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Palaeolimnological Surveys of Lough Erne and Lough Melvin (Northern Ireland)

Final Report to the Department of Environment (NI)
With Funding by the Inter-Reg Programme

N. John Anderson, Simon T. Patrick and Peter G. Appleby

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1. EXECUTIVE SUMMARY

1.1 Aims

The specific aims of the project were:

- A palaeolimnological investigation of Lough Melvin.
- Re-investigation of the Battarbee (1974) Lough Erne cores and application of diatom-phosphorus calibration models to estimate background total phosphorus (TP) concentrations.
- Palaeolimnological analysis of recent cores (taken in 1994) from Lough Erne at three of the locations used by Battarbee.
- Derivation of diatom-inferred phosphorus concentrations for the last 20 years.
- Comparison of the recent (last 20 years) sediment record and diatom-inferred TP with contemporary lake phosphorus data from Aquatic Sciences, DANI.
- Stratigraphic comparison of the 1994 and 1974 cores.

1.2 Results

1. Eight sediment cores were taken in total; two from each site (master and backup): Tongree, Upper Lough Erne; Manor House, Lower Lough Erne; Broad Lough, Lower Lough Erne; main basin, Lough Melvin.

2. All cores were extruded (0.5 and 1 cm intervals) and dry weight and loss-on-ignition analyses completed for all levels. Backup cores have been archived at the Environmental Change Research Centre, University College London.

3. Master cores (three from Lough Erne and one from Lough Melvin) have been dated by the University of Liverpool using radiometric methods. Dating results indicate very high recent sediment accumulation rates at the Upper Lough Erne site (core TG2); 0.93 g cm^{-2} yr^{-1}; ~3 cm yr^{-1}) and at the Manor House site in Lower Lough Erne (core MH2) (0.44 g cm^{-2} yr^{-1}; >1.5 cm yr^{-1}). The Broad Lough has lower rates of sediment accumulation (0.2 g cm^{-2} yr^{-1}) and Lough Melvin substantially lower (0.032 g cm^{-2} yr^{-1}). The dry mass accumulation rate profiles from the Manor House and Broad Lough cores indicate increased sediment accumulation rates since ~1940, and these results confirm those from the earlier investigations.

   The long term increase in sediment accumulation rates are probably the result of increased drainage and agricultural activity in the Lough Erne catchment. The short term variations are probably related to lake level fluctuations in Lower Lough Erne and flooding events in the riverine Upper Lough.

4. Battarbee's data from the 1974 cores have been re-coded and TP inferred using the North-west European training set. Results suggest that historical TP concentrations were not substantially lower than present day levels.

5. Diatom analyses were undertaken for all four master cores. Diatoms were largely dissolved by 5 cm depth at Lough Melvin. Results for the 1994 Manor House and Broad Lough cores suggest that there has been considerable change in the diatom flora between the 1974 and 1994 cores. There are, however, some taxonomic problems/differences still to be resolved. For example, *Cyclostephanos* cf. *tholioformis*, a small (~5-6 μm diameter) centric diatom is important at both sites but was not found by Battarbee. *Skeletonema subsalsum* was first recorded in the lake in 1980 (Gibson *et al.*, 1993) and is well recorded at the Manor House site. The ^{210}Pb date for its initial expansion (~1979) in the Manor House core agrees very well with the phytoplankton data.

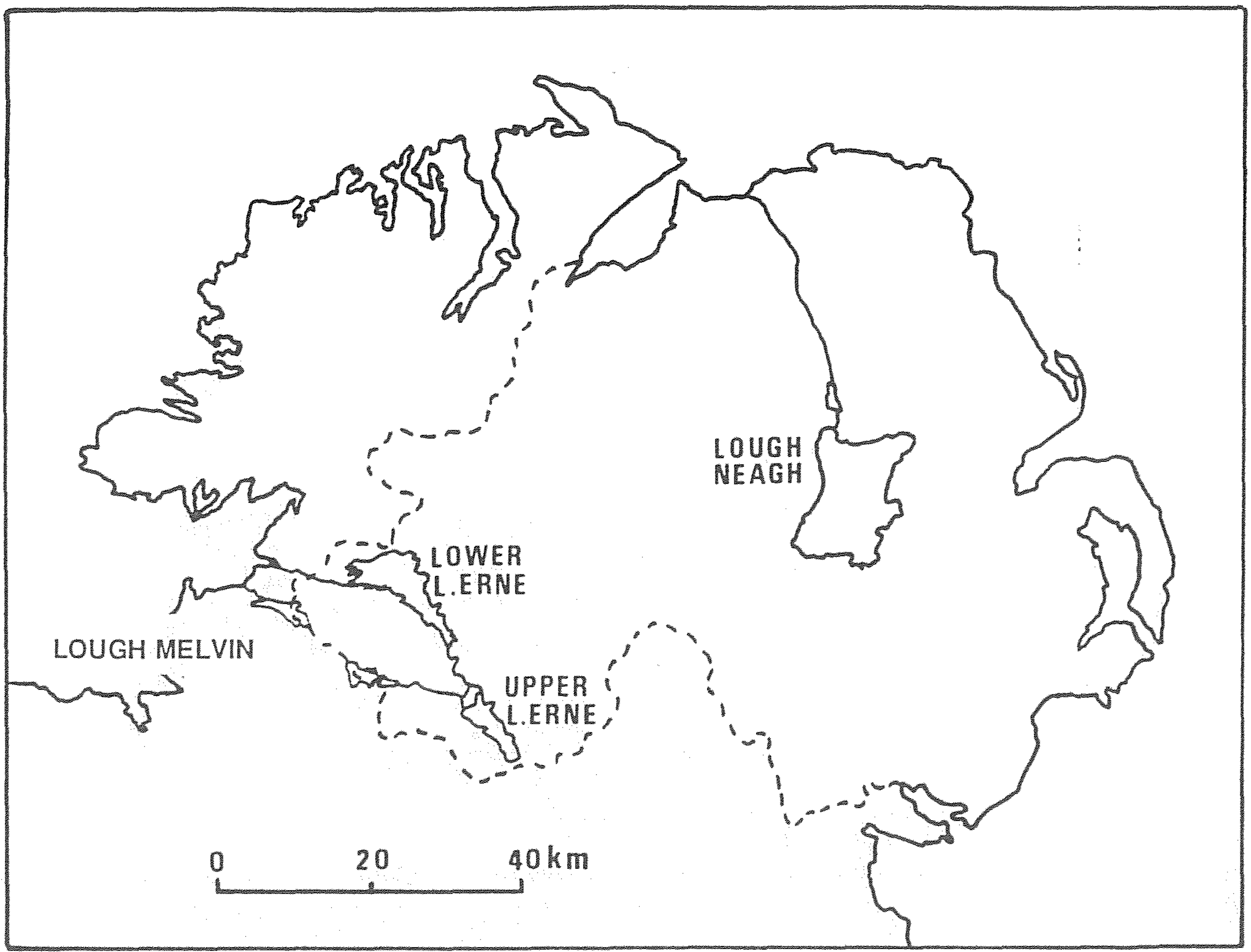
6. The mean diatom-inferred (DI) TP estimates for the last 15-20 years are higher than the monitored values (DI-TP values are: Tongree 138 μg TP l^{-1}; Manor House, 143 μg TP l^{-1}; and the Broad Lough 87 μg TP l^{-1}). There is also an upward trend in the DI-TP values at the Manor House and Broad Lough core sites, which contrasts with the relatively stable values derived obtained by DANI. These differences are probably due to the dominance of *Skeletonema subsalsum* and *Stephanodiscus* cf. *mintulus* in the 1994 cores at Tongree, Manor House and Broad Lough, neither of which are found in the Northern Irish diatom-phosphorus dataset nor in the expanded North-west European training set.

2. INTRODUCTION

Eutrophication continues to a major problem for freshwaters in Northern Ireland (HMSO, 1990; Gibson *et al.*, 1995). Nutrient point-sources, as elsewhere, have been relatively easy to reduce (Foy *et al.*, 1995). However, P loss from agricultural land (i.e. diffuse inputs) has been implicated in the recent observed increase in P in Lough Neagh by both contemporary sampling programmes and process studies (Foy *et al.*, 1995). For the smaller water bodies in the Province, a palaeolimnological investigation of six rural lakes also concluded that nutrient losses from agricultural land was the most likely cause of the observed post-1950 increase in P concentrations in these lakes (Anderson, 1996).

In contrast to Lough Neagh, the catchment of which includes some of the most productive agricultural land in the Province (i.e. parts of Counties Down and Antrim), Loughs Erne and Melvin, can be considered as lying at the poorer end of an agricultural productivity gradient (Fig. 1). Lough Erne's large and diverse catchment contains a variety of agricultural activity. However, much of the catchment of Lough Melvin is comparatively poor and unproductive, being dominated by upland moorland and scrub-grazing land.

Fig. 1 **Location of Lough Erne (Upper and Lower) and Lough Melvin**



Although Lough Melvin has been studied intermittently by the Aquatic Sciences Division at Department of Agriculture (NI) (DANI), little is known about its background status. By Northern Irish standards, Lough Melvin is considered a relatively pristine lake in terms of its nutrient concentrations (~20 µg TP l^{-1}). As a site with both high amenity and ecological significance (i.e. its trout varieties), it is important to know if the lake is beginning to change. For comparison, the TP concentrations of Upper Lough Erne and the Broad Lough of Lower Lough Erne, are in the region of 70-80 and 40-50 µg TP l^{-1}, respectively (Foy *et al.*, 1993).

It is the possibility of deriving information about the past conditions in a lake by use of its sediment record (Anderson, 1993) that lead the Department of Environment (NI) (DoE[NI]) to support a palaeolimnological survey of both Upper and Lower Lough Erne (Battarbee, 1977; 1986). Battarbee's approach to reconstructing the nutrient history of Lough Erne was essentially qualitative in that it did not provide any estimates of the past P concentrations in the lake. The development of a diatom-P calibration dataset for Northern Ireland (Anderson *et al.*, 1993), now permits the possibility of reconstructing the past TP concentrations by applying this transfer function to the diatom assemblages preserved in the sediments (e.g. Anderson & Rippey, 1994).

It is now over 20 years since the first sediment cores were taken from Lough Erne (Battarbee, 1977; 1986) and for the period since 1974 the lake has been monitored by DANI (Gibson *et al.*, 1980; Foy *et al.*, 1993). There is then, the opportunity to compare the water sampling and phytoplankton data with the sediment record, for both diatoms and total P. The DANI monitoring data indicate that has been little or no change in the P concentrations over the last 20 years within the Lough Erne system.

3. AIMS

The aims of this present study were:

- A palaeolimnological investigation of Lough Melvin.
- Re-investigation of the Battarbee (1974) Lough Erne cores and application of diatom-P calibration models to estimate background TP concentrations.
- Palaeolimnological analysis of recent cores (taken in 1994) from Lough Erne at three of the locations used by Battarbee.
- Derivation of diatom-inferred P concentrations for the last 20 years.
- Comparison of the recent (last-20 years) sediment record and diatom-inferred TP with contemporary lake P data from Aquatic Sciences, DANI.
- Stratigraphic comparison of the 1994 and 1974 cores.

4. STUDY SITES

Lough Erne and Lough Melvin are three of the largest lakes in the north of Ireland (Fig. 1). Lough Erne is situated mainly in Northern Ireland although considerable parts of the catchment of the Upper Lough, in particular, are located in the Republic. The majority of Lough Melvin is in the Republic with its catchment split between the two. The extent of agricultural development of the lakes' catchments (i.e. fertiliser application) tends to be higher in Northern Ireland and so the P loading to Lough Erne reflects these differences. The Lough Melvin catchment is less developed than the majority of the Erne catchment, with correspondingly lower P loadings. The mean depths of Lower Lough Erne and Lough Melvin are similar but the largely riverine Upper Lough Erne is generally much shallower (Table 1). It has been estimated that 40% of Upper Lough Erne and approximately 10% of the area of Lough Melvin are islands. The water chemistry and limnology of Lough Erne have been described in detail by Gibson *et al.* (1980), whereas Lough Melvin has been less intensively studied. Phosphorus concentrations have changed little in the Broad Lough as indicated by DANI monitoring data, being 52 μg TP l^{-1} in 1975 and 48 μg TP l^{-1} in 1994. Although the data are more limited, there is little suggestion of significant trends in P concentrations in the Upper Lough. The sewage works at Enniskillen represents a major P input to the Lower Lough (Gibson *et al.*, 1980), whereas the village of Garrison is the primary point sewage source feeding Lough Melvin.

Table 1 Physical characteristics of Upper and Lower Lough Erne and Lough Melvin

	Upper Lough Erne	**Lower Lough Erne**	**Lough Melvin**
Location	54°14′ N 7°32′ W	54°30′ N 7°50′ W	54°25′ N 8°8′ W
Elevation	46 m	45.7 m	40 m
Catchment area	3514 km^2	4212 km^2	217.5 km^2
Lake area*	34.5 km^2	109.5 km^2	24 km^2
Mean depth	2.3 m	11.9 m	8.3 m
Maximum depth	27 m	69 m	45 m
Lake volume	0.08×10^9 m^3	1.3×10^9 m^3	0.199×10^9 m^3
Mean TP concentration	70-80 μg l^{-1}	50 μg l^{-1}	20 μg l^{-1}

* Excluding islands

5. METHODS

5.1 Fieldwork and coring

Fieldwork was undertaken in January 1994, and cores retrieved from Lough Melvin (main basin; Fig. 2) and Upper Lough Erne (Tongree; Fig. 3) and Lower Lough Erne (Manor House; Fig. 3). Due to weather conditions it proved impossible to sample the Broad Lough of Lower Lough Erne during the January fieldwork period. The Broad Lough was eventually cored successfully in August 1994 and a core retrieved from 60 m water depth. Core locations match those of Battarbee's earlier study very closely (Fig. 3).

At all sites, two cores were taken, one for primary data analysis and one for backup (in case of core loss etc.). Both the entire backup core and any remaining sediment from the primary cores will be archived at the Environmental Change Research Centre, University College London (ECRC-UCL).

Fig. 2 **Bathymetry of Lough Melvin, showing the main, 40 m basin, where the core was taken**

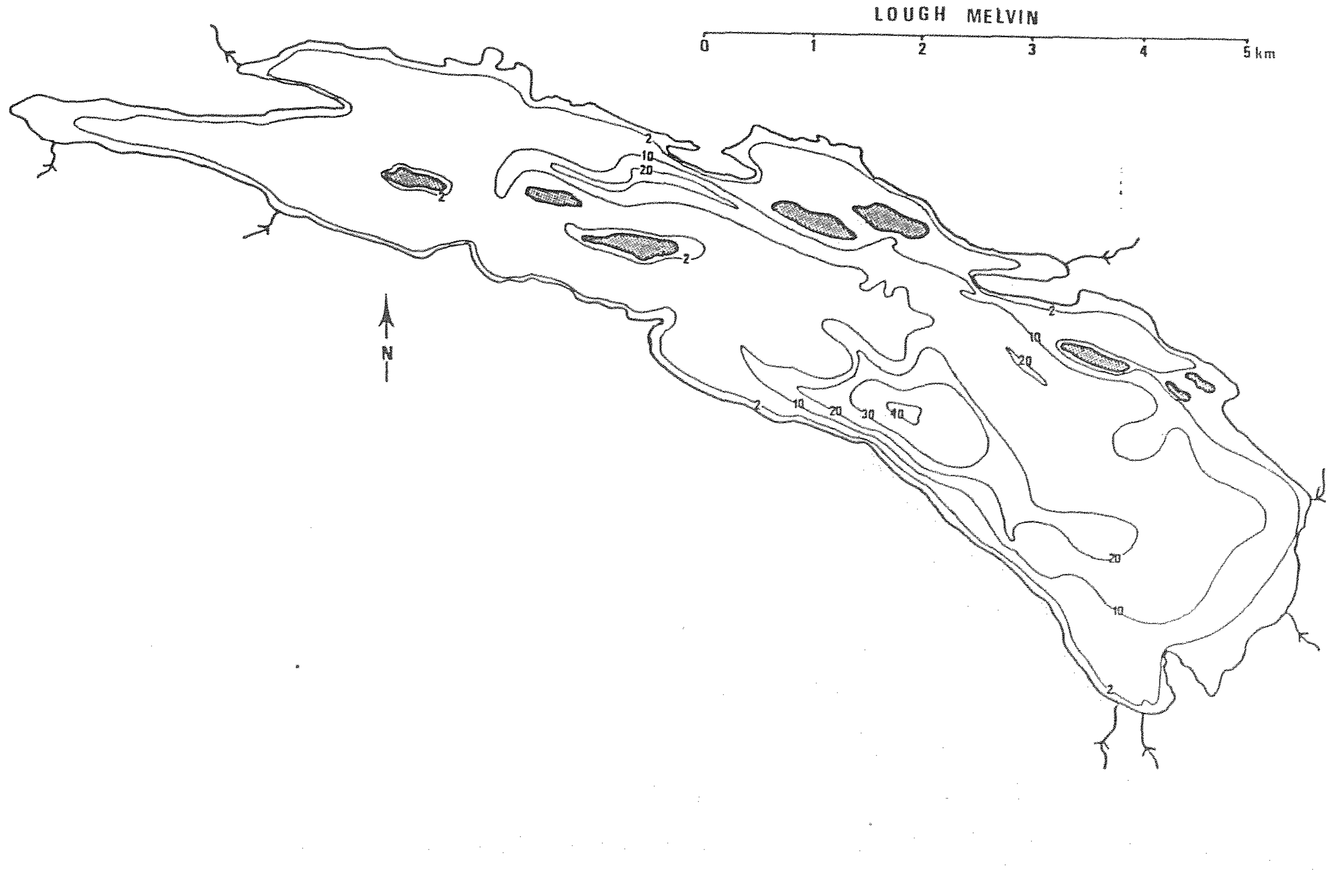
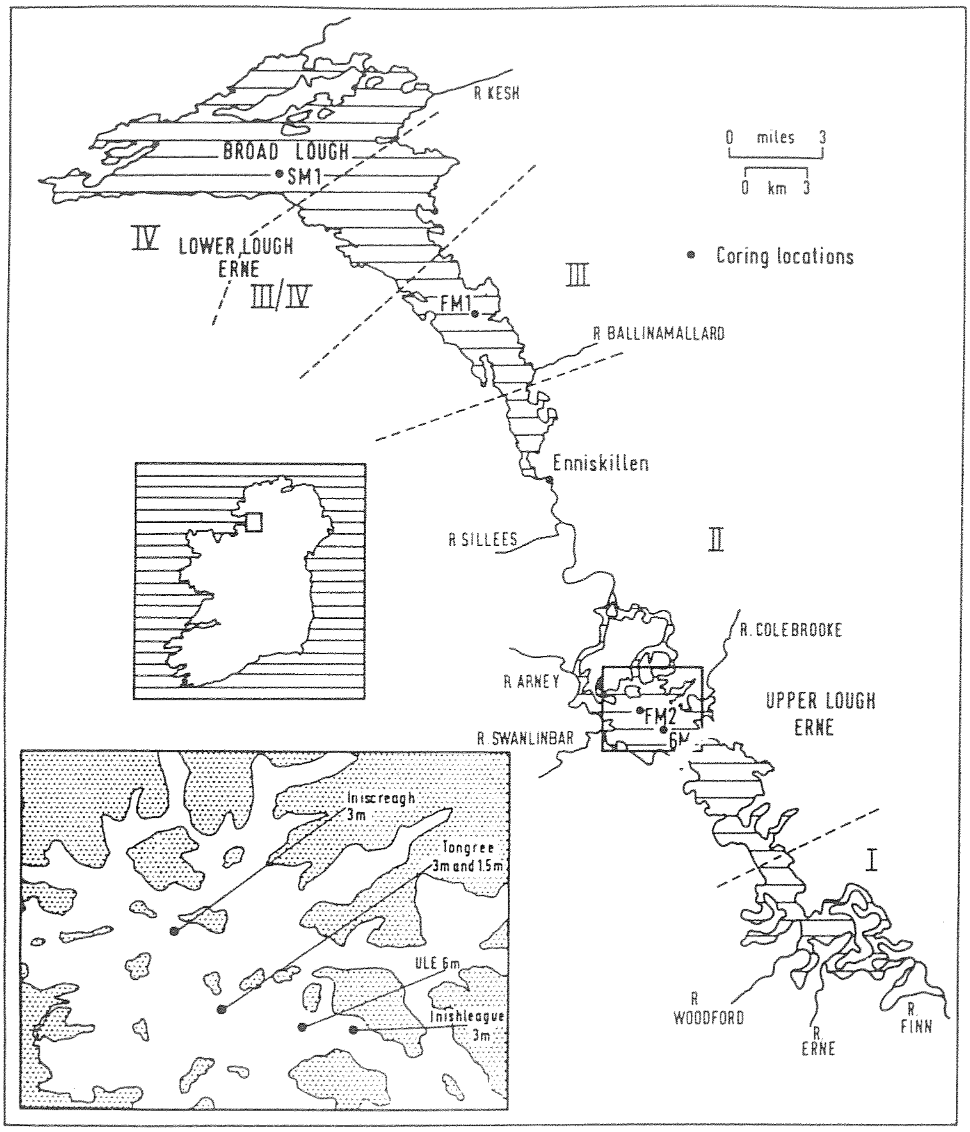


Fig. 3 Location of coring sites on Upper and Lower Lough Erne



5.2 Laboratory analyses

5.2.1 Core extrusion and sediment analyses

The cores were transported upright to the laboratory at Traad Point (Freshwater Laboratory, University of Ulster) where they were extruded vertically and placed in plastic bags. All cores were extruded at 0.5 cm intervals over the surface 20-30 cm, in order to obtain the best possible resolution. Below this depth (30 cm) cores were extruded at 1 cm intervals. This extruding strategy proved to be largely irrelevant given the very high accumulation rates found at the Upper Lough Erne and Manor House sites.

Sediment dry weight (percent DW) was determined by drying overnight in an oven at 105°C, and organic content by loss-on-ignition (LOI; two hours at 550°C) and carbonates (LOI for one hour at 1000°C). Wet density (g cm^{-3}) was determined by packing a brass vial of known volume. These analyses were undertaken at the ECRC-UCL.

Samples were shipped to the Geobotany Division at the Geological Survey of Denmark (DGU), where they were freeze dried and sub-samples extracted for diatom analysis.

5.2.2 Diatom analyses

The methodology used for the preparation of the sediment samples for diatom analysis followed Renberg (1991). The relative frequency abundance of all species (including unidentified forms) was determined as the percentage of the total diatom count (Battarbee, 1986).

Diatom-inferred total P (DI-TP) was calculated using a weighted averaging partial least squares (WA-PLS) model. WA-PLS is a recent development (ter Braak & Juggins, 1993) which utilises more information in the species distributions than does simple Weighted Averaging. WA-PLS has been shown to result in better predictive models when used with large datasets, such as the North-west European combined dataset. Species optima were derived from the North-west European training set which is a combination of five regional datasets (the main ones being from Northern Ireland, South-east England, English Meres and Denmark) and covers a wide range of TP concentrations (10-1000 μg TP l^{-1}) (Bennion *et al.*, 1996).

