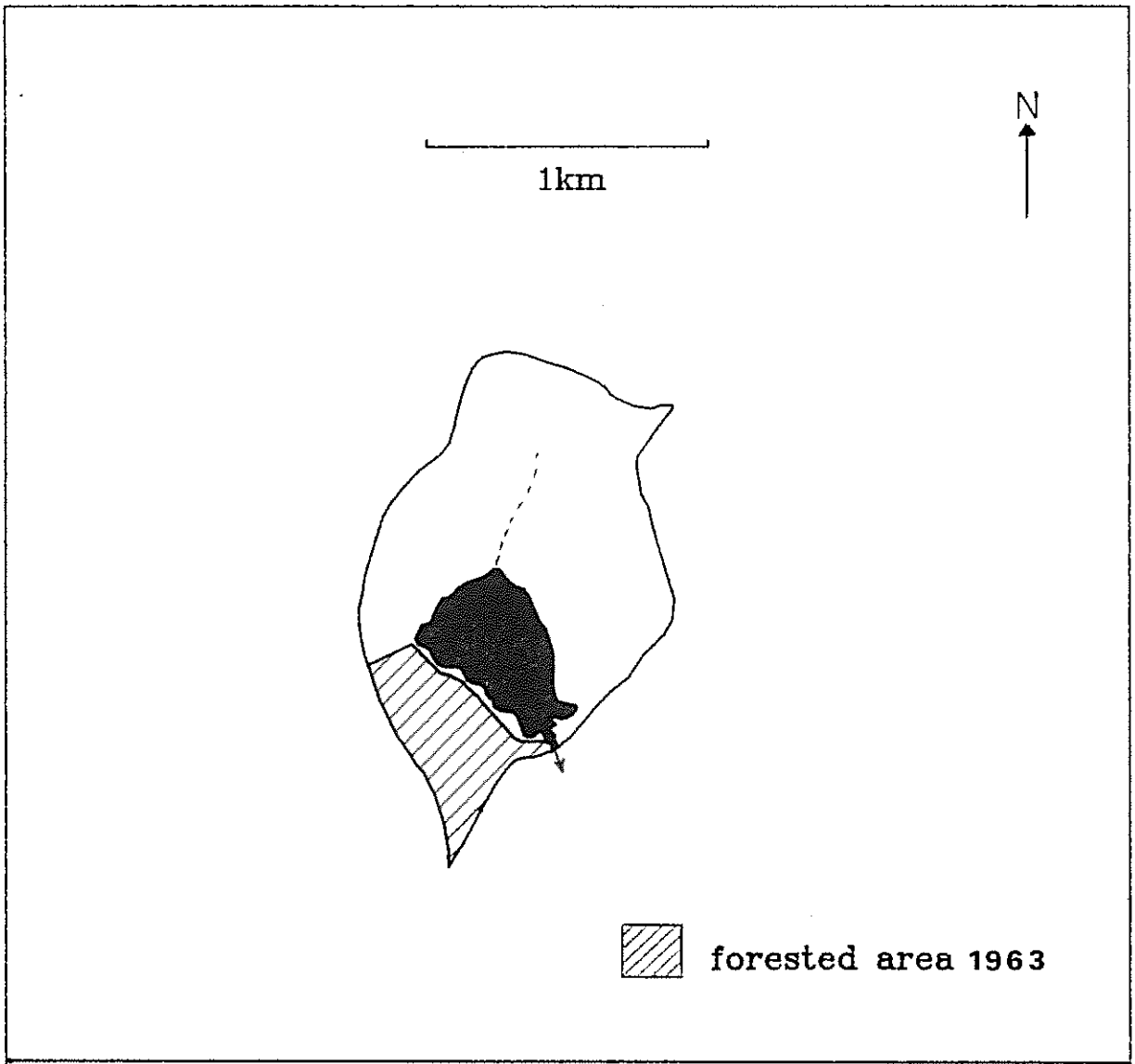


Fig.1.6. Loch Fleet Catchment.

SECTION 2 - WATER QUALITY

Water samples and water quality data were collected during eight visits to the lake sites between November 1981 and November 1982. At each site water temperature was recorded and water samples collected for (i) pH and conductivity measurements and (ii) chemical analysis in the laboratory.

Water temperature measurements were restricted to the littoral area and therefore are particularly sensitive to short term changes in insolation. It was noted that on sunny days water temperature around rocks and boulders was c. 0.5° C higher than in sandy areas; temperature measurements were always made in the latter areas.

All water samples were collected from immediately below the water surface in the littoral, in about 40 cm depth of water. During sampling care was taken to avoid collecting resuspended particulate material. However, on two occasions successive wind-incuded water turbulence made this impossible.

Samples for water pH and conductivity measurement were collected in acid pre-washed dark glass 100 ml bottles and readings taken within 6 hours of collection. An E.E.L. field pH meter accurate to about ±0.1 unit of pH was used for acidity measurements. Conductivity measurements were made using W.P.A. equipment and converted to 18° C assuming a 2% change in conductivity per 1° C. Temperature, pH, hydrogen ion concentration and conductivity measurements are given in Tables 2.1a (unafforested site catchments) and 2.1b (afforested site catchments). Mean values of water temperature, pH, hydrogen ion concentration and conductivity are given in Table 2.2. Geometric mean pH values were calculated from mean hydrogen ion concentrations.

Water samples for laboratory analysis of the major cation and anions were

collected in acid pre-washed 100 ml polypropylene containers and stored within 6 hours of collection at -20° C. Chemical analyses were carried out at the Research Laboratories (Leatherhead), Central Electricity Generating Board, using a Technicon AA2 system. Results of the chemical analyses are presented in Tables 2.3a and 2.3b. Concentration means for each site are given in Table 2.4.

Water chemistry data for the White Laggen Burn, an inflow to Loch Dee, were supplied by Dr. Tervet of the Solway River Purification Board, Dumfries, and are shown in Table 2.5.

TABLE 2.5 WATER CHEMISTRY DATA FOR TWO SITES IN THE WHITE LAGGAN BURN - AN INFLOW STREAM TO LOCH DEE.

($Ca\ CO_3$ was applied to the stream at both sites in October 1981 and to site 2 in 1980. Concentrations in mg l^{-1})

Date	pH	Conductivity $\mu S\ cm^{-1}$	Ca	Mg	Na	K	Fe	Al	SiO_2*	SO_4	Cl
SITE 1 Above the road bridge and above the Black Laggan Burn inflow.											
2/ 2/1982	5.1	25	1.12	0.58	2.57	0.46	0.02	0.20	1.1	-	4.2
6/ 4/1982	5.8	36	1.89	0.93	4.06	0.47	-	0.11	1.2	0.8	9.4
4/ 5/1982	5.4	50	1.95	1.13	5.80	0.46	-	0.10	1.3	1.2	11.8
29/ 6/1982	5.8	37	1.43	0.78	3.26	0.15	-	0.14	1.0	0.4	5.2
31/ 8/1982	5.9	28	1.23	0.59	3.46	0.14	-	0.12	0.9	0.8	5.6
6/10/1982	5.5	30	0.94	0.51	2.93	0.37	-	0.17	1.0	0.5	6.8
7/12/1982	6.1	34	1.46	0.78	3.48	0.32	-	0.11	1.6	4.7	8.0
SITE 2 Below the road bridge											
17/11/1981	7.2	38	3.30	0.92	3.26	0.41	-	0.20	1.6	10.2	9.0
23/ 2/1982	6.0	40	2.08	1.11	3.36	0.54	-	0.08	1.9	1.0	8.4
6/ 4/1982	5.6	35	1.71	0.95	3.86	0.39	-	0.01	1.2	1.1	8.6
11/ 5/1982	6.8	59	2.53	1.07	4.96	0.38	-	0.03	1.4	0.5	9.4
29/ 5/1982	5.7	36	1.43	0.79	3.16	0.13	-	0.06	0.9	0.3	5.4
17/ 8/1982	6.5	36	1.85	0.89	3.78	0.17	-	0.11	1.0	NS	6.8
6/10/1982	5.3	25	0.99	0.53	2.83	0.43	-	0.19	1.0	0.4	7.9
23/11/1982	5.1	43	1.07	0.74	4.69	0.45	-	0.21	0.8	2.8	12.0

*Concentration calculated as mg Si l^{-1}

TABLE 2.4 MEAN VALUES FOR THE WATER QUALITY DATA GIVEN IN TABLE 2.3. ALL CONCENTRATIONS ARE AS mg l^{-1}

	Ca	Mg	Na	K	Fe	Al	SiO_2	SO_4	Cl
ROUND LOCH OF GLENHEAD	0.39(0.17)	0.26(0.05)	1.62(0.32)	0.20(0.08)	0.07(0.03)	0.09(0.04)	0.47(0.28)	2.57(0.85)	4.43(1.35)
LOCH ENOCH	0.21(0.07)	0.20(0.08)	1.34(0.56)	0.26(0.18)	-	0.09(0.04)	0.27(0.16)	2.14(0.62)	3.58(0.63)
LOCH VALLEY	0.25(0.08)	0.22(0.06)	1.45(0.97)	0.24(0.8)	0.03(0.01)	0.10(0.03)	0.25(0.17)	1.30(0.18)	4.43(3.72)
LOCH DEE	0.52(0.28)	0.34(0.16)	1.47(0.76)	0.30(0.20)	0.04(0.01)	0.07(0.01)	0.32(0.31)	2.74(1.45)	5.00(2.31)
LOCH GRANNOCH	0.44(0.18)	0.25(0.10)	1.47(0.65)	0.27(0.07)	0.05(0.01)	0.13(0.05)	0.55(0.39)	3.04(1.36)	3.93(1.13)
LOCH FLEET	0.45(0.26)	0.28(0.14)	1.62(0.91)	0.20(0.06)	0.06(0.04)	0.12(0.05)	0.49(0.58)	3.19(1.49)	3.28(1.30)

TABLE 2.2 MEAN VALUES FOR WATER QUALITY DATA GIVEN IN TABLE 2.1

	Mean Temperature (°C)	Mean pH	Mean $[H^+]$ (μ eq H^+ l^{-1})	Mean Conductivity (μS cm^{-1} at 18°C)
ROUND LOCH OF GLENHEAD	9.0(4.5)	4.7	18.6(5.5)	30(4.6)
LOCH ENOCH	7.0(4.4)	4.5	28.9(6.8)	30(8.0)
LOCH VALLEY	8.5(4.6)	4.7	19.7(3.4)	31(4.1)
LOCH DEE	9.0(4.3)	5.3	5.4(3.6)	37(14.8)
LOCH GRANNOCH	9.1(4.3)	4.6	24.1(9.2)	38(4.9)
LOCH FLEET	8.6(4.2)	4.6	28.0(12.1)	35(4.3)

() Standard deviation of the mean values

SECTION 3 - COLLECTION OF SEDIMENT CORES AND ROUTINE LABORATORY MEASUREMENT OF SEDIMENT CHARACTERISTICS

Core Collection

Samples of lake sediment from the deepest point in each loch were collected using a Mackareth mini-corer (Mackareth 1969) operated from an inflatible boat. Sampling was carried out during August 1980 (Lochs Dee and Grannoch), May 1981 (Round Loch of Glenhead, Loch Valley and Loch Fleet) and May 1982 (Loch Enoch).

The Mackareth mini-corer enables a ca 90 cm long column of sediment with an undisturbed sediment/water interface to be collected from the lake bed. The sediment core samples were carefully transported back for laboratory analysis at UCL. Cores were first extruded and sectioned at 1 or 0.5 cm intervals to enable measurement of wet density (g cm^{-3}), percentage dry weight and percentage loss on ignition (at 550° C) (see Battarbee 1978). Results of these analyses for each core from each site are presented in Tables 3.1-3.6 and in Figures 3.1-3.6.

Down-core changes in the three measured sediment characteristics, wet density (WD), percentage dry weight (DW) and percentage loss on ignition (LOI) show no consistent trends within the group of sites. The most marked change is seen in the percentage loss on ignition profiles from the Round Loch of Glenhead (RLGH) and Loch Fleet cores, where a strong increase occurs towards the surface. In Loch Fleet the depth immediately below the large LOI rise is characterized by peaks in WD and DW. The LOI profiles from Lochs Dee, Enoch and Valley (LVALL) are rather irregular but show a decreasing trend towards the surface. The WD, DW and LOI profiles in the Loch Grannoch (LGR) core are fairly uniform except for a small change in LOI and DW at about 30 cm depth.

