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MID- TO LATE-HOLOCENE FOREST COMPOSITION AND THE EFFECTS OF CLEARANCES IN THE COMBE HAVEN VALLEY, EAST SUSSEX

by Christine Smyth and Simon Jennings

Forest composition stages for the past 6000 years have been identified for a small catchment in East Sussex. Palynological analysis supported by radiocarbon measurements of two sites within the valley has been undertaken in order to examine the relationship between changes in forest composition, including clearance phases, and valley sedimentation. A variety of causes exist for alterations to the forest, ranging from natural edaphic changes on the valley floor to widespread anthropogenic clearance, the latter predominant from the Iron Age. Archaeological investigations have shown that the Combe Haven valley was a centre for the early iron industry. Anthropogenic forest clearance from approximately 2900 b.p. was responsible for the formation of the present floodplain when biogenic sediments were replaced by minerogenic deposits as a result of slope wash. A major decline in arboreal pollen frequencies on both pollen diagrams corresponds closely with the deposition of minerogenic sediments in the valley bottom. However, the initiation of forest clearance and slope wash appears to be diachronous within the valley.

INTRODUCTION

The Weald of southeast England contains many valleys and low lying coastal areas (Levels) which have accumulated considerable depths of sediments over the last 10,000 years (Holocene), reaching a maximum at the coast of 33 metres (Jennings 1985, Jennings & Smyth 1985, Jennings & Smyth 1987). The sediments have proved problematical in attempts to reconstruct vegetational change through pollen analysis. Hiatuses in the valley infills (Scaife & Burrin 1983) and estuarine minerogenic sequences resulting from marine incursions (Jennings & Smyth 1987) restrict the terrestrial pollen record. At coastal sites, locally derived saltmarsh pollen and considerable quantities of reworked pollen hinder the reconstruction of Holocene forest history (Jennings 1985). Nonetheless, the reconstruction of the Holocene vegetation record has been achieved by Moffat (1984) for the eastern Pevensey Levels (Fig. 1), while a more complete Holocene record has been obtained for valley sites adjacent to Pett Level (Waller 1987) and for the Vale of the Brooks, Ouse valley (Thorley 1981).

The Combe Haven valley has received detailed investigation. Extensive deposits of *in situ* peat capped by approximately 1 metre of silty clay have provided a reliable record of vegetational history from the mid-Holocene. Smyth (1986) has discussed the sequence of vegetational change, and it is the aim of this paper to focus attention specifically upon the forest history of the valley. In particular the relationship between changes in the composition and extent of the forest and valley infill have been investigated. One important objective of the work has been to examine the cause of a major episode of forest depletion in the Iron Age, and to assess the effect on valley sedimentation. Since one possible explanation is anthropogenic forest clearance, assimilating archaeological information with pollen and sedimentological data has been an important approach in this study.

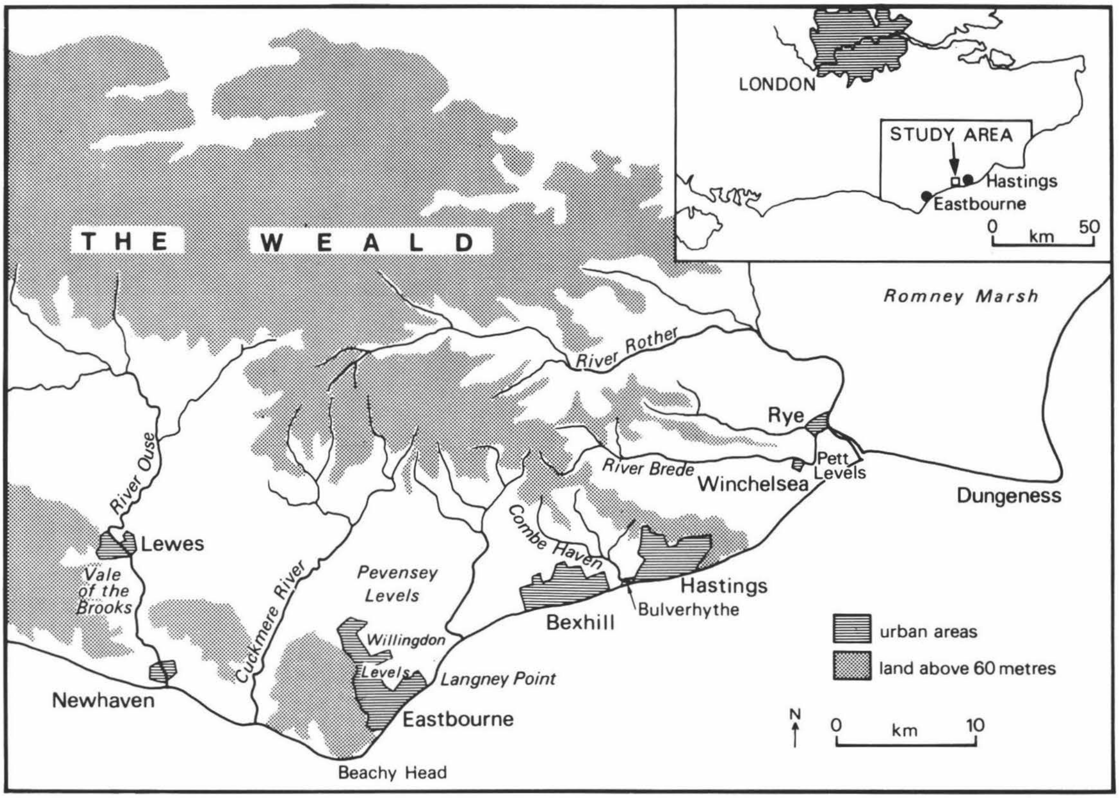

Fig. 1. Location map of South East England showing the study area of the Combe Haven valley, East Sussex.

