Quaternary Research in Britain and Ireland

A history based on the activities of the Subdepartment of Quaternary Research, University of Cambridge, 1948 - 1994

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Part I

Antecedents

Preface

This history began life as an attempt to record the activities and contributions of the Subdepartment of Quaternary Research in the University of Cambridge. The Subdepartment was founded in 1948 and was replaced by the Godwin Institute for Quaternary Research in 1995 . This period saw a huge expansion of interest and research into the various sciences concerned with interpreting the environmental changes identified in the Quaternary, their causes, and their connection with plant and animal life and human evolution. The research funding for the subject vastly increased, stimulated by the evident importance of environmental change for the life we see today. Here I look back at these developments to try and trace their genesis and history over the period I was associated with the Subdepartment. In writing such a history of the Subdepartment, I soon found that the question arose, as it does with all attempts of the kind: where is the beginning ? We are naturally led back to achievements of research before the foundation of the Subdepartment, and we have to trace the infancy of the subject. This is all the more complex in a field of research which involves so many disciplines – geology, botany, archaeology, geography, geochronology, and so on. I have chosen to start through a botanical entrance, and to consider how this subject came to be involved in stratigraphy and other relevant subjects before and during the development of the Subdepartment; an appropriate entrance since the founder of the Subdepartment was the botanist Harry Godwin.

This approach means that we have to look back many years at the development of the botanical element in Quaternary research, and this will return us to the pioneering work of Clement Reid in the latter part of the nineteenth century. His contribution to the subject on many fronts illustrate the way in which matters later developed, notably in relation to colleagues in north-west Europe, and they form a firm foundation for the history. From the time of Reid's contributions, the history is conveniently divisible into two further periods prior to the foundation of the Subdepartment in 1948: from the early 1900s to 1929, and from 1930 to the late 1940s. These divisions form the basis for Part I. Part II concerns the history of the Subdepartment, with a detailed account of the research and those involved in it. Part III gives a wider and more general view of developments in Quaternary research in Britain before and during the time of the Subdepartment.

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Chapter 1

The contribution of Clement Reid (1853-1916) to the foundation of Quaternary research

Nothing sums up Clement Reid's attitude to his work better than the preface to his short book on *Submerged Forests* (Reid 1913; Plate 1):

> *'Knowledge cannot be divided into compartments, each given a definite name and allotted to a different student. There are,and always must be, branches of knowledge in which several sciences meet or have an interest, and these are somewhat liable to be neglected. If the following pages arouse an interest in one of the by-ways of science their purpose has been fulfilled'.*

In the same book Reid noted the presence of several species of beetle and the stamens with pollen of willowherb in peat dredged from the Dogger Bank in the North Sea and drew conclusions about the nature of the fen environment at the time and the implications for past changes of sea level. The 'by-ways of science' he discusses in the book have of course now become a mainstream of research, with the increased knowledge and recognised significance of environmental history, sea-level change and climatic change.

Clement Reid's philosophy had been evident from the days he started his work with the Geological Survey in 1874, and must have developed at an early stage in his life, for he took a wide interest in field natural history during his boyhood (Groves 1917; Preece & Killeen 1995). He started with the Geological Survey under the guidance of H.B.Woodward in south-west England, and in 1876 moved to Norfolk, with Woodward, and started his classic investigation of the Quaternary deposits of the coastal sections of north and east Norfolk (Cromer Memoir, Reid 1882). These sections, in addition to their remarkable geological interest, were rich in plant and animal remains, terrestrial, freshwater and marine. The combination suited Clement Reid's approach and he became fully involved in the identification of the fossils, and their interpretation in terms of stratigraphy, climatic significance and sea-level changes. He engaged the assistance of many leading specialists for the work of identification, as shown by the list of acknowledgements in the preface of the Cromer Memoir, a foretaste of the multi-disciplinary approach of today. Later the work was extended to the Pliocene deposits of Britain (Reid 1890), especially those of East Anglia; the Pliocene at that time included the 'pre-glacial' deposits of the Norfolk and Suffolk coasts, already dealt with in the Cromer Memoir. The

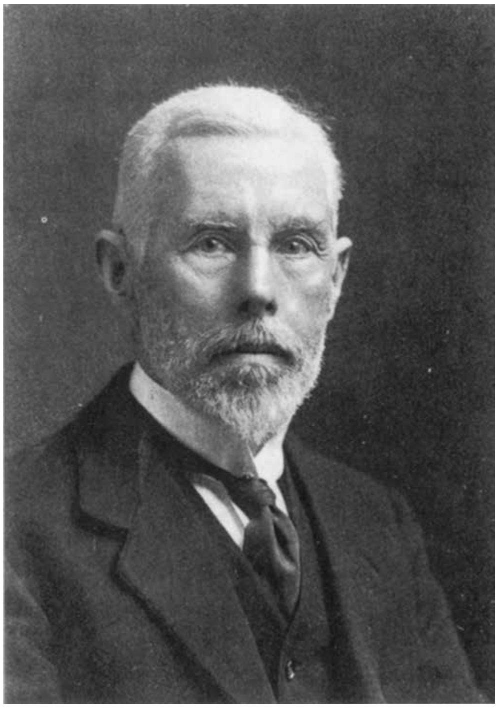

Plate 1. Clement Reid (1853-1916) (from Groves 1917).

resulting synthesis of geology, stratigraphy, vegetational and faunal history was a remarkable achievement, presenting a firm foundation for the enlargement of the research carried out decades later.

Clement Reid's botanical work at Cromer was aided by W.Carruthers, who identified collected plant remains from the coastal sections, and by A.G.Nathorst of the Geological of Sweden, who instructed him 'on the mode of occurrence, and method of collecting the fossil arctic plants' (Reid 1882). Nathorst (1873) had already visited sections on the Norfolk coast in 1872 and collected remains of arctic plants from horizons between the Forest Bed and the glacigenic sediments. Nathorst's advice to Clement Reid was an early example, perhaps the first, of a relation with Scandinavian geologists interested in Quaternary palaeobotany which was later strongly developed to our advantage.

Reid's great interest in Quaternary palaeobotany was later expressed in his book 'The origin of the British Flora' (Reid 1899), which listed sites with Quaternary floras, gave a stratigraphy to the sites (Preglacial, Early Glacial, Interglacial, Late Glacial, Neolithic) and enumerated the plant records from these sites. The stratigraphical units are simple; he realised complexity existed, but wanted to avoid the uncertainties of the time. The inclusion of archaeological contexts for some of the sites is an indication of his wide interests in the subject.

The plant records from this book were the basis for Godwin's later compilation of Quaternary plant records, started in 1942. The compilation led to his publication of 'the History of the British Flora in 1956, in which he vividly described Reid's contribution to the subject.

Reid wrote that 'this problem of the origin of our flora is one which can be solved, I think, by the historical method, and that seems to be the proper mode of attacking it' (Reid 1899). He allied stratigraphy with the plant records, with the consequence that he was able to revise Edward Forbes' (1846) ideas of the effect of climatic change on plant distribution and offer a substantial factual base for considering the history of the flora. He interpreted the results which emerged in terms of changing climate and distribution of the species. Chapter One of the book outlines Reid's approach to the subject. To develop the work, he made a reference collection of seeds and fruits of British plants, and studied in the field their means of dispersal, times of ripening and the abundance or scarcity of ripe seeds. He looked at plants as a field naturalist, and had some criticism of a practice of taxonomy which confused what we would now call ecotypes with well-defined sub-species; this aspect of interpretation of the fossil record still makes for much difficulty today.

Clement Reid's achievement was not followed up for some time. Indeed the work on the Cromer coast fossiliferous deposits, in spite of their evident interest and importance, was not resumed until the 1950s. The development of the subject took a long and interrupted path between Reid's contribution and the founding of the Subdepartment in 1948.

Chapter 2

From the early 1900s to 1929

Scandinavia and Britain: two regions, two histories

In Scandinavia, Quaternary deposits mask the mainly Precambrian bedrock over wide areas. The deposits include glacigenic sediments, varved clays, marine sediments and terrestrial and lacustrine organic sediments, all combining to record the detailed history of the retreat and dissolution of the Scandinavian ice-cap and the accompanying isostatic recovery. It is hardly surprising that the study of these sediments and their relation to such significant changes as land uplift and Baltic Sea history became a major geological activity in geological surveys and other state institutions and universities in Scandinavia at an early date. Quaternary sediments were all-important in research on economic resources and land-use: for example using erratic trains for tracing bedrock mineral resources, or studies of peat terrain in agricultural or forestry studies.

The mapping of the sediments, the construction of methods of correlation via varved clay studies, marine limits and peat stratigraphy, and palaeontological studies of organic and marine sediments combined to lead to a chronology of late- and post-glacial history. This chronology became a basis for the expansion of the subject in Europe, especially after the meetings and publications of the International Geological Congress in Stockholm in 1910. A glance at the chronological and stratigraphical tables of Gams & Nordhagen (1923) and Woodhead (1928) will show the influence of the Scandinavian contribution to the subject in many fields in the wider Europe.

In Britain, however, with a history of geological survey of the wide range of rocks of all systems, and the associated economic importance of the mineral resources, less emphasis was placed on the investigation of Quaternary deposits. Perhaps also the stratigraphical complexity resulting from multiple glaciation made for difficulties in the analysis of Quaternary stratigraphy. We see that the earlier approach to Quaternary research in Scandinavia than in Britain stems, naturally, from the national needs and the opportunities available in the pursuit and understanding of the subject.

Developments in Scandinavia

The imminence of the International Geological Congress in Stockholm in 1910 led to the publication of papers on the state of research on what was to be a main theme of the Congress – postglacial climatic change. De Geer and Sernander

(1908) wrote on the development of the varve chronology and on evidence of climate change from the study of peat stratigraphy. The latter was a subject of controversy. Interpretation of peat successions in Norway and Sweden had became a central part of attempts to understand post-glacial climatic changes and the immigration of the flora. In this survey Sernander took into account Lewis' observations in Scotland and those of Weber in north-west Germany and he summarised the case for the Blytt-Sernander scheme of alternating drier and wetter periods: Boreal (dry), Atlantic (wet), Sub-boreal (dry), Sub-atlantic (wet). Von Post (1946) later described the development of the Blytt-Sernader scheme. At the time, there were strong critics of this scheme, including Andersson, who in a separate arcticle (1909), also intended as an introduction for the Congress, gave a wide-ranging account of the methods for determining climates (including geological and stratigraphical, palaeontological, biogeographical and astronomical). This contribution is interesting in reflecting thoughts on these matters before pollen analysis became a very significant contributor to the discussion.

During this time pollen analysis (or pollen statistics as it was termed) developed as a technique applied to Quaternary sediments. The history has been described by Erdtman (1943), Faegri & Iversen (1950) and Faegri (1973, 1981), and took place largely in Scandinavia and north Germany in the late part of the 19th century and the first two decades of the 20th century. Lagerheim and other Swedish scientists, both geologists and botanists, contributed or published pollen analyses early in the century. L. von Post (1909) used frequency classes for *Picea* pollen and gave pollen records for other taxa from several sites in central Sweden. He traced the migration of forest trees and related the sequences to the Baltic stages. Von Post refined the methods involved in analysis and in the presentation of results in his classic paper of 1916, giving a series of quantitative analyses along a transect of sites (von Post 1916, translated in von Post 1967), later developed a regional synthesis of forest history in southern Sweden, using information from over 200 sites (von Post 1924). O.G.E. Erdtman (1897-1973), took a botanical approach to the subject, publishing his thesis in 1921. This is considered to be the first detailed pollen-analytical paper to be published in a so-called 'congress' language (Hedberg 1973) and made a wide impact on the spread of the subject in Europe and further afield. The advances concerned not only late-glacial and post-glacial vegetational history (and chronology), but also earlier temperate stages (*e.g.* Jessen & Milthers 1928).

Developments in Britain

In the early 1900s moves were afoot by ecologically-minded botanists to develop studies of British vegetation, a history described in detail by Tansley (1947), Lowe (1976) and Sheail (1987). A founding meeting of a Central Committee for the Survey and Study of British Vegetation was held in Leeds in 1904, the four members present being C.E.Moss (Manchester), W.G.Smith (secretary, Leeds), A.G.Tansley (London), and T.W.Woodhead (Huddersfield). Others, including F.J.Lewis (Liverpool), R.Ll. Praeger (Dublin) and W.M.Rankin (Portsmouth) communicated their support to the meeting. The purpose was to further vegetation survey in particular and ecology in general, following surveys which had started following individual initiatives in various parts of Britain. The meeting had a distinct northern flavour, perhaps reflecting the initiative of W.G.Smith and the achievements in mapping vegetation, mainly in northern Britain, by Moss, R. and W.G.Smith and Lewis. At a further meeting of the Committee in Liverpool in 1905, Lewis gave a summary of his work on peat mosses of south-west Scotland. W.G.Smith, the secretary of the Committee, remarked that "This system of continuous investigations on peat bogs has already greatly advanced our knowledge of the composition of peat, and of the succession of vegetation on moors, while the bearing of the work on glacial theories is evident" (Smith 1905). Of these early students of vegetation study, Lewis and Woodhead both made significant contributions to Quaternary research, to be described later.

In 1911, an International Phytogeographical Excursion was held in the British Isles, proposed and largely organised by A.G.Tansley, with a subcommittee of the Central Committee arranging the details of the field excursions (Shaeil 1987). Lewis was one of this small group. One of a number of international guests was F.E.Clements (Minneapolis), the leading American ecologist. He wrote of impressions and reflections on the meeting, commenting in particular, with his interest in plant succession, on the value of the study of peat: "To one impressed with the complex relations between moor and heath , "Hochmoor", "Flachmoor" and fen, it seems that an exact study of all the factors and population changes for a long period will be necessary for a solution. The importance of doing this is greatly emphasised by the widespread opportunities for tracing the vegetation movements of the past in the almost innumerable peat sections. These serve as an invaluable link between the successions of today and of the immediate geological past. It seems beyond question that their thorough study will reveal much of the development and structure of vegetation long since disappeared. British Botany contains no more alluring field than this of correlating the peat deposits and connecting their successions with those in existence at present." (Clements 1912).

Against this botanical background we can look at developments in Quaternary paleobotany. The study of macroscopic remains pioneered by Clement Reid was developed by Mrs E.M.Reid and her associate Miss M.E.J.Chandler. Making use of Clement Reid's reference collection, Miss Chandler made a detailed study of the plant remains from organic seams in Late Devensian fluviatile gravels at Barnwell Station, Cambridge, known to contain a rich flora of 'full-glacial aspect'. This was the first really detailed study of such an assemblage (Chandler 1921). The assemblage was re-examined in 1970 by Bell and Dickson (1971), with some amendments but no substantial alteration of the ecological interpretation of the flora.

The study of plant remains in post-glacial peat was pursued by F.J.Lewis during the first decade of the twentieth century. As a member of the Central Committee described above, he was involved in primary surveys of vegetation, especially moorland, in northern England (Lewis 1904). With the encouragement of the geologist James Geikie, he also started a study of the peat deposits of northern England and Scotland, adding a geological dimension to the vegetation survey

(Lewis 1905, 1906a,b, 1907, 1911). He distinguished a sequence of horizons within Scottish peat mosses with alternating 'forest beds' with woody remains interrupting the peat succession, and made an early attempt to correlate climatic change in Britain with stratigraphy of organic beds. He suggested the 'forest beds' were interglacial in character, while the peat accumulated under more severe conditions.He correlated these episodes with the interglacial/glacial schemes of Geikie (e.g. Geikie 1895). Such a kind of correlation was revised by Samuelsson (1910), who showed how Lewis' units might be more convincingly correlated with the established Blytt-Sernander scheme of post-glacial alternate wet and dry periods based on the stratigraphy of Scandinavian peat deposits (see e.g. Godwin & Clapham 1951; Godwin 1975; Birks 1975).

A further study of plant remains in peat was made by T.W.Woodhead (1863-1940), one of the four founding members of the Central Committee for the Survey and Study of British Vegetation. Woodhead had surveyed woodlands in the Huddersfield area, and in pioneer studies had related soil profiles to the distribution of species (Woodhead 1904, 1906). He had wide interests in natural history and geology, and had studied plant ecology with Carl Schröter in Zürich. Apart from this contribution, he also made an analysis of Pennine peat types, with anatomical studies of peat-forming plants (Woodhead 1924).

Woodhead must have appreciated the point when Lewis brought to the attention of the 1905 meeting of the Committee the notion that a better understanding of the present vegetation would emerge from a study of peat stratigraphy, with its significance for climatic change. Woodhead understood this well, and in his later Presidential Address to the British Ecological Society (Woodhead 1929), he noted that "In any attempt to extend our knowledge of plant succession we are obliged to resort to the historical method, and in doing so we need at the outset the greatest help that can be offered not only by the different groups of botanists, but by the geologist, geographer, meteorologist and archaeologist". These words echo the thoughts of Clement Reid.

In 1923 the British Association for the Advancement of Science met in Liverpool and during the meeting appointed a Committee 'To investigate Quaternary peats of the British Isles'. At the 1923 meeting, P.G.H. Boswell gave an introductory lecture to Section C (Geology) on the geology of the Liverpool district, and there was a lecture by C.B.Travis on the coastal peats of south-west Lancashire, with an excursion to the sites. The formation of the Committee seems likely to have been the result of Boswell's interest in the Quaternary and in peat beds, perhaps stimulated by Erdtman's visit to Scotland the previous year (Erdtman 1924). The British Association Committee included members with a wide collection of interests, including: Boswell, L.H.Tonks (secretary), M.E.J.Chandler, H.J.Fleure, R.Ll.Praeger, Mrs E.M.Reid, A.W.Stelfox, C.B.Travis, A.E.Truman, W.B.Wright, and later K.S.Sandford. The result was a minute that 'The subject of peat beds and submerged forests for systematic research by the Corresponding Societies having been referred at the Liverpool Meeting to a Committee of the British Association on Quaternary Peats, the Corresponding Societies are requested to put themselves in communication with the Secretary of the Committee Mr L.H.Tonks, Red Bank

House, Birtle, near Bury'. Small grants were made annually to the Committee from 1923 to 1928.

In response to this development a committee was set up in Hull under the chairmanship of Professor P.F.Kendall, with a suggestion that investigations should be carried out in the Mersey and Humber areas, with a local committee for each area. The proposed Humber area committee included the botanist C.A.Cheetham and also Miss Whitaker in the Leeds Geological Department, who was then investigating peat under the microscope (Sheppard 1924). Following this Travis contributed a paper on the peat beds of the Lancashire coast (Travis 1926), determining tree and non-tree pollen taxa and giving some pollen percentages, 'according to the methods of von Post and Erdtman'. Clearly Erdtman's visit to Britain had stimulated interest in the subject. But this early attempt to organise or kindle a wider interest in Quaternary research seems to have petered out, despite the varied specialities and distinguished names on the Committee(s).

However, there was increasing interest at the time in peat stratigraphy in northern Britain. Pearsall (1924) pointed out problems in relating the Pennine peat succession and the associated archaeological horizons (from Mesolithic to Bronze Age) of Buckley and Woodhead (see below) to Lewis' Scottish succession, and also to the Scandinavian sequence of Blytt and Sernander, with responses by Forbes (1925), Tonks (1925), Wright (1925) and rejoinders by Pearsall (1925). Questions were raised of the factors, local or of wider climatic origin, which might affect the changes in peat composition observed.

Pollen analysis in Britain

In Britain, Samuelsson (1910) reported the presence of various pollen and spore taxa in peats he examined in northern England and Scotland, in order to compare the peat sequences of Lewis to those of Scandinavia and the Blytt-Sernander divisions of post-glacial time. Lagerheim made the analyses, which were qualitiative.

In 1922, Salisbury reported the Scandinavian development of pollen analysis and brought Erdtman's 1921 paper to the attention of a wider audience, with the consequences described below. "In an extensive and fascinating paper Erdtman (1921 Arkiv. für Botanik, 1921) describes the occurrence of pollen of various trees in the successive layers of peat in a number of moors and fens in Sweden. Both the statistical results and the distribution of vegetative organs in the peat seem to indicate a succession from below upwards, through Fen with sedges, *Menyanthes, Cladium,* etc; Fen Carr; Pine; and ultimately *Sphagnum.* Although there is some irregularity in the percentage curves for the different species of pollen, most of these seem to indicate an earlier phase in which deciduous trees were more abundant; whilst the recent peat tends to show an increase of *Pinus* and *Picea* corresponding to a diminution or total absence of the deciduous species, especially *Corylus* and others generally associated with less acid conditions." (Salisbury 1922).

In 1924 W.H. Burrell, Director of the University Herbarium at Leeds, in association with C.A.Cheetham, described research "in the past eight years" on upland peats of the Yorkshire Pennines (Burrell 1924). The work was connected with the Geological Department at Leeds, who were investigating peat under the microscope, specifically research by Elsie Whitaker, a post-graduate student. Burrell noted that "her method of working at minute organisms, with high power lenses, impressed us as likely to yield good results, if the evidence could be correctly interpreted, and we have developed this side of the work in addition to the field observations." Burrell's paper includes a page of photos under the microscope (with good resolution) of spores, pollen grains (*Tilia*, *Betula*, a tetrad), seeds and moss and *Eriophorum* leaves, some unidentified. A number of macroscopic remains from peats are also described.

In 1922 Woodhead discussed the history of the flora in his Presidential Address to the Yorkshire Naturalists' Union on Botanical Survey and Ecology in Yorkshire (Woodhead 1923). He commented on Clement Reid's contribution to the subject and on the question of the interpretation of the significance of so-called arctic and alpine species in the flora. At this time Woodhead appears to have been active in inviting Erdtman to Britain to study the pollen content of peat profiles (Pearsall 1964; Salisbury 1964). He stayed with Woodhead for a time at Huddersfield (Cheetham 1925). Salisbury (1964) considered Woodhead a pioneer in "the application of Scandinavian methods of the study of pollen profiles to British vegetation".

Erdtman's pollen-analytical research in Scotland was noted in *The Naturalist* in 1924, with description of localities, and of the methods of pollen analysis developed in Sweden, together with notes on the species recorded (Anon. 1924). In 1922, Erdtman had visited many sites in Scotland and the Scottish Isles and collected several hundred pollen samples with the co-operation of the Geological Survey. A few years later he visited many sites elsewhere in Britain and Ireland, often with local guides. The resultant pollen diagrams (Erdtman 1928) were interpreted to clarify particular points of interest in relation to British vegetational history, *e.g.* immigration of trees (Erdtman 1926), or to support wider syntheses (Erdtman 1924; communicated to the Linnean Society of London by Salisbury, 1928). The latter were related to the Scandinavian outline of post-glacial history and the Blytt-Sernander scheme, and to evidence from central Europe. Travis' (1926) analyses of coastal peats was a rare 'native' contribution to vegetational history, while Erdtman was contributing pollen analyses to significant sites, e.g. peat sections of the southern Pennines and their archaeology (Woodhead & Erdtman 1926).

Erdtman's contribution to vegetational history and pollen analysis in the British Isles was a catalyst for developments, its importance noted by Godwin (1967) in his history of the development of pollen analysis in Britain. The 1928 paper, in a Swedish geological journal, dealt with the detail of sites, starting with an outline of post-glacial events in south-west Sweden, used as a basis for comparison with the results from the British Isles. Tables for the comparison were given for England and Wales, Ireland and the Isle of Man, and Scotland. The tables showed the Blytt-Sernander periods, the related archaeology, geology, or land-level changes, the immigration and maximum frequency of certain plants, and prevalent kinds of peat. The 1929 paper in the Journal of Ecology gave an extended interpretation of the results, with more discussion of the forests of the Blytt-Sernander periods in north-west Europe and of times of peat formation, and a presentation of the three tables of 1928. Woodhead is acknowledged for help with the translation of this paper, no doubt assisted by his wide knowledge of research on Quaternary vegetational history in continental Europe (see *e.g.* Woodhead 1928, 1931). Erdtman, as is the general experience of pollen-analysts, received requests for analyses from a variety of sites, often in the interests of archaeology (*e.g.* Burchell 1928). His work resulted in a wide dissemination of the use of the technique.

These matters underline the Swedish influence in the development of the subject. Following Nathorst's visit in 1872, we see a further debt in the interest engendered by Erdtman's visits in 1922 and later. A similar connection was developed in 1921, when H.Osvald, the distinguished Swedish peat ecologist, paid a visit to Britain and with Pearsall visited bogs and moors in northern England (Pearsall 1964; Godwin 1973). The result was increased understanding of mire vegetation as seen at present, and of associated peat types which could be identified in sections of peat.

Woodhead's interest in the Pennine peat and its origin and relation to the degeneration of woodland in the Pennine area led him to study the contexts of archaeological sites associated with the peat; for example the relation of the peat to Mesolithic artefacts below the peat and a Roman road within the peat). A pollen diagram by Erdtman from the peat site of Warcock Hill, Marsden, showed the relation of the archaeology, including the Roman road to the peat succession (Woodhead & Erdtman 1926; Woodhead 1929). These investigations were some of the earliest in Britain to investigate the relation between vegetational history and archaeology. They followed the many earlier studies of the relation of early man to the geological succession (e.g.Lyell 1863), or, at particular sites, to the palaeobotany, *e.g.* the Palaeolithic site at Hoxne, Suffolk (Reid 1896). But the use of pollen analyses refined the stratigraphy and enabled the interpretation of vegetational and wider environmental conditions associated with the archaeology, the possibilities of which had already been demonstrated by Scandinavian studies.

Woodhead's work was firmly based on his wide botanical knowledge, and notably extended into relating man's activities to vegetational history and aspects of Quaternary geology. This is clearly seen in his Presidential Address to the British Ecological Society in 1927, entitled 'History of the vegetation of the southern Pennines' (Woodhead 1929). There are sections on the Ice Age and its effect on vegetation, interglacial conditions, the last glaciation, nunataks, post-glacial changes, methods of dating, stratified remains in peat including archaeology, pollen-statistics, analysis of tree-pollen grains in peat, age of the moorland flora, origin of the peat, degeneration of the forest, degeneration of the moss moor and regeneration. There are also many apposite remarks and judgements about Quaternary research, including a helpful comment on correlation of events with the continent: " While such admirable results have been worked out we should be on our guard, and not be too eager to correlate our finds with those on the Continent , nor be unduly influenced by classifications founded on an examination of deposits in other countries". Woodhead's paper is a landmark in the history of the subject.

A memorial to Woodhead's achievement lies in his work to found the Tolson Memorial Museum of Huddersfield and the design of exhibits underlining an ecological and ecosystem approach to man's history and activities in the Huddersfield area (Pearsall 1940, 1964). Subsequent to these researches in the north of England, activities in Quaternary palaeobotany moved south. Woodhead became less involved, both in vegetation survey and palaeobotany. Tansley and Moss, founders of the Vegetation Committee with Smith and Woodward in Leeds in 1904, both moved to Seward's Department of Botany in Cambridge in 1907, Tansley taking a lead in the development of vegetation description and ecology. Later, Tansley and Seward both encouraged M.E. and H. Godwin to take up the subject of vegetational history in the early 1930s, with the results described in the next chapter.

Chapter 3

The early 1930s

Progress on the Continent

As Woodhead (1931) pointed out, the development of Quaternary research was greatly stimulated by the proceedings of the Stockholm International Geological Congress in 1910. By the 1920s there was a large literature on Quaternary palynology. Erdtman regularly compiled bibliographies of literature on pollen statistics (e.g. Erdtman 1927, 1930, 1932, 1934), the first of these covering earlier publications. These were invaluable contributions, giving a record of sites and literature from each country. In the first, tree-pollen grains are illustrated by drawings, and a map is given of European sites investigated by pollen analysis. The map gives a good idea of the geographical range of investigations before 1927. In a later compilation, Erdtman (1937) gave a more structured analysis, showing publications on methods and theory, morphology of pollen and spores, Pre-Quaternary research and Quaternary publications from various countries. A list of pollen and spore taxa recorded from European post-glacial deposits is also given in the 1937 bibliography, showing the great advances in pollen identification, tree and non-tree pollen as well as spores, which had been made by that time. A contrast is seen with the pollen analyses of the 1920s, which are often confined to tree pollen (and *Corylus*).

H.Gams also published bibliographies of pollen analysis from 1927 onwards into the 1930s The first (Gams 1927) included a survey of the results of pollen analysis in Europe and its significance for vegetational and climate history. Later bibliographies (e.g. Gams 1929a,b, 1931) listed methods and regional publications.

Post-glacial stratigraphy and sedimentology were also developed, particularly of organic sediments, with wide-ranging surveys made possible by the large number of site studies, e.g the compilation of Gams and Nordhagen (1923) on post-glacial climate change and Quaternary stratigraphy in Europe, the compilation edited by Stoller (1931) of the stratigraphy and palaeontology of the alluvium of Germany, the lake sediment studies of Lundqvist (1927), and the series of handbooks edited by von Bülow (e.g. 1929) entitled Handbuch der Moorkunde. Interglacial palynology was also being developed in this period, e.g. the classic work of Jessen and Milthers (1928) on Danish interglacials, and Szafer (1926) on an interglacial in Poland.

In northern Europe the relation between vegetational history and chronology had been broadly established by de Geer's Scandinavian varve studies, with linkage also to the history of the Baltic, as usually shown in correlation tables of the time (*e.g.* Erdtman 1928, Woodhead 1929). Von Post's two students' pocket books on Swedish and European post-glacial forest history also illustrate how far matters had proceeded on the continent by the early 1930s (von Post 1933a,b).

As an illustration of the detail of publications in the early 1930s, the account by Bertsch (1931) of the extensive wetland of the Federseeried in Württemburg provides a model. Numerous excavations, borings, pollen diagrams and analyses of macroscopic plant remains were used to reconstruct the history of the lake in the late-and post-glacial , with pollen zones linked to and transgressing the successive sediments units which filled the lake. Archaeological investigations, which involved occupation horizons, boats and trackways, were linked to the vegetational and environmental history in a very detailed way. The organic sediments were associated with occupation evidence from the Upper Palaeolithic through to the Meso- and Neolithic, Bronze Age, Iron age, Roman times, and up the present. This type of work, also pursued in other countries, must have provided a standard for the research which developed on similar lines in Britain and Ireland later in the 1930s.

This brief description of continental progress show how much had to be learnt by Quaternary paleobotanists in the British Isles, where the contributions of Erdtman were practically the sole developments of the 1920s.

Fifth International Botanical Congress, Cambridge, August 1930 (Brooks and Chipp 1931)

This Congress brought together many botanists who had been investigating vegetational history in Europe and further afield. The President of the Congress was the palaeobotanist A.C.Seward, Professor of Botany at the University of Cambridge. The Phytogeography and Ecology Section Sub-Committee, which organised the section, was chaired by A.G.Tansley, with H.Godwin and E.J.Salisbury among the members. The Recorder for the Section was A.G.Tansley, with H.Godwin as Secretary. A significant part of the proceedings was a joint discussion with the Palaeobotany Section on "Post-glacial changes of vegetation in north-western Europe in relation to those in the rest of Europe". The contributions show clearly how far the subject of vegetational history had advanced in continental Europe in the 1920s.

The first contribution, by L.von Post , was on "Problems and Working-lines in the Postarctic Forest History of Europe". He introduced the subject by writing that 'The pollen-statistical exploration of the evolution of the European forests since the last glaciation has now attained such a degree of completeness that the general features of forest development are coming into sight'.and that 'it was evident that the fundamental causes of the whole movement have been changes of climate'. He discussed revertence, regional parallelism, tree immigration and other matters. He thought the 'classical terminology of time, established by Blytt and Sernander' should be transferred to the history of science. He preferred a three stage scheme for post-glacial history, with a first period of the appearance and increase of heat-loving trees, a second where these reached a culmination, and a third where they showed a decrease. These ideas were developed by von Post in his Vega lecture of 1944 (von Post 1946).

Other speakers concerned themselves with vegetational history in Central Europe (K.Rudolph, P.Keller), Romania (Cluj), Poland (Szafer) and N. America (Sears). Woodhead gave a summary of his work on the vegetational history of the Southern Pennines, a much more local contribution, and Erdtman discussed the interpretation of *Corylus* pollen values in Europe (Erdtman 1931). Apart from Woodhead's contribution, there were no others were recorded from Britain or Ireland. A more general discussion followed these contributions, involving problems such as identifiaction of tree limits, pollen identification, pollen dispersal, and tree immigration. The associated exhibits were by H.Gams, with maps and diagrams illustrating the development of European post-glacial forests, and by Woodhead, who showed his twelve models illustrating aspects of post-Glacial development in the Huddersfield district of Yorkshire. Other events of Quaternary interest were associated with the Palaeobotany Section. There was an excursion to the gravel pit at Barnwell, Cambridge, led by T.M.Harris, where peat beds with an arctic flora, dating from the last glaciation, were examined. Miss S.A.Hotham (Mrs Anne Richards) mounted an exhibition of seeds and leaves from the site.

The major joint discussion of the Phytogeography and Ecology section and the Palaeobotany section on 'Post-glacial changes of vegetation…', with the first contribution by von Post, provided an important stimulus for Quaternary palaeobotanists, especially those with an interest in pollen analysis. The presence of phytpogeographers and ecologists must have enhanced the discussions. The Swedish contribution was very evident, with von Post, Erdtman, Samuelsson and Osvald at the meeting. From further south in Europe came K.Rudolph (Czechoslovakia), W.Szafer (Poland), P. Keller (Switzerland) and E.Pop (Romania), amongst others. The ecologists from overrseas included H.C.Clowes, H.A.Gleason, and R.Nordhagen. Those who had contributed to the subject in Brtiain and Ireland included Erdtman, K.B.Blackburn and Woodhead, who had contributed to the joint discussion. K.B.Blackburn was involved in pollen analytical research on peats in northern England in collaboration with the geologist A.Raistrick. The ecologists from Britain and Ireland included A.R.Clapham, H.Godwin, W.H.Pearsall, R.Ll. Praeger, E.J.Salisbury, A.G.Tansley and A.S.Watt. It seems likely that from the springboard of this Congress that the rapid development of studies of vegetational history in Britain and Ireland in the 1930s took off. The Sub-Committee which organised the discussion, with Tansley and Godwin involved, must have been pleased with its evident success and the resulting meeting of minds in vegetational history, ecology and phytogeography.

Seward's Plant Life Through the Ages (1931, 1933)

The two editions of Seward's *Plant Life through the Ages* neatly summarise the state of studies of vegetational history in Britain at the time. In the first edition of the book (1931), Seward, in the chapter on The Quaternary Period, a pollen diagram by Erdtman from Chat Moss, Lancashire, is reproduced, and a table is given showing Woodhead's summary of the history of vegetation of the Southern Pennines, in relation to archaeology and peat formation. The account relies to a large extent on Woodhead's 1928 and 1929 papers. In the second edition (1933), there are added references to papers by Blackburn (1931) on possible glacial survivals in the British Flora, by Erdtman (1931) on boreal hazel forests and pollen statistics, by H.& M.E.Godwin (1933) on British Maglemose harpoon sites, and by Praeger (1932) on the problem of the Irish fauna and flora. The two editions thus straddle the period immediately after the Fifth International Botanical Congress in 1930, at the beginning of the great enlargement of pollen-analytical studies in Britain and Ireland during the 1930s. A point of interest in relation to reworking of fossils is the illustrative drawing of cold stage plants recorded in the Devensian gravels at Barnwell, Cambridge, which, in addition to many typical cold stage species, includes a branch of the temperate tree *Carpinus betulus*, a reworked fruit of which was found in the assemblage.

The post-Congress period

In the period immediately after the 1930 Congress, significant papers were published on vegetational history in Europe for readers in the British Isles. Woodhead (1931) summarised the history of the subject in Europe for *Science Progress*. From the historical point of view, he noted that there was a revival of interest in plant geography and the history of vegetation at the 1905 Vienna International Botanical Congress (he had been studying with Schröter in Zürich at about that time), and that, five years later, at the International Geological Congress at Stockholm, 'the Scandinavians revealed such a wealth of detail of detail bearing on the problems of the post-glacial history of North-west Europe that we may date the modern developments of post-glacial research from this time'. He tabulated correlations of post-glacial events across North-western Europe, with de Geer's varve chronology, the Blytt-Sernander climatic periods, Munthe's Baltic stages, archaeological periods, and vegetation in the British Isles, Denmark, Sweden, Norway, Finland and Bavaria.

F.E.Weiss also brought the great interest of recent continental research to a wider audience by a commentary (Weiss 1931) on Rudolph's contribution to the 1930 Botanical Congress and publication of his synthesis based on central European forest history (Rudolph 1930).

Following Erdtman's pollen analyses, and published soon after the Botanical Congress, were the important contributions of A.Raistrick and K.B.Blackburn. Raistrick, then at Armstrong College, Newcastle, was an associate of Woodhead's, a leader in the subject of coal palynology (Marshall 2005), an authority on the glacial geology in the north of England and with a strong interest in archaeology.

Blackburn, at the same institution, contributed the botanical expertise, in terms of ecological and palaeontological knowledge. Lunn (1983) recalled that K.B.Blackburn 'had learnt the technique' (of pollen analysis) 'in Sweden from L.von Post, who had pioneered it there, and from her own published work and teaching mainly stemmed the subsequent great expansion of palynology in Britain.'

Pearsall (1964) recognised the contribution if these two when he commented that Erdtman's pollen analyses 'with those done by A.Raistrick and K.Blackburn (1932) at a slightly later time represent the beginning of a line of approach which, under Godwin's leadership, has made outstanding contributions to our knowledge and modes of thought'. Raistrick and Blackburn published a pollen diagram of a moor in Northumberland (1931), pie diagrams from two sites in the Lake District (1932a) and a series of three papers on the late-and post-glacial periods in the North Pennines, West Yorkshire and Durham (1932b), in which investigations Godwin assisted in the field. These three contributions described last glacial events and deglaciation in the area, possible glacial survivals in the flora, and the post-glacial peats. The peat deposits were classified according to their geomorphological setting and their range of elevation noted. The following were distinguished: fell-top peats, valley-head peats, channel peats, pond peats and shore peats. Tree-pollen diagrams were given from peat deposits of each of these classes. Notably, non-tree pollen taxa were used to clarify local environmental conditions (e.g. *Drosera*, *Montia*, *Scabiosa succisa*, *Valeriana*, *Typha latifolia*). The eight pollen diagrams were compared with those of Erdtman and the Blytt-Sernander climatic periods. This was a real advance in the subject in Britain, involving co-operation between a geologist and a botanist. In addition, the archaeology of the sites examined was related to pollen diagrams (Raistrick 1933), as in the Fenland sites to be discussed. Later, Raistrick and Blackburn (1938) published research on the glacial and post-glacial history of Linton Mires in Wharfedale. The biological contribution by Blackburn included detailed peat stratigraphy, pollen analysis, macro plant analysis and mollusc analysis, from which an ecological history of the area was constructed.

Raistrick had also co-operated with Woodhead in studying post-glacial plant remains from a section near Leeds. Macroscopic remains only were reported; 'careful microscopic examination… failed to reveal any pollen grains' (Raistrick & Woodhead 1930). Raistrick himself had realised the significance of pollen analysis and published an account of the techniques of the pollen analysis of peat, referring to Erdtman's work, and commenting on his own experiences (over two years) in taking samples, preparing slides and analysing pollen (Raistrick 1932). The paper contained leading references to continental work of the time. He thought 'it would be an excellent thing' if a grid of reference sections from peat deposits which he had started in the north of England could be extended over other peat-bearing parts of Britain, a hope that took many decades to (partially) achieve. Marshall (2005) considered Raistrick to be Britain's premier palynologist, involved in both peat studies and Carboniferous coal seams.

Erdtman's work in the 1920s and the stimulation of the 1930 Botanical Congress was starting to bear fruit. Looking back at the early decades of the century, it seem clear that Woodhead, with his botanical background, wide archaeological and geological interests, and promoter of Scandinavian science, Raistrick, with his geological and archaeological interests, and Blackburn with the botanical interest, were pioneers in the development of the subject.

Chapter 4

Research Committees of the early 1930s

Before describing developments in the 1930s in more detail, two major initiatives deserve separate mention: the Fenland Research Committee and the Committee for Quaternary Research in Ireland.

The Fenland Research Committee

The Fenland Research Committee was founded in Cambridge in 1932. The purpose of the Committee was to encourage the integration of research in archaeology with the wider field of the natural sciences (geology, palaeontology, environmental history). The need was especially apparent in the Fenland basin, where the post-glacial sediments were associated with a rich archaeological record, giving a clear opportunity for co-operative research of a kind that had been developed on the Continent. A full account of the founding of the Committee has been given by Smith (1997). The Honorary Secretary of the Committee and a prime mover was the archaeologist Grahame Clark, and the President A.C.Seward. The Vice-President was Major G.Fowler, at the time transport manager of the Ely sugar beet factory and acknowledged expert on the extinct waterways of the Fenland. H. and M.E.Godwin were amongst the founder membership, which came to represent a wide variety of archaeologists and natural scientists. The Committee continued until the 1940s. The Godwins contributed the essential palaeobotanical work to excavations carried out by Grahame Clark, starting with the Bronze Age site of Plantation Farm, Shippea Hill, with excavations in 1931 and 1932 (Clark 1933), and continuing with further excavations at the nearby multi-period site at Peacock's Farm (Clark et al. 1935). As a result correlations were obtained in detail of the archaeology, geology and vegetational history of this part of Fenland, laying the foundation for an integrated environmental history of Fenland, which became a standard for other parts of the country. The work of the Committee later extended co-operation beyond the Fenland, e.g. with the formation of an Essex Coast Sub-Committee (Warren et al. 1936).

The Committee for Quaternary Research in Ireland

R.Ll. Praeger had a long-held interest in the origin of the Irish flora and flora (see e.g. Praeger 1932). He attended the 1930 Botanical Congress, and in the same year discussed the problem with R.Nordhagen (also at the Congress) at Killarney, as he

Plate 2. Knud Jessen at the interglacial site at Herning, Jutland 1953 (photo R.G.West).

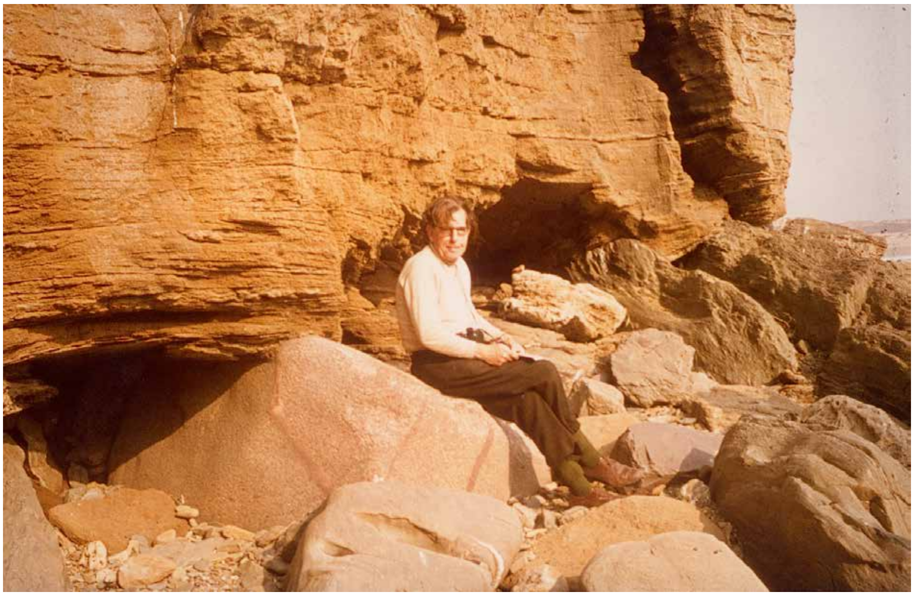

Plate 3. G.F.Mitchell on the wave-cut platform at Croyde, N.Devon, 1974 (photo R.G.West).

recounted in the Quaternary Research Number of the *Irish Naturalists' Journal*, volume 5, of 1934. This has articles on the origin, composition and purpose of the Committee, and also a paper by J.G.D.Clark (1934) on what had been achieved in the Fenland by the Fenland Research Committee at that time. Praeger, Chairman of the Committee, was clearly impressed by the progress in continental Europe, and Nordhagen had suggested that K.Jessen of Copenhagen, with his experience of multidisciplinary investigations - pollen analysis, plant macro analysis and archaeology - in the Danish Quaternary, would be an excellent person to assist the Committee. Funding was found, Knud Jessen (Plate 2) and his assistant H.Jonassen, visited Ireland in the summers of 1934 and 1935, and investigated many sites of archaeological and topographic interest, in co-operation with Irish colleagues. The funds provided for the training of two field assistants, one of whom was G.F.Mitchell (Plate 3), who subsequently became the outstanding leader of Quaternary research in Ireland. Jessen's studies established the detail of late- glacial and post-glacial vegetational history in Ireland, greatly expanding the earlier outline by Erdtman (1928), and relating the sequence to the archaeology. The three-fold division of the late-glacial was established at a number of sites, including the well-known Ballybetagh site. This classic work was not published until 1949 (Jessen 1949), hardly surprising considering the number of sites studied (49) and the resulting huge task of analysis.