TABLE 3.1 WET DENSITY, PERCENTAGE DRY WEIGHT AND PERCENTAGE ORGANIC MATERIAL DATA FOR THE ROUND LOCH OF GLENHEAD SEDIMENT CORE

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
0.0	-	2.32	47.06
0.5	1.0618	4.88	38.81
1.0	-	5.97	37.93
1.5	1.0548	6.59	39.60
2.0	-	6.98	38.78
2.5	1.0603	7.29	38.10
3.0	-	7.43	38.89
3.5	1.0589	7.61	39.62
4.0	-	7.54	39.83
4.5	1.0603	7.45	40.35
5.0	-	7.59	39.55
5.5	1.0522	7.12	38.82
6.0	-	6.86	41.94
6.5	1.5660	7.61	40.78
7.0	-	7.71	40.22
7.5	1.0563	7.69	47.57
8.0	-	7.72	45.08
8.5	1.0534	7.66	44.88
9.0	-	8.02	45.45
9.5	1.0559	7.99	41.67
10.0	-	8.24	42.06
10.5	-	8.62	42.86
11.0	-	8.63	43.84
11.5	1.0519	8.34	44.20
12.0	-	8.89	44.12
12.5	-	8.53	43.81
13.0	-	8.86	45.39
13.5	1.0536	8.41	44.76
14.0	-	8.50	46.83
14.5	-	8.42	47.47
15.0	-	8.61	43.95
15.5	1.0563	8.64	44.44
16.0	-	8.54	46.67
16.5	-	8.37	44.80
17.0	-	8.50	45.59
17.5	1.0592	8.50	47.33
18.0	-	8.78	46.39
18.5	-	8.56	48.57
19.0	-	8.83	48.94
19.5	1.0550	8.28	52.89
20.0	-	8.31	49.59
20.5	-	8.59	49.66
21.0	-	8.52	49.63
21.5	-	8.84	47.54
22.0	-	8.91	48.19
22.5	-	9.46	48.99

TABLE 3.1 cont.

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
23.0	-	8.57	49.40
23.5	1.0518	8.81	49.67
24.0	-	8.58	47.37
24.5	-	8.59	48.32
25.0	-	8.69	48.36
25.5	-	8.73	58.06
26.0	-	8.50	47.83
26.5	-	8.76	45.21
27.0	-	8.41	46.43
27.5	1.0521	8.65	48.84
28.0	-	8.68	45.51
28.5	-	8.44	46.91
29.0	-	8.33	45.08
29.5	-	8.16	48.78
30.0	-	8.26	49.21
30.5	-	8.75	46.05
31.0	-	8.36	48.41
31.5	1.0520	8.19	50.00
32.0	-	8.24	51.49
32.5	-	8.41	48.70
33.0	-	8.28	47.40
33.5	1.0561	8.52	46.96
34.0	-	9.18	46.88
34.5	-	9.74	45.61
35.0	-	9.78	45.45
35.5	1.0664	10.17	43.40
36.0	-	10.56	39.73
36.5	-	10.67	40.66
37.0	-	11.00	39.87
37.5	1.0711	11.49	40.10
38.0	-	10.60	39.39
38.5	-	10.19	37.91
39.0	-	10.32	37.82
39.5	1.0650	10.37	35.81
40.0	1.0748	11.12	31.32
41.0	1.0778	11.56	28.02
42.0	-	11.68	27.68
43.0	1.0832	11.76	28.04
44.0	-	12.00	26.22
45.0	1.0792	11.36	25.63
46.0	-	11.34	24.65
47.0	1.0789	11.51	26.52
48.0	-	10.26	28.68
49.0	1.0702	10.29	28.57
50.0	-	10.55	28.84
51.0	1.0753	10.38	28.25
52.0	-	10.89	27.31
53.0	1.0817	10.70	28.23
54.0	-	11.08	26.21
55.0	1.0816	11.36	26.82

TABLE 3.1 cont.

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
56.0	-	10.65	28.08
57.0	1.0773	10.85	27.63
58.0	-	11.19	27.97
59.0	1.0739	10.75	28.69
60.0	-	10.40	29.67
61.0	1.0739	10.11	30.13
62.0	-	10.75	28.63
63.0	1.0780	11.31	28.57
64.0	-	11.23	27.92
65.0	1.0747	10.81	32.58
66.0	-	10.29	35.02
67.0	1.0686	10.02	38.69
68.0	-	10.26	39.76
69.0	1.0725	11.02	35.38
70.0	-	11.78	32.57
71.0	1.0782	12.14	31.65
72.0	-	12.53	30.61
73.0	1.0849	12.93	28.26
74.0	-	12.95	27.86
75.0	1.0873	13.64	27.36
76.0	-	14.34	26.15
77.0	1.0871	14.49	25.22
78.0	-	15.18	26.21
79.0	1.0974	15.70	23.92
80.0	-	15.68	25.31
81.0	-	15.80	26.90

TABLE 3.2 WET DENSITY, PERCENTAGE DRY WEIGHT AND PERCENTAGE LOSS ON IGNITION DATA FOR THE LOCH ENOCH SEDIMENT CORE

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
0.0	1.0735	9.06	62.58
0.5	1.0755	10.39	59.85
1.0	1.0725	8.99	57.14
1.5	1.0680	8.38	54.62
2.0	1.0595	7.22	59.09
2.5	1.0730	9.26	56.06
3.0	1.0780	8.66	58.45
3.5	1.0700	8.52	60.83
4.0	1.0695	9.68	60.91
4.5	1.0710	9.43	57.14
5.0	1.0715	9.29	64.55
5.5	1.0675	10.66	66.43
6.0	1.0770	12.87	74.25
6.5	1.0750	10.87	70.68
7.0	1.0735	9.94	65.28
7.5	1.0780	10.61	68.07
8.0	1.0770	11.14	67.54
8.5	1.0775	11.04	68.75
9.0	1.0765	10.37	68.03
9.5	1.0705	10.27	67.46
10.0	1.0715	9.75	67.59
10.5	1.0750	9.80	65.06
11.0	1.0660	10.95	63.85
11.5	1.0700	9.91	66.37
12.0	1.0745	10.24	65.49
12.5	1.0755	10.96	67.68
13.0	1.0735	11.21	70.00
13.5	1.0805	10.89	70.33
14.0	1.0875	13.75	70.86
14.5	1.0835	14.27	67.68
15.0	1.0885	13.23	77.18
16.0	1.0815	-	70.94
17.0	1.0765	11.26	66.96
18.0	1.0745	10.74	68.22
19.0	1.0675	12.46	65.91
20.0	1.0770	11.93	73.17
21.0	1.0805	12.85	65.44
22.0	1.0835	12.67	71.75
23.0	1.0780	12.10	69.87
24.0	1.0765	11.23	74.34
25.0	1.0750	10.94	77.61
26.0	1.0730	10.85	76.02
27.0	1.0735	11.62	77.55
28.0	1.0815	12.89	80.83
29.0	1.0775	12.46	74.69
30.0	1.0745	11.24	74.81
31.0	1.0710	11.12	75.98
32.0	1.0690	11.74	77.62
33.0	1.0715	11.48	77.72

TABLE 3.2 cont.

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
34.0	1.0660	11.32	79.27
35.0	1.0685	11.32	76.26
36.0	1.0635	11.96	78.64
37.0	1.0740	11.93	78.49
38.0	1.0725	12.15	79.19
39.0	1.0690	12.15	78.79
40.0	1.0675	12.38	77.93
41.0	1.0735	12.84	75.23
42.0	1.0730	12.77	75.94
43.0	1.0700	13.25	74.89
44.0	1.0705	12.35	76.76
45.0	1.0780	12.46	79.05
46.0	1.0760	12.75	82.20
47.0	1.0710	11.37	80.19
48.0	1.0760	12.46	79.51
49.0	1.0770	13.43	78.77
50.0	1.0720	11.70	79.81
51.0	1.0715	12.20	81.74
52.0	1.0750	12.64	81.00
53.0	1.0700	12.10	78.28
54.0	1.0720	12.57	79.61
55.0	1.0685	12.35	80.00
56.0	1.0690	12.42	81.71
57.0	1.0765	13.31	79.79
58.0	1.0730	13.54	80.90
59.0	1.0730	14.92	71.43
60.0	1.0815	20.22	56.81
61.0	1.0930	16.61	65.28
62.0	1.0930	13.78	78.68
63.0	1.0825	13.28	82.72
64.0	1.0775	13.62	83.13
65.0	1.0785	15.79	76.13
66.0	1.0730	13.84	82.96
67.0	1.0765	14.12	76.66
68.0	1.0705	14.16	80.99
69.0	1.0720	14.40	81.55

TABLE 3.3 WET DENSITY, PERCENTAGE DRY WEIGHT AND LOSS ON IGNITION DATA FOR THE LOCH VALLEY SEDIMENT CORE

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
0.0	-	2.98	31.04
0.5	1.0522	6.22	37.68
1.0	-	6.57	43.21
1.5	1.0577	7.58	38.89
2.0	-	8.67	37.61
2.5	1.0683	9.13	37.90
3.0	-	9.55	40.00
3.5	1.0682	10.92	39.11
4.0	-	10.14	38.10
4.5	1.0679	10.69	20.41
5.0	-	12.46	33.95
5.5	1.0782	12.07	34.41
6.0	-	13.00	27.65
6.5	1.0929	12.63	28.30
7.0	-	12.02	31.58
7.5	1.0751	10.45	37.06
8.0	-	11.70	35.29
8.5	1.0814	13.19	29.45
9.0	-	13.02	33.16
9.5	1.0880	12.92	32.23
10.0	-	12.37	31.21
10.5	-	10.42	35.71
11.0	-	11.03	39.29
11.5	1.0704	10.58	38.37
12.0	-	10.01	41.07
12.5	-	10.77	38.46
13.0	1.0685	9.97	41.62
13.5	-	10.22	43.45
14.0	-	10.29	41.67
14.5	-	10.56	42.79
15.0	1.0723	9.92	42.26
15.5	-	10.51	43.57
16.0	-	10.62	57.75
16.5	-	10.46	47.34
17.0	1.0616	10.60	45.96
17.5	-	10.94	46.55
18.0	-	9.75	45.64
18.5	-	9.77	45.53
19.0	1.0619	9.79	45.74
19.5	-	9.57	52.50
20.0	-	9.60	44.02
20.5	-	8.72	39.87
21.0	-	8.74	42.77
21.5	-	9.70	42.61
22.0	-	9.53	42.86
22.5	-	9.32	44.21
23.0	1.0650	9.70	41.62
23.5	-	10.44	37.97
24.0	-	10.00	42.16
24.5	-	10.80	42.11

TABLE 3.3 cont.

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
25.0	-	9.83	43.64
25.5	-	9.58	43.04
26.0	-	9.80	45.81
26.5	-	9.52	45.21
27.0	-	9.37	45.75
27.5	1.0613	9.43	45.14
28.0	-	9.65	46.25
28.5	-	8.05	52.82
29.0	-	9.39	45.76
29.5	-	9.44	45.96
30.0	-	9.36	46.79
30.5	-	9.05	49.04
31.0	-	9.26	47.06
31.5	1.0562	9.26	47.70
32.0	-	9.88	45.40
32.5	-	9.66	45.20
33.0	-	9.77	45.74
33.5	-	9.71	43.71
34.0	-	9.21	47.10
34.5	-	9.26	51.91
35.0	-	8.42	52.73
35.5.	1.0616	8.23	42.86
36.0	-	8.74	45.04
36.5	-	9.35	48.72
37.0	-	10.22	45.36
37.5	-	10.41	42.93
38.0	-	10.48	43.70
38.5	-	10.16	47.97
39.0	-	10.65	41.82
39.5	1.0654	9.73	45.16
40.0	-	10.04	47.65
41.0	-	9.79	49.15
42.0	-	9.22	45.95
43.0	1.0683	10.89	42.52
44.0	-	9.99	45.68
45.0	-	10.38	44.51
46.0	-	10.06	59.65
47.0	1.0576	9.82	45.38
48.0	-	11.21	42.48
49.0	-	10.71	44.68
50.0	-	10.01	50.60
51.0	1.0720	9.80	50.62
52.0	-	10.84	51.26
53.0	-	9.90	54.50
54.0	-	10.99	53.64
55.0	1.0681	10.30	49.17
56.0	-	10.16	51.61
57.0	-	9.83	50.00
58.0	-	9.08	50.00
59.0	1.0595	9.32	49.04

TABLE 3.3 cont.