SITE DESCRIPTION

The catchment covers an area of approximately 52 km.[2] (Fig. 2), the geology consisting of Ashdown Sand, Wadhurst Clay and Tunbridge Wells Sand, members of the Hastings Beds (Gallois 1978). The Combe Haven is an underfit stream on a floodplain that lies for the most part at only + 1 to + 2 metres O.D., well below Mean High Water Spring Tides. A coastal gravel barrier and a sluice prevent flooding by the sea.

FIELDWORK TECHNIQUES

Hand augering every 200 metres (Fig. 2) using a gouge auger, and borehole records supplied by East Sussex County Council (Site Investigation Unit), Southern Water Authority and the British Geological Survey were used to establish the lithostratigraphic units of the valley (given below).

A reliable reconstruction of vegetational history requires well-preserved and stratigraphically undisturbed pollen samples. These conditions are usually best found in peat deposits. A mid-valley site (CH. 1), where the hand auger encountered the maximum recorded depth of peat, was therefore selected for pollen analysis. A down-valley site (CH. 2) was also investigated. Here the peat is interdigitated by estuarine, minerogenic deposits which have yielded data on sea-level tendencies. The examination of these two sites (located on Fig. 2) has given an important spatial dimension to the reconstruction of vegetational history. The auger provided a complete record of the sediments to

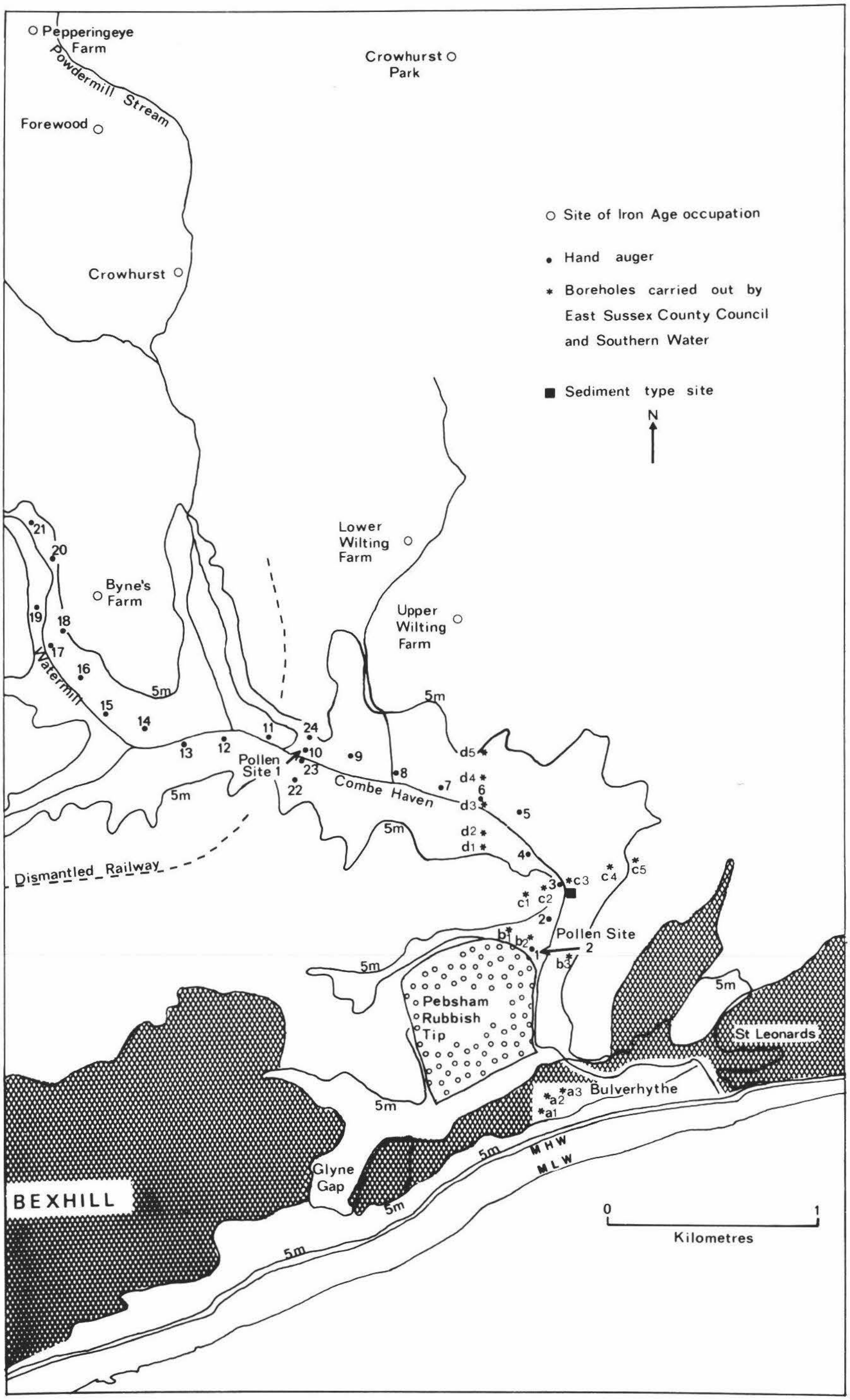

Fig. 2. Location of the augerhole and borehole sites used to construct the lithostratigraphic long- and cross-profiles for the Combe Haven valley. Pollen sites are indicated. For cross-profile data see Jennings and Smyth (1987).