Chapter 5

Progress in Cambridge

The beginnings

In the development of Quaternary research at Cambridge in the early 1930s, the subject had the support of the Professors of Botany and Geology, respectively A.C.Seward and O.T.Jones, and the archaeologists M.C.Burkitt and J.G.D.Clark. At the time archaeology in Cambridge was undergoing a renewal, with Grahame Clark's account of the Mesolithic in Britain (Clark 1932) and his recognition of the importance of the natural sciences for the subject (Smith 1997). This background greatly supported H. & M.E.Godwin at the beginning of their palaeoecological research, as did Tansley's support. In effect, research in the subject moved from the northern interests described above to Cambridge, a parallel to the movement south of active members of the Vegetation Committee in the early 1900s.

Clark had visited Denmark and Sweden in 1929 during the course of his post-graduate research and had evidently appreciated the state of the subject in relation to natural sciences that had developed in Scandinavia. The background

Plate 5. Margaret Godwin (portrait by Freeman, J.Godwin).

Plate 4. Harry Godwin, founder of the Subdepartment (photo F.T.N.Elborn).

thus gained, augmented by later visits to The Netherlands and Germany, can be seen in the substantial introductory chapter, entitled 'The natural history of of the area of settlement', of his book on the Mesolithic settlement of northern Europe (Clark 1936).

Godwin (1978; Plate 4) wrote "In 1931, following a suggestion from A.G.Tansley, my wife began research in pollen analysis, a technique recently brought to notice by papers written in English by the Swede G.E. Erdtman……". Plate 5 is a portrait of Margaret. The combination of these 'forces' resulted in what can only be termed an explosion of activity in Quaternary research. Clark's interest in archaeology and the Godwins' start in pollen analysis, both supported by Fowler's knowledge of the Fenland, resulted in advances on a broad front. The research was also assisted by H.Godwin's previously developed interests in Fenland plant succession at Wicken Fen (*e.g.* Godwin & Tansley 1929). Godwin later (1985) enlarged on the beginning of his active interest in the subject: "…what began as Margaret's research project rapidly became a joint venture. This was in part a consequence of the heavy pressure on my own time of lecturing, demonstrating and supervision, incidentally so irregular that the prolonged continuous laboratory attention demanded by experiments in plant physiology grew less and less attainable, and after scrapping several half-completed experiments at great waste of time and trouble, I recognised how much simpler I should find it to utilise broken time by sitting down to do microscopic counting of pollen. One must add of course that the elegance and promise of the pollen-analytic investigations drew me powerfully towards this opening field of 'palaeoecology'". A fuller account of Godwin's contribution to the subject as it developed in later years is given by West (1988).

In addition to pollen analysis, investigation of macroscopic plant remains in the Fenland sediments was started by M.H.Clifford, research student of Godwin. The work facilitated the interpretation of the succession of Fenland sediments. Clifford (1939) devised keys to the identification of plant remains in Fenland sediments, including wood, seeds and fruits, leaves, rhizomes, rootlets and mosses. In identification of seeds and fruits he had the assistance of M.E.J.Chandler, the colleague of Mrs Reid.

The early work in pollen analysis was supported by a Royal Society grant in aid of 'pollen-analytic investigations of lowland peats', a title of contrast to the many previous investigations of upland peats in northern Britain. From the first, requests were received for analyses from samples unearthed from a variety of sites discovered by distant correspondents (*e.g.* Gardiner 1934). But the plans of members of the Fenland Research Committee and the aims of the botanists involved of necessity took precedence.

Fenland investigations

Pollen analyses associated with archaeology and with sea-level changes in Fenland started at about the same time. Two papers published in 1933 foreshadow later advances.One dealt with pollen analyses from sediments associated with Maglemose harpoons in eastern England and from peat trawled from the North Sea bed at the

Leman and Ower Banks (H. & M.E.Godwin 1933a). The Godwins had visited one of the Yorkshire coastal sites with the archaeologist A.L. Armstrong in 1932. The results were compared with similar finds in Denmark and Estonia, where they could be related to the forest history, the Blytt-Sernander climatic periods, the Baltic stages and de Geer's varve chronology. A Boreal age was indicated for the harpoons in all three areas, and sea-level changes in the North Sea were also clarified.

The second, associated with the Fenland Research Committee, analysed pollen from a deep excavation in Fenland sediments at St Germans, near King's Lynn, a site brought to the Godwins' notice by Major Fowler in 1932. The section showed four thin peat beds separated by fine estuarine sediments. The pollen analyses, in which K.B.Blackburn advised on technique, indicated that the the whole sequence was post-Boreal in age. The 'Two-Foot' peat bed also showed detail of a succession of plant communities (salt-marsh – carr - oak woodland -salt-marsh) associated with change in relative land/sea-level. The pollen analyses were related to the Blytt-Sernader periods, Baltic stages and archaeology, but it was also noted that in the interpretation of pollen analyses of lowland peats 'considerable allowances must be made for edaphic influences, and especially for vegetational succession , before correlation can be attempted on the basis of climatic control of tree-pollen frequency' (H. & M.E.Godwin 1933b).

The research on sea level change continued throughout the 1930s and 1940s. Pollen analyses of samples from coastal excavations collected in 1931 at Swansea, brought to notice by O.T.Jones at the time, and in 1932 at Southampton were published in 1940 (Godwin 1940a; H. & M.E.Godwin 1940). A series of samples from coastal peats at Brancaster and Hunstanton, Norfolk, and Ingoldmells, Lincs, were related to the Blytt-Sernander periods (H. & M.E.Godwin 1934). As research in the Fenland progressed, a synthesis became possible of relative land- and sea-level changes in Fenland (Godwin 1940b), and this synthesis was later extended to coastal peat beds of the British Isles and the North Sea (Godwin 1943, 1945).

The co-operation with archaeologists, starting with the Maglemose harpoon paper noted above, extended to a Mesolithic site at Broxbourne, Essex, studied for many years by Hazzledine Warren (Warren *et al.* 1934), where pollen analyses showed that a Mesolithic horizon was sealed by Boreal peat. It was greatly expanded with research under the aegis of the Fenland Research Committee, especially at sites excavated by Grahame Clark. The first was the Early Bronze Age site excavated in 1931 and 1932 at Plantation Farm, Shippea Hill (H. & M.E.Godwin 1933c), where Bronze Age finds and an earlier industry were related to vegetational history of the succession Fenland sediments (Lower Peat, Fen Clay, Upper Peat), and so to the Blytt-Sernander periods. Accounts of the vertebrate fauna, molluscs and foraminifers accompanied the excavation report.

Excavations in 1934 at the neighbouring site of Peacock's Farm established the relationships of Mesolithic, Neolithic and Bronze Age horizons to the Fenland succession (Clark *et al.* 1935). Pollen diagrams through the Lower and Upper Peat, analyses of macroscopic plant remains through the Lower Peat, and reports on the vertebrate fauna and mollluscs were given. The papers on Plantation Farm and

Peacock's Farm represented a multi-disciplinary approach to archaeological sites and set a standard for such excavations.

Further similar excavation reports were subsequently published in association with the Fenland research Committee: Methwold (Godwin *et al.* 1934); Mildenhall Fen (H. & M.E.Godwin 1936); Stuntney (Clark & Godwin 1940); Essex coastal peats (Warren *et al.* 1936).

The work of the Fenland Research Committee in the 1930s thus laid a very substantial foundation for the correlation of archaeology to the forest history, thence to continental forest history, archaeology and sea level changes. The increased knowledge of forest history in the Fenland enabled a more detailed comparison with continental sequences than had been possible before. The Boreal/Atlantic transition, indicated by the rise of pollen of *Alnus* and the fall of pollen of *Pinus* and *Corylus*, became the earliest 'marker' horizon for these comparisons.

These archaeological correlations led to interesting points of discussion at an early date. Thus the relative dating by pollen analysis of Mesolithic and Bronze Age horizons in the Fenland led Godwin & Clark (1934) to suggest revisions for the age of Pennine peats, described by Woodhead & Erdtman (1926) and Raistrick (1933), as early Atlantic, leading them to suggest that the peats were more likely to be Sub-boreal in age by reason of their contained Bronze Age artefacts. But later investigations of Pennine peats by Conway (1947, 1954) supported the view that peat formation began in favourable places at a time close to the Boreal/Atlantic transition.

Extension of Fenland research

Following investigations at particular sites in the Fenland, palaeoecological research turned to investigate the wider problem of the environmental history of the region. Wood Fen, near Ely, was notable for its buried 'forests' within the peat , described by Skertchley (1877; Miller & Skertchley 1878). The area was re-investigated by the Godwins and Clifford (1935), who related levels in the peat with tree stumps or logs to pollen diagrams and analyses of plant macroscopic remains. The pollen analyses included certain non-tree pollen taxa, including aquatic plant taxa (*Typha, Sparganium, Potamogeton*), Gramineae, Chenopodiaceae and fern and *Sphagnum* spores. Changes of water level and trophic conditions were demonstrated, and conclusions drawn about the importance of local fen woods in determining the nature of the pollen diagrams, and about the factors controlling fen development: the nature of the vegetation succession, edaphic and topographic effects such as those produced by relative movements of land and sea, and climatic change. These conclusions laid a basis for the further development of investigations of Fenland palaeoecology. Subsequently, Wheeler (1992) made a detailed palaeoecological study of the Wood Fen sediments, relating and dating the successional and allogenic changes seen there to the wider Fenland succession.

The Fenland investigations were then extended westwards to the embayment in the Fen margin at Woodwalton, Hunts, where the peats were little affected or damaged by peat-cutting, drainage or alluviation by neighbouring rivers. The sequence of a lower peat, fen clay and upper peat were again found, but with the development of acidic *Sphagnum* peat above the fen clay, with the later development of marls in shallow meres. This succession was then extended eastwards to the South Level of the Fens, to connect with the Wood Fen sediments (Godwin & Clifford 1938). As a result of this vast programme of boreholes in the Fenland sediments, a stratigraphy for the Fenland post-glacial sediments was drawn up, summarised as a Lower Peat, Fen Clay, Upper Peat, and a final phase with silt and the mere sediments. This sequence could be correlated with the Blytt-Sernander periods, relative changes of land- and sea-level and with the archaeological horizons investigated earlier. The chronology was determined by the Blytt-Sernander periods and their relation to the de Geer chronology and Baltic stages. Pollen diagrams from the stratigraphical investigations were published later (Godwin 1940b, p.248), and a regional pollen zonation established. This was related to the Blytt-Sernander periods and to Jessen's pollen zones in Denmark, and became a standard as pollen analytical investigations extended throughout Britain. A consequence of the stratigraphical work was a possible explanation of the ancient water courses of the Fens which are marked by raised sinuous bands of fine inorganic sediments known as roddons. They appear to originate largely as levee sediments of tidal creeks, their exposure accentuated by compaction and wastage of peat (Godwin 1938a; Waller 1994).

Godwin (1978) wrote of the Fenland research and its relation to palaeoecology and archaeology in his book *Fenland: its ancient past and uncertain future*. This greatly enlarges the brief account I have given, aimed at showing the development of the subject in the 1930s. Waller (1994) has described the much more recent intensive investigations which have been carried out by the successor to the Fenland Research Committee, The Fenland Project, which basically had the same aims as the former, with multi-disciplinary research supporting the archaeology of this scientifically very rich and extraordinary area.

Basic principles

In the 1933 papers by H.& M.E.Godwin brief outlines was given of techniques of pollen analysis and developments in the subject in northern Europe, so giving a background to the research reported. Raistrick (1932) had already given a detailed account of the techniques involved in pollen analysis, as mentioned above. A much more detailed account appeared in 1934, when Godwin published two highly significant papers on pollen analysis (Godwin 1934a,b). The first dealt with the technique and interpretation of pollen analyses (Plate 6), the second with the general applications of pollen analysis. Godwin brought together and discussed the results of research in continental Europe. The reference lists in the papers show how much had been achieved by that time on the continent, both in terms of vegetational history and in observations on pollen production, dispersal and similar matters related to the interpretation of pollen diagrams in terms of vegetation.

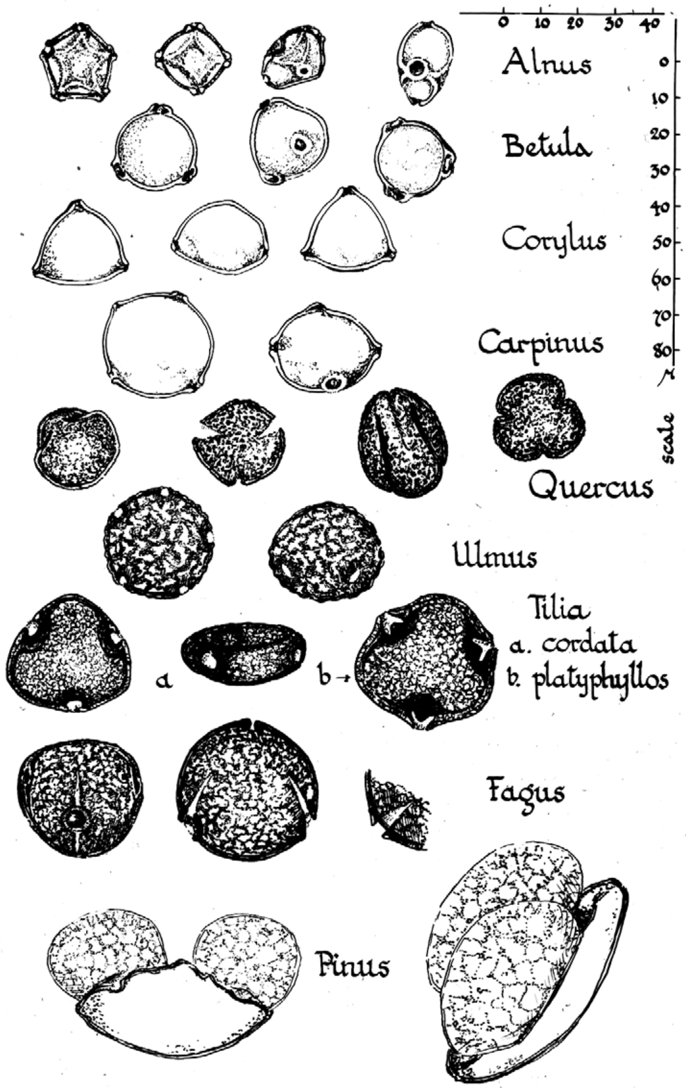

Plate 6. Drawings of common tree pollen grains (Godwin 1934a; Godwin Archive).

The first paper included details of preparation of samples, identification of pollen grains, differential pollen preservation, calculation and presentation of results, pollen downwash, and the pollen spectrum as index to forest composition. The last referred to recent research on pollen production by trees, wind transport and the problem of localisation of pollen sources, flotation and water transport , and the possible effects of time of flowering, a subject raised by Erdtman at the 1930 Botanical Congress. In retrospect it is interesting to see particular problems of identification at that time: *Salix/Fraxinus, Hippophae/Fagus, Corylus/Myrica.* Size statistics of *Betula* and *Tilia* are quoted, as are the problems of identifying species of trees.

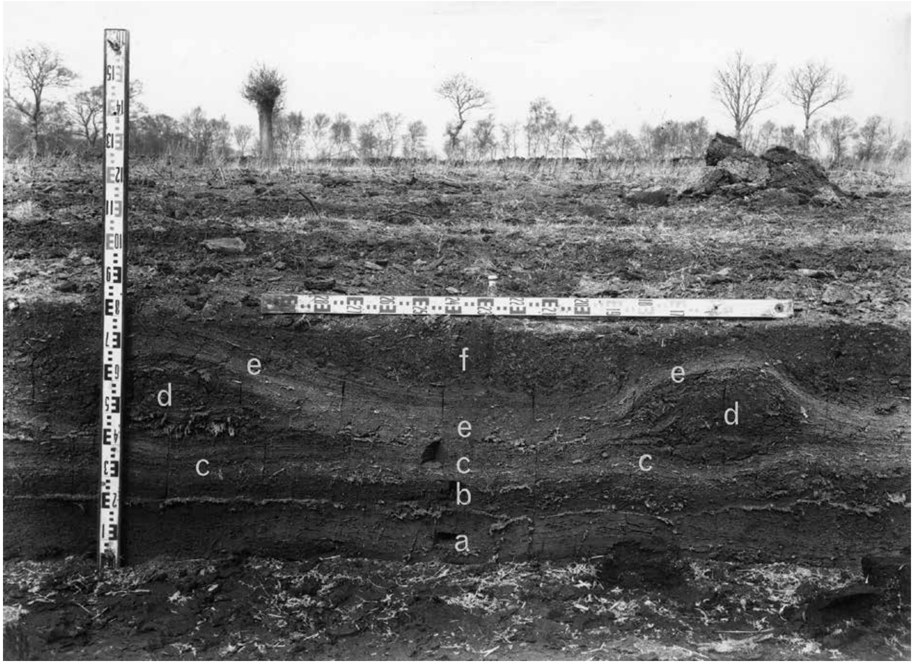

Plate 7. A peat section at Godwin's Piece, Westhay, Somerset Levels, 1948. The peat types reveal the history of peat-forming plant communities at the site: a, fresh Sphagnum peat with aquatic Sphagna, a flooding horizon; b, humified Sphagnum-Calluna-Eriophorum peat, resulting from slower peat growth under drier conditions; c, fresh Sphagnum peat with Sphagna and Scheuchzeria, a flooding horizon; d, humified Eriophorum-Calluna peat showing growth of hummocks on the bog surface; e, fresh Scheuchzeria peat with aquatic Sphagna formed between hummocks and growing over them on further flooding; f, humified forest floor of recent vegetation (Godwin Archive).

In the general application paper, regional pollen analyses are described as a means of determining vegetational history, as well as the basis for relative chronologies. Local influences and regional parallelism are discussed in terms of plant succession, soil conditions, altitude, regional parallelism and revertence. Correlation of forest history with other time indices is then discussed, with reference to geological matters (Baltic stages, de Geer's varve chronology), and to climate change. Here the Blytt-Sernander climate periods are summarised, but it is pointed out that with the extension of knowledge of vegetational history south of Scandinavia to the rest of Europe, von Post's suggestion of a three-fold scheme (approach of the warm period, culmination of forest elements characteristic of the warm period, and decrease of these with the appearance or return of dominant forest constituents of the present day) has 'clear advantages'. This scheme was described in von Post's lecture to the 1930 Botanical Congress, when he suggested the Blytt-Sernander scheme should be transferred to the history of science.

In the matter of climatic change, the second paper also discussed the significance of the *Grenz-horizont* in raised bog peat successions and Granlund's related recurrence-surfaces, noting the difficulty of the interpretation of these in terms of particular parameters of climate change and bog growth. The relation of archaeological periods to forest history is also discussed, with pollen analysis giving environmental detail to archaeology as well as a means of relative dating. The final parts of the paper are devoted to comparing the state of investigations in Britain with those on the Continent. Little had been done in the British Isles on the contribution of pollen analysis to historical plant geography, though much had been done on the Continent. The absence or infrequency of pollen of tree genera characteristic of the later part of the post-glacial on the Continent (*e.g. Abies, Picea, Fagus, Carpinus*) made zonation of post-Boreal time more difficult in Britain, especially with the complexity of climatic gradients and the few forest indicator genera. It was possible for Godwin to present two maps of the British Isles showing pie diagrams of late Boreal and early Atlantic pollen analyses, and compare them with similar diagrams from lowland sites on the North Sea margin of the Continent. The phenomenon of regional parallelism was evident on a north-south line in these maps.

I have gone to some length to describe the detail of these two papers published in 1934. They show that Godwin had mastered the huge literature on the subject which had been published on the continent, but which had hardly featured in botanical or geological research in Britain, apart from the contributions described in an earlier chapter, even though it had been in the public domain for at least two decades. It is interesting to speculate why this this should be so. Perhaps there is a parallel or association with the background of the introduction of ecology into botanical teaching in Britain in the 1920s (see *e.g.* Boney 1991; Godwin 1985; West 1988). But even though Salisbury (1922) had discussed the significance of Erdtman's 1921 paper for botanists in *Science Progress*, few had taken up the challenge. Some contributions appeared in the more local natural history or archaeological journals in the north of Britain, Erdtman published in the Journal of Botany (1926) and Journal of Ecology (1929), and Woodhead also in the Journal of Ecology (1929), so little substantive research apart from Erdtman's had been displayed.

The expansion of research in Britain

By 1940 the development of research allowed Godwin to present a revised pollen zonation for England and Wales, with maps with pie diagrams for the major post-glacial zones then distinguished (IV; V; VIa,b,c; VIIa,b; VIII), though the post-zone VI zones were considered rather tentative, for reasons mentioned above (Godwin 1940b).

In the meantime, research on peat stratigraphy allied to vegetational history was extended to Somerset (Godwin 1941) (Plate7), Wales (Godwin & Mitchell 1938), Cornwall (Conolly *et al.* 1950) and Shropshire (Hardy 1939), many sites associated with archaeological features. Hardy, a post-graduate student who graduated in Archaeology and Anthropology in Cambridge and undertook vegetational history research under Godwin's direction (Godwin & Mitchell 1938), visited von Post in Stockholm in 1936. In Scotland G.K.Fraser collected a series of samples from two Scottish bogs, and visited von Post in Stockholm in 1936 to work on them (Fraser & Godwin 1955). At a later date Conway (1947, 1954), who was a research student of Godwin's in the early 1930s, re-investigated the upland Pennine peats studied in the 1920s and 1930s. Several other pollen analysts contributed much to the research in the Botany School, including M.S.Cowell (1936, Fenland), H.M.P.Brown (Whitmore) (1936-1942, many sites) and M.Dainty (1944-5, Somerset).

The increasing interest in vegetational history in the 1930s prompted wider discussions of the implications for climate history and the origin of the British flora. Regarding the former, Godwin (1935) was at pains to point out the difficulties of climate interpretation based on vegetation history, with reference to an earlier discussion of post-glacial climates and the forests of Europe. He underlined the problems involving climatic interpretation of peat growth and of pollen-analytical data, and of determining the ecological requirements of tree genera, concluding that there was not sufficient evidence for closer analysis of past climates, with the need to acquire much more knowledge of the autecology of forest trees (a need still present today).

In 1935 a discussion meeting was held at the Royal Society on the origin and relationship of the British flora (Seward 1935), reviving the arguments raised on the matter by Forbes (1846) and Clement Reid (1899). The discussion was centred on:

I. British floras antecedent before the Great Ice Age (Mrs E.M.Reid),

II. The Quaternary Ice Age:

- a. geology (P.G.H.Boswell),
- b. the effect of the extension of ice on pre-glacial vegetation as revealed by plant macroscopic remains (M.E.J.Chandler),

III. Post-glacial floras:

- a. vegetation phases reconstructed from pollen-analysis of peat (H.Godwin)
- b. sources from which the present flora was derived
    - i. evidence in favour of survival of the British flora in glacial times (A.J.Wilmott)
    - ii. are most of the present British plants post-glacial immigrants (E.J.Salisbury)

Raistrick contributed on evidence for nunataks in the Pennines and associated survival of species (cf. the later account of the Teesdale flora by Turner *et al.* 1973), and on the comparison of pollen-analytical results from northern England with those of the Fenland, and G. du Rietz on glacial survival of plants in Scandinavia and the British Isles. There followed a full discussion with comments by many leading authorities of the day, the whole showing how developments in palaeoecology had greatly helped interpretation of the origin of the flora, and highlighting particular problems, *e.g.* the needs pointed out by W.B.Turrill for investigating the history of each species separately and for increased cyto-genetical knowledge of species, needs which should be re-iterated today.

The developments in vegetational history were further disseminated by a lecture given by Godwin to the Geologists' Association in 1941 (Godwin 1941), which covered the many fields of research related to geology. The method of pollen analysis was described, together with pollen diagrams, zonation and regional parallelism. Archaeological and geological correlations were discussed, the latter including climate and bog stratigraphy, lake stratigraphy, coastal stratigraphy and sea level change. The lecture summarises the width of the dvelopments which had occurred in the previous ten years.

The great expansion of knowledge I have described above was certainly assisted by the ready publication of the results obtained. This is before the days of specialised journals for Quaternary research. A main vehicle for publication was *The New Phytologist*, the journal founded by Tansley in 1902. Godwin succeeded Tansley as Editor, together with A.R.Clapham and W.O.James, in 1932, and many of the publications described above were published in that journal. In 1938 the journal instituted a series of publications entitled 'Data for the Study of Post-glacial History' (Godwin 1938b). The aim was to encourage short notices of particular sites or points of interest, and the opportunity was taken to suggest standardisation of sediment symbols, with publication of the system put forward by Faegri & Gams (1937). The series ran to No. XVII in 1955. In addition the *Philosophical Transactions of the Royal Society of London* was ready to publish the lengthy papers on the Fenland, which also greatly helped the foundation of the subject.

Chapter 6

Developments in research to the 1950s

In the 1930s and 1940s developments in Britain largely followed the lead given by researchers in Scandinavia and continental Europe. In Denmark, under the leadership of J.Iversen, fundamental investigations of the late-glacial period (discussed by Iversen (1954) and of the effect of man on vegetation (Iversen 1941, 1949) were published, concerned especially with the botanical interpretation of pollen data. The Vega Lecture of von Post (1946) summarised progress on a more global scale. There was a huge expansion of studies of sites of post-glacial and interglacial age throughout Europe, with syntheses such as the classic work of Firbas (1949) *Waldgeschichte Mitteleuropas*. The expansion was supported by the

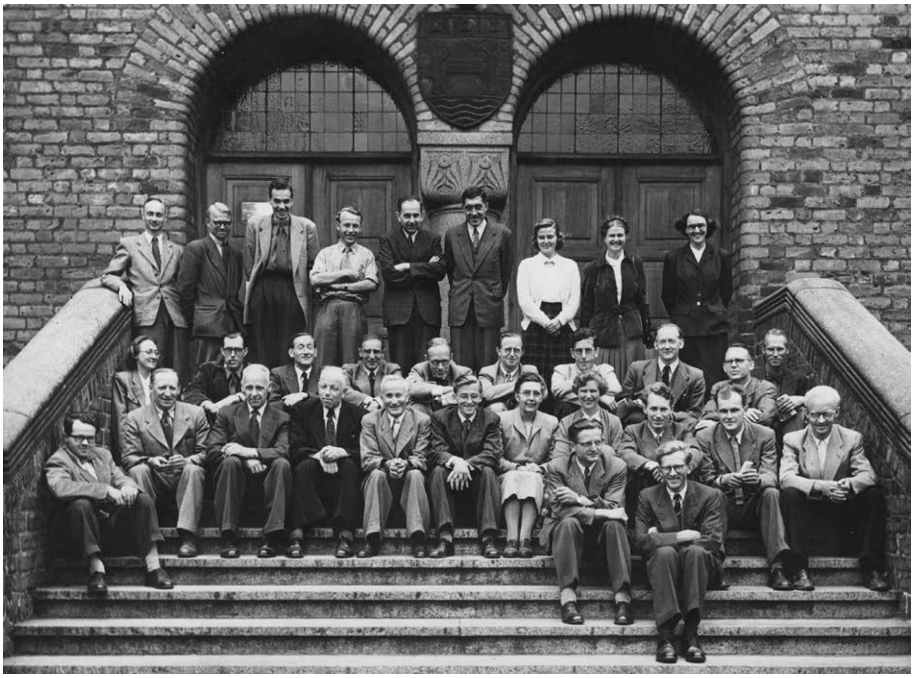

Plate 8. Members of the Third International Meeting of Quaternary Botanists, Copenhagen, 1953 (Copyright Geological Survey of Denmark and Greenland).
From left to right: Back row. A.Andersen, P.Ingwersen, H.Tj.Waterbolk, H.Krog, F.Firbas, M.Welten, M.Davis, A.Conolly, V.Conway. Middle row. I.Brandt, J.Troels-Smith, R.Schütrumpf, A.Clapham, K.Faegri, H.Jonassen, G.F.Mitchell, H.Godwin, J.Iversen, M.Fries. Front row. S.Jørgensen, F.Florschütz, F.Overbeck, W.Ludi, G.Lang, K.Blackburn, M.-B.Florin, U.Hafsten, J.Donner, A.Danielsen. Front steps. S,Andersen, V.Mikkelsen, R.West.

publication of text-books on pollen or pollen analysis, including Wodehouse (1935), containing a chapter by Erdtman on "Pollen statistics – a botanical and geological research method", in which he underlined the importance of "ascertaining the composition of the present forests and of studying the processes connected with the catching and preservation of pollen in peat and muck under formation (the "Actuopaleontology" of the bogs)", a subject which later became a foundation for the interpretation of pollen diagrams. Later were published the two influential books, Erdtman's (1943) *Introduction to Pollen Analysis* and Faegri & Iversen's (1950) *Textbook of Modern Pollen Analysis*. The latter further stressed a botanical approach to the subject rather than an "old-fashioned" geological pollen analysis.

These major developments of the 1940s and 1950s could be said to mark a high point in the history of Quaternary palaeobotany. Many of them were discussed at the 3rd International Meeting of Quaternary Palaeobotanists in 1953, appropriately held in Copenhagen. Plate 8 is a photo of the members of the meeting on the steps of the Geological Survey of Denmark and Greenland, an assemblage which included many of the founders and pioneer exponents of the subject.

Though peat stratigraphy provided a basis for the formulation of post-glacial vegetation and climatic history, stratigraphy of lake sediments soon added a new dimension to the subject. Limnology developed a historical aspect by analysis of lake sediments. Lundqvist's (1927) book on lake sediments and lake development, based mainly on Swedish investigations, illustrated the nature and variety of lake sediments and described the factors controlling sediment distribution and sequences in lakes, as well as dating sediments, field methods of boring (including the Hiller sampler), and microfossil contents of sediments. In Britain, such work became supported by the Freshwater Biological Association's laboratory adjacent to Windermere in the Lake District, founded in 1930. Here the sediments of Windermere became subject to detailed investigation, enabled by the invention of coring equipment (Jenkin *et al.* 1941). This allowed the stratigraphy of the North Basin of Windermere to be clarified and given a preliminary interpretation, described by Pennington (1943). Late-glacial and post-glacial parts of the succession were suggested, and the diatom and pollen content analysed. The work was an important milestone in several respects, including the invention of coring equipment, the analysis of sediments and diatoms, and the account of late-glacial sediments. It also led to the relating of lake evolution to catchment and land use factors.

Apart from the general increase in knowledge of post-glacial forest history, three strands of research stand out as particularly significant, the late-glacial (covering the end of the last glacial stage), man's influence on vegetation history and interglacial deposits.

The Devensian late-glacial

Jessen's investigations in Ireland in 1934 and 1935, coupled with Farrington's on the deglaciation of the Wicklow Mountains, demonstrated clearly the late-glacial oscillation already widely established in Scandinavia and Europe (Zones I, II and

III; a lower (Zone I) and upper (Zone III) *Dryas* clay and an intervening more organic sediment of the Alleröd interval of amelioration (Zone II)) (Jessen & Farrington 1938). The prospects for the expected finding of a late-glacial record in Britain were discussed by Godwin (1940c). The analyses of the oldest sediments of Windermere established the existence in the lake of a similar sequence, the interpretation supported by analyses of the sediment, pollen, diatoms and macroscopic plant remains (Pennington 1943, 1947). Studies at other sites also gave evidence of the late-glacial oscillation. At Hawks Tor in Cornwall, sections in 1935 and later showed organic sediments within solifluction sediments at china-clay workings (Conolly *et al.* 1950), and in north London late-glacial sediments were recorded in floodplain sediments of the Lea Valley (Allison *et al.* 1952). At both these sites a wide variety of pollen taxa and macroscopic plant remains were identified, with R.Andrew contributing to a great improvement in pollen identification and A.P.Conolly and J.Allison likewise to the identification of macroscopic plant remains. Late-glacial sediments at Hockham Mere (Godwin & Tallantire 1951) and Lopham (Tallantire 1953) were also encountered and analysed in the extension of the Fenland researches eastwards into East Anglia from 1939 onwards.

These early investigations of late-glacial sediments were put into a wider context from a biological and geological point of view by Godwin (1947) and, in specific relation to the spreading of the British Flora, by Godwin (1949).

Man's influence on vegetation history

Iversen's detailed pollen analyses of Danish and Swedish post-glacial sediments, published in 1941 and augmented (1949) in a 1946 lecture in Cambridge at an international meeting of Quaternary botanists assembled by Godwin, opened up a field of pollen analysis which enabled a clear relation to be made between man's cultural activities and vegetation change, in particular the forest composition and non-tree pollen representation. Iversen's contribution, the significance of which was discussed by Godwin (1944a), showed how forest composition was changed and forest cover reduced by the actions of prehistoric man (Plate 9). The subject was approached in an account by Pearsall & Pennington (1947) on the ecological history of the Lake District, in which the organic and pollen content of the Windermere sediments were related to archaeological periods. In East Anglia, the sediments at Hockham Mere yielded a detailed pollen diagram which showed clear evidence of forest decline and heath development in the Breckland; this change was discussed in relation to Neolithic and later occupation in the area (Godwin 1944b; Godwin & Tallantire 1951). The decline of *Ulmus* associated with these changes, identified in Iversen's pollen diagrams, and also in the Fenland and Somerset pollen diagrams, was taken to mark the boundary between Zones VIIa (Atlantic) and VIIb (Sub-boreal). The decline was discussed by Iversen (1941), who thought it 'something of a riddle', perhaps associated with climate change at the Atlantic/Sub-boreal boundary or with Neolithic culture or both. Possible causes have been much discussed since then, with the addition of elm disease as a possible cause.

The relation between vegetation history and archaeology was expanded by the work on the Somerset Levels, where prehistoric trackways were related to bog stratigraphy and climatic change (Godwin 1946,1948; Clapham & Godwin 1948). Analyses of plant macroscopic remains from archaeological sites also added to this relationship (*e.g.* Conolly 1941).

Interglacials

By the late 1920s much had been done on the continent to investigate the palaeobotany of interglacial sediments. Outstanding amongst this work was the contribution of Jessen & Milthers(1928) on interglacial deposits of Jutland and north-west Germany, by virtue of the palynological detail and the co-operation of botanist (Plate 2) and geologist. The vegetational histories of the last and penultimate temperate stages were described by them in detail. The Quaternary stratigraphy of northern Europe was well-established, with considerable detail known of glacial events (Elster, Saale, Warthe, Weichsel) and interglacial periods, developed by Keilhack and by Woldstedt (see *e.g.* 1929, 1954), and reported in Wright's (1937) *Quaternary Ice Age.* Matters lagged in Britain, however, as with studies of the late- and post-glacial. A short report by Erdtman on six pollen analyses from the interglacial deposits at Hoxne, Suffolk, appeared in Moir's (1935) account of the archaeology at that site, indicating the presence of temperate pollen assemblages. Later Erdtman (1953) published a note on secondary pollen at the site. In 1938 interglacial deposits were discovered north of Cambridge, associated with an ancient floodplain of the River Cam. Pollen analyses from the fine sediments showed temperate pollen assemblages, with the presence of *Carpinus* in certain samples were published much later (Hollingworth *et al.* 1950), and a correlation with the Jessen's zones *f* and *g* of the Eemian (Last) Interglacial was suggested. The correlation was strengthened by Walker (1953) who showed that Jessen's zone *i* was also present. Such was the situation in Britain by the end of the 1940s.

Plate 9. J.Troels-Smith and K.Faegri at Draved Wood, Denmark, 1953, illustrating forest clearance with a Stone Age flint axe (photo R.G.West).

Chapter 7

Establishment of the Sub-department of Quaternary Research

A proposal in 1938

With the experience of the success of the Fenland Research Committee and of the possibilities of co-operation, Godwin made a case in November 1938 for the establishment of a body or institution which would support such co-operative research into the Quaternary. The proposals received 'sympathetic support' from the Faculty Boards of Biology 'A', of Archaeology and Anthropology, and of Geography and Geology, and were considered by the General Board and discussed in 1939. But further discussion was postponed by financial stringency and the outbreak of the war.

The proposals described the subject of Quaternary research and the many disciplines involved. A combination of these was required to advance knowledge. The success of the Fenland Research Committee had led to an increased demand for co-operationacross the borders of archaeology and natural sciences, and a mechanism was needed to facilitate these developments. The separate subjects concerned were: botany, zoology, geology, archaeology, climatology and geography.

The need was for a separate research body, which would both encourage the activities of specialists in various fields and promote collaboration in the study of the major problems of Quaternary history by the formation of a single institution. Quaternary research was supported by Government in several western European countries; for example, the Geological Surveys of Sweden, Denmark and Germany and State Universities in Sweden have played a large part in pioneering the subject. The case for Cambridge as a centre for this research was made, noting that the next meeting of the International Association for Quaternary Research (INQUA) was to be held in Cambridge in 1940.

It was proposed that the new body would carry out independent pieces of research, act as a clearing house for co-ordination of of the work of extra-mural researchers, assist in identification and intepretation of Quaternary material, and possibly provide short post-graduate lecture courses.

The aims would be best met by providing a small number of workers to cover some of the following areas. These naturally represent the particular interests at the time and were stated: 'peat stratigraphy in the field, identification of wood, fruits and seeds, and other plant material, pollen-analysis (a basic system of reference to former forest-history: for use as a chronological and climatic index), identification of diatoms, foraminifera, mollusca, bones, etc.(these are plants and animals whose remains are often abundant and which are valuable indices of local and climatic conditions), counting of varves clays (a system of determining the age of lake deposits in years from their lamellar structure), glacial geo-morphology, archaeology. It was suggested that 'four workers of junior research status should be given sufficient stipend for full-time work, say £300 p.a. initially, rising to £400.' Such would have the statuis of Assistants in Research. The total annual cost was estimated at £2,500 p.a. But even if the immediate prospects of such an establishment was not possible, some support, in the form of subsidy for a particular researcher for a limited time on a specific problem, would be valuable.

Re-iteration of the proposal in 1943

In 1943 the General Board asked Faculty Boards to make statements of post-war needs and proposals for developments. Godwin re-stated the 1938 proposal to the Faculty Boards of Biology 'A', of Archaeology and Anthropology, and of Geography and Geology. The aims remained the same as before, with the addition of an enlarged note on how natural sciences could contribute to archaeological matters, and the impoortance dating of human fossils. The case was strengthened by a list of members of the University who had been most prominently concerned with research in Cambridge on problems of the Quaternary: Ten in the Faculty of Archaeology and Anthropology; six in the Faculty of Biology 'A'; eight in the Faculty of Geography and Geology. The cost was re-assessed at £1760 p.a.

The General Board's proposal

In October 1948 the General Board reported on Godwin's proposal, which had received support from the three Faculty Boards (Cambridge University Reporter 1948/9). The Board outlined the case for supporting Quaternary research. It had already in 1947 recommended the establishment of an Assistant in Research post in Botany(Quaternary Research) from 1 October 1947 (Cambridge University Reporter 1946/7), and J.Allison was appointed from 1 October 1947 for two years as assistant in research to Dr Godwin. They now recommended establishment of a Readership in Quaternary Research, that the Reader should be a member of the three Faculty Boards, that Dr Godwin be appointed to the Readership, and that a Sub-department of Quaternary Research be established in the Department of Botany, with the Reader as Director. The proposals, from the Faculty Board of Biology 'A', received support from the other two Faculty Boards on the understanding that Dr Godwin as Director of the Sub-department of Quaternary Research would be responsible for the direction of research in the Sub-department not only to the Head of the Department of Botany but also to the Heads of the Departments of Geology and of Archaeology and Anthropology. The recommendations were approved by the University in October 1948.

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Part II

The Subdepartment of Quaternary Research

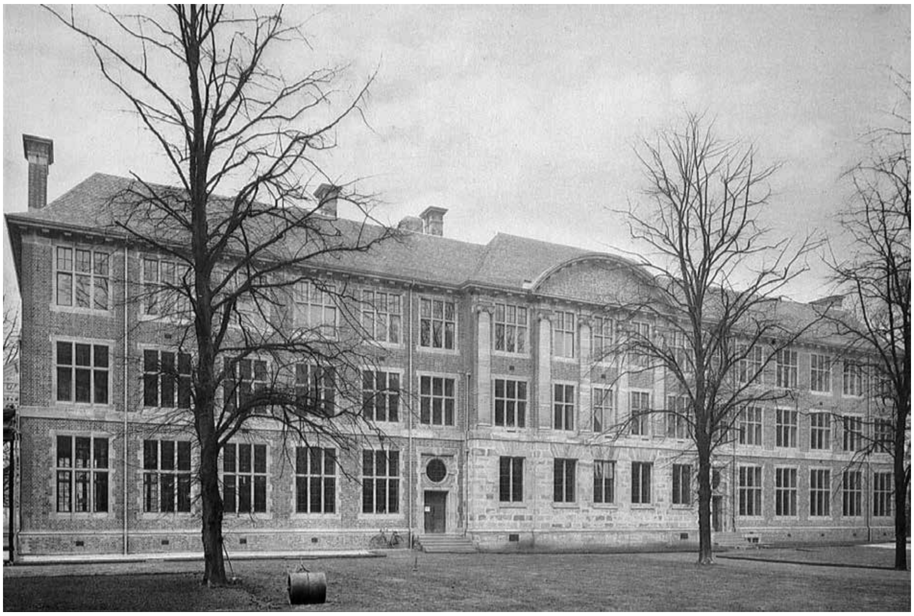


Plate 10. The Botany School, University of Cambridge, north front, 1904.

Plate 11. Members of the Subdepartment of Quaternary Research, 1952/3.
From left to right: R.Andrew, S.C.Seagrief, A.G.Smith, C.A.Lambert, S.L.Duigan, D.Walker, H.Godwin, E.H.Willis, R.G.West (photo F.T.N.Elborn, Subdepartment Archive).

Introduction

The Subdepartment was first established in the Botany School (Plate 10). During the period it existed, from 1948 to 1994, the subject expanded greatly from the foundations already described. The history is naturally a mirror of the wider development of the subject. It reflects the huge increase of research activity made possible by increased funding, a result of the recognition of the significance of the subject in understanding the environmental changes which are fundamental to the planet's health and human survival.

The Subdepartment's achievements in the period 1948-1994 are recorded in the 45 Reports of the Subdepartment, annual except for the first (1948-1950), published in the *Cambridge University Reporter*, and which contain a wealth of detail. My account is based on these reports, and describes major developments which took place as the activities of the Subdepartment expanded in research and teaching, reflected in the photos Plate 11, members of the Subdepartment in the Academic Year 1952/3 and Plate 12, members and colleagues of a Subdepartmental expedition to a complex site at Beetley, Norfolk, in 1983.

Behind the teaching and research lie the facts concerning organisation, staff, research associates, post-graduate students, and teaching. These aspects of the Subdepartment are described, with the research progress then considered in more detail. Finally, the closure and achievements of the Subdepartment will be discussed.

Plate 12. Members of a Subdepartment expedition to Beetley, Norfolk, November 1983 (Subdepartment Archive).
From left to right: J.Wymer, P.L.Gibbard, D.Smith, R.C.Preece, S.M.Peglar, A.Wintle, M.Warren, P.Lambley, P.A.Ventris, C.Turner, J.D.Scourse, J.Dye, S.Heptinstall, R.A.Housley, R.G.West, M.E.Pettit.

Chapter 1

Organisation and people

Organisation

The Director of the Subdepartment was responsible for the direction of research to the Heads of the Departments of Botany, Geology (later Earth Sciences) and Archaeology from its establishment in 1948 to 1986. The Director was also a member of three Faculty Boards of the associated departments: Biology 'A', Geography and Geology, and Archaeology and Anthropology, which was invaluable in keeping in touch with developments in those Departments and for organising inter-departmental teaching. In 1986 the Head of the Department of Geography was added to the list, formally recognising the contribution made by that subject to the work of the Subdepartment. The Director from time to time consulted the Heads and submitted the Annual Report to them for approval before transmission to the General Board. H. Godwin was Director from 1948 to 1966, R.G. West from 1966 to 1988, and N.J. Shackleton from 1988 to 1994.

From the beginning the members of the Subdepartment were infused by joint enthusiasms under the leadership of Harrry Godwin. Donald Walker put the situation well in his introduction to the volume of essays in Harry Godwin's honour (Walker & West 1970): "Harry Godwin entered Cambridge University as an undergraduate in 1919 and remained there until his retirement in 1968. In the intervening years, his enthusiasm, industry and humanity have been inexhaustible sources of stimulus and guidance to innumerable students and colleagues. The authors of these essays offer them in gratitude for having had an opportunity to share in the excitement." There was much sharing of fieldwork activities by members of the Subdepartment, an essential and enjoyable part of the activities, especially since there was so much to be learned in the field in those days. A peak of such co-operation took place in 1983 when a large number of members and associates of the Subdepartment descended on the gravel pits of Beetley in Norfolk to carry out stratigraphical work and levelling (Plate 12).