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
60.0	-	9.26	48.42
61.0	-	9.73	49.48
62.0	-	10.70	48.66
63.0	1.0659	9.98	47.55
64.0	-	9.74	47.12
65.0	-	9.14	49.14
66.0	-	10.87	47.12
67.0	1.0739	11.37	44.32
68.0	-	11.96	43.17
69.0	-	10.69	45.89
70.0	-	10.94	51.03
71.0	1.0612	10.66	47.34
72.0	-	11.57	46.74
73.0	-	11.01	55.56
74.0	-	11.06	58.11
75.0	1.0535	11.49	56.85
76.0	-	11.67	54.17
77.0	-	11.42	53.93
78.0	-	11.62	50.00
79.0	1.0686	12.14	54.69
80.0	-	11.52	52.80
81.0	-	11.81	53.46
82.0	-	12.29	50.52
83.0	1.0634	12.24	52.83
84.0	-	12.34	48.59
85.0	-	12.27	51.55
86.0	-	12.44	52.91
87.0	-	13.21	49.53

TABLE 3.4 WET DENSITY, PERCENTAGE DRY WEIGHT AND LOSS ON IGNITION DATA FOR THE LOCH DEE SEDIMENT CORE

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
0.0	1.0425	6.72	31.85
1.0	1.0486	8.44	30.81
2.0	1.0734	9.48	25.66
3.0	1.0940	13.06	22.84
4.0	1.0746	10.17	27.88
5.0	1.0579	9.25	31.80
6.0	1.0648	9.58	30.70
7.0	1.0712	9.86	31.80
8.0	1.0716	10.22	31.61
9.0	1.0567	9.66	29.94
10.0	1.0616	11.44	27.62
11.0	1.0614	10.17	29.41
12.0	1.0691	10.61	30.77
13.0	1.0703	11.22	30.29
14.0	1.0664	10.31	29.38
15.0	1.0715	11.15	29.73
16.0	1.0738	10.48	29.55
17.0	1.0728	11.05	30.40
18.0	1.0792	11.35	31.88
19.0	1.0765	11.85	31.08
20.0	1.0774	11.66	31.37
21.0	-	10.61	36.72
22.0	1.0569	10.34	33.91
23.0	-	11.01	34.13
24.0	1.0686	11.01	33.33
25.0	-	11.70	47.97
26.0	1.0723	12.98	39.47
27.0	-	12.24	39.69
28.0	1.0708	12.07	38.89
29.0	-	11.70	37.32
30.0	1.0700	11.01	41.38
31.0	-	10.10	41.44
32.0	1.0662	10.54	41.76
33.0	-	10.18	39.69
34.0	1.0654	10.93	38.00
35.0	-	10.57	42.14
36.0	1.0775	10.97	38.83
37.0	-	10.81	38.10
38.0	1.0725	11.08	37.84
39.0	-	11.42	39.54
40.0	1.0673	11.37	37.00
41.0	-	11.58	39.55
42.0	1.0760	11.73	39.02
43.0	-	12.03	36.54
44.0	1.0770	12.33	35.33
45.0	-	11.68	36.07
46.0	1.0785	12.36	34.04
47.0	-	12.06	35.60
48.0	1.0673	12.39	34.29
49.0	-	12.56	33.12
50.0	1.0760	12.11	33.79
51.0	-	12.23	33.90
52.0	1.0770	12.25	34.00

TABLE 3.5 WET DENSITY, PERCENTAGE DRY WEIGHT AND LOSS ON IGNITION DATA FOR THE LOCH GRANNOCH SEDIMENT CORE

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
0.0	1.0614	9.90	38.34
1.0	1.0694	13.25	37.96
2.0	1.0762	11.94	34.57
3.0	1.0849	12.58	39.64
4.0	1.0725	12.82	39.29
5.0	1.0774	12.60	41.53
6.0	1.0812	12.62	40.70
7.0	1.0821	12.93	40.14
8.0	1.0775	12.96	40.97
9.0	1.0823	12.97	40.20
10.0	1.0807	12.82	40.83
11.0	1.0831	13.43	40.69
12.0	1.0787	12.98	40.64
13.0	1.0881	13.30	40.18
14.0	1.0852	13.63	41.23
15.0	1.0851	13.53	42.37
16.0	1.0838	13.96	42.62
17.0	1.0810	14.58	43.23
18.0	1.0873	14.77	42.51
19.0	1.0856	14.93	42.14
20.0	1.0626	12.72	40.30
21.0	-	11.90	41.83
22.0	1.0760	12.38	40.78
23.0	-	12.96	41.53
24.0	-	12.39	41.84
25.0	1.796	12.29	42.27
26.0	-	12.57	42.12
27.0	1.0845	13.07	41.31
28.0	-	15.62	32.83
29.0	1.0876	13.44	30.32
30.0	-	10.63	35.08
31.0	1.0746	10.53	37.56
32.0	-	12.21	36.25
33.0	1.0884	12.56	40.00
34.0	-	12.36	41.98
35.0	1.0737	11.84	40.74
36.0	-	12.17	42.35
37.0	1.0760	12.16	43.39
38.0	-	12.15	44.44
39.0	1.0785	12.44	40.93
40.0	-	12.95	36.11
42.0	1.0783	12.46	35.23
46.0	1.0773	13.32	35.06
48.0	1.0801	13.35	35.61
50.0	1.0827	12.86	36.86
52.0	1.0788	12.35	39.78
54.0	1.0776	13.10	38.07
56.0	1.0760	13.14	37.94
58.0	1.0745	13.33	38.81
60.0	1.0691	12.60	41.80

TABLE 3.5 cont.

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
62.0	1.0773	12.32	43.89
64.0	1.0807	12.75	42.01
66.0	1.0797	13.09	42.21
68.0	1.0749	12.77	40.64
70.0	1.0636	12.56	47.00
72.0	1.0701	12.48	47.37
74.0	1.0778	13.05	42.92
76.0	1.0704	12.57	49.36
78.0	1.0739	12.84	53.04
80.0	1.0728	12.17	58.67
82.0	1.0697	12.86	57.33
84.0	1.0756	14.14	54.65
86.0	1.0688	16.87	52.23

TABLE 3.6 WET DENSITY, PERCENTAGE DRY WEIGHT AND LOSS ON IGNITION DATA FOR THE LOCH FLEET SEDIMENT CORE

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
0.0	1.0605	7.62	38.03
1.0	1.0666	8.40	38.10
2.0	1.0750	9.63	47.29
3.0	1.0574	9.89	48.37
4.0	1.0582	8.82	55.36
5.0	1.0529	8.63	53.45
6.0	1.0509	7.80	58.06
7.0	-	8.45	58.01
8.0	1.0510	8.70	54.93
9.0	-	8.80	55.06
10.0	1.0559	9.10	57.06
11.0	-	8.75	56.45
12.0	1.0452	8.65	56.77
13.0	-	8.65	61.90
14.0	1.0541	8.43	64.77
15.0	-	8.74	63.13
16.0	1.0464	8.68	60.43
17.0	-	8.52	61.29
18.0	1.0553	8.86	57.43
19.0	-	8.77	54.89
20.0	1.0662	9.80	50.00
21.0	-	15.76	22.31
22.0	1.0947	11.10	17.79
23.0	-	12.00	13.96
24.0	1.1136	15.11	12.13
25.0	-	18.04	9.95
26.0	1.1624	17.88	11.19
27.0	-	18.90	14.32
28.0	1.1194	15.57	16.89
29.0	-	16.25	13.62
30.0	1.1095	13.70	15.81
31.0	-	11.69	17.54
32.0	1.0875	11.91	19.71
33.0	-	10.75	23.04
34.0	1.0704	10.64	23.67
35.0	-	11.60	22.10
36.0	1.0793	11.72	21.00
37.0	-	10.81	22.73
38.0	-	11.88	19.60
39.0	-	11.69	21.34
40.0	1.0792	11.20	22.61
41.0	-	11.51	21.89
42.0	-	11.50	23.36
43.0	-	11.72	23.50
44.0	1.0728	11.70	23.88
45.0	-	12.19	23.58
46.0	-	11.60	23.44
47.0	-	12.30	21.85
48.0	1.0811	12.43	22.79
49.0	-	12.82	22.81
50.0	-	12.81	22.26

TABLE 3.6 cont.

Depth in Sediment (cm)	Wet Density (g cm^{-3})	Dry Weight (%)	Loss on Ignition (%)
51.0	-	12.20	23.08
52.0	1.0795	12.18	24.16
53.0	-	11.94	25.00
54.0	-	11.62	25.00
55.0	-	11.69	24.88
56.0	1.0748	11.55	26.27
57.0	-	11.88	26.61
58.0	-	11.64	26.86
59.0	-	11.90	26.64
60.0	1.0734	11.69	25.74
61.0	-	12.14	25.24
62.0	-	12.15	25.81
63.0	-	11.97	26.67
64.0	1.0779	12.41	26.27
65.0	-	12.74	24.78
66.0	-	12.87	24.75
67.0	-	13.26	24.52
58.0	1.0858	13.25	25.48
69.0	-	13.45	25.84
70.0	-	13.26	25.67
71.0	-	12.88	24.91
72.0	1.0873	13.44	24.31
73.0	-	13.50	24.20
74.0	-	13.95	24.60
75.0	-	14.34	23.53
76.0	1.0977	14.91	22.16
77.0	-	15.00	19.32
78.0	-	14.80	18.80
79.0	-	14.97	19.41
80.0	1.0974	14.48	19.60
81.0	-	14.51	19.50
82.0	-	14.49	19.87
83.0	-	15.38	17.72
84.0	1.1062	15.75	16.67
85.0	-	15.76	16.62
86.0	-	16.31	17.65

FIG. 3.1.

WET DENSITY, DRY WEIGHT AND LOI FOR RLGH

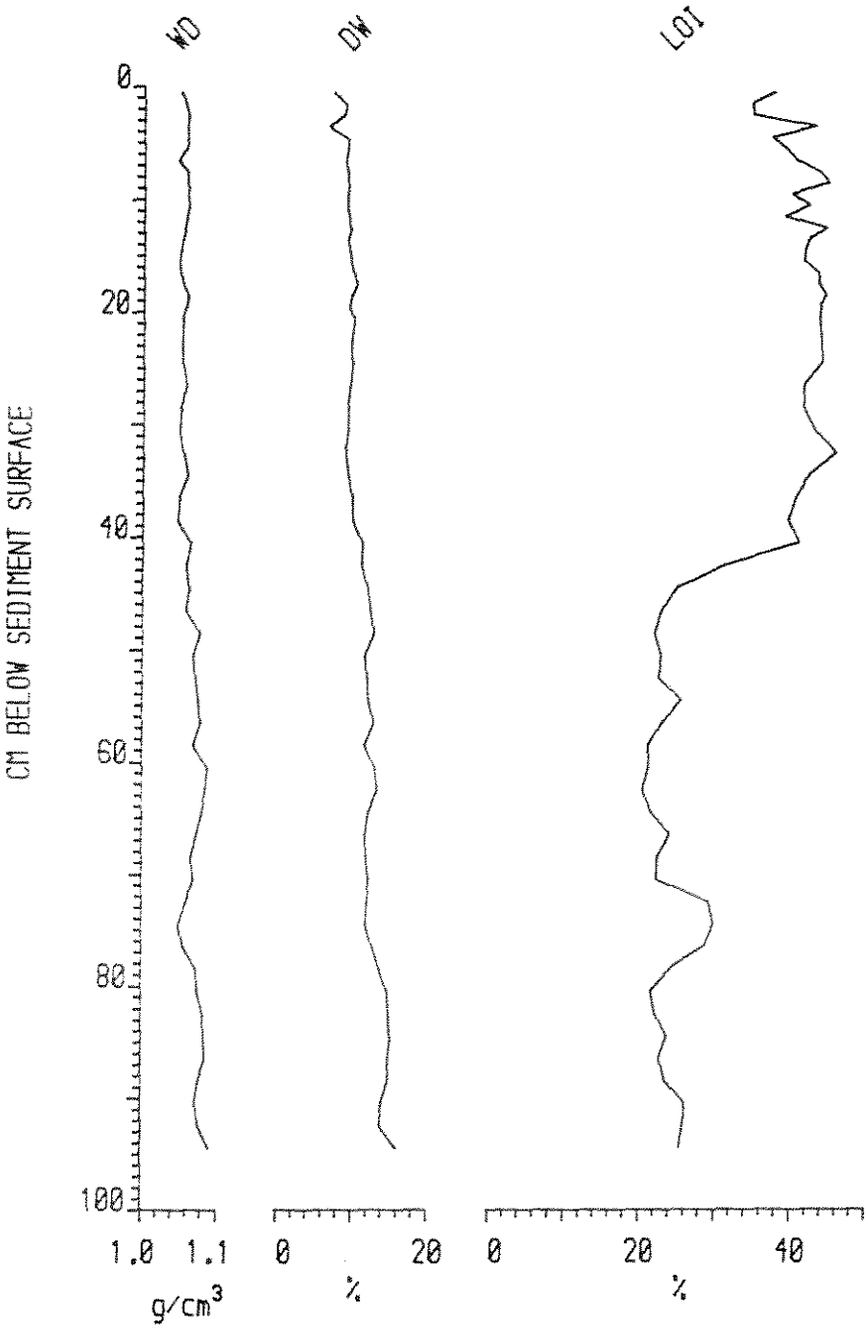


FIG. 3.2.