the limit of penetration. No erosion surfaces have been found within the lithostratigraphy.

THE LITHOSTRATIGRAPHIC UNITS OF THE VALLEY

The unconsolidated sediments fill the valley to a maximum recorded depth of 24 metres and are composed of basal gravels, clays, silts, sands and peat. Four lithostratigraphic units are recognised (Figs. 3 & 4)

Unit 1–River Gravels. Their presence has been established from borehole data. They appear to form a basal deposit.

Unit 2–Lower Silty Clay. This extensive deposit is predominantly silty clay in texture (Fig. 4), but up-valley there is an increase in sand. This unit is generally blue to blue-grey in colour, and the minerogenic layer that separates the two peat layers at the seaward end of the valley (Fig. 3) belongs to this unit. Here fossils of the mollusc *Scrobicularia plana* (da Costa) and of the diatoms *Navicula hungarica* Grunow, *Bacillaria paradoxa* Gmelin, *Cymatosima beligica* Grunow and *Nitzschia navicularis* (De Brébisson) Grunow indicate a brackish water depositional environment.

Unit 3–Combe Haven Peat. This unit consists of *in situ Phragmites* (reed) peat with macrofossils of *Alnus* (alder) and can be traced throughout the valley. The peat is approximately 4 metres thick, although it is thinner in the upper part of the valley. At the seaward end there are two distinct peat layers separated by an intercalation of Lower Silty Clay which wedges out in an up-valley direction. Within the Combe Haven Peat are thin lenses of clay. The Combe Haven Peat may be represented on the foreshore by a submerged forest bed, although radiocarbon dating is required to confirm this. Borehole logs indicate deeper peat layers, including a basal peat (Fig. 3).

Unit 4–Upper Silty Clay. This upper unit is found throughout the valley except at the coast where it is replaced by marine gravel (Fig. 3). The Upper Silty Clay extends to a depth of around 80 cm., is stiff to very stiff and is highly oxidised as indicated by orange mottling. A shallow surface loam of approximately 10 cm. forms the present surface of the valley. Despite its homogenous appearance, the Upper Silty Clay is composed of estuarine and freshwater facies.

RESULTS OF THE RADIOCARBON ANALYSIS

Six lithostratigraphic boundaries have been dated. Their locations are shown on Fig. 3 and the results given in Table 1. Careful sampling for the radiocarbon analysis was undertaken to ensure that comparable horizons were used. No bulk sampling was employed and the deeper samples (SRR-2681, SRR-2682, SRR-2683 SRR-2685) were recovered by a large gouge auger from a single augerhole at both sites. The shallower samples (SRR-2680 and SRR-2684), to which particular reference is made in this paper, were taken from open pits constructed especially for the sampling. In this way contamination was avoided. Therefore, it is considered that the age difference between SRR-2680 and SRR-2684 is real, and this implies a diachronous onset to Upper Silty Clay deposition. The radiocarbon dated samples provide a chronostratigraphic framework for the study of sea-level tendencies within the valley, a subject which is more fully discussed in Jennings & Smyth (1987).

RESULTS OF THE POLLEN ANALYSIS

Representation of the data

The standard technique for the isolation of pollen and spores was followed (Moore & Webb 1978). Two relative pollen diagrams are presented. The CH. 1 diagram (Figs. 5 & 6) covers the entire Combe Haven Peat and Upper Silty Clay sequence. For CH. 2 (Figs. 7 & 8) pollen has been analysed from the Upper Silty Clay and from the top levels of the Combe Haven Peat. On both diagrams the pollen sum is 300 dry