Academic activities were joined by wider joint and social activities related to Quaternary research, such as the invention by S.L.Duigan of a shield and motto for the Subdepartment (Plate 13) and by meals with courses related to Quaternary matters (e.g. a menu showed the following sequence: Succession Stratigraphique–Zeuner, Crème de champignons Godwin et Andrew, Crevettes dérivées Florschütz, Canard rôti à la Seamer, Pouding tardiglaciale cryoturbatique, Café humifié). A card game, somewhat similar to rummy, was invented in 1952/3, entitled 'Correlations', illustrated by S.L.Duigan. A series of cards signified well-

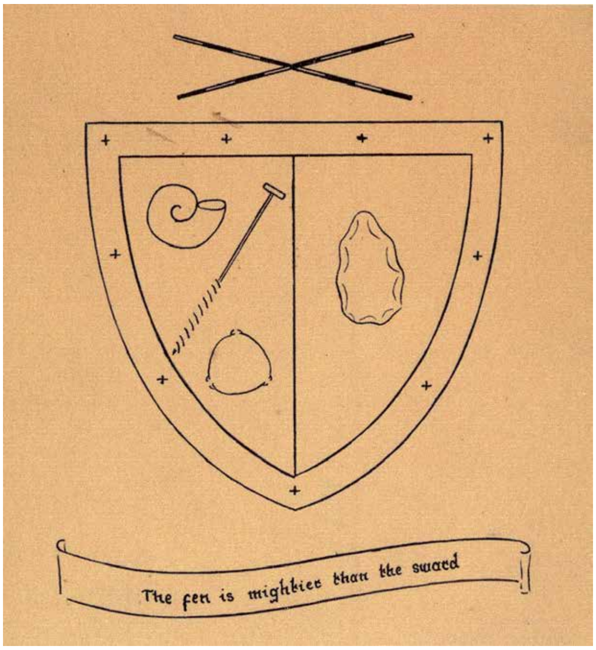


Plate 13. Shield and motto of the Subdepartment of Quaternary Research, designed by S.L.Duigan and members of the Subdepartment, c.1953.

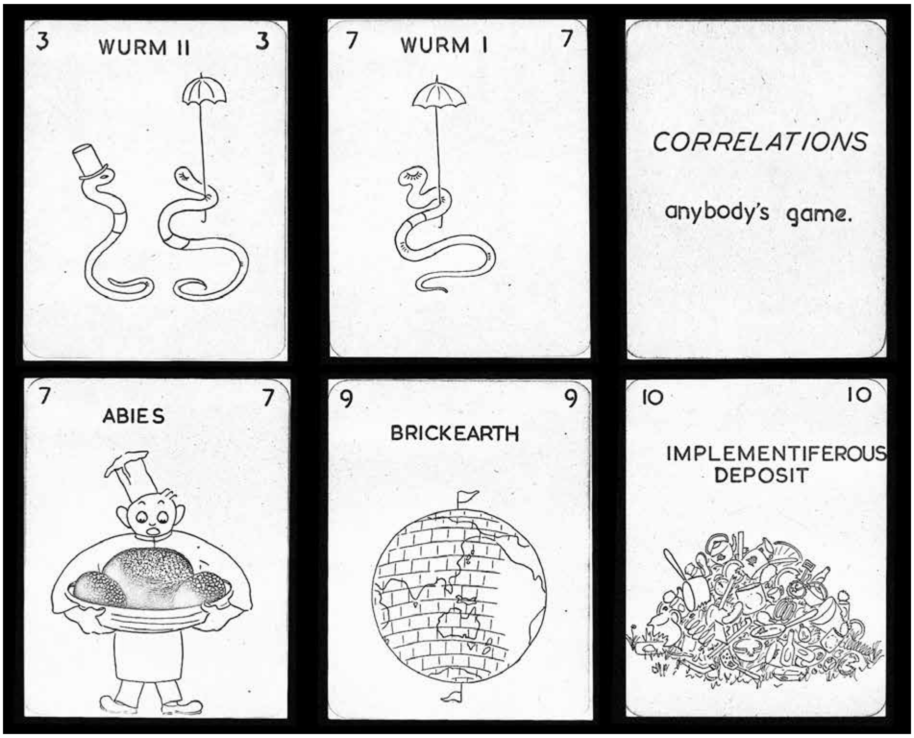


Plate 14. A selection of cards of the game 'Correlations', drawn by S.L.Duigan.

known stratigraphic units (Plate 14). An additional series of cards were related to distinguished authorities, and the aim was to collect a series of stratigraphic units and relate them to stratigraphic sequences of the authorities. A summary of the rules stated that: 'Correlations is a game for any number of people. The rules are not clearly recognised (…….,1950), and are hardly ever adhered to consistently (……..,1951). Some players ignore all the rules all the time (………,1939). The game could be played. A set was accepted by the library of a learned society. A cartoon of the time by S.L.Duigan is shown in Plate 15.

Laboratories

At first the laboratories involved in the work of the Subdepartment, mainly botanical, were housed in the Botany School (Plate 10), where they remained till the dissolution in 1994. The pollen analysis laboratory, in a former small preparation room of very inconvenient design attached to the Elementary Laboratory, remained in use until 1985, when new and larger laboratory came into use.

When the building of the radiocarbon dating equipment started in 1952, this was also housed in rooms in the Botany School. Five years later the equipment was moved away to huts at 5, Salisbury Villas, Station Road, Cambridge, because of the danger to the radiocarbon project of the concentrations of radioarbon used in plant physiological experiments in the Botany School. This laboratory also came to house the equipment involved in stable isotope research. Twenty years later, in 1977, the radiocarbon and oxygen isotope laboratories moved back into central Cambridge into a building on the New Museums Site, named the

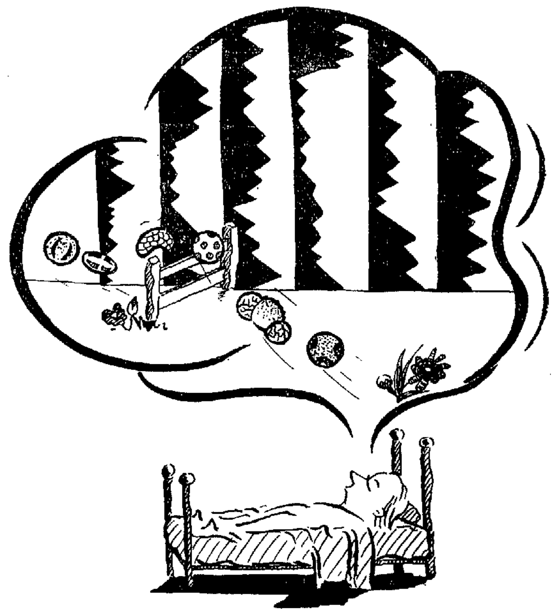


Plate 15. A cartoon by S.L.Duigan (The Tea Phytologist, 1954).

Godwin Laboratory, which was, fortunately, sufficiently large to accommodate the important developments in dating, isotope analysis and sedimentology which were then taking place. The isolation of the radiocarbon and isotope laboratories from the activities in the Botany School from 1957 to 1977 made for some difficulties, so that the return to the central Godwin Laboratory was a very welcome event which greatly encouraged the collaboration so essential to the subject.

Academic staff

The academic staff of the Subdepartment and those of the Department of Botany associated with the Subdepartment, together with their times of tenure, are shown in Figure 1 and below. The University had an established line of appointments relating to research responsibility, starting at Assistant in Research, to Senior Assistant in Research, thence to Assistant Director in Research, the first two being approximately equivalent to Assistant Lecturer, the last to Lecturer. Such positions are indicated below by (R). Positions held in the Department are indicated by (T). The times below in parenthesis show when the person concerned joined the Subdepartment as a research student or research assistant. The research positions in the Botany School were held largely by botanists in the earlier days of the Subdepartment, until 1971 when the geologist P.L.Gibbard (Plate 16) was appointed.

Plate 16. P.L.Gibbard examining Wolstonian proglacial deposits at Feltwell, Norfolk (photo A.Bitinas).

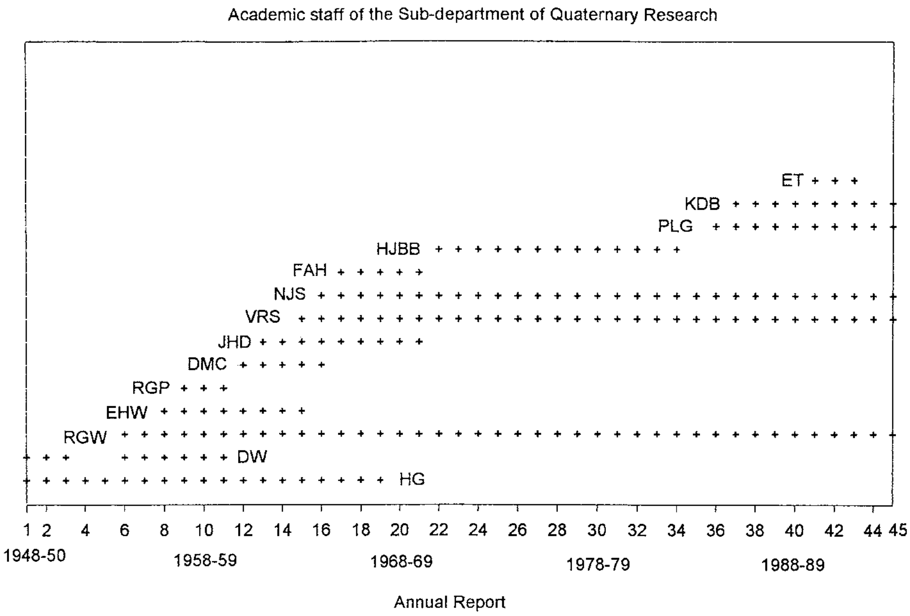


Figure 1. Academic staff of the Subdepartment of Quaternary Research. HG, H.Godwin; DW, D.Walker; RGW, R.G.West; EHW, E.H.Willis; RGP, R.G.Pearson; DMC, .M.Churchill; JHD, J.H.Dickson; VRS, V.R.Switsur; NJS, N.J.Shackleton; FAH, F.A.Hibbert; HJBB, H.J.B.Birks; PLG, P.L.Gibbard; KDB, K.D.Bennett; E.T, E.Thomas.

The staff were recruited from within the University and from other Universities, and covered a wide range of expertise, in response to important developments in the subject. Their interests in Quaternary research were necessarily wide, but, in summary, their main fields of activity and the positions held (R or T) were as follows. Periods of their time as research students or research assistants are given in parentheses:

J.Allison: Palaeoecology (macroscopic plant remains), archaeology. 1947 - 1949 (R).

H.Godwin: Palaeoecology, chronology, sea-level change, archaeology. 1948 – 1968 (T). (Director 1948 –1966, Reader in Quaternary Research 1948 -1960, Professor of Botany 1960-1968.)

D.Walker: Palaeoecology, chronology, archaeology. 1949 –1950, (1950-52) 1952 –1953, 1955 –1960 (R).

R.G.West: Palaeoecology, stratigraphy. (1951 - 1954), 1954 - 1956 (R), 1957 - 1991 (T). (Director 1966-1986, Reader in Quaternary Research 1968-1975, Professor of Palaeoecology 11975-1977, Professor of Botany 1977-1991.)

E.H.Willis: Radiocarbon dating, chronology. (1952 -1957) 1957 – 1964 (R).

R.G.Pearson: Faunas, especially Coleoptera. 1957 – 1960 (R).

D.M.Churchill: Palaeoecology, archaeology, sea-level change. 1960 –1965 (R).

J.H.Dickson: Palaeoecology, Bryophyta. 1961 – 1970 (R).

V.R.Switsur: Radiocarbon dating, dendrchronology, dendroclimatology. 1964 – 1994 - (R)

N.J.Shackleton: Stable isotopes, marine geology, chronology, archaeology. (1961-1964), 1964 – 1994 – (R). (Director 1988 –1994, Reader in Quaternary Palaeoclimatology 1987 – 1991, Professor of Quaternary Palaeoclimatology 1991-).

F.A.Hibbert: Palaeoecology, chronology. 1965 – 1970 (R).

H.J.B.Birks: Palaeoecology, numerical analysis. (1965 -) 1971 - 1975 (R), 1975 – 1983 (T).

P.L.Gibbard: Sedimentology, stratigraphy, palaeogeography. (1971 -), 1984 – 1994 - (R)

K.D.Bennett: Palaeoecology, chronology. (1979 -), 1985 - (R).

E.Thomas: Marine geology. 1989 –1992 (T). Joint appointment with Department of Earth Sciences.

Assistant Staff

The Subdepartment was particularly fortunate to gain the services of able assistant staff members throughout its life. These included both full-time and part-time staff, who became expert in their own special fields to the great advantage of Quaternary research, and whose contributions are now recalled.

The Subdepartment began in 1948 with a single part-time assistant, Ms R.Andrew, already employed by Godwin to assist in pollen analysis and build up a pollen reference collection of slides. She continued to advise and assist in pollen analysis, building up the pollen reference collection, until retirement in 1976. Thereafter, she continued for several years part-time, involved in pollen analytical work supported by grants to members of the Subdepartment. Ms C.A.Lambert (Dickson) joined the staff in the early 1950s and developed the collection of macroscopic plant remains and expertise in identification, and also oversaw the botanical laboratories until 1963, contributing thereafter part-time until 1970. She became an authority on macroscopic plant remains, especially those associated with archaeological investigations in a later part of her career at Glasgow. Ms M.Ransom (1963 -1968) and Ms A.Loader (1966 -1970) followed in Ms Lambert's tradition, as did Mrs M.E.Pettit who was appointed in 1970, becoming expert in identification of macroscopic plant remains. Mrs Pettit resigned in 1975, subsequently returning part-time to work in many projects in the Sub-department, including the identification of many assemblages from temperate and cold stage deposits, and the compilation of data bases. Dr S.M. Peglar joined the staff in 1971, taking over supervision of the laboratories in the Botany School, overseeing the reference collections and carrying out much pollen-analytical research with its associated interpretation. Dr Peglar was assisted by Ms F.Wilson (1978 -1982) and Mrs J.Dye (1982 – 1994). Dr Peglar resigned in 1989, when Mr S.Boreham (1989 –1994 -) was appointed in her place, supervising the laboratories in the

	1953/4-57/8	58/9-62/3	63/4-67/8	68/9-72/3	73/4-77/8	78/9-82/3	83/4-87/8	88/9-92/3	93/4-
Ph.D. (total 67)	7	5	7	6	9	9	3	11	10
M.Sc.	-	-	-	-	1	-	1	-	-
Ph.D. associated or based in other Depts	-	-	-	-	-	-	1	2	3
Palaeoecology									
l-gl, p-gl, British Isles	3	3	3	3	5	7	1(3)	2(3)	1
overseas	-	-	-	-	-	-	-	-	2
+ archaeological interest	-	x	-	-	xx	x	x	x	x
+ sea-level interest	x	-	-	-	x	x	-	-	-
diatoms	-	-	x	-	x	x	-	-	-
palaeolimnology	-	-	-	-	1	-	-	(1)	-
cold stage & interglacial & associated geology	3	1,x	1	3	2	1	2	1	2
Pollen transport, pollen rain	-	-	-	-	2	x	-	-	-
Pollen structure, development	-	-	1	-	-	-	-	-	-
Marine palynology	-	-	-	-	-	1	-	-	1
Fauna	-	1	1	-	-	-	-	-	-
Quaternary geology	-	-	-	-	-	-	(1)	4(4)	1
Palaeoclimatology, stable isotopes, palaeoceanography	-	-	1	-	-	-	1	3	1
Radiocarbon	1	-	-	-	-	-	-	-	-
TL	-	-	-	-	-	-	-	1	-
ESR	-	-	-	-	-	-	-	-	1
Dendrochronology, dendro	-	-	-	-	-	(1)	1	-	4(1)
M.Phil. (Q.R.)	-	-	-	-	-	1	4	8	1

Table 1. Numbers, in 5-year classes, of graduates, Ph.D., M.Sc., M.Phil. and their main subject areas by academic year of graduation. The 93/4 class gives a total for all graduates who started in the final years of the Sub-Department, but graduated in that year or later. M.Phil. numbers in parenthesis. x, area contributing to major theme. Titles of dissertations in Appendix A

Botany School, and, as well as dealing with the palaeobotanical work, developed sedimentological sides of the research. Other members of the assistant staff with shorter periods of service included Ms M.J.Burroughs (1963/4), Ms J.M.Heyes (191964/66), Ms L. Upchurch (1968/9), Ms K.Guyton (1969/72), Ms S.Bobyk (1975) and Mr T.P.Cosgrove (1976-77).

The first technical assistant of the radiocarbon dating project was Mr R. Burleigh, appointed in 1958, who contributed greatly to the early achievements in radiocarbon dating. He left in 1962 for the Atomic Energy Authority, and was replaced as technical assistant by Mr G.A.Sutton. Mr J. Banfield assisted in the Radiocarbon Laboratory from 1961 to 1963, followed by Mr C.A..Raven. He resigned in 1963/4, and was succeeded by Mr M.A.Hall as scientific assistant. In 1967/68 Mr Sutton left, and Mr Hall became senior technician assisted by Mr A.P.Ward as scientific assistant. With the development of the palaeotemperature laboratory, Mr Hall moved in 1969 to an N.E.R.C. research assistantship in that laboratory and his place as technical assistant in the radiocarbon laboratory was taken by Mr C.Devine. In 1974 Mr Devine resigned. Mr Ward made a major contribution to the radiocarbon laboratory in the succeeding years, leaving in 1987/88. Radiocarbon dating was supported by English Heritage from 1984/5 to 1987/88, with the employment of J.L.Bounden. Members of the Radiocarbon Dating Laboratory are pictured in Plate 17.

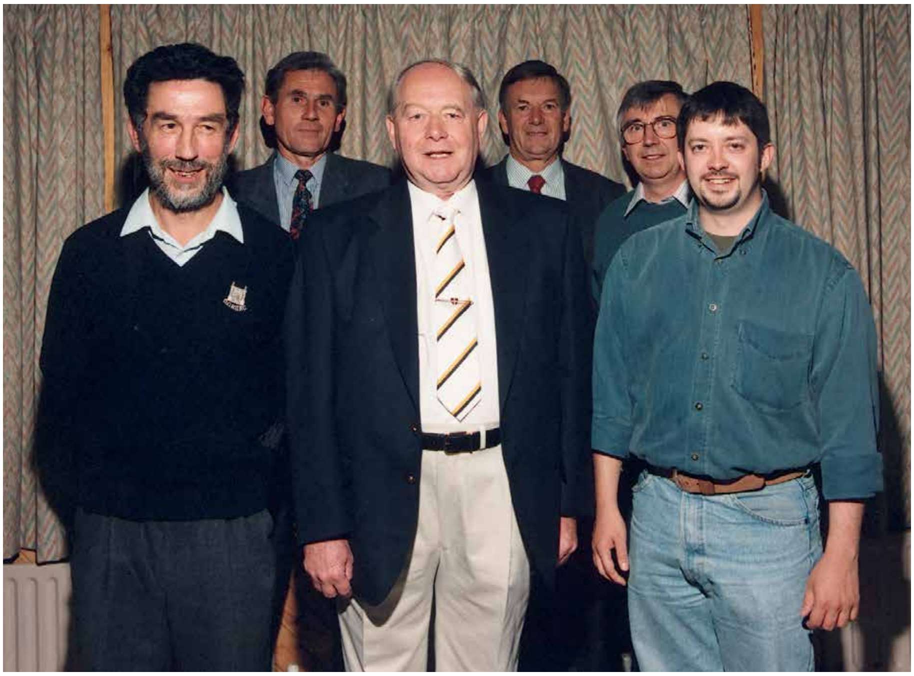


Plate 17. Staff of the Radiocarbon Dating Laboratory, from left to right: J.Banfield (1961-62), G.Sutton (1962-67), V.R.Switsur (Director 1964-96), R.Burleigh (1958-62), M.A.Hall (1964-69, 1988-1996), A.Gerrard (1988-1996) (Godwin Laboratory Archive).

In 1975 N.E.R.C. support to the palaeotemperature laboratory was increased with the appointment of Mr Q.C.Given as assistant. He left in 1978 and was succeeded by Mr C. Solanki (1978/79 – 1983/4). Two developments followed which expanded the research of the Subdepartment through grants to N.J.Shackleton, from N.E.R.C. to establish to a TL laboratory, and from S.R.C. to develop seasonality studies of prehistoric occupation through isotope analyses of molluscs. These developments were made possible by the facilities made available by the new Godwin Laboratory in 1977. As a result there was an integration of equipment use and technical and research assistance in the Laboratory, later enlarged further by N.E.R.C. and E.E.C. grants to support dendrochronological and dendroclimatology research under the aegis of V.R.Switsur. Mr Hall, together with Mr Solanki, later succeeded by Mr M.Tabecki (1981/82 – 1984/85) and Ms J.Cartlidge (1985/86 – 1987/88) continued to assist the palaeotemperature project.

Mr Hall was appointed Technical Officer in 1987, and became associated with both the radiocarbon and stable isotope laboratories, together with the other facilities which developed later. He supervised the Godwin Laboratory to the time of dissolution (and after). Over the period of his appointment in the Subdepartment, from 1963/4 - 1993/4, he made an absolutely outstanding contribution to its activities, and was a prime contributor to the successes of the laboratories and research conducted in the Godwin Laboratory and its antecedents.

The TL laboratory, N.E.R.C.-supported, with A.G.Wintle in charge, started in 1978/79, with Mr C. Solanki first appointed as technical assistant in 1981/82, later followed by Ms S.Packman from 1985/86 to 1988. When A.G.Wintle left the laboratory in 1987/9, R. Grün took responsibility for the TL laboratory and began a project on ESR dating.

The seasonality studies using stable isotopes, S.E.R.C.-supported, started in 1979/80 and developed with Dr M.R.Deith assisted first by Mrs S.Wanek (1979/80 – 1981/82), later by M.Tabecki (1981/82 – 1985/86). From 1986/87 to 1987/88 Dr Deith continued with M.A.F.F.–supported research on growth rates in molluscs.

In the radiocarbon and palaeotemperature laboratories, from 1988/89 to the time of dissolution, A.C.Gerrard (1987/88 -), Ms J.Proud (1988/89 – 1990), D.Pate (1989/90 –1993/94), Ms L.Booth (1990/91 – 1993) and Ms E.R.Foster (1993/94) provided technical assistance, with S.J.Crowhurst (1988/89 -) providing assistance with computing and age modelling.

With the development of the N.E.R.C. (TIGGER)- supported isotope dendroclimatology, Ms S.Rossiter and Ms E.M.Field were appointed to the technical staff in 1991/92, and J.E.Rolfe in 1993/4.

The appointments described above reflect the expansion of Quaternary research during the life of the Subdepartment. The number of University -supported staff members from 1948 to 1994 was remarkably small (M.A.Hall, A.P.Ward, A.C.Gerrard). The expansion resulted from increased funding from research councils and others (e.g. M.A.F.F., E.E.C., English Heritage). The founding of the Godwin Laboratory was the catalyst which made such expansion possible, within the demands on space always being made very cogently in all sectors of the University. Plate 18 is a photo of the members of the Godwin Laboratory in 1884/5.

Within the long list of staff whose work was essential to the developments described above, the success of the Subdepartment was in no small way due to those who made their contributions and developed their expertise over a long period, including R.Andrew, C.A.Dickson (Lambert), S.M.Peglar and M.E.Pettit in the Botany School, A.P. Ward in the radiocarbon laboratory and M.A.Hall, first in the radiocarbon laboratory, then in the palaeotemperature laboratory and finally in the Godwin Laboratory as a whole.

Post-Graduate students

Ph.D. students

The first Ph.D. involving Quaternary research was awarded to M.H.Clifford in 1938/9, for a dissertation entitled 'The post-glacial vegetational history of the East Anglian Fenland', describing research carried out in the investigations of Fenland sediments, supervised by Godwin (see above). After the establishment of the Sub-department in 1948, a series of post-graduate students came to the Sub-department, listed together with titles of dissertations in Appendix A, a total of nearly 70 in the life of the Sub-department. The first, D.Walker (1953/54), studied both interglacial and post-glacial vegetational history, and subsequently the subjects

Plate 18. Members of the Godwin Laboratory, 1984/5.
From left to right: N.Holman, A.Wintle, C.Heusser, L.Heusser, E.Birchfield, J.D.Scourse, S.Forman, H.Kennedy, A.Carter, V.Mullane, M.A.Hall, A.Ward, N.J.Shackleton, M.Tabeski, R.C.Preece, M.Deith E.Boyle, R.Corfield, C.Whiteman (Godwin Laboratory Archive).

extended into Quaternary geology, faunal history, dating, palaeoclimatology and marine geology as Quaternary research developed and expanded to make use of the variety of disciplines relevant to the subject. The expansion was supported by the increasing amount of financial support for post-graduates by the developing research councils, especially NERC, and later by the EEC. The graduate students came from a wide variety of places. In the early days, a number were from overseas, but these decreased as the subject became more widely taught, expanding again later when dating advances became active. The majority of students were graduates of institutions within the British Isles, most from outside Cambridge.

An analysis of the subjects studied is given in the Table. This attempts to categorise the subjects according to the major discipline involved in the research, not always clear-cut because of the interdisciplinary nature of much of the work done. Late-and post-glacial vegetational history, together with vegetational history allied to geology of earlier periods, form the two main strands of research, enlarged in later times with developments of dating methods, palaeoclimatology and marine geology. The faunal subjects are minor; here, stronger parallel developments took place in the Zoology Department. In the later years a number of students from other Departments (including Archaeology, Geography, Earth Sciences, Physics, Anglia Polytechnic University) worked in the Sub-department's laboratories, a reflection of the expansion of Quaternary research into other Departments.

The development of certain areas within Quaternary research was strongly advanced by many graduate students. Amongst others may be mentioned D.Walker (vegetational history, peat stratigraphy), E.H.Willis (radiocarbon dating), N.J.Shackleton (isotopic analyses and palaeoceanography), H.J.B.Birks (numerical analysis of Quaternary data), F.G.Bell and D.G.Wilson (macroscopic plant remains), P.E.P.Norton (marine Mollusca), J.H.Dickson (Quaternary bryophytes), J.Turner (vegetational history related to anthropogenic factors), P.L.Gibbard (Quaternary geology), with many others named in later in the sections on particular Quaternary subjects.

M.Phil. in Quaternary Research students.

Discussions were started in 1978 to establish a one-year interdisciplinary course, the M.Phil. in Quaternary Research. The arrangements were completed in co-operation with the Departments of Botany, Geography, Geology and Zoology, and combined alternative taught courses and an original dissertation reporting research.

The course was taken by a number of post-graduate students in later years, the number restricted by the availability of funding for such courses at the time. The dissertations covered a variety of Quaternary disciplines (see Appendix A).

Researchers

As the Subdepartment built up in the 1950s, an increasing number of researchers became involved in the work of the Subdepartment. These included those working within the Subdepartment, including Research Fellows of Colleges and Research

Councils, research assistant and post-doctoral appointments supported by grants from a variety of bodies, and visiting scientists who made use of the facilties offered by the Subdepartment. In very significant addition there were always members of staff (and research students) involved who belonged to other Departments than Botany. The Subdepartment acted as a natural focus for Quaternary research, as intended by its founder.

A brief account of these various categories follows. A list is given in Appendix B.

Co-operation with other Departments

There was always support over a long period of time. for Quaternary research from members of Departments other than Botany. This was greatly enhanced by the fact that the Departments concerned were only a few minutes walk away. B.W.Sparks in Geography, a leading authority on non-marine molluscs, collaborated in many research projects. C.L.Forbes, R.W.Hey and B.M.Funnell in Geology, and K.A.Joysey in Zoology, also contributed in this way. In Archaeology, collaboration established in the days of the Fenland Research Committee continued with various members of staff, including J.G.D. Clark and C.B.M. McBurney.

Research Fellows

Cambridge College Research Fellowships were awarded to several Ph.D. graduates of the Subdepartment, which were invaluable in supporting the development of significant areas of Ph.D. research. Most were in the area of plant palaeoecology. A small number of Research Council post-doctoral fellowships were awarded, in the fields of Pleistocene fauna and ESR dating.

Grant-supported researchers and research associates

A large number of research assistants and post-doctoral researchers held positions in the Subdepartment as a result of research grants or grants for visiting scientists. The number greatly enlarged in later years as the subject expanded. The subjects covered included (with approximate numbers) plant palaeoecology (13), palaeoecology related to archaeology (5), marine and isotope geology (9), dating (C14, TL, ESR)(6), and geology (2). A number of contributors to particular fields may be mentioned. D.G.Marsden (Wilson) developed work on macroscopic plant remains, including those those related to archaeological sites and the Cromer Forest Bed. The geological side was expanded by the work of P.L.Gibbard on the Thames valley and elsewhere and the increased use of analytical equipment. A.G.Wintle developed the TL research (1978/79)and R. Grün the ESR work(1987/8). In the area of faunas, R.Preece came to the Subdepartment in 1982/3 to begin work on non-marine molluscs and moved to an appointment in the Department of Zoology in 1986. A.J.Stuart came in 1971/2 as an N.E.R.C. research fellow to work on vertebrate faunas and later moved to the Department of Zoology, where later A.M.Lister and other research students began research on faunas. C.Turner continued active association with the Subdepartment following his Ph.D. palaeoecological research from 1966/76 till the dissolution while holding teaching posts at Birkbeck and the Open University. T. van Andel was appointed to an Honorary Professorship in Quaternary Research in 1989/90, and became involved in many activities, both research and tedaching, in the Subdepartment and associated Departments. The increased application of isotope studies to various subjects led to wider use of the facilities which had been developed in the Godwin Laboratory and the later years of the Subdepartment saw an enlargement in the variety of visiting researchers from other Departments and institutes, with studies of dendrochronology, dendroclimatology, ESR dating, and plant physiology.

Visitors and visits

The Annual Reports (up to no. 44) of the Subdepartment contain sections on visitors to the Subdepartment and visits or activities of the members. These sections became very, perhaps very much, too lengthy and bloated towards the end, as did another section on acknowledgements of assistance. But in retrospect they do provide a mirror of the increasing activity in Quaternary research, made year by year, and as such are an unusually complete record of an interdisciplinary scientific activity as it developed.

Chapter 2

Teaching, reference collections, databases, research

Teaching

Teaching in the subject started long before the establishment of the Subdepartment in 1948. A course on ' Peat stratigraphy and pollen analysis' was given was given in the Botany School by Godwin from 1936/37 until he retired in 1968. Until 1966/67 the course was a special course available for all students interested in the subject. Later it became a part of the Natural Sciences Tripos Part II Botany course, and evolved to include palynology and palaeoecology until the Subdepartment was dissolved.

Other Part II Botany courses contributed to Quaternary research. A course on 'History of the British Flora' was started by Godwin in 1966/67 and continued thereafter, and in 1986/87 a course on 'Vegetation history of the World's main climatic regions' began. A course on 'Tertiary and Quaternary palaeobotany' was given from 1965/66 to 1970/71.

The subject also began to be taught in Part IB Botany of the Natural Science Tripos. From 1966/67 there were contributions to a course on 'Evolution and phytogeography', later developed to include phytogeography, the history of the British flora and palaeoecology, and also contributions to a course on 'Dynamics and physiology of World vegetation'.

In the Department of Geology, W.B.R.King gave a course of lectures on 'Quaternary stratigraphy' in Part II of the Natural Sciences Tripos while he was Woodwardian Professor, from 1943 – 1955. After his retirement, a special course notable for its interdisciplinary approach to the Quaternary was started in 1955/56. This was entitled 'The Quaternary Period', was held in the Department of Geology, and was given by Dr R.W.Hey of the Department and members of the Subdepartment. The course attracted students from many Departments. The number of lecturers in the course increased as the subject expanded. In 1986/87 the course was transferred to the Geography Department, where it became an important Part II option, dividing into 'Quaternary environments' and 'Quaternary chronology' sections, as well as retaining the interest of a wide variety of students, including M.Phil. students.

Although occasional lectures on Quaternary subjects, particularly chronology, had been given before by members of the Sub-department in the Department of Archaeology, in 1968/69 a specific interdisciplinary course for this Department was started. This was entitled 'Man's Quaternary Environment' with both lectures and also practical classes on such topics as sediments, pollen analysis and dating. The course was given by members of the Subdepartment and of the Department of Zoology. In 1986/87 the course expanded to 'Environmental archaeology' and later evolved to 'Bioarchaeology'. Alongside this course, lectures and practicals were also regularly given by members of the Subdepartment on chronology and dating, with occasional subjects such as magnetic susceptibility scanning.

Lectures or practicals were also contributed from the late 1960s onwards to Pt II Geology (later Earth Sciences) by members of the Subdepartment, on isotopes in geology, sedimentology, physical and chemical evolution of the Earth, palaeoceanography amd micropalaeontology. From 1969/70 practical classes in Quaternary techniques for Pt II Geography students and others were held, and later lectures were contributed to the Geography Department course on 'The Quaternary of Britain'. Lectures were also later contributed to a Pt II General course on 'Ecology and the impact of human activity on natural communities'. From 1975/76 members of the Zoology Department associated with the Subdepartment (A.J.Stuart, A.M.Lister) expanded Quaternary teaching into other Departments with lectures on Pleistocene faunal history and evolution.

Apart from regular field trips associated with these various courses, which emphasised the importance of field experience in the subject, courses were also organised from time to time for both internal and external students. These involved lectures, field work and laboratory techniques for sediment description, identification of organic remains, and dating techniques. The courses reflect the increase in activity and widening of interest in Quaternary research as time went on.

In 1952 such a course was run in Cambridge, with field excursions to the Fenland and Cambridge area. Identification tasks included plant remains and fresh-water molluscs. Also in 1952, D.Walker led a field trip to sites of varied interest in the north of England. In 1952/53 members of the Quaternary Discussion Group held a field excursion visiting the interglacial site at Hoxne and sites in the Breckland with exposures of glacial and periglacial deposits. The participants included the senior geologists S.E.Hollingworth and O.T.Jones, and the Breckland ecologist A.S.Watt, a reflection of the wider interests Quaternary research was stimulating. In 1955/56 Godwin ran a laboratory and field course for all-comers, attracting 22 undergraduates, research students and staff members from 11 Universities in Britain and Ireland, the Inspectorate of Ancient Monuments for Scotland and the Macaulay Institute in Aberdeen. In 1967/68 a similar course, attracting a similar wide-ranging group of 18 participants was held in Cambridge and the Preston Montfort Centre of the Field Studies Council. In 1968/69 a course was held by D.G.Wilson on environmental archaeology for London University students, and in 1981/82 and 1983/4 courses on biogenic sediments and peat stratigraphy were run at the request of the Soil Survey of England and Wales for their members. In 1983/4 a course on pollen analysis was run for 14 members of the Quaternary Research Association.

The expansion of teaching during the life of the Subdepartment reflects the growing significance of Quaternary research for biologists, geologists, geographers and archaeologists. The interdisciplinary structure of the Subdepartment enabled the members to respond to the need to teach to students of various disciplines. The University recognised this need by the appointment of academic staff who were able to combine their research activity with teaching effectively. But such appontments were not easily obtained. Competition with established Departments for posts was acute, with interdisciplinary subjects liable to fall between the cracks.

There are clearly times when the importance of such interdisciplinary subjects as Quaternary research must be recognised by wider support, and it was fortunate that the development of the Subdepartment was so recognised from 1948, very largely as a result of the timely proposals of Godwin.

Colloquia

From 1950 regular colloquia were held for the discussion of problems of Quaternary history – trhe Quaternary Discussion Group. These evening meetings were well-attended by research students and staff from many Departments in the University and from institutions further afield. The colloquia were given by researchers within various Departments and by visitors, and covered the very wide variety of topics associated with Quaternary research, shown by the lists in the Annual Reports from 1952. The meetings performed an invaluable service in bringing together Quaternary researchers for informal discussion of the developments which were occurring in biological, geological, archaeological and geographical aspects of the subject. The lists of topics show that no opportunity was lost to engage visitors in contributing to meetings, with many prominent Quaternary scientists leading discussions, in addition to research students and staff reporting on their work. The colloquia were an expression of the need for the Subdepartment to bring together the diverse disciplines involved at a time when the necessity for a multi-disciplinary approach was becoming more and more obvious as the subject expanded.

Later, from 1966 onwards, short informal discussion meetings were from time to time held at 'lunch clubs', which still furthered the exchange of developments.

Reference collections

The formation of reference collections for pollen and macroscopic plant remains was greatly facilitated by the very large and well-curated Herbarium of the Botany School, together with taxonomic advice of the Curators and their staff. Both pollen and seeds and fruits from herbarium sheets were accumulated in the reference collections, with a record kept of the of the source herbarium sheet of seeds and fruits from 1972 (QSD collection) and of pollen from 1974. The collections required care and maintenance, which became more difficult, in terms of staff time available, as they expanded in later years. They were used not only by members of the Subdepartment but by many visiting researchers, and were probably the most comprehensive in the country.

Macroscopic plant remains

In the 1930s M.H.Clifford built up a collection of about 350 species of seeds and fruits and other plant remains (mosses, leaves, rootlets, rhizomes) in connection with his research on Fenland organic sediments (Plates 19, 20). Most were species involved in peat formation. The collection was constantly enlarged as research expanded into floras obtained from temperate stage sites, cold stage sites, and archaeological sites, with contributions by A.P.Conolly, J.Allison and F.G.Bell amongst many others. The collection was frequently consulted by visiting researchers with problems of identification of macroscopic plant remains, including biologists and archaeologists, as well as zoologists researching bird diets (AR 19).

Pollen and spores

The pollen reference collection (Andrew 1970) was started in the 1930s, and expanded greatly in the late 1940s when R.Andrew took up her post as technician in charge of the collection (Plates 21, 22). At that time there were research developments involving late-glacial sediments and Neolithic land use, both requiring extensive knowledge of non-tree pollen taxa (well-recorded on the continent), and the reference collection was enlarged accordingly. Enlargement continued throuthout the life of the Subdepartment, as recorded in the Annual Reports. R.Andrew kept 'A Practical Pollen Primer' throughout her time in the Subdepartment, recording brief descriptions and with thumbnail sketches of pollen and spore taxa, arranged on the basis of pollen morphology. This was of great use to research students and visitors, leading them to the reference slides which were appropriate to identification. In 1984 it was published by the Quaternary Research Association (Andrew 1984). The taxonomy was based on J.E.Dandy's *List of British Vascular Plants* (1958). The pollen morphological descriptions used were famous for their homely and vivid descriptive terms, which to beginner and experienced alike were immediately recognisable. But they were not considered 'politically correct', or better perhaps, scientifically correct, by the experts of the various schools of nomenclature. In 1986 the collection was reclassified according to the *Flora Europaea* (Tutin *et al.* 1964-1980), since there was expansion of research on continental sites in Greece and Scandinavia. As slides were prepared, sets were made and sold to augment a fund for support of pollen analysis. Pollen reference collections require a great deal of curation as slides age and are replaced or added, more so than macro collections. This presented a problem in the later years of the Subdepartment.

Databases

Godwin began a database for Quaternary plant records in 1942, using a perforated card system, the card illustrated by Godwin (1956). The card included information on age, pollen zonation, part identified, geological and archaeological relations and many other items for each plant record. Godwin started by incorporating the records in Clement Reid's 1899 book and continued to add records until to 1950 or shortly thereafter. The data and their interpretation were published in Godwin's

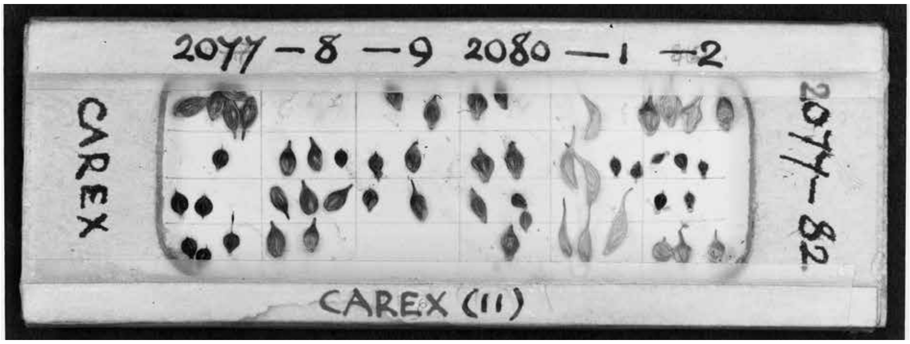


Plate 19. Slide of reference material for identification of macroscopic plant remains: fruits and nuts of Carex spp. Each column contains examples of a single species identified by a number, in this case the London Catalogue number (photo F.T.N Elborn).

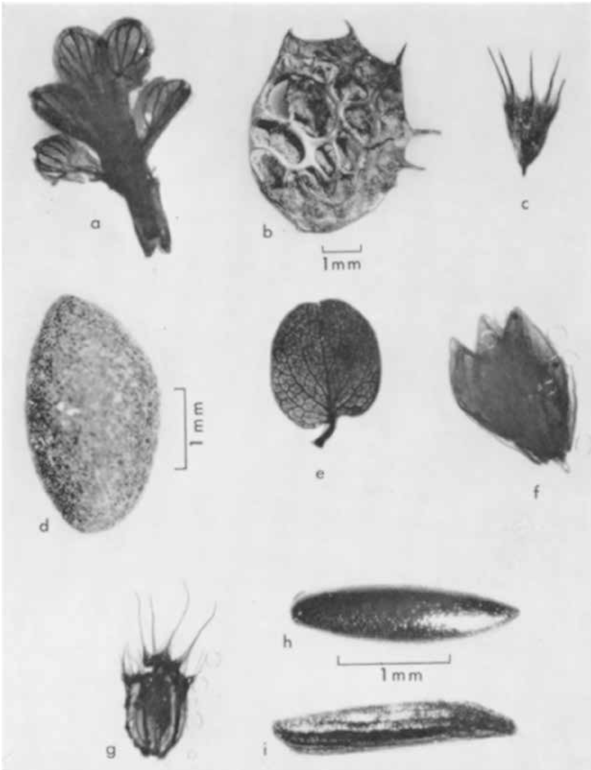


Plate 20. Plant macroscopic remains: a, Saxifraga oppositifolia, leafy shoot ; b, Onobrychis vicifolia, pod; c, Armeria maritima, calyx; d, Naias marina, fruit; e, Salix polaris, leaf; f, Helianthemum canum, capsule; g, Scabiosa columbaria, fruit; h, Naias flexilis, fruit; i, Naias minor, fruit; a,b,c,e,f,g from Devensian deposits at Earith, Huntingdonshire (photos F.G.Bell, all to same scale); d,h,i from interglacial deposits at Bobbitshole, Ipswich, Suffolk. (photos R.G.West)

'The History of the British Flora' subtitled 'A Factual Basis for Phytogeography' (Godwin 1956). The book was a landmark in the history of Quaternary research in the British Isles, and gave a firm foundation for the development of the subject. With the great increase of plant records and of the knowledge of their associated geological context in the next 20 years, Godwin decided to write a second edition of the book when he retired in 1968. Information was added to the database up 1970. A new card which could be used with an ICL group-select sorter was designed with the advice of F.H.Perring, then at the Biological Records Centre of

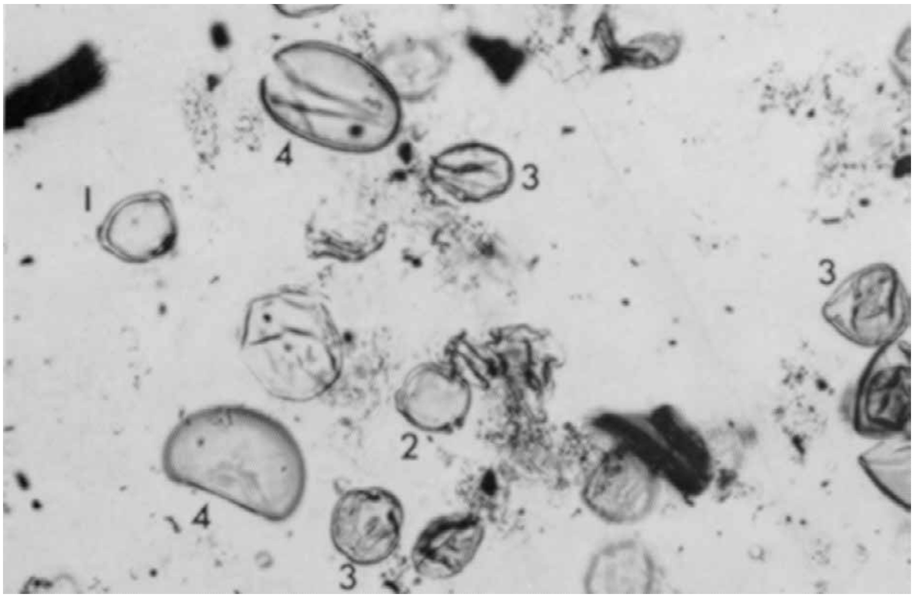


Plate 21. Pollen preparation from a late Holocene peat in Scotland, x 260: 1, 3-pored grain of Corylus; 2, 3-pored (septate) grain of Betula; 3, 3-furrowed grain of Quercus; 4, Filicales spores (photo R.G.West).