WET DENSITY, DRY WEIGHT AND LOI FOR ENOCH

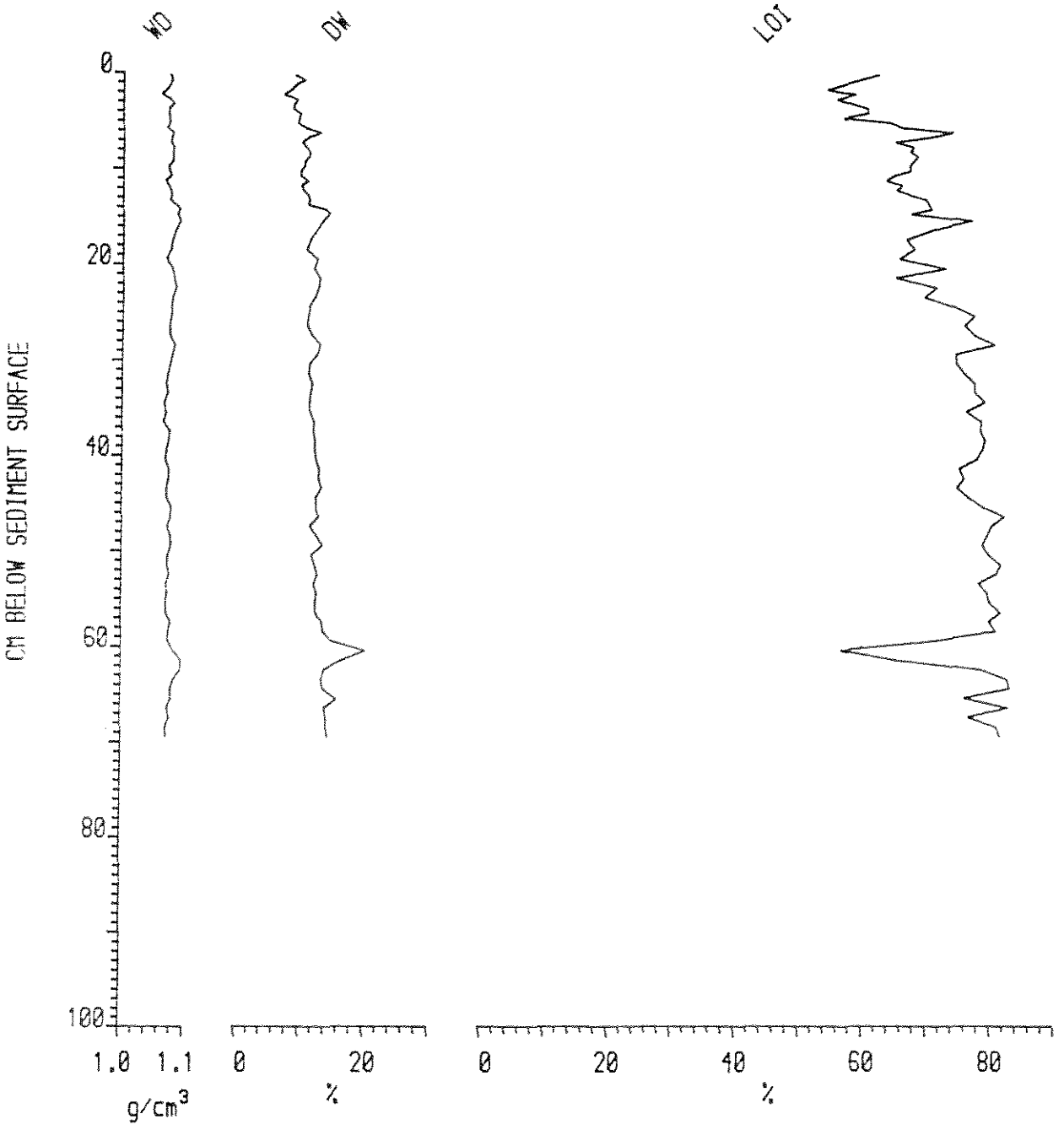


FIG. 3.3.

WET DENSITY, DRY WEIGHT AND LOI FOR LVALL

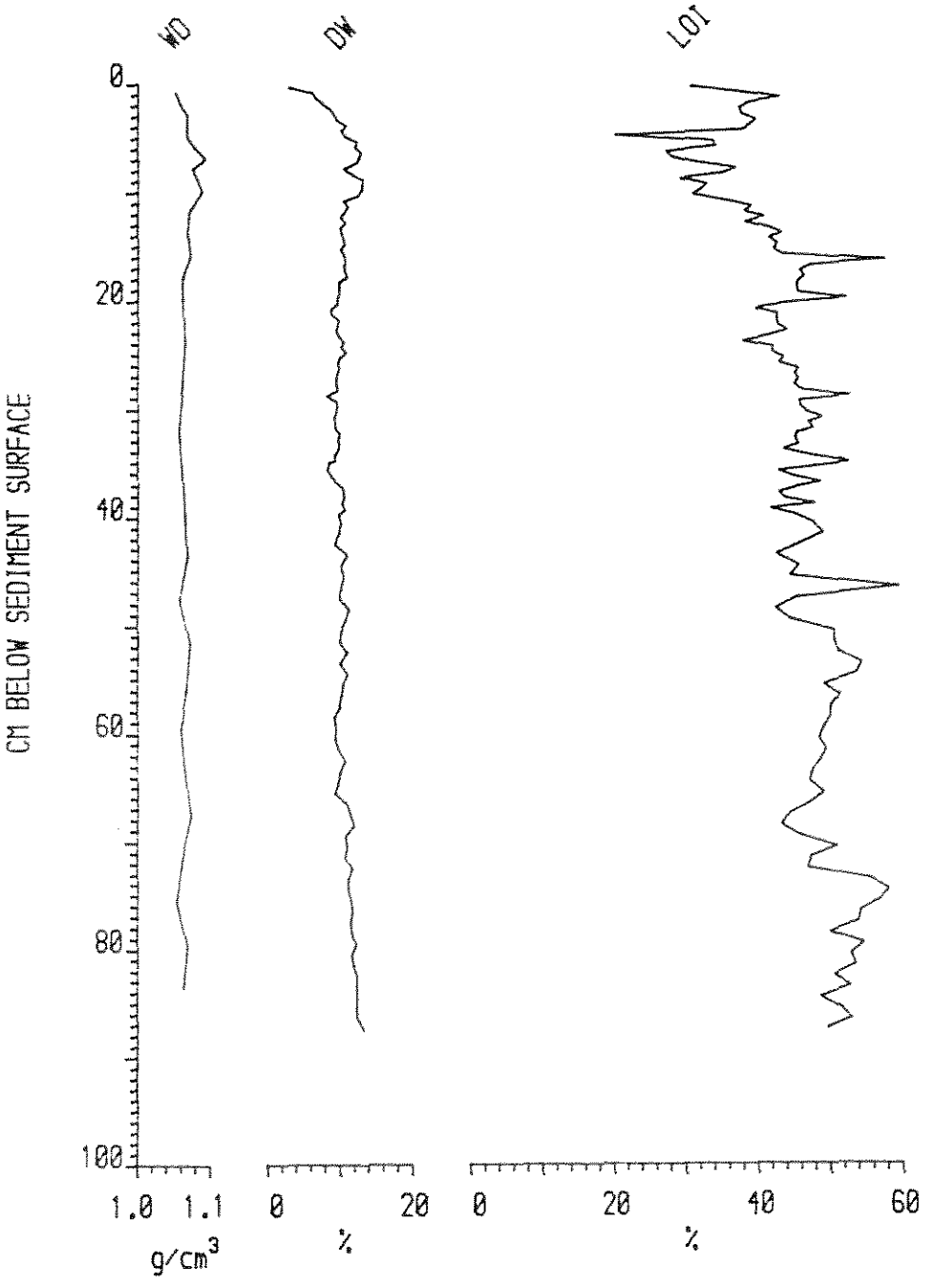


FIG. 3.4.

WET DENSITY, DRY WEIGHT AND LOI FOR DEE

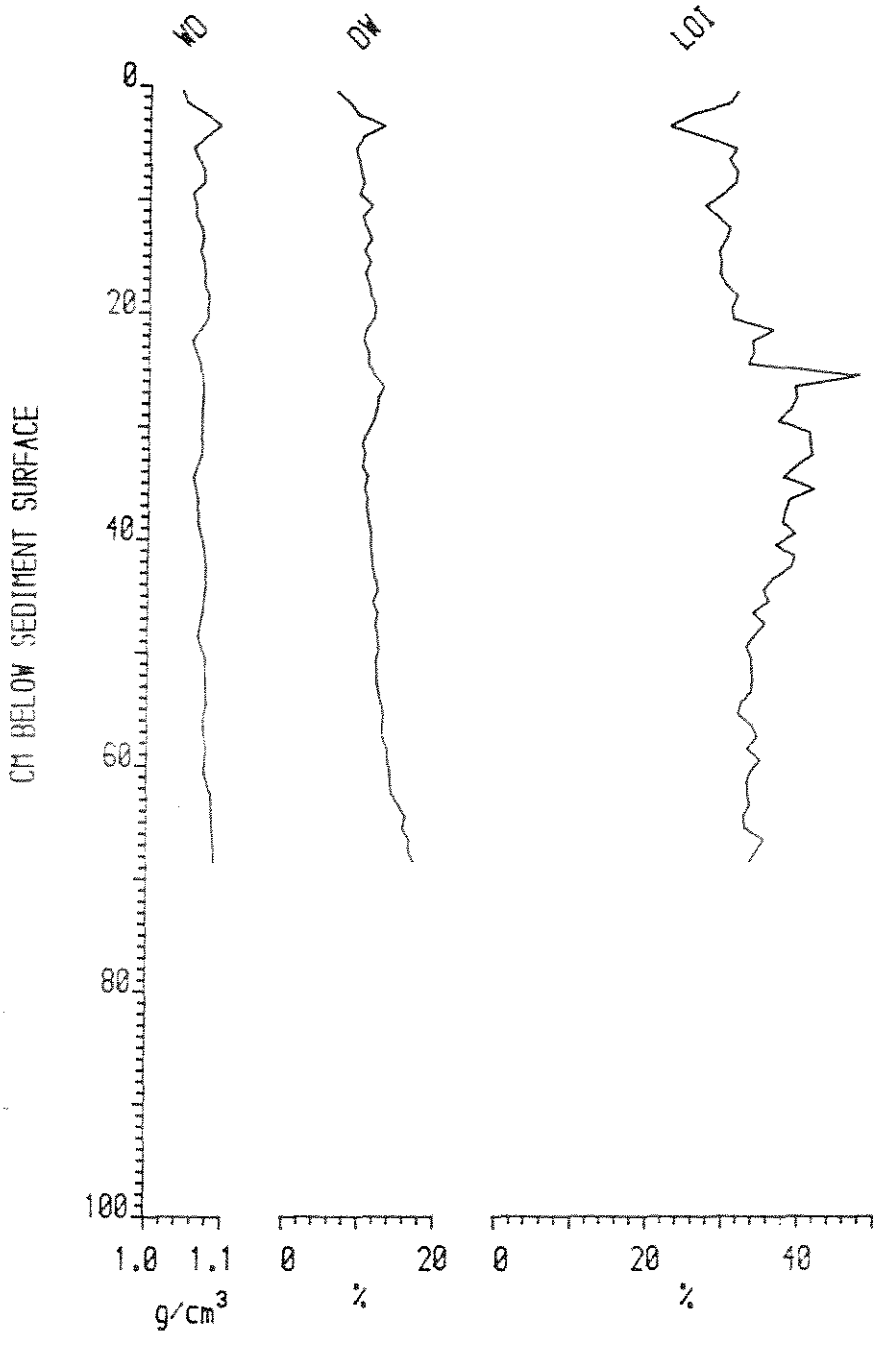


FIG. 3. 5.