A two component WA-PLS model was used for the historical reconstructions, as this model has the lowest errors of prediction, determined by jack-knifing ($RMSE_{jack} = 0.21 \log_{10}$ TP units) (Bennion *et al.*, 1996). The calculations were made using the program CALIBRATE (Juggins & ter Braak, unpublished computer program) with mean annual TP, transformed to $\log_{10}$. Final diatom-inferred values reported here have been back transformed from $\log_{10}$ values.

5.3 Dating

After freeze drying and sub-sampling for diatom analyses, the remaining sediment from the master cores only was sent to the Radiometric Dating Laboratory at the University of Liverpool. Samples were analysed for ^{210}Pb, ^{226}Ra, ^{241}Am, ^{137}Cs and ^{134}Cs using standard gamma assay (Appleby *et al.*, 1986; Appleby *et al.*, 1991).

Core chronologies were determined by the CRS (constant rate of supply) model (Appleby *et al.*, 1978; Appleby & Oldfield, 1983) although for the Upper Lough Erne core, TG2, the ^{210}Pb chronology was constrained by using the ^{137}Cs peaks as reference levels (Oldfield & Appleby, 1984).

The full ^{210}Pb dating report by Peter Appleby is included here as Appendix 1.

6 RESULTS

6.1 Tongree (Upper Lough Erne)

6.1.1 Coring

Cores were retrieved from a water depth of approximately 14 m, close to the position of the 1974 6 metre Mackereth core; i.e. slightly upstream of the original ULE-FM 2 core. This slightly different location is not considered to be significant in terms of this study. The analysed core, TG2, was 92 cm in length.

6.1.2 Dry weight and LOI (Fig. 4)

LOI is nearly constant at 17% throughout the length of the core (Fig. 4). Percent dry weight varies around 26-29% below 20 cm depth, above which it declines steadily, reaching ~10% at the core surface. LOI percentages at 1000°C are very low (< 5%) and indicative of minimal $CaCO_3$ content.

6.1.3 Dating

This site proved to have extremely high sediment accumulation rates (> 3 cm yr^{-1}) covering a period of only ~40 years. Unsupported ^{210}Pb activity was very low throughout the core and the chronology for this core is largely based on a well resolved Chernobyl ^{137}Cs peak (1986 = 28 cm). The accumulation rate derived from this dated level was then extrapolated to the base of the core and the ^{210}Pb chronology calculated accordingly. The sediment accumulation rate in this core was sufficiently high that the weapons testing ^{137}Cs peak was not found.

6.1.4 Diatoms (Fig. 5)

The core is dominated by a number of planktonic taxa and lower percentages of benthic *Fragilaria* species. The main change is the replacement of *Stephanodiscus parvus* by *Skeletonema subsalsum* as the dominant species above 25 cm depth (ca. 1988). *Cyclostephanos* cf. *tholiformis* was relatively constant throughout the analysed section while *Aulacoseira granulata* replaced *A. ambigua* above 15 cm depth. *A. islandica* declined to trace levels at 20 cm. There is an indication that *Cyclostephanos dubius* was increasing in abundance in the basal sample analysed (45 cm).

6.1.5 Diatom-inferred TP (Fig. 6)

Prior to 1986, DI-TP values varied between 110 and 130 μg TP l^{-1}. Values dropped to ~100 μg TP l^{-1} around 1990 but then increased to 175-200 μg TP l^{-1} in the most recent levels. The mean DI-TP value is 138 μg TP l^{-1} (range: 97-205). The measured TP values for Upper Lough Erne are ~70 μg TP l^{-1}.

Figure 4 Dry weight and LOI (550°C and 1000°C [carbonates]) for Upper Lough Erne (Tongree)

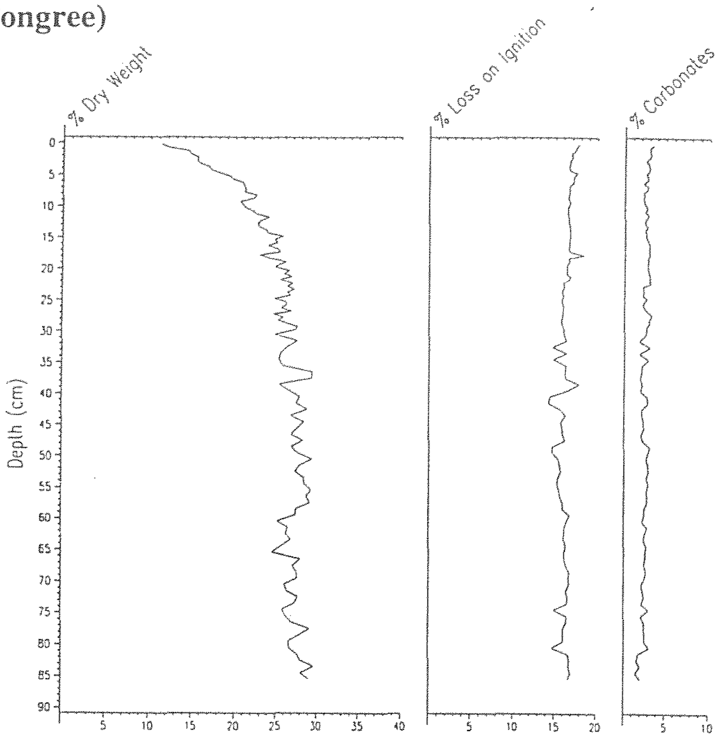


Figure 5 Diatom stratigraphy for Upper Lough Erne - Tongree (TG2), 1994 core

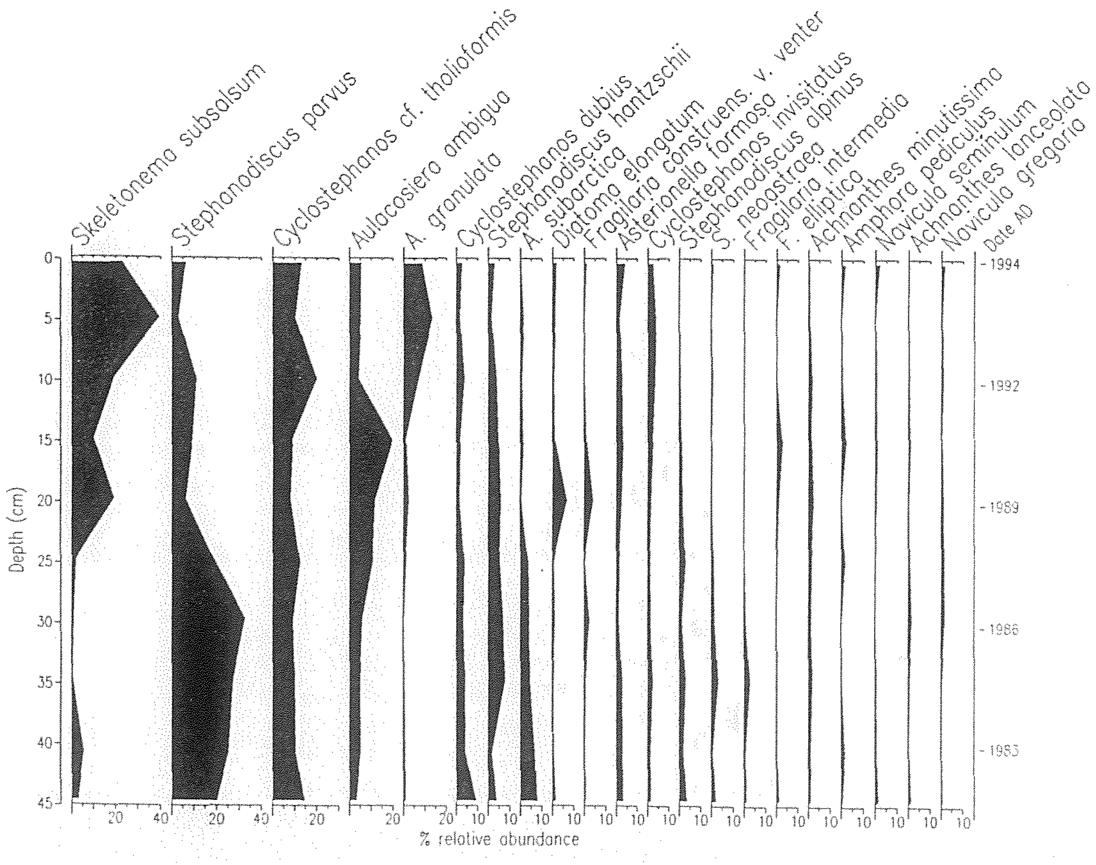
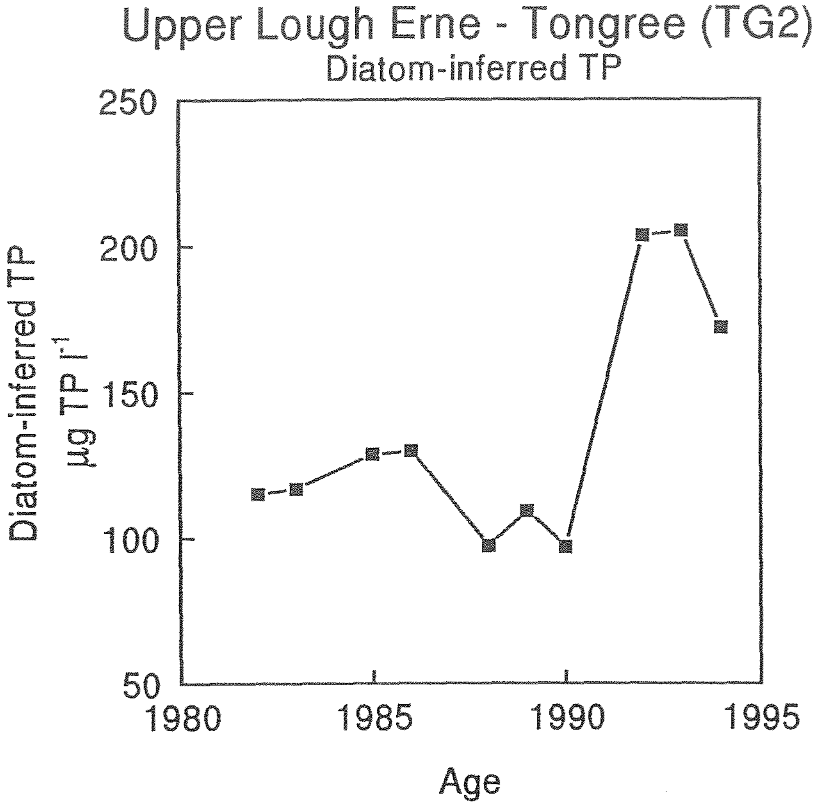


Figure 6 Diatom-inferred TP for Upper Lough Erne - Tongree (TG2), 1994 core, plotted against ^{210}Pb age



6.2 Manor House (Lower Lough Erne)

6.2.1 Coring

Cores were obtained from 16 m water depth, close to the original location of the 1974 core, LLE-FM1. The core used for analyses was MH2.

6.2.2 Dry weight and LOI (Fig. 7)

Percent dry weight varies around 25% between 20 and 85 cm depth and declines to 10% at the core surface. LOI is nearly constant at 15% throughout the core, although there is a slight increase towards the core surface. Carbonates are below 5% throughout the length of the core.

6.2.3 Dating

Both ^{137}Cs peaks (weapons testing and Chernobyl) were present in this core and there was good agreement between the ^{210}Pb CRS chronology and the ^{137}Cs dates. Total ^{210}Pb activity was low and unsupported ^{210}Pb showed only a slight decline with depth, again indicating a high sediment accumulation rate. The mean accumulation rate increased during the early 1940s and post 1950 accumulation rates are around 1.5 cm yr^{-1}, approximately twice those estimated for the period prior to 1940.

6.2.4 *Diatoms (Fig. 8)*

The diatom assemblages in the surface 40 cm are dominated by planktonic diatoms, primarily small centrics (including *Skeletonema subsalsum*), together with *Aulacoseira* spp. *Skeletonema subsalsum* increases from low values around 26 cm (with a slight tail associated with sediment bioturbation), with a second more pronounced increase from ca. 15 cm. There is a reciprocal decline in *Stephanodiscus parvus*. The other dominant diatom throughout the analysed section is *Cyclostephanos tholioformis*. *Aulacoseira ambigua* is present at ~10% below 15 cm but declines above this depth; there is a slight increase in *A. granulata* above 10 cm depth.

The increase in *Skeletonema* around 27 cm depth represents the period (1980) when this diatom arrived in Lough Erne (Gibson *et al.* 1993). This level is dated to 1979 by radiometric methods (see Appendix 1). Allowing for some downward mixing of the diatom assemblages and the small possible error (±2 years) in the dating results, there is very good agreement between the two approaches and confirms the high sediment accumulation rates.

6.2.5 *Diatom-inferred TP (Fig. 9)*

The weighted averaging models (both Ulster and North-west European) considerably overestimate the TP concentrations at this site (Fig. 9). The mean DI-TP was 143 µg TP l^{-1} (range: 89-209 µg TP l^{-1}), which compares with water column estimates of around 70-90 µg TP l^{-1}.

Figure 7 **Dry weight and LOI (550°C and 1000°C [carbonates]) for Lower Lough Erne (Manor House)**

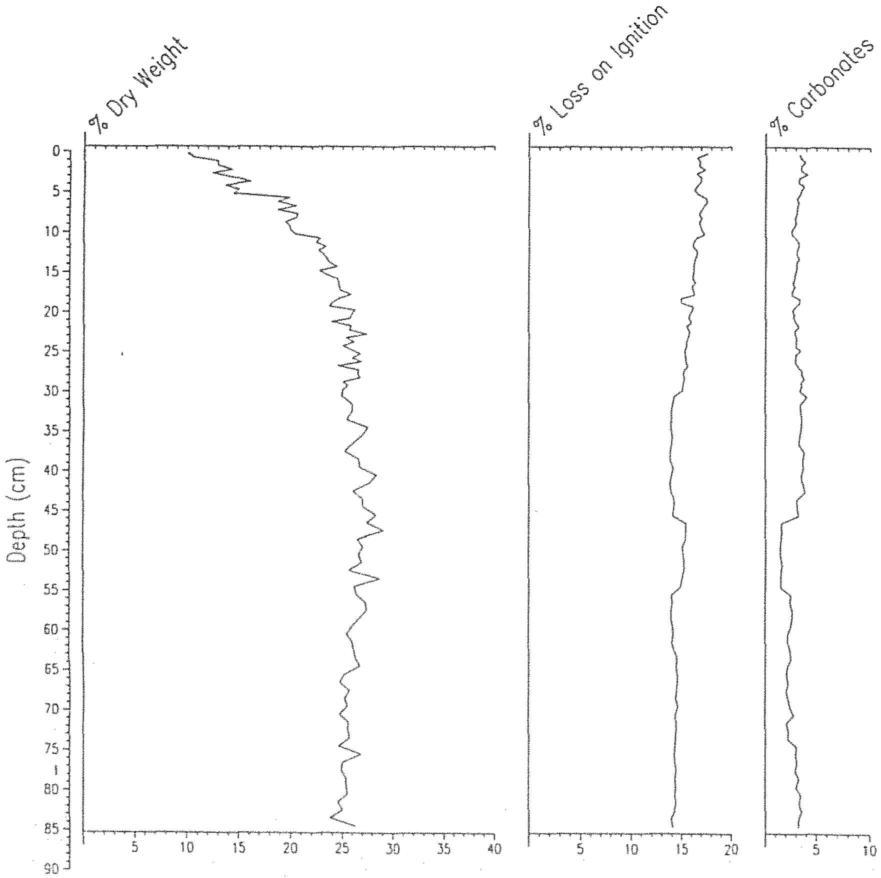


Figure 8 Diatom stratigraphy for Lower Lough Erne - Manor House (MH2), 1994 core

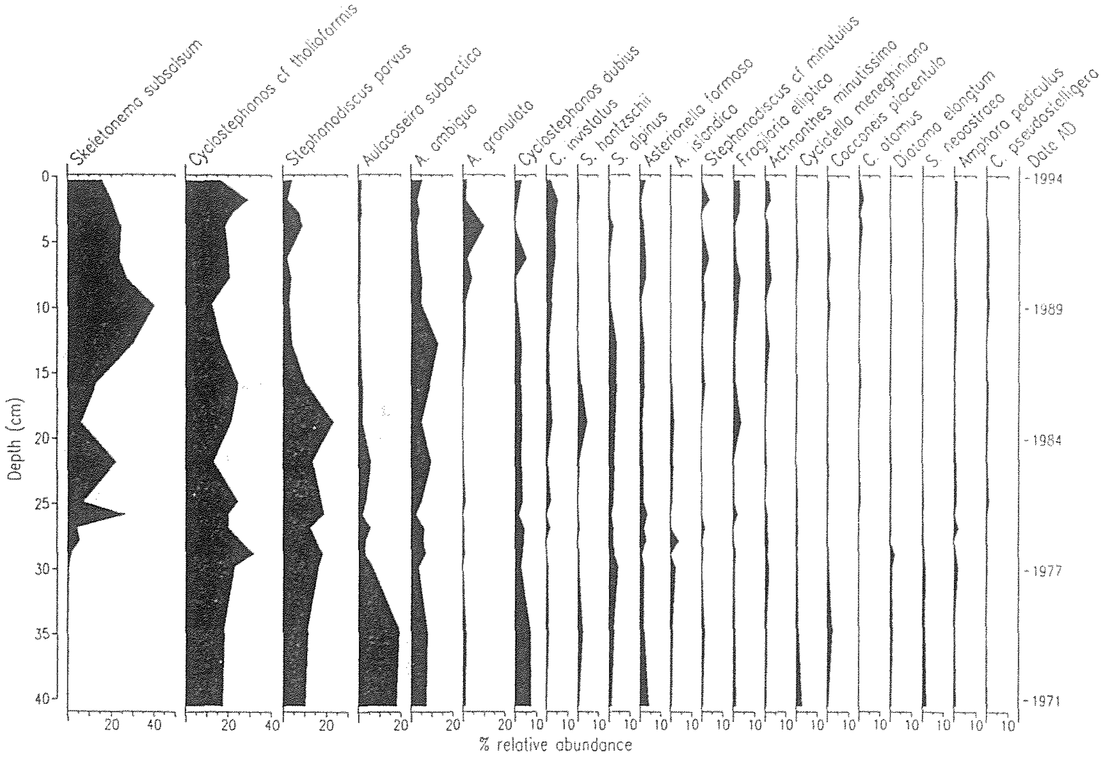
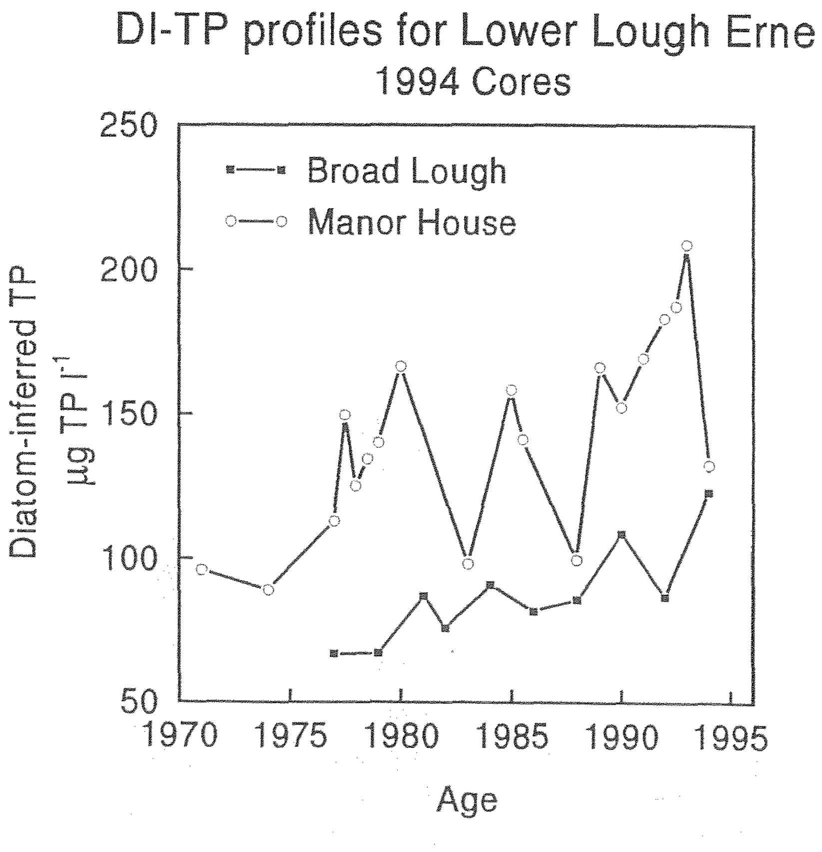


Figure 9 Diatom-inferred TP for Lower Lough Erne - Manor House (TG2) and Broad Lough (BRDL1), 1994 cores, plotted against ^{210}Pb age



6.3 Broad Lough (Lower Lough Erne)

6.3.1 Coring

The analysed core (BRDL1) was nearly 85 cm long and was taken from the deepest part of the basin (60 m water depth), close to the water sampling station used by DANI (Fig. 3).

6.3.2 Dry weight and LOI (Fig. 10)

Percent dry weight declines from ca. 20% at the core base to about 15% at 10 cm depth, above which it declines to ~5% at the core surface. LOI increases steadily from 12% at the core base to nearly 20% at the core surface. There are few features in either profile.

6.3.3 Dating

Total ^{210}Pb activity was higher at this site, and its decline with depth indicate lower sediment accumulation rates compared to the Manor House and Tongree sites. The ^{137}Cs profile had two distinct peaks, the lower of which coincided with ^{241}Am activity, indicating the weapons testing period around 1963 (~28 cm depth). A constrained ^{210}Pb chronology using this dated horizon indicates an increase in accumulation rates during the 1950s. Since 1960, the mean accumulation rate has been 1 cm yr^{-1}, compared to 0.42 cm yr^{-1} prior to 1950.

6.3.4 Diatoms (Fig. 11)

Diatoms were analysed to 18 cm depth (Fig. 11). Owing to the higher than expected sediment accumulation rates, these analysed levels do not overlap with the 1974 core. The assemblages are quite similar to Manor House (Fig. 8), but as found by Battarbee (1984, 1986) *Aulacoseira subarctica* has higher percentages in the Broad Lough, reflecting the lower nutrient conditions there. *Aulacoseira subarctica* declines above 11 cm and there is a reciprocal increase in a small centric, tentatively described as *Stephanodiscus* cf. *minutulus*. *Cyclostephanos* cf. *tholioformis*, as at the Manor House site, is again an important component of the diatom assemblages, but *Skeletonema* has much lower values (generally < 10%).

6.3.5 Diatom-inferred TP (Fig. 9)

The mean inferred TP value for the analysed samples was 87 µg TP l^{-1} (range: 66-123 µg TP l^{-1}), and although lower than Manor House, as is the case with the contemporary values, is still an over-estimate. The lake TP concentrations have been stable around 50 µg TP l^{-1} over the last 20 years (DANI unpublished data).