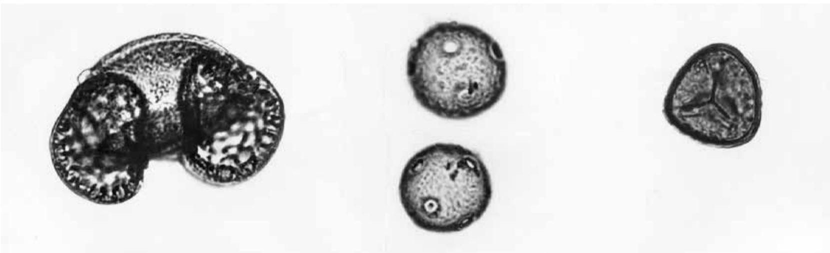


Plate 22. Pollen grains of left, Pinus syvestris (x 480); the central body and two wings is found in many species of conifer. centre, Plantago lanceolata (plantain)(x 480); the grains have a verrucate surface and bordered pits scattered on the surface; the plant is frequently associated with land clearance phases in the later part of the Holocene. right, spore of Sphagnum recurvum (x 400) with the trilete scar often found in lower plant spores (photos R.G.West).

the Nature Conservancy. The design and use of this card were described by Deacon (1972). There were about 60,000 cards and 550 site cards in the database. This second edition was published in 1975 (Godwin 1975) and reprinted in 1984. In addition to the vast increase of records, associated with advances in identification, stratigraphy, archaeology and climatic interpretation, there were soon developments in interpretation based on the new data, such as the work on the immigration of *Corylus* by Deacon (1973) and on numerical analysis of the past and present flora of the British Isles by Birks, Deacon & Peglar (1975). The database was successful in providing much information to enquirers about the history of taxa, especially for those writing accounts for the 'Biological Flora of the British Isles'.

The production of the 1975 database was made possible by grant-in-aid from N.E.R.C. After that time, there was not the staff available in the Subdepartment to devote time to updating the database as well as to their normal duties in support of research and teaching. However, in 1991 further N.E.R.C. support was given in order to compile a database for Quaternary cold stage records of pollen and macroscopic plant remains from the British Isles up to the end of 1995. These had greatly increased in number and stratigraphical and taphonomical clarity since the early 1970s, an increase justifying separate treatment. The resulting electronic database was used to interpret the nature and significance of cold stage floras, with publication in 2000 (West 2000a).

J.H.Dickson compiled a database for Quaternary bryophytes of the British Isles, starting in 1959/60, and relating the records to their associated geology and archaeology (Dickson 1973). The data enabled him to consider bryophyte associations through to the present-day, and discuss the formation of present bryophyte distributions.

A database for radiocarbon dates was started in 1972/73, with the aim of providing a chronological framework for major pollen stratigraphic events in Britain and northern Europe. Extraction of dates from *Radiocarbon* up to Vol. 17 (1975) was completed, but in 1976/77 ceased because of lack of staff time. Compilations of radiocarbon dates have subsequently been published elswhere.

A wider recognition of the significance of such databases as these was made in the 1990s, when a Europe-wide compilation of pollen data was started on the continent, grant-aided by the E.C. This is the European Pollen Database, covering data from the present and previous temperate stages, with the aim of assisting palaeoclimatic reconstructions.

Research

'The primary object of research in the Subdepartment is the elucidation of various aspects of the glacial and post-glacial prehistoric period, and particularly the co-ordination of geological, botanical, zoological, and archaeological evidence of conditions in this period. It has been natural and economical to work most intensively in the field of pollen-analysis which has already been developed, and to work outwards from palaeobotanical or palaeoecological investigations. As opportunity offers other lines of approach will be taken up.'

So wrote Godwin in the preamble to the first report of the Subdepartment of 1948-1950. The survey of research which follows shows the consequence of this philosophy.

The aim is to present a brief outline of the research activities of the Subdepartment as they developed. Details of the work and of the resulting publications are to be found in the Annual Reports, each covering an academic year (except the first, which covers two years). The Annual Report number references given (AR …) are to accounts of the particular research in Annual Reports or to their bibliographies. A small number of literature references are given where it is thought useful. The list of research dissertations in Appendix A also provides a guide to the subject areas developed. Quaternary research often requires longer term investigations than is usual in laboratory sciences. The work is time consuming and, if co-operation is involved, as is often the case with multi-disciplinary science, completion times can be lengthy. So the successive Annual Reports will often refer to continuing research projects over quite a period of time.

The total numbers of publications in the Annual Reports (Figure 2a), can be dissected into sub-totals relating to different disciplines within Quaternary research. Such division is made difficult by the interdisciplinary nature of much of the research reported, especially in the later years as collaboration increased. But the attempt has been made, taking the criterion of the major interest involved. Figures 2b to 2m give the breakdowns resulting, following the categories used in the descriptions of research. They show clearly the trends in research.

The plethora of information in the Annual Reports has meant much culling of the reports and selection of items. Usually principal investigators only are mentioned. The subject sections may overlap, a result of the inter-disciplinary and co-operative nature of the research. There is relatively more detail of the research of the earlier years of the Subdepartment. The later reports include Quaternary research carried out by members of other Departments, often in collaboration with the Subdepartment, a change brought about by the increasing interest in Quaternary research as the Subdepartment developed and funding availability increased.

The subjects start with vegetational history, the field Godwin named as the starting point in the quotation above, followed by a series of heads which I hope cover the many other fields of Quaternary research which came to be involved.

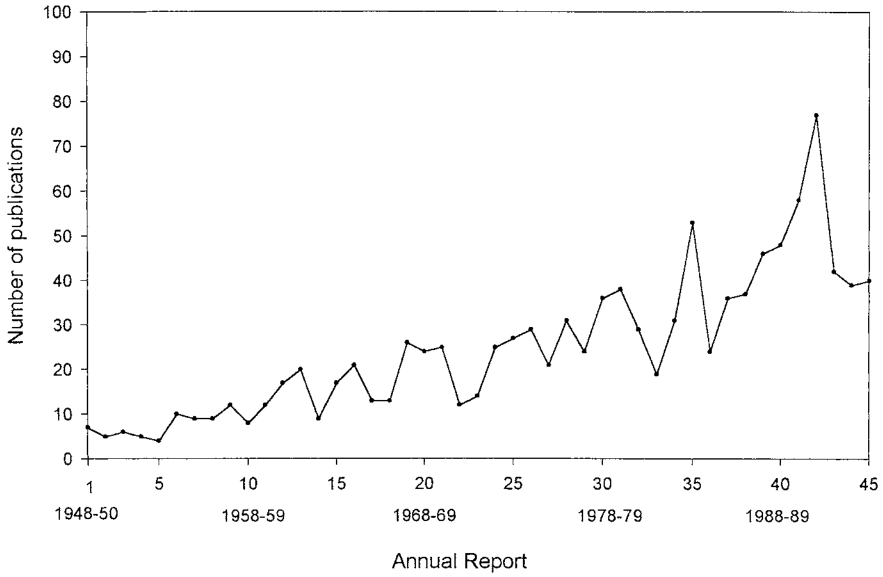


Figure 2a. Total number of publications recorded in Annual Reports 1948-1994.

Chapter 3

Research: vegetational history, including palaeoecology and palaeolimnology

As underlined in the preamble to the first of the Reports, pollen analysis was taken to be the entrance to the development of the Subdepartment's research, and this first group of subjects to be considered are united by their association with pollen analysis, and by extension, palaeoecology and palaeolimnology. Three separate areas of research are considered: the vegetational history of the Devensian late-glacial and the Flandrian in this chapter, and of pre-Flandrian temperate stages and of cold stages in the next two chapters.

Vegetational history: Devensian late-glacial and Flandrian

(publication numbers, Figure 2b)

The work of the Fenland Research Committee, as we have seen, concentrated on Flandrian vegetational history, sea-level change and archaeology. These subjects were the foundation from which the research evolved when the Subdepartment was founded, together with the beginnings of the investigation of the Devensian late-glacial and of interglacial (temperate stage) deposits. With the advent of the Subdepartment, the establishment of Assistant-in-Research posts and increasing support available for research studentships, particularly from the Nature Conservancy and the D.S.I.R., there was a rapid expansion of research in the first years of the Subdepartment. The research students undertook projects which involved all the aims of the Fenland Research Committee, vegetational history (late-glacial and Flandrian), sea level change and archaeology, plus the geology of the late-glacial. This was in Godwin's tradition of the broad approach in Quaternary research, hardly possible nowadays. I suppose the situation is analogous to the breadth of a scientist's approach to a subject in the 19th century, compared with the later specialisation, as occurred in the Subdepartment. The development of the research is summarised in the first section, with subsequent sections concerning aspects of palaeoecology and palaeolimnology.

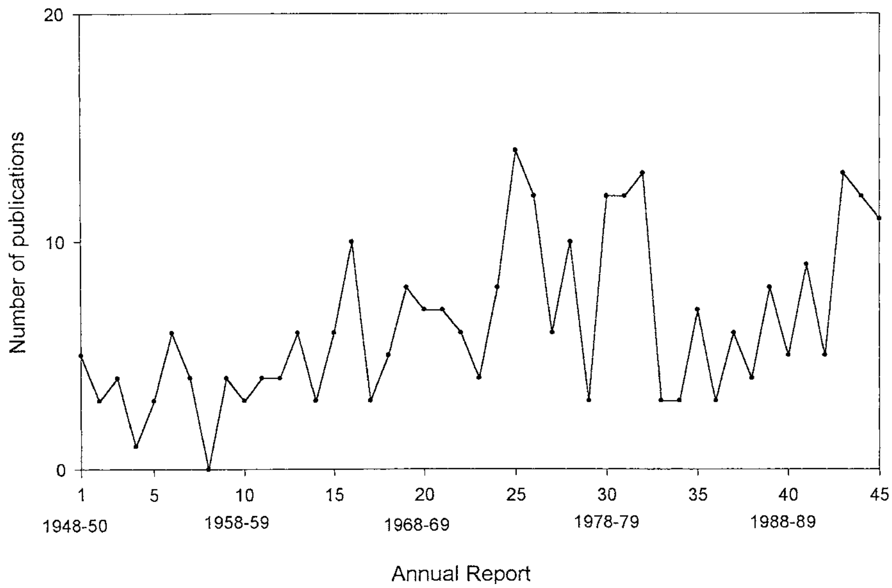


Figure 2b. Pollen analysis, late- and post-glacial vegetational history, palaeoecology, palaeolimnology.

Development of Devensian late-glacial and Flandrian research

By the late 1940s pollen analysis had been applied to many sites spread thinly through England and Wales (apart from the detailed work in the Fenland; see Pt I Chapter 5). Research in the Subdepartment became more focused through the projects of research students in particular areas. A wide coverage of sites achieved in the course of time, especially in the areas of glaciated terrain with kettle-hole lakes and in coastal regions where relative sea level rise resulted in organic sedimentation. Sites well inland and outside the mrgin of the Late Devensian glaciation were rarer, particularly so in the Midlands of England.

D.Walker, on being appointed Assistant-in-Research in 1949, undertook research on late-glacial and Flandrian sites in the north of England. He contributed palaeoecology of the late-glacial and Flandrian to the Mesolithic excavations at Star Carr, Lake Pickering (AR 1,2) and developed a research project in the Cumberland lowland, involving vegetational history of lake and mire sites, sea level change, archaeology and late Quaternary geology. In the early 1950s A.G.Smith undertook similar wide-ranging research in coastal districts of northern England, including the lower Trent area in the east and lowland Lancashire, and J.J.Donner investigated late-glacial and Flandrian vegetational history and the relation to late Devensian retreat stages in Scotland. In Wales, the site at Cwm Idwal in Snowdonia was investigated (AR 5).

In southern England, S.C.Seagrief investigated sites in Hampshire and Surrey. Meanwhile Godwin's work on the Somerset Levels, in co-operation with archaeologists, continued, paying attention the features of mire stratigraphy and their significance for archaeology and climatic change.

In the late 1950s and 60s, there were research projects on late Quaternary geology and vegetation in north Wales (AR 6, B.Seddon), on the Whittlesey Mere region of Fenland (AR 10, Vishnu-Mittre), on late-glacial and Flandrian in south Westmorland (AR 8, F.Oldfield), on post-Neolithic vegetational history in Britain (AR 10, J.Turner), which involved many mire sites in northern Britain and Wales, on late-glacial and Flandrian vegetational history in Scotland, including Orkney (AR 13, 14, N.T.Moar) and on the late-glacial and Flandrian of Blelham Tarn in the Lake District (AR 14, G.H.Evans).

A programme of obtaining detailed pollen diagrams with close radiocarbon dating was started in the mid 1960s in order to clarify the problem of synchroneity of pollen zone boundaries (AR 17, F.A.Hibbert). In the late 1960s and subsequently, research in Scotland was greatly developed, first with studies of Skye (H.J.B.Birks) and of 'buried forests' in the peat deposits of south-west Scotland (H.H.Birks), which they both in later years extended very widely in Scotland. In conjunction with this work, vegetational history studies were also made in Argyll (AR 24, L.Rymer), Eastern Highlands (AR 26, B.Huntley), Skye and north-west Scotland (AR 26, W.Williams; AR 30, P.Kerslake). The vegetational histories of the Western and Northern Isles were also studied (AR 38, J.Fossitt, K.D.Bennett; AR 42, J.Bunting).

In England, research projects were extended to the late-glacial and Flandrian vegetational history of Cornwall (AR 23, A.P.Brown), the Shropshire Meres (AR 25, P.Beales), the lower Thames estuary (AR 26, R.J.N.Devoy), East Anglia in the Waveney valley (AR 31, A.Alderton) and to the meres (AR 31, K.D.Bennett), and to north Wales (AR 30).

The academic and assistant staff of the Subdepartment were all involved in aspects of these researches. D.M.Churchill was involved with vegetational history related to sea level change and archaeology, J.H.Dickson with the bryophyte floras, F.A.Hibbert with late-glacial and Flandrian vegetational history and pollen zone boundaries, H.J.B.Birks with vegetational history of Scotland and K.D.Bennett with tree population studies of the Flandrian. Pollen analyses and macro analyses associated with the projects were contributed by C.A.Lambert (Dickson), M.E.Pettit, S.M.Peglar and S.Boreham, who also maintained and enlarged the reference collections essential for the research.

The publication of the British Ecological Society's Symposium on 'Quaternary Plant Ecology' held in 1972 in Cambridge (Birks & West 1973), with many contributionbs by members of the Subdepartment, epitomises the many developments in the subject since the founding of the Subdepartment. Likewise, the publication of the second edition of Godwin's 'History of the British Flora' in 1975 reflects the accumulation of records and the improvements in interpretation and chronology which had occurred by that time.

Zonation

Von Post (1946) considered that 'pollen statistics was designed mainly to serve as a means of determining geological time'. Thus pollen zones were used as a basis for dividing post-glacial time by the pioneers in Scandinavia. In Britain, Godwin

(1940, 1956) described a similar series of zones, enabling preliminary correlations of vegetational history across north-west Europe. Questions of synchroneity of pollen zones across a region had always been a matter of debate, and when radiocarbon dating was applied to Devensian late-glacial and Flandrian sediments, it soon became clear that this method would replace the use of pollen zones as a basis for chronology and correlation. At the same time, rules of stratigraphical nomenclature began to be applied to pollen assemblages (West 1970), leading to the subdivision of pollen diagrams into local or regional pollen assemblage biozones, entities which could be compared between sites and dated by radiocarbon, so facilitating a vision of varying vegetation across a region at particular times. The first detailed application of radiocarbon dating to a 'standard' diagram was at Scaleby Moss, Cumbria (Godwin, Walker & Willis 1957), where a sequence of dates from pollen zone boundaries was determined. Thereafter, as well as the dating of pollen assemblage zones from studied sites becoming a normality, a programme of research by F.A.Hibbert and V.R.Switsur to obtain dates from long pollen diagrams in various parts of the country began in the late 1960s (AR 17). The distinction of pollen assemblages using methods of numerical analysis was later developed by H.J.B.Birks (AR 23, 28) and K.D.Bennett (AR 45).

Peat stratigraphy

Godwin's research on peat stratigraphy, climatic change and archaeology continued in the early years of the Subdepartment (AR 1, 12). D.Walker investigated the relation between peat stratigrasphy and surface ecology of Irish raised bogs, in search of the realities of the 'regeneration complex ' of surface patterns of vegetation (AR 11). Recurrence surfaces in raised bogs were studied by J.Turner (AR 11, 13) and H.J.B.Birks (AR 16). Levels with tree remains in peat sequences in northern Britain , as described by F.J.Lewis in the early 1900s, were studied in Scotland by H.H.Birks (AR 17) and later K.D. Bennett in Shetland (AR 37), and H.F.Lamb in Ireland (AR 34). here correlation with pollen diagrams and radiocarbon chronology led to re-evaluation of their significance.

Woodland history

With the development of historical ecology in the late 1960s by O.Rackham, in particular the history of woodland, pollen analysis came to be applied to the subject by the investigation of sediment sequences within or adjacent to present woodland. L.Rymer made detailed analyses of the recent history of Knapdale, Argyll (AR 24), and H.J.B.Birks of sediments in the 'ancient woodland' of Bradfield Woods, Suffolk (AR 25). He extended the programme, via small basins and mor humus horizons, to include local woodland history in the Lake District (AR 26, AR 30) and East Anglia (AR 29). Woodland history in East Anglia was studied by R.H.W.Bradshaw (AR 27), S.M.Peglar (AR 30), and C.Lees (AR 39), and in north Wales by M.E.Edwards (AR 32). The history of wooded islands in Scottish lochs was studies by P.D.Kerslake (AR 31).

Contributions to biogeography

The refugial status of upland areas was tested by pollen analysis at Cwm Idwal in Snowdonia (AR 5, Godwin), Teesdale (AR 18, Hibbert) and the Scottish Highlands (AR 26, Huntley), all areas showing survival of late-glacial/early Flandrian plants of open communities through the Flandrian. With the compilation of the database for fossil records completed in the early 1970s (see section on Databases), it was possible to reconstruct aspects of vegetational history: the history of the *Corylus* rise (AR 24, Deacon), isopoll maps for the British Isles at 5000 BP (AR 24, Birks, Deacon & Peglar). The second edition of Godwin's History of the British Flora (1975) treated the biogeography of the British Isles and the British flora in great detail, offering an authoritative view of the fossil evidence obtained by that time. With later accumulated records, isopoll maps were produced for Scotland of major pollen types in the Flandrian (AR 28, H.H.Birks), and pollen maps for Europe, 0 –13000 years ago, were begun in 1977 (AR 29, Huntley, Birks) and completed in 1981 (AR 32)(Huntley & Birks 1983). With progress in research in southern Europe, Quaternary refugia for north European trees came to be considered (AR 40, Bennett, Tzedakis, Willis). The biogeography of bryophytes was studied in detail by J.H.Dickson (AR 11), based on his new evidence from the Devensian late-glacial and Flandrian.

Palaeolimnology

Palaeolimnology of late-glacial and Flandrian sediments was developed at the F. B.A.'s Windermere laboratory. In the Subdepartment there was co-operation with limnologists as well as 'in-house' research from time. D.Walker co-operated with F.E. Round (Bristol) to relate pollen zones to diatom zones in the late-glacial and Flandrian sediments at Kentmere (AR 8). Later, G.H.Evans studied diatom succession in relation to pollen diagrams at Blelham Tarn and an adjacent kettle-hole in the Lake District (AR 14). P.W.Beales carried out a palaeolimnology study of late-glacial and Flandrian sediments of Shropshire meres, analysising pollen and Cladocera to interpret lake development and anthropogenic effects (AR 26). Diatom analyses were used by R.J.Devoy (AR 27) and A.M.Alderton (AR 31) in their studies of the sediments of the lower Thames and Waveney valley respectively. H.H.Birks co-operated with the F.B.A. researchers in investigating sediments of Loch Dungeon, Loch Maree and Loch Leven in Scotland (AR 19, 20,21).

Marine palynology

A project on the the palynology of deep-sea sediments in the north-east Mediterranean was carried out C.D.Bates, with the aim of relating the marine palynology to terrestrial records of the region and to oxygen isotope stratigraphy (AR 29), and investigating factors affecting the constitution of the marine assemblages, such as fluvial transport and marine sedimentation.

Pollen dispersal and vegetation; surface samples

The relation of pollen rain to the source vegetation has naturally always been a prime interest to pollen analysts, with many studies of the relation within many vegetation types. In the Subdepartment, such studies started with particular problems of interpretation in mind. In 1956 the interest of pollen of *Helianthemum* in Devensian late-glacial sediments and of M.C.F.Proctor's interest in the taxonomy and ecology of *Helianthemum* species led to a survey of pollen in surface samples in localities in Britain, Ireland and the Continent where *Helianthemum* still persists (AR 8). From 1961/2 J.Turner began studying surface samples relating to arable or pastoral agricultural practices and to dispersal distances of tree pollen in connection with her research on forest clearances in Neolithic and post-Neolithic times (AR 14). A wider study started in 1967 when R.M.Peck began a research project on pollen dispersal by air and water in a small catchment with reservoirs at Osmotherly on the edge of the North York Moors, using Tauber traps in air and water, with associated cores in reservoir sediments, measurements of atmospheric and stream activity and vegetation survey (AR 20). From 1969 R.Sims carried out further analyses of surface samples in East Anglia relating to agricultural practice to assist interpretation of evidence of post-glacial forest clearance (AR 21).

Many studies were carried out on the relation between vegetation and pollen rain in various places and for particular purposes: Iceland, by L.Rymer (AR 22); Outer Hebrides, by R.G.West and R.Randall (AR 21); Skye by H.J.B.Birks (AR 18) and I.C.Prentice (AR 24), other areas of Scotland by H.J.B. Birks, H.H.Birks (AR 25,26), B.Huntley (AR 25) and K.D.Bennett (AR 43); north-west Ireland by J.Fossitt (AR 42); north-west Europe, by I.C.Prentice (AR 26). R.H.W.Bradshaw analysed surface samples in relation to woodland history in eastern and southern Britain (AR 27). These studies led to an increased understanding of the problems of interpreting pollen spectra in terms of source plants and vegetation, in both forested and more treeless areas. They also came to assist interpretation of vegetational change in terms of environmental change.

Analysis of recent assemblages of plant macro remains were also made with similar aims: in Minnesota lakes by H.H.Birks (AR 24); in Alaska tundra floodplains by R.G.West (AR 41).

Numerical analysis, software development

In the late 1960s H.J.B.Birks began to apply techniques of numerical analysis to problems of interpreting fossil pollen assemblages by comparing them to modern pollen spectra. Comparisons were made between montane pollen spectra in Scotland and fossil pollen assemblages. He expanded this approach very actively through the 1970s, with the co-operation of A.D.Gordon, B.Huntley and J.Line, developing many aspects of numerical analysis of palaeoecological data, including zonation of pollen diagrams, treatment of stratigraphical data from different sites and their comparison, surface pollen data analysis and the preparation of isopollen maps in the British Isles and in north-west Europe. Morphometric variations of macroscopic remains and pollen of various species were also investigated, demonstrating variation in time (*Menyanthes*) and also in space (*Picea abies* in Europe). In the mid-1970s I.C.Prentice carried out a detailed analytical study of spatial variations in modern pollen rain in Scotland and north-west Europe, a fundamental part of which involved numerical analysis. During this period computer programs were written and improved for the handling (presentation, analysis) of pollen analytical data (H.J.B.Birks, B.Huntley; POLLDATA). Later K.D.Bennett developed software for transferring pollen counts to a pocket computer and for a wide-ranging program (PSIMPOLL) for pollen-analytical data and deciding zonation methods.

Interpretations, techniques

Pollen analysis evolved as the methodology became more widely used and investigated. Developments in the Subdepartment reflected this, and certain of these are mentioned here. Distinctions between the sources of pollen in sediments were analysed: by recognition of reworked pollen (AR 9, late-glacial, West, Suggate); by analysis of different sedimentary components (AR 19, mosses within late-glacial sediment, Birks); by analysis of sediments of different origin but same age in nearby sites (AR 14, Blelham, Evans; AR 19, Loch Dungeon, H.Birks; AR 35, Norfolk, Heptinstall).

With the detailed application of radiocarbon dating to pollen diagrams, it became possible to improve greatly the interpretation of diagrams through the production of 'absolute pollen diagrams' giving a measure of pollen influx over time. Pennington & Bonny (1970) had applied the methodology, following Davis & Deevey (1964), to late-glacial sediments in the Lake District. Such investigations of pollen influx started to be made in different sedimentary basins (AR 23, northern England, Birks) and in tree population studies (AR 34, East Anglia, Bennett). Detailed analyses of sediments evolved as it became clear how they aided environmental interpretations and chronology, for example, charcoal (AR 40, 42), tephra (AR 43), chemical stratigraphy (AR 43) and magnetic susceptibility (AR 44). Preparation methods for clay-rich sediment were improved (AR 30, Bates, Coxon, Gibbard).

Pollen morphology and structure

(publication numbers, Figure 2c)

Pollen morphology was studied in detail by optical and electron microscopy. In the 1950s optical studies of Ericaceae pollen (F.Oldfield) and *Tilia* pollen (Vishnu-Mittre), and D.Walker and D.E.Bradley used a carbon replica technique for the e-m study of *Corylus* and *Myrica* pollen. E-m studies of *Tilia* pollen were made by C.Chambers. In the 1960s e-m facilities were installed in the Botany School and were used by H.Godwin, P.Echlin and R.T.Angold to study the ontogeny of pollen grains and the origin of the exine. In 1965 the potentialities of the Cambridge Instrument Company's Stereoscan e-m were tested on pollen grains of varying type and its use for studying pollen morphology clearly appreciated. The technique was later used for identification of Bryophyte spores by J.H.Dickson, and a

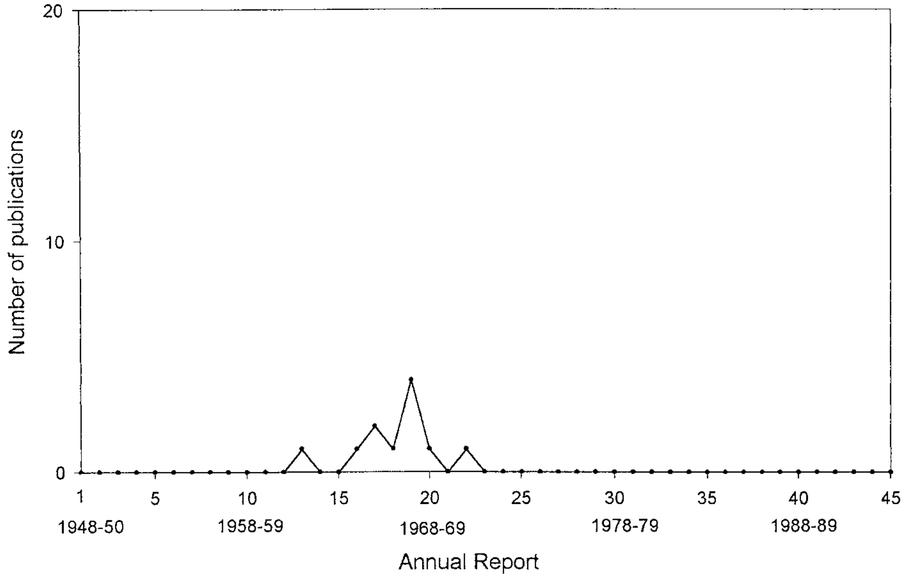


Figure 2c. Pollen structure and development.

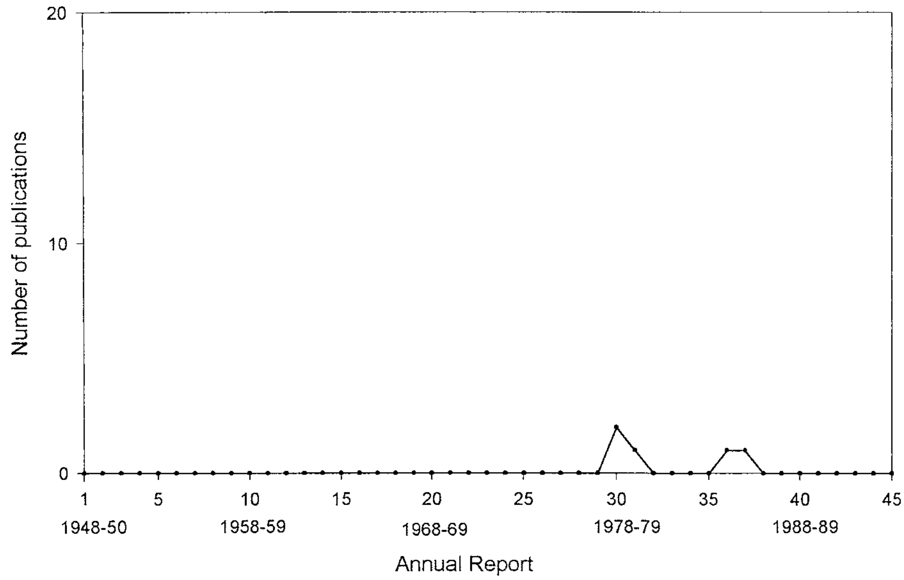


Figure 2d. Airborne spores.

library of photographs was started. Optical studies continued from time to time, sometimes in relation to taxonomic studies, as with the families Dipterocarpaceae (D.M.Churchill, P.Ashton) and Fagaceae (D.M.Churchill, P.Soepadmo). The installation of a comparison microscope with phase contrast in 1969 assisted with optical identification problems, and facilities for fluorescent microscopy were added in 1970, useful for obtaining distinctions between reworked and contemporary pollen and spores (AR 22).

In 1984 R.Andrew completed her *Practical Pollen Guide to the British Flora* (Andrew 1984). This was based on the reference collection she had accumulated, curated and used for identification since she came to the Botany School in the late 1940s, and reflected her long experience in pollen analysis.

Air spora

(publication numbers, Figure 2d)

In 1965/66 negotiations began to start a survey of daily atmospheric pollen and spore content on behalf of the local hospital board chest clinic, utilising the experience of pollen and spore trapping and dispersal in the Subdepartment. U.Allitt was appointed in 1967 to a research post to carry out the work. The aim was principally to assist clinical studies of hay fever and other allergies, but it also was related to palynological studies and to plant pathology research in the Department. Tauber traps and automatic volumetric spore traps were set up, and analyses started in early 1968, and daily counts were made from April onwards. Comparisons were made of the trapping powers of Hirst and Tauber traps, and of roofed and unroofed Tauber traps. The work complemented the studies of R.M. Peck on pollen dispersal in North Yorkshire. This work continued for many years, and as it did so a spore reference collection was accumulated. It was necessarily accompanied by many identification problems of the fungal spores trapped; the Commonwealth Mycological Institute assisted with these. This led in 1974 to the commencement of an atlas of airborne spores, work supported by the A.R.C.

Applications with relevance to fauna

Pollen and macro analysis of sediments containing molluscs enabled a correlation of vegetational and mollusc history, as at Apethorpe, Northants (AR 11, late-glacial and Flandrian), and in tufas in the south of England and elsewhere (e.g. AR 11, 27, 32), and a site showing the *Ulmus* decline in Oxfordshire (AR 42).

Applications with relevance to archaeology

A general account of co-operation with archaeologists is given in a later section. Here the palaeobotanical contribution in the Flandrian is considered separately. Apart from trying to satisfy the many and regular requests for identification of plant remains from archaeological sites, the Subdepartment contributed much palaeobotanical analysis, and environmental and dating evidence to many archaeological projects. Investigations of the early Flandrian Mesolithic site of Star Carr (AR 2 (and later AR 43)) led the way and showed the advantages of such co-operation. Later, the palaeobotany of further Mesolithic sites was studied (Stump Cross, AR 8; Thatcham, AR 12). In the tradition of Iversen's 'landnam' expositions, pollen-analytical research was carried out at many sites, in sediment sequences of both raised bogs and lakes. In the former, J.Turner carried out detailed studies of vegetational changes accompanying forest clearances in the Neolithic and later, in western and northern Britain. The work distinguished temporary and permanent episodes of clearance, and also pastoral/arable practices (AR 10, 15). The distinctions were supported by studies of surface samples related to dispersal of pollen from trees and agricultural practices. The history of forest clearances in northern England was investigated in similar detail by D.Walker (AR 11). In East Anglia, lake sediments were the source of similar information, at Old Buckenham Mere (AR 15), further investigations at Hockham Mere (AR 23), Diss Mere (AR 33), Quidenham Mere (AR 37). The variety of site conditions made comparisons of clearance histories possible.

Regional palaeobotanical studies in association with archaeological research were continued in the Somerset Levels (trackways, AR 18; Glastonbury Lake Village, AR 35) and in the Fenland (AR 37), mainly with a view of providing the environmental detail, the chronological importance of pollen analysis being replaced by radiocarbon dating by this time.

The identification of macroscopic plant remains from archaeological sites continued an important part of the work of the Subdepartment, as at Ehenside Tarn, Cumbria (AR 8), Wingham, Kent (AR 8) and many other sites noted in the Annual Reports. D.G.Wilson made a special study of the palaeobotany of Iron Age/Romano-British sites and contributed many excavation reports (AR 20, 26, 28).

In the later years of the Subdepartment, the importance of the biological contribution to archaeology (archaeological sciences) became fully recognised throughout the country and separate units or institutes for specialised study were set up in many places, associated with archaeological excavations and laboratory research.

Applications with relevance to land/sea level change

A general account of this area of research is given in a later section. Here the palaeobotanical contribution in the Devensian late-glacial and Flandrian is considered separately. Many of the early research students of the Subdepartment were working in coastal areas where there was clear evidence of changes of land/sea level. Late-glacial marine clays in south-west Scotland were related to late-glacial pollen zones by J..J.Donner (AR 7). The presence of Flandrian marine or estuarine sediments overlain by organic sediments was recorded in detail and related to pollen zones in northern England in the Solway area (AR 7, D.Walker), and south-west Lancashire and the Lower Trent Valley (AR 3, A.G.Smith). The latter work aimed at comparing changes on the east and west coasts at the latitude of c. 54° N. Further coastal sites in southern England were investigated by Churchill (AR 13). Later, specific projects on the Thames estuary (AR 27), the Waveney Valley (AR 31) in East Anglia and the Fenland (AR 37) involved detailed palaeoecological work to interpret the relation between sea level change, vegetation and environment.

As with the archaeological connection, the study of Flandrian land/sea level changes became a subject in its own right in the later years of the Subdepartment, greatly aided by the development of radiocarbon dating, and became less central to the work of the Subdepartment.

Overseas research

In addition to the Subdepartment's work in the British Isles, research overseas on vegetational history started early and greatly expanded later as funding possibilities and international co-operation increased. The following is a selection of the areas of such research recorded in the Annual Reports: Atlantic coast of France (AR 9); W.Europe (AR 32); Greece (AR 34, 37, 44); Hungary (AR 42); North America (Wisconsin, AR 11; Minnesota, AR 22, 32; Alaska, AR 31; Ontario, AR 37, 43; Labrador, AR 30); Chile (AR 42); Peru (AR 44); Gough Island (AR 38).

Chapter 4

Research: vegetational history of pre-Flandrian temperate stages and cold stages

(publication numbers, Figure 2e)

Pre-Flandrian temperate stages

Clement Reid in his pioneer work in the 19th century recorded macroscopic plant remains from many temperate stage (interglacial) sediments in Britain. But while in northern Europe the vegetational history of temperate stages had begun to be described in detail in the 1920s and 30s, there was little progess in Britain. It was not that temperate stage sediments were lacking in Britain; many had been carefully recorded in the 19th century by Geological Survey officers (of whom Clement Reid was one) in their Memoirs, and also by local geologists. So that when the technique of pollen analysis came to be applied to temperate stage sediments in Britain, there was no shortage of sites. Thus a site in the Nar Valley, Norfolk, described by C.B. Rose in 1835 was successfully re-examined. Many of such sites were in the widely glaciated area of East Anglia and related to a known till or terrace, which was a distinct advantage to those researching in Cambridge.

As mentioned earlier, investigation of temperate stage sediments at Histon Road, Cambridge, began in the late 30s. Investigations at this site, together with investigations at Clacton-on-Sea, were described in the 1st Report (1948-1950). At this early stage the pattern of vegetational history indicated correlation of the Histon Road site with the Eemian (AR 1), and the Clacton site (AR 2) with the Mindel-Riss interglacial. In the first years of the Subdepartment such investigations were rapidly expanded by staff and research students in the Subdepartment, including the sites of Nechells, Birmingham (AR 4), Hoxne, Suffolk (AR 4), Cromer Forest Bed (AR 5)(Plates 23, 24), with investigations started by S.L.Duigan long after Clement Reid's work, Bobbitshole, Ipswich (AR 7), Selsey, Sussex (AR 8) and the Nar Valley (AR 7).

As these researches continued, a pattern of temperate stage vegetational history emerged which allowed comparison with that seen in northern Europe, and correlations were put forward of the three temperate stages recorded in East Anglia (Ipswichian, Hoxnian, Cromerian) with the Eemian, Holstein and Cromer interglacials of the continent described by Woldstedt (West 1955). Subsequently (AR 9) deep borehole samples from the Early Pleistocene marine sediments of

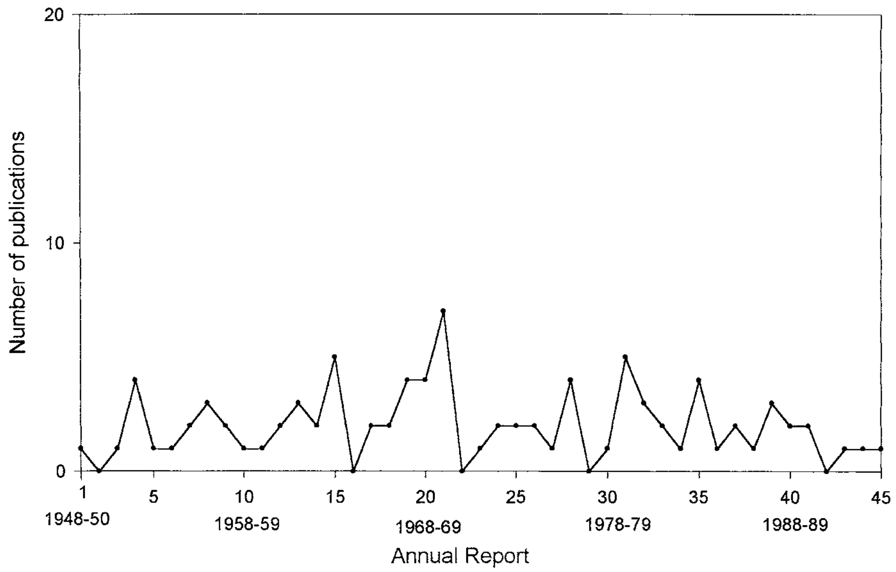


Figure 2e. Pre-Flandrian temperate stages, cold stages and associated geology.

the Crag at Ludham, Norfolk, provided pollen-analytical evidence (backed by foram analyses by B.M.Funnell) of Early Pleistocene climatic and vegetational history, adding further temperate (and cold) stages in pre-Cromerian time (AR 12) (West 1963). This succession was later expanded by pollen-analytical studies from boreholes (Stradbroke, AR 22) and open section (Bramerton, AR 29), and correlations were made with the Netherlands Early Pleistocene succession. These advances were summarised in the Geological Society's 'A correlation of Quaternary deposits in the British Isles' of 1973 (Mitchell *et al* 1973), where the temperate stages were based on type sites (see also Chapter 5).

In later years, knowledge of stratigraphy greatly increased, and as the complexity of climatic change became more apparent from the terrestrial and deep sea records, the simple scheme of these early days became much augmented, as shown by the Geological Society's 'Revised Correlation of Quaternary deposits of the British Isles' of 1999 (Bowen 1999).

These advances in Quaternary stratigraphy were thus largely based on pollen-analysis, allied to stratigraphies regional to the sites. Pollen analysis was playing the same part in stratigraphy as it was in the Flandrian in pre-radiocarbon days, providing a relative chronology. This use of pollen analysis as a prime contributor to stratigraphy was open to the criticism that other methods of determining stratigraphy must not be neglected (see discussion in West 1963). But the contribution of pollen-analysis to stratigraphy via the distinctions seen in temperate stage vegetational history, supported by stratigraphical evidence, did actually work to offer a foundation, with principles, for the development of Quaternary stratigraphy in Britain. It provided a relative chronology which could be applied to problems of sea level change, archaeology and terrace formation, for example.

Plate 23. Foreshore at West Runton, Norfolk, 1954. Organic sediments of the Cromerian Upper Freshwater Bed, overlain by the earliest glacial sediments of East Anglia (photo R.G.West).

Plate 24. Members of the Anglo-Dutch Excursion of 1954 on the coast at Bacton, Norfolk, discussing the Cromer Forest Bed. From the left: S.E.Hollingworth, I.M.van der Vlerk, A.J.Pannekoek, H.E.P.Spencer, S.L.Duigan, F.Florschütz (photo J.J.Donner).

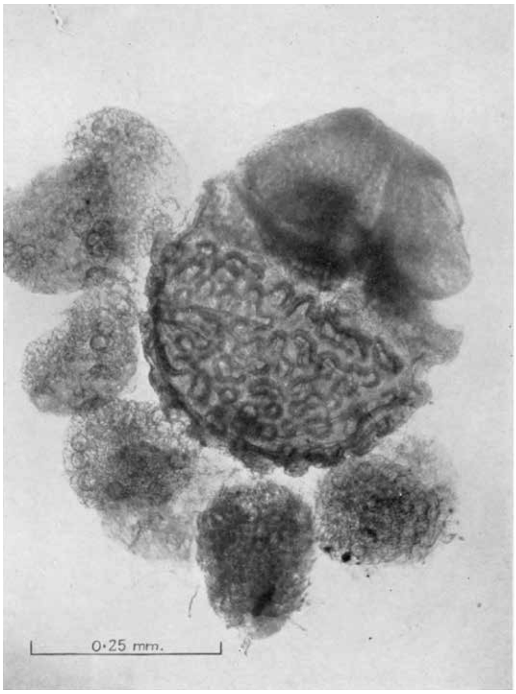


Plate 25. Megaspore of Azolla filiculoides with eight massulae attached, from the interglacial deposits at Hoxne, Suffolk (photo R.G.West).

Plate 26. D.G.Wilson on the Norfolk coast examining a section of the Cromer Forest Bed Series, with an arctic freshwater bed in a channel overlying Cromerian laminated tidal sediments and below till at Paston, Norfolk (photo R.G.West).

Long sequences of vegetational history through temperate stages were found to be more common in the older temperate stages. Examples are at Hoxne (Ho,AR 4), Marks Tey (Ho,AR 16), Ludham (Pre-Cromerian, AR 12), West Runton (Cr, AR 19), Beeston (Pa, AR 19), and Slade Oak (Ho, AR 31). The site of Beetley was remarkable for sequences through three temperate stages, two above one another (AR 42), older than the local Flandrian. Records from the Ipswichian (Last) temperate stage were found to be more fragmentary and mostly associated with fluviatile environments, except for the remarkable site at Wing (AR 28). By 1980 it was possible to summarise and characterise vegetational histories of successive temperate stages in East Anglia (AR 32, West 1980).

The detailed studies of temperate sediments led to an increase in the number of exotic taxa identified, e.g. at Hoxne (*Azolla filiculoides*, Plate 25*)*, Wing (*Brasenia, Bruckenthalia, Dulichium*, AR 28), Broomfield (*Euryale ferox,* AR 39), Swanton Morley (*Acer monspessulanum*, AR 22), Fugla Ness (*Daboecia*, AR 19), Cromer Forest Bed Series (Wilson 1973), e.g. Pakefield (*Corema*, AR 21), Gt Blakenham (*Azolla tegeliensis*, AR 42). Two other noteworthy pollen analytical results were the discovery of a high non-tree pollen phase in the Hoxnian temperate forest at a number of sites (Hoxne, AR 5; Barford, AR 23), and the association of high non-tree pollen episodes in the Ipswichian associated with large mammal presence, implying herbivore effects (Beetley, AR 19; Barrington, AR 26). Rather high non-tree pollen frequencies were also associated with the sediments containing the two elephant skeletons at Aveley in the Thames valley (AR 15).

The discovery of pollen in the Early Pleistocene marine sediments of the Ludham borehole (AR 9) led to many investigations of the East Anglian Crag at outcrop and in boreholes, which resulted in combination with the foram studies of B.M.Funnell in a formalisation of Early Pleistocene stratigraphy (Funnell & West 1977). Many sites and boreholes were analysed, in co-operation with B.M.Funnell (forams) and P.E.P.Norton (molluscs), including Ludham (AR 13), Easton Bavents (13), Sizewell (AR 13), 'Icenian' Crag sections (AR 24), Bramerton (AR 29), Covehithe (30), Aldeburgh and Sizewell (AR 36), Gt Blakenham (AR 42), Westleton Beds ((AR 45). Coralline Crag sediments were also analysed, with the pollen spectra compared with Brunssumian spectra from the Netherlands (AR 27).

