WORKING PAPERS

No. 12

ROYAL SOCIETY SURFACE WATER ACIDIFICATION PROJECT (SWAP)

PALAEOLIMNOLOGY PROGRAMME

Research Co-ordinators:

Richard W. Battarbee and Ingemar Renberg

JULY 1985

PALAEOECOLOGY RESEARCH UNIT

DEPARTMENT OF GEOGRAPHY

UNIVERSITY COLLEGE LONDON

SWAP PALAEOLIMNOLOGY PROGRAMME

Programme co-ordinators: Rick Battarbee and Ingemar Renberg

In September 1983 the Royal Society launched a £5,000,000 research programme funded jointly by the Central Electricity Generating Board and the National Coal Board to investigate mechanisms of surface water acidification in Norway, Sweden, and the United Kingdom. The Management Committee of the programme identified palaeolimnology as a key area of research and we were invited to submit an integrated proposal that was aimed not only at tracing acidification history at important sites but also at evaluating alternative hypotheses for lake acidification in each of the three countries. We were also encouraged to use as wide a range of techniques as possible. The programme approved by the Management Committee initially in June 1984 and finally in December 1984 is summarised in the following pages. A number of projects began on October 1st 1984 and all remaining projects are scheduled to begin on April 1st 1985. The programme will be completed by September 1988 when the final results will be presented at an open discussion meeting.

Project 1: Palaeolimnology and acidification history of 6 study sites in Norway, Sweden, and the UK

A substantial proportion of the effort within the programme will be devoted to the comprehensive study of the recent palaeolimnology of a series of 6 lakes. These are located close to the experimental stream catchments that are being studied by others in the main SWAP programme. The location of these sites has not yet been finalised but three will be in Scotland (Trossachs, Cairngorms, and the North-west), two in Norway (Birkenes, and one other), and one in Sweden (in the Gårdsjön area). It is hoped that these sites will represent a range of acidification conditions from heavily polluted to relatively clean areas, and one of the main aims of this project is to assess the timescale and extent of acidification at each of these sites.

Project 1a: Diatom, pollen, and geochemical analysis

Principal investigators: **Ingemar Renberg** and **Rick Battarbee**

Project 1(a) is concerned with fieldwork, diatom, pollen, geochemical and catchment analysis and will be carried out mainly by our own laboratories. The second part (projects 1(b)-1(j)) includes more specialist analysis and will be carried out by appropriate personnel in the three countries. These individuals will in most cases work on material from all sites, and where necessary from sites in other projects.

Field work for this project will take place between March 1985 and July 1986 and will prgressively generate samples for projects 1(b)-1(j) below. The first samples should be available in summer 1985.

Project 1(b) 210Pb dating - UK sites

Frank Oldfield and **Peter Appleby** (Liverpool)

The aim of this project is to provide a reliable chronology

of sediment accumulation at each site for approximately the last 150 years. The work will be divided between Liverpool and Uppsala laboratories (see project 1(j) below). In Liverpool direct gamma assay will be used to measure ^{210}Pb, ^{226}Ra, and ^{137}Cs activities on the same sample. Since the measurements are non-destructive samples can be re-used for other purposes. Dates from these measurements will be calculated by Peter Appleby on the basis of the most appropriate dating models.

Project 1(c) Magnetic measurement of lake sediment

Frank Oldfield

The main aim of this project is to provide for each site a full magnetic characterisation of the recent sediments of the lake catchment and of atmospheric deposition. These data, some of which can be acquired in a rapid and non-destructive way, can be used in core selection procedures and core correlation, in identifying shifts in sediment source associated with catchment disturbances, and in recording atmospheric deposition of magnetic particles resulting from fossil fuel combustion and industrial processes over the last two centuries.

Project 1(d) PAH analysis

Brian Rippey (Ulster)

Studies of PAH in lake sediments in Europe and America have all concluded that higher concentrations and more complex mixtures found in recently deposited sediments are the result of input from anthropogenic sources from combustion of fossil fuels, usually by atmospheric transport. PAH measurements will consequently be made on cores from all sites using HPLC separation and detection by fluorescence. Individual PAH's will be identified in an attempt to distinguish between petroleum and other combustion products.