Figure 10 Dry weight and LOI (550°C) for Lower Lough Erne (Broad Lough)

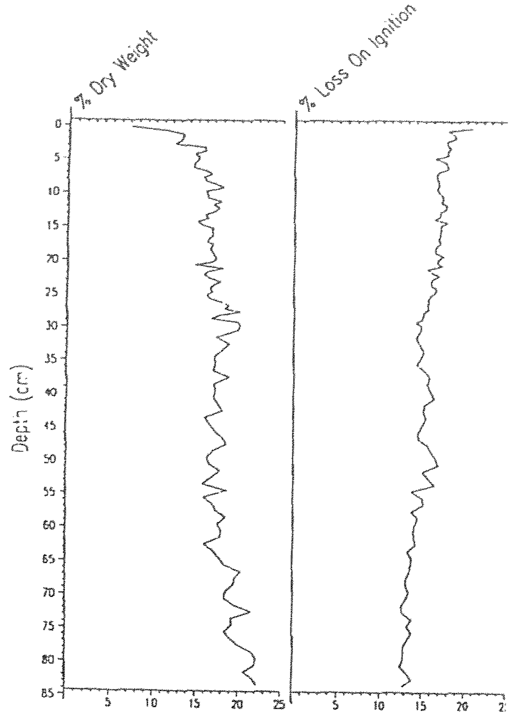
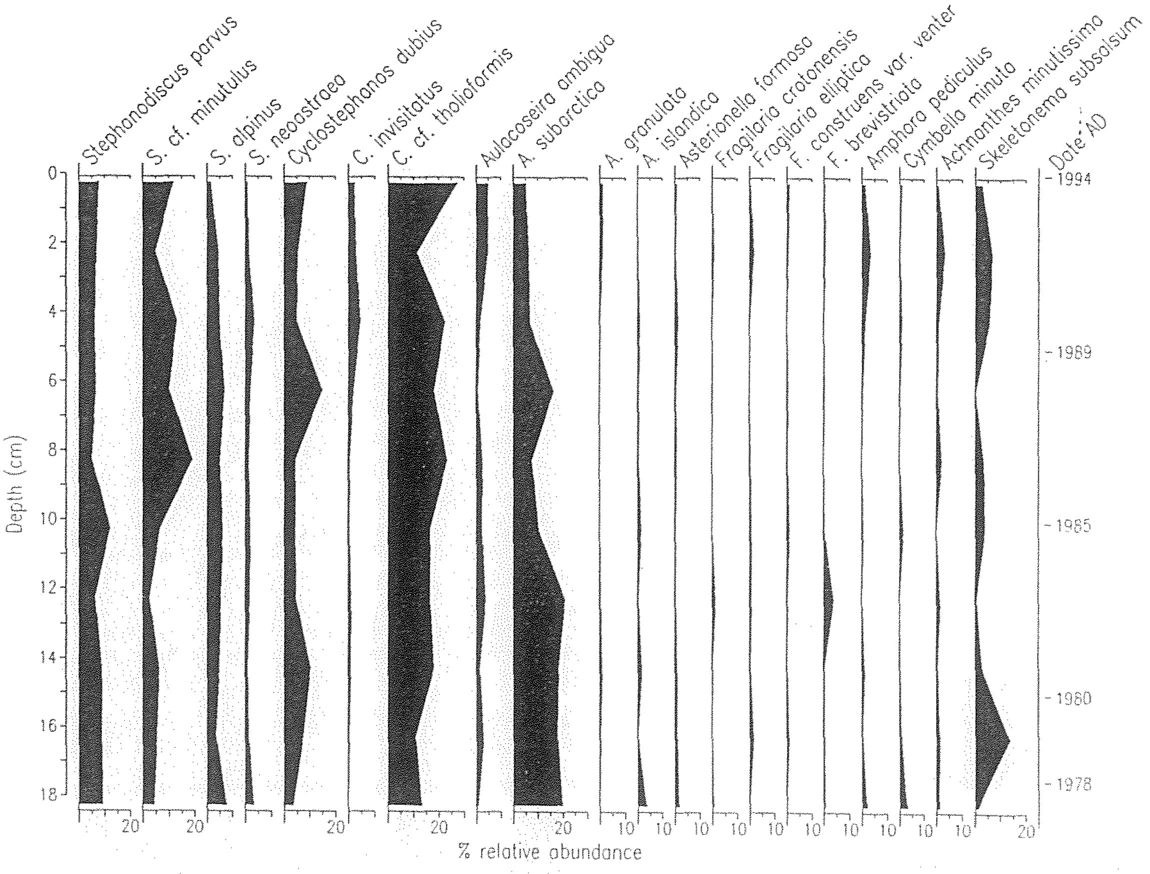


Figure 11 Diatom stratigraphy for Lower Lough Erne - Broad Lough (BRDL1), 1994 core



6.4 Lough Melvin

6.4.1 Coring

Two cores were obtained from the main basin in ~40 m water depth (Fig. 2). The master core MV 1 was 81 cm in length.

6.4.2 Dry weight and LOI (Fig. 12)

There is a major increase in percent DW below 60 cm depth, from 35% to > 50%. This feature may be related to those observed at the base of the cores taken from Lough Erne in 1974 (Battarbee, 1986). Between 5 and 60 cm depth, percent DW varies between 25 and 35%, and declines to ~12% at the core surface. Below 60 cm, LOI is constant at 5%, and after an isolated peak at 60 cm, increases slowly to 30 cm, where it reaches 13-14%. There is some suggestion of recent disturbance in the lake or catchment as indicated by the variable LOIs over the surface 10 cm. Carbonates are around 2-3% throughout the core.

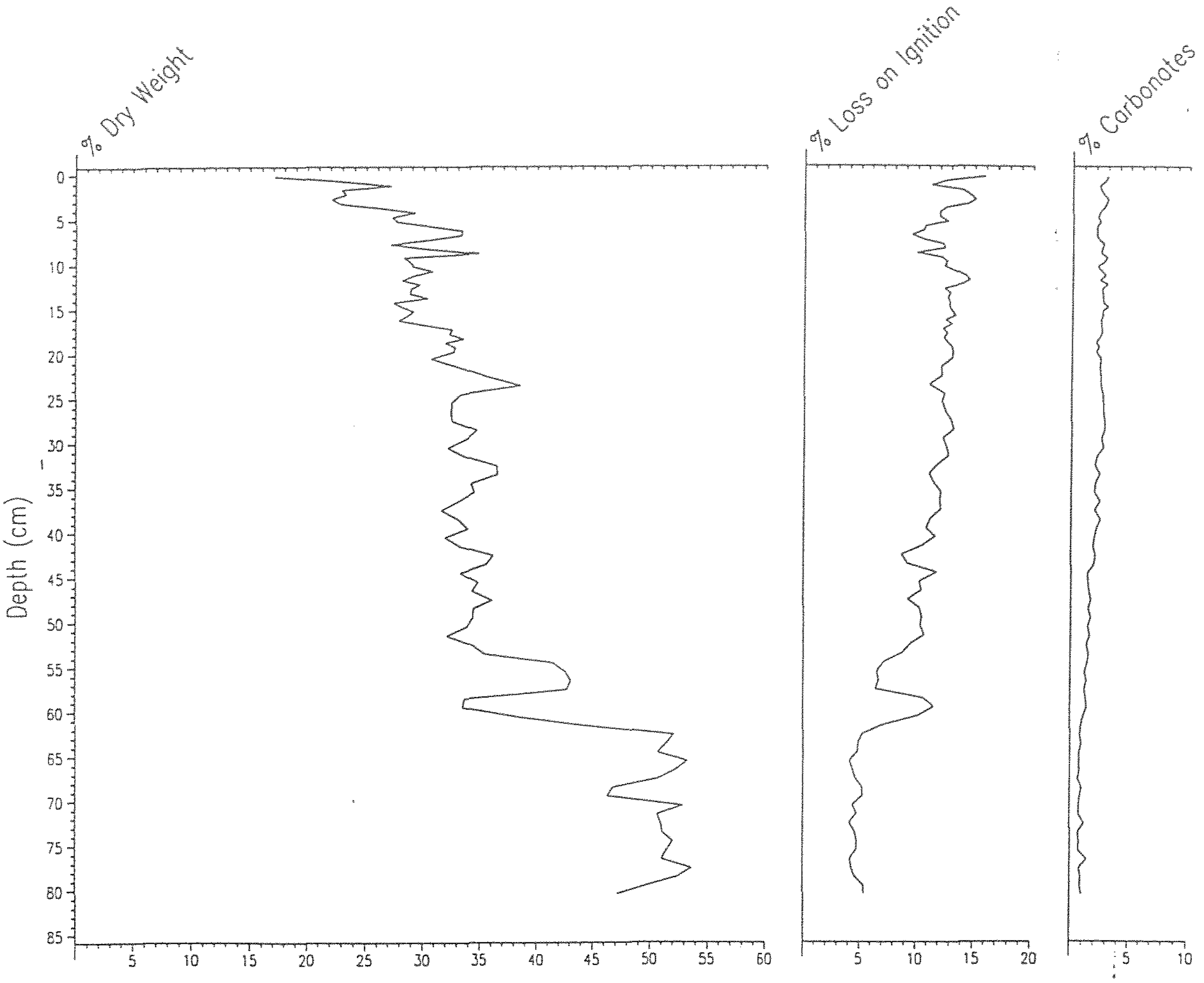
6.4.3 Dating

^{137}Cs and ^{241}Am profiles were clearly defined in this core and ^{210}Pb equilibrium was reached at only 16 cm, indicating low accumulation rates. The ^{210}Pb profile is variable and suggests a period of increased sediment accumulation during the 1930s, more constant rates between ~1940 and 1970 and slightly higher accumulation rates since the mid-1970s. However, these accumulation rates (0.032 g cm^{-2} yr^{-1}) are substantially lower than those found at Lough Erne.

6.4.4 Diatoms

The whole core was prepared for diatoms at 0.5 cm intervals over the top 20 cm and 2 cm intervals below this depth. Unfortunately, diatom preservation decreased rapidly in the surface sediments and were nearly totally dissolved below 4-5 cm depth. However, the dominant diatom present in the surficial sediments was *Aulacoseira subarctica* together with lower percentages of *A. ambigua*, *Asterionella formosa*, *Stephanodiscus neoastraea*, *S. alpinus*, *S. parvus* and a small unknown form found similar to that found in the Broad Lough (*S.* cf. *minutulus*). *Cyclotella glomerata* was also present, indicating the lower nutrient status of the lake, as this small centric is only found in lakes with less than 20-30 µg TP l^{-1}.

Figure 12 Dry weight and LOI (550°C and 1000°C [carbonates]) for Lough Melvin



6.5 Re-investigation of the 1974 survey Lough Erne cores

The original diatom count data were provided by R.W. Battarbee. As far as was possible these data were re-coded and entered into a spreadsheet for transformation and matching with the diatom-P calibration datasets. The re-coded and re-plotted diatom stratigraphies from the 1974 cores are presented in Figs 13-15. Only the dominant taxa have been plotted. A discussion and ecological interpretation of the stratigraphies is given by Battarbee (1986).

The diatom-inferred TP estimates are presented in Figs 16-18. The Manor House (Fig. 17 and Tongree (Fig. 16) estimates are generally closer to expected values than those derived from the 1994 cores. The inferred TP values at depth are, however, quite high: higher than one would expect from the eutrophication hypothesis.

The diatom-inferred TP values for the 1974 Broad Lough core (Fig. 18), are extremely variable, and although lower than those from the 1974 Manor House and Tongree cores, difficult to interpret in relation to Battarbee's inferences of changing lake productivity. However, the latter was based on the changing diatom accumulation rates. It has been shown that quantitative estimates of changing diatom productivity, such as those used by Battarbee (1986), biovolume accumulation rates, need not relate directly to more general measures of lake productivity, such as TP. The problems of reconciling interpretation of DI-TP and diatom accumulation rates have been discussed elsewhere (cf. Fritz *et al.*, 1993, Anderson, 1996).

Figure 13 Re-coded and re-plotted diatom stratigraphy for 1974 Tongree core

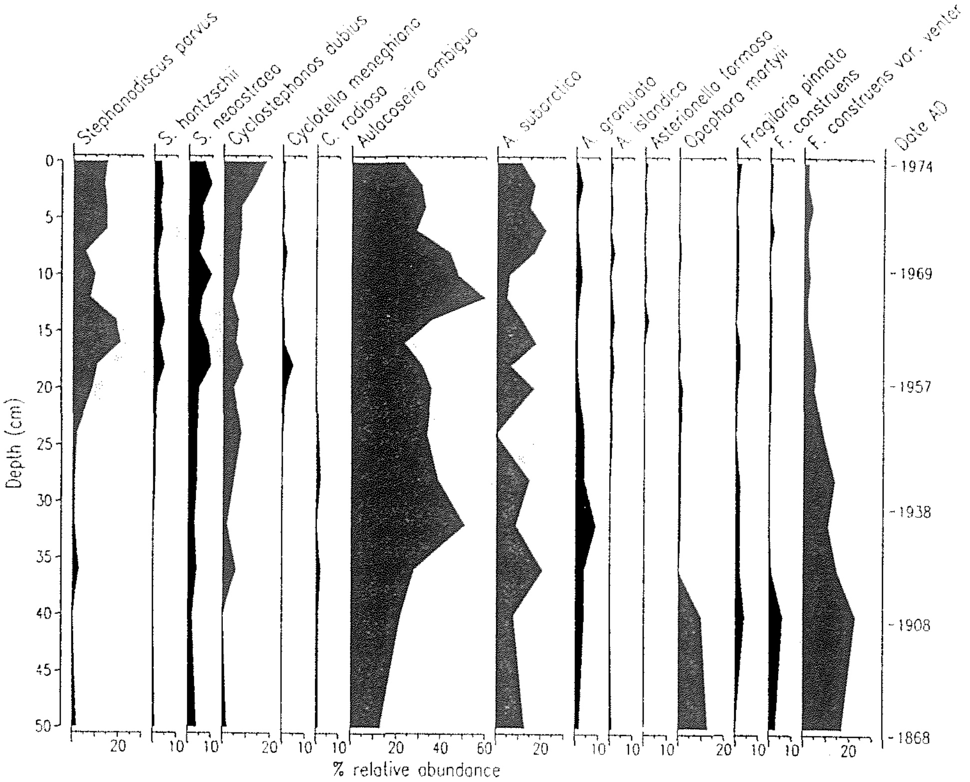


Figure 14 Re-coded and re-plotted diatom stratigraphy for 1974 Manor House core

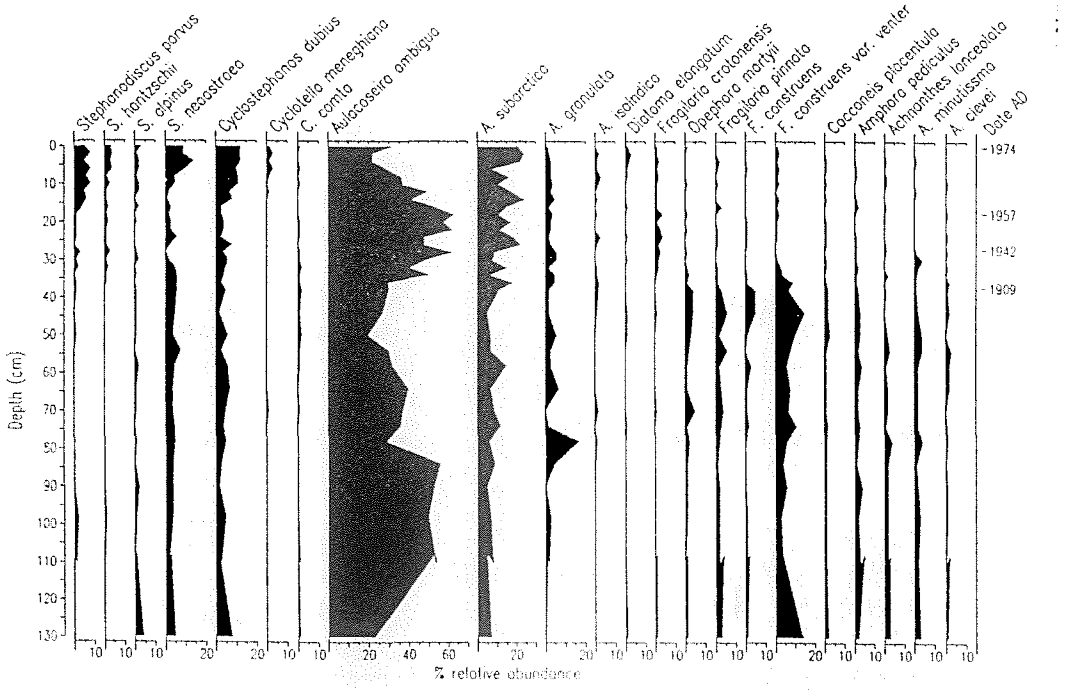


Figure 15 **Re-coded and re-plotted diatom stratigraphy for 1974 Broad Lough core**

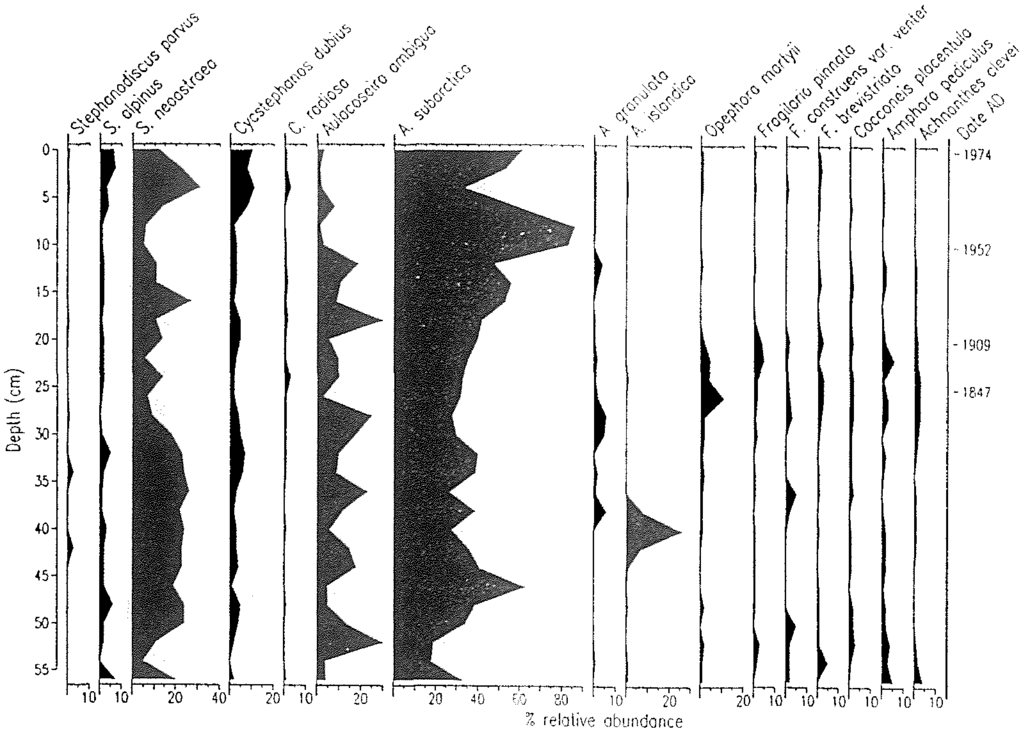


Figure 16 **Diatom-inferred TP concentrations for Upper Lough Erne (Tongree) 1974 core plotted against depth**

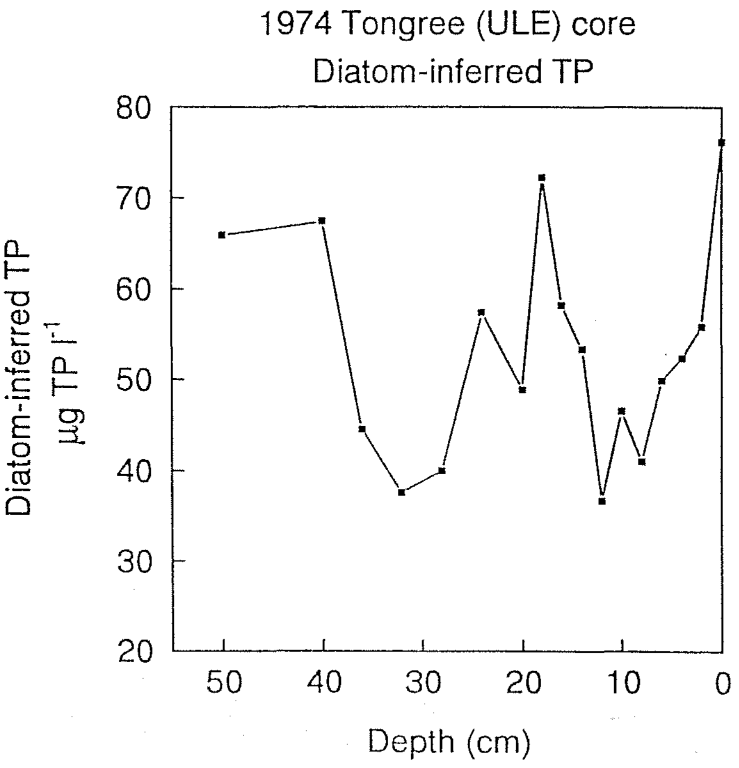


Figure 17 **Diatom-inferred TP concentrations for Lower Lough Erne (Manor House) 1974 core plotted against depth**

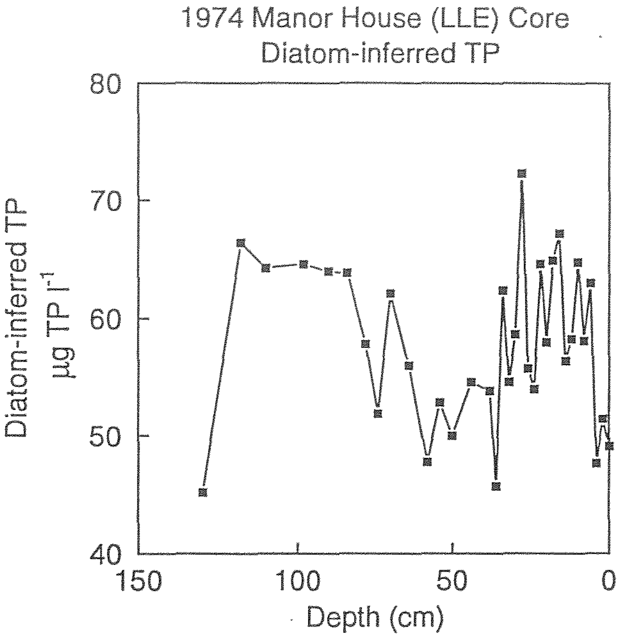
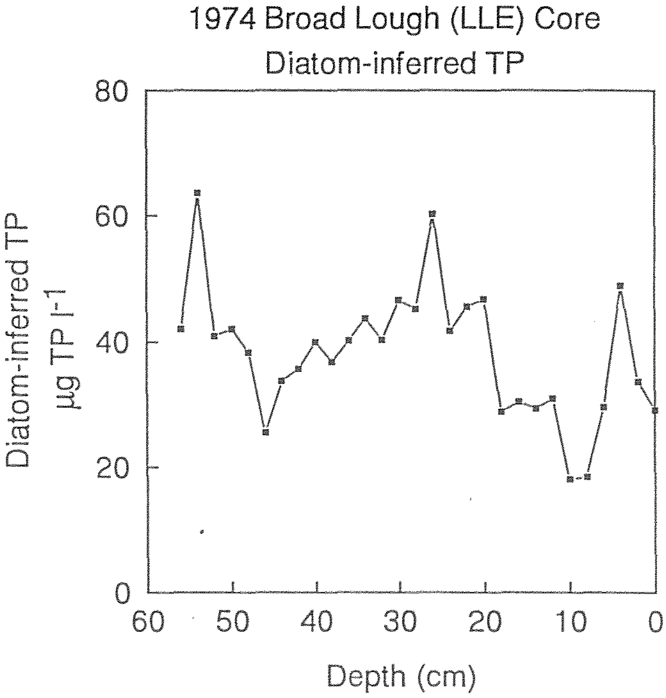


Figure 18 **Diatom-inferred TP concentrations for Lower Lough Erne (Broad Lough) 1974 core plotted against depth**



7. DISCUSSION

7.1 Comparisons of the 1994-survey cores with the 1974 survey cores

Comparisons of the 1974 and 1994 cores using dry weight and LOI profiles were not particularly useful. Neither the Tongree core (TG2) from Upper Lough Erne or the Broad Lough core (Figs 4 & 10) have the characteristic increase in dry weight at their base as found in the earlier cores (Battarbee, 1986b). The absence of this feature is probably merely a reflection of the continued high sedimentation rates which has buried these features at greater depth in the sediment. Similarly, the LOI profiles from The Broad Lough, Manor House and Tongree are too featureless to permit any correlation with early cores.