The investigation of temperate stage palaeobotany soon came to involve co-operation with researchers involved with the palaeontology of the sediments, freshwater and marine, including B.M.Funnell (forams); B.W.Sparks, R.C.Preece (non-marine molluscs); P.E.P.Norton (marine molluscs); G.R.Coope (Coleoptera); A.J.Stuart, A.M.Lister (vertebrates); J.E.Robinson (ostracods); R.J.N.Devoy (diatoms). Such a multidisciplinary approach became the rule as time progressed, as at , *e.g.*, these sites: Wretton (AR 23), Bramerton (AR 29), Earnley (AR 31), Trafalgar Square (AR 32), Little Oakley (AR 40). But one result of this was the time it took to achieve publication of important sites with a multi-authored manuscript. The organisational background of the Subdepartment supported these often lengthy investigations.

Relative dating of temperate stage sea level changes was made possible by pollen analysis. Such changes were demonstrated in Ipswichian, Hoxnian, Cromerian and Pastonian temperate stages, including: Selsey (AR 10), Block Fen (33), Somersham (33), Wimblington (AR 45), March (45), Eye (38), Nar Valley (AR 7, 34), Peterborough (AR 22), Essex coastal sites (41), Earnley (31), West Runton (22, 31), Beeston (31). Relative dating by pollen analysis of temperate sediments associated with Palaeolithic sites, following the tradition of the Fenland Research Committee, continued strongly, with investigations of palaeobotany and archaeology, as at Clacton (AR 2), Hoxne (AR 5) and High Lodge (AR 15).

The sites studied in the Subdepartment were by no means confined to East Anglia. Thus sites were studied in Shetland (AR 14, 22, 30), the Thames valley (Gibbard 1985, 1994), the Midlands (AR 23, 28, 39), and the south coast (AR 10, 37), as well as overseas in Spain (AR 33) and Greece (AR 42, 44).

Cold stages

Clement Reid, E.M. Reid and M.E.J.Chandler all made contributions to the constitution of floras associated with cold stages in the Quaternary, through the identification of macroscopic plant remains. In the late 1940s such studies were developed under Godwin's guidance, and combined with pollen analyses to improve interpretation of cold stage floras. This work was greatly facilitated by the presence of the excellent herbarium in the Botany Department and the compilation of an effective reference collection of macroscopic plant remains. Advances in identification and interpretation were made by several researchers in the Subdepartment, including J.Allison, S.L.Duigan, C.A.Dickson (see Dickson 1970), F.G.Bell (whose dissertation was a landmark in these developments; see Bell 1970), D.G.Wilson and M.E.Pettit. The use of S.E.M. for identification in addition to light microscopy was introduced (AR 18).

Two aspects of the interpretation of cold stage floras presented problems to researchers in the Subdepartment. One was the separation of reworked from contemporary plant remains (pollen and macros) in a particular sample (e.g. at Earith; see Bell 1970), a problem illustrated by the pictorial reconstruction in Seward's book (1933) of 'an English Landscape in the latter part of the Glacial Period', which shows typical cold stage species plus *Carpinus betulus* leaves, following the finding of reworked *Carpinus* fruits in cold stage assemblages, as at Earith. The second was a result of interdisciplinary research on cold stage samples. Discrepancies between the climatic interpretations from flora and beetles, as at the Sidgwick Avenue, Cambridge site (AR 9) presented a problem. Such interdisciplinary research greatly expanded as the subject developed (e.g. at Kempton Park, Gibbard *et al.* 1981, AR 31), and as a result underlined the problems of climatic interpretation based on contemporary floras and faunas in cold stages.

Occurrence of cold stage floras

One result of the increase in the construction industry after the war was the excavation of sand and gravel quarries in the river terrace sediments of lowland Britain. These were the source of the many investigations of cold stage floras in the Subdepartment, found in seams of organic sediments within mainly fluviatile sediments. Other floras were found in coastal sections of Quaternary sediments, as on the Norfolk and Suffolk coasts (AR 16) and the Isles of Scilly (AR 35), underlying or overlying temperate stage sediments in kettles or valley fills (e.g. Marks Tey, AR 16) and also in boreholes (e.g. AR 12).

Age of cold stage floras

Cold stage floras over a wide time range were investigated in the Subdepartment. Using the stratigraphic nomenclature of the account of cold stage floras given by West (2000a), they included many Devensian sites (e.g. AR 17, 33), a number dated by radiocarbon; Wolstonian (e.g. Broome, Norfolk, AR 39) and Late Wolstonian sites, Anglian and Late Anglian sites, all within the glaciated area of south-east England, as well as 'preglacial' sites from coastal sections in East Anglia (Arctic Freshwater Beds of Clement Reid) (Plate 26), Early Pleistocene floras from coastal sections and borehole sequences through the marine Early Pleistocene of East Anglia (Baventian, Thurnian, Pre-Ludhamian cold stages) (AR 12). As well as floras found within river terrace sediments, floras were also analysed from fine sediments associated with glacigenic sequences, as at Chelford (Devensian, interstadial, AR 8), Corton (Anglian, AR 18) and Four Ashes (AR 27). But most of the evidence for cold stage floras came from sediments within terrace sequences.

Results of analyses

The results of the many analyses from the Subdepartment, made throughout its life, presented a clear picture of the flora and vegetation during the recurrent cold stages of the Quaternary, from the earliest times to the last cold stage: a rich herbaceous flora with accompanying grassland during the stadials ('full-glacial') and interstadials with an increased representation of trees, including conifers. The survival of a flora during the cold stages of the Quaternary is strongly suggested by this evidence. Indeed, certain sites within a short distance of the margin of the Late Devensian ice sheet showed a rich flora (e.g. Beetley, Norfolk, 25 km away, 16.5 ka BP (AR 33); Somersham, 60 km away, 18.75 ka BP (AR 42)). The analyses also gave a greatly improved knowledge of the flora in phytogeographical terms, with consequences for the interpretation of present plant distributions and taxonomy and cold stage climates.

Chapter 5

Research: geology

(publication numbers, Figure 2f)

Although the Subdepartment was founded in the Botany School with the members of mainly botanical allegiance, geological co-operation and advice on Quaternary matters was ready in the Department of Geology. W.B.R.King was teaching a course on Quaternary stratigraphy in that Department and R.W.Hey was an active Quaternary researcher. The arrival of J.J.Donner (University of Helsinki and a pupil of M. Sauramo) as a research student in the Subdepartment in 1952 brought the Scandinavian experience of Quaternary geology, particularly relevant since his research in Scotland was multidisciplinary and involved glacial retreat stages, raised beaches and allied vegetational history.

27. Hand-boring of Holocene diatomite to over 17m at Kentmere, Cumbria, c.1955 (R.Ross, D.Walker, A.T.Grove, R.G.West).

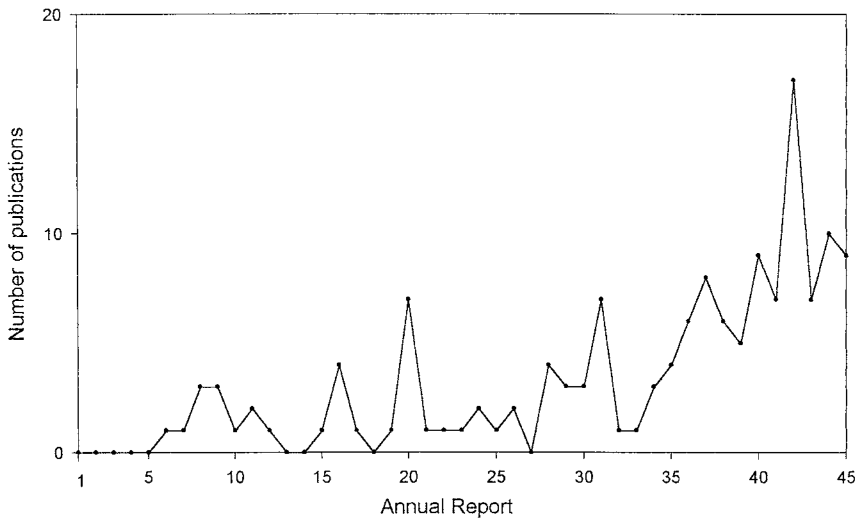


Figure 2f. Geology, stratigraphy

The development of the geological side was also greatly helped by a British-Irish-Dutch Quaternary excursion in 1952, when members of the Subdepartment visited the Netherlands, and by a reverse visit in 1954 of Dutch colleagues to East Anglia. These started a long association with Dutch colleagues in several areas of Quaternary research. A second important encouragement came from research students in the Subdepartment joining Quaternary field excursions to The Netherlands, north-west Germany and Denmark, in particular an excursion through north-west Germany led by P.Woldstedt (Bonn) with his students, and an excursion of the Deutsches Quartärvereinigung in north-west Germany led by K.Gripp, U.Rein, A.Rust and others. These excursions were multidisciplinary (including archaeology), and brought vividly to our notice the progress made in Quaternary research on the continent, in particular with sedimentology, stratigraphy and periglacial processes, and also with the techniques which had been applied.

Many aspects of Quaternary geology were covered as the subject developed and some major areas can best be dealt with under separate headings, as follows.

Coring and sediment recognition

Godwin wrote that he learnt much of his 'peatland' skills from the Swedish botanist H.Oswald when he made a visit to to survey the peat bogs of Ireland together with Tansley and Oswald in 1935. There Oswald taught him the use of the Hiller peat borer (Plate 27) and introduced him to the classification of mires, the field identification of *Sphagna*, the recognition of sediments in cores and bog sections and the use of von Post's descriptive terminology and scales of humification (Godwin 1973). Oswald's genetic classification of organic sediments, together with Troel-Smiths (1955) descriptive method for sediments, formed a basis of teaching in the Subdepartment for many years. It was supported by a comprehensive 'museum'

28. S.M.Peglar demonstrating pollen-analytical results from cores taken by a 2″ piston corer in the foreground at the opening of the Godwin Laboratory by the Duke of Edinburgh, Chancellor of the University, June 1982 (photo C.Chalk, Godwin Laboratory Archive).

of sediment types started by Godwin, which was extremely useful to beginners in the subject, as were all research students in the early days and many later. In 1953 D.Livingstone came to the Subdepartment for a year and helped with many field activities to our advantage, especially in his knowledge of techniques and fragmentary animal remains in sediments.

Later, in 1963, J.G.Ogden Jr came for a time, by coincidence a time of such cold conditions that thick ice formed on lakes in East Anglia. With his experience he helped in the construction of a Livingstone sampler (Plate 28), which was then used to obtain cores through the ice at Old Buckenham Mere, with the help of the Part II Botany class. Later, F.A.Hibbert developed a larger Livingstone corer, of 2” diameter, which became much used in the Subdepartment. In 1965 the Subdepartment acquired a Pilcon drilling rig which was able to take 4” percussion cores in interglacial sediments, which was successfully used on many occasions. A specially designed 4” piston corer was later designed for use with the Pilcon, with the purpose of obtaining larger samples of post-glacial sediments for radiocarbon and macro analysis. The use of the Pilcon was hard work, but it meant that contractors need not be involved at important sites, so responses were more rapid. It was useful at this time in the development of the subject, but its use was not so attractive later on, when radiocarbon dating came to need much smaller samples.

Quaternary stratigraphy

In the early 1950s British stratigraphy and its relation to continental stratigraphy was an area of much discussion (see summary in West 2000b; also Part III Chapter 1; marine stratigraphy, Chapter 8). On the continent, stratigraphy had been clearly developed in the preceding three decades by the application of stratigraphy of glacial sediments and pollen analysis, as already discussed. With pollen analysis well-established in the Subdepartment, there was a clear opportunity to extend pollen-analytical studies backwards into earlier parts of the Quaternary, as indeed had already started in the late 1940s. From the 1950s interglacial deposits came to be studied in detail both from the geological and palaeoecological sides, extending back into the Early Pleistocene Crag deposits of East Anglia. This led to the construction of schemes of stratigraphy combining vegetational history with lithostratigraphy, eventually resulting in a Geological Society of London publication in 1973 of *A correlation of Quaternary deposits in the British Isles*, with type localities for interglacials based on vegetational history and a suggested correlation with north-west European stratigraphy (Mitchell *et al.* 1973). Research in the Subdepartment played a large part in the construction of this stratigraphy. An important corresponding development in the work of the Subdepartment was the application of rules of stratigraphic nomenclature, with definition of formal lithostratigraphical and biostratigraphical units.

Contributions to geology, glacial and fluviatile

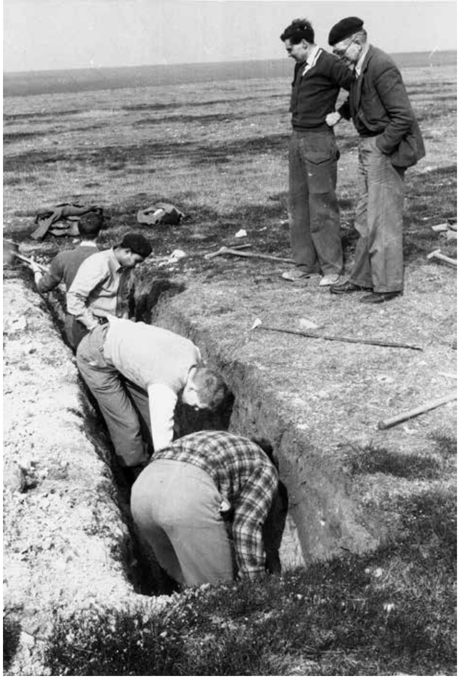
Stone orientation studies of tills in East Anglia and the East Midlands (AR 5,6), following methods used in northern Europe, led to the reconstruction of ice movements. Similar measurements were made in active ice marginal to an ice-sheet in North-East Land (AR 6). Detailed analysis of glacial, fluvioglacial and fluviatile sediments, including clast analysis and numerical analysis of constituents became the norm from the early 1970s, e.g. with the glacial and terrace sediments of the Thames Valley area (e.g. AR 23,25, 28, 37), with Marly Drift of north Norfolk (AR 37) and the North Sea Drift Formation of north Norfolk (AR 42).

Glacial limits

A number of research projects assisted in determining limits of particular glacial advances. They included Devensian late-glacial retreat stages in Scotland (AR 5,7), Devensian late-glacial cwm glaciation in north Wales (AR 8), extent of the Late Devensian ice sheet in eastern England (AR 9) and associated proglacial lake sediments (AR 44), limit of the Anglian glaciation in the Thames Valley area (Vale of St Albans) (AR 23,25), and extent of the Devensian Irish Sea Ice in the southern Irish Sea (AR 35).

Regional studies

Projects undertaken by research students usually involved multidisciplinary studies of particular areas of Quaternary interest, with the result that training was given in such an approach to the Quaternary and that this was applied to the area in question. In addition, members of the staff of the Subdepartment pursued their own, often regional, projects. An idea of the extent of the contribution by both these "sources" of research is given by the following selection of projects: Devensian retreat stages and raised beaches in Scotland (AR 5,7), north Norfolk glacial topography (AR



29. A.S.Watt, right top, with R.M.S.Perrin, supervising the digging of a trench across vegetation stripes at Eriswell High Warren, Norfolk, 1956 (photo Subdepartment Archive).

7), Devensian late-glacial cwm glaciation in north Wales (AR 8), glacial deposits in Langdale, Lake District (AR 9), Quaternary of the Waveney Valley, East Anglia (AR 19, 29), Quaternary of the Vale of St Albans (AR 23,25), Quaternary of the Middle Thames (AR 28) and Lower Thames (AR 37) (two very extensive and exemplary studies by P.L.Gibbard (1985, 1994) and colleagues), Quaternary of the Scillies and south-west England (AR 35), Quaternary of the Nar Valley, Norfolk, and central Norfolk (AR 35), Quaternary of the southern Fenland AR 29, 36, 37, 38), Quaternary history of the Solent River (AR 40), Quaternary buried channels of coastal Essex (AR 41), and the pre-Devensian sediments of Herefordshire (AR 44).

Periglacial phenomena

Here again, attending Quaternary excursions in north-west Europe in the early 1950s, and later to Poland under the guidance of J.Dylik, illustrated the importance of studying periglacial effects seen in exposures, and soon such phenomena were described, mainly in East Anglia: involutions on the Norfolk coast (AR 9), Breckland stone stripes (AR 7,15) (Plate 29), cryogenic structures at Wretton, Norfolk (AR 13), rimmed ground-ice depressions at Walton Common, Norfolk (AR19) (Plate 30), thermal contraction cracks on the Norfolk coast at Covehithe (AR28), Suffolk (AR 30) and in the Fenland (AR 44), thermokarst in the Fenland (AR 41), 'brickearths' of the Thames Valley (AR 35), and a survey of the stratigraphy of periglacial features in East Anglia (AR 21).

Changes of relative land/sea level

(publication numbers, Figure 2g).

Evidence for sea level change had interested Godwin from the time of the start of pollen-analytical investigations in the Fenland in the 1930s (see Part I). This aspect of Quaternary research became a normal part of the many research projects carried out by graduate students in later years. This is hardly surprising. With the long coastline of Britain and the many low-lying embayments fostering peat formation in association with estuarine sediments, as in Fenland, any investigation of vegetational history was liable to move into the coastal domain of interdigitating estuarine and organic sediments. Early in the history of the Subdepartment , matters of sea level change were integral to many regional vegetational history studies, such as those of D. Walker in the Cumberland lowland, A.G.Smith in lowland Lancashire and the lower Trent valley, S.C.Seagrief in valleys in south-east England and F.Oldfield in south Westmorland, while J.J.Donner related Devensian late-glacial marine sediments to vegetational history in western Scotland.

With the development of radiocarbon dating in the Subdepartment in the early 1950s, the chronology of sea level change became an important part of the dating programme. Dating enabled publication of a global sea-level curve in 1957. D.M.Churchill, appointed in 1960, started many investigations of coastal sites, with the aim of establishing the age of sea level changes and the recognition of isostatic and eustatic components of change. Sites included many on the south coast and the east coast, including the Thames estuary and Fenland. Post-Neolithic differential warping, based on studies of coastal beds, was judged to be +25ft in Scotland to –35ft at Tilbury in south-eastern England and Holland (AR 15). This period of more intensive sea level studies ended in 1965, when he returned to Australia. Subsequently, sea-level change remained an important part of research on vegetational history , as with the work of R.J.N.Devoy in the Thames estuary (AR 26)and A.M.Alderton in the Waveney valley in East Anglia (AR 31).

Sea level changes in interglacial temperate stages also became the subject of investigation from the earliest days of the Subdepartment. Investigations of the Clacton Channel, with evidence for marine transgression in the Hoxnian temperate stage, were reported in the first Annual Report. In the later 1950s investigations of temperate stage sediments with evidence for marine transgression were made in the Nar valley in East Anglia (AR 9)and on the south coast at Selsey and Stone (AR 10), resulting in indications of sea level change in different temperate stages. Subsequently, many further sites with evidence for sea-level change in temperate stages were investigated in the context of vegetational and environmental history, including sites in East Anglia at Peterborough (AR 22), the Fenland (AR 45), the Nar valley (AR 33), the Norfolk and Suffolk (AR 31) and Essex coasts (AR 42), and on the south coast at Earnley (AR 31) and on the Isle of Wight (AR 37). The later studies often included, besides vegetational history, analyses of molluscs, forams and diatoms, used to identify more clearly the detail of environmental changes associated with sea level change. Taken as a whole, the work on temperate stage sea-level change covered many periods in the Middle and Upper Pleistocene,

30. Peat-filled ground-ice depressions with rims at Walton Common, Norfolk, Late Devensian in age, 1968 (Copyright reserved Cambridge University Collection of Air Photographs).

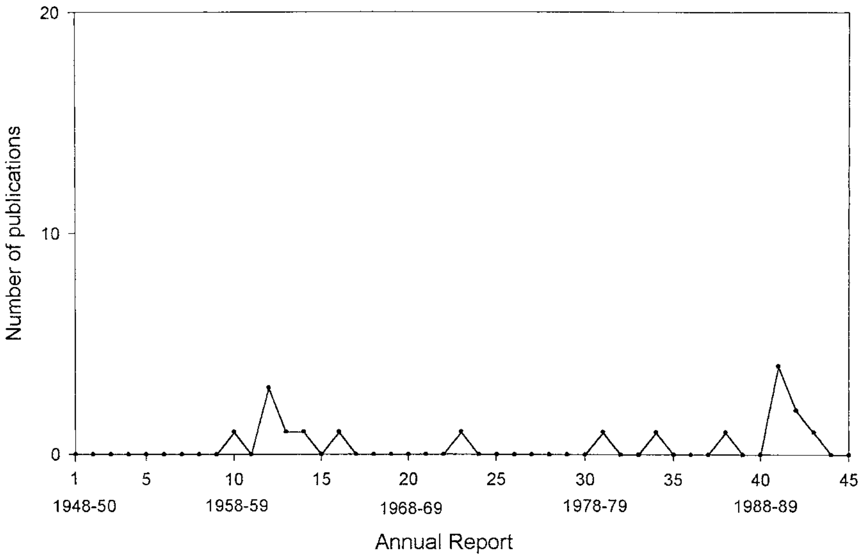


Figure 2g. Sea level.

following the time of Lower Pleistocene marine sedimentation in East Anglia. Relative sea levels in pre-Cromerian cold stages were also identified, as at Covehithe (AR 29) and the Norfolk and Suffolk coasts (AR 29, 31). The site studies began to reveal the possibilities of such research for identifying eustatic and isostatic sea level change as well as tectonic effects through the Pleistocene.

Overseas research

In addition to research in Britain, members of the Subdepartment carried out various research projects in several overseas areas. They included Svalbard (glacial processes, Late Quaternary events and sediments (AR 6, 30), Finland (sedimentology, AR 39, 44), Canada (tills, AR 28, 35, 43), Alaska (taphonomy, AR 42) and Greece (sedimentology, Quaternary history (AR 44).

Chapter 6

Research: faunas and archaeology

Faunas

(publication numbers, Figure 2h)

The interdisciplinary research of the Subdepartment was greatly favoured by the presence in neighbouring Departments of staff members interested in Quaternary faunas, marine and non-marine. These included B.W.Sparks in Geography, K.A.Joysey in Zoology, and B.M.Funnell in Geology. Also very important were the reference collections which supported these interests in the Museum of Zoology and the Sedgwick Museum.

From the early 1950s B.W.Sparks, whose principal interest was in geomorphology, applied his expertise in the identification and ecology of non-marine molluscs (developed with the support of the malacologist Hugh Watson) to Quaternary faunas in co-operation with members of the Subdepartment. He made many studies of Late Quaternary faunas in the Cambridge region and of temperate stage faunas in East Anglia and further afield. Analyses were carried out of samples in stratigraphical sequences, in close relation to palaeobotanical analyses, with results revealing faunal and environmental changes in, *e.g.*, the

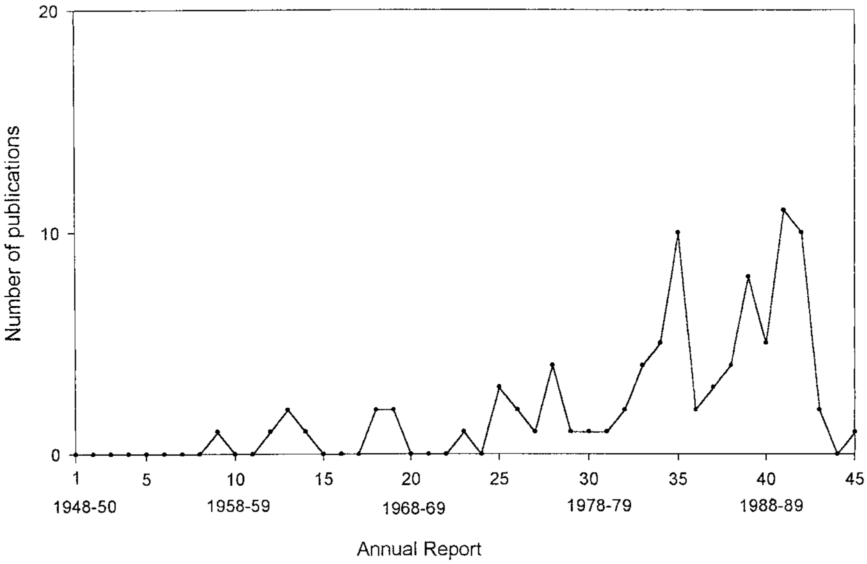


Figure 2h. Fauna.

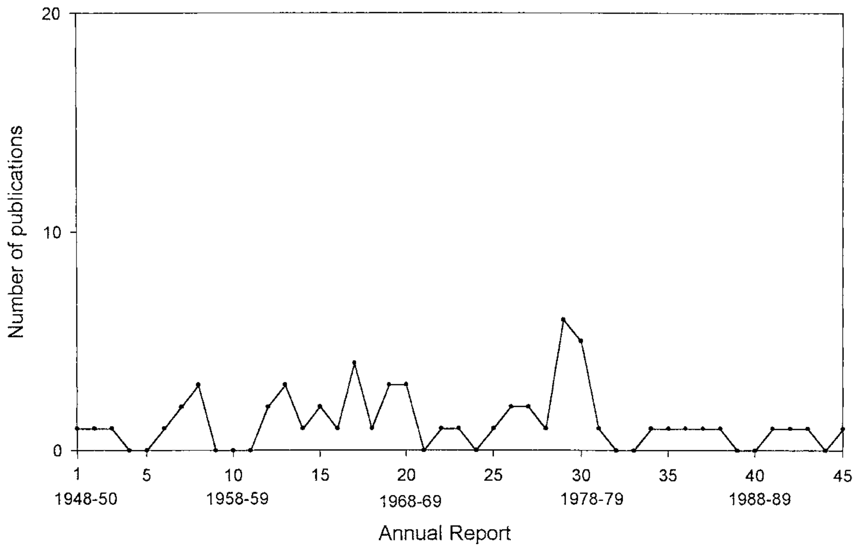


Figure 2i. Archaeology.

Flandrian, Ipswichian, Hoxnian and Cromerian temperate stages. These placed the subject on a firm footing, with the significance of this area of Quaternary research for environmental history fully realised. At Apethorpe mollusc assemblages were related to vegetational history from the Devensian late-glacial through the Flandrian (AR 11, B.W.Sparks, C.A.Lambert). At the South Downs site of Brook, Kent, late-glacial sediments with molluscs and plant remains were radiocarbon dated (AR 13), in collaboration with M.P.Kerney (Imperial College). Similar collaboration with him was extended to urther sites in the south-east of England (AR 26).

In 1982 R.C.Preece came as a visitor to the Subdepartment to continue his studies of non-marine mollusc faunas, making substantial contributions in co-operation with members of the Subdepartment on temperate and cold stage faunas and their chronology. He moved to the staff of the Museum of Zoology in 1986, continuing co-operation on a variety of important sites subsequently, including tufas in Ireland (AR 36).

R.G.Pearson was appointed to the staff of the Subdepartment in 1957, with the long term aim of investigating the palaeoecology and zoogeography of beetles. He carried out analyses of post-glacial, late-glacial and cold stage beetle assemblages in conjunction with members of the Subdepartment, but research in this area ceased after he left for Liverpool University in 1960. This field of faunal research was expanded with great success by F.W.Shotton and his students at Birmingham at this time and subsequently. Flandrian Cladoceran assemblages were analyysed by P.W.Beales in his study of the palaeolimnology of Shropshire meres (AR 25) and a Hoxnian temperate stage site in Hertfordshire (AR 26).

P.E.P.Norton began research on marine mollusc assemblages of the Early Pleistocene (including those from the Ludham Borehole) in 1960. There was support available from the reference collections in the Museum of Zoology and the Sedgwick Museum, as well as strong interest from the museums in Ipswich and Norwich. The assemblages were closely related to the palaeobotanical studies

Plate 31. B.M.Funnell extracting cores from the deep borehole through early Pleistocene sediments at Ludham, Norfolk, 1959 (R.G.West).

of the same sediments, resulting in a close relation being established between the marine faunas (of the East Anglian Crags) and vegetational history in the early part of the Pleistocene. Norton continued the research when he left for a position at Glasgow University, studying many important Crag sites in co-operation with the Subdepartment, and maintaining strong contacts with colleagues in the Netherlands. At the same time B.M. Funnell at the Geology Department was studying foraminiferal faunas from the the Ludham Borehole and other Crag sites in East Anglia (Plate 31), and here it was possible again to combine faunal and palaeobotanical studies of the same sections. Co-operation in this area continued successfully after Funnell moved to the University of East Anglia.

Important faunal sites came to be studied in relation to vegetational history, e.g. Ilford (AR 14), but this area of research was greatly enhanced when in 1971 A.J.Stuart came to the Subdepartment as an N.E.R.C. Research Fellow to study vertebrate faunas. He paid particular attention to palaeoecology and the association of faunas with vegetational history. In 1975 he moved to the Museum of Zoology and continued studies of vertebrate faunas in temperate and cold stages in Britain and Europe and their evolution, backed by the interest of K.A.Joysey at the Museum. Co-operation at archaeological sites (e.g. Hoxne) was also involved. A.M.Lister joined the group in 1976, and there was much subsequent co-operation between the members of the Museum of Zoology and of the Subdepartment, involving particular sites from the Early Pleistocene onwards, and their stratigraphy and and evidence for faunal evolution.

From this brief survey it will be clear that the Subdepartment was helped to promote and maintain interdisciplinary research through the presence of active researchers on Quaternary faunas in Departments close by. As a result, approaches to faunal analysis were established through a thorough basis in stratigraphy, and pioneer contributions were made in several areas. Notably, successful co-operation continued after members left the Subdepartment, enhancing the spread of interdisciplinary research.

Archaeology

(publication numbers, Figure 2i)

The co-operation with archaeologists which began in the 1930s with the Fenland Research Committee continued and expanded during the life of the Subdepartment. Environmental archaeology, originating from the work of the Fenland Research Committee, became a subject in its own right. Archaeologists began to realise more widely the importance of biological and geological evidence for past environments, to be obtained during excavation. The result was that from the beginning the staff of the Subdepartment were bombarded with requests for advice, assistance and co-operation, as recorded in the Annual Reports. The pressure increased once the radiocarbon laboratory was established in the 1950s, with the necessity for establishing secure chronologies and the shortage of dating facilities in the country at the time.

All the Annual Reports contain accounts of co-operation with archaeologists and archaeological projects, and this was probably the major and longest-lasting area of co-operation in the work of the Subdepartment. The research involved investigations of particular sites, and longer, more comprehensive, studies, both in the British Isles and overseas. All staff members were alive to the interests of archaeology, as these could be seen in the study of prehistoric environments. The result was a huge continuing co-operative effort. I have tried to give an impression of the strength and diversity of the Subdepartment's contributions in the following account.

Several major co-operative projects spanned lengthy periods. At the beginning, a major contribution to J.G.D.Clark's Star Carr project (Clark 1954) was made by H.Godwin and D.Walker (AR 2). Interestingly, this Mesolithic site, at the edge of Lake Pickering in Yorkshire, came to be re-studied in later years, when research methods had greatly evolved, as recorded in the latest Annual Reports (AR 43). Other important projects the Subdepartment continued to be, or became, involved in were: excavations at the Neolithic site of Ehenside Tarn (AR 9, D. Walker), the work on the Somerset Levels and their trackways and sites (AR 1, 19), later in co-operation with J.Coles in the 1980s (AR 33), the Fenland Research Project in the 1980s (AR 37), and projects in Greece (AR 37).

The co-operation covered all periods, from Palaeolithic to Mediaeval. Work included in the earliest Annual Reports concerned Palaeolithic sites at Clacton (AR 2) and Hoxne (AR 4). Later, many Palaeolithic sites were studied from palaeobotanical or geological points of view, such as High Lodge (AR 14), sites in the Thames Valley (32, 34), and also wider afield, e.g. Ambrona in Spain (AR 31). Mesolithic sites were studied from the first, a Pennine Mesolithic site (Stump Cross) by D.Walker (AR 8), and in the 1960s by D.M.Churchill (Westward Ho!, Thatcham) (AR 12), and in the 1970s a Mesolithic dating project was under way with V.R.Switsur and R.Jacobi.

The interest in Neolithic and post-Neolithic vegetational history, already shown by the 1940s research noted earlier in Part I, greatly enlarged, especially following the increased ability to identify non-tree pollen (based on the expanding pollen reference collection). The sites included raised bogs, lake sequences and archaeological sites. Post-Neolithic changes, especially forest clearance and the evidence for pastoral or arable agriculture, were studied in detail by J.Turner from 1958 (AR 10, 15). H.Godwin published work on the history of land use in the 1960s, also with reference to particular crops (e.g.*Cannabis*), based on lake sediment sequences (AR 17), and later very detailed pollen diagrams from lake sediments in East Anglia (e.g.Diss Mere, S.M.Peglar *et al.*) (AR 33) revealed much detail of vegetational history associated with land use in East Anglia. Studies were also made on particular problems, *e.g.* the Bronze Age Dartmoor 'reaves' (AR 30, S.C.Beckett) and chambered cairns in Sutherland (AR 31, J.Huntley).

As well as pollen-analytical evidence, studies of macroscopic plant remains associated with archaeological sites were pursued throughout the life of the Subdepartment. These contributed much to the understanding of the identification and utilisation of crop plants and weeds. In particular, in the early 1970s D.G.Wilson made an extended study of material from Iron Age and Romano-British sites (AR 22).

As facilities developed in the radiocarbon laboratory, and particularly from 1977 when the Godwin Laboratory started, there was increased collaboration with archaeologists. The radiocarbon laboratory of the Subdepartment, under the direction of E.H.Willis and later V.R.Switsur carried out much work in relation to archaeological projects. These came from within the University, but also from many outside sources (see the radiocarbon section). The stable isotope laboratory was also concerned with archaeological research, in particular the studies on seasonal habitation and food preferences through stable isotope analysis of molluscs were carried out by N.J.Shackleton and M.R.Deith on coastal sites in South Africa, the Mediterranean and Portugal in the 1970s and 80s (AR 21, 23). There was also collaborative work on C and N isotopes of bone collagen from archaeological sites (AR 43, H.P.Schwarz). The ESR facilities in the Godwin Laboratory were used in a study of the dating of tooth enamel and its application to Palaeolithic archaeology (AR 42,43, R.Grün, W.J.Rink) in the late 1980s. Facilities in the Godwin Laboratory also made co-operation on dendrochronology possible and work on timbers from archaeological sites in the Fenland, including Flag Fen (AR 39), was carried out in the 1980s.

This brief review, in no way comprehensive, gives an indication of how the Subdepartment became involved in many archaeological projects where environmental or chronological needs had to be met. These were satisfied by the botanical, geological and physical expertise available in the Subdepartment, and were catalysed by the close association of Subdepartment members with other Departments, through common lecture courses and seminars, and of course by the common interest and excitement which these sciences could bring to archaeology.

Chapter 7

Research: radiocarbon dating

(publication numbers, Figure 2j)

Establishment of the Radiocarbon Laboratory

In the late 1940s W.F.Libby developed the science of radiocarbon dating, publishing in 1952 his book on the subject (Libby 1952). A later edition in 1955 expanded the treatment and included lists of dates already obtained from many countries. Amongst them were the dates submitted to him by Godwin from various sites in England. Godwin (1951) commented on the results, discussing the problems involved. The significance of the method for Quaternary research was very quickly recognised. In July 1952 Godwin and A.G.Maddock (Department of Chemistry, Cambridge) obtained a grant from the Nuffield Foundation of £8400 over 5 years " for a research programme on the application of radio-carbon assay to Quaternary research, the work to be carried out under the direction of Dr Godwin." E.H.Willis (Plate 32) was appointed in December 1952 to undertake the design and building of the equipment, with advice from A.G.Maddock. He later gave a revealing insight into this historic period of development in an article in the newsletter of the Godwin Institute for Quaternary Research (Willis 1996).

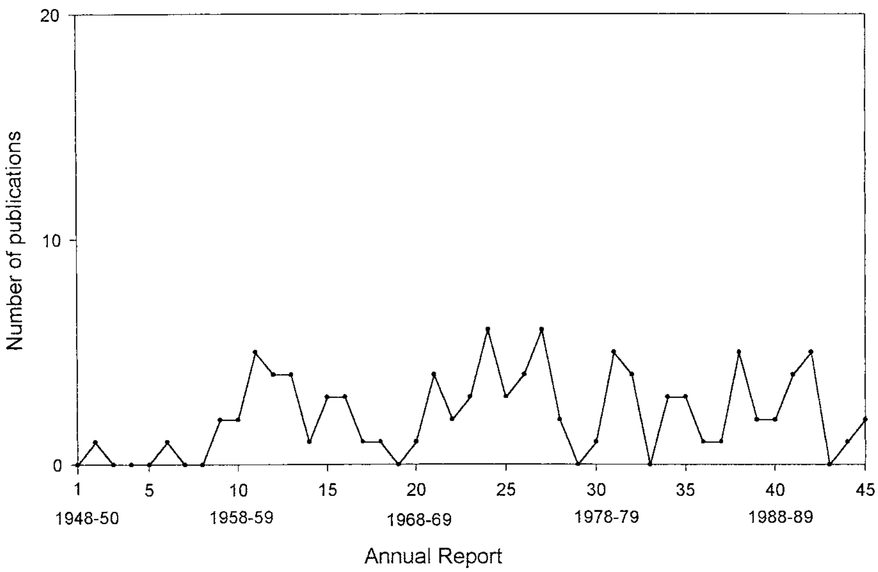


Figure 2j. Radiocarbon dating.

Plate 32. E.H.Willis placing a counter inside a lead castle in the basement laboratory of the Botany School, University of Cambridge, 1956 (Godwin Laboratory Archive).

At first a gas (acetylene) counter inside an anticoincidence shield was built, the gas later replaced by carbon dioxide under pressure, as developed by H. de Vries in the Netherlands. Preliminary datings were achieved in 1955/56. Samples for analysis had already been accumulated, and these were to be used for critical testing of assumptions basic to the applications of pollen analysis in geological, climatic and vegetational history." (Annual Report 1952/53). In 1955 Godwin and Willis arranged an informal conference in Cambridge to which were invited active researchers in radiocarbon dating in Britain and Europe, and also four outstanding Americam researchers. Techniques, principles and applications were discussed, to the great benefit of the subject. This followed an earlier meeting for European researchers in Copenhagen in 1954, and was itself followed by a series of regular international meetings, the first in Andover, U.S.A., in 1956 where the first results of the Cambridge laboratory were presented. In 1962 the conference was held in Cambridge, with some 80 participants representing active radiocarbon laboratories in 17 countries. Amongst discussion on past natural radiocarbon activity and other important matters, it was agreed to maintain the accepted 'Libby' value of the half-life of radiocarbon of 5568 years.

In 1964 Willis resigned as director of the laboratory and moved to the U.S. V.R.Switsur was appointed in his place.

The advantage of a radiocarbon dating laboratory within an organisation such as the Subdepartment quickly became apparent. Co-operative projects to achieve results in important areas of Quaternary research could be developed, especially as research areas expanded with increasing numbers of graduate students. Those involved in dating were actively involved in the programmes. The areas where the first dates were obtained concerned pollen zone boundaries, late-glacial chronology, land/sea level change, and important archaeological sites. These remained the prime targets for the establishment of radiocarbon chronologies for many projects in many parts of the country in subsequent years.

Publication of dates

Fifteen date lists from the Radiocarbon Laboratory were published in *Radiocarbon*, the first in 1959, the last in 1981. Lists of additional dates were given in the Annual Reports for 1982/3 (AR 34) and 1985/6 (AR 37). Thereafter dates tended to be published in the papers which reported the research to which they were relevant, detailed in the Annual Report bibliographies.

Laboratory history

The Laboratory was first established in 1953 in the Botany School, a basement room adapted for the counters and a separate laboratory for gas preparation. Dates began to be produced in 1955/6. The equipment was improved rapidly, with reduction of background and a new counter. In 1957/8 the Laboratory had to move to a new site, prefabricated huts, at 5, Station Road, Cambridge, because the introduction of carbon-14 as a tracer for plant physiological experiments in the Botany School jeopardised the low-level counting requirements of the laboratory (see Willis 1996). This was a blessing in disguise since it allowed the development of much improved facilities. The downside was the distance from colleagues in the Subdepartment, who remained in the Botany School. In 1961 a second gas proportional counting channel was installed in the laboratory, which led to increased dating capacity and improved checks on fundamental principles of the method. The equipment, both preparation lines with bomb combustion and counters, was redesigned by V.R.Switsur during 1965-68, when operation was resumed with two counters. The distance drawback, together with lack of space, became more apparent as interest and activity in Quaternary research increased.

Eventually, closer links were re-established and enlargement made possible when new especially designed laboratory facilities were allocated to the Subdepartment on the New Museum Site, near the Botany School. These began life in 1977, named the Godwin Laboratory and opened by him in 1979 in a speech which gave a resumé of the history of the Subdepartment's activities of radiocarbon dating and stable isotope research. In the new laboratory, the equipment was up-dated and liquid scintilllation counting adopted, with further upgrading in the 1980s.

Research activities

As the laboratory developed, its activities naturally widened. Advice on setting up radiocarbon dating facilities was given to various organisations including the National Physical Laboratory and the Oxford University Research Laboratory for Archaeology and the History of Art (AR 8) and later to laboratories at the Universities of Belfast and Birmingham (AR 15). "In-house" projects were started by Willis. They included measurements, in conjunction with laboratories at Copenhagen and Heidelberg, of the activity of wood from a section of *Sequoia gigantea* in the Botany School extending at intervals of 50 years over a period of 1300 years, indicating past cyclic shifts in atmospheric concentration of radiocarbon on either side of the present value, rather than the hoped-for stability (AR 10; Willis, Tauber & Münnich 1960) (Plate 33). The variation was later determined elsewhere over a much longer time by similar analysis of Bristle Cone Pine wood. Bomb-produced radiocarbon fallout from atmospheric nuclear tests was also analysed in the 1950s via measurements on the annual oat crop 1953-59 and annual rings of *Populus nigra* in the same period (Godwin & Willis 1960, 1961) enabling study of the the exchange rates of carbon dioxide between various phases of the carbon reservoir (AR 11). In the early 1960s, exchange of radiocarbon between the troposphere and stratosphere after further bomb explosions was studied by carbon dioxide collection at high altitudes with the aid of an modified Canberra bomber (AR 13). The laboratory provided the the only British systematic assay of radiocarbon in the

Plate 33. The segment of the Sequoia trunk used to calibrate the radiocarbon time-scale over 1800 years (photo M.A.Hall, Godwin Laboratoiry Archive).

atmosphere resulting from thermonuclear weapon-testing (AR 12). The laboratory also housed the M.R.C.'s strontium 90 fallout project in the same period, providing the required low level background counting facility (AR 12).

In 1978, an intercomparison study of methods and results was started in co-operation with other laboratories in the U.K., later extending to European laboratories (AR 30, 31). Later, a Radiocarbon Liaison Group with representatives of 10 University departments was set up to assist collaborative studies (AR 36, 37).

The dating programme dealt with two facets, the first involving research projects of the Subdepartment aiming to establish chronologies for different aspects of Quaternary research, the second dating samples considered sufficiently important submitted by other Departments in the University and by other institutions. In the first decade the dating programme was highly focussed on dating events in three areas: post-glacial vegetational history, in particular pollen zone boundaries across Britain, as illustrated by the earliest of such studies at Scaleby Moss, Cumbria (Godwin, Walker & Willis 1957); secondly, the Devensian late-glacial period, establishing the radiocarbon ages of Zones I, II and III of the late-glacial in Britain and their correspondence with Scottish and Scandinavian late-glacial geology (Godwin & Willis 1959); and thirdly, radiocarbon dating of the eustatic rise in ocean level after the last glacial stage, relating sea level change dates in north-west Europe to those in Australasia and north America (Godwin, Suggate & Willis 1958).

A fourth area of interest from the first was the dating of samples relating to important archaeological sites, such as the Mesolithic sites at Star Carr and Stump Cross in Yorkshire (AR 8). Later Godwin (1970) drew together archaeological radiocarbon dates in Britain, and considered their relation to environment, vegetation history and chronology. These were the four areas where radiocarbon chronology was developed, but, as mentioned above, the work was accompanied by research on wider aspects of radiocarbon study.

The applications of radiocarbon dating to projects in the Subdepartment continued to increase as facilities improved and more research workers, particularly graduate students, became involved in the later decades. Certain aspects are briefly outlined under the following particular headings. Full details are given in the Annual Reports.

Vegetational history, peat stratigraphy, geology, climate

As pollen-counting power increased in the first decade, dating was applied to sites in many parts of Britain, samples being obtained from both peat sequences and lake sediments. In the 1960s ages were obtained for recurrence surfaces and flooding horizons in peat sequences, pollen zone boundaries in several parts of the country , forest clearance phases in Neolithic and post-Neolithic time, and sea level change. Later, close dating of sequences enabled calculation of pollen influx and sedimentation rates, allowing more detailed knowledge of e.g. tree population changes, as the ecological interpretation of pollen diagrams became more rigorous. From the early 1960s, there was much increased interest in Scottish vegetational history, on the mainland as well as, later, the Western and Northern Isles, and dating of the sequences studied, including levels with tree remains (the Forestian of Lewis, see earlier), was a major activity of the laboratory. Dating of humus podzols by residual radiocarbon activity was investigated in the Breckland area of East Anglia (Perrin, Willis & Hodge 1964).