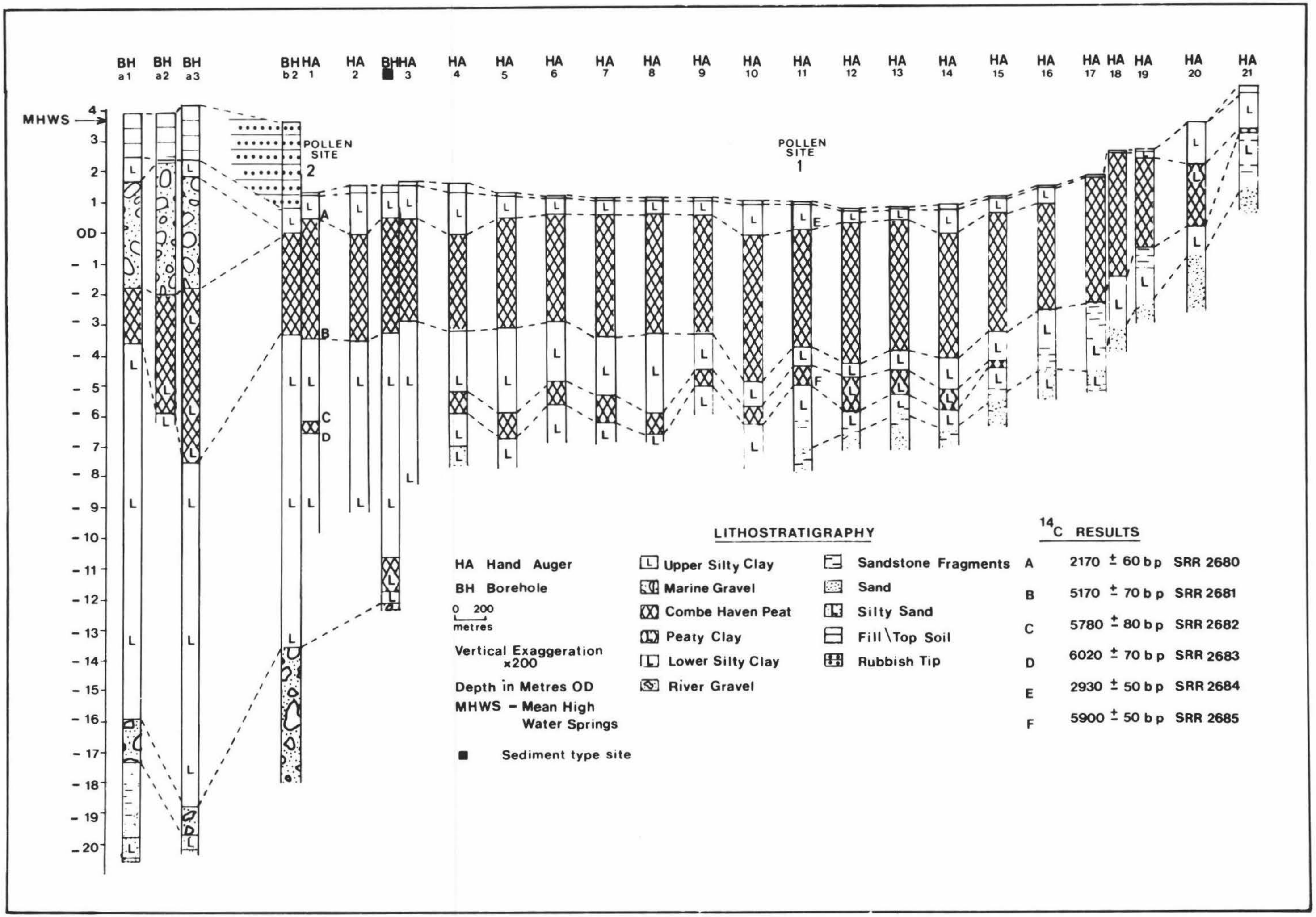

Fig. 3. The long-profile of the Combe Haven valley including lithostratigraphic units and radiocarbon results. The pollen sites are indicated.

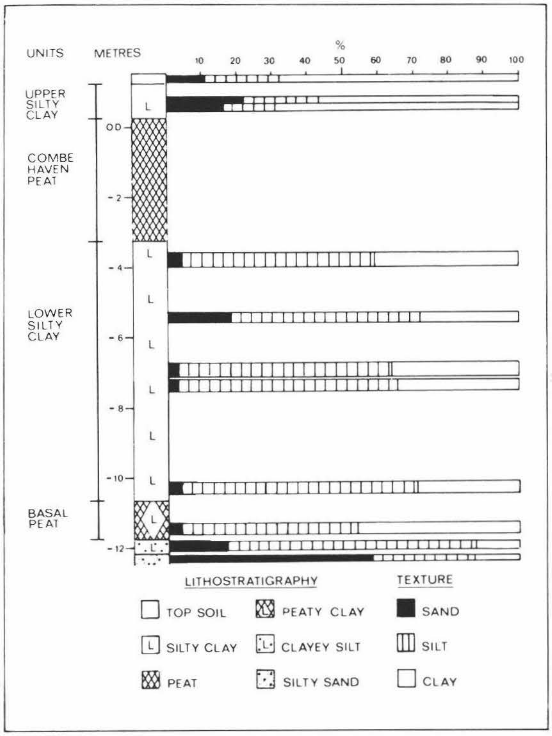

Fig. 4. Sediment type site for the Combe Haven valley including particle size analysis and lithostratigraphic units.

land and marsh pollen excluding *Alnus* (because of overrepresentation), aquatics and spores. The frequency of pre-Quaternary pollen and spores and of Hystrichospheres was also recorded. All depths on the pollen diagrams refer to below ground surface. Local forest composition zones (LFCZ) are annotated on these diagrams. They represent episodes of changing forest history in the valley. Each LFCZ is based upon significant changes in the arboreal pollen (AP) record, and as such is distinct from the more conventional local pollen assemblage zones which are also annotated on the diagrams and are discussed in Smyth (1986). The LFCZs for both sites are summarized in Table 2.