WET DENSITY, DRY WEIGHT AND LOI FOR LGR

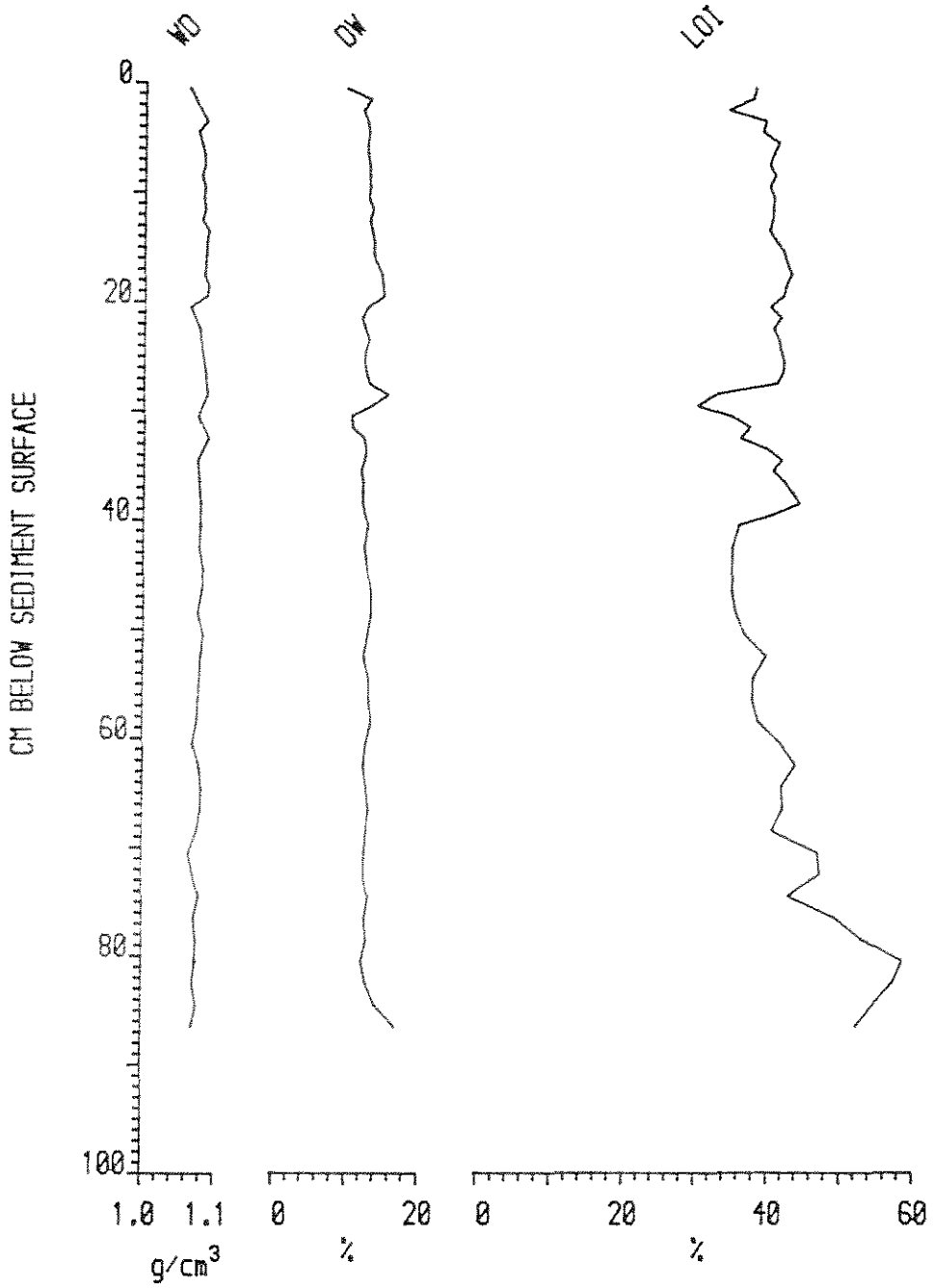
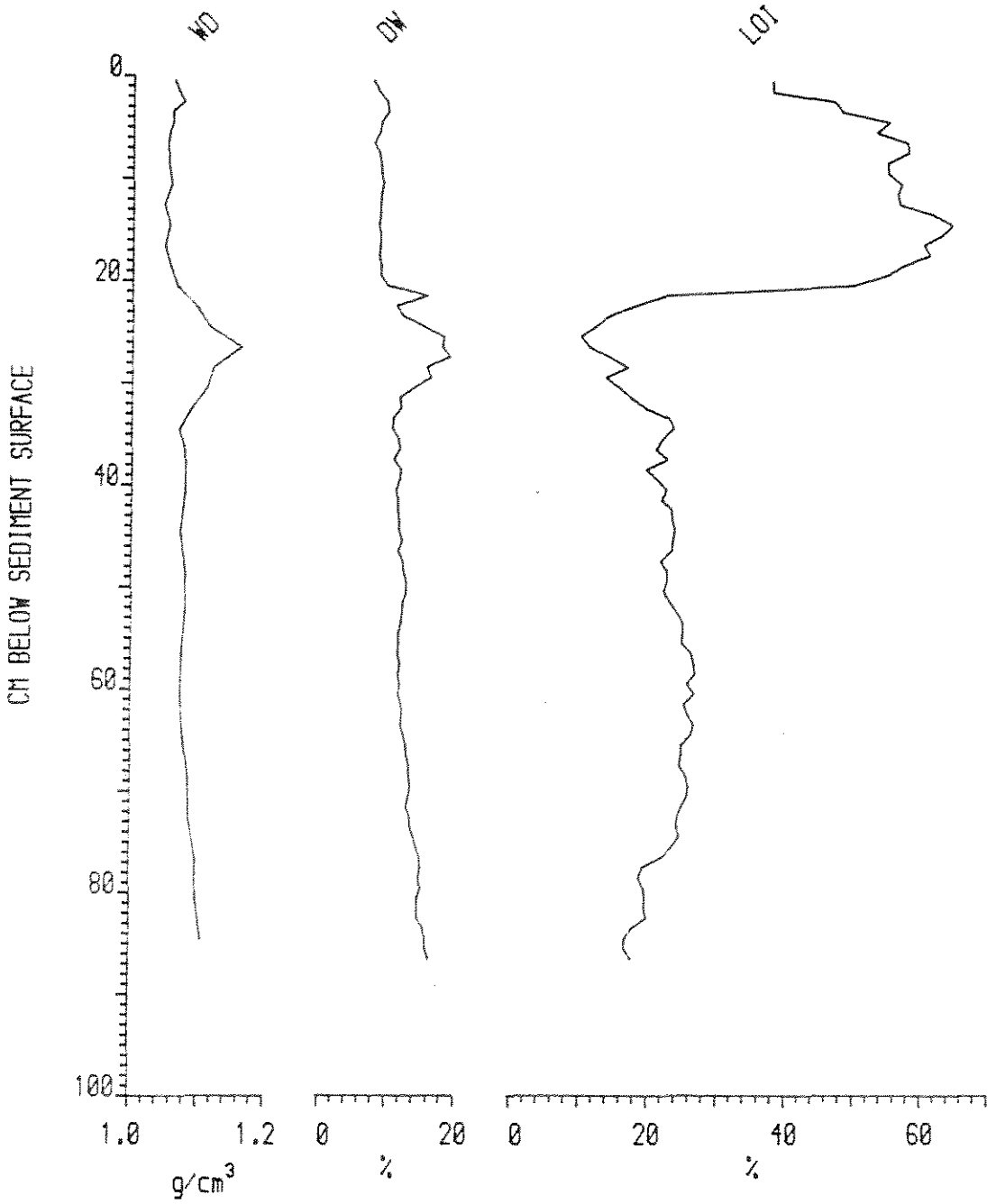


FIG.3.6.

WET DENSITY, DRY WEIGHT AND LOI FOR FLEET



SECTION 4 - RADIOMETRIC ANALYSES AND SEDIMENT DATING METHODS

The concentration of ^{210}Pb was measured in sub-samples of dry sediment from selected depths in each core (see Häsänen 1977). The ^{210}Pb concentration was used to calculate the age of the sample and to enable age depth curves to be constructed for each core. Triplicate ^{210}Pb analysis of L. Dee 4-5 cm sample gave a mean concentration of 25.49 p Ci g^{-1}, with a standard deviation of ±o.84. Age calculations were carried out by assuming the constant rate of supply (c.r.s.) model of unsupported ^{210}Pb accumulation in lake sediments (see Appleby & Oldfield 1978). In sediment cores which did not show a monotonically declining ^{210}Pb concentration (Lochs Dee, Grannoch and Fleet) with depth, measurements of ^{226}Ra were performed to allow estimation of supported ^{210}Pb concentrations. Concentrations of ^{210}Pb and ^{226}Ra are given for each core in Tables 4.1 to 4.6; sediment age and accumulation rate data with cumulative percentage errors (estimated from the ^{210}Pb counting error only) are also included. Age-depth and accumulation rate curves are given in Figs. 4.1-4.6 (for data point errors see Tables 4.1-4.6).

In addition to the ^{210}Pb dating methods three sediment samples were submitted for radiocarbon dating. The three samples selected were from the base of the Round Loch of Glenhead, Loch Dee and Loch Grannoch cores. In each case the adjacent core sections had to be bulked to obtain a total ca 7 g carbon required for the analysis. Results of the radiocarbon dating procedure are given in Table 4.7.

Examination of the ^{210}Pb dating curves for the cores from the Round Loch of Glenhead, Loch Enoch and Loch Valley shows a straight-line relationship between age and depth and a fairly constant rate of sediment accumulation, the rate, however, varies markedly between sites. Sediment accumulation through time has not, however, been so constant in the other three cores, this is especially so for the Loch Grannoch and Loch Fleet. The

TABLE 4.1 ^{210}Pb DATA AND CRS CALCULATED SEDIMENT AGE AND ACCUMULATION RATES FOR THE ROUND LOCH OF GLENHEAD SEDIMENT CORE

Depth (cm)	Total ^{210}Pb (p Ci g^{-1})	Cumulative Unsupported ^{210}Pb (p Ci cm^{-2})	Date (AD)	Age (yr)	Sediment Accumulation Rate (mg cm^{-2} yr^{-1})	Sediment Accumulation Rate (mm yr-1)	Standard Error (%)	^{226}Ra (p Ci g^{-1})
0.0	0.0	8.15	1981	0	-	-	-	-
1.25	31.08±.56	6.75	1975	6± 1	7.6	1.4	3.7	-
2.25	20.32±.59	5.23	1967	14± 1	9.6	1.3	5.0	-
3.25	18.26±.51	4.00	1958	23± 1	8.4	1.1	5.4	-
4.75	11.71±.48	2.64	1945	36± 2	9.8	1.3	7.5	-
6.75	8.25±.28	1.63	1929	52± 3	10.3	1.3	10.0	-
8.75	6.06±.22	1.02	1914	67± 4	11.6	1.4	15.0	-
10.75	4.68±.17	0.68	1901	80± 6	15.6	1.7	22.6	-
12.75	4.44±.12	0.45	1883	93± 9	12.7	1.4	29.8	-
14.75	4.03±.17	0.29	1874	107±13	13.0	1.4	41.9	-
18.75	3.61±.12	0.12	1844	137±29	12.8	1.4	95.0	-
21.75	3.54±.10	0.05	1817	164±37	7.3	0.8	122.7	-
24.75	3.32±.15							
30.25	3.26±.12							
34.75	3.66±.10							
40.50	3.50±.12							
44.50	3.45±.13							
60.50	3.44±.09							
74.50	3.41±.13							

Unsupported ^{210}Pb equilibrium depth is 30.5 cm.