Archaeology

Dating of events in relation to archaeology remained important throughout the life of the Subdepartment. Major dating programmes were carried out in respect of prehistoric settlements (Star Carr, Thatcham, Westward Ho!), trackways, boats, Mesolithic chronology, and Fenland investigations. The last, supported by the Historic Buildings and Monuments Copmmission and English Heritage in the late 1980s, revised and greatly enlarged Godwin's interpretation of the 1930s. In later years the interest extended to continental sites in France and the Mediterranean countries.

Faunas

Dating was applied to sequences with changing non-marine molluscan faunas in south-east England, including the Channel Tunnel excavations, and north Wales, in the late 1970s and 1980s, giving a chronology for mollusc assemblages. Radiocarbon assays of different mollusc species were made to test the validity of the method.

Sea levels

Dating of samples indicative of relative land/sea level change continued throughout. In the 1960s a wider survey was made of coastal sites in southern England, extended to the Thames estuary in the 1970s, and later to further sites in southern and south-west England and southern Ireland.

Overseas projects

From the mid-1970s the laboratory increased collaboration with projects overseas, carried out by members of the Subdepartment or other institutions, involving dating for vegetational or environmental history and archaeology. The countries or areas included Ethiopia, East Africa, Labrador, Greece, Morocco, Jamaica, Crete, Pyrenees, Chile and Peru.

Chapter 8

Research: mass spectrometry, palaeotemperatures and deep sea sediments

(publication numbers, Figure 2k)

The evolution of this area of research, from the first application of mass spectrometry to the later study of deep sea sediments, is reflected in the headings used in the Annual Reports:

Mass spectrometry, AR 13 (1961/62) to AR 20 (1968/69)

Palaeotemperature measurement ; AR 22 (1970/71) to AR 25 (191973/74)

Palaeotemperature analysis, AR 26 (1974/75) to AR 29 (1977/78)

Palaeotemperature laboratory; AR 21 (1969/70), AR 30 (1978/79) to AR 38 (1986/87)

Palaeotemperature/ocean sediment stratigraphy AR 39 (1987/88) to AR 40 (1988/89)

Palaeotemperature and ocean sediment stratigraphy, AR 41 (1989/90)

Deep sea sediments AR 42 (1990/91) to AR 45 (19993/94)

Establishment of the laboratory

There is no better way of describing the beginning of this research than by giving extracts of the relevant annual reports, written by Godwin, Director at the time.

12th Annual Report (1960/61): "In the spring of 1961, a generous grant from D.S.I.R. enabled the first steps to be taken in the establishment of a mass spectrometric laboratory. The aim is twofold: to assist the radiocarbon laboratory in the assay of carbon 13/12 ratios for isotopic fractionation corrections and to measure palaeotemperatures by means of oxygen 18/16 isotopic analysis. The latter technique, conceived by Urey and developed by Emiliani, should provide information concerning the temperatures which existed at the time of growth of foraminifera in Crag deposits, currently being investigated by Dr West and Dr Funnell. The Subdepartment has secured the services of Mr N.J.Shackleton, Clare College, as research assistant for the project." The mass spectrometer laboratory was housed in the Subdepartment's Station Road laboratory, together with the

Plate 34. N.J.Shackleton's moving steel tape for sorting Foraminifera in the Station Road laboratory, 1965 (Godwin Laboratory Archive).

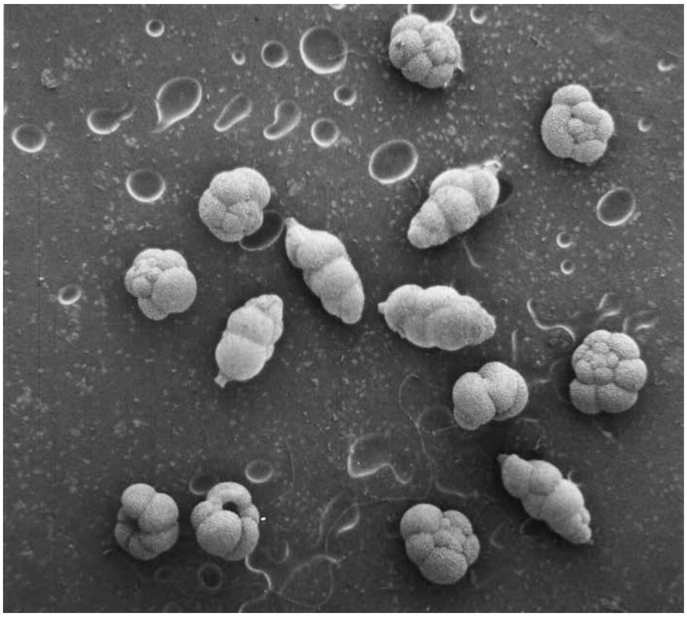


Plate 35. Foraminifera awaiting picking and sorting (x 55) (Godwin Laboratory Archive).

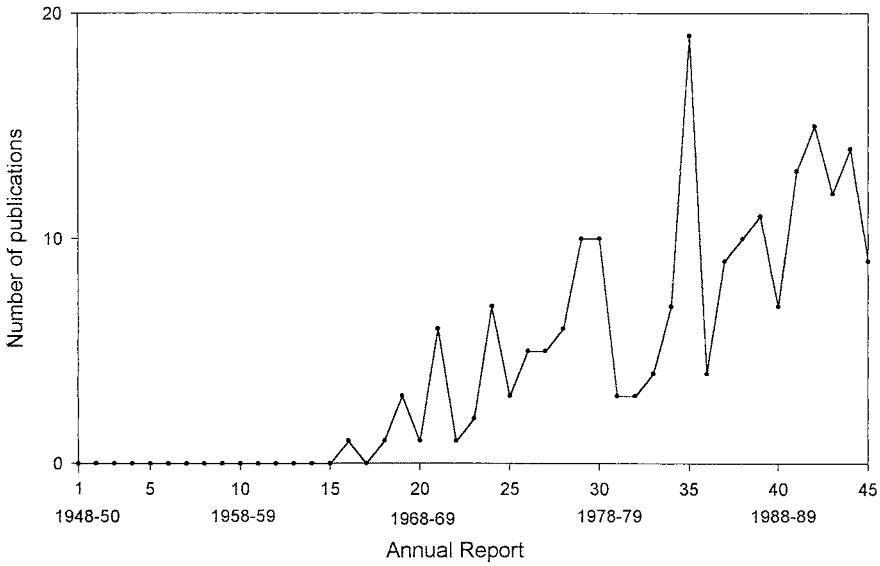


Figure 2k. Stable isotopes, marine geology

radiocarbon laboratory. Plate 34 is of a moving steel tape used at this time in the Station Road Laboratory for sorting Foraminifera (Plate 35).

13th Annual Report (1961/62): "The M.S. 3 Mass spectrometer, provided by D.S.I.R., was delivered in April 1962, and Mr N.J.Shackleton has been employed under the direction of Dr Willis in adapting it to achieve the desired accuracy for the determination both of carbon12/carbon 13 ratios and the more exacting oxygen 16/oxygen 18 ratios. The modifications now permit measurement of the C_{12}/C_{13} ratios to 0.1%$_0$ so that all future radiocarbon dates (and many past ones for which material exists) can be corrected for fractionation effects. It is hoped to achieve next the increase of sensitivity for us to undertake the oxygen isotope assays for research on palaeotemperatures." In the same year N.J.Shackleton joined the research ship *Horizon* in the Mediterranean and obtained cores from the southern Adriatic for investigating the record of Late Pleistocene climatic changes. It was noted that each mass-spectrometric measurement will require a sample of some 500 foraminifera, and techniques for extraction were being considered. Soon after this he took charge of the mass spectrometry laboratory., assisted by M.A.Hall (Plate 36).

Development

In the subsequent year the sensitivity of the mass-spectrometer was greatly improved and palaeotemperature determinations were being first made on *Elphidiella hannai* from the early Pleistocene Crag of the Ludham borehole in Norfolk. Improvement of the spectrometer and preparation lines continued in 1963/4, so that determinations could be made with about 1 mg of carbonate, and this "may permit readings to be made for different species of foraminifera within a

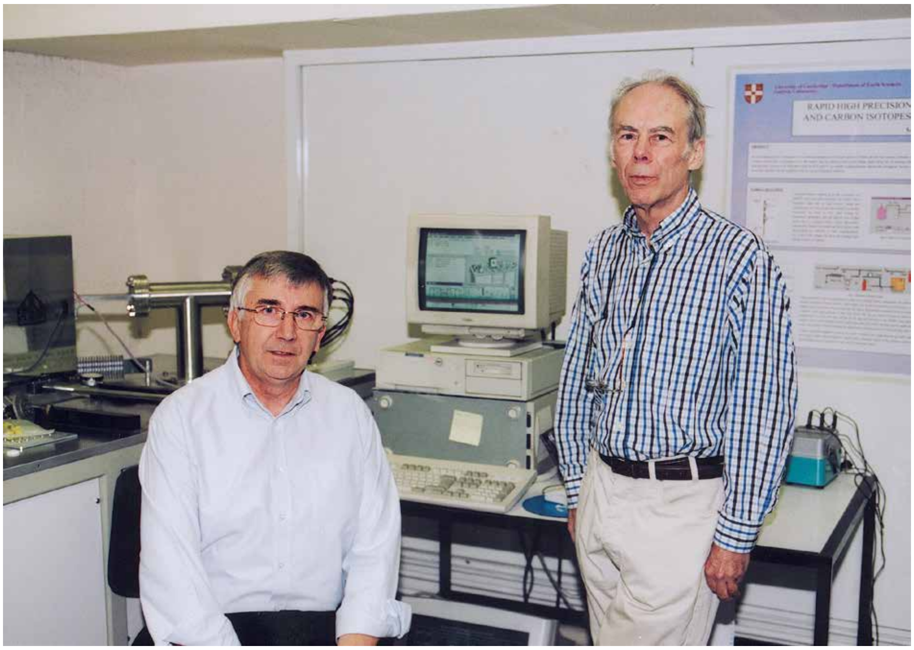


Plate 36. M.A.Hall and N.J.Shackleton in the Godwin Laboratory, 2004 (Godwin Laboratory Archive).

core." (AR 15). Further improvements continued, with problems of fractionation overcome. Samples of mollucs for palaeotemperature determinations were collected from archaeological contexts at Knossos, widening the significance of the method to archaeological interests.

In 1966/67 (AR 18) the palaeotemperature laboratory came into regular production, and development of the research programme proceeded apace under the direction of N.J.Shackleton. Samples for analysis from Caribbean core A 179-4 were made available by D.B.Ericson of the Lamont Geological Observatories. The results agreed satisfactorily with Emiliani's results, though the analytical technique differed. The Annual Report noted that " The particular virtue of the system developed by Dr Shackleton is that it permits the measurement of very small samples", enabling comparison, for example, the isotopic fluctuations of benthonic and planktonic foraminifera. The implications of similarity were very significant for interpretation of curves of isotopic temperatures and of Pleistocene temperature data. This was accompanied by a theoretical study by N.J.Shackleton, continued in later years, of isotopic composition of continental ice sheets, suggesting the possibility that the isotopic data may yield information relating directly to ice advance and retreat. The archaeological interest was continued by the collection of stalagmite fron Epirus in association with a Palaeolithic excavation, for investigation of climatic change.

Improvement in output of isotopic data continued, and in 1968/69 an expansion of research was made possible by the award of an N.E.R.C. grant for the study of Palaeotemperatures and Palaeosalinities in the Upper Pleistocene, in collaboration

Plate 37. N.J.Shackleton (second from left) at sea examining cores (Godwin Laboratory Archive).

with D.J.Wiseman of the British Musuem (Natural History), starting with a core from the Indian Ocean. Earlier modifications of the processing system had led to the measurement of samples as small as 0.4mg calcium carbonate, allowing the measurement of large single benthonic forams. With further improvements, samples of one-tenth of this size could be analysed without loss of precision, so that planktonic forams also could be analysed individually. This enabled much more detailed study of the life habitat in the water column of foram species and the meaning of palaeotemperature determinations in terms of the contribution of temperature and ice volume effects. The number of determinations in the year increased as the processes involved improved: 2000 in 1971/72, 2400 in 1972/73, over 3000 in 1973/74.

At this time important collaboration began with CLIMAP, a joint Lamont-Brown University-Oregon State University research project funded by N.S.F., with work on the western equatorial Pacific core V 28-238, the collaboration funded by an N.E.R.C. grant 'Oxygen Isotope Palaeoclimatology of the Middle Pleistocene' (AR 23) (Plate 37). A new mass spectrometer was installed, and data were obtained from over 30 cores, spanning the north, central and south Pacific, Indian Ocean, and Indian and Atlantic sectors of subantarctic waters. The majority of the cores were studied in connection with the CLIMAP project, with an immediate aim of constructing a world climate map at the height of the last glacial 18000 years ago. The results emphasised the great importance of oxygen isotope analyses for stratigraphy of deep sea sediments, enhanced by the establishment of the relation of this stratigraphy to the Brunhes-Matuyama magnetic reversal in core V 28-238

(Shackleton & Opdyke 1973). The relation was confirmed in the Atlantic in a study of the relation of the isotope curve to trade wind strength with D.W.Parkin.

Subsequent research areas

The Annual Reports give much detail of the rapid advances which succeeded these developments. They were facilitated by the move to the larger Godwin Laboratory on the central site. Collaboration with researchers on marine sediments and palaeontology in the U.S. and Europe expanded. As deep sea drilling programmes and techniques developed, cores became available from the major oceanic areas, and multidisiciplinary research flourished. I try to summarise these developments by picking out a number and relating them to the Annual Reports.

- Extension of the isotopic record back to the Miocene (AR 25)
- Evidence for changing activity of the Antarctic ice sheet (AR 25, 41)
- Change in character of glacial/interglacial parts of the O.I. curve before c. 850ka. (AR25)
- Refining of Middle Pleistocene marine stratigraphy (AR 26, 37)
- Relation of O.I. stratigraphy to radiolaria and coccolith extinctions (AR 26, 28)
- O.I. records related to radiolaria temperature estimates (with J.D.Hays, J.Imbrie *et al.*), with periodicities at c. 40ka and 22ka (AR 26)
- Indication of effects of changes of Earth's orbital geometry on climatic change and faunas (Milankovitch cycles) (AR 27, 28, 36, 39)
- O.I. and palaeomagnetic stratigraphies related (AR 29)
- CLIMAP development (AR 28, 29, 31)
- Relation of O.I. Stage 5e to Eemian temperate stage via Barbados coral terraces (AR 28)
- East Mediterranean sapropels dating (AR 30)
- Panama Basin piston cores improve stratigraphic resolution (AR 31, 39 (O.I Stage 104))
- Onset of major ice-rafting in North Atlantic (AR 33)
- Development of astronomically tuned time scale by SPECMAP project (AR 33)
- Deep sea record, atmospheric CO_2, and climatic change (AR 34)
- Carbon isotope record for last 70 ma (AR 35)
- Sea levels and O.I. stratigraphy, Huon Peninsula (AR 36)
- Marine nutrient distribution patterns via Cd/Ca ratios and phosphate (AR41)

- BOFS studies in North Atlantic (AR 43)
- Milankovitch cycles and magnetic intensity (AR 44)
- Climate and ocean circulation in Western Equatorial Atlantic and relation to Amazon discharge, 40 ma (AR 45)

The list gives an indication of the research development and achievements of the mass spectrometric research of the Subdepartment. In the later years it greatly expanded in co-operation with the Department of Earth Sciences as deep sea sediments became the target for multidisciplinary research.

The expansion of research in the marine Quaternary, after many decades of study of the terrestrial sequence, uncovered totally new horizons and made possible a global view of Quaternary marine environments and climatic history, approaching a necessary balance with terrestrial studies, both required for an understanding of the earth's climate system in the Quaternary.

Chapter 9

Research; TL and ESR dating, palaeomagnetism, dendrochronology and dendroclimatology

(publication numbers, Figures 2l, 2m)

Thermoluminescence

In the 1970s TL datings were discussed in relation to radiocarbon dating programs, but not until the arrival of TL equipment in 1979, under an N.E.R.C. grant to N.J. Shackleton, did a programme of TL research start under the direction of A.G.Wintle. The equipment was brought into use the following year. Loess samples were collected from a variety of important sites in Britain and the continent, and the methodology and theoretical background were continually improved. A particular problem encountered at the beginning was the non-linearity of the TL response of older samples, but a successful programme of dating involved later Pleistocene loess sequences in Britain and the continent. In some cases it was possible to suggest annual loess deposition rates at particular times in Belgium and France from the results. Dating of beach and dune sands was also investigated. Sediments from important archaeological sites such as Swanscombe were also dated. In the 1980s investigations of cover sands in the Netherlands and Denmark were made, and a project by L.P.Zhou on Chinese loess sequences started, combining TL research with MS measurements. In 1992 a similar co-operative project started on the chronology of Tadjikistan loesses, with results suggesting a connection between dust accumulation and size of continental ice sheets.

ESR dating

With the arrival of R.Grün in the Godwin Laboratory in 1987 and the development of ESR equipment, a programme of dating of tooth enamel in relation to Palaeolithic archaeology began. The application of the method to mollusc shells and corals was investigated, and experiments were carried out to assess the ESR use of both geological and microcrystalline quartz for chronological studies.

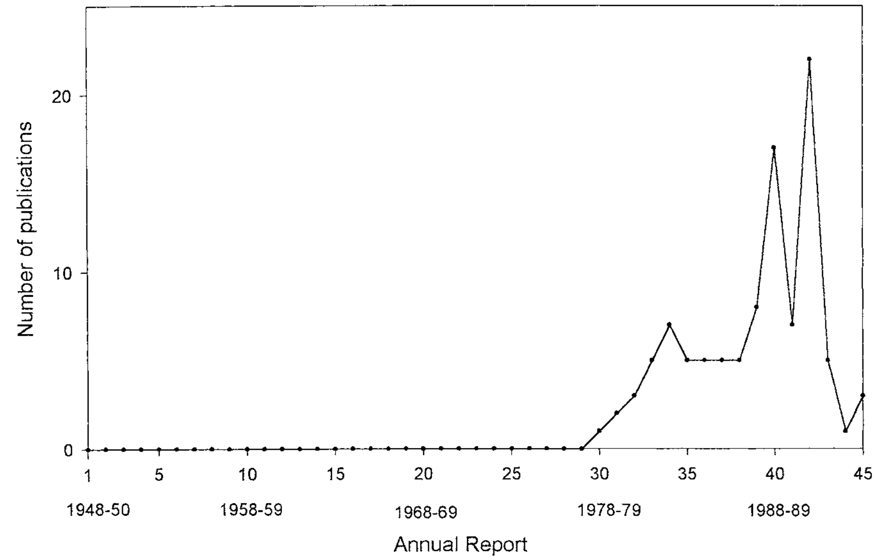


Figure 2l. TL, ESR, magnetics.

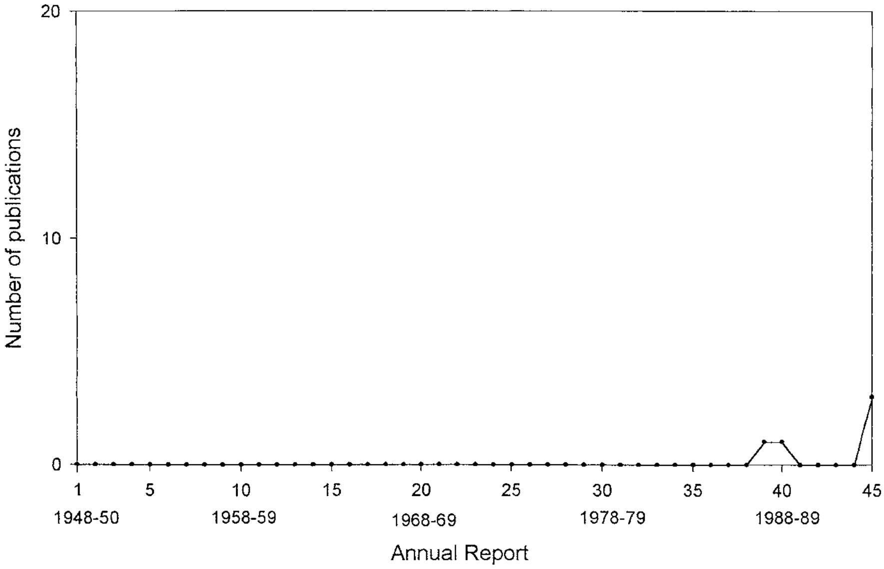


Figure 2m. Dendrochronology, dendroclimatology.

Palaeomagnetism

Though early in the 1970s attempts had been made in the Subdepartment to study palaeomagnetic properties of interglacial lake sediments, not until much later was the subject undertaken in more detail. In 1987 a portable magnetic susceptibility (MS) system was acquired for the measurement of deep sea cores or sediment samples and loessic sediments (AR 39, 40) . In subsequent years it was widely used for work in the field, ship-board, in core repositories, for loess palaeosol sequences, rock-shelter sediments and other terrestrial sediments, and also for archaeological site surveys. The equipment was in particular use for recognition and investigation of variation and cyclicity in ocean sediments, and also for the investigation of MS in Chinese loess sequences with palaeosols, where geographical variations related to post-depositional effects could be detected, perhaps related to local palaeoclimates. In relation to the latter, MS studies of loess sequences in major climatic regions were begun, and analyses were made, *e.g.*, for tephra layers in Flandrian sediments (AR 39, 43) and Greek cores (AR40).

The above techniques involved physical and geological sciences, with consequences for chronology and environmental interpretation. The background of co-operation in the Subdepartment and with the neighbouring Departments of Earth Sciences and Archaeology greatly facilitated the breadth of this work.

Dendrochronology, dendroclimatology

Collection of cross-sections of buried oaks from Fenland by V.R.Switsur began in 1976 with the long-term aim of investigating the possibilities of obtaining environmental information and developing a local dendrochronology master curve for Fenland. Collection continued over subsequent years, and analysis of ring width measurement and cross matching began. Investigations of timbers from Fenland archaeological sites, including Flag Fen, were made by N.A.Holman. Later, in 1985 the work continued in collaboration with M.Baillie in Belfast. Dendrochronological work was also extended to Crete and other Greek islands in a collaborative study of recent climatic change in that area. Timbers from local builings were later studied to aid their dating. The ring measurement equipment found an added use in the Subdepartment for the measurement of varved sediments and varve composition.

Work on Isotope dendroclimatology was started by V.R.Switsur in 1983. Measurement of oxygen isotopes in individual rings or parts of rings of oak were made and techniques developed to overcome the considerable difficulties. In collaboration with other Institutes and Universities, a programme of analyses of O, C and H isotopes from recent oak chronologies in East Anglia and Northern Ireland began in the early 1990s (oak, AR 35, M.V. Mullane; pine, AR 44, N.J.Loader). Similar research was extended to Europe in 1993, with the aid of EC funds. The experience gained in techniques associated with mass-spectrometry in the Godwin Laboratory greatly facilitated this field of research.

Chapter 10

Dissolution, achievements, reflections

Dissolution

In 1992, a committee to enquire into the future of the Subdepartment was set up by the General Board. Following the enquiries of this committee, the General Board made proposals on future developments in Quaternary science in the University (Cambridge University Reporter 1994/5), the essence of which was to replace the Subdepartment by the Godwin Institute for Quaternary Research. This came about at the end of 1994, and resulted in the disbandment of the Subdepartment. The academic staff and their associated assistant staff were assigned to other Departments: N.J.Shackleton and M.A.Hall to the Department of Earth Sciences, P.L.Gibbard to the Department of Geography, with V.R.Switsur and K.D. Bennett remaining in the Department of Plant Sciences.

The organisation of the proposed Godwin Institute for Quaternary Research involved a Director and an informal Advisory Board representing interests from various Departments, with the intention of embracing more effectively the many interests of the Quaternary community in the University. This change is reported in a foreword to the last of the Annual Reports (No.45, 1993/4), and in the first of the newsletter series of the Institute, named Camqua, issued in the Easter Term 1994. There was a hope that it would be possible to continue an Annual Report for the new Institute, but the series was discontinued.

The Annual Reports, as we have seen, portray the development of the subject on an international scale, reflecting the post-war expansion of sciences connected with environmental history and its analysis. By the 1990s the subject had become much expanded and its significance more widely. Collaboration was taking place between several Departments in three Schools of the University, as pointed out by the General Board's Report. Such collaboration had indeed existed since the time of the Fenland Research Committee, but the scale of activity, the widening of horizons, and the funding needs had obviously increased immensely.

The many areas of research covered in the life of the Subdepartment became specialisations of their own. Thus the archaeological interest in natural science was enlarged by the establishment of the MacDonald Institute of the Department of Archaeology and Anthropology, such areas as sea level change and periglacial studies became subjects in their own right, and glacial geology became more popular in departments of geology and geography. All these areas became focused by the development of international meetings and new funding arrangements such as the Science-based Archaeology Committee of the S.E.R.C. Research studentships, at first a few available from the D.S.I.R. and Nature Conservancy (which both supported research students in the Subdepartment soon after its inception), later much augmented as the subject expanded by awards of grants or studentships from the N.E.R.C., S.E.R.C., E.C. and other bodies.

It can be said that the Subdepartment acted as a seeding agency for Quaternary research in the University, as indeed its founder envisaged. On the one hand there was the spread of teaching into other Departments than Botany, the spread of collaboration in teaching (undergraduate and post-graduate) and research with other Departments, and the increased availability of funding from a variety of sources. On the other hand, the width of the evolved subject combined with the savings needed by the University, made it difficult to pursue life as a separate and effective institute within the Botany Department, where it had started because of the botanical interest in the first place. The subject exploded over the time of the Subdepartment, and the result was the end of the Subdepartment and the beginning of the Godwin Institute.

Achievements

These are clear from the accounts of individual research areas given above. In retrospect, from the research point of view, perhaps the most significant were both generated by Godwin, the establishment of the radiocarbon laboratory and the stable isotope laboratory. Both laboratories were the basis of many important advances. Also very significant was the development of Quaternary stratigraphy. From the standpoint of terrestrial stratigraphy in Britain, pollen analysis became an important technique giving evidence for the recognition of stratigraphical units, as already developed on the continent. The extensive experience of pollen analysis in the Subdepartment gave the edge to work in the Subdepartment at the time when Quaternary stratigraphy was under much more active examination in the early 1950s, with palaeontology beginning to contribute to stratigraphy on an equal level with glacial geology. In the marine area, on the much wider global scale, oxygen isotope stratigraphy was developed, with the co-operation which marine geology requires for success.

There was much done on the basic processes on which pollen analysis rests for its interpretation, for example, the relation between vegetation and pollen deposition, pollen dispersal, and numerical analysis of the data. Macroscopic plant remains were also investigated in similar ways. In these and other areas of palaeoecology, the expertise available in the Department of Botany and the presence of an excellent herbarium gave the research an invaluable advantage. The many geological contributions on stratigraphy and processes accompanied these developments, emphasising the importance of close interdisciplinary co-operation.

This interdisciplinary co-operation was based on the varied expertise of the staff of the Subdepartment and their interests naturally governed developments. These interests and the expertise were often wide, as with Godwin's in ecology, geology and archaeology. Added to these in later times were, for example, those of Walker (ecology, geology), Willis (chemistry, physics), Shackleton (physics, geology), Gibbard (geology, stratigraphy), and Birks and Bennett (ecology). The early members of staff had wide fields of activity, at a time when specialisation was hardly possible or advantageous. In the organisation, there was every opportunity to expand particular interests, as with Dickson (bryology), Shackleton (stable isotopes in archaeology, pre-Quaternary research), Birks (numerical analysis, the National Vegetation Classification).

These developments in interdisciplinary research were aided by the expansion of teaching, first by lectures and practical classes in various Departments, later by the institution of the M.Phil. in Quaternary Research.

There was thus a wide coverage of the many areas of Quaternary research in the Subdepartment. If one was to name an area where more research would have been timely and better developed it would be the integration of terrestrial and marine sequences via the available techniques such as pollen analysis.

Interdisciplinary research was encouraged in the Subdepartment's environment, which acted as a centre for the propagation of such research. As the subject enlarged, co-operation became wider within the University and with outside institutes and researchers. This was often stimulated by the demands for dating or environmental reconstruction. By the time the Subdepartment ended, in the early 1990s, any look at a Quaternary journal shows that most research reports were multi-authored, as indeed were those of the Fenland Research Committee in the 1930s, but with a huge increase of analytical power and variety of expertise.

Reflections

There are always certain problems in the successful development of interdisciplinary science. The most important is the establishment of posts. There is always competition for new posts or for permission to fill established posts, competition fostered by both funding problems and the needs of major Departments with large numbers of students. In the late 1960s five members of staff (or six if the Professor of Botany is included) were in post, a build-up from the late 1950s (Figure 1), declining to four members of staff at the dissolution. This can be considered a substantial achievement for an interdisciplinary subject, presumably supported by realisation of the significance of the subject in the wider scientific community. The expansion of the Subdepartment also provided a valuable niche for a number of inter-disciplinary researchers who might otherwise have fallen into the cracks between Departments and for whom the Subdepartment provided an excellent research opportunity.

A problem for members of staff in an interdisciplinary subject is the career structure. An interdisciplinary academic wants to keep in touch with the parent subject or subjects, yet develop essential contacts with cognate subjects. The career structure is not straightforward in a small establishment, and the possibilities of appointments to mainstream Departments has to be maintained. Nevertheless, the opportunities for research can result in greatly improved prospects.

I have already mentioned the value of the Department of Botany to developments in the Subdepartment. The Herbarium, with the associated expert taxonomists, was an essential support, but there were also botanists well-versed in ecological matters, such as plant succession, the detail of vegetation change and experimental taxonomy. Godwin had long experience of wetland ecology with his work on Wicken Fen and other wetland communities, and A.S. Watt likewise had carried out much analytical research on changes in the Breckland plant communities. Quaternary research placed these ecological studies in a long term historical context, as in the chronology of hydroseres, mires or forest development and transitions, and provided a very necessary but often neglected fourth dimension to the study of plant ecology.

Such support for Quaternary research from the plant sciences (and vice versa) has much to offer over and above these areas. One example is in the sphere of the history of ecotypic content or "speciation" within Linnaean species. One of the weakest points in the environmental interpretation of fossil assemblages is the lack of knowledge of ecotypic variation in living species. Here the contribution of topics involved in the biology of plant systematics and evolution, such as isozyme and DNA analysis, will be significant when considering the effects of climatic change against the background of the historical element offered by Quaternary research, e.g. in the form of preserved seeds or fruits of known age. In this respect the loss of Quaternary research to botany departments is unfortunate, and opportunities for new interdisciplinary research may be lost or hindered.

My account is written from my own perspective, with principle interests in palaeoecology and stratigraphy. I leave to others more detailed consideration, on one hand of the contributions of physics and chemistry to these developments, on the other hand of the place of these developments in the wider field of the environmental sciences. On the personal level, looking back at this history, I realise how fortunate I was to be involved from the early days of the Subdepartment, and how much was owed to Godwin for his leadership in the establishment and enlargement of the Subdepartment. There is no better summary of his contribution than that given in his 1970 Festschrift (Walker & West 1970): "Harry Godwin entered Cambridge University as an undergraduate in 1919 and remained there until his retirement from the Chair of Botany in 1968. In the intervening years his enthusiasm, industry and humanity have been inexhaustible sources of stimulus and guidance to innumerable students and colleagues. The aurthors of these essays offer them in gratitude for having had an opportunity to share in the excitement."

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Part III

A wider view

Introduction

Connections between developments in Quaternary research in Scandinavia, north-west continental Europe and Britain have already been mentioned in Parts I and II. A wider perspective of the work of the Subdepartment may be obtained by considering some aspects of developments in the subject which are seen before and during the time of the Subdepartment. These concern particular fields of research and also matters in the wider academic environment. They are not intended as a history, but rather a reflection of some of my own interests.

Chapter 1

Aspects of the geology

Stratigraphy: the search for a system

Lamplugh's presidential address to the Geology Section of the British Association in 1906 (Lamplugh 1906) can be taken as a starting point for a view of the history of the vexed subject of Quaternary stratigraphy. He wrote '… now I find confronting me an intractable mass of facts and opinions, of my own and other people, terribly entangled, out of which it seems to grow ever more difficult to extract the true interpretation. That the glacial deposits possess some quality peculiarly stimulating to the imagination will, I am sure, be recognised by everyone who has acquaintance with glacialists or with glacial literature.' His view will be shared by many today.

By the time Lamplugh wrote his opinions on the subject of 'British Drifts and the Interglacial Problem', the drift in Britain had been extensively described or mapped, as for example, the work of S.V.Wood Jr and F.W.Harmer in the eastern counties, described by Harmer (1908) Some ten years earlier James Geikie (1895) had produced his scheme for the classification of European glacial deposits, totalling six glacial epochs and five interglacial epochs, influenced by Croll's ideas of changing astronomical conditions producing recurrent climatic change. Lamplugh thought that if Croll's theory could be sustained 'it would have given into the hands of the geologist a first instalment of that absolute measure of geological time which which he so ardently desires', more recently given by the advances relating to the work originated in the 1930s by Milankovitch's development of the Astronomical Theory. However, Lamplugh searched for geological substantiation of the Geikie system, and after considering evidence for multiple glaciation and the existence of interglacials in Europe, concluded that it was premature to attempt the arrangement of British drifts on the Geikie basis, and that the British evidence for the Interglacial hypothesis was nowhere satisfactory. '.. it is useless to set about the solution of our intricate problem until we have all the factors at command'.

Soon after this Penck and Brückner's (1909) scheme for the central European alpine glaciations, a local scheme with a geomorphological basis, as it was described by van der Vlerk (1955), set the 4-fold glacial event history of Günz, Mindel, Riss and Würm which became in the following decades a widely-used, even global, scale for divisions of glacial and related events. W.B.Wright's 'The Quaternary Ice Age' of 1914 starts with a remark that 'the study of glacial geology has of late years made such strides that it is no easy matter to keep abreast of recent developments', a view which has been re-stated by many writers of books on the Quaternary to the present day and will continue to be as the available knowledge inexorably expands.

The book covered a wide group of subjects – glacial geology, stratigraphy, fauna, archaeology, the astronomical theory of climatice change and many related topics. Wright paid especial attention to the Isostatic Theory of sea-level oscillation and dedicated the book to 'T.F.Jamieson, originator of the Isostatic Theory'.

Following Wright's book, a succession of contributions on the Quaternary of Britain were published, a witness to the expanding interest of the Quaternary in many disciplines. These may be mentioned, with their particular interest: Kennard (1916, a malacologist), Kendall (1917, a geologist), Brooks (1919, a meteorologist, discussion in detail of correlations with the continent of Europe), Warren (1924, an archaeologist) and Slater (1929, a geologist). In this period, continental research had expanded greatly, with chronology improved by de Geer's contribution on varves, stratigraphy improved by the work of geological surveys, as in Sweden, Denmark, and Germany, and in palaeontology with increased knowledge of faunas and floras, both cold stage and temperate stage. The German division of Elster, Saale and Weichsel (names based on rivers and areas of glaciation) came into use in the 1920s (Woldstedt 1929, 1934, 1954, 1955). Jessen and Milthers' (1928) landmark account of interglacial vegetation history in Denmark and north-west Germany, a combination of botanical and geological expertise, was published. Gams' (1930, 1935) reviews of palaeobotany and microstratigraphy (pollen analysis) and its relation to the division of the Diluvium of central, northern and eastern Europe offered a summary of the situation at the time.

The second edition of Wright's book appeared in 1937, dedicated this time to 'R.L.Praeger, discoverer of the Climatic Optimum'. Prefatory remarks noted that 'The second edition has required ….. little modification, but considerable amplification of various parts of the subject has been rendered essential by the progress of research.' Also, that the Interglacial Question was more exhaustively treated, that there were considerable advances in British and European drift studies, and that the interlocking of these with the stages of the archaeological succession gave hope for correlations. The 'masterly generalisations of Breuil' in reference to archaeological nomenclature (e.g. as given by Breuil 1939) were also noted. However, 'we are hardly in a position to construct correlation tables of use to anyone except the maker. It is recommended therefore that the reader should compile his own. He will find it a useful and entertaining exercise, which will prevent many parts of the book becoming dull.'

The relation between the British Pleistocene sequence and those of the continent began to be explored in more detail after about 1935. The matter must have been stimulated by Zeuner's (1935) detailed account of the Pleistocene chronology of central Europe, based on lectures he was invited to give by W.B.R.King at University College, London. Boswell (1936), Zeuner (1937) and Woldstedt (1934, 1950) discussed correlations between Britain or the British Isles and the Alpine and north German sequences, including the stratigraphy, palaeontological and archaeological evidence. Woldstedt (1950) reported pollen analyses by Paul Thomson of organic beds of the Cromer Forest Bed Series at West Runton, the samples collected during a field excursion of the 1948 International Geological Congress in London; these gave an important new light on the vegetational history of an older part of the

Pleistocene, with a suggestion of a relation to the Günz-Mindel Interglacial of the Alps.

Bull (1942) wrote a review of the Pleistocene succession in Britain, with lengthy discussion contributions by numerous researchers, a useful reflection of the state of Pleistocene stratigraphy at the time. The correlation table of this paper shows glacial events separated by intervals described as interglacials and named after particular terraces.

On the continent, a very significant development in the early 1950s was the formulation in the Netherlands of a series of local stages in the Quaternary characterised by their geology and palaeontology, a combination produced by the geologist, I.M.van der Vlerk and the botanist, F.Florschütz (1950, 1953). They described the sediments, fauna and flora of sequence of stages (1-7 below), with the nomenclature based on type sediments (temperate stages: Tiglian (2), Needian (4), Eemian (6)), or areas where the sediments were displayed (cold stages: Taxandrian (3), Drenthian (5), Tubantian (7)), with the Praetiglian (1) preceding the Tiglian and marking the first clear cold stage of the Quaternary. This work showed how a local Quaternary sequence could be established without resort to the pervasive Alpine nomenclature. Especial significance was paid to the possibility of using interglacials as a starting point for a classification (van der Vlerk 1955). The publications of van der Vlerk and Florschütz gave the most important syntheses of Quaternary straitgraphy in north-west Europe yet made, based on extensive stratigraphy and knowledge of the fauna and flora, and erecting a local scheme with defined subdivisions which gave the independence from the Alpine sequence deemed necessary by van der Vlerk. These advances resulted from an appreciation of stratigraphical principles and showed what could be done to advance the state of Quaternary stratigraphy.

A move towards the same feeling was earlier expressed by Arkell (1943) in his account of the raised beaches of the north Cornish coast. He discussed the problems of applying continental schemes, such as those of Penck and Brückner and Breuil's Somme sequence (Breuil 1939), with all their problems, to Britain. He said ' it was essential to find a classification and nomenclature free from such ambiguities and independent of assumed but unproven correlations'. He issued a clear-cut call for a more local terminology and established an independent framework for the limited area of his own research, carrying it over to the Midlands and the Thames in a scheme which involved four glaciations, with initials in alphebetical order to aid the memory: Berrocian (Be), Catuvellaunian (Ca), Cornovian (Co) and Cymrian (Cy). The names relate to areas or tribal territories where the sediments are well-developed. The use of tribal areas in stratigraphy has not been uncommon, e.g. Taxandrian in the Netherlands, Devensian in the British scheme.

Thus there are 'type' areas, but not 'type' sections. Arkell (1947, 1951) developed this theme more widely to the Thames terraces and London basin. The division into units was based on the glaciations, as named above, and interglacials, in which river terraces played a significant role. The latter provided the evidence in terms of fauna and artefacts, which indicated interglacial conditions. The complexity

Plate 38. F.W.Shotton, left, examining an elephant tooth at Waverley Wood Farm, Leamington Spa, 1989 (Subdepartment Archive).

of terraces is now better recognised and understood, with components related to fluviatile conditions in both cold and temperate stages.

Shotton (1953) (Plate 38) in his classic account of the Midlands Quaternary related his succession of glacial stages to Arkell's scheme, and to the sequences in The Netherlands and northern Germany, but omitting Eastern England and the Lower Thames because of the 'points of dispute and variety of interpretation between those areas'. The main glaciation in the Midlands was correlated with Arkell's Ca glaciation, the Drenthian of The Netherlands, the Saale of Germany and the Riss of the Alps, with a substantial case made for such a correlation of British with continental glaciations. The contributions of Arkell and Shotton (both with very major achievements in pre-Quaternary geology) can be seen to be central to the change from the use of continental to local terminology for defined subdivisions of the Quaternary in Britain, following the philosophy of van der Vlerk and Florschütz in The Netherlands.

In 1955 W.B.R.King gave the Anniversary Address to the Geological Society on 'The Pleistocene Epoch in England' which reviewed the recent advances in the Midlands, Thames valley, East Anglia and northern Britain, and the fixing of the Plio-Pleistocene boundary. The address had the advantage of giving a personal view of developments. He noted the arguments for local stratigraphical nomenclature, as proposed by van der Vlerk (1955) and that 'more objective thinking would be possible if the Alpine nomenclature of Penck and Brückner were not used in Britain.' He also 'thought it might be help if a committee were set up, not to try to formulate correlations, but to propound an agreed nomenclature for the English divisions of the Pleistocene deposits'. In the 1960s the Quaternary Era Sub-committee of the Geological Society started to discuss such matters.

The arguments for developing a local stratigraphy were complemented by van der Vlerk's (1955) suggestion in relation to Pleistocene stratigraphy, that 'would it not be more efficient to take the interglacial deposits instead of the glacial ones as starting points ' for the subdivision of the Pleistocene, because of the difficulties of interpreting the variety of sediments (moraines, terraces, etc.) associated with glacial (or stadial) events. He discussed the fauna and flora associated with four successive interglacial times then known in The Netherlands, Eastern England and Germany.

The East Anglian Quaternary was known to have an extraordinarily rich record of sites, many unstudied since the nineteenth century, and it was realised that van der Vlerk's concepts could be applied to the East Anglian Quaternary. Thus West (1955, also 2000a) distinguished three interglacials on stratigraphical grounds, supported by the available palaeobotanical evidence. They were correlated with the three interglacials (nomenclature of Woldstedt 1954: Cromer, Holstein, Eemian), and thus Quaternary sequence, of north Germany. The succession so distinguished in East Anglia was offered as 'a working basis which accords with present evidence, and which will provide the hypotheses on the testing of which future work may turn.' Later, stages were distinguished in the Lower Pleistocene on the same principles (Funnell 1961; West 1961). A survey of the division of the Quaternary in Britain using stage names, on the principles put forward by van der Vlerk and Florschütz, recognised a number of cold and temperate stages in the Lower, Middle and Upper Pleistocene (West 1963). At the same time an International Stratigraphical Lexicon for the Neogene and Pleistocene of Britain was published (Oakley & Baden-Powell 1963). This gave useful accounts of stratigraphical terms which had accumulated over the years to describe particular units.

In the 1960s international moves to establish stratigraphical codes and usage gained momentum. The Stratigraphical Code Sub-Committee of the Standing Stratigraphical Committee of the Geological Society was set up and reported in 1967 ('Code' 1967). Soon after 'Recommendations on stratigraphical usage' were published by the Geological Society ('Code' 1969). An appendix to this gave a stratigraphical table for the British Quaternary, drawn up by the Quaternary Era Sub-Committee of the Stratigraphy Committee of the Geological Society. This table gave a list of stages, with type localities and the lower limits of stages defined by reference to lithostratigraphy or pollen zone boundaries. In essence, this was a product of the van der Vlerk way of developing Quaternary stratigraphy.

This tabulation and its principles were brought before a discussion meeting of the Geological Society in 1969, whose proceedings were published in 1970 ('Code' 1970). This discusssion produced a number of criticisms, amongst which were: the tabulation was premature, there was a multiplicity of local names, the balance of the application of lithostratigraphical and biostratigratigraphical principles was a problem, the term Devensian was unnecessary. It was pointed out that the table of stages in the Code (1969) was intended to provide a framework, based on the evidence at that time, for a formulation of a Quaternary stratigraphy according to the recommendations concerning stratigraphical nomenclature. It was recognised that future investigations would certainly result in modification.

These discussions led to the publication of the Geological Society's 'A correlation of Quaternary Deposits in the British Isles' (Mitchell *et al.* 1973), which brought together stratigraphical details and nomenclature (up to 1 January 1971) for nine principal regions of the British Isles, including regional stages for Ireland. Correlation of these on the basis of standard stages as envisaged in the 1969 table was given in regional tables. So King's suggestion of 1955 was finally met. The effect of the classification is seen in its widespread use in the volume of 'British Quaternary Studies' (Shotton 1977), produced on the occasion of the INQUA meeting in Birmingham in 1977.