Project 1(e) S isotope

under discussion

Project 1(f) Chironomid analysis

Yngve Brodin (Uppsala)

The main aims of this project are to assess the influence of acidification on macrobenthic fauna communities and to evaluate the use of chironomids as indicators of environmental change caused by acidification. It is hypothesised that acidification will result in a less diverse fauna, a characteristic change in the dominance of different taxa, and an increase in the proportion of carnivorous species. Standard techniques will be used and taxonomic identifications will be mainly based on comparisons with laboratory-reared specimens.

Project 1(g) Cladocera

Jens-Petter Nilssen (Oslo)

Lake acidification leads to shifts in planktonic cladocera populations, especially in the genera Bosmina and Daphnia, and to changes in the Chydoridae. Remains of these taxa will be identified and counted in the sediment at all sites. A further Cladocera project aimed at evaluating morphological change as an indicator of fish predation is described below (project 4a).

Project 1(h) Chrysophyceae

Gertrud Cronberg (Lund)

Chrysophytes produce resting stages in the form of endogenously formed siliceous cysts and the family

Mallomonadaceae in addition have cells covered with loosely attached silica scales. Both scales and cysts are preserved in lake sediments and can be used to reconstruct chrysophyte populations. Since many species have restricted environmental distributions and are sensitive to changes in pH these microfossils can be used to trace acidification history.

Project 1(i): Carbonaceous particles (soot)

Ingemar Renberg and Maria Wik (Umea)

The combustion of fossil fuels generates carbonaceous particles that are emmitted into the atmosphere along with other pollutants. Lake sediments contain a record of these particles that reflects the history of soot deposition. Particles from oil combustion can be distinguished from coal derived particles and the stratigraphic record should correlate with other indicators of atmospheric contamination including trace metal, magnetic and PAH profiles.

Project 1(j): 210Pb dating - Scandinavia sites

Farid El-Daoushy (Uppsala)

210Pb in cores from Scandinavian sites will be measured at Uppsala using standard alpha spectrometry. Comparisons will be made with samples measured in Liverpool using gamma counting (see project 1b, above).

Project 2(a): Causes of lake acidification: an evaluation of the land-use hypothesis in Norway

Principal investigator: **Ivan Rosenquist** (Oslo)

This project aims to evaluate the view that acidification in Norway is related more to vegetation regeneration following land abandonment than to acid precipitation. Professor Rosenquist has proposed an explicit test of this hypothesis based on the observation that many lakes with the medieval name Fiskelos had, despite the name, good fish populations until the recent twentieth century decline. It is suggested that these lakes acidified and lost their fish populations after land abandonment in medieval times but that fish returned after the land was improved by later settlers. This situation allows a palaeolimnological test of a land-use acidification hypothesis to be conducted in the absence of the confusing influence of acid deposition from anthropogenic sources.

Pollen analysis will be used to identify suitable sites and a full range of analyses will be used to assess the extent of any early acidification. These data will be compared with similar data for nineteenth and twentieth century change and with data from a nearby control site where little vegetational change has occurred over the last 100 years. All other possible explanation for ecological change over the last 2000 years will be considered.

Personnel on this project include:

Helge Hoeg - pollen analysis
Bjørg Stabell - diatom analysis
Turid Winje - geochemical analysis

and those listed under projects 1(b)-1(j) above.

Project 2(c): Causes of lake acidification: afforestation in the UK

Principal investigator: **Rick Battarbee** (London)

Many upland areas of the UK have been afforested since 1945 with introduced coniferous species, and it has been noted in Scotland and in Wales that afforested stream catchments tend to be more acid and have poorer brown trout fisheries than adjacent moorland control catchments. The mechanism for such an effect is unclear but several possibilities exist including base cation depletion by forest growth and enhanced interception of dry deposition from the atmosphere. On the other hand in Galloway it has been shown that lake acidification is largely independant of afforestation. This project therefore aims to assess the palaeoecological evidence for the possible acidifying effects of afforestation by comparing the pre- and post-afforestation sediments of lakes with afforested catchments in areas of high and low acid deposition.

Personnel include:

Annette Kreiser - diatom analysis
Tony Stevenson - pollen analysis
Brian Rippey - geochemical analysis
Simon Patrick - catchment history

and those listed under projects 1(b)-1(j) above.

Project 3: Causes of lake acidification: **evidence** from pre-industrial sediments in Sweden

Principal investigator: **Ingemar Renberg** (Umeå)

This project, as project 2a, aims to test various land-use hypotheses by reference to earlier times when land-use change took place in the absence of significant quantities of atmospheric acid deposition.