TABLE 4.2 ^{210}Pb DATA AND CRS CALCULATED SEDIMENT AGE AND ACCUMULATION RATES FOR THE LOCH ENOCH SEDIMENT CORE

Depth (cm)	Total ^{210}Pb (p Ci g^{-1})	Cumulative Unsupported ^{210}Pb (p Ci cm^{-2})	Date (AD)	Age (yr)	Sediment Accumulation Rate (mg cm^{-2} yr^{-1})	Sediment Accumulation Rate (mm yr^{-1})	Standard Error (%)	^{226}Ra (p Ci g^{-1})
0.0	-	24.98	1981	0	-	-	-	-
1.25	33.19±.17	20.73	1975	6± 1	20.4	2.1	7.1	-
4.25	21.74±.22	13.75	1962	19± 1	21.1	2.0	3.0	-
8.25	10.09±.12	7.56	1943	38± 1	27.3	2.4	3.1	-
12.25	7.02±.11	4.46	1926	55± 2	25.0	2.2	3.7	-
14.25	5.14±.08	3.35	1917	64± 2	28.5	2.2	4.3	-
17.50	4.29±.06	1.89	1898	83± 2	20.9	1.6	5.7	-
20.50	3.04±.06	1.08	1880	101± 3	21.6	1.7	8.8	-
23.50	2.35±.04	0.60	1861	120± 5	21.2	1.7	14.4	-
26.50	1.99±.05	0.34	1843	138± 7	20.8	1.7	21.0	-
32.50	1.61±.05	0.10	1804	177±16	23.2	1.9	49.6	-
38.50	1.51±.05	0.04	1769	212±18	20.9	1.6	69.9	-
44.50	1.49±.08							
50.50	1.46±.07							
56.50	1.43±.08							
62.50	1.32±.04							
65.50	1.32±.04							
68.50	1.59±.08							

Unsupported ^{210}Pb equilibrium depth is 41.5 cm

TABLE 4.3 ^{210}Pb DATA AND CRS CALCULATED SEDIMENT AGE AND ACCUMULATION RATES FOR THE LOCH VALLEY SEDIMENT CORE

Depth (cm)	Total ^{210}Pb (p Ci g^{-1})	Cumulative Unsupported ^{210}Pb (p Ci cm^{-2})	Date (AD)	Age (yr)	Sediment Accumulation Rate (mg cm^{-2} yr^{-1})	Sediment Accumulation Rate (mm yr^{-1})	Standard Error (%)	^{226}Ra (p Ci g^{-1})
0.0	-	20.32	1981	0	-	-	-	-
1.25	36.41±.28	18.41	1978	3± 1	17.9	2.1	3.2	-
4.75	24.61±.20	9.54	1957	24± 1	14.7	1.3	3.9	-
6.75	14.91±.25	5.56	1939	42± 2	16.4	1.3	5.5	-
9.25	11.14±.22	2.77	1917	64± 3	12.7	1.0	9.1	-
11.25	7.40±.11	1.54	1898	83± 5	15.8	1.3	15.5	-
13.75	6.54±.17	0.82	1878	103± 9	11.7	1.1	27.8	-
16.25	5.30±.15	0.39	1854	127±17	13.1	1.2	34.8	-
25.25	4.30±.09							
35.25	4.32±.30							
45.50	4.34±.09							
50.50	3.89±.12							
55.50	3.54±.07							
65.50	4.10±.06							
75.50	3.20±.12							
79.50	3.35±.13							

^{210}Pb equilibrium depth is 31.6 cm

TABLE 4.4 ^{210}Pb DATA AND CRS CALCULATED SEDIMENT AGE AND ACCUMULATION RATES FOR THE LOCH DEE SEDIMENT CORE

Depth (cm)	Total ^{210}Pb (p Ci g^{-1})	Cumulative Unsupported ^{210}Pb (p Ci cm^{-2})	Date (AD)	Age (yr)	Sediment Accumulation Rate (mg cm^{-2} yr^{-1})	Sediment Accumulation Rate (mm yr^{-1})	Standard Error (%)	^{226}Ra (p Ci g^{-1})
0.0	-	56.70	1980	0	-	-	-	-
1.50	27.43±.21	53.52	1978	2± 1	64.8	7.9	2.7	-
2.50	43.31±.27	50.38	1976	4± 1	37.7	3.3	2.8	-
4.50	25.27±.44	42.50	1971	9± 1	56.3	5.1	3.5	-
7.50	28.81±.25	34.74	1964	16± 1	40.0	3.8	3.9	-
9.50	24.76±.40	29.42	1959	21± 1	39.9	3.6	4.2	1.79±.06
12.50	17.27±.24	22.99	1951	29± 2	46.0	3.9	5.3	-
19.50	8.72±.21	14.10	1935	45± 2	62.0	5.3	7.8	1.64±.04
24.50	6.45±.±0	10.67	1926	54± 3	69.3	5.6	10.1	
29.50	4.44±.07	8.31	1918	62± 4	94.9	7.5	12.6	-
31.50	4.02±.07	7.72	1916	64± 4	105.6	9.3	13.6	-
34.50	3.691.07	7.03	1913	67± 4	114.9	10.1	15.0	-
39.50	3.47±.20	5.99	1903	72± 5	115.9	9.3	17.6	1.86±.11
49.50	2.91±.08	4.27	1897	83± 7	122.1	9.5	28.9	1.82±.11
52.50	2.73±.07	3.85	1894	86± 8	115.4	8.4	25.8	1.69±.07
59.50	2.55±.07	2.91	1885	95±10	103.0	6.8	33.4	1.67±.05
68.50	2.04±.06	1.96	1872	108±15	141.4	8.9	51.3	1.57±.06
69.50	2.13±.05	1.88	1871	109±16	104.9	6.7	52.0	

Unsupported ^{210}Pb equilibrium depth is >70 cm

TABLE 4.5 ^{210}Pb DATA AND CRS CALCULATED SEDIMENT AGE AND ACCUMULATION RATES FOR THE LOCH GRANNOCH SEDIMENT CORE

Depth (cm)	Total ^{210}Pb (p Ci g^{-1})	Cumulative Unsupported ^{210}Pb (p Ci cm^{-2})	Date (AD)	Age (yr)	Sediment Accumulation Rate (mg cm^{-2} yr^{-1})	Sediment Accumulation Rate (mm yr^{-1})	Standard Error (%)	^{226}Ra (p Ci g^{-1})
0.0	-	32.36	1980	0	-	-	-	-
4.50	5.99±.29	31.05	1973	2± 0	301.0	22.5	9.3	-
9.50	5.37±.28	29.06	1976	4± 0	350.7	24.9	11.3	-
15.50	5.41±.18	26.82	1973	7± 0	317.5	21.4	8.1	2.69±.11
19.50	5.81±.20	25.04	1971	9± 0	255.2	17.7	7.6	-
25.50	6.23±.16	22.35	1968	12± 1	198.2	14.6	6.0	-
27.50	8.44±.21	21.19	1966	14± 1	114.6	8.0	4.9	-
28 50	9.29±.28	20.14	1964	16± 1	95.1	6.1	5.4	-
29.50	15.56±.73	18.68	1962	16± 1	46.9	3.3	6.5	-
30.50	26.88±.36	16.38	1958	22± 1	21.1	1.7	3.7	2.68±.10
32.50	13.90±.23	12.35	1949	31± 1	34.2	2.8	4.8	-
33.50	10.49±.25	11.08	1945	35± 1	44.1	3.3	5.8	-
34.50	8.02±.23	10.21	1942	38± 1	59.2	4.5	6.8	-
35.50	6.70±.21	9.61	1941	39± 1	73.7	5.7	7.6	-
37.50	6.04±.13	8.65	1937	43± 2	78.9	6.0	7.5	-
39.50	5.42±.20	7.86	1934	45± 2	87.0	6.3	8.5	-
49.50	4.68±.15	4.58	1917	63± 2	66.6	4.8	10.0	-
59.50	4.07±.11	2.27	1894	86± 4	45.3	3.3	14.4	-
69.50	3.38±.18	0.95	1866	114± 6	35.5	2.6	17.9	-
79.50	3.18±.08	0.32	1831	149± 9	19.6	1.4	26.8	-
85.50	2.97±.05	0.15	1805	179±16	30.4	2.1	30.1	2.82±.01

Unsupported ^{210}Pb equilibrium depth is >86 cm

TABLE 4.6 ^{210}Pb DATA AND CRS CALCULATED SEDIMENT AGE AND ACCUMULATION RATES FOR THE LOCH FLEET SEDIMENT CORE

Depth (cm)	Total ^{210}Pb (p Ci g^{-1})	Cumulative Unsupported ^{210}Pb (p Ci cm^{-2})	Date (AD)	Age (yr)	Sediment Accumulation Rate (mg cm^{-2} yr^{-1})	Sediment Accumulation Rate (mm yr^{-1})	Standard Error (%)	^{226}Ra (p Ci g^{-1})
0.0	-	51.30	1980	0	-	-	-	-
2.50	17.51±.35	48.08	1978	2± 1	111.6	11.8	14.7	-
4.50	12.55±.53	45.88	1976	4± 1	167.1	18.0	15.7	-
9.50	7.16±.24	43.33	1975	5± 1	379.8	44.1	17.7	-
14.50	5.75±.23	42.06	1974	6± 1	598.9	65.3	19.8	3.52±.06[1]
19.50	6.83±.19	40.16	1972	8± 2	337.9	30.3	18.1	-
24.50	6.39±.19	37.09	1970	10± 2	299.3	18.9	19.4	-
27.50	5.61±.19	34.80	1968	12± 3	308.9	15.5	20.8	-
28.50	9.33±.21	33.84	1967	13± 3	143.5	7.7	20.8	-
29.50	10.00±.23	32.56	1965	15± 3	125.1	7.3	21.6	-
30.50	10.49±.20	31.27	1964	16± 3	112.3	7.3	22.4	-
31.50	10.87±.14	30.13	1963	17± 4	103.0	7.7	23.2	-
32.50	8.96±.25	29.20	1962	18± 4	125.4	10.3	24.1	-
34.50	8.09±.25	27.82	1960	20± 4	134.1	11.0	25.3	-
39.50	5.47±.15	25.47	1958	22± 5	200.7	15.9	27.6	-
49.50	4.63±.15	23.21	1955	25± 6	243.3	18.9	30.4	1.62±.05[2]
59.50	4.89±.20	21.95	1953	27± 6	266.4	20.2	32.5	-
69.50	5.43±.15	20.83	1951	29± 7	350.9	24.3	34.4	-
79.50	8.48±.20	17.86	1946	34± 9	200.4	12.6	39.5	-
86.50	9.87±.29	13.85	1933	42±12	175.9	10.6	41.9	7.47±.09[3]

Unsupported ^{210}Pb equilibrium depth is >87 cm

[1] 15.5 cm depth [2] 48.5 cm depth [3] 85.5 cm depth

TABLE 4.7 RADIOCARBON DATING RESULTS FOR THE ROUND LOCH OF GLENHEAD, LOCH DEE AND LOCH GRANNOCH SEDIMENT CORES

Site	Sample Depth In Core (cm)	^{14}C Age (years BP)	$^{13}C/^{12}C$ (0/00)	^{13}C Adjusted Age (years BP)
Round Loch of Glenhead	74-80	1970±80	-26.09	1950±80
Loch Dee	62-68	2110±60	-26.52	208±70
Loch Grannoch	80-87	1780±60	-26.35	1760±60

±Indicate one standard deviation, based on the counting statistic alone.

irregular ^{210}Pb concentration and few ^{226}Ra measurements on the Fleet core make its chronology very tentative and further ^{226}Ra analyses are required. The radiocarbon dating results (Table 4.7) show that sediment at the bases of the three selected cores is about 2,000 years old. However, as some of the carbon in these samples has undoubtedly been derived from eroding catchment peat it is likely that the estimated ages are too old. This is especially so for the Loch Grannoch and Loch Dee cores where the ^{210}Pb calculated sediment dates for the base of each core are only 174 and 109 years BP, respectively.

The variation in ^{210}Pb concentration and consequently the sediment accumulation rate data in Lochs Dee and Grannoch and Fleet doubtless reflect land-use changes. So far, however, only the sediment chronology from Loch Grannoch provides clear evidence relating catchment afforestation methods and accelerating lake sediment accumulation.