The extrusion of the cores at 0.5 cm intervals over the surface 30 cm with the aim of obtaining higher resolution was irrelevant with sediment accumulations rates > 1 cm yr^{-1}.

In general, diatom analysis has proved to be a useful technique for monitoring change in lakes and for correlating new cores with old ones (e.g. Anderson *et al.*, 1990; Anderson & Rippey, 1994). However, the approach has not been that straightforward in this study, in part because of the high sediment accumulation rates; but also because of changing taxonomy.

Because the sediment accumulation rates were higher than expected, diatom analyses of the 1994 cores were only made to a depth which overlapped in time with the earlier core at one location - Manor House (Fig. 8). As a result, dating has proved to be very important in correlating the different sets of cores. However, in the Manor House core, the overlapping samples still indicate some taxonomic differences.

Both the 1994 Manor House (MH2) and Tongree cores (TG2) and, to a lesser extent the Broad Lough core (BRDL1), are dominated by four small centric diatoms (*Stephanodiscus* cf. *minutulus*, *Cyclostephanos* cf. *tholiformis*; *C. invisitatus*; *Skeletonema subsalsum*) none of which were recorded by Battarbee (1986). In the case of *Skeletonema* this is because it was not present at that time. Phytoplankton sampling suggests that it only arrived in the lake around 1980 (Gibson *et al.* 1993).

While many of the taxa and their taxonomic identification are unambiguous (e.g. *Aulacoseira subarctica*; *A. ambigua*, *A. islandica*, *Cyclostephanos dubius*, *Cyclotella radiosa* (*comta*) and *Asterionella formosa*) and so can be readily matched between the recent analyses and the original, there remain a number of problems. These include a number of the smaller *Stephanodiscus* and *Cyclostephanos* species which are important in the diatom-P training set. These small centric diatom genera have been the focus of considerable attention by diatom taxonomists in the period since Battarbee's original study (e.g. Anderson, 1990 and references therein). Species concepts have undoubtedly changed as a result, making direct comparisons difficult. Many of these taxa are also very small (< 6-8 µm on average) making identification very difficult.

Further work on the older material is clearly required to ascertain whether there has been real community change or merely changes in taxonomy. It had been hoped that it would be sufficient to work directly from Battarbee's original count data, but it will clearly require a complete re-investigation of the raw material. Quantitative, statistical treatment of between-core comparisons using the diatom stratigraphy is not feasible until there has been further taxonomic work.

There are, however, similarities between the cores. The increases in *Cyclostephanos dubius* at the base of the analysed part of the 1994 Manor House core (MH2) and to a lesser extent, the Tongree core (TG2), suggests some agreement with the top of 1974 and 1994 cores. Increased *C. dubius* values are characteristic of the tops of the 1974 cores (see Figs 13-15). There are also higher percentages of *A. subarctica* in the Broad Lough 1994 core (Figure 11) compared to Manor House and Tongree, as found by Battarbee (1984; 1986). In the Northern Ireland training set, this diatom has lower TP optima compared to *A. ambigua* and its distribution within the Lough Erne system reflects the changing nutrient concentrations along its length (Battarbee, 1984).

7.2 Comparisons of dry mass accumulation rates

The ^{210}Pb profiles indicate that the 1994 Lough Erne cores all have significantly higher accumulation rates than those taken in 1974 (Oldfield *et al.*, 1978; Battarbee, 1986b) (see Fig. 17 and the full dating report in Appendix 1). However, there is quite good agreement for the Broad Lough and Manor House cores in terms of the dry mass accumulation rate trends, if not in actual rates (Fig. 19). These differences between the 1974 and 1994 cores are, in part, merely a reflection of the spatial variability of dry mass accumulation rates in lake basins. The differences in rates for the period 1963-1974/1986 between the 1974 and 1994 cores (see Table 7 in Appendix 1) are probably within the range for the lake as a whole. Spatial variability of sediment accumulation rates will be greater in a large, riverine and complex system such as Lough Erne. There is a clear need for a multi-coring approach if this variability is to be assessed, i.e. for estimating increased sediment yield from the catchment.

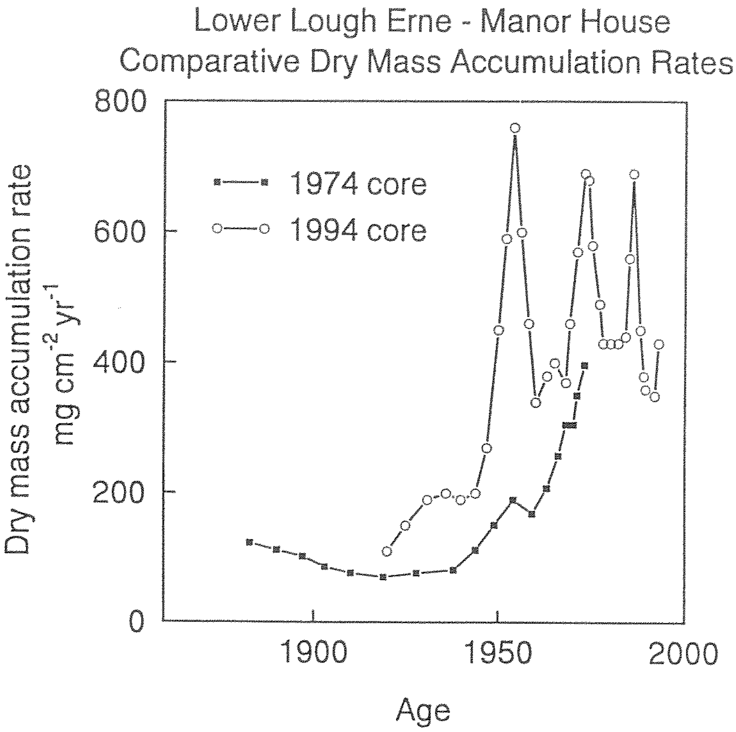
There are two aspects of changing dry mass accumulation rates that have to be considered, both of which have implications for the causal processes:

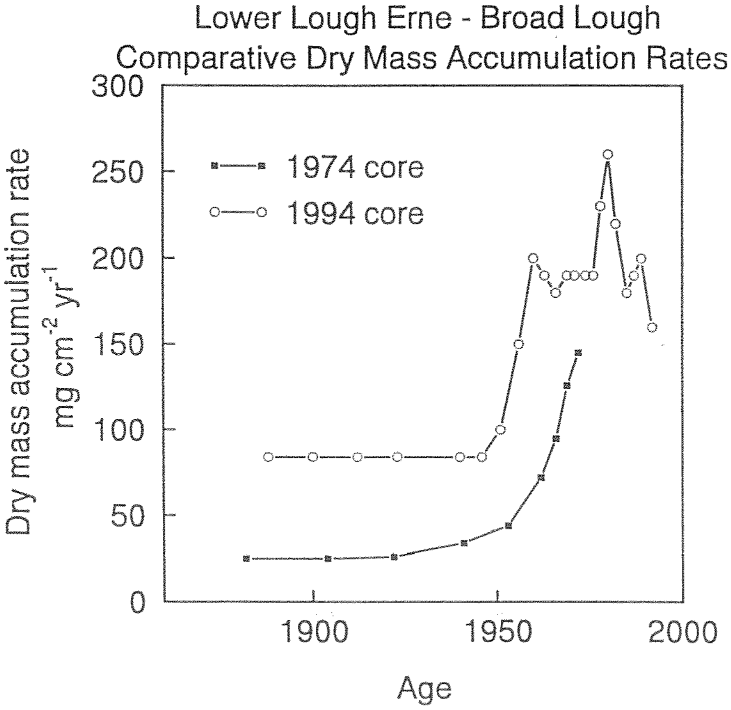
- long-term (~50 year) increases in dry mass accumulation rates
- short-term peaks (1-5 year), reflecting re-suspension and flood events

The longer-term increased sediment accumulation rates after ~1950 are probably the result of a number of factors, but primarily land-use change within the catchment. Drainage patterns have changed substantially in the post war period within Northern Ireland (Wilcocks 1979), and there has been an increase in the area of field drains. Increased agricultural activity in general and the intensification of farming in the post war period will also have contributed to this increase in catchment erosion. It is unclear whether this increased sediment yield is derived from surface soil losses or primarily channel, bank-side erosion.

However, as indicted above, in-lake processes might also account for some of the variability. The isolated high peaks (as opposed to the general increase after 1950) in Upper Lough Erne might be related to atypical flow events within the Upper Lough, due to catchment flooding. This flooding and increased discharge might be expected to remove sediment that has been in temporary storage within the lake and catchment and move it downstream. Comparisons with long-term flow data available for Enniskillen would be useful in attempts to clarify the cause of the peaks in sediment accumulation.

Figure 19 **Comparative dry mass accumulation rates (1974 v 1994) in Lower Lough Erne (Manor House and Broad Lough) cores**





An alternative explanation is suggested for the Lower Lough, however, where recent sediment trapping at the Broad Lough site has found substantial increases in sediment catch (DANI unpublished; C.E. Gibson pers. Comm.). Annual sediment trapped for the year February 1995-February 1996 was 1645 g m^{-2} (dry weight). Even allowing for problems in comparing sediment trap and sediment core accumulation rate data, this figure compares well with the mean sediment accumulation rate since 1950 derived from the ^{210}Pb data (ca. 2000 g m^{-2} yr^{-1}). In 1995-1996 there was increased sediment trapped associated with a major lowering of lake level below 45.6 m AOD. It is probable that a major re-suspension event occurred in marginal sediments as this was also a period of low flows. The high peak (0.25 g cm^{-2} yr^{-1}) around 1980 in the Broad Lough core and the three peaks of ca. 0.7 g cm^{-2} yr^{-1} in the Manor House core (Fig. 19) may also be related to rapid changes in lake level. Unfortunately, it was not possible to analyse these dry mass accumulation rate data in relation to the long-term lake-level records for the Lower Lough.

An important question, is how widespread are the high sediment accumulation rates within the basin? Localised high accumulation rates may merely be the result of variable sedimentation patterns within the Lough Erne system. If the high accumulation rates were confirmed at a number of other sites - by taking more cores - it would further support the hypothesis that erosion rates within the Lough Erne catchment have increased substantially since 1950.

7.3 Diatom-inferred TP values

One of the main aims of this present project was to reconstruct TP concentrations using the newly developed weighted averaging models. Unfortunately, there is a generally poor agreement between the diatom-inferred values and monitored concentrations. Application of the diatom-P model suffered from the no-modern analogue problem, where diatoms present in the sediment core assemblages are not present in the training set.

The poor fit of the DI-TP results were not unexpected, as *Skeletonema*, which comprises around a third of the assemblage on average at Manor House, is not contributing to the inference model as it is absent in the diatom-TP training sets. In the Broad Lough core, despite the abundance of *Skeletonema* being substantially reduced compared to Manor House, the small unknown centric (*S.* cf. *minutulus*) which reaches ca. 15% is also absent from the training set. It is encouraging, however, that at the Broad Lough, the DI-TP values for the two basal - pre-*Skeletonema* - samples (ca. 60 μg TP l^{-1}), which date to 1977-1979, are approaching the monitored level (ca. 50 μg TP l^{-1}). Measured TP at the Broad Lough site was 52 μg l^{-1} in 1975. That there is an analogue problem between the training set and the diatom assemblages in the sediment cores, caused in part by the occurrence *Skeletonema* is also supported by the lower reconstructed DI-TP values from the 1974 cores, where *Skeletonema* was absent.

However, for the 1974 cores there is the problem of defining the TP optima of *Fragilaria* spp. In the Manor House and Tongree cores, *Fragilaria* becomes an increasingly dominant component of the diatom assemblages below 20-30 cm depth (Figs 13 & 14). It is possible that this increased abundance was a function of light transmission to greater depths due to enhanced water clarity. This better light climate would have benefitted *Fragilaria*, a benthic genus, and as such is unrelated to nutrient effects. However, in the training set the presence of *Fragilaria* today in nutrient rich shallow lakes, with high TP concentrations, increases their TP optima, perhaps artificially.

The Tongree and Manor House locations are also essentially part of a riverine system, where there is lots of particulate matter in the water column which will influence both TP measurements and the amount of P available to diatoms and algae in general. These problems might introduce some error in to the relationship between DI-TP and monitored values. Ultimately, however, this is an analogue problem which might be resolved by increasing the type and range of lakes included in the training sets.

In discussing the lack-of-fit of the DI-TP values it is also important to consider the effect of seasonality in water chemistry, the definition of an annual TP mean and finally its relationship to algae. Diatoms tend to be associated with higher TP values of the late winter, early spring period, whereas the model attempts to reconstruct mean annual TP values. Looking at the seasonal variability of TP in Lough Erne (see Figs 5 & 10 *in* Gibson *et al.*, 1980) it is clear that there is considerable inter-annual variability around the annual 'mean' value. Because of the influence of the Enniskillen sewage works, TP concentrations can pass 100 µg TP l^{-1} in the Spring in the Manor House part of the Lower Lough, and may reach nearly 150 µg TP l^{-1} at Friar's Leap, immediately below the sewage works (Gibson *et al.*, 1980). While this problem - defining annual means and the timing of the growth period of diatoms - may result in some of the lack of fit between DI-TP estimates and monitored values (see Rippey *et al.*, 1996) it can not account for all of it.

To conclude, there is a clear need for better analogues for the diatom assemblages typical of the larger lakes in the north of Ireland.

7.4 Matching of core and phytoplankton records

Interestingly, while *Skeletonema* causes problems for the DI-TP reconstructions, it is this diatom which demonstrates clearly the faithfulness of the sediment record. The good agreement between the arrival of *Skeletonema* in the phytoplankton record (Gibson *et al.*, 1993) and the ^{210}Pb date of its increase in the sediment cores from the Broad Lough and Manor House sites confirms the high sediment accumulation rates and the accuracy of sediment cores in recording change in the overlying water column. The difference in the timing of the increase in *Skeletonema* between Tongree (Upper Lough Erne) and Manor House may reflect differences in the rate of its expansion upstream rather than errors in the radiometric dating of the Tongree core. The increase of *Skeletonema* in TG2 post dates the clear ^{137}Cs Chernobyl peak. In contrast to the mismatch in the expansion of *Skeletonema*, there is good agreement in the dating of the slight increase in *Aulacoseira granulata* at both Manor House and Tongree around 1989-1990.

In all probability it is the high dry mass sediment accumulation rates which enhance the sedimentary preservation of *Skeletonema*, an extremely lightly silicified diatom (cf. Gibson *et al*, 1993). Often such lightly silicified diatoms (e.g. *Rhizosolenia*) are not preserved in sediments because of rapid dissolution in the water column or in the reactive surface sediments. However, preservation of diatoms is often enhanced by a combination of high diatom productivity and high dry mass accumulation rates (Reynolds, 1986). These factors result in the rapid burial of the diatoms and their removal from the reactive surface sediments, and hence enhance preservation.

7.5 Diatom dissolution in Lough Melvin

In contrast to the preservation of *Skeletonema* in Lough Erne, an opposite explanation probably applies to the poor preservation of diatoms in Lough Melvin sediments. Lower diatom productivity combined with low dry mass sediment accumulation rates means that the smaller numbers of diatoms produced in the water column spend a longer period in the reactive surface sediments. It is in these biochemically active surface sediments that the majority of diatom dissolution takes place. Other factors which may contribute to the poor preservation in Lough Melvin are its water depth, which might result in some dissolution in the water column (Reynolds, 1986), and the oxic sediment-water interface. The latter will result in greater bioturbation and fragmentation of diatom frustules by benthic invertebrates. Despite its water depth, the orientation of the lake and its general location means that it is highly wind stressed and rarely stratifies. As a result the surficial sediments are prone to re-suspension. In contrast, the Broad Lough, although deeper has greater diatom productivity and higher dry mass sediment accumulation rates. It is possible that the shallower and more sheltered secondary basin at Lough Melvin might have better diatom preservation.

8 CONCLUSION

The ^{210}Pb and ^{137}Cs profiles indicate extremely high sediment accumulation rates, with particularly high rates (up to 3 cm yr^{-1}) since 1950. These results are confirmed by the good agreement between the arrival of *Skeletonema* in the phytoplankton as determined by phytoplankton records (Gibson *et al.*, 1993) and its ^{210}Pb date in the sediment cores. It appears that the high sediment accumulation rates are the result of land-use changes within the catchment, and the present results confirm the increases found in the earlier, 1974 cores.

Unfortunately, the application of the Northern Irish and North-west European diatom training sets for diatom-inferred TP concentrations has not been as successful as its use in the smaller Irish lakes (Anderson, 1996). Diatom-inferred TP concentrations are greater than measured values and also indicate upward trends over the last 20 years, again contrasting with the monitored data. There are clear analogue problems caused by the arrival of *Skeletonema*, the ecology of which, and the reasons for its expansion in Lough Erne, are not fully understood. However, there are also some taxonomic problems and further taxonomic work and reinvestigation of the Battarbee material is required. There is a clear need for better analogues for large lakes. This requires that the current diatom-P training sets be improved and enlarged to cover large lakes, or the creation of a larger lakes training set.

Further analysis of the 1994 cores to a greater depth is required because of the very high sediment accumulation rates found in these cores. The sampling strategy used was inappropriate given the (unforeseen) very high sediment accumulation rates. Further analyses will also help clarify if there have been major shifts in the diatom assemblages or there are fundamental taxonomic problems still to be resolved.

9. PROPOSED FUTURE WORK FOR LARGE LAKES IN NORTHERN IRELAND

1. Expansion of the Northern Irish diatom-P training set to include larger lakes.

2 Including the Fermanagh surface sediment samples taken by Anderson in October 1992. These may include *Skeletonema*.

3. Comparison of flow data from Enniskillen and dry mass accumulation rates.

4. Try to find *Skeletonema* in some other lakes in the area: need for analogues for the Manor House stratigraphy.

5. Re-core the second and shallower basin at Lough Melvin; the shallower water depth may reduce dissolution; it may also be more sheltered with less re-suspension.

6. Core Lough MacNean in an effort to identify possible timescales of recent change in the larger lakes in this area. Initial analysis of samples form a short core taken by Dr D.H. Jewson (Freshwater Laboratory, University of Ulster) suggest diatom preservation is better in this shallower system.

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APPENDIX 1 DATING REPORT (P.G. Appleby)

Radiometric Dating of Sediment Cores from Loughs Erne and Melvin

Methods

Dried sediment samples from four cores:

TG2	Upper Lough Erne	cored	February 1994
MH2	Lower Lough Erne	"	"
BRDL1	Lower Lough Erne	"	August 1994
MV1	Lough Melvin	"	February 1994

were sent to the Liverpool University Environmental Radiometric Laboratory for dating by ^{210}Pb and ^{137}Cs. The samples were analysed for total ^{210}Pb, ^{226}Ra, ^{137}Cs, ^{134}Cs and ^{241}Am by direct gamma assay using Ortec HPGe GWL series well-type coaxial low background intrinsic germanium detectors (Appleby *et al.* 1986). Background radiation was suppressed passively by housing the detectors in lead castles with 100mm thick walls lined with 3mm copper, and actively by using sodium iodide (NaI(Tl)) escape suppression shields. ^{210}Pb was determined via its gamma emissions at 46.5 keV, and ^{226}Ra by the 295 keV and 352 keV γ rays emitted by its daughter isotope ^{214}Pb. ^{137}Cs was measured by its emissions at 662 keV, ^{134}Cs by its emissions at 605 keV and 795 keV, and ^{241}Am by its emissions at 59.5 keV. The absolute efficiency of each detector was determined from a series of calibrated sources of known activity. Corrections to each count were made for the effect of self absorption of low energy γ rays within the sample (Appleby *et al.* 1992). In the case of ^{134}Cs, corrections were also made for the effect of cascade summing.

Results

The results of the radiometric analyses are given in Tables 1-4 and shown graphically in Figs.1-4. Values of the shortlived radionuclide ^{134}Cs (which derives solely from fallout from the 1986 Chernobyl reactor fire) have been corrected for radioactive decay since May 1986.

Using the ^{134}Cs/^{137}Cs ratio of ca.0.61 typical of Chernobyl fallout, total ^{137}Cs activity has been partitioned into its components deriving from weapons test and Chernobyl respectively. Table 5 gives values of a number of parameters characterising the record of fallout radionuclides in each core, including the unsupported ^{210}Pb inventory, mean ^{210}Pb flux, and the ^{137}Cs inventory from both the atmospheric testing of nuclear weapons and the 1986 Chernobyl reactor accident.

Figs.1-3 and Table 5 also compare present results from Lough Erne with those for cores collected from similar locations during an earlier study in 1974/5 (Battarbee 1986).

Lead-210 Activity

Two of the cores (TG2 from Upper Lough Erne and MH2 from Lower Lough Erne) were characterised by low ^{210}Pb activity in the surficial sediments and a relatively slow decline in unsupported ^{210}Pb activity with depth. In both cores there were significant levels of unsupported ^{210}Pb in the basal samples at ca.80 cm (Figs.1b & 2b), from which it may be presumed that both were from sites of very rapid sediment accumulation.

Significantly higher ^{210}Pb activities in the surficial sediments of the second Lower Lough Erne core (BRDL1), coupled with a more rapid decline in ^{210}Pb activity with depth (Fig.3b) suggest lower accumulation rates at this site. Sedimentation was nonetheless still rapid and the basal samples at 80 cm were only just in ^{210}Pb/^{226}Ra equilibrium.