A composite diagram has been constructed for both pollen sites (Figs. 9 & 10) showing the percentage of AP excluding *Alnus,* which is shown separately, and the percentage of non arboreal pollen (NAP), excluding aquatics and spores. The number of deteriorated and indeterminate grains are also presented on these diagrams. Corrected frequencies for *Tilia* (lime) are provided for CH. 1 to allow for the

TABLE 1
Summary of the radiocarbon analysis from Combe Haven 1, and Combe Haven 2.

Results of the radiocarbon analysis— mid-valley site (CH. 1).

Laboratory No.	*Age yr. b.p.*	*Depth (metres O.D.)*
SRR–2684	2930 ± 50	+ 0.31
SRR–2685	5900 ± 50	− 5.02

Results of the radiocarbon analysis— down-valley site (CH. 2).

Laboratory No.	*Age yr. b.p.*	*Depth (metres O.D.)*
SRR–2680	2170 ± 60	+ 0.43
SRR–2681	5170 ± 70	− 3.45
SRR–2682	5780 ± 80	− 6.15
SRR–2683	6020 ± 70	− 6.56

TABLE 2
Summary of the Combe Haven Local Forest Composition Zones (LFCZ).

Combe Haven 1.

Depth (cm.)	*LFCZ*	*Description*
50– 0	6	Deforestation
110– 50	5	*Alnus-Salix-Corylus-Quercus*
140–110	4	*Salix*
200–140	3	*Alnus-Salix-Quercus-Tilia-Corylus*
500–200	2	*Alnus-Tilia-Salix-Quercus-Corylus*
620–500	1	*Tilia-Alnus-Quercus-Corylus*

Combe Haven 2.

Depth (cm.)	*LFCZ*	*Description*
75– 0	2	Deforestation
95– 75	1	*Alnus-Salix-Corylus -Quercus*

underrepresentation of this taxon on pollen diagrams due to its relatively limited pollen productivity and dispersal. The method outlined in Greig (1982) was used to calculate the corrected values. A corrected diagram for most AP types at this site is presented in Smyth (1986).

PROBLEMS OF INTERPRETATION

The under- and overrepresentation of taxa as a result of differences in pollen productivity and dispersal rates is a major consideration when interpreting pollen diagrams. Equally important is an understanding of the provenance of the pollen recorded at the site under investigation. At well-forested sites pollen dispersal tends to be local, but with decreasing forest cover the source area of pollen increases (Jacobson & Bradshaw 1981). This is important for the interpretation of pollen data that show forest clearance because, as a result of a wider provenance, a greater diversity of pollen types is likely to be found as frequencies of AP decrease. As forest cover diminishes pollen is recorded from plant communities located further from the site under investigation. Applying these considerations to the Combe Haven valley pollen data suggests that for LFCZs which indicate a well forested landscape, the source for most of the pollen was the floodplain and lower slopes local to the site, probably within 20 to 30 metres (Jacobson & Bradshaw 1981). During periods of decreased forest cover, pollen was recorded from a wider domain which included upper slopes and a greater area of the floodplain.

An intriguing interpretative problem, salient to the study, is the relationship between sedimentation and the pollen record. At both Combe Haven pollen sites significant changes in the pollen data correlate with transitions between biogenic and minerogenic sedimentation. The cause of this correlation may be two-fold. First, an edaphic change on the valley floor could alter the sedimentary environment and the vegetation. For example, a marine incursion onto a freshwater marsh would result in a switch from biogenic to minerogenic deposition, with a concurrent replacement of freshwater taxa (for example, *Alnus*) by salt tolerant plants (for example some species of Chenopodiaceae (Goosefoot)). Second, anthropogenic forest clearance on valley sides could initiate soil erosion. This would be recorded on the valley floor by a decrease in AP simultaneous with a change from biogenic to minerogenic sedimentation. Distinguishing between these two causes requires a careful appraisal of both the pollen record and the lithostratigraphy.

FOREST HISTORY

LFCZ 1 (620–500 cm.) *Tilia-Alnus-Quercus-Corylus*

The sediments of this LFCZ consist of thin, interbedded peat, peaty clay and clay that began to form between 6020 ± 70 b.p. (SRR-2683) and 5900 ± 50 b.p. (SRR-2685). This was a time of environmental flux with dramatic changes to both the vegetation and sediments of the Combe Haven valley. The lack of NAP (Figs 6 & 9) suggests a closed canopy, and therefore local pollen dispersal 20 to 30 metres from the site (Jacobson & Bradshaw 1981). *Quercus* (oak), *Ulmus* (elm), *Tilia* and some of the *Corylus* (hazel) were probably growing on the valley sides close to the site of CH. 1. The high *Alnus* pollen frequencies and presence of macrofossils indicates that it was dominant in the valley bottom. Fig. 9 emphasises the status of *Tilia* which attains corrected pollen frequencies as high as 72 per cent. This suggests that *Tilia* dominated the forest vegetation of the valley close to the site during LFCZ 1. It is generally accepted that this genus favours well drained soils and higher slopes (Godwin 1975), but Manaut *et al* (in Godwin 1975) have indicated that *Tilia* could be locally abundant at the foot of slopes, near but not on the valley bottoms. However, the high pollen frequencies of *Tilia* in LFCZ 1 suggest that *Tilia* had colonised the lower slopes and may even have become