Project 3a aims to assess whether short term fluctuations in lake acidity have taken place prior to the most recent acidification period, and whether the practise of sampling at spaced intervals down a sediment core hides smaller scale natural fluctuations in acidity. This project will be primarily concerned with diatom analysis.

Project 3b is designed to assess the effect of the well documented post Iron Age decline in agriculture in Middle Norrland on the acidity of lakes. In many ways this decline, clearly recorded in pollen diagrams, is analagous to the land-use changes that have taken place in modern times. Both pollen and diatom analysis will be used in this study.

Project 3c considers the possible acidification effect of spruce forest expansion that has occurred especially in S. Sweden during the last few hundred years by using the 3000 BP natural spruce immigration in Sweden as a pre-industrial analogue. To avoid possible paludification influences only lakes without peatlands in their catchments will be selected.

Project 3(d): Causes of lake acidification: the post-glacial perspective

Principal investigator: **Elizabeth Haworth** (Windermere)

There have been many studies of the post-glacial development of acid, oligotrophic lakes but few of these in the UK have included a detailed analysis of the uppermost sediments where any effects of recent acidification are recorded. It is consequently proposed to revisit and resample two sites, one in England and one in the north-west of Scotland and carry out a detailed analysis of sediment deposited during the last 200 years or so. These data will then be integrated with existing data on changes over the last 10,000 - 15,000 years at these sites and an assessment will be made of the relative importance of the various acidification processes over this time period. Diatom analysis will be the main technique used.

Project 4a: Evidence for changes in fish population in acid lakes from the analysis of zooplankton assemblages in sediment cores

Principal investigator: **Jens Petter Nilssen** (Oslo)

Although the main concern in acidified lakes is loss of fish populations it is impossible to directly trace such changes in lake sediments in a quantitative way. This project aims to evaluate the use of zooplankton microfossils in sediments as an indirect indicator of fish populations. A number of lakes with well-documented fish losses will be chosen for sediment coring. In each case there will be an attempt to assess the extent to which changes in cladocera size and shape before and after fish loss matches predicted changes as observed in enclosure experiments with and without fish. 210Pb dating will be required to identify the expected stratigraphic location of fish loss, and diatom analysis is needed to reconstruct and trace pH history.

Project 4b: The history of atmospheric deposition in ombrotrophic peat bogs with special reference to magnetic particles

Principal investigators: **Frank Oldfield** and **Dicky Clymo**

The identification of atmospheric dusts and aerosols in lake sediments is complicated by the presence of analagous material derived from the catchments of lakes. Deposition on ombrotrophic peats, however, is exclusively atmospheric and the peat record potentially contains an unrivalled history of atmospheric pollution much of which can be traced using magnetic mineral techniques. This project is concerned with an evaluation of this approach, especially with respect to:

a. the link between magnetic minerals and heavy metals

b. the importance of surface microtopography in particle distribution in time and space

c. the possible post-depositional movement of magnetic particles and solutes in peats

d. the possible solution of magnetic minerals in peats.

Project 4d: Structure and reaction of diatom communities in acid rain regions

Principal investigator: **Frank Round** (Bristol)

Despite the universal use of diatoms in lake sediments as indicators of pH and pH change there are many relevant facets of diatom ecology that are relatively poorly known. Chief of these is the composition and relative importance of the communities from which core diatoms are derived. This project aims to sample a range of habitats from a number of acid lakes in Wales, to separate living from dead cells, and to assess the relative indicator value of the various taxa. In addition sites sampled in the English Lake District between 1948 and 1951 will be resampled to ascertain whether significant change has taken place.

Project 4e: Rotifer resting eggs as indicators of freshwater acidification

Principal investigator: **Linda May** (Edinburgh)

This project aims to explore the use of rotifer resting eggs preserved in lake sediments as indicators of lake acidification. The technique will be tested at sites in Galloway, south-west Scotland where diatom analysis has already shown acidification to have occurred.

It is proposed to test two methods of determining the species composition of past rotifer communities. The first takes advantage of the fact that the outer shells of rotifer resting eggs are unique for each species. An identification key for this purpose will be compiled. The second method involves the incubation of sediments in order to induce resting eggs to break their dormancy and hatch. Although this method has already been successfully used with surface sediments it is not yet known whether similar results can be obtained from older sediments.