Accumulation rates in the Lough Melvin core (MV1) appear to be almost an order of magnitude lower than in Lough Erne and ^{210}Pb equilibrium was reached at a depth of only 16 cm (Fig.4a). Although low sedimentation rates might be expected to result in high surficial ^{210}Pb activity, maximum ^{210}Pb activity in this core was no higher than in BRDL1. There were however major differences between the inventories (Table 5). Whereas the ^{210}Pb inventory in the Lough Melvin core was comparable to that supported by the atmospheric ^{210}Pb flux (~80 Bq $m^{-2}y^{-1}$), all three Lough Erne cores had ^{210}Pb inventories 3-4 times geater than the atmospherically supported value. Reasons for this could include substantial sediment focussing, or large inputs of allochthonous ^{210}Pb.

In all four cores, irregular variations in the ^{210}Pb profiles suggest significant departure from uniform sedimentation. It is also evident from the ^{210}Pb profiles that the 1994 Lough Erne cores all have significantly higher accumulation rates than those taken in 1974.

Artificial Fallout Radionuclides

All three cores from Lough Erne contained a well resolved ^{137}Cs/^{134}Cs peak recording fallout from the 1986 Chernobyl accident (Figs.1c-3c). The depths at which these occurred ranged from 10 cm in BRDL1 to 28 cm in TG2. Both Lower Lough Erne cores also contained a second deeper ^{137}Cs peak that was identified by an associated ^{241}Am peak (Appleby *et al.* 1991) as deriving from the 1963 fallout maximum from the atmospheric testing of nuclear weapons. The absence of a such a feature in the Upper Lough Erne (TG2) profile suggests that the base of the core (85 cm) post-dates 1963. This is consistent with the accumulation rate calculated from the Chernobyl peak which if extrapolated would place 1963 at a depth of more than 90 cm.

The Lough Melvin core had a well resolved ^{137}Cs peak at 3.25 cm that could be attributed to the 1963 weapons fallout maximum by virtue of its close association with a well defined ^{241}Am peak (Fig. 4c). Elevated ^{137}Cs activities in the top 1.5 cm were presumably due to Chernobyl fallout though a distinct 1986 peak could not be resolved.

Table 6 lists chronostratigraphic horizons (Chernobyl and weapons test ^{137}Cs) for each core, together with those for the 1974/5 cores (weapons test ^{137}Cs and diatoms). Table 7 gives mean accumulation rates for each core calculated from these horizons.

Core Chronologies

^{210}Pb chronologies were calculated using the CRS model (Appleby *et al.* 1978), though for core TG2 it was necessary to use the ^{137}Cs dates as reference levels (Oldfield & Appleby 1984) because of the abbreviated ^{210}Pb record. Use of the CIC ^{210}Pb dating model was precluded by the presence of significant non-monotonic irregularities in the ^{210}Pb profiles (Appleby & Oldfield 1983). Results of the ^{210}Pb calculations are shown in Figs. 5-8, together with the dated levels (1986 and 1963) determined from the artificial fallout records. In those cases where there were significant discrepancies between the ^{210}Pb and ^{137}Cs dates, corrected chronologies were calculated using the ^{137}Cs dates as reference levels. The results of these corrections are included in the core chronologies given in Tables 8-11.

Upper Lough Erne - Core TG2

This site has extraordinarily high accumulation rates. The 1986 level, recorded by the well-resolved ^{134}Cs/^{137}Cs peak (Fig. 1c), occurs at a depth of 26-31 cm, giving a mean accumulation rate for the past decade of 0.93 ± 0.08 g $cm^{-2}y^{-1}$ (3.5 cm y^{-1}). Extrapolating the post-1986 chronology dates the base of the core at 84.5 cm to 1965, supporting the inference from the absence of a weapons fallout peak that the entire core post-dates 1963. Because of the highly abbreviated record it was not possible to calculate an independent ^{210}Pb chronology. Fig.5 and Table 8 give the constrained CRS model ^{210}Pb chronology calculated using the estimated basal date of 1965 as a reference level (Oldfield & Appleby 1984). The results suggest accelerating rates during the late 1970s and a period of particularly rapid accumulation during the 1980s. Fig.5 also plots sedimentation rates for the 1974 core FM2 from this location, and shows that the 1994 core continues a trend observed in the 1974 core.

Lower Lough Erne - Core MH2

The recent chronology of this core is well constrained by two well resolved ^{137}Cs peaks at depths 14-18 cm (1986) and 48-53 cm (1963). Fig.6 shows that these dates are in relatively good agreement with the CRS model ^{210}Pb chronology, which places 1986 at 14.3 cm depth and 1963 at 45 cm depth. The ^{210}Pb calculations slightly underestimate the large increase in accumulation rates in recent decades. Revised ^{210}Pb dates for the post-1963 period have been calculated using the 1963 ^{137}Cs date as a reference level, and appropriate corrections made to the pre-1963 dates. Fig.6 compares the revised sedimentation rates for MH2 with those calculated for the corresponding 1974 core (FM1). Both cores suggest that there was a transition to more rapid accumulation rates during the early 1940s. Mean post-1950 accumulation rates in MH2 are 0.43 ± 0.05 g $cm^{-2}y^{-1}$ (1.5 cm y^{-1}), compared to ca.0.20 g $cm^{-2}y^{-1}$ (0.6 cm y^{-1}) before 1940.

Lower Lough Erne - Core BRDL1

As in MH2, the recent chronology is constrained by two well resolved ^{137}Cs peaks, at depths 8-13 cm (1986) and 30-36 cm (1963), that are again in relatively good agreement with the CRS model ^{210}Pb chronology (Fig.7). This puts 1986 at 7.3 cm depth and 1963 at 28.3 cm depth, again slightly underestimating the large increase in accumulation rates in recent decades. Revised ^{210}Pb dates for the post-1963 period have been calculated using the 1963 ^{137}Cs date as a reference level, and appropriate corrections made to the pre-1963 dates. The resultant chronology

(Table 10) dates the main increase in accumulation rates to the 1950s, and gives a mean post-1960 accumulation rate of 0.19 ± 0.02 g $cm^{-2}y^{-1}$ (1.0 cm y^{-1}), compared to ca.0.084 g $cm^{-2}y^{-1}$ (0.42 cm y^{-1}) prior to 1950. The changes during 1950-74 are similar to those observed in the corresponding 1974 core SM1 (Fig.7).

Lough Melvin - Core MV1

The CRS model ^{210}Pb calculations for this core indicate an episode of rapid accumulation during the 1930s, a period of fairly uniform sedimentation rate during 1946-70 of 0.026 ± 0.004 g $cm^{-2}y^{-1}$ (0.12 cm y^{-1}), and another brief episode of rapid accumulation during the past decade. Both episodes of rapid accumulation are characterised by strongly non-monotonic features in the ^{210}Pb profile (Fig.4a). Because the earlier episode occurs close to the limits of detection, it was not possible to obtain reliable dates for older sections of the core. The ^{137}Cs peak at 3.25 cm and ^{241}Am peak at 4.25 cm indicate that the 1963 level in the core can be placed at a depth 3.75 ± 0.75 cm. Fig.8 shows that this is in good agreement with the ^{210}Pb results, which put 1963 at 4 cm depth.

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Table 1. <u>Upper Lough Erne:</u> <u>Core TG2</u>

^{210}*Pb Data*

Depth		^{210}Pb Concentration				^{226}Ra Conc	
		Total		Unsupp			
cm	gcm^{-2}	$Bqkg^{-1}$	±	$Bqkg^{-1}$	±	$Bqkg^{-1}$	±
0.25	0.03	110.0	10.6	51.4	11.0	58.6	2.8
4.25	0.69	110.1	7.0	59.6	7.2	50.5	1.8
8.25	1.62	114.9	8.9	61.4	9.1	53.5	2.1
12.25	2.65	109.8	8.4	59.2	8.5	50.6	1.7
20.25	4.95	82.7	8.7	31.9	8.9	50.8	1.9
26.25	6.82	87.2	8.4	38.6	8.5	48.6	1.5
28.25	7.44	94.4	7.6	42.4	7.8	52.0	1.8
30.50	8.15	96.2	8.3	42.9	8.5	53.3	1.8
36.50	10.04	85.0	7.2	29.4	7.3	55.6	1.6
44.50	12.71	80.6	5.4	24.3	5.6	56.3	1.4
52.50	15.42	88.5	6.5	36.8	6.6	51.7	1.2
60.50	18.16	100.9	8.1	49.3	8.2	51.6	1.4
68.50	20.71	90.4	6.2	39.3	6.4	51.1	1.2
76.50	23.29	85.0	6.4	31.3	6.6	53.7	1.4
84.50	26.00	84.1	5.8	33.9	5.9	50.2	1.0

(b) ^{137}*Cs,* ^{134}*Cs and* ^{241}*Am Data*

Depth	^{137}Cs Conc		^{134}Cs Conc		^{241}Am Conc	
cm	$Bqkg^{-1}$	±	$Bqkg^{-1}$	±	$Bqkg^{-1}$	±
0.25	159.2	4.5	61.9	1.9	0.0	0.0
4.25	159.0	3.0	61.8	1.0	0.0	0.0
8.25	171.1	3.0	70.9	2.0	0.0	0.0
12.25	200.3	3.1	92.6	1.9	0.0	0.0
20.25	261.9	3.3	181.0	1.3	0.0	0.0
26.25	394.4	4.0	190.7	0.6	0.0	0.0
28.25	453.1	4.5	285.8	1.2	0.0	0.0
30.50	352.7	3.9	209.4	0.0	0.0	0.0
36.50	90.5	2.1	11.4	1.8	0.0	0.0
44.50	76.8	1.9	0.8	0.0	0.0	0.0
52.50	59.4	1.4	0.0	0.0	0.0	0.0
60.50	72.4	1.8	0.0	0.0	0.0	0.0
68.50	67.8	1.5	0.0	0.0	0.0	0.0
76.50	66.4	1.6	0.0	0.0	0.0	0.0
84.50	62.4	1.3	0.0	0.0	0.0	0.0

Table 2. Lower Lough Erne: Core MH2

^{210}Pb Data

Depth		^{210}Pb Concentration				^{226}Ra Conc	
		Total		Unsupp			
cm	gcm^{-2}	Bqkg^{-1}	±	Bqkg^{-1}	±	Bqkg^{-1}	±
0.25	0.03	119.3	12.1	59.3	12.5	60.0	3.1
4.25	0.62	147.7	11.0	92.9	11.3	54.8	2.5
8.25	1.44	137.3	8.3	80.1	8.6	57.2	2.0
10.25	1.90	127.2	9.9	73.8	10.0	53.4	1.6
12.25	2.43	122.2	7.8	66.8	8.0	55.4	1.8
14.25	2.98	89.4	7.4	36.3	7.5	53.1	1.6
16.25	3.55	99.5	8.7	41.2	8.9	58.3	2.1
20.25	4.71	105.7	8.2	55.2	8.4	50.5	2.0
28.25	7.16	109.2	9.6	46.8	9.9	62.4	2.3
36.50	9.73	80.3	7.1	23.6	7.3	56.7	1.5
44.50	12.31	97.0	6.4	40.5	6.5	56.5	1.2
48.50	13.66	94.0	7.4	32.5	7.6	61.5	1.9
52.50	14.95	95.8	6.3	33.2	6.5	62.6	1.5
56.50	16.25	78.7	5.9	18.5	6.1	60.2	1.6
60.50	17.53	72.9	7.9	10.9	8.1	62.0	1.9
68.50	20.01	94.1	8.3	31.0	8.5	63.1	1.6
76.50	22.46	89.0	5.6	18.3	5.8	70.7	1.6
84.50	24.86	91.3	5.9	26.2	6.1	65.1	1.6

(b) ^{137}Cs, ^{134}Cs and ^{241}Am Data

Depth	^{137}Cs Conc		^{134}Cs Conc		^{241}Am Conc	
cm	Bqkg^{-1}	±	Bqkg^{-1}	±	Bqkg^{-1}	±
0.25	140.3	5.1	42.0	2.4	0.0	0.0
4.25	171.0	3.6	100.3	1.7	0.0	0.0
8.25	185.8	3.5	86.0	1.0	0.0	0.0
10.25	209.2	3.0	95.1	0.0	0.0	0.0
12.25	249.2	3.3	123.3	1.9	0.0	0.0
14.25	268.8	3.5	140.2	0.0	0.0	0.0
16.25	366.7	3.8	215.0	1.6	0.0	0.0
20.25	132.2	2.6	36.6	1.7	0.0	0.0
28.25	69.9	2.2	16.1	2.3	0.0	0.0
36.50	97.2	2.1	0.0	0.0	0.0	0.0
44.50	148.2	2.0	0.0	0.0	1.6	0.4
48.50	180.1	3.1	0.0	0.0	3.4	0.8
52.50	209.2	2.5	0.0	0.0	2.8	0.5
56.50	97.4	2.2	0.0	0.0	1.1	0.4
60.50	75.0	2.2	0.0	0.0	0.0	0.0
68.50	34.2	1.4	0.0	0.0	0.0	0.0
76.50	31.4	1.6	0.0	0.0	0.0	0.0
84.50	46.1	1.8	0.0	0.0	0.0	0.0

Table 3. Lower Lough Erne: Core BRDL1

^{210}Pb Data

Depth		^{210}Pb Concentration				^{226}Ra Conc	
		Total		Unsupp			
cm	gcm^{-2}	Bqkg^{-1}	±	Bqkg^{-1}	±	Bqkg^{-1}	±
0.25	0.02	460.6	36.3	371.2	37.3	89.4	8.3
5.25	0.76	271.7	26.6	197.7	27.4	74.0	6.3
10.25	1.65	263.7	21.4	185.3	21.8	78.4	4.5
15.25	2.57	201.5	22.4	114.2	23.0	87.3	5.1
20.25	3.50	214.9	17.2	139.3	17.6	75.6	3.6
25.25	4.42	195.7	15.3	116.2	15.8	79.5	3.9
30.50	5.51	167.3	15.3	104.3	15.5	63.0	2.9
35.50	6.52	138.4	13.3	69.9	13.6	68.5	3.0
40.50	7.49	163.6	8.8	104.1	8.9	59.5	1.6
50.50	9.41	118.8	9.3	55.4	9.5	63.4	1.9
60.50	11.33	90.5	7.8	22.6	8.0	67.9	1.6
70.50	13.39	81.2	6.6	12.9	6.9	68.3	1.7
80.50	15.68	69.9	8.8	4.7	9.0	65.2	1.8

(b) ^{137}Cs, ^{134}Cs and ^{241}Am Data

Depth	^{137}Cs Conc		^{134}Cs Conc		^{241}Am Conc	
cm	Bqkg^{-1}	±	Bqkg^{-1}	±	Bqkg^{-1}	±
0.25	328.7	14.8	127.0	0.0	0.0	0.0
5.25	500.0	13.9	257.8	5.4	0.0	0.0
10.25	813.3	10.8	495.0	6.3	0.0	0.0
15.25	147.3	5.8	0.0	0.0	0.0	0.0
20.25	175.2	5.5	0.0	0.0	1.5	0.7
25.25	298.7	7.0	0.0	0.0	1.7	0.6
30.50	492.7	7.5	0.0	0.0	4.5	1.1
35.50	176.5	4.6	0.0	0.0	4.6	1.2
40.50	29.0	1.4	0.0	0.0	0.0	0.0
50.50	8.2	1.4	0.0	0.0	0.0	0.0
60.50	0.8	0.8	0.0	0.0	0.0	0.0
70.50	0.0	0.0	0.0	0.0	0.0	0.0
80.50	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. Lough Melvin: Core MV1

^{210}Pb Data

Depth		^{210}Pb Concentration				^{226}Ra Conc	
		Total		Unsupp			
cm	gcm^{-2}	Bqkg^{-1}	±	Bqkg^{-1}	±	Bqkg^{-1}	±
0.25	0.05	258.7	14.3	207.4	14.6	51.3	2.9
1.25	0.31	146.9	10.8	101.0	11.1	45.9	2.3
2.25	0.59	225.2	14.5	171.2	14.9	54.0	3.1
3.25	0.86	208.4	12.6	147.2	12.8	61.2	2.4
4.25	1.17	152.7	11.8	103.5	12.1	49.2	2.4
5.25	1.51	134.8	10.5	76.2	10.8	58.6	2.5
6.25	1.89	78.7	7.7	20.2	7.9	58.5	2.1
7.25	2.29	63.4	6.9	6.0	7.1	57.4	1.7
8.25	2.65	92.3	9.3	22.5	9.6	69.8	2.3
9.25	3.05	91.5	8.6	17.1	9.0	74.4	2.6
10.25	3.40	95.5	5.8	25.5	6.0	70.0	1.6
11.25	3.77	86.3	10.6	8.8	10.9	77.5	2.4
12.25	4.13	80.0	9.8	6.4	10.2	73.6	2.8
15.25	5.20	80.1	7.7	5.5	8.0	74.6	2.2
17.25	5.93	71.3	6.8	-1.2	7.0	72.5	1.6
20.50	7.27	72.6	8.3	-2.2	8.5	74.8	2.2

(b) ^{137}Cs and ^{241}Am Data

Depth	^{137}Cs Conc		^{241}Am Conc	
cm	Bqkg^{-1}	±	Bqkg^{-1}	±
0.25	303.9	5.6	0.0	0.0
1.25	271.0	4.6	0.0	0.0
2.25	258.1	5.3	0.0	0.0
3.25	335.1	4.5	2.4	1.0
4.25	299.1	4.6	4.0	1.0
5.25	242.7	4.1	2.0	0.9
6.25	82.0	2.8	0.7	0.3
7.25	21.0	1.3	0.0	0.0
8.25	23.9	1.8	0.0	0.0
9.25	32.1	2.0	0.0	0.0
10.25	31.1	1.6	0.0	0.0
11.25	18.4	1.6	0.0	0.0
12.25	14.1	1.7	0.0	0.0
15.25	0.0	0.0	0.0	0.0
17.25	0.3	0.9	0.0	0.0
20.50	0.0	0.0	0.0	0.0

Table 5 Radionuclide Parameters of L. Erne and L. Melvin Cores

	Unsupported ^{210}Pb						^{137}Cs			
	Max Act.		Inventory		Flux		Weapons		Chernobyl	
	Bq kg^{-1}	±	Bq m^{-2}	±	Bq $m^{-2}y^{-1}$	±	Bq m^{-2}	±	Bq m^{-2}	±
1974/5 cores										
Upper L. Erne										
FM2	65	10	5587	437	174	14	15674	285		
Lower L. Erne										
FM1	85	12	7953	701	248	22	14966	306		
SM1	302	34	8087	400	252	13	15902	373		
Mean values			7209		224		15514			
1994 cores										
Upper L. Erne										
TG2	61	9	10277	555	320	17	22365	3039	22844	528
Lower L. Erne										
MH2	93	11	8950	538	279	17	25942	2283	10177	233
BRDL1	371	37	13149	635	409	20	20932	2821	11536	371
Mean values			10792		336		23080		14852	
Lough Melvin										
MV1	207	14	2542	164	79	6	6140	222	940	188
Atmospheric fluxes			~2630		~82		~3280			

Table 6 Chrono-stratigraphic Horizons of L. Erne and L. Melvin Cores

	Depth		Date
	cm	gcm^{-2}	
1974/5			
Upper Lough Erne			
Core FM2			
^{137}Cs peak	18.5 ± 2.5	3.90 ± 0.66	1963
Diatom horizon	38.0 ± 2.0	9.64 ± 0.58	1910
Lower Lough Erne			
Core FM1			
^{137}Cs peak	14.5 ± 1.5	3.35 ± 0.41	1963
Diatom horizon	35.0 ± 2.0	8.91 ± 0.54	1910
Core SM1			
^{137}Cs peak	9.5 ± 1.5	1.38 ± 0.26	1963
Diatom horizon	19.0 ± 2.0	3.06 ± 0.42	1910
1994			
Upper Lough Erne			
Core TG2			
^{137}Cs peak (Chernobyl)	28.3 ± 2.5	7.44 ± 0.66	1986
^{137}Cs peak (Weapons)	>84.5	>26	1963
Lower Lough Erne			
Core MH2			
^{137}Cs peak (Chernobyl)	16.3 ± 2.0	3.55 ± 0.44	1986
^{137}Cs peak (Weapons)	50.5 ± 2.5	14.31 ± 0.71	1963
Core BRDL1			
^{137}Cs peak (Chernobyl)	10.3 ± 2.5	1.65 ± 0.46	1986
^{137}Cs peak (Weapons)	33.0 ± 3.0	6.03 ± 0.55	1963
Lough Melvin			
Core MV1			
^{137}Cs peak (Weapons)	3.75 ± 0.75	1.00 ± 0.20	1963

Table 7 Mean Sedimentation Rates Determined from Chrono-stratigraphic Horizons

Core	Mean Sedimentation Rate 1910-1963 $g\ cm^{-2}y^{-1}$	1963-1974/86 $g\ cm^{-2}y^{-1}$	1986-1994 $g\ cm^{-2}y^{-1}$
1974/5			
Upper Lough Erne			
FM2	0.108	0.355	
Lower Lough Erne			
FM1	0.105	0.305	
SM1	0.032	0.125	
1994			
Upper Lough Erne			
TG2		>0.807	0.930
Lower Lough Erne			
MH2		0.468	0.444
BRDL1		0.190	0.206
Lough Melvin			
MV1		0.032 (1963-94)	

Table 8 Upper Lough Erne: ^{210}Pb Chronology for Core TG2

Depth	Cum Dry	Chronology			Accumulation Rate		
	Mass	Date	Age				
cm	gcm^{-2}	AD	y	±	$gcm^{-2}y^{-1}$	cmy^{-1}	± (%)
0.00	0.00	1994	0				
2.50	0.40	1994	0	2	0.94	5.2	16
5.00	0.86	1993	1	2	0.86	4.2	13
7.50	1.44	1992	2	2	0.82	3.5	15
10.00	2.07	1992	2	2	0.81	3.1	15
12.50	2.72	1991	3	2	0.83	3.0	15
15.00	3.44	1990	4	2	1.01	3.5	19
17.50	4.16	1989	5	2	1.20	4.1	24
20.00	4.87	1989	5	2	1.39	4.7	28
22.50	5.65	1988	6	2	1.29	4.3	26
25.00	6.43	1988	6	2	1.17	3.8	24
27.50	7.21	1987	7	2	1.03	3.3	20
30.00	7.99	1986	8	2	0.96	3.1	20
32.50	8.78	1985	9	2	1.08	3.4	22
35.00	9.57	1985	9	2	1.23	3.8	24
37.50	10.37	1984	10	2	1.35	4.1	25
40.00	11.21	1983	11	2	1.41	4.3	25
42.50	12.04	1983	11	2	1.46	4.4	24
45.00	12.88	1982	12	2	1.47	4.4	23
47.50	13.73	1981	13	2	1.29	3.8	22
50.00	14.57	1981	13	2	1.11	3.3	20
52.50	15.42	1980	14	2	0.93	2.7	18
55.00	16.27	1979	15	2	0.83	2.5	18
57.50	17.13	1978	16	2	0.73	2.2	18
60.00	17.99	1977	17	2	0.64	1.9	17
62.50	18.80	1975	19	2	0.64	1.9	17
65.00	19.59	1974	20	2	0.66	2.0	17
67.50	20.39	1973	21	2	0.68	2.1	17
70.00	21.19	1972	22	2	0.70	2.2	18
72.50	22.00	1971	23	2	0.73	2.2	19
75.00	22.81	1970	24	2	0.76	2.3	21
77.50	23.63	1968	26	2	0.75	2.3	21
80.00	24.48	1967	27	2	0.71	2.1	20
82.50	25.33	1966	28	2	0.67	2.0	19