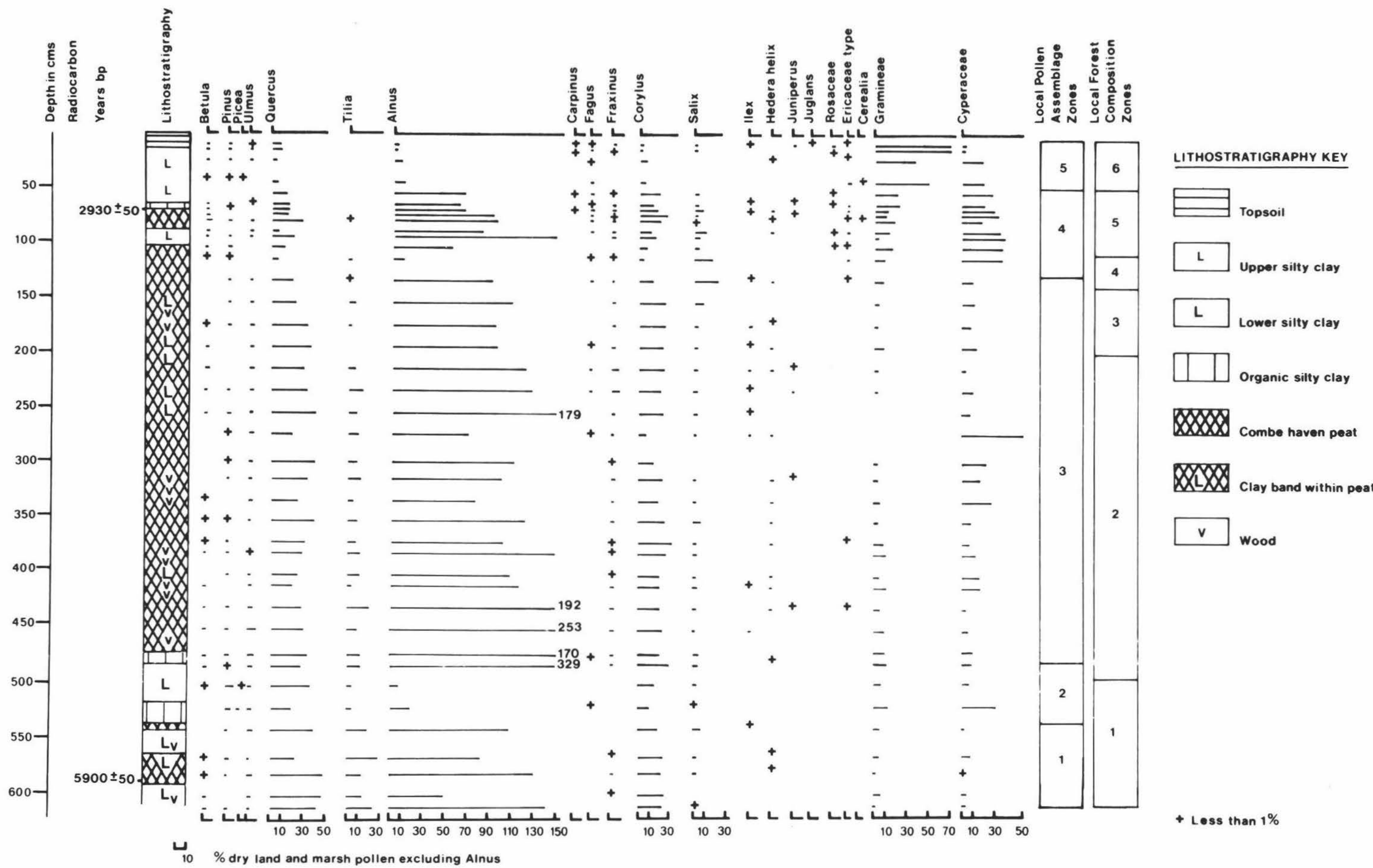

Fig. 5. Radiocarbon dated stratigraphic sequence and relative pollen diagram from Combe Haven 1: arboreal types, Gramineae, Cerealia and Cyperaceae.