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Fig. 4.1. Round Loch of Glenhead.

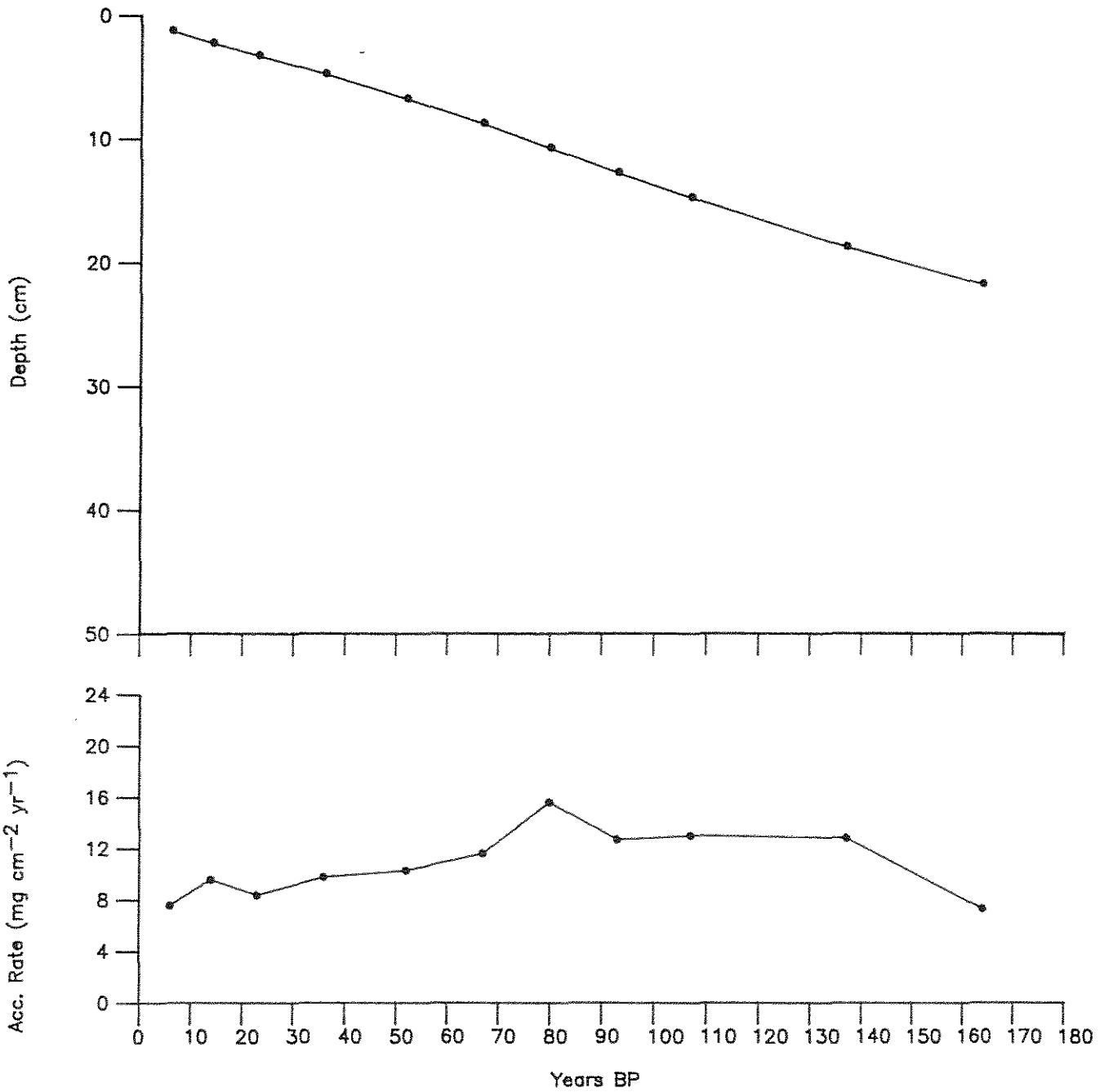


Fig. 4.2. Loch Enoch.

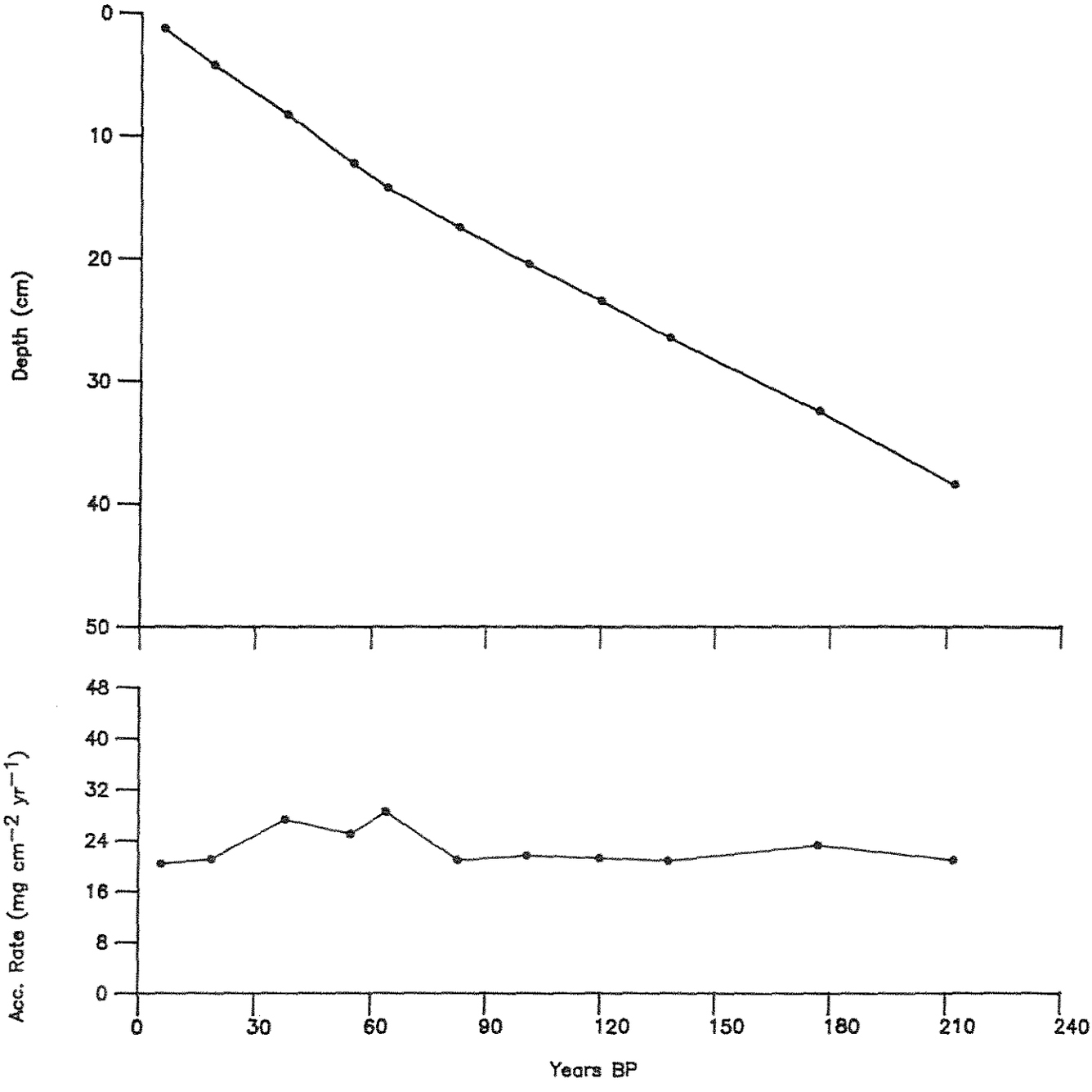


Fig. 4.3. Loch Valley.

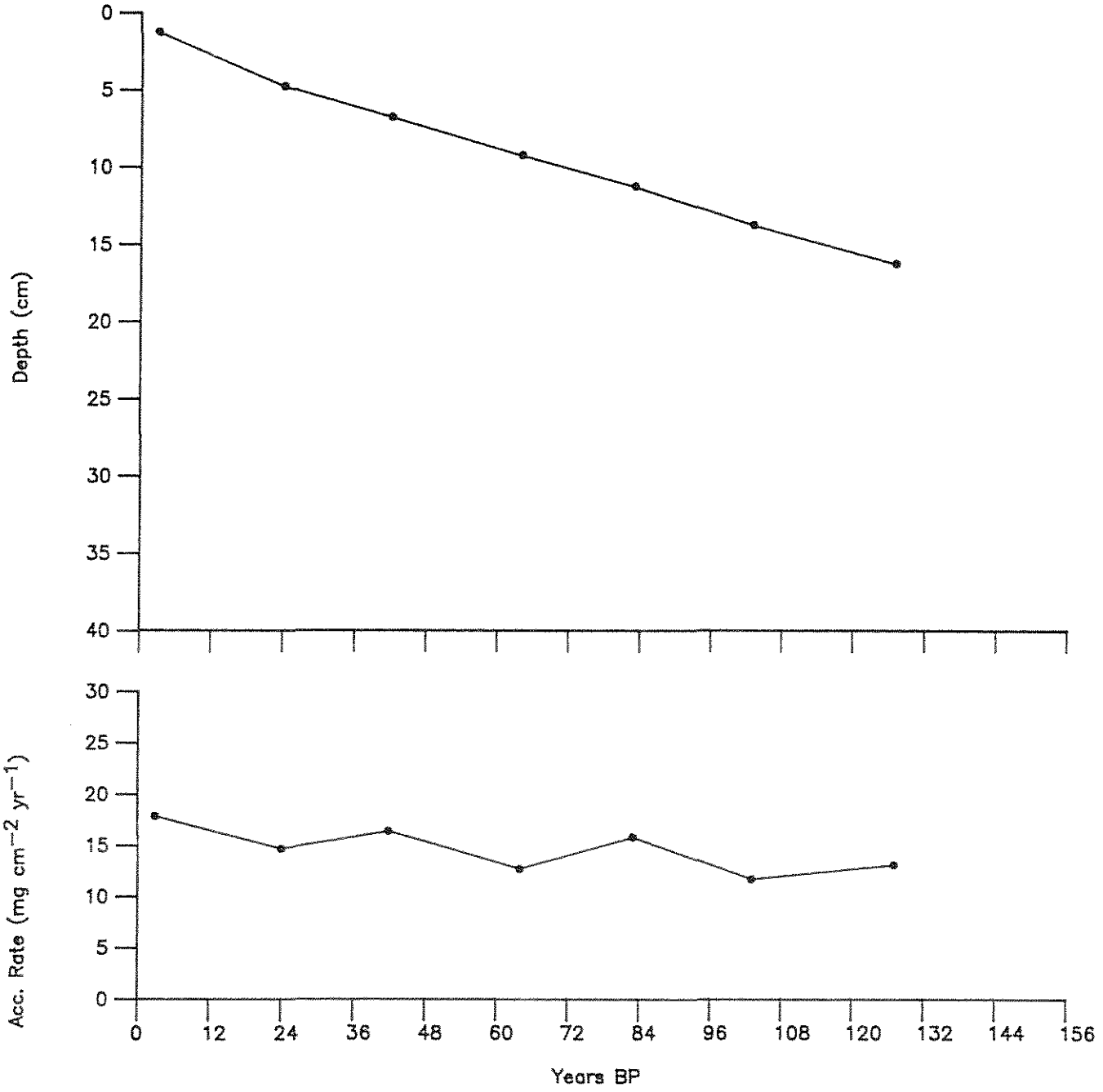


Fig. 4.4. Loch Dee.