By the 1960s and 1970s the study of sediments of the oceans had led to the emergence of the marine oxygen isotope stratigraphy (e.g. Shackleton & Opdyke 1973), with an understanding of its significance in offering interpretation of palaeotemperatures and global ice volumes over the time span of the Quaternary. Discussion of the relation between terrestrial and marine stratigraphy became possible (e.g. Shackleton & Turner 1967; Shackleton 1967; Mangerud *et al.* 1979). This advance clearly demonstrated a much greater complexity of Quaternary environmental changes, as shown in the oceans, compared with that identified in terrestrial sequences. The use of the new detail was allied with many developments in geochronology, such as radiocarbon dating, TL, ESR and OSL dating, magnetic polarity, together with amino-acid chronology. The application of the new dating techniques (see e.g. Smart & Frances 1991) allowed chronology to be developed on a much firmer basis. In addition, studies of polar ice cores and the refinement of the relation between Milankovitch cycles and the stratigraphy of marine sediments and ice accumulations further improved chronological insight.

The revision of the 1973 correlation paper by a further committee of the Geological Society (Bowen 1999) incorporated many of these developments. It provided a longer and informative introduction to the history of the subject, greatly added stratigraphical details, and included a separate section on the Thames Valley and a section on the continental shelf.

In the search for a general system to relate geological observations of evidence for climatic change, such as that demonstrated by glaciation, to wider causes of climatic change, the astronomical theory of climatic change caused by variation of the earth's orbit and axis has taken precedence, with contributions over a long period of time by Herschel, Adhémar, Croll, Ball and, most importantly, Milankovitch (see Zeuner 1959; Imbrie & Imbrie 1979). Milankovitch cycles, if they can be identified in sedimentary sequences, may provide a global scale for chronology, as envisaged by Lamplugh. Other systems which have gained more than local application have also arisen, including Penck & Brückner's Alps scheme, systems based on Palaeolithic industries, the Eustatic Theory (see Zeuner 1959), the identification of global oxygen istope stages in marine stratigraphy and the chronologies related to the advances in dating techniques.

At the other end of the scale of these complexities are the terrestrial sequences, local to particular areas, expressions of the particular climatic changes in each of those areas, which have to be married to the wider schemes. Successful correlation should lead to the clarification of the relation between local terrestrial and regional marine sequences (Gibbard & West 2000), and this will lead to clarification of ocean/atmosphere relations in different parts of the globe. There always has been a temptation to relate local sequences to a wider chronology, as seen in the wide use of the Penck and Brückner scheme in the early part of the last century, and indeed this was a necessary part of the process of progress. But the danger was that use of the system was liable to slow advances in stratigraphy, as recognised, for example by Arkell and van der Vlerk. There is clearly a danger that reliance for local correlation on a wide regional or global system of stratigraphy might inhibit advances in local stratigraphies, as discussed by Langford (2002; the 'reinforcement syndrome'). But we have to start somewhere in correlation, and provided the problem is recognised, advances will be made which are supported by the construction of secure local stratigraphies which contribute to a wider more regional or even global framework.

Sediments and structures

In this long-standing and classic area of Quaternary research, involving both stratigraphy and processes, much has been learnt in the last few decades. Certain of these developments are reflected in the *Technical Guides* of the Quaternary Research Association. These started in 1984 and included guides on sediments, dating, and many other fields of research.

Whiteman (2000) has discussed the history of advances in till studies and genesis in East Anglia. The problem is the distinction of tills derived from ice advances from particular directions, associated with their stratigraphic relation. Following Harmer's (1928) detailed studies of the distribution of erratics in eastern England, provenance studies were continued by Baden-Powell (1948). Solomon (1932,1935) studied the heavy minerals in glacial and pre-glacial sediments, and this approach was extended by studies of mechanical and mineralogical composition of tills in eastern England by Perrin *et al.* (1979). Even so, problems of direction of ice movement and age of tills still remain (Whiteman 2000). Studies of the provenance of far-travelled clasts in gravels, marine and fluviatile, were carried out by Hey (1967, 1976). Such studies, based on clast analysis, became increasingly important in the recognition of river systems of the Middle Pleistocene in areas marginal to glaciation. Knowledge of the finer periglacial sediments, including loess and coversand (Catt 1977), has also greatly increased, in terms of stratigraphy and age, the latter much enhanced by the development of luminescence dating.

Till macro-fabric studies started in the 1950s (West & Donner 1956). Studies of genesis of tills and deformation of glacigenic sediments expanded in the 1980s. The 'glacial tectonics' papers by Slater (1926, 1927) were pioneer in this respect. He had started to draw the Norfolk coastal sections in detail in 1919 and continued this work to 1928. These coastal sections have continued to receive intensive study since that time (Whiteman 2000).

Knowledge of the stratigraphy of sediments of the continental shelf has increased hugely in the last few decades, as seen by comparing the account of the Quaternary of the North Sea by McCave *et al.* (1977) with the contribution on the shelf stratigraphy in the later correlation paper (Bowen 1999) by Cameron & Holmes (1999).

Subjects which have benefited by these advances are depostional processes, till stratigraphy and chronology, periglacial geology, the geology of the continental shelf, and the recognition of the complexity of sequences associated with a fluviatile regime, such as are found in river terraces, which in many cases, if not most, reflect environmental changes of more than one stage.

Periglacial phenomena

Periglacial effects were illustrated or discussed in publications from an early date. Thus J. H. Blake drew features in his coastal sections at Corton, Suffolk, very similar to thermal contraction cracks, in places where they were much later seen to be such cracks, a testimony to his powers of observation (Blake 1884; Gardner & West 1975). Marr (1920) drew a section he saw in the Traveller's Rest Pit (Observatory Gravels) which clearly showed the presence of striking thermal contraction cracks, with detailed structure, coalescing and diverging as the quarry extended. They were explained in terms of 'subterranean erosion'.

Clement Reid described involutions in coastal sections of Norfolk and discussed the possibility of their origin in freeze/thaw effects (Reid 1882). He later (Reid1887) discussed the origin of dry valleys and Coombe Rock in Sussex in terms of cold climate effects. Solifluxion phenomena in the Lake District were described by Hollingworth (1934), who made reference to Hogbom's (1914) classic paper on frost effects. The significance of Coombe Rock as a stratigraphical marker and climate indicator in the Lower Thames area was appreciated by King and Oakley (1936). Paterson (1940), with the benefit of observations in Baffin Island in the Canadian Arctic in 1934, described in considerable detail vertical and horizontal sections through the contraction cracks at the Travellers' Rest Pit in Cambridge (previously described by Marr), as well as involutions seen in the same pit, with a discussion of their origin in terms of periglacial climate.

The two volumes of *Geologische Rundschau* devoted largely to Quaternary geology and climate of 1944 (Bd 34, edited by C.Troll, with a translation of the contained paper in Troll (1958)) and 1952 (Bd 40, edited by M.Schwarzbach) reported much valuable reseach on periglacial matters, as did reports on permafrost matters in northern North America (e.g. Muller 1947). The founding of the journal *Biuletyn Periglacjalny* in 1954, editor Jan Dylik, quickened research, which rapidly expanded into the many areas now included in periglacial research, including patterned ground, pingos, involutions, solifluction, and climates The INQUA Meeting in Poland in 1961 with excursions directed by Dylik encouraged these developments. In Britain, Te Punga (1956) made an early survey of periglacial phenomena in southern England and Worsley (1987) summmarised progress in developing a permafrost stratigraphy. The width of further developments in Britain and Ireland are illustrated in the collection of contributions edited by Boardman (1987) and the book by Ballantyne and Harris (1994).

Palaeopedology

Recognition and description of buried soils has long contributed to Quaternary stratigraphy, as with the soils which divided units of the loess stratigraphic sequence in Europe. The subject revived in Britain with the archaeological interest in buried soils, shown by the publication of Cornwall's (1958) book on soils for archaeologists. Dalrymple (1956) applied methods of soil micromorphology to buried soils, using thin sections, and Osmond (1956) reviewed the development of such studies. Soils within Quaternary sequences began to be studied more intensively subsequently, with soils in loess sequences and glacigenic sequences being described (see Valentine & Dalrymple 1976). By the 1980s, a review by Rose *et al.* (1985) of palaeosols in the British Quaternary reported on palaeosols with formal type sites in the East Anglian Quaternary of soils formed in temperate and interstadial times. Kemp's (1987) study of a buried Middle Pleistocene soil near Ipswich, Suffolk, exemplifed the rapid advances made in this area, with conclusions regarding age, genesis and environmental significance. Palaeontology associated with buried soils was developed at the same time with contributions, for example, by Dimbleby (1955; see also Godwin 1958) on pollen in soil profiles and Kerney (1963) on molluscs.

Geology and archaeology

The close relation between geology and archaeology, arising in the eighteenth century and crystallising in the nineteenth century, is now widely recognised. Daniel (1975) has given a historical account of the relationship, brought into prominence in the middle of the nineteenth century by the question of the antiquity of man. Prestwich and Evans, a powerful combination of geologist and archaeologist, carried the day, but not without some misgivings on the geological side about the realities. Thus around 1859 Godwin-Austen wrote to Prestwich "The Antiquity of Man question,….., is doomed to be damaged by bad evidence and worse reasoning." "The only thing that can save us is to restrict us to the Silurian system for a year or so." (G.A.Prestwich 1899). But by the end of the nineteenth century, a vast amount of data had accrued on the relationship, reflected in the title of the three editions (1874-1894) of James Geikie's comprehensive book on 'The

Great Ice Age and its relation to the antiquity of man'. Geologists were involved in the controversies relating to eoliths and rostro-carinates in the early part of the twentieth century, since proving the antiquity of these flints was the task of geologists, regardless of the views about their true nature (see Coles 1968).

The later controversy surrounding the Piltdown finds in the early 1900s did nothing to help the relationship, with scepticism reflected in the remark by R.A.Smith at the time that the whittled elephant bone from Piltdown "that he could not imagine any use for an implement that looked like part of a cricket bat" (discussion, in Dawson & Woodward 1915). With the forgery exposed in the 1950s (Weiner *et al.* 1953; Weiner 1955), facts about the finds were made clear, though much subsequent discussion has taken place about the perpetrator(s) (e.g. Spencer 1990).

A landmark was the purposeful re-investigation of the Hoxne (Suffolk) Palaeolithic site, first described by Frere (1800), by a Committee of the British Association in 1896, with the aim of clarifiying the relation of Palaeolithic man to the Glacial Epoch. The report by the secretary of the Committee, Clement Reid (1896), is a model of geological observation, allied to vegetational and climatic history, leading to a clear conclusion. The success was due in large part to Reid's geological experience, combined with his knowledge of plants as fossils and living.

Artefacts in Quaternary sediments came to be regarded as fossils, as, for example, by J.E.Marr (1920) in relation to his account of the Pleistocene of the Cambridge area: "we may now pass to the consideration of the fossils, including the implements." Marr was one of a group of distinguished geologists, mainly concerned with Palaeozoic matters, who took a strong interest in archaeology, especially Palaeolithic, and the relation to stratigraphy. They included W.J.Sollas, McKenny Hughes, W.B.Wright, O.T.Jones, P.G.H.Boswell, W.B.R.King, W.J.Arkell and F.W.Shotton.

In the early 1930s Boswell contributed much discussion to the relation of geology to early man, particularly in an address to the Geology Section of the British Association (Boswell 1931, 1932). King's co-operation with K.P.Oakley (King & Oakley 1936) formulated a history of the Lower Thames terraces allied to the archaeology. The artefact nomenclature of the Abbé Breuil and the results of his work on the succession of Lower Palaeolithic industries in the Somme Valley (e.g. Breuil 1939) were applied to the classification of the Thames Pleistocene by King & Oakley. Arkell (1951) noted that the succession of Paleolithic implements had been used as a principal criterion for correlation of deposits of the Lower and Upper Thames by King & Oakley and himself. The use of Palaeoliths as fossils in this way had been considered by Hazzledine Warren (1924) in his Presidential Address to the Geologists' Association on 'Pleistocene Classifications'. Here he purposely took the human culture stages of France as a basis for a time scale, 'done as an experiment, in order to see how matters will work out on this basis.' The resulting table showing the relation of the culture stages to the succession of ice ages as proposed by 12 authorities, including Penck and Brückner, illustrates the difficulties. After considering these, Warren concludes 'my general moral of the whole matter is that we need less theory and more facts, such as members of the Geologists' Association may harvest from the fertile soil of England'.

However, the contribution of archaeology to stratigraphy remained significant for some time, as we have seen. A reflection of the state of affairs in the 1940s is given in the paper by Bull (1942) on Pleistocene chronology, which refers to, amongst the stratigraphical terms, the Late Acheulian Glaciation. The long discussion on this paper summarises the views prevalent at the time with many researchers.

In the 1950s, however, the wide recognition that stratigraphical principles were of over-riding importance reversed this situation. Zeuner (1959) in the preface of the second edition of his book 'The Pleistocene Period' wrote that 'Pleistocene chronology is the clock by which archaeological, or rather Palaeolithic time, is to be measured, and it makes nonsense of time-counting to use as clocks the very objects it is desired to time.' Time has strongly re-inforced this logical view, especially following the much increased knowledge of the chronology. The work of Palaeolithic archaeologists, notably J.J.Wymer, has contributed much to this change of view, as he has discussed in his review papers (Wymer 1974, 1988), with a resulting much clearer relationship of Palaeolithic industries to the stages of the Pleistocene.

Inter-disciplinary research on the lines pioneered by Clement Reid has now become the rule in investigations of Palaeolithic and later archaeology. Reid, in addition to his Palaeolithic interests, worked on the plant remains of Neolithic and Roman sites, combining the results in his classic book on the 'Origin of the British Flora' (Reid 1899). Such work has extended to many groups of organisms as well as the sedimentology of sites, and to much improved dating techniques. Such work started in earnest with the Fenland Research Committee in the 1930s, and with the Star Carr excavations twenty years later, as described in Parts I and II. The demand heard in the early 1950s from archaeology for 'men in white coats' has indeed been answered. The Science and Engineering Research Council's institution in 1978 of a Science-based Archaeology Committee providing research support greatly improved the development of scientific applications to archaeology, especially in the physical and biochemical areas (including biomolecular archaeology). The founding of the Association for Environmental Archaeology in 1979 bought together many researchers involved in excavations and research laboratories throughout the country.

Thus the relation between geology and archaeology has been totally transformed during the time of the Subdepartment, as witnessed also in its own achievements.

Dating

The early years of the Subdepartment co-incided with the advent of radiocarbon dating, producing a revolution for dating, previously dominated in north-west Europe by de Geer's varve chronology in Scandinavia (later compared with radiocarbon chronology by Tauber 1970). By the time of the closing of the

Subdepartment in 1994, there had been a huge expansion of dating methods, both physical and chemical, and the development of dendrochronology, as may be seen by reference to the books on the matter by Aitken (1990) and Smart and Frances (1991). Similarly in the marine sphere, sub-division of the deep-sea palaeontological record by the relation of datum levels (biohorizons) to oxygen isotope stages, magnetic reversals and potassium/argon dating has led to well-developed marine chronologies (e.g. Berggren 1980), with the possibility of Milankovitch cycles also aiding chronology. Comments on certain of these developments follow.

Radiocarbon dating

Publication of the first radiocarbon dates in the early 1950s was followed by much investigation of the method, both in relation to the stratigraphical or sedimentary context of the samples and to the factors which affected the radiocarbon content of the samples. It took several years of such research to establish a satisfactory interpretation of the radiocarbon assays. This was assisted by comparison of assays of tree rings in known dendrochronologies, and by studies of sources of error in terms of contamination by intrusive sources of radiocarbon. Some early events in the history of the application of the method are worth mention as illustration of the problems. In the late 1950s, the possibility of dating the late Eemian and last glacial interstadials aroused great excitement, especially since one of the sites dated was the interstadial site at Chelford, Cheshire. The development was a result of assays at Groningen by H.de Vries (1958), using a large counter. Later, using isotopic enrichment (Haring *et al.* 1958), it was suggested the method could be used to extend back to 70000 years. Dates were suggested for early interstadials, such as 64000 (before the present) for the Amersfoort Interstadial of the Early Weichselian in The Netherlands. A chronology for the Weichselian was developed over the next few years (Denmark and The Netherlands: Andersen, de Vries & Zagwijn 1960; The Netherlands: van der Hammen *et al.* 1967). Later the difficulties of accepting these ages in relation to other evidence of age became apparent, with a much greater age indicated for the Early Weicheslian interstadials. The clarification of these problems owed much to the publication of the radiocarbon assays in detail in the journal *Radiocarbon* (volume 1, 1959).

Later, an instructive controversy arose when N.R. Page (1972) described radiocarbon assays from East Anglia which telescoped all the glacial sediments of East Anglia into the last glaciation. Shotton (1973) commented on Page's sequence in terms of the samples assayed and their interpretation, pointing out the width and variety of the evidence which controverted the consequences of Page's assays.

Such matters as these led to a much closer understanding of the interpretation of assays, also encouraged by the needs of archaeologists in their search for satisfacory dating. Thus, Waterbolk (1971) stated a series of propositions with the aim of improving the utilisation of radiocarbon dates in archaeology, underlining the problems involved. Radiocarbon chronologies were also affected as understanding of variation in atmospheric radiocarbon concentration increased. The straightforward use of a simple decay curve based on constant concentration was replaced by curves which showed for example a plateau in the curve (Mellars 1990), or by evidence for variation in concentration by discrepancies with tree ring data (e.g. Friedrich *et al*. 1999) or other evidence for age (e.g. Beck *et al*. 2001). The relation of radiocarbon dates to other dating evidence has lead to the production of calibration curves and tables attempting to establish the relationship, and portrayal of dates in relation to these calibrations has been a subject of much discussion (e.g. Gillespie & Gowlett 1986).

The time limit of satisfactory dating is still a matter of opinion. The older dates above, say, 30000 years, have increasing likelihood of errors due to contamination, added to which may be the effects of changing atmospheric radiocarbon concentrations (e.g. Gowlett & Hedges 1986). But many assays are beyond this figure, and still need to be treated with care and careful examination of stratigraphical context.

The small number of radiocarbon laboratories in the United Kingdom in the 1950s (British Museum, Institute of Archaeology (University of London), University of Cambridge, National Physical Laboratory) was later increased (including the University of Birmingham, the Queen's University (Belfast), University of Wales at Cardiff, A.E.R.E. Harwell), with the Natural Environment Research Council Radiocarbon Dating Laboratory at East Kilbride playing an important role from 1972. This contributed to assays in many areas of Quaternary research and effectively encouraged the wider use of dating (Bowen & Harkness 1986).

In the late 1970s radiocarbon dating using accelerator mass spectrometry was developed (Mast 1978), and the Science-based Archaeology Committee of the Science Board of the Science and Engineering Research Council awarded a special grant to Oxford University for the an AMS laboratory, which became effective in 1983. The method allowed the use of samples of as small as 1mg of carbon, hus opening up new horizons not only in archaeology (Gowlett & Hedges 1986), but other areas of Quaternary research. The advance was parallel in effect to the great reduction in sample size which became normal in oxygen isotope analysis in the late 1960s.

Other dating methods

The development of first TL (1950s), and later ESR and OSL (1970s and 1980s) dating, described by Aitken (1990) and Smart & Frances (1991), made possible the dating of fine-grained sediments such as loess and coversands, as well as calcites and components of bones and teeth. This added a battery of dating methods, and allowed a chronology of sediments and thus environments, complementing the dating evidence of organic materials by radiocarbon, and offering the possibility of checking chronologies derived from a variety of methods of dating.

Chemical methods

In the 1940s the possibilities of dating by fluorine content of bone were advanced by Oakley (1948). He proposed that the method should be used to determine relative ages of fossil human bones, including investigation of the Piltdown finds.

The method, based on increasing fluorine content with age, was later tried out in the 1950s for determining longer Quaternary chronologies in Europe, as by Richter (1958). But its particular use since then has been mainly in relation to archaeological contexts in more recent time. Since the late 1960s analysis of D/L ratios of non protein amino acids in fossil shells has been used to construct amino acid chronologies, since epimerisation is related to age of the fossil and to subsequent burial history (Sykes 1991). The ratios give relative ages of shells, both marine and freshwater, at different levels at a site and between sites, with a resultant aminostratigraphy. The chemistry is complex, being dependent to a degree on envirionmental conditions during the life of the organism and on conditions of preservation, but the use of the method contributes to assessment of relative age (see McCarrol 2002).

Dendrochronology

Following the pioneer work of Douglass on dendrochronology in south-west U.S.A. in the 1920s, research on European dendrochronology developed in the 1940s, in relation to the relative dating of archaeological sites. With the introduction in the 1960s of computers and statistical approaches, the subject greatly expanded, and provided an absolute dating method which could be allied to radiocarbon dating to test chronologies. A 7000 year chronology for western Europe was put forward in 1984 (Pilcher *et al.* 1984). Since that time, chronologies have been published for times back to c.12000 BP (Friedrich *et al.* 1999), supporting interpretation of radiocarbon dates, and providing a well-dated source for dendroclimatological studies.

Chapter 2

Aspects of the biology

Developing interest

The developing interest in Quaternary research in Britain in the 1940s was reflected by interdisciplinary meetings held from time to time. In 1947 the British Association for the Advancement of Science meeting in Dundee organised a discussion in the Archaeology and Anthropology Section on 'Dating the Past' with F.E.Zeuner, K.P.Oakley, H.Godwin and A.L.Armstrong contributing (Report of the British Association 1948). In 1959, the Linnean Society of London held a 2-day symposium on Quaternary Ecology, introduced by H.Godwin (Godwin 1961). There were contributions on active areas of research at that time, including peat stratigraphy and bog regeneration (D.Walker), the Atlantic-Sub-boreal transition(A.G.Smith), the Full- and Late-glacial periods in France (F.Oldfield), post-glacial history of *Juniperus* in Scotland, climatic and edaphic indications from the Late-glacial flora (A.P.Conolly), interglacial and interstadial vegetation in England (R.G.West), glacial and interglacial insect faunas (G.R.Coope), ecology of Quaternary Coleoptera (R.G.Pearson) and the interpretation of Quaternary non-marine Mollusca (B.W.Sparks).

In 1964 at the Jubilee Symposium of the British Ecological Society (Jubilee Symposium , British Ecological Society 1964), a session was devoted to Quaternary Ecology, with contributions on retrogressive vegetational succession in the Post-glacial (J. Iversen), interrelations of ecology and Quaternary palaeobotany (R.G.West), ecological relations of Late- and Post-glacial vertebrate faunas in norhtern Europe (M.Degerbøl) and non-marine Mollusca and Quaternary ecology (B.W.Sparks). The British Ecological Society held a further symposium on Quaternary Plant Ecology in 1972, held over three days in Cambridge in 1972 (Birks & West 1973). The speakers and 145 participants were international and the sessions, giving again an insight into the research areas of the time, concerned: methodological problems, pollen dispersal and sedimentation, pollen representation, plant macrofossil assemblages, vegetational history and community development, and limnological history. The content of these successive meetings shows the rapid development of the subject internationally in the 1950s and 60s.

International meetings which also nurtured the development of Quaternary research were the series of field excursions organised as the International Phytogeographical Excursions. These began in 1911. This first excursion, organised by Tansley and his colleagues, made an extensive tour of the British Isles. The participants were an international group of 11 phytogeographers and taxonomists, and included those, such as F.E.Clements, with an interest in the relation between present and past vegetation (Shaeil 1987). Participants in subsequent meetings in various countries in Europe and elsewhere also usually included members with an interest in vegetation history. Thus the VIth I.P.E. in Rumania in 1931 included H.Godwin, W.Szafer and P.W.Thomson. The IXth I.P.E. was held in 1949 in Ireland, with 23 participants from 12 countries. Here, the interest in Ireland as a focus for problems of phytogeography and vegetation history attracted a large number of members who had a strong interest in vegetation history. These included H.Gams, K.Jessen (who had recently published his classic work on the Irish Late- and Post-glacial; see Part I), J.Iversen, F.Firbas, W.H.Pearsall, A.R.Clapham, H.Godwin, R.Nordhagen, M.Welten, A.G.Tansley and S.A.Cain. Sections showing late-glacial sediments and peat stratigraphy were demonstrated by K.Jessen and G.F.Mitchell, and there was a discussion on the glacial and post-glacial history of Ireland led by G.F.Mitchell, as well as well as the more classic phytogeographic subjects of methods of classifying plant communities (led by J.Braun-Blanquet and R. Tüxen; see Webb 1950) and the Atlantic Flora (led by D.A.Webb). Many of the I.P.E. participants were leaders in the study of vegetational history in Europe and clearly the meeting was a stimulant to the development of Quaternary research in the field.

Directly after the 1949 I.P.E. meeting a short and informal meeting was held in Dublin for those many botanists present who had an interest in Quaternary vegetational history in north-west Europe, in addition to other Quaternary researchers (Mitchell 1952). This was organised by G.F.Mitchell and the Committee for Quaternary Research in Ireland, and participants included K.B.Blackburn, S.A.Cain, A.R.Clapham, V.M.Conway, A.Farrington, F.Firbas, H.Gams, H.Godwin, J.Iversen, J.N.Jennings, K.Jessen, M.P.H. Kertland, W.Lüdi, F.Markgraf, G.F.Mitchell, G.Negri, R.Nordhagen, H. Parkes, J.B.Simpson and M.Welten. There was a field excursion and sessions discussed identification of plant remains, the Late-glacial period, the Boreal/Atlantic transition, post-glacial marine transgressions, the Atlantic/Sub-boreal transition and the establishment of agriculture in north-west Europe, and recurrence surfaces.

The 1949 Dublin meeting of Quaternary botanists was the second of a series which started in 1946 with a meeting at Cambridge, organised by H.Godwin. This earlier meeting on 'Quaternary history and pollen-analysis' was important in bringing together Quaternary researchers from north-west Europe after the war. The participants included K.B.Blackburn, A.P.Conolly, G.Dubois, A.Farrington, K.Faegri, F.Florschütz, H.Godwin, H.A.Hyde, J.Iversen, K.Jessen, G.F.Mitchell, W.H.Pearsall, J.B.Simpson and W.Tutin. At the meeting Iversen gave a lecture, later published as his classic paper on 'The influence of prehistoric man on vegetation' (Iversen 1949).

Subsequently, such meetings were held every few years and were very influential in the development of Quaternary botany. The third meeting in Copenhagen in 1953 was particularly important, meeting as it did at the place where Jessen and Iversen had made so many fundamental contributions. Plate 8 is a photograph of the participants, reflecting interests in Quaternary botany in Europe and U.S.A. Later, meetings were held in Switzerland (1957, supported by the Rübel Geobotanical Institute, which had been involved in Quaternary palaeobotany for many years), Germany (1962), Norway (1968) and elswhere, but with the expansion of the subject and the establishment of many new foci for Quaternary research and the associated meetings, there was a certain dilution of the expertise so evident in the early meetings when Quaternary researchers and field botanists combined their interests.

Palaeoecology and ecology

To those interested in phytogeography in the early time of the Subdepartment two books of prime interest, stressing the significance of the fossil record, were Cain's *Foundations of Plant Geography* (1944) and Wulff's *Historical Plant Geography* (1950, originally 1933). Both were concerned with the Pleistocene and with the preceding longer geological record, with Cain particularly concerned with principles of palaeoecology. Both were written as pollen analysis was becoming established as a standard practice.

The Pleistocene interest was enhanced in 1949, when the members of the Committee on Interrelations of Pleistocene Research of the U.S. National Research Council published a review of Pleistocene research. This contained a stimulating and detailed review of the biogeography of the Pleistocene by E.S.Deevey (1949). The review covered both European and North American historical biogeography, and related geological events of the Pleistocene with present plant and animal distributions in the two regions, including the relationships of the British and Irish faunas to changing sea levels. Deevey stressed the importance of the fossil record for bioeography and lamented there was not more of it. Godwin's *History of the British Flora* (1956), subtitled 'A Factual Basis for Phytogeography', met such a demand for Britain and provided a biogeographical synthesis based on a very substantial and well-documented plant fossil record. The year before, Matthews' (1955) book on the origin and distribution of the British Flora combined his deep knowledge of phytogeography with the increasing knowledge of the fossil record at that time.

The study of the fossil record gave an opportunity for a link to be made between the present and past distribution of a species, giving the possibility of long term monitoring of distribution changes. Since preservation of the fossil record is confined to particular terrestrial ecosystems which preserve sediments and fossils, these possibilities are not universal, but they are widespread. The monitoring can be applied to species if their remains are clearly identifiable, or to vegetation formations if combinations of taxa are recognisable. Where pollen analysis is concerned, a proportion of identifications may be specific, but the location of the parent species may be inexact. Where macroscopic remains are concerned, the proportion of specific identifications may be greater and the location of the parent species more exact. Thus pollen sequences from lakes reflect regional development of vegetation and migration of taxa in that region, whereas sequences of richly organic sediments such as are found in mires and forest mor soils reflect more local changes. The result is that evidence is obtained from both contexts about vegetation formation changes, forest composition changes, and migration of taxa, calibrated by radiocarbon or other forms of dating.

The evidence here in the Pleistocene in north-west Europe and elsewhere is for vast changes in communities from forest to herb vegetation over comparatively short periods, showing the responses of vegetation to environmental change and a re-jigging of plant communities as conditions change. Such changes are well-illustrated by Grichuk and Grichuk 's (1960; see West 1964) scheme of vegetation changes in the Russian Plain at the time of maximum glaciation.

But for more exact knowledge of the history of plant communities, rather than species, the possibilities are limited. Green and Dolman (1988) described the possibilities of using fine resolution pollen analysis to connect present communities with those of the immediate past. One possibility is the record present in autochthonous and actively growing peat deposits, with identification of pollen and macroscopic remains over a period. This was demonstrated by Walker & Walker (1961) in their study of regeneration of Irish peat bogs, by Walker (1970) on direction and rate of change in post-glacial hydroseres, and recently by Hughes & Barber (2003) in their study of fen-bog transitions in raised bogs in Britain and Ireland. Such studies have provided much-needed connection between living communities and the past.

This type of connection, and that obtained by studying the larger scale changes mentioned above, are often neglected by text-books on ecology, fundamental as they are to the study of the present constitution of vegetation. As pointed out by Ebach (2003), 'historical biogeography is our link with the evolutionary, geographical and geological past' and historical patterns must not be ignored in biogeographical, or indeed ecological, studies.

Pollen analysis

G.Erdtman's *Introduction to Pollen Analysis*, published in 1943, while giving an introduction to the subject, provided in particular a detailed account of pollen and spore morphology and classification, with family-by-family descriptions of pollen and spore morphology. The accounts were well-supplied with careful drawings, useful for supporting identifications. But to the beginning research student in vegetational history, this had to be complemented by the *Text book of Modern Pollen Analysis* by the botanists K.Faegri and J.Iversen, published in 1950. This became the Bible of the science of pollen analysis, introducing all the developments in pollen analysis which had been made in the previous decades in northern Europe. Written succinctly by two of the leading exponents of the subject, judicial and critical, it also contained a most useful pollen key, which was an invaluable guide to identification, to be coupled with use of the reference collection of pollen slides. A second edition appeared in 1964, incorporating advances in the subject and a chapter on pre-Quaternary pollen analysis by H.T.Waterbolk. 'Modern' was omitted in the title. The preface says 'The term "modern" in the title of the first edition was a challenge: the challenge of botanists that botanical reasoning should be applied to in what is essentially a botanical method, as against the "old-fashioned " geological pollen analysis. What was then a challenge has now been generally accepted, at least in principle.'

A third edition was planned in 1971, but with Iversen's death later in that year, the revision was completed by Faegri and published in 1975. This edition reported and discussed the many advances made in the 1960s and 1970s. The chapter on pre-Quaternary pollen analysis was omitted; by then this subject had greatly expanded, and was naturally more geologically inclined. The third edition was enriched by Faegri's critical views on many aspects of pollen analysis, as the reader will see from the preface. In retrospect, the prefaces of the three editions reflect the huge advances made in the subject from 1950 to 1975. The book on 'Quaternary Palaeoecology' by H.J.B.Birks and H.H. Birks, published in 1980, brought together the many advances made in the subject at this time, dealing with both botanical and zoological aspects in considerable detail.

The expansion of reference collections of pollen slides and the application of the Faegri and Iversen pollen keys led to a great expansion in identification of taxa. Pollen floras began to be published, such as the photographic 'Leitfaden der Pollenbestimmung' of Beug (1961) and the 'Northwest European Pollen Flora' (Punt 1976) and the complexity of pollen diagrams increased as the treatment of data became more analytical.

The huge expansion of pollen analytical data from many parts of Europe during this period instigated the start of the compilation of the European Pollen Data Base in 1989, aiming to place the data in an accessible format, with associated chronology. Preceding and associated with this was the International Geological Correlation Project (158B, starting 1977), assembling information on palaeoecological changes in Europe in the last 15000 years (Beaulieu 1996). The increase in data available is shown by the coverage of this volume: regional syntheses of vegetational histories in 21 countries (Berglund *et al.* 1996).

Treatment of data

The data of pollen analysis provide information first on the history of identifiable individual taxa and their associates in an assemblage and secondly on the history of vegetation, as exemplified by pollen diagrams. The history of taxa is more straightforward. Presence, abundance and absence can be recorded, and a history of a taxon developed, as by Firbas (1949; 1952) and in Godwin's *History of the British Flora* (1956, 1975). Szafer (1935) portrayed the history of forest trees in the post-glacial in Poland by means of isopolls (synchronous lines defining areas with similar pollen representation of a taxon), based on 152 sites. Firbas(1935) adopted a similar approach in analysing late-glacial vegetation in central Europe. With the advent of radiocarbon dating and the accumulation of pollen data, such syntheses were much improved, as shown by the pollen maps of of Europe assembled by Huntley and Birks (1983).

Pollen diagrams express a history of vegetation, and may require division into recognisable units, characterised by particular taxa. Historically, the system of zonation of pollen diagrams developed in Scandinavia, with a numerical system of zones (late-glacial, I to III; post-glacial, IV to IX), with post-glacial zones related to the Blytt-Sernander Baltic chronology and also to the principal tree genera (e.g. Hazel-Birch Period) which characterised them. Jessen's (1949, Plate XVI) scheme of late- and post-glacial development in Ireland, and its relation to zoning in England and Scandinavia is an excellent example of chronology and pollen zonation as developed at the time. Here, chronology was amplified by positioning the rational borders of tree genera and comments on maxima and minima of tree genera within the zones.

With the increase in pollen-analytical activity and the consequential realisation of the complexities of vegetational history in time and space, a more rigorous treatment of subdivision of pollen diagrams became a necessity. Cushing (1967a) was confronted with this problem in Minnesota in his study of Late-Wisconsin pollen stratigraphy, and used a system of naming pollen assemblage biozones, 'named, defined and described in accordance with the Code of Stratigraphic Nomenclature (American Commission of Stratigraphic Nomenclature, 1961).' They are thus formal biostratigraphic units. The wide application of such treatment of pollen diagrams followed, allowing much improved analysis of vegetational history, either regional (regional pollen assemblage biozones), or local (local pollen assemblage biozones). Later, the usually subjective nature of zonation prompted proposals for a more objective approach, using methods of numerical analysis (Dale & Walker 1970; Walker 1971; Walker & Wilson 1978; Birks 1974; 1986).

Description of pollen diagrams from the pre-post-glacial cold or temperate stage (interglacial) sediments via the use of pollen assemblage biozones has become normal practice. The interpretation of vegetational history in temperate stages had already been improved by schemes of division suggested by Firbas (1949), Iversen (1958) and Andersen (1966), which identified cycles of change of vegetation within such stages (protocratic, mesocratic, oligocratic, telocratic; successors to von Post's (1946) system). These ideas were discussed by Turner & West (1968), who suggested a sequence of four substages characterised by their pollen assemblages could be applied to temperate stage vegetational history (pre-temperate, early-temperate, late-temperate and post-temperate).

With the great expansion of the application of pollen analysis to vegetational history came much fundamental research on the origin of pollen assemblages, much of which is reported and analysed in the third edition (1975) of Faegri and Iversen's textbook and also in that of Birks and Birks (1980). The research involved such questions as pollen preservation in sediments, pollen dispersal and transport, and the relation of pollen deposition to vegetation in an area, as will be briefly outlined to show the character of these advances.

Differential preservation of pollen in sediments of varying constitution was effectively studied by Havinga (1971), while Cushing (1967b) distinguished various types of degradation of pollen which were of significance in the interpretation of pollen diagrams. These investigations had relevance to a number of areas, including interpretation of pollen assemblges in various sediments, and research related to archaeological sites and soil science.

The problem of identification of re-worked (secondary, derived) pollen had long been realised and discussed by Iversen (1936), and these more recent investigations greatly enlarged understanding of the problem.

Interpretation of pollen diagrams in terms of the origin of assemblages involves the study of taphonomy, analysing the multitude of possible factors affecting pollen deposition in sediments (Fagerstrom 1964; West 1973). Such analysis involves considering pollen production, selective pollen dispersal by air and water, and pollen deposition, to form an assemblage which may suffer weathering or diagenesis. Many important studies of these were carried out earlier in the history of pollen analysis, e.g. Pohl's (1937) study of pollen production of anemophilous plants and Aario's (1940) study of the tree limit and subrecent pollen spectra in Lappland. They greatly expanded in the 1960s and 1970s when there was clear necessity to improve understanding of the relation between pollen diagrams and vegetation if vegetational history was to be understood in detail.

The complexity of pollen transport and dispersal was underlined when pollen trapping experiments, such as those using specially designed traps by Tauber (1977), or those by Peck (1973) in a Yorkshire catchment, were carried out. It became apparent that vegetation structure was an important factor in pollen dispersal, to be added to the seasonal nature of pollen production and the pollen quantities released by anemophilous plants. The contributions to the British Ecological Society's symposium in 1972 (ed. Birks & West 1973) illustrate the research of the time in these areas.

Additional to the pollen trapping exercises, much was published on the connections between vegetation and contemporary pollen deposition in sediments in many different vegetation formations, with the direct aim of improving interpretation of pollen diagrams. Iversen in 1947 (Faegri & Iversen 1975) proposed three categories of pollen taxa, those which produce large amounts of pollen, those which produce more moderate amounts and those which are scarecly represented. Correction factors based on these categories could be applied to pollen percentages to give an improved picture of the originating vegetation. Andersen (1970) made a very detailed study of pollen productivity and representation of northern European trees based on surface pollen samples, and determined correction factors of a similar nature. This offered a critical discussion of the methods and results involved. M.B.Davis (1963) contributed many ideas on the relation between vegetation and contemporary pollen spectra, calling the relation of the abundance of a particular taxon to its value in a pollen spectrum the R-value. This value could be applied to fossil assemblages to improve reconstruction of past vegetation.

The results of these investigations give clear indications of how pollen spectra may be usefully re-interpreted using correction factors, especially where the evidence for correction factors has an association with the fossil vegetation studied in the locality. Thus interpretation of the recent history of forest communities may be illuminated by these studies. The wider use of such factors applied to larger areas which have seen substantial changes of vegetation and climate is problematical.

Even so the analyses draw attention to the kind of difficulties which have to be faced in the interpretation of pollen diagrams.

With the advent of radiocarbon dating, the percentage representation of pollen taxa in a pollen diagram could be replaced by a more exact calculation of pollen quantity in a series of analysed samples. In developing the idea of absolute pollen frequency, M.B.Davis (1969) made a further contribution here by determining pollen concentration (grains/unit volume or mass), and pollen influx (grains deposited/ unit surface area/year) as measures shown in a pollen diagram, thus avoiding distortions due to use of percentages of a basic pollen total. Pennington & Bonny (1970) published percentage and absolute pollen diagrams from the same Devensian late-glacial site in the Lake District, demonstrating the method and advantages of this improvement, with Pennington (1973) later discussing absolute pollen frequencies in lake sediments in more detail. The use of pollen concentrations and pollen accumulation rates as measures of vegetation change in lake sequences where sedimentation is complex was discussed by Bennett (1983).

Macroscopic plant remains

In an ideal world of palaeoecological research, a study of macroscopic remains should accompany and complement pollen analysis. But the latter's applications for studying vegetational history are more easily applied, and to a wider range of sediments, than the analysis of macroscopic remains, and so have attained a priority. However, macroscopic remains give better opportunities for identification of species, and consequently for the history of species and for environmental deductions following the identification of species. But the interpretations are beset by the same problems which are encountered in pollen analysis: origin of the fossil assemblages in terms of vegetation, and analysis of the processes which determine the constitution of the assemblages, i.e. taphonomy. Similar advances have been made in this sphere as with pollen analysis.

Dickson (1970) has written an account of the development of studies of macroscopic plant remains in Britain. In Cambridge, the basis for the development was the building of a macro reference collection, derived and related to the Departmental Herbarium. The publication of seed atlases in the decades under review (Bertsch 1941; Beijerinck 1947; especially Katz, Katz & Kipiani 1965) greatly assisted identifications, as did monographs on particular genera (e.g. *Potamogeton*, Jessen 1955; Aalto 1970). Identifications were also assisted by the use of scanning electron microscopy (Dickson 1970; *Arenaria*, Bell 1968; Ericaceae, Huckerby *et al*, 1972).

In parallel with the analysis of the factors affecting pollen production, dispersal and deposition discussed above, similar research was carried out on the formation of fossil macro assemblages. These assemblages naturally tend to be much more local in their origin than pollen assemblages. Several studies of the relation of species in local vegetation to deposition of macros in lake sediments revealed the complexity of the taphonomy of the assemblages. Spicer & Wolfe (1987) showed that there were differences in assemblages between high- and low-energy depositional environments, the former giving the best taxonomic representation of source vegetation, the latter better reflecting the spatial distribution of taxa in the source vegetation; also that, though there are species similarities between the source vegetation and the assemblages, abundance of a taxon in the source is not necessarily reflected by abundance in the assemblage. Studies of sedimentation of macro remains (influx) in lakes by H.H.Birks (1973), Drake & Burrows (1980), Collinson (1983) and Hill & Gibson (1986) revealed similar complexities, with effects, for example, caused by wind dispersal, wind direction, sinking rates of macros, and sorting by currents. Contemporary assemblages from organic sediments in fluviatile environments, such as are found in cold stage periglacial river gravels, have also been studied in relation to contemporary tundra vegetation, assisting with the interpretation of cold stage macro assemblages (Holyoak 1984; West *et al.*1993, 2000b).

Grosse-Brauckmann (1972, 1974) provided a valuable account of plant remains in autochthonous sediments of mires, including peats of various origin. The taphonomy of macroscopic remains in such a context has also been investigated (Greatrex 1983). The situation is simpler, with mainly local derivation of macroscopic remains, enabling more precise relations to be made of present to past vegetation, as mentioned above.

However, in spite of these advances, it is clear that much remains to be done to analyse the complexity of the taphonomy of both pollen and macro assemblages if more precision is needed in investigations of vegetational history.

Faunas

Forbes' (1846) classic account of the connection between the present fauna and flora of the British Isles and the geological and climatic changes associated with the 'Northern Drift' gave geological reason to support well-known facts of biogeography. At that time knowledge of the geology had not advanced far, but as with the flora, there were many later biogeographical accounts of the history of the fauna or of different groups (e.g. Scharff 1899; the collection of papers on the colonisation of the British Isles in the Mémoires, **3**, of the Société Biogéographie (1930); Beirne 1952; beetles, Ste-Claire Deville 1930; butterflies, Ford 1945). These generally followed on the lines of Forbes' thinking, the interpretations often paying attention to taxonomic, ecological or zoogeographical evidence.

Deevey, in his 1949 review of Pleistocene biogeography, wrote that 'One of the most popular topics in all biogeography is the question whether the whole of the fauna and flora of the British Isles immigrated in post-glacial times, or whether some fraction survived from an earlier time'. The popularity refers to a large literature on the subject, with the relatively small fauna and flora and isolation of the British Isles making the subject an attractive area for debate. The debate, recorded in the references above, was often largely based on present distributions, with only a minor degree of geological input.

With the development of a more substantial stratigraphic framework in the 1950s and 1960s and the improvement of geochronology, the history of the fauna and zoogeography, as with the history of the flora, took on a new lease of life. So did the techniques used in analysing the fossil faunas, as it did with floras. Faunal assemblages, terrestrial, limnic and marine, were analysed in their stratigraphic context from many sites of varied age through the Pleistocene, with quantitative methods applied where possible (as with the palaeobotanical data, especially pollen analysis). The results led to a great enhancement of knowledge about environments of deposition, climate, the history of taxa and animal communities, and the use of the records for developing chronology via the use of 'zone fossils'.