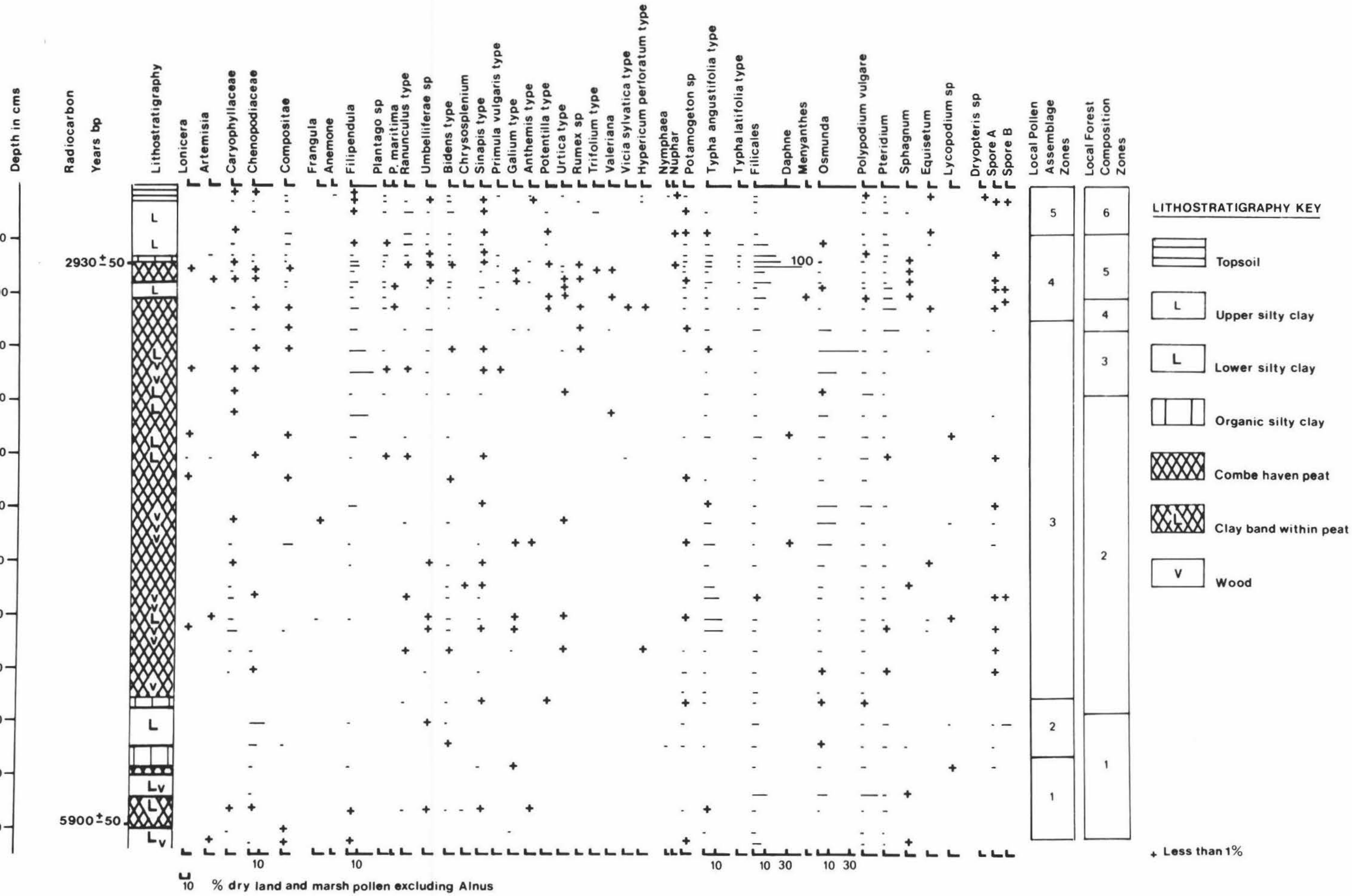

Fig. 6. Radiocarbon dated stratigraphic sequence and relative pollen diagram from Combe Haven 1: herbaceous and aquatic pollen and spores.

established on the valley bottom within 20 to 30 metres of CH. 1. These high values for *Tilia* support the opinion that this genus was an important, if not a dominant member of the indigenous forest over much of south and east England during the mid-Holocene (Turner 1962, Moore 1977, Baker *et al* 1978, Greig 1982).

These *Tilia* values are not thought to indicate selective preservation due to the pollen's high resistance to deterioration. Instead they are believed to be a true reflection of the vegetation because the pollen of this genus attains high frequencies where pollen preservation is good (Fig. 9). Moreover, the frequency of *Tilia* pollen declines in some of the minerogenic horizons in which deterioration is greater.

Changes in the pollen spectra in this LFCZ correlate with lithostratigraphic changes. The organic layers contain high AP counts but dramatic declines in most tree genera accompany the silty clay deposits. These variations in the sedimentary and pollen records may denote an initial rise in the water-table consequent upon the valley being flooded by the sea. Chenopodiaceae pollen within the silty clay layers indicate the proximity of the sea to CH. 1 and are accompanied by increases in Gramineae (grass) and Cyperaceae (sedge) pollen suggesting the establishment of a salt marsh community. Furthermore, the most extensive layer of silty clay can be traced down-valley to CH. 2 (Fig. 3) where the diatom assemblage described earlier indicates a brackish water environment. The frequency of *Pinus* (pine) pollen increases and *Picea* (spruce) pollen is recorded at the point where other AP decline in the silty clay layers. This may also be evidence for the establishment of estuarine conditions. It is possible that *Pinus* may have been growing on the drier valley sides as suggested by its almost continuous presence throughout the diagram. However, there are two possible explanations for the increase in *Pinus* and the appearance of *Picea* pollen. First, as observed by Stanley (1969), long distance transportation of buoyant, winged conifer pollen can result in their overrepresentation in estuarine and marine sediments. This characteristic has been noted at a number of British sites (for example Godwin 1975, Devoy 1979, Jennings 1985). Second, reworking of pre-Holocene sediments under postglacial estuarine conditions may explain the presence of exotic *Picea* pollen, and increases in *Pinus* pollen, in Holocene estuarine sediments (Jennings & Smyth 1987). This uncertainty in the pollen record precludes the use of *Pinus* and *Picea* pollen as reliable indicators of vegetational history during this phase.