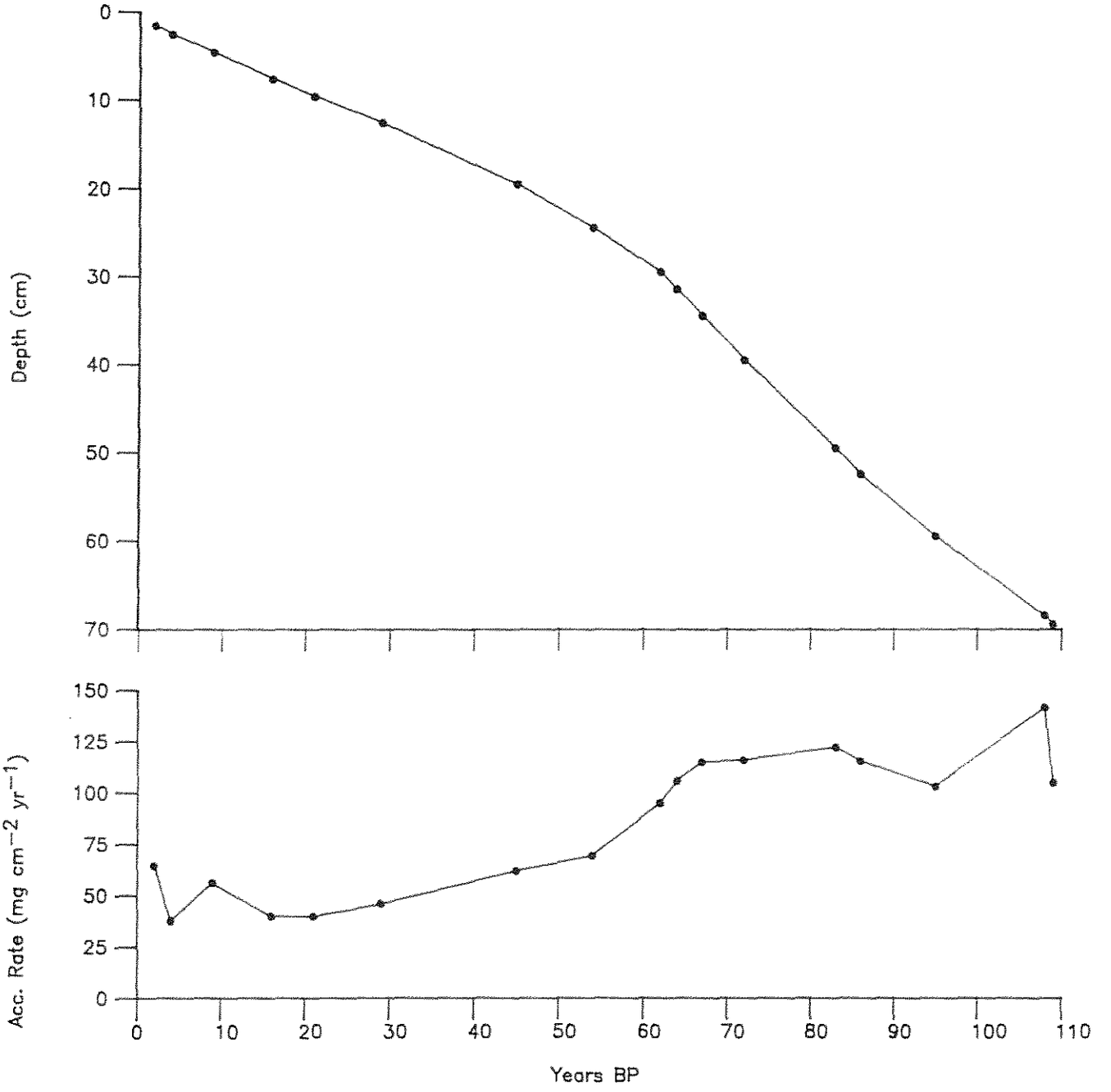


Fig. 4.5. Loch Grannoch.

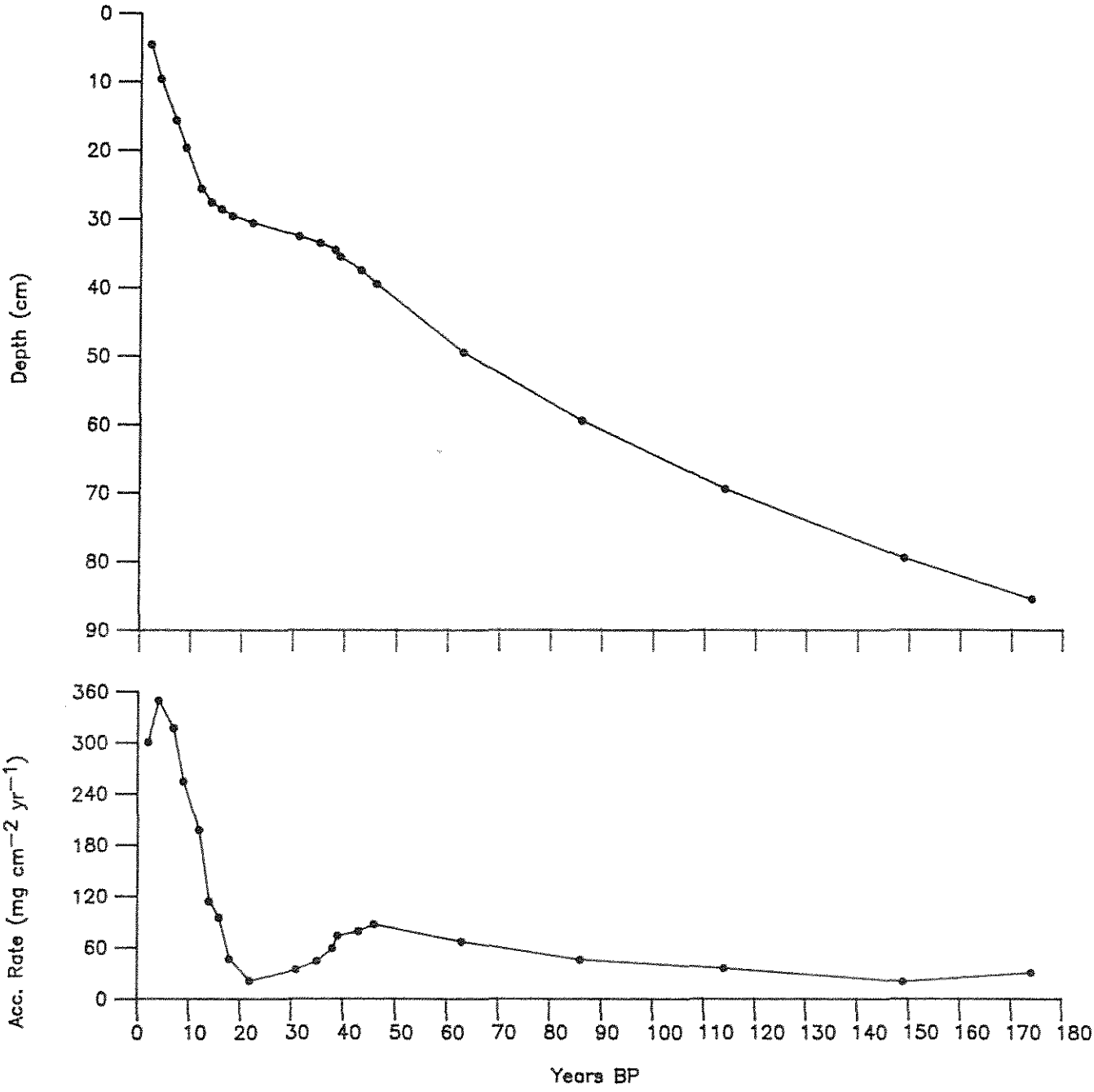
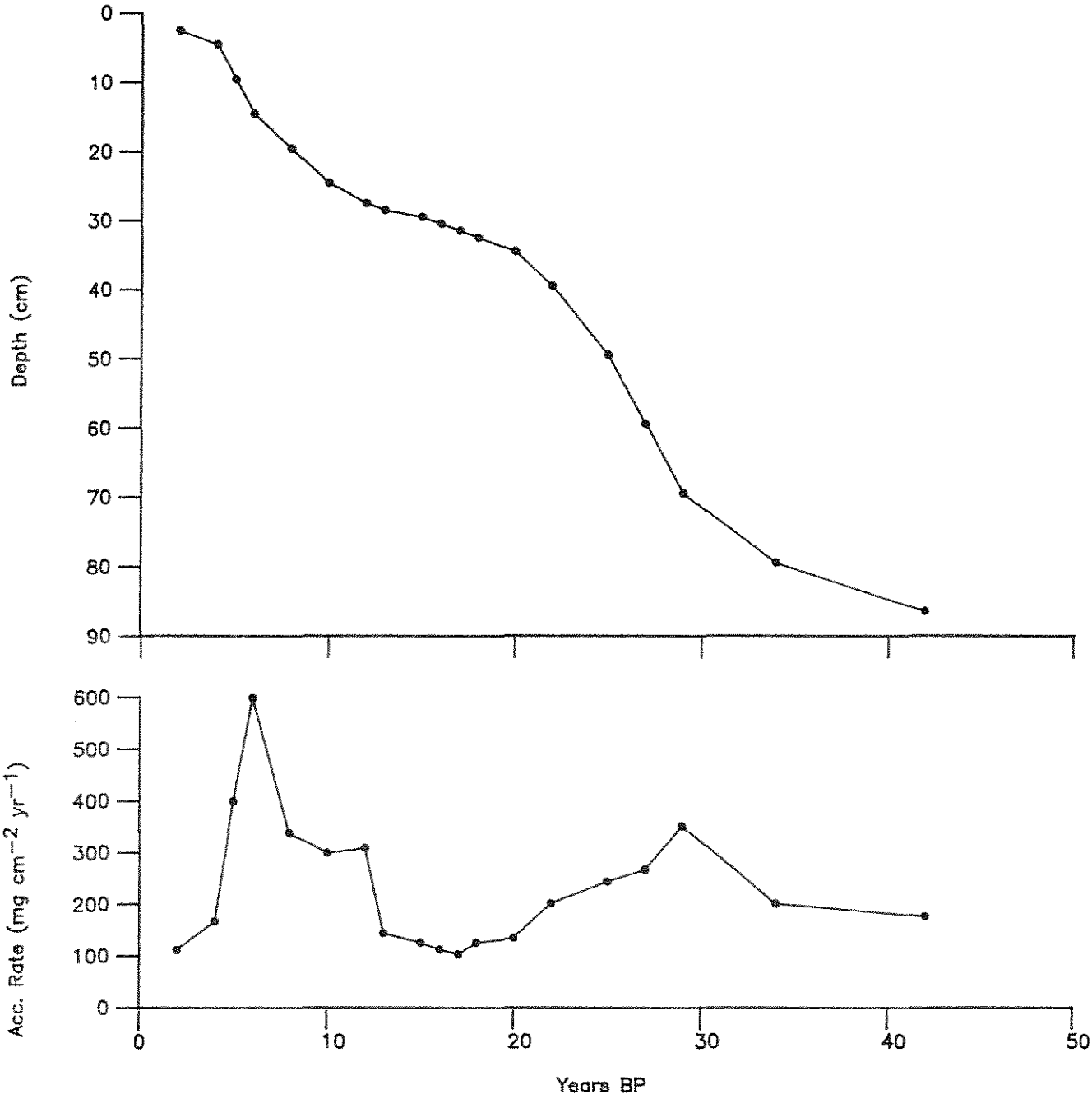


Fig. 4.6. Loch Fleet.



REFERENCES

Appleby, P.G. & Oldfield, F. 1978 The calculation of lead-210 dates assuming a constant rate of supply of unsupported ^{210}Pb to the sediment. Catena 5: 1-8.

Battarbee, R.W. 1978 Observations on the recent history of Lough Neagh and its drainage basin. Phil. Trans. R. Soc. B281: 303-345.

Birks, H.H. 1972 Studies in the vegetational history of Scotland. II Two pollen diagrams from the Galloway Hills, Kirkcudbrightshire. J. Ecol. 60: 183-217.

Harriman, R. & Morrison B.R.S. 1982 Ecology of stream draining forested and non-forested catchments in an area of central Scotland subject to acid precipitation. Hydrobiologia 88: 251-263.

Häsänen, E. 1977 Dating of sediments, based on ^{210}Po measurements. Radiochem., Radioanal. Letters 31: 207-214.

Mackareth, R.J.H. 1969 A short core sampler for subaqueous deposits. Limnol. Oceanogr. 14: 145-151.

Rosenqvist, I.T. 1978 Alternative sources for acidification of river water in Norway. Sci. Tot. Environ. 10: 37-49.

Smith, S. 1813 General View of the Agriculture of Galloway. London, Macmillan; 388 pp.

Wright, R.F. & Henriksen, A. 1980 Regional survey of lakes and streams in southwestern Scotland, April 1979. Internal Report 72/80, SNSF Project, Norway. 63 pp.