Project 4f: Diatom evidence for the reversibility of lake acidification

Principal investigators: **Roger Flower** and **Rick Battarbee**

One of the most important ecological and political issues is the extent to which lake acidification is a reversible process. The literature so far has been based on theoretical models that assume reversibility but do not consider the rate of lake response. A palaeolimnological evaluation of this question is possible in the UK since sulphur emissions have decreased by between 30 and 40 per cent since 1970 and since an approximately linear response in sulphur deposition and in the frequency of highly acidic precipitation events has been recorded in Scotland.

In order to assess whether this decrease in atmospheric loading and deposition has been passed on to surface waters it is proposed to carry out a microstratigraphic diatom analysis of sediments deposited over the last 20-30 years at a site in Galloway where acidification has already been shown to have occurred.

MAIN PARTICIPANTS

Dr Peter Appleby Department of Theoretical and Applied Mathematics University of Liverpool LIVERPOOL UK	^{210}Pb dating	1b
Dr Rick Battarbee Palaeoecology Research Unit Department of Geography University College London 26 Bedford Way LONDON WC1H 0AP UK	diatoms administration	1a, 2c
Mr Frode Berge 2920 Leira Valdres Norway	diatoms	1(a)i, 4a
Dr Yngve Brodin ~~Department of Zoology~~ ~~Section of Entomology~~ ~~University of Uppsala~~ ~~Box 561~~ ~~S-751 22 UPPSALA~~ ~~Sweden~~ Naturvårds styrelsen Mariestad Sweden	chironomids	1f
Professor Dicky Clymo Dept. of Biological Sciences Queen Mary College LONDON	chemistry	4b
Dr Gertrud Cronberg Institute of Limnology Box 3060 S-220 03 LUND Sweden	chrysophyceae	1h

Dr Farid El-Daoushy Institute of Physics Uppsala University Box 530 S-751 21 UPPSALA Sweden	210Pb dating	1j, 4a
Dr Roger Flower Palaeoecology Research Unit Department of Geography University College London 26 Bedford Way LONDON WC1H OAP UK	diatoms	1a,2c
Dr Elizabeth Haworth Freshwater Biological Assoc. The Ferry House, Ambleside, Cumbria LA22 OLP UK	diatoms	3d
Mr Helge Hoeg Historisk Museum Fredericksgt. 2 OSLO Norway	pollen	1(a)i, 2a
Ms Annette Kreiser Palaeoecology Research Unit Department of Geography University College London 26 Bedford Way LONDON WC1H OAP UK	diatoms	2c
Dr Jens-Petter Nilssen Institute of Biology PO Box 1050 Blindern, OSLO 3 Norway	cladocera	1g, 4a

Professor Frank Oldfield Department of Geography University of Liverpool LIVERPOOL UK	210Pb dating magnetics	1b, 1c 4b
Mr Simon Patrick Palaeoecology Research Unit Department of Geography University College London 26 Bedford Way LONDON WC1H 0AP UK	catchment history	1a, 2c
Dr Ingemar Renberg Dept. of Ecological Botany Umea University S-901 87 UMEA Sweden	diatoms soot administration	1a(ii),1i, 3a-c
Dr Brian Rippey University of Ulster Limnology Laboratory Traad Point Drumenagh, Nr Magherafelt Co. Londonderry. N. Ireland	geochemistry	1(a)iii 1e, 2c
Professor Ivan Rosenquist Department of Geology PO Box 1047 Blindern N-0316 OSLO 3 Norway	sedimentology	2a
Professor Frank Round Department of Botany University of Bristol Woodland Road BRISTOL BS8 1UG UK	diatoms	4c

Dr Bjorg Stabell Department of Geology PO Box 1047 Blindern N-0316, OSLO 3 Norway	diatoms	2a
Dr Tony Stevenson Palaeoecology Research Unit Department of Geography University College London 26 Bedford Way LONDON WC1H OAP UK	pollen	1a,2c
Mr Anders Timberlid 5900 Hoyanger Norway	land-use	1(a)i
Ms Maria Wik Dept. of Ecological Botany Umea University S-901 87 UMEA Sweden	soot	1i
Dr Turid Winje Department of Geology PO Box 1047 Blindern N-0316, OSLO 3 Norway	geochemistry	1(a)i, 2a