Table 9 Lower Lough Erne: ^{210}Pb Chronology for Core MH2

Depth	Cum Dry	Chronology			Accumulation Rate		
	Mass	Date	Age				
cm	gcm^{-2}	AD	y	±	$gcm^{-2}y^{-1}$	cmy^{-1}	± (%)
0.00	0.00	1994	0				
2.50	0.36	1993	1	2	0.43	2.7	17
5.00	0.77	1992	2	2	0.35	1.9	13
7.50	1.29	1989	3	2	0.36	1.8	12
10.00	1.84	1989	5	2	0.38	1.6	14
12.50	2.50	1988	6	2	0.45	1.6	15
15.00	3.19	1986	8	2	0.69	2.4	22
17.50	3.91	1985	9	2	0.56	1.9	21
20.00	4.64	1984	10	2	0.44	1.5	17
22.50	5.40	1982	12	2	0.43	1.4	18
25.00	6.16	1980	14	2	0.43	1.4	20
27.50	6.93	1978	16	2	0.43	1.4	22
30.00	7.70	1977	17	2	0.49	1.6	25
32.50	8.48	1975	19	2	0.58	1.9	27
35.00	9.26	1974	20	2	0.68	2.1	30
37.50	10.05	1973	21	3	0.69	2.2	30
40.00	10.86	1971	23	3	0.57	1.8	26
42.50	11.67	1969	25	3	0.46	1.4	22
45.00	12.48	1968	26	3	0.37	1.1	20
47.50	13.32	1965	29	3	0.40	1.2	24
50.00	14.14	1963	31	3	0.38	1.1	24
52.50	14.95	1960	34	3	0.34	1.0	22
55.00	15.76	1958	36	3	0.46	1.5	30
57.50	16.57	1956	38	4	0.60	1.9	45
60.00	17.37	1954	40	4	0.76	2.0	70
62.50	18.15	1952	42	4	0.59	2.0	64
65.00	18.93	1950	44	5	0.45	1.4	51
67.50	19.70	1947	47	5	0.27	0.86	37
70.00	20.47	1944	50	5	0.20	0.64	33
72.50	21.24	1940	54	6	0.19	0.63	35
75.00	22.00	1936	58	7	0.20	0.66	37
77.50	22.76	1931	63	10	0.19	0.63	42
80.00	23.51	1925	69	12	0.15	0.50	40
82.50	24.26	1920	74	14	0.11	0.37	39

Table 10 Lower Lough Erne: ^{210}Pb Chronology for Core BRDL1

Depth	Cum Dry Mass	Chronology Date	Age		Accumulation Rate		
cm	gcm^{-2}	AD	y	±	$gcm^{-2}y^{-1}$	cmy^{-1}	± (%)
0.00	0.00	1994	0				
2.50	0.35	1992	2	2	0.16	1.02	13.5
5.00	0.72	1989	5	2	0.20	1.20	15.4
7.50	1.16	1987	7	2	0.19	1.13	15.1
10.00	1.61	1985	9	2	0.18	1.03	14.5
12.50	2.06	1982	12	2	0.22	1.20	17.9
15.00	2.52	1980	14	2	0.26	1.40	21.7
17.50	2.99	1978	16	2	0.23	1.24	19.5
20.00	3.45	1976	18	2	0.19	1.03	16.7
22.50	3.91	1974	20	3	0.19	1.00	17.2
25.00	4.38	1971	23	3	0.19	0.99	18.0
27.50	4.89	1969	25	3	0.19	0.94	19.1
30.00	5.41	1966	28	3	0.18	0.89	20.3
32.50	5.91	1963	31	4	0.19	0.94	22.5
35.00	6.42	1960	34	4	0.20	1.01	24.9
37.50	6.91	1956	38	5	0.15	0.79	23.9
40.00	7.39	1951	43	5	0.10	0.53	21.9
42.50	7.87	1946	48	4	↑	↑	
45.00	8.35	1940	54	5			
47.50	8.83	1935	59	5			
50.00	9.31	1929	65	6			
52.50	9.79	1923	71	7			
55.00	10.27	1917	77	8	0.084	0.42	
57.50	10.75	1912	82	9			
60.00	11.24	1906	88	10			
62.50	11.74	1900	94	11			
65.00	12.26	1894	100	12			
67.50	12.77	1888	106	14	↓	↓	
70.00	13.29	1881	113	15			

Table 11 Lough Melvin: ^{210}Pb Chronology for Core MV1

Depth	Cum Dry Mass	Chronology			Accumulation Rate		
		Date	Age				
cm	gcm^{-2}	AD	y	±	$gcm^{-2}y^{-1}$	cmy^{-1}	± (%)
0.00	0.00	1994	0				
0.25	0.05	1993	1	2	0.037	0.15	10.9
0.50	0.11	1991	3	2	0.043	0.17	11.8
0.75	0.18	1990	4	2	0.050	0.19	12.8
1.00	0.24	1989	5	2	0.057	0.21	13.7
1.25	0.31	1987	7	2	0.064	0.23	14.6
1.50	0.38	1986	8	2	0.055	0.20	14.6
1.75	0.45	1984	10	2	0.047	0.17	14.6
2.00	0.52	1982	12	2	0.039	0.14	14.5
2.25	0.59	1981	13	2	0.031	0.11	14.5
2.50	0.66	1978	16	2	0.030	0.11	15.3
2.75	0.73	1976	18	3	0.029	0.10	16.0
3.00	0.79	1974	20	3	0.028	0.10	16.8
3.25	0.86	1971	23	3	0.027	0.09	17.5
3.50	0.94	1968	26	4	0.027	0.09	19.2
3.75	1.01	1966	28	4	0.026	0.09	20.9
4.00	1.09	1963	31	5	0.026	0.08	22.6
4.25	1.17	1960	34	5	0.026	0.08	24.3
4.50	1.25	1956	38	6	0.026	0.08	27.0
4.75	1.34	1953	41	7	0.025	0.07	29.6
5.00	1.42	1949	45	8	0.024	0.07	32.2
5.25	1.51	1946	48	9	0.023	0.07	34.9
5.50	1.60	1943	51	10	0.033	0.09	40.8
5.75	1.70	1941	53	11	0.043	0.11	46.7
6.00	1.79	1938	56	12	0.053	0.14	52.6
6.25	1.89	1936	58	13	0.063	0.16	58.5
6.50	1.99	1934	60	13	0.064	0.17	62.5
6.75	2.09	1932	62	13	0.065	0.17	66.5
7.00	2.19	1931	63	14	0.066	0.17	70.5
7.25	2.29	1929	65	14	0.067	0.18	74.5
7.50	2.38	1929	65	15	0.062	0.16	73.1
7.75	2.47	1928	66	15	0.056	0.15	71.7
8.00	2.56	1928	66	16	0.050	0.13	70.3
8.25	2.65	1927	67	16	0.044	0.12	68.8
8.50	2.75	1925	69	17	0.044	0.12	73.5
8.75	2.85	1923	71	19	0.044	0.12	78.2
9.00	2.95	1921	73	20	0.044	0.12	82.9
9.25	3.05	1918	76	21	0.044	0.12	87.5
9.50	3.14	1915	79	23	0.038	0.10	89.5
9.75	3.23	1912	82	26	0.032	0.09	91.4
10.00	3.31	1909	85	28	0.026	0.07	93.3
10.25	3.40	1906	88	30	0.020	0.06	95.2