The advances concerned many faunal groups; a number of these have already been noted above in Part II of my account. In summary, a very partial selection to demonstrate the width of these developments may be mentioned: vertebrates, the syntheses of Stuart (1982) and Yalden (1999); non-marine molluscs, the work of B.W.Sparks and M.P.Kerney in analysis of assemblages, and P.E.P.Norton in analysis of marine assemblages; beetles, the contributions of F.W.Shotton and G.R.Coope; foraminifers, the analyses of Early Pleistocene assemblages by B.M.Funnell; ostracods and cladocerans, particularly significant for analysis of aquatic environments, reviewed by Frey (1964) in his wide-ranging survey of faunas in lake and mire sediments and their interpretration. Many of these advances are recorded in the volume published at the time of the 1977 INQUA meeting in Birmingham (Shotton 1977).

Interpretations

Having considered some of the advances made in the acquisition of data about fossil assemblages, some problems of interpretation can now be discussed. Three important areas stand out here: the attempts to draw evidence from what appear to be present-day analogues, the analysis of present-day processes, both biological and physical, leading to the formation of potential fossil assemblages, and climatic reconstruction.

Analogues

Historically, analogues have been sought for cold stage herbaceous vegetation in northern plant communities of the tundra. But the combinations of species, plant and animal, found in cold stage assemblages contain elements of present-day tundra and steppe, resulting in the well-established concept of the mix of steppe-tundra vegetation in cold stages (Hibbert 1982; West 2000a,b). Plant communities showing the mix still survive in certain localities in Siberia and Alaska, indicating the possibilities of a spectrum of assemblages across the major steppe and tundra divide, and illustrating the mobility of species in responding to variations in climate, following the Gleasonian view of each species responding individually to change in accordance with its ecological requirements.

Another area where analogues have been sought is in the relation of a particular vegetation type or plant community to pollen rain in the vicinity, with the purpose of relating fossil pollen assemblages to parent vegetation. The result is the comparison of past vegetation or communities with present vegetation or communities. The comparisons may be generally valid, but lack precision because of specific identifications are more difficult with pollen evidence than with the identifications made on the basis of macroscopic remains in cold stage assemblages.

Analogues have also been sought for periglacial phenomena for the purpose of climatic reconstruction. For example, the presence of thermal contraction cracks in cold stages indicating a climate similar to that where cracks occur today.

Though analogues may lead to a first approximation of reconstruction, the problem is that they often involve a leap across latitudes or longitudes: in the case of Britain, say, comparing communities or processes above the Arctic Circle with conditions or fossil occurrences or communities at 55°N or the Greenwich meridian. Such travel brings with it many complex changes in the parameters of climate, including seasonal changes, day-length, insolation, precipitation, etc., all of which will affect the distribution of biota, and control genetic diversity and selection. Such problems of interpretations based on 'present-to-past' were discussed, for example, by Iversen (1954) in relation to the Late-Glacial flora of Denmark, by Seddon (1967) in relation to fossil records of aquatic plants, and by Degerbøl (1964) in relation to vertebrate faunas in northern Europe.

Processes

As described earlier, analysis and understanding of the processes involved in the formation of pollen and plant macroscopic assemblages has greatly advanced. The research has included biological processes such as pollen production and dispersal mechanisms, and physical processes such as pollen transport in the air and macro transport under fluviatile conditions. Both lead to selective deposition and preservation, knowledge of which is basic to interpretation of the fossil assemblages. The sheer quantity of pollen and macros deposited and preserved in assemblages, together with knowledge of local flora and vegetation where taphonomy is studied, make these investigations possible. The same can be said for taphonomy studies relating to such often abundantly represented groups as molluscs, forams and ostracods. It is clear that a background knowledge of the taphonomy of presently-forming assemblages under different depositional processes, whether they be micro- or macro-assemblages, is essential for improving the interpretation of fossil assemblages of all kinds, though difficulties will remain where quantitative analyses of assemblages are not possible.

One of the main process-related problems of interpretation of fossil assemblages is the decision on whether any of the taxa are reworked from earlier deposits. The sedimentary context may give a pointer, especially if derived clasts of different origin are present in a sediment, as in the upper lacustrine sediments of the temperate stage site at Hoxne, Suffolk (Bed C, West 1956). The presence of temperate Ipswichian fossils in clasts within overlying Devensian fluviatile gravels

(West *et al.* 1994) illustrates a similar effect. Macroscopic fossils in a fluvial context may be reworked from temperate stage sediments into later cold stage sediments, and have been frequently distinguished (e.g. *Carpinus*, *Corylus*, *Thelycrania,* Bell 1970), but are only distinct when there is a strong contrast between the climatic requirements of the contemporary and derived taxa. In the Netherlands wind-blown Eemian marine shells were found in Tubantian last cold stage sediments, and in a Pleniglacial *Dryas* flora was shown to contain many Eemian macrofossils (*Carpinus*, *Corylus*, *Quercus*, *Brasenia*) (Zagwijn pers. comm.).

The problem of reworked pollen was early recognised by Iversen (1936). Phillips (1972) suggested a method of identification by fluorescent microscopy of reworked taxa in pollen assemblages. The separation of contemporary and reworked taxa is even more difficult than with macrofossils. But the problem, likely to arise in sediments of a long-lived fluvial system, remains one of the difficulties of interpretation of fossil assemblages.

Past climates

Inferences about past climates may be drawn from physical conditions for processes, as with periglacial phenomena, or from biological evidence. The latter can be used on a broad scale, as with climates indicated by vegetation formations (tundra, temperate deciduous forest, etc.), or on the finer scale of using evidence of climate indicated by species. These are based on the relation of the present distribution of a species to climatic parameters thought to control its range. The classic contribution by Iversen (1944) on *Viscum*, *Hedera* and *Ilex* as temperature indicators in the Danish post-glacial exemplifies this approach. Godwin (1949) summarised evidence for climate change in the British post-glacial as indicated by pollen analysis, and stressed the problems of reconstruction. Changes of climate indicated by changes of northern range in species in fossil assemblages were used in reconstructions (non-marine molluscs, Sparks 1964; macroscopic plant remains, West 1957). Conolly & Dahl (1970) discussed maximum summer temperatures in relation to the modern and Quaternary distribution of arctic-montane species in the British Isles. Degerbøl (1964) examined the relation of climate to the distribution of vertebrates in Late- and Post-glacial northern Europe. More recently, Atkinson, Briffa & Coope (1987) have developed the approach of using ranges of species in a beetle assemblage, the Mutual Climatic Range method, to assess the climatic sighnifiance of the assemblages.

The problem of using present distributions and their relation to climate lies in several areas. One is succinctly stated by Deevey (1949): 'The distribution of every species is virtually a law unto itself; worse, it is a law that is incapable of precise formulation, and that nobody understands fully, for every change of range may have a separate explanation.' This is a statement of the Gleasonian view of the individuality of species. Secondly, the climatic factors controlling the range of a species may well vary in different parts of its range, as must be the case of a widely distributed species such as *Corylus avellana* (from the Atlantic coast to Asia Minor).

This leads to the thought that the morphological stability of species (especially those parts identified in fossil assemblages) belies their variability in ecological terms. The Gleasonian individuality can be recognised in the morphological species, but not the biotype content of the species, as was recognised by Degerbøl (1964) in his comments on vertebrate fossils in northern Europe. The question is: how do you proceed from the simplistic approach using the morphological ('Linnean') species as the basis for reconstruction to an approach based on knowledge of ecotypes within the species ? With plants this may be reflected in the known variability within a species, but this is an extreme case, and the extent of the ecotypic variability is rarely, if ever, known. Re-jigging of communities under climatic change must take place in association with selection of ecotypes, but this is not recognisable when the only identification is to morphological species.

Thus, in the case of plants, the cold stage flora in Britain contains a great variety of phytogeographical elements, indicating that members of the cold stage flora are now in regions of very varied climate and environment (West 2000b). But how this phenomenon is related to ecotype selection is of course unknown.

A final problem in this area of interpretation is the possibility of changes in the ecology of a species, discussed in the case of non-marine molluscs by Sparks (1964). In conclusion, the present limitiations of climatic reconstruction offer a great challenge to improvement by increased knowledge of ecotypes of species, whether plant or animal, perhaps to be gained through the techniques of moleclular biology.

Chapter 3

The Quaternary community

Quaternary associations, especially the Quaternary Research Association

With the founding of the International Quaternary Association at a meeting in Copenhagen in 1928, those interested in Quaternary studies began international activities and co-operation, so also stimulating the formation of more local groupings in different countries. In the United States, the Friends of the Pleistocene, started by R.F.Flint, had their first meeting in 1934. Described as a quintessential 'non-organisation' supporting field excursions and sprouting regional Friends' meetings in other parts of the States, the 50^{th} annual reunion meeting of the original Eastern Group was held in 1987. The history of the Friends and the personalities involved has been described in a lively way by R.P.Goldthwait (1989).

In Germany the Deutschen Quartärvereinigung was founded in 1948, after discussions at a field meeting organised by E.Ebers in southern Germany in 1947. Annual meetings with lectures and field meetings followed, and later the publication of the journal *Eiszeitalter und Gegenwart* in 1951 (see Mitteilungen der Quartärvereinigung 1951) By 1949 there were about 200 members. As a research student I attended field meetings and found them an eye-opener to possibilities of Quaternary research, with the subject well in advance of activities at home. Many other regional Quaternary Associations were subsequently formed.

In Britain, geological excursions to study Quaternary geology had long been held, not only by regional geological societies, such as the Yorkshire Geological Society and the Norwich Geological Society, but particularly by the Geologists' Association. From their founding in 1858, such excursions were frequently held and recorded in some detail in the *Proceedings*. These reports were invaluable to later researchers. Such an excursion was the centenary excursion held in 1958 to study the Pliocene and Pleistocene in East Anglia (Baden-Powell & West 1960).

The following account of developments in Britain is based on papers, memoranda and minutes which I have kept. In January 1963 a letter was circulated by R.W.Hey and R.G.West to some 75 people with a known interest in Quaternary research asking for comments on the suggestion of holding 'short informal meetings devoted to Quaternary studies' (Appendix 1). A questionnaire accompanied the letter, asking for comments on the timing and frequency of such meetings, whether they should be all in the field or partly 'inside', and whether an excursion in East Anglia would be supported. In the event, about 65 replies were received, all in favour, with the majority in favour of 2 to 3 day meetings, mostly or all outdoors, either annually or biennally. F.W.Shotton offered to lead an excursion centred on Birmingham, which took place from 13-16th April 1964, with G.R.Coope acting as local secretary. 64 people attended the meeting. A committee of six was appointed, with L.F.Penny as Secretary, with the function of choosing future places to meet. Durham was chosen for 1965. But this function devolved on to all at the later annual meetings, with appointment of local secretaries to arrange the field meetings. At the Durham meeting a fee of 2/6d was collected to pay for costs of postage, etc., as at later meetings, and local secretaries acted as treasurers. The Durham meeting (80 attended) decided that the annual meetings should be in the field, with talks on the places to be visited, plus any exhibits members brought along.

After the Annual Field Meetings at Edinburgh (1966, 82 participants), Canterbury (1967, 78 participants) and S.E.Ireland (1968, 51 participants, bedevilled by a foot-and-mouth outbreak), there was a move to add short short field meetings, three of which were held in 1968/69, as well as discussion meetings, the first of which, on 'Biological evidence for Weichselian environments', was held in January 1970 in Birmingham. Study courses began to be also arranged, the first in Iceland in the summer of 1968 and a second in The Netherlands, Belgium and Germany in 1970.

This was a time of expansion of membership, for example: 1965, 165; 1967, 141; 1968, 198; 1969, 219; 1971, 330; 1972, 375; 1973, 406; 1974, 460; 1976, 530; 1977, 488. A Memorandum noted that in 1969 the approximate composition of the membership was, accepting the difficulties of classification in an intgerdisciplinary subject, as follows: geographers, 45.5%; geologists, 31.5%; botanists, 9%; soil scientists, 7.5%; archaeologists, 2%; civil engineers, 1%; climatologists, 0.5% (Francis 1969).

The period 1968-1974 was a time of much development, effected during the Honorary Secretaryships of E.A.Francis (1968-1970) and W.G.Jardine (1970-1974). The development compares with the transition of the informal British Vegetation Committee to the British Ecological Society in 1912, a change probably common to all significant informal scientific groupings.

Matters became far more formal in 1968, when it was suggested, quoting excerpts from Francis (1968), "that it might be easier for individual participants or the Group as a whole to gain financial support to attend British or foreign-based meetings if an alternative name including the word 'Research' were adopted". A previous questionnaire showed that 84 members were in favour of a change in the name, 35 against. "A small minority of members evidently think that a change of name is merely a prelude to the loss of informality including the introduction of a journal (it happened in 1986 !), but the committee as a whole has every intention of preserving informality. It is quite beyond the scope or the finances of the membership to produce a journal."

If a change of name were to be agreed, the aims should be specified, and the Committee agreed the following function: "The .... exists to bring together those interested in research into the problems of the Quaternary, and to organise meetings, principally in the field, at which members can demonstrate, observe and discuss phenomena and techniques relevant to these problems." A number of names were suggested by members, including Quaternary Researcxh Association (70), Quaternary Research Group (15), Quaternary Field Study Group (5), Quaternary Studies Association (5), The Quaternary Society (2), British Quaternary Association (1), British Quaternary Researcfh Group 9(1) and British Quaternary Society (1). A majority of the Committee thought that Quaternary Research Association best expressed the function, considering "that the word 'Association' describes accurately the corporate form of our membership, and that since members are not confined to Britain, the inclusion of the word 'British' would be inappropriate." (E.A.Francis 1968). In relation to the last point, H.Godwin thought that the inclusion of the 'British' would secure the claim for the Association to be the representative body in this country for INQUA, and that the movement must be in that direction. In fact at a much later date the Association did assume this function.

The next step was the formulation of a constitution for the Quaternary Research Association. At the Annual Meeting In 1969 the 'continuity' Committee originally set up in 1964 recommended that it be replaced by an Executive Committee which should represent the interdisciplinary nature of the Association, and include the offices of President, Secretary and Treasurer. The Minutes report that 'The energy and independence for which members of the Q.R.A. are noted, were well displayed during the ensuing election of officers and members of the Executive Committee'. There were elected a President (R.G.West), Secretary (E.A.Francis), and Treasurer (D.Q.Bowen), and members (D.S.Peake, F.M.Synge, J.N.Hutchinson, E.Watson, F.W.Shotton, E.H.Brown). The meeting then proposed that the Executive Committee prepare a draft constitution for the Quaternary Research Association. This was duly prepared, discussed at the 1970 Norwich Annual Meeting, amended to conform with requirements from the Charity Commissioners, and adopted at the January meeting in 1971.

At the Norwich meeting in 1970, it was suggested that a Quaternary Newsletter be sent to members from time to time, and the first was issued in September 1970. The Newsletter was intended to supplement the Circulars, which were concerned with the business of the Q.R.A., and to cover a broader field: "to provide members of the Quaternary Research Association with miscellaneous information relating to the Quaternary, including brief notes on the scientific results of the work of the Association. Another function of the Newsletter is to provide a means of communication between Quaternary research workers.

Several members have enquired if the Association organises an information service. In response to these enquiries it is proposed to include in the Newsletter a section in which members and others can indicate problems in which they are interested and in which they wish to exchange information with others who share these interests." This first Newsletter was compiled by W.G.Jardine, and contained much information on Quaternary activities, nationally and internationally. By 1974, the Newsletter was issued three times a year. There was discussion about the nature of the Newsletter and whether it was regarded as a publication. It was pointed out that it was not for sale to the public and could hardly be considered a publication. The original informal staus of the Newsletter was confirmed.

The Circular of November 1983 brought to wider attention past suggestions that a journal should be published by the Q.R.A, and gave the case for the need for such a journal. A voting slip on the issue was sent to members, asking whether they would support the publication by purchase. The numbers returned were: 102 for, 22 against, abstention 1. The proposal in the Circular was supported by detail, including two editions per year, A4 size, publication handled by the Association, appointment of an Editor, a cost of £10 a year to members. The journal, entitled Journal of Quaternary Science, started publication in conjunction with Longman Group in 1986, with J.J.Lowe as Editor. The editorial in the first number describes the background of the launch of the Journal. Its success is shown by the increase in the frequency of publication in its early years: twice a year, 1986-1989; three times a year, 1989-1990; four times a year (change to Wiley), 1991-1995; six times a year, 1996-.

The development of the Quaternary Research Association parallels the expansion of the Subdepartment of Quaternary Research, and emphasises the impetus gained by the subject in a relatively short time. The realisation of the necessity for interdisciplinary research forms the basis for the changes in both organisations, with the responses described above.

Quaternary research centres

The need for interdisciplinary teaching and research, as seen in the formation of the Subdepartment of Quaternary Research, was recognised much more widely in the following years. The Freshwater Biological Association formed a Quaternary Research Group at Windermere in 1967. Quaternary research centres were formed at Royal Holloway (University of London), Coventry University, and Cheltenham and Gloucester College of Higher Education. Quaternary teaching and research also became a part of the many centres for environmental research later established. These included the School of Environmental Sciences at the University of East Anglia (1968), and those at the University of Ulster at Coleraine, University of Brighton, University of Durham, and University College (London). Many of these developments were to be associated primarily with departments of geography, rather than earth science or biological departments, but gave scope for a great variety of inter-disciplinary courses at undergraduate and post-graduate levels.

Research support

The development of the subject depended to a great extent on the award of research studentships or grants supporting research students. In Cambridge in the 1930s the D.S.I.R. supported the work of M.H.Clifford in the Fenland, and, in the post-war period, D.Walker's research on the late- and post-glacial in north-west England. When the Nature Conservancy was established in 1949, funds for research support became available, and award of research studentships became a part of the Conservancy's work to encourage the scientific base for their policies.

H.Godwin was a founder member of the Nature Conservancy and encouraged the Quaternary vegetation history interest, so that such studentships became a possibility for Quaternary research in vegetational history. One such studentship was awarded to me in 1951 for research on interglacial vegetational history. These studentships greatly encouraged the development of the subject, and were later replaced by studentships awarded by the Natural Environment Research Council when it was established in 1965. In addition, research grants from the N.E.R.C. became of prime importance in supporting Quaternary research. Studentship awards were also later established by the Science-based Archaeology Committee (established 1978) of the Science Board of the Science and Engineering Research Council. Research grants from this source aided many projects witrh a Quaternary interest, especially in the field of dating.

Journals

Journals devoted to the Quaternary have a long history, but not until the 1950s did such publications start to proliferate. An early example was the *Glacialists', Magazine*, started by P.F.Kendall in 1890, but lasting only to volume 5 in 1897. Papers of Quaternary interest were published in the relevant general scientific journals, for example the *Quarterly Journal of the Geological Society*, the *Proceedings of the Geologists' Association* and the *Journal of Ecology*, the last of which contained significant papers on vegetational history in the 1920s. These arrangements satisfied the need at the time and had the advantage of bringing the subject to the notice of a wider audience in geology and biology.

Opportunities changed in the early 1930s. Papers on pollen analysis and post-glacial vegetational history in the 1930s found publication in *The New Phytologist*, of which H.Godwin was an Editor, with longer papers in the *Philosophical Transactions of the Royal Society of London*, communicated to the Society by A.C.Seward. This journal supported many important and detailed papers on geological and biological Quaternary research in subsequent years, until the late 1980s when editorial polices changed. Such lengthy papers were not usually acceptable to other journals, but this style of the reporting of detailed Quaternary research at the time was invaluable to the development of the subject. With Godwin as an Editor, *The New Phytologist* especially accepted a long series of papers on Quaternary vegetational history, until policies changed in the 1990s.

The changes in editorial policies noted above were paralleled by the great expansion of Quaternary research starting in the 1950s, and the consequential increase in demand for publication. Thus an amazing number of new series titles relevant to Quaternary research started publication, including the following, with date of start:

1938 *Quartar*; 1951 *Eiszeit und Gegenwart*; 1954 *Quaternaria*; 1954 *Biuletyn Peryglacjalny*; 1954 *Grana Palynologica* (n.s.); 1959 *Pollen et Spores*; 1965 *Palaeogeography, Palaeoclimatology, Palaeoecology*; 1967 *Review of Palaeobotany and Palynology*; 1970 *Quaternary Research*; 1970 *Quaternary Newsletter*; 1972 *Boreas*; 1974 *Journal of Archaeological Science*; 1974 *Journal of Biogeography*; 1982 *Quaternary*

Science Reviews; 1983 *Circaea*; 1986 *Journal of Quaternary Science*; 1989 *Quaternary International*; 1990 *Quaternaire*; 1990 *Permafrost and Periglacial Processes*; 1990 *Quaternary Perspectives*; 1991 *Holocene*; 1991 *Quaternary Proceedings*.

A reverse danger of this proliferation is a hiding in specialised journals of the significance of the subject to the wider geological and biological audience. The increasing number of multi-authored papers in these journals reflects the expansion of the subject and the accompanying increased specialisation of researchers.

Envoi

In the first years of the Subdepartment, the small group of people under the leadership of Harry Godwin were working in an ideal productive environment. The accommodation in the Elementary Laboratory Annexe of the Botany School provided a minimal and very irregular area of space, with the microscope benches, reference collections, preparation areas and sinks, and even a fume cupboard for pollen sample preparations (including the use of HF) all within a few feet . In retrospect, the resulting esprit de corps was enormously encouraging, since everyone knew and appreciated the excitement given by the novelty and significance of the research. Discussions in the Annexe were a source of much education. Thus, when the Hoxne interglacial site was under pollen analysis, each extension of the pollen diagram by the depth of a short core was a subject of intense interest and speculation, and similarly with all the new discoveries of interglacial, late-glacial and post-glacial sites in various parts of the country. The field investigations in all these areas were often communal, an ideal combination of education and enjoyment.

It is not easy to recall the background of the state of knowledge at the time, except that there was in view a huge potential, and that we had much to learn from what had been achieved in northern Europe in many areas of Quaternary research. Stratigraphy in Britain was a foggy subject of much dispute and more correlation. Pollen analysis was beginning to be applied to many problems of vegetational history in many parts of the country, not only in the strict ecological sense, but also as an indispensable tool in relation to the wider spheres of, for example, sea level change, climatic change, stratigraphic implications and archaeological investigations. These activities carried the imprint of the earlier Fenland Research Committee, with its co-operative research in field and laboratory, but added to them were the innovations in field and laboratory techniques and the very significant introduction of radiocarbon dating.

In the following years research on terrestrial vegetational history, stratigraphy and chronology expanded vastly, with the addition of marine studies of sediments, palaeontology and chronology. As knowledge advanced, the excitement of investigation of newly discovered sites which gave so much novel insight, became accompanied by selection of sites for defined purposes. With the increased documentation of Quaternary environmental variations, particularly climate, came the recognition of the use of proxy data for assessing the degree and nature of climatic change, with the possibility of a satisfactory chronology emerging. With increased funding, associated rightly with the perception that climatic change was a subject of prime importance for the future, and that knowledge of the past was necessary for prediction, the population of Quaternary researchers expanded rapidly. An increasing number of sciences became involved, terrestrial,marine and atmospheric. This is reflected in the increasing number of multi-authored papers published as the research developed. Increased co-operation between the sciences was obviously essential for studying the history of the environment. The concomitant increase of the data bank posed problems. International committees were formed to bring together the many disciplines, organise major projects and dispense progress reports (e.g. International Geological Correlation Projects, International Geosphere-Biosphere Programme, INQUA commissions, PAGES, etc.). Wider correlations between terrrestrial, marine and ice core sequences became a reality, improving the construction of global circulation models and aiming to improve understanding of the world climate systems.

This is one end of the axis of expansion of Quaternary research. At the other end, across the wide spectrum of Quaternary research, is the need to increase understanding of the biota, in particular the relation of the species to its environment, if inferences about past environments from biota are to be substantiated. This means an understanding of the biotype content of species. There needs to be a linking of biotypes of present species with their Quaternary precursors, via techniques of molecular biology. Here lies the value of a collection of fossil identified species in stratigraphic context of the kind maintained by the Subdepartment of Quaternary Research. As I was reminded by Donald Walker recently, a catchphrase in the Subdepartment in its early days was a cry of 'depauperisation of the biotypes' when the context of a fossil did not seem to fit in with the environment of the modern distribution of the taxon. That was fifty years ago, and the problem remains.

At the same British Association meeting in Liverpool in 1923 when a Committee was appointed 'To investigate Quaternary peats of the British Isles' (see Part I, Ch.2), A.G.Tansley was President of Section K (Botany). His address was entitled 'Some aspects of the present position of botany'. His final paragraphs expressed concern about new developments at that time made it difficult 'to focus the whole subject from a viewpoint determined by current knowledge' and 'this power will come to be possessed by fewer and fewer botanists and the subject will definitely and finally break up into a number of specialised and un-co-ordinated pursuits'. 'Do we want this to happen ?' His answer was 'No !' 'I do not think that there is any question that the most advanced research worker , …., benefits substantially by having had a training which is at once the broadest and most vital that is possible' (Tansley 1923). The same thoughts may have entered the heads of those now teaching Quaternary research. No such problem was obvious at the inception of the Subdepartment of Quaternary Research, but the existence of a similar question now about Quaternary research shows how far we have come.

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Woldstedt,P. 1934 Einige probleme des osteuropäischen Quartärs. *Jahrbuch der Preussischen Landesanstalt für 1933*, **54**, 371-387.

Woldstedt,P. 1950 Das Vereisungsgebiet der Britischen Inseln und seine Beziehungen zum festländischen Pleistozän. *Geologisches Jahrbuch*, **65**, 621-640.

Woldstedt,P. 1954 *Das Eiszeitalter.* 2nd Ed. Bd 1. Stuttgart, Ferdinand Enke.

Woldstedt,P. 1955 *Norddeutschland und angrenzende gebiet im Eiszeitalter*. Stuttgart, K.F.Koehler Verlag.

Worsley, P. 1987 Permafrost stratigraphy in Britain – a first approximation. In *Periglacial processes and landforms in Brtiain and Ireland*, ed. J.Boardman, pp. 89-99. Cambridge University Press.

Wright,W.B. 1914 *The Quaternary Ice Age*. London, Macmillan.

Wright.W.B. 1937 *The Quaternary Ice Age*. 2nd Ed. London, Macmillan.

Wulff,E.V. 1950 *An Introduction to Historical Plant Geography*. Waltham, Mass., Chronica Botanica. (translation of the original 1933 Russian version).

Wymer,J.J. 1974 Clactonian and Acheulian industries in Britain – their chronology and significance. *Proceedings of the Geologists' Association*, **85**, 391-421.

Wymer,J.J. 1988 Palaeolithic archaeology and the British Quaternary sequence. *Quaternary Science Reviews*, **7**, 79-98.

Yalden,D. 1999 *The history of British Mammals*. London, T. & A. Poyser.

Zeuner,F.E. 1935 The Pleistocene chronology of central Europe. *Geological Magazine*, **72**, 350-376.

Zeuner,F.E. 1937 A comparison of the Pleistocene of East Anglia with that of Germany. *Proceedings of the Prehistoric Society*, 1937, 136-157.

Zeuner,F.E. 1959 *The Pleistocene Period*. 2nd Ed. London, Hutchinson.

Appendix A

Graduate students, Sub-department of Quaternary Research

Ph.D., except where M.Sc. indicated. Academic Year of graduation to Ph.D., M.Sc.

1938/39 M.H.Clifford The post-glacial vegetational history of the East Anglian Fenland.

1953-54 D.Walker Studies of the Inter-glacial and Post-glacial history of British Vegetation.

1954/55 S.L.Duigan The vegetational history of English interglacial deposits.

R.G.West The Pleistocene vegetation and geology of East Anglia.

1955/56 J.J.Donner The geology and vegetation of late-glacial retreat stages in Scotland.

S.C.Seagrief A pollen analytic investigation of the Quaternary Period in Britain.

A.G.Smith Studies of the late Quaternary history of some coastal districts of northern England.

1956/57 -

1957/58 E.H.Willis The applications of radicarbon dating to Quaternary research.

1958/59 B.Seddon Geology and vegetation of the Late Quaternary period in North Wales.

L.A.Stevens Studies in the Pleistocene deposits of the British Isles.

1959/60 Vishnu-Mittre Post-glacial history of the Whittlesey Mere Region of East Anglian Fenland.

1960/61 R.G.Pearson The Coleoptera from some Late Quaternary deposits and their significance for zoogeography.

1961/62 J.Turner Post-Neolithic vegetational history in Britain.

1962/63 -

1963/64 N.T.Moar The history of the late Weichselian and Flandrian vegetation in Scotland.

1964/65 P.E.P.Norton Studies of the Pleistocene Mollusca of East Anglia.

G.H.Evans Late-Quaternary history of the Blelham Basin.

J.H.Dickson Historical biogeography of the British Moss Flora.

1965/66 -

1966/67 C.Turner Middle Pleistocene vegetational history and geology in East Anglia.

1967/68 N.J.Shackleton The measurement of palaeo-temperatures in the Quaternary Era.

R.T.Angold The ontogeny and fine structure of the pollen grain of *Endymion non-scriptus* (L).

1968/69 F.G.Bell Weichselian glacial floras in Britain.

1969/70 H.H.Birks Studies in the vegetational history of Scotland.

H.J.B.Birks The Late-Weichselian and present vegetation of the Isle of Skye.

1970/71 -

1971/72 R.B.Beck The Lower Pleistocene geology and vegetational history of East Anglia.

1972/73 A.P.Brown Late-Weichselian and Flandrian vegetation of Bodmin Moor, Cornwall.

L.M.Phillips Pleistocene vegetational history and geology in Norfolk.

1973/74 -

1974/75 P.L.Gibbard Pleistocene stratigraphy and vegetational history of Hertfordshire.

R.M.Peck Pollen transport and deposition in Oakdale, North Yorkshire.

L.Rymer The palaeoecology and historical ecology of the parish of North Knapdale, Argyllshire.

1975/76 P.W.Beales Palaeolimnological studies of a Shropshire mere.

R.E.Sims The vegetational history of East Anglia related to agricultural practice. (M.Sc.)

1976/77 R.J.N.Devoy Flandrian sea-level change and vegetational history of the Lower Thames estuary.

B.Huntley The past and present vegetation of the Morrone Birkwoods and Caenlochan National Nature Reserves.

I.C.Prentice Studies on modern pollen spectra.

W.Williams The Flandrian vegetational history of the Isle of Skye and the Morar peninsula.

1977/78 A.R.Hall The vegetational history and geology of the Late Pleistocene deposits at Wing, Rutland.

1978/79 R.H.W.Bradshaw Modern pollen representation factors and recent woodland history in S.E. England.

1979/80 P.Coxon Pleistocene environmental history in central East Anglia.

1980/81 M.E.Edwards Ecology and historical ecology of oakwoods in N. Wales.

1981/82 C.D.Bates Pollen stratigraphy from deep-sea cores in the Cilicia basin, north-east Mediterranean.

1982/83 A.M.Alderton Flandrian vegetational history and sea-level change of the Waveney Valley.

K.D.Bennett Tree population history in the Flandrian of East Anglia.

P.D.Kerslake Vegetational history of wooded islands in Scottish lochs.

H.F.Lamb Late Quaternary vegetational history of the forest- tundra ecotone in north-central Labrador.

D.G.Wilson On plant macrofossils from archaeological sites in Britain.

1983/84 -

1984/85 J.D.Scourse Late Pleistocene stratigraphy of the Isles of Scilly and adjoining regions.

1985/86 P.A.Ventris Pleistocene environmental history of the Nar Valley, Norfolk.

1986/87 M.V.Mullane The analysis of oxygen isotope ratios in cellulose from tree rings. (M.Sc.)

1987/88 R.M.Corfield The environmental control of the evolution of Palaeogene and Early Eocene planktonic Foraminifera.

1988/89 -

1989/90 K.Willis Late Quaternary vegetational history of Epirus, northwest Greece.

1990/91 L.Allen The evolution of the Solent River system during the Pleistocene.

J.A.Fossitt Holocene vegetation history of the Western Isles, Scotland.

J.C.Woodward Late Quaternary sedimentary environments in the Voidomatis Basin, northwest Greece.

A.J. Chepstow-Lusty Nannoplankton as indicators of climatic variability in the Upper Pliocene.

1991/92 J.P.Lunkka Sedimentology of the Anglian glacial deposits in north-east Norfolk.

G.J.Fyfe The morphology and sedimentology of the Salpausselkä I moraine in southwest Finland. (with Geography)

P.C.Tzedakis Vegetation dynamics in north-west Greece in response to Quaternary climatic cycles.

L.Zhou Thermoluminescence dating and environmental magnetism of loess from China.

J.Le Temperature and carbonate dissolution variability in the western equatorial Pacific during the Late Quaternary.

1992/93 M.A.Maslin A study of the palaeoceanography of the N.E.Atlantic in the Late Pleistocene.

1993/94 M.J.Bunting Environmental history and human impact in Orkney, Scotland.

S.H.Lumley Late Quaternary vegetational history of the Taitao Peninsula, Chile.

1994/95 J.L.Fuller Holocene forest dynamics in southern Ontario, Canada.

A.E.Richards The Pleistocene stratigraphy of Herefordshire.

H.M.Roe Pleistocene buried channels in eastern Essex.

1995/96 N.J.Loader The stable isotope dendroclimatology of *Pinus sylvestris* from northern Britain.

1996/97 -

1997/98 C.Gao Sedimentology and stratigraphy of the River Great Ouse, Southern England.

1998/99 D.L.Hemming Stable isotopes in tree rings: biosensors of climate and atmospheric carbon dioxide variations.

I.Robertson Tree response to environmental change.

1999/00 C.G.Glaister Palynology of late Pleistocene marine sediments in North Denmark.

Graduate students from other Departments.

1986/87 R.A.Housley (Archaeology) The environment of Glastonbury Lake Village.

1988/90 M.Morecroft (Botany) Altitudinal trends in the photosynthetic characteristics and nutrient relations of selected mountain plants.

1989/90 P.N.Pearson (Earth Sciences) Evolution and phylogeny of Palaeogene planktonic Foraminifera.

1993/94 A.C.Barker (Anglia Polytechnic University) Stable isotopes dendroclimatology in oaks from Finland.

1994/95 N.A.S. Beveridge (Earth Sciences) Palaeoceanography of the Eastern Atlantic.

1997/98 M.Jonas (Physics) Electron spin resonance dating and dosimetry of tooth enamel.

M.Phil. in Quaternary Research

1980/81 A.H.C.Carter Dendrochronology and climatic change.

1983/84 S.Heptinstall Late Devensian and Flandrian vegetational history of a tributary of the River Wensum, Worthing, Norfolk.

1984/85 S.M.S.Burn Lateglacial and Flandrian vegetational history in East Anglia.

1985/86 D.Warlow Flandrian of an offshore area of north-east England.

1986/87 L.Allen Quaternary history of the Solent River (see Ph.D. title 1990/91).

1988/89 A.Wheeler Flandrian deposits of eastern Fenland.

1989/90 J.Packham Raised beaches and associated deposits at Black Rock, Brighton, Selsey and Boxgrove.

K.Hill Holocene pollen and charcoal record in Shetland.

1990/91 C.A.Bannerman Glacial deposits of northern Norfolk (Glaven Valley).

M.E.Ruse Post-glacial alluvial deposits in the Colne Valley.

A.E.Richards Quaternary deposits of Herefordshire (see Ph.D. title 1994/95).

1991/92 S.H.Dawson Chemical stratigraphy of a Late-glacial sediment profile, North Humberside.

R.E.Teed Devensian and Holocene vegetational history, Eccles Carr, Norfolk.

1993/94 E.M.Field Measurement of stable isotopes in tree rings for climatic reconstruction.

Other graduate students noted in Annual Reports

1949-1950	K.Pike British interglacial deposits
	K.Bachem Deposits at Peterborough and Hungate, York.
1956-1958	F.Oldfield Vegetational history and sea level change, south Westmorland.
1967-1968	S.M.Nye Sub-fossil moss assemblages, Lake District.
1982/3-1985	G.A.Southgate TL dating of beach and dune sediments.
1984/5-1989/9	N.A.Holman (Archaeology) Dendrochronology and archaeology in the East Anglian Fenland.
1986-1988	K. Bryant Vegetational history in the English Midlands.
1991/2-1993/4	M.Garbutt (with Geography) Esker sedimentology in the hydraulics of subglacial water flow.
1991/92-1992/93	A.Craighead (Archaeology) Marine Mollusca as palaeoclimatic indicators in Cantabrian Spain.

Appendix B

List of researchers

The list, not guaranteed or intended to be a complete record, but rather representative of the activities of the Subdepartment, includes local co-operators, research fellows, grant-supported researchers (assistants, post-docs), research associates, and also a selection of grant-supported visiting scientists.

Abbreviations:

First column is subject area: A, archaeology; Ag, agriculture; B, botany; D, dating; G, E.S., geology; Ge, geography; MI, marine geology, istope geology; Z, zoology.

2nd column: R, research assistant; P, post-doctoral position; (Rs, research student), vis, visiting.

3rd column: source of funds if known.

College fellows: C, Clare; CH, Clare Hall; G, Girton; N, Newnham; Sel, Selwyn; SS, Sidney Sussex.

AR, Annual Report Number with first mention.

Local co-operators

Ge B.W.Sparks, R.B.G.Williams, A.T.Grove

G C.L.Forbes, R.W.Hey, B.M.Funnell, C.V.Jeans

A J.G.D.Clark, J.Coles, C.B.M.McBurney

Ag R.M.S.Perrin

College Fellows

B	D.Walker	C.	AR 3	Vegetation history, Quaternary geology
B	R.G.West	C.	AR 5	Vegetation history, Quaternary geology
B	J.Turner	N.	AR 12-15	Post-glacial vegetational history, forest clearance, spread of agriculture
B	J.H.Dickson	C.	AR 14	Quaternary history Bryophyta

B	F.A.Hibbert	CH.	AR 19	Vegetational history, radiocarbon dating
B	H.H.Birks	N.	AR 23-25	Scottish vegetational history, macroscopic plant remains
B	H.Lamb	SS.	AR 33, 34	Vegetational history Labrador, Morocco
Z	A.Lister	G.	AR 33	Pleistocene vertebrate fauna
G,B	J.D.Scourse	G.	AR 36	Quaternary of Scillies and SW England
B	K.J.Willis	Sel.	AR 42-45	Vegetational history Greece, Hungary

Research Council Fellows

Z	A.J.Stuart	NERC	AR 23	Pleistocene vertebrate fauna
D	E.Rhodes	NERC	AR 42, 43	ESR dating
B	K.J. Willis	NERC	AR 42-45	Vegetational history Greece, Hungary

Grant-supported research members of the Subdepartment (in order of time)

D	R	Nuffield	E.H.Willis	AR 3	Radiocarbon dating
MI	R	DSIR	N.J.Shackleton	AR 12	Palaeotemperatures, oxygen & carbon isotopes
B	R	NERC	D.G.Marsden (Wilson)	AR 15	Macroscopic plant remains
B	R	DSIR	R.E.Angold	AR 15	E-M pollen development
B	R	ARC	U.Allitt	AR 19	Aerobiology (air spora)
B	R	NERC	J.Deacon	AR 20	Quaternary plant records
BA	P	Arch.	S.Beckett	AR 27	Somerset palaeoecology
B	R	SRC,NERC	R.Andrew	AR 28	Pollen atlas, pollen analysis
G	P	NERC	P.L.Gibbard	AR 28	Quaternary Thames Valley
B	P	NERC	B.Huntley	AR 29	Pollen maps
D	P	NERC	A.G.Wintle	AR 30	TL dating
A	R,P	SRC	M.R.Deith	AR 31	Isotope analysis and seasonality studies
B	R	IBM	J.Line	AR 32	Numerical analysis
MI	P	Vis NJS	J.Backman	AR 32	NJS research
B	R	NERC	M.E.Pettit	AR 32	Macroscopic plant remains
D	P	Vis AGW	H.Proszynska	AR 32	TL loess

MI	P	Vis NJS	S.Cang	AR 33	Pacific marine geology
B	P	HBMC CCC	A.M.Alderton	AR 34	Fenland palaeoecology
Z	P	Vis	R.Preece	AR 34	Non-marine molluscs
G	R	NERC	C.Whiteman	AR 36	Quaternary Lower Thames
B	P	HBMC CCC	M.Waller	AR 37	Fenland palaeoecology
D	P	EEC SERC	R.Grün	AR 38	TL & ESR dating
MI	P	NERC	S.G.Robinson	AR 39	Magnetic susc. marine sediments
MI	P	Vis NJS	J.Erez	AR 39	NJS research
B	P	Vis KDB	C.Lees	AR 40	Flandrian woodland history
MI	P	NERC	C.Bertram	AR 42	Palaeoceanography
BA	P	NERC/ McDonald Inst.	P.Day	AR 42	Star Carr palaeoecology
B	P	NERC	M.H.Field	AR 42	European pollen data base
B	P	NERC	J.A.Fossitt	AR 42	NW Ireland palaeoecology
D	P	NATO	W.J.Rink	AR 42	ESR dating
MI	P	NERC	L.Le	AR 43	Western Pacific forams
B	P	NERC	P.C.Tzedakis	AR 43	Greece palaeoecology
MI	P	NERC	M.Chapman	AR 44	Palaeoceanography
MI	P	NERC	A.J.Chepstow-Lusty	AR 44	Discoasters
B	P	EC	A.Davis	AR 44	European pollen database
B	P	EC	M.F. Sanchez –Goni	AR 44	Epirus, Pyrenees palaeoecology
MI	P	EC	P.Sjoerdsma	AR 44	Marine palaeodatabase
D	P	McDonald Inst.	L.P.Zhou	AR 44	TL loess
B	P	Leverhulme	S.Lumley	AR 45	Chile palaeoecology

Research associates

B	F.E.Round (Birmingham)	AR 2	Diatom analysis
B	C.Turner (OU)	AR 19, 24- 42	Palaeoecology, geology
Z	R.C.Preece (Z)	AR 33- 45	Pleistocene faunas (molluscs)
Z	A.J.Stuart (Z)	AR 29-42	Pleistocene faunas (vertebrates)
Z	A.M.Lister (Z)	AR 29-32, 35-42	Pleistocene faunas (vertebrates)

Z	J.Egginton (Z, Rs)	AR 32,33	Pleistocene faunas (vertebrates)
ZA	K.Scott (Cropper) (A,Rs)	AR 32-34	Pleistocene faunas (archaeology)
B	R.B.Austin (J.Innes Inst.)	AR 41	Isotopes and plant physiology
G	T.van Andel (E.S.)	AR 42	Palaeoceanography, climates
D	A.H.C. Carter	AR 43	Dendrochronology
D	J.H.Waterhouse (APU)	AR 43	Isotope dendroclimatology
D	E.A.Marseglia (Cavendish)	AR 44	ESR dating

Visiting the Subdepartment for a substantial time

G	R.P.Suggate (NZ Geol.Survey)	AR 9	Quaternary geology and pollen analysis
BA	M.J.Kajale (Pune)	AR 35	Fenland palaeoecology
B	Gurdip Singh (ANU)	AR 39	Global development of vegetation & climate

Miscellaneous student visitors

B	B.Madsen	AR 28	Churchill Scholar	Palaeoecology Isle of Lewis
B	T.C.Hunt	AR 32	Watson Scholar	Devensian late-glacial palaeoecology

Quaternary research in Britain and Ireland

During the later part of the last century there was rapid development of the study and understanding of the changing environments of the last 2 million years. This came to provide a firm background for today's knowledge of the significance and importance of climatic change. Interdisciplinary research has been a prominent, if not essential, contributor to the successes achieved. In illustration of this connection, I describe here such developments in the University of Cambridge. In 1948 the University established a Subdepartment of Quaternary Research, with teaching and research activities covering geological, biological and archaeological topics. An interdisciplinary approach was an essential ingredient, and the research covered both terrestrial and marine spheres. The book traces the history of Quaternary research in Britain and Ireland, particularly the continental influences which stimulated research and indeed led to the establishment of the Subdepartment.

The early years of the Subdepartment were an exceptionally exciting time for Quaternary researchers. This period saw the development of radiocarbon dating and of marine geochemical studies, together with the improvement of interpretation of palaeobotanical data, and the consequent incorporation of a vast accession of new information relating to these subjects. Stratigraphy, the binding topic of Quaternary research, became much better understood: first, in the terrestrial sphere with the formulation of divisions of the Quaternary based on accepted geological principles and providing a measure of the passage of time to students of the several disciplines involved, including landscape history, ecosystem history and archaeology, and secondly in the marine sphere a formulation of units defined by isotope studies.

The organisation of the Subdepartment and the problems of developing interdisciplinary science are considered. An important aspect is the variety of staff and students involved in interdisciplinary research and teaching. In order to give a complete an account as possible of the activities of the Subdepartment, a listing of staff and students and their interests is compiled, which I think is necessary to give a rounded view of the Subdepartment as a whole.

Research topics and their development are considered one-by-one, and the numbers of publications in each sphere are summarised over the life of the Subdepartment, giving a clear view of how research developed over the period of 45 years. These activities were brought to an end in 1994, with the dissolution of the Subdepartment, which is described, together with a discussion of achievements and the voicing of some reflections.

In a final part, I take a wider view of the history of Quaternary research, with aspects of geology and biology considered, together with notes on the Quaternary community, research support and journals.

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