Fig.1a

Upper Lough Erne
Total ^{210}Pb Activity versus Depth

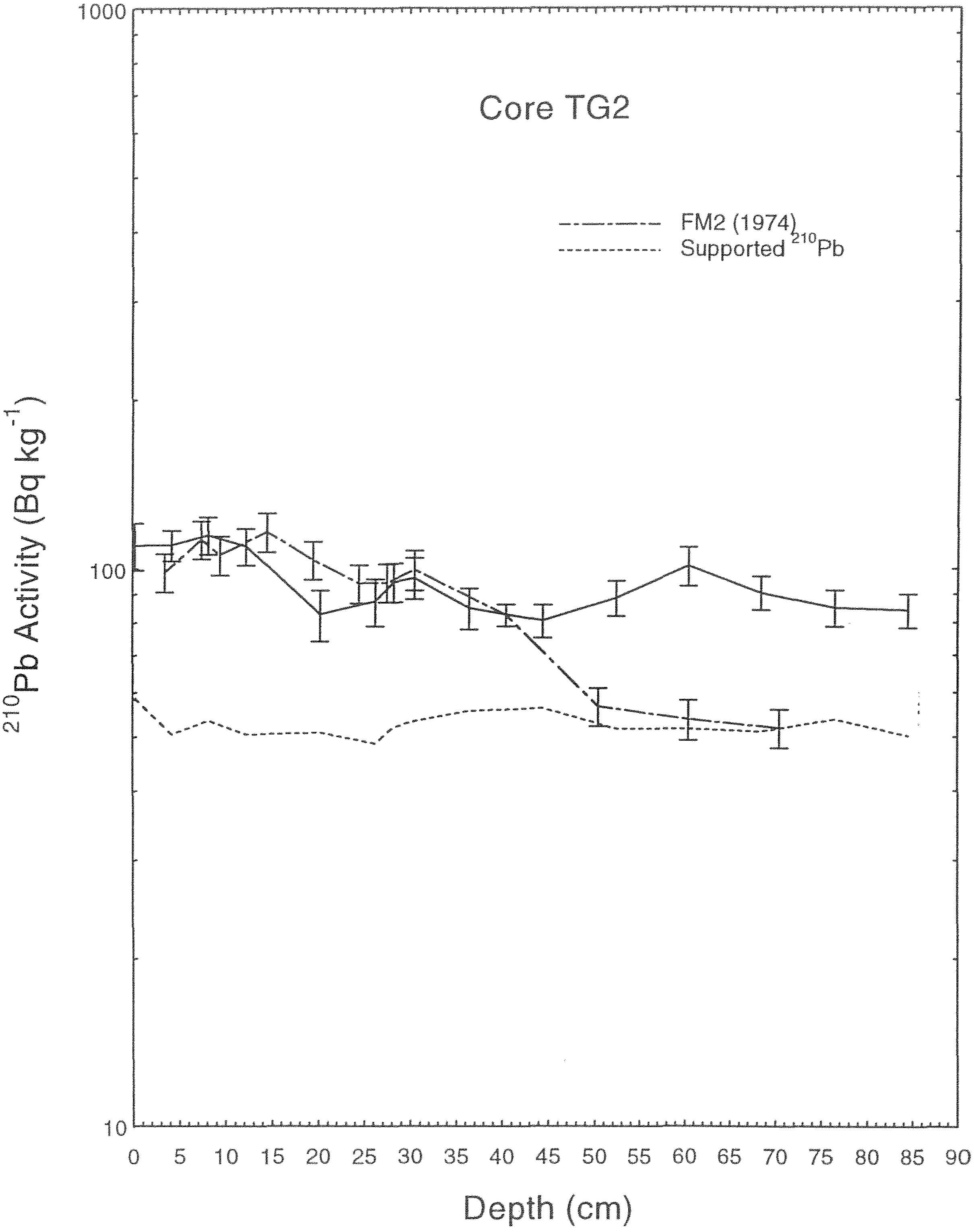


Fig.1b

Upper Lough Erne
Unsupported ^{210}Pb Activity versus Depth

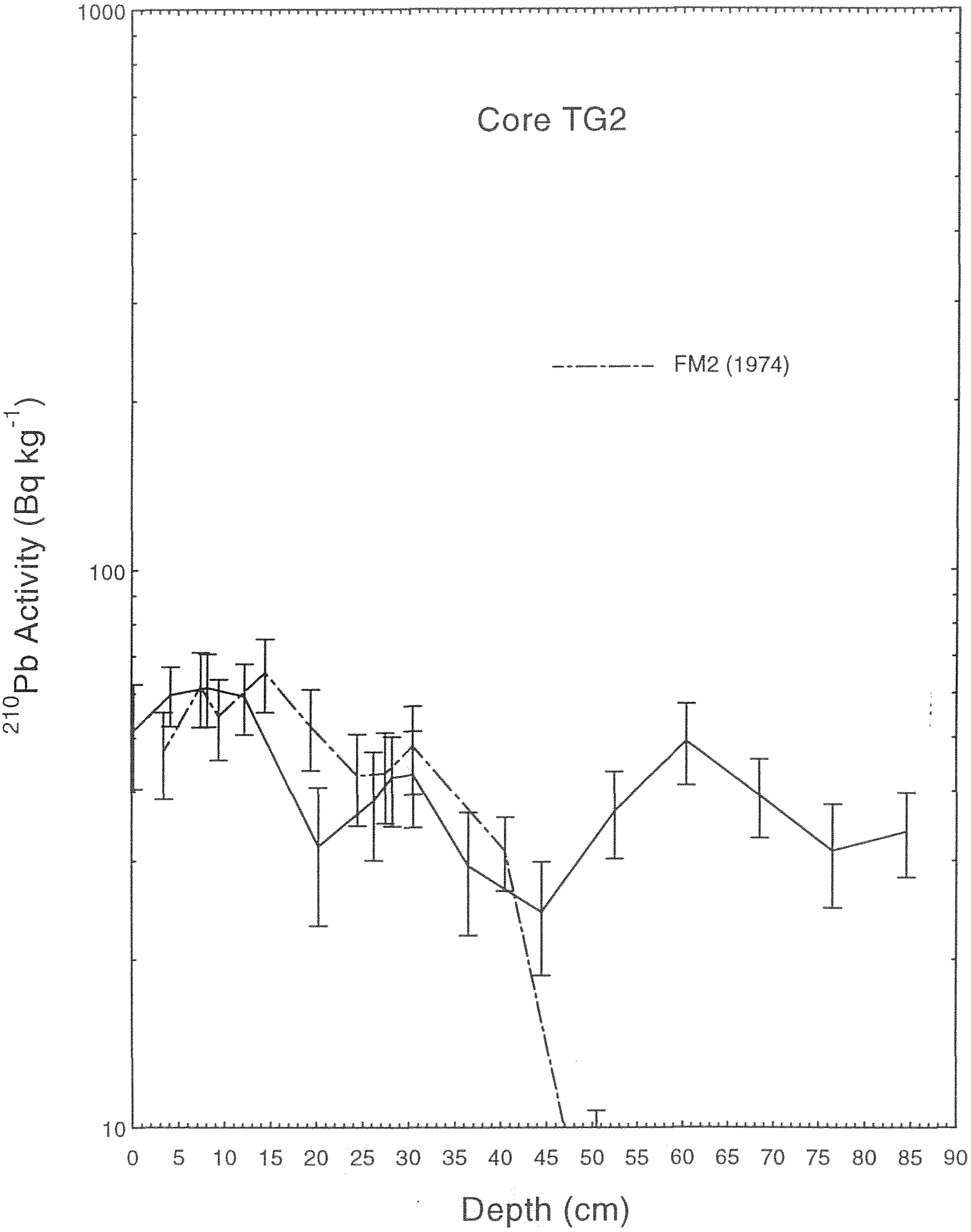


Fig.1c

Upper Lough Erne
^{137}Cs & ^{134}Cs Activity versus Depth

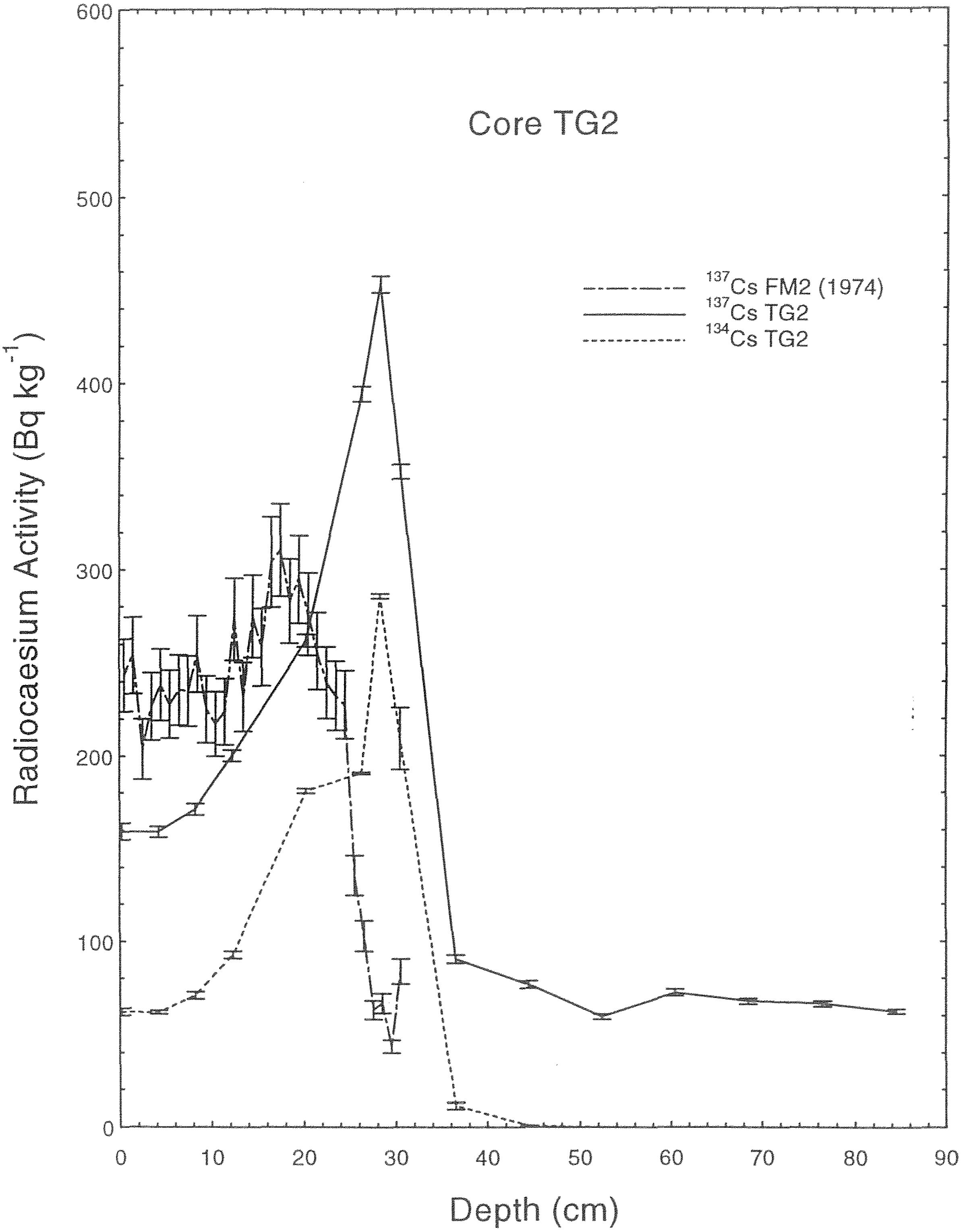


Fig.2a

Lower Lough Erne
Total ^{210}Pb Activity versus Depth

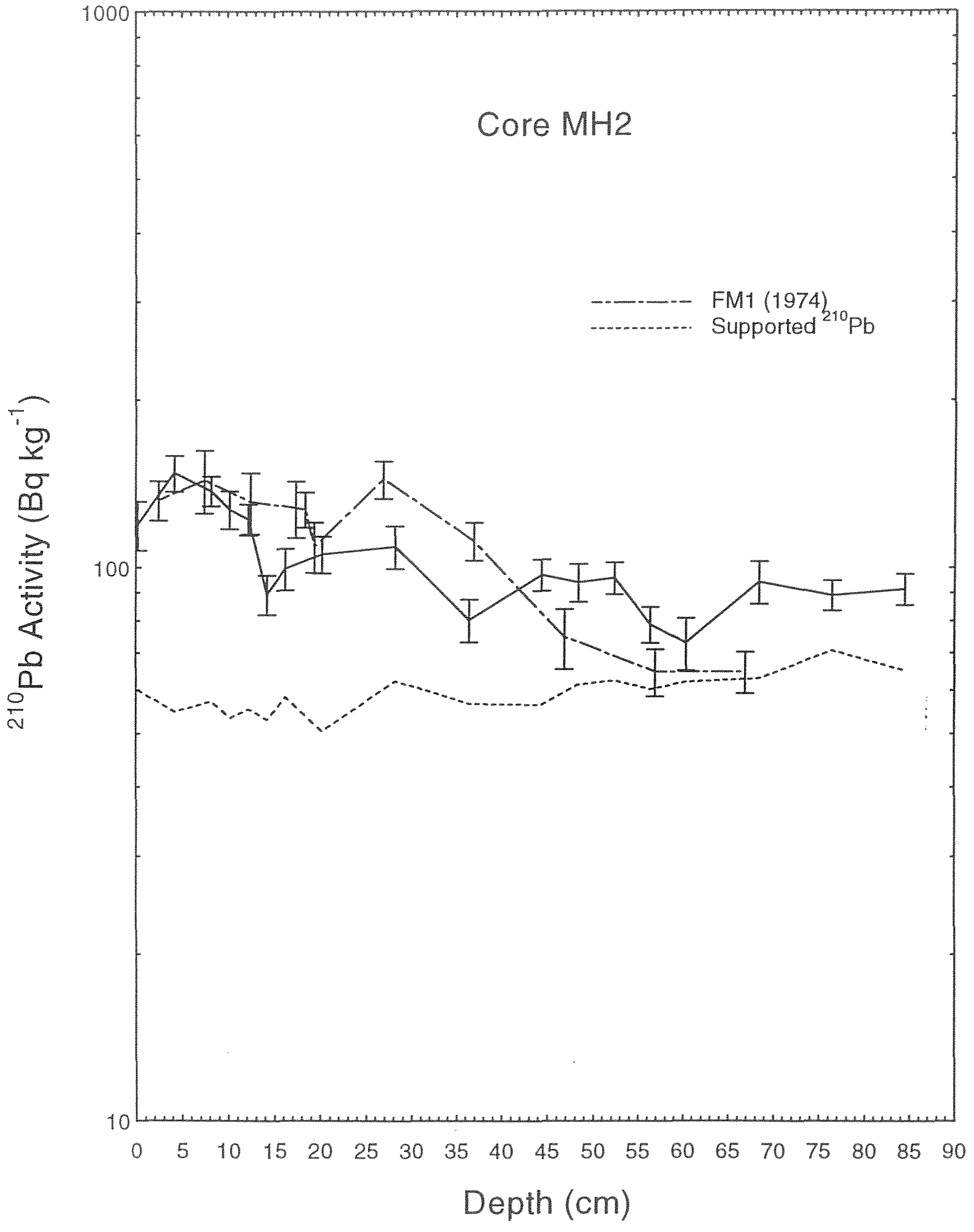


Fig.2b

Lower Lough Erne
Unsupported ^{210}Pb Activity versus Depth

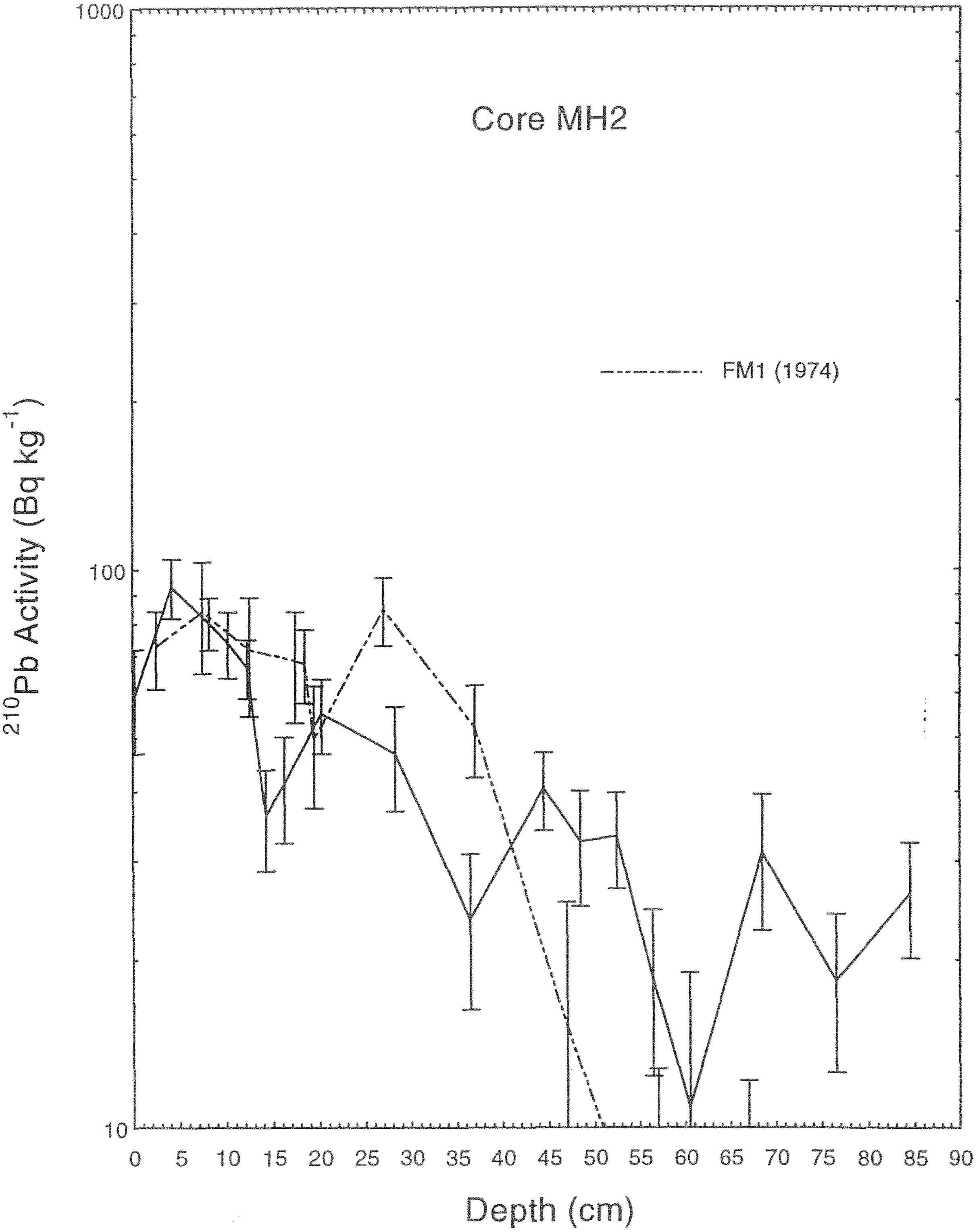


Fig.2c

Lower Lough Erne

^{137}Cs, ^{134}Cs & ^{241}Am Activity versus Depth

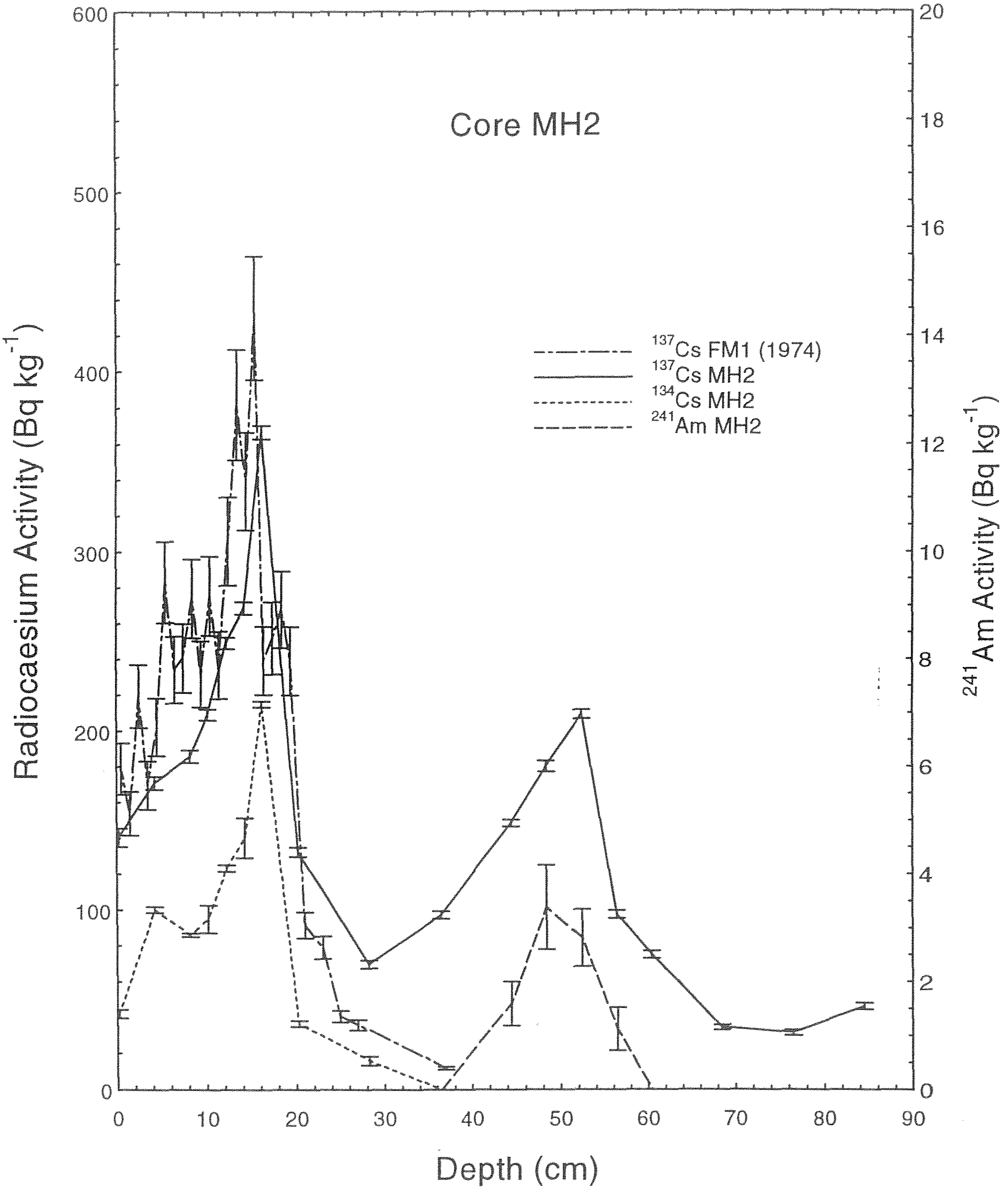


Fig.3a

Lower Lough Erne
Total ^{210}Pb Activity versus Depth

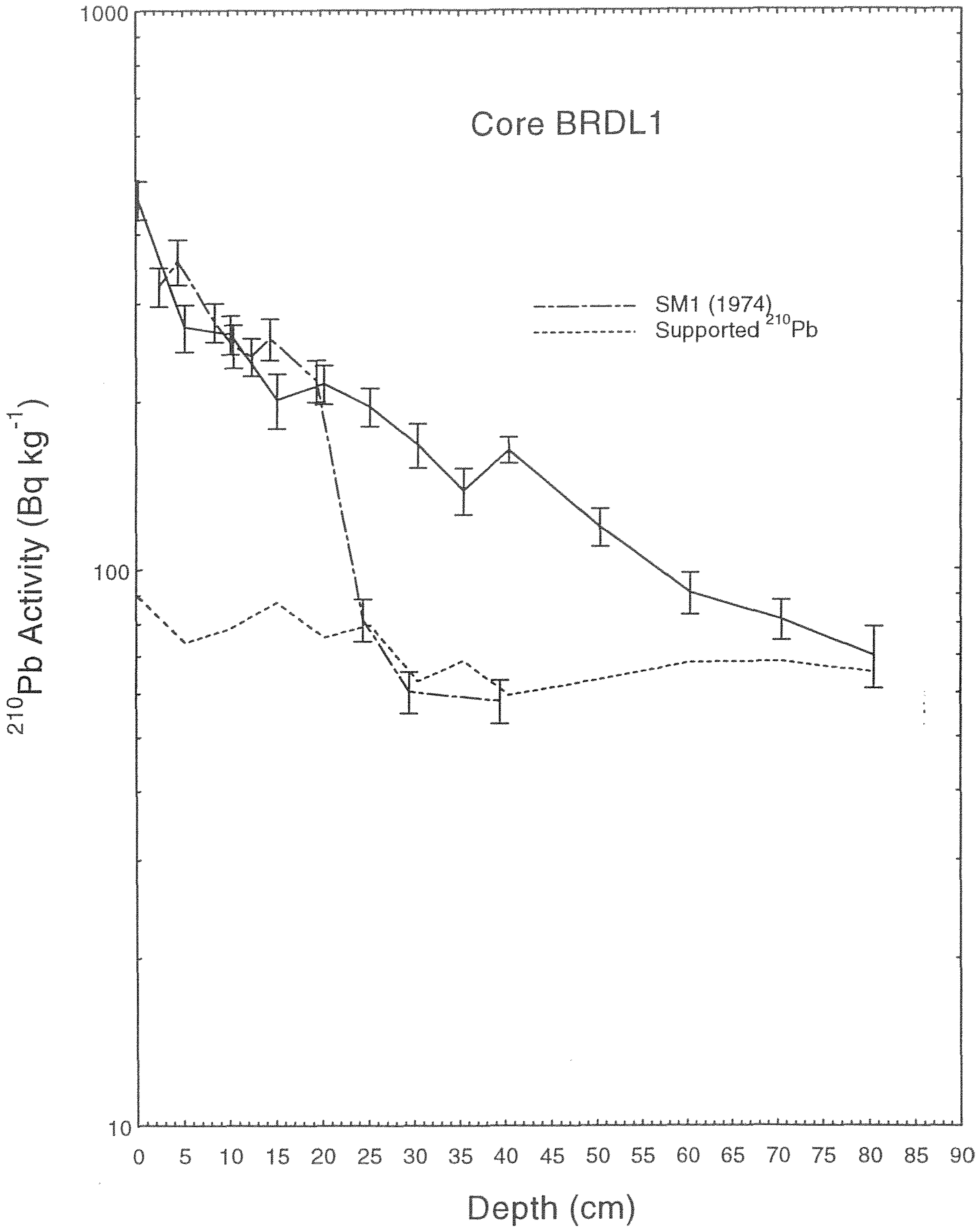


Fig.3b

Lower Lough Erne
Unsupported ^{210}Pb Activity versus Depth

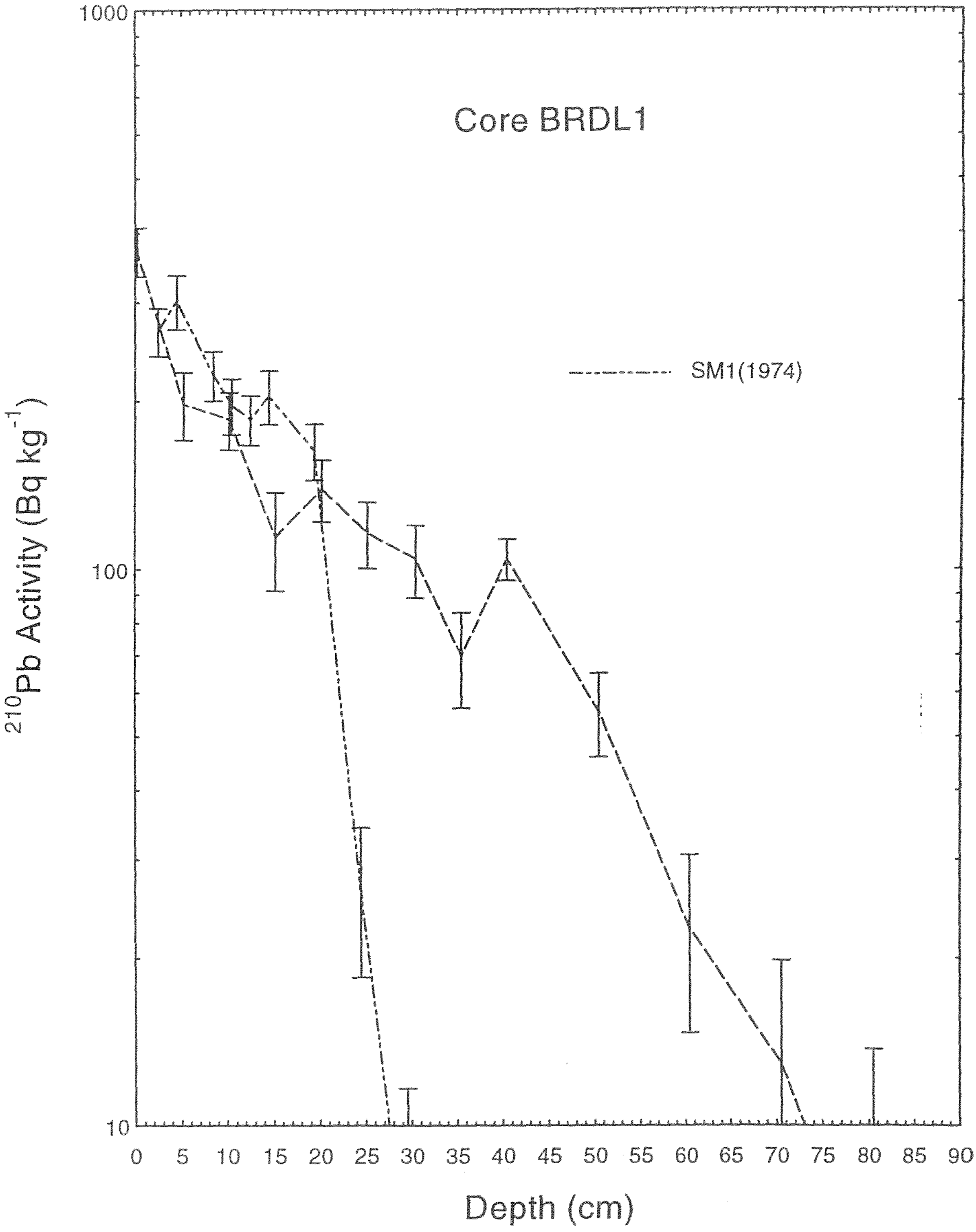


Fig.3c

Lower Lough Erne

^{137}Cs, ^{134}Cs & ^{241}Am Activity versus Depth

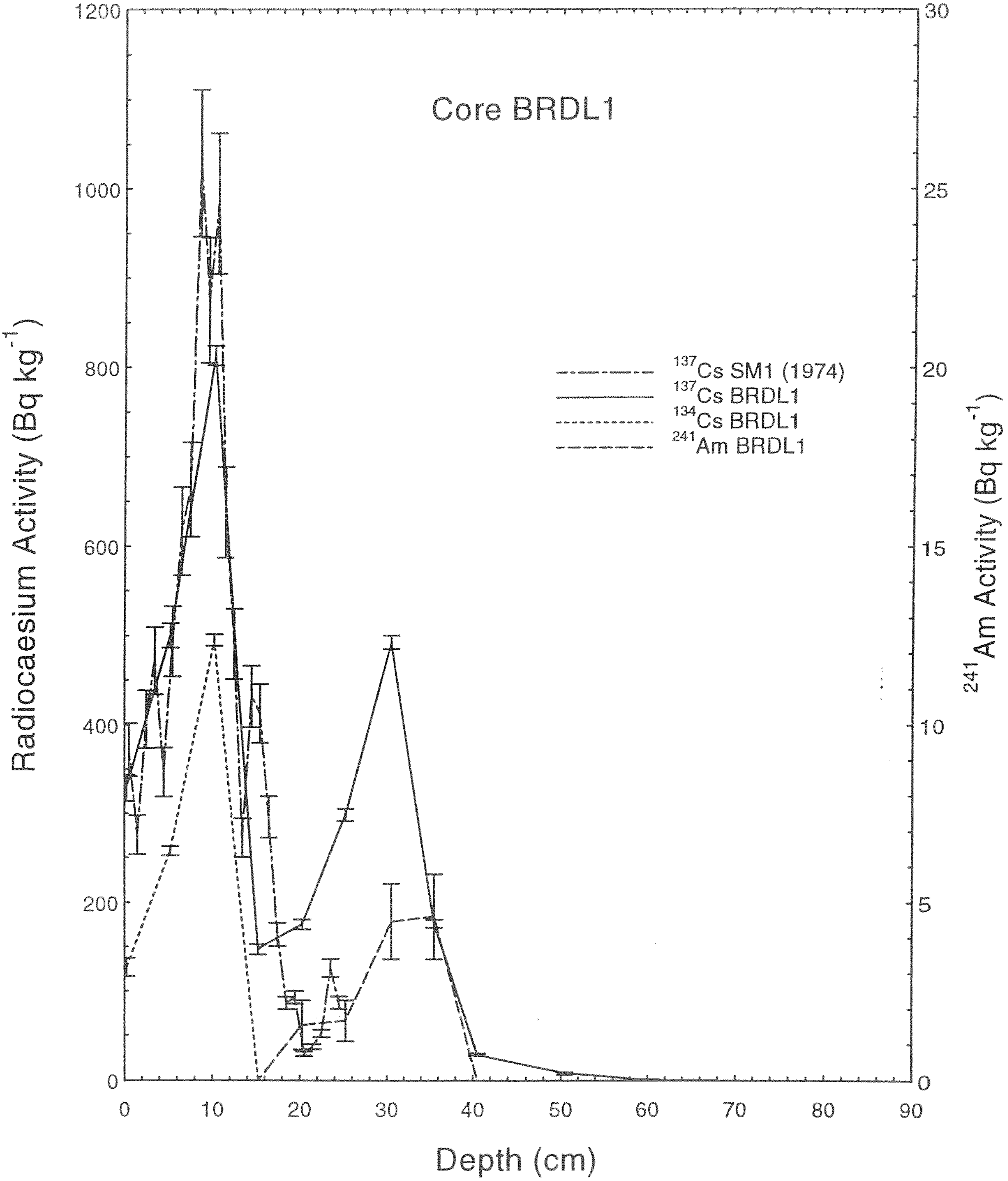


Fig.4a

Lough Melvin
Total ^{210}Pb Activity versus Depth

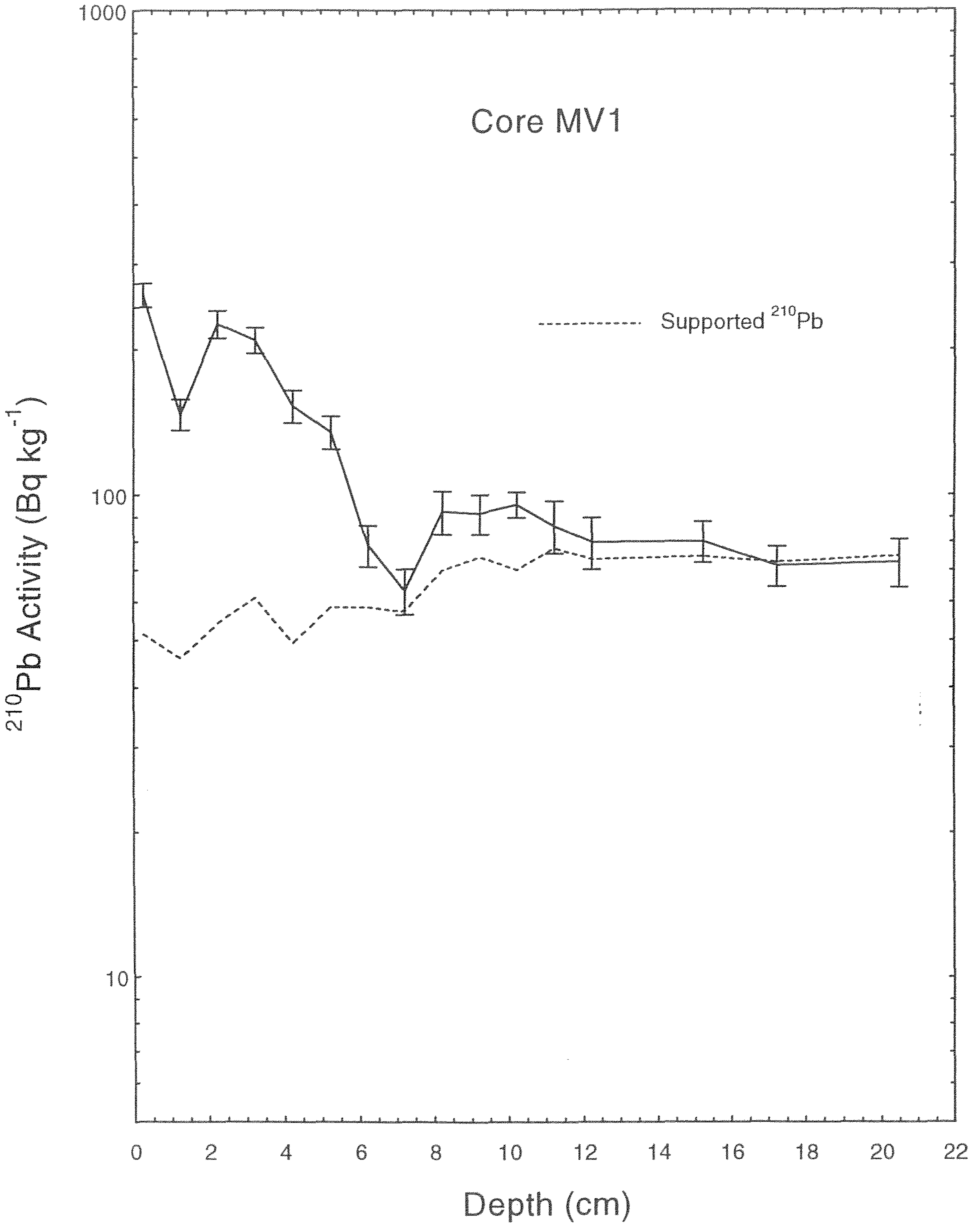


Fig.4b

Lough Melvin
Unsupported ^{210}Pb Activity versus Depth

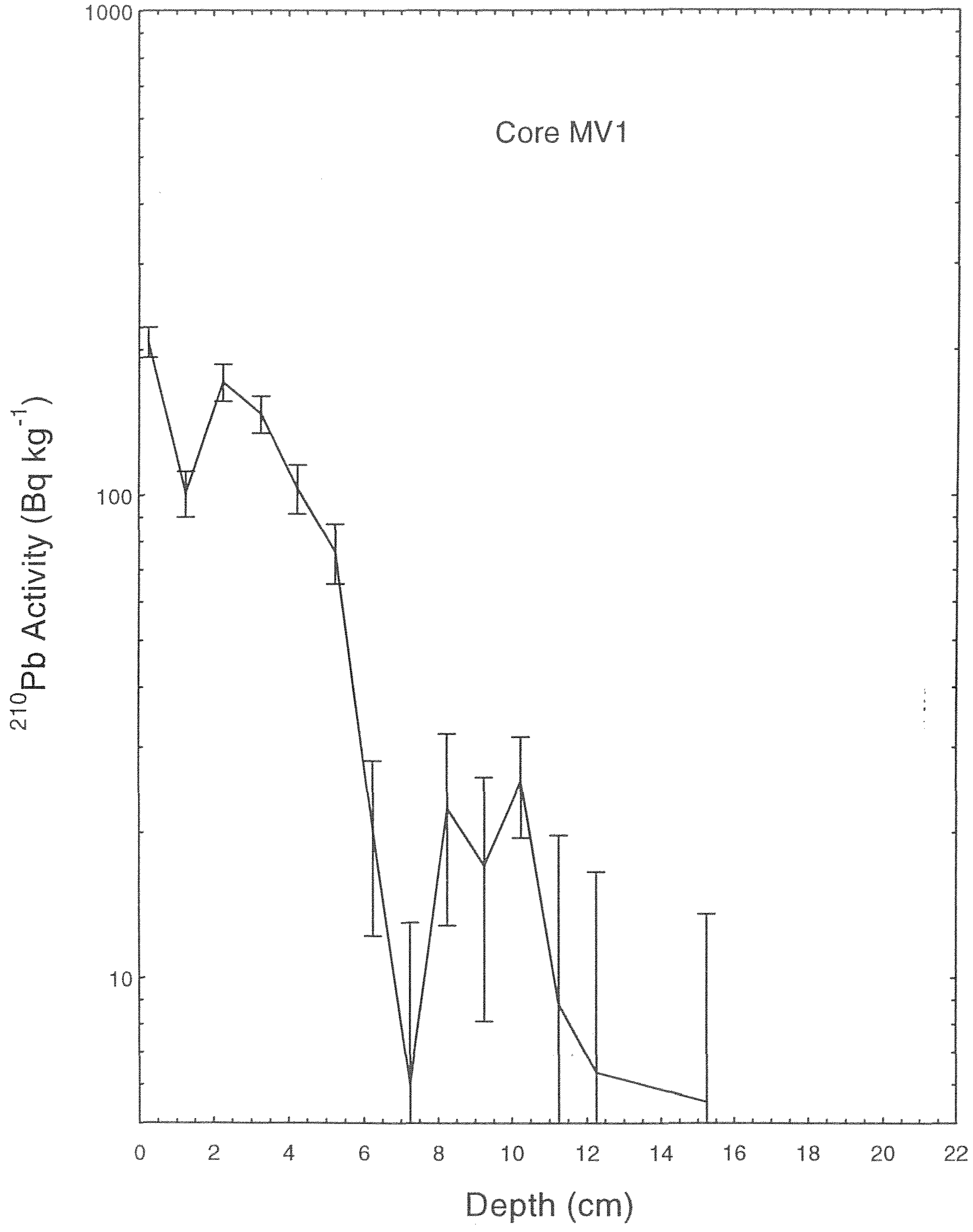


Fig.4c

Lough Melvin

^{137}Cs & ^{241}Am Activity versus Depth

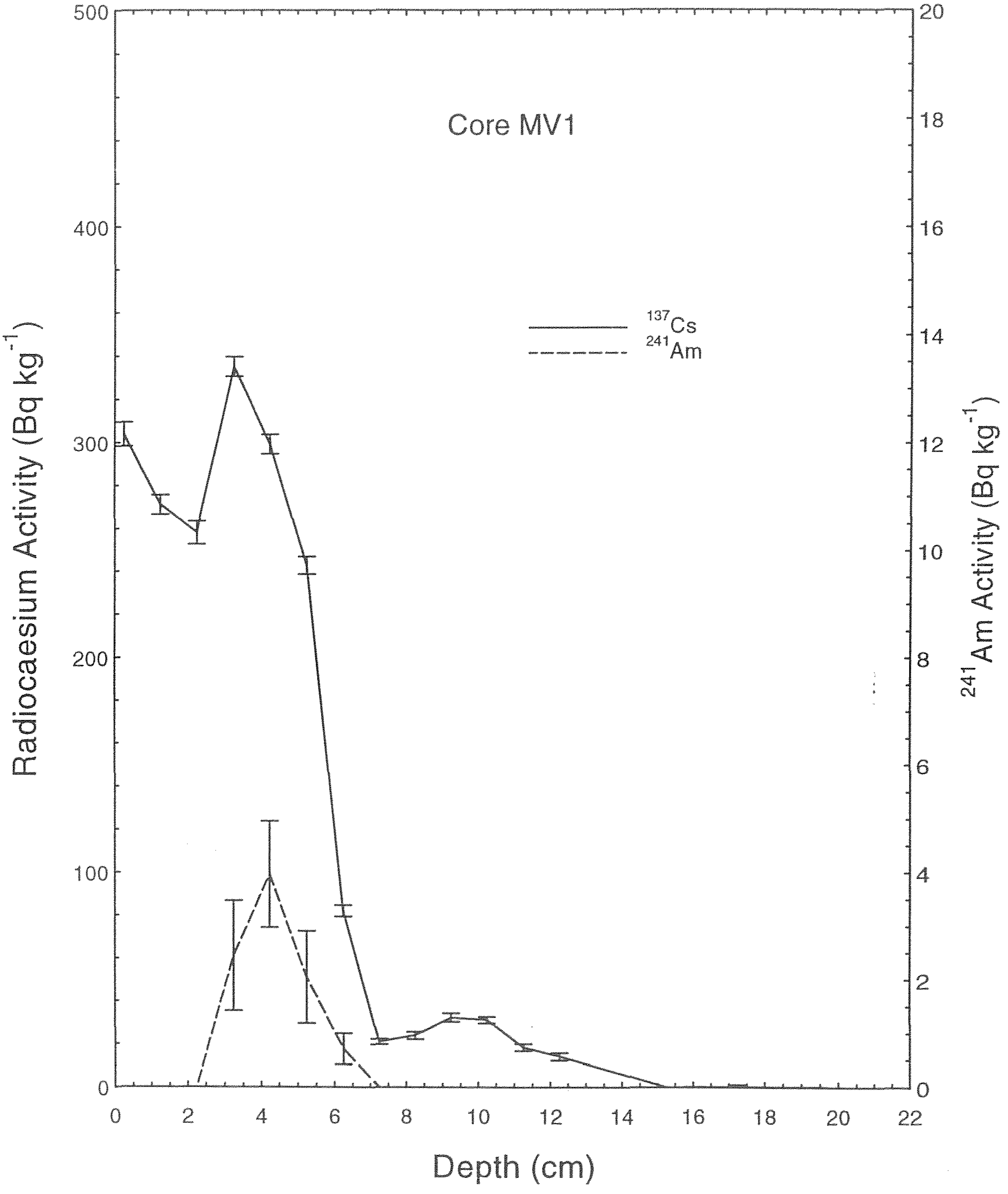


Fig.5

Upper Lough Erne Core TG2
Depth versus Age

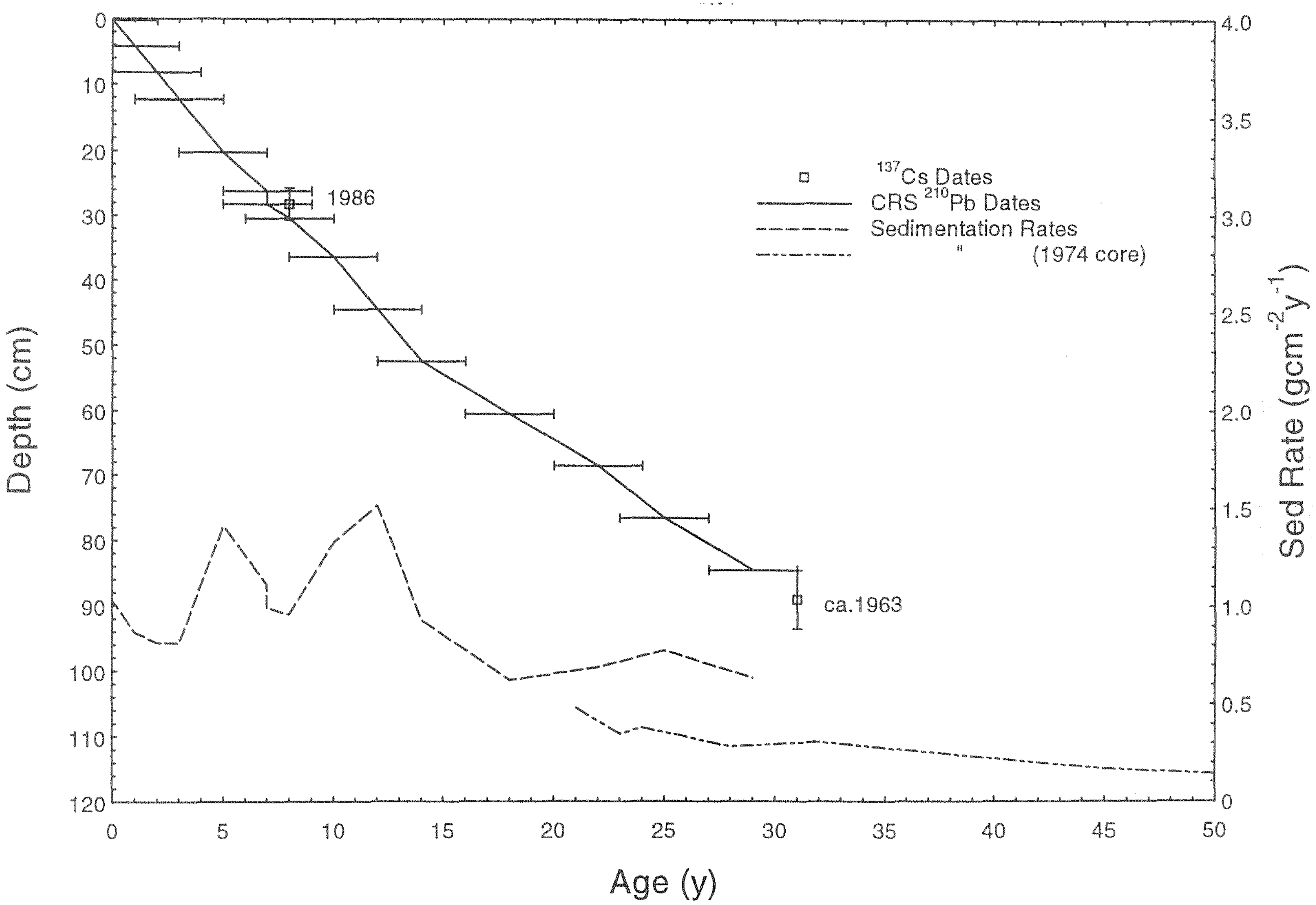


Fig.6

Lower Lough Erne Core MH2
Depth versus Age

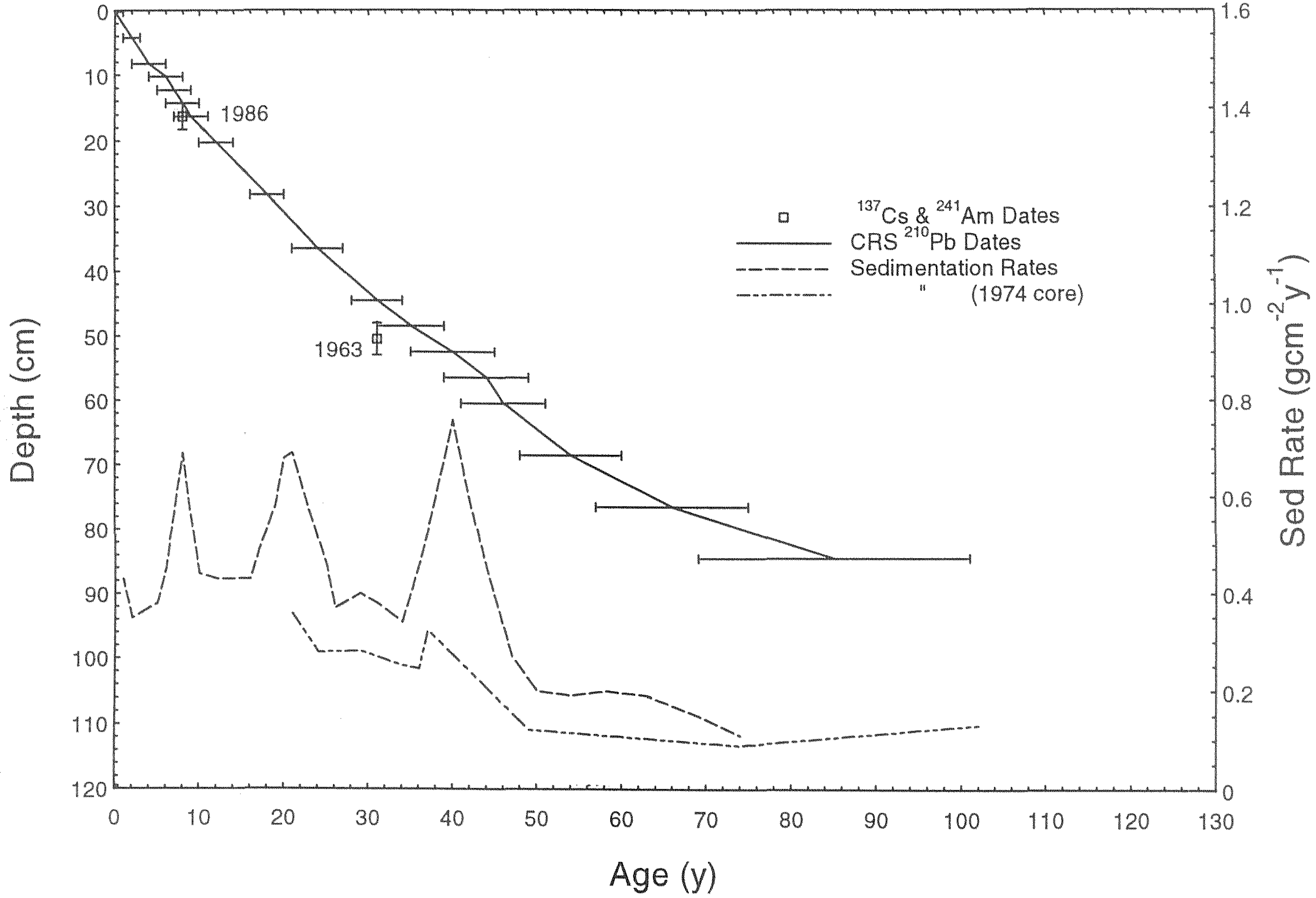


Fig.7

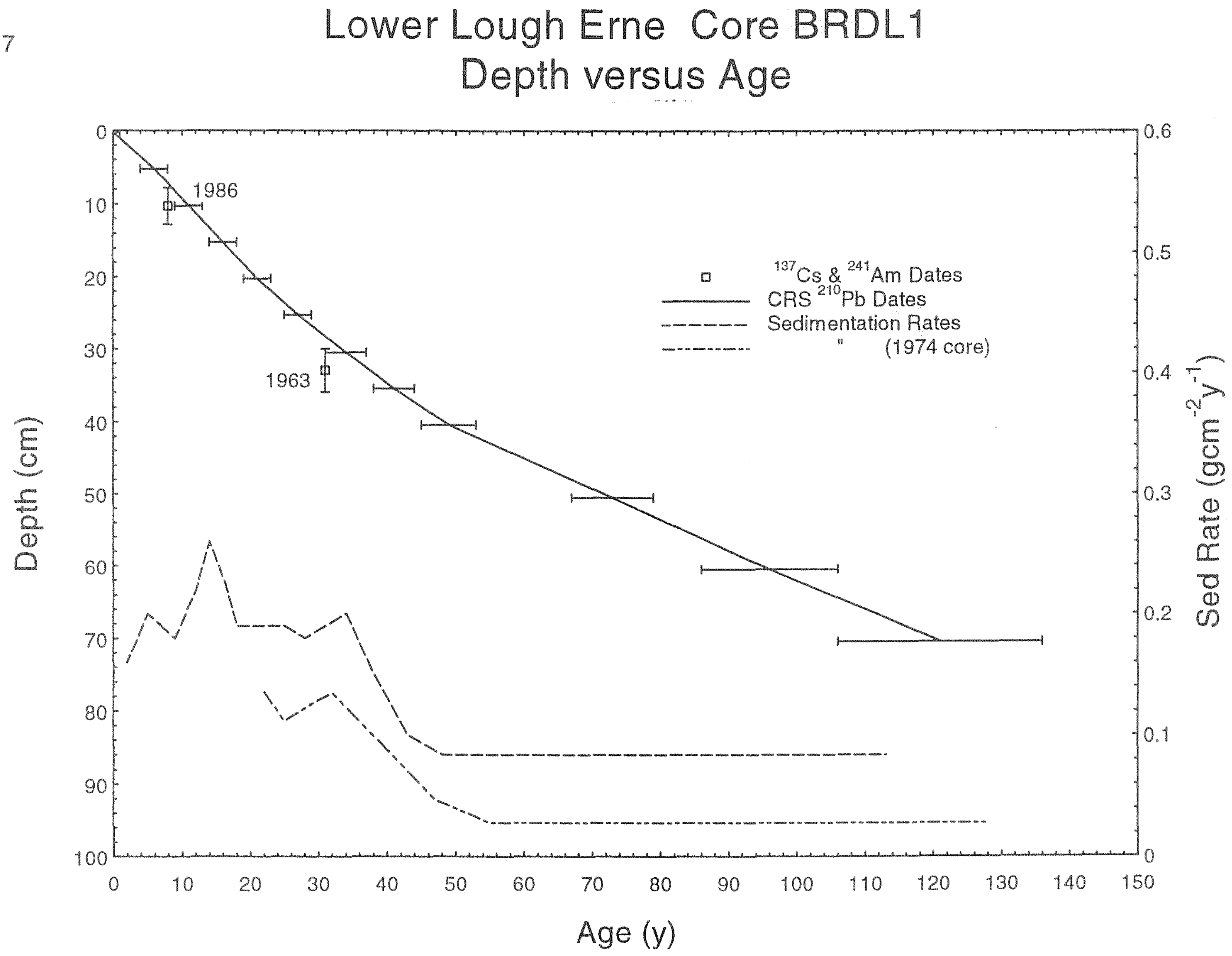
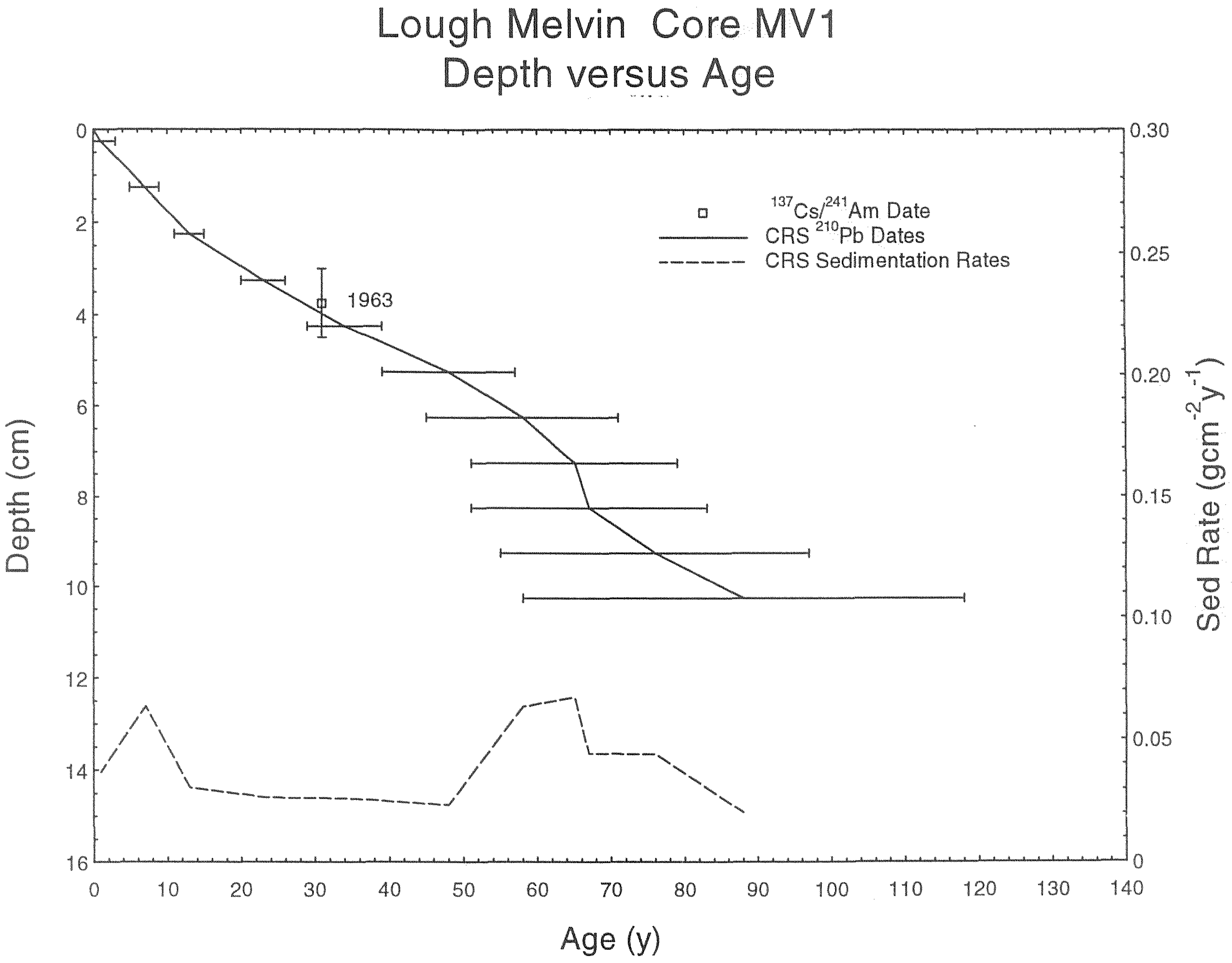

Lower Lough Erne Core BRDL1
Depth versus Age
^{137}Cs & ^{241}Am Dates
CRS ^{210}Pb Dates
Sedimentation Rates
" (1974 core)
1986
1963
Depth (cm)
0
10
20
30
40
50
60
70
80
90
100
Sed Rate (gcm^{-2}y^{-1})
0.6
0.5
0.4
0.3
0.2
0.1
0
Age (y)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

Fig.8


Lough Melvin Core MV1
Depth versus Age
$^{137}Cs/^{241}Am$ Date
CRS ^{210}Pb Dates
CRS Sedimentation Rates
1963
Depth (cm)
0
2
4
6
8
10
12
14
16
Sed Rate ($gcm^{-2}y^{-1}$)
0.30
0.25
0.20
0.15
0.10
0.05
0
Age (y)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140