The increase in salinity associated with the estuarine environment discussed above had a devastating effect on the valley floor vegetation, notably on *Alnus, Corylus,* and *Salix* (willow) which decline to low values. The decline in *Tilia* from 27 per cent to 5 per cent (Figs. 5 & 9) is further evidence for this genus growing on the valley bottom. There is little evidence to suggest that anthropogenic factors have influenced LFCZ 1. There is an absence of ruderal pollen normally associated with anthropogenic clearance. The evidence suggests edaphically induced responses by the vegetation as a result of a marine incursion.

LFCZ 2 (500–200 cm.) *Alnus-Tilia-Salix-Quercus-Corylus.*

A reduction of the marine influence in the valley is indicated in LFCZ 2 by a recovery of most tree genera that had dramatically declined in the previous LFCZ. A succession on the valley bottom from salt marsh to fen carr dominated by *Alnus* is depicted on the pollen diagram (Fig. 5).

A significant feature of LFCZ 2 is the recognition of several temporary clearance phases, including the 'Elm Decline'. Fig. 9 shows a decline in AP at 412 cm. which is associated with a lithostratigraphic change from peat to peaty clay. The decline in *Tilia* and *Ulmus* values with a corresponding increase in NAP, notably Gramineae, *Artemisia* (mugwort/wormwood) and Caryophyllaceae (Campion) indicate an anthropogenic clearance at the 412 cm. level. The exposure of woodland soils by such temporary clearances could have initiated local colluviation into the valley bottom. Godwin and Vishnu-Mittre (1975) interpreted similar bands of clay as colluviation following selective clearances of *Tilia* at sites in eastern England.

On the pollen diagram (Fig. 5) the temporary disappearance of *Ulmus* is marked by the fall in frequencies from 8 per cent at 452 cm. to less than 1 per cent at 382 cm. and the disappearance at 372 cm. Although this may seem slight as a basis for delimiting the 'Elm Decline', it is nevertheless consistent with *Ulmus* pollen values from other parts of southeast England (Devoy 1979, Thorley 1981). This point on the Combe Haven valley pollen diagram has not been dated, but the beginning of peat formation at CH. 1 has been radiocarbon dated to 5900±50 b.p. (SRR-2685). From its stratigraphic position, it is likely that the *Ulmus* decline corresponds with a *c.* 5000 b.p. date. Pollen of *Plantago* sp. (plantain) appear for the first time, and there is an increase in other NAP in a greater variety than before. Therefore, this 'Elm Decline' probably had an anthropogenic cause, although disease, killing elms and creating cleared areas, would have had a similar effect on the pollen record.

The reduction of cleared areas after the decline in *Ulmus* is shown by the decrease and disappearance of many of the herbaceous pollen types that had expanded during the clearance phases. However, the upsurge in pollen of a more local nature, notably Cyperaceae, *Typha angustifolia* type (reedmace), *Filipendula* (meadowsweet) and spores of *Osmunda* (royal fern), suggests that the environment remained moist, at least on the valley floor in the vicinity of CH. 1. *Quercus, Alnus,* and *Tilia* pollen decline slightly at the 332 cm. and 272 cm. levels and the lack of ruderal pollen associated with anthropogenic influences suggests the cause was a rise in the water table. Additionally, at 252 cm. and 232 cm., peaty clay layers do not correspond with any decrease in AP, and probably represent meandering channels that had little effect on the vegetation.

LFCZ 3 (200–140 cm.) *Alnus-Salix-Quercus-Tilia-Corylus*

A complex lithostratigraphy of peat and peaty clay lenses is found in LFCZ 3. The peaty clay layer at 192 cm. is concurrent with a major decline in *Tilia* pollen (Fig. 9). *Fagus* (beech) pollen is present in low frequencies as *Tilia* declines and later, in LFCZ 5 becomes established when *Tilia* pollen dies out. Thorley (1981) found the same pattern in the Ouse valley (East Sussex) where the appearance of *Fagus* pollen accompanied the decline of *Tilia.* Van Zeist (1964) argues that *Fagus* expanded following Bronze Age and Iron Age clearances. If so, the appearance of *Fagus* may also be a facet of an increased source area of pollen dispersal due to a reduction in the forest cover.

The decline in AP in LFCZ 3 indicates the onset of more substantial clearance. *Polypodium* (polypody) declines, probably due to a loss in tree cover (Moore P.D., pers. comm. 1986). There is also a slight increase in herbaceous pollen that indicates anthropogenic clearance, namely *Plantago* sp., *Rumex* sp. (dock) and Caryophyllaceae.

LFCZ 4 (140–110 cm.) *Salix*

The forest component dramatically changes within this zone. All AP except *Salix* decrease sharply, especially *Quercus,* which until this zone had remained relatively unchanged on the pollen diagram. This reduction in AP indicates the first major anthropogenic clearance of large areas of the forest as opposed to selective or temporary clearances. These larger scale clearances were probably associated with the iron industry. The Combe Haven valley contains the basic materials required for iron working. The best ore is found in the lower levels of the Wadhurst Clay which overlies the Ashdown Sand. The sandstone may have been used for furnace construction. The Combe Haven catchment contains several iron working sites; Pepperingeye, Byne's Farm, Forewood and Crowhurst Park (Fig. 2). Straker and Lucas (1938) and Cleere (1978) have provided evidence for the latter site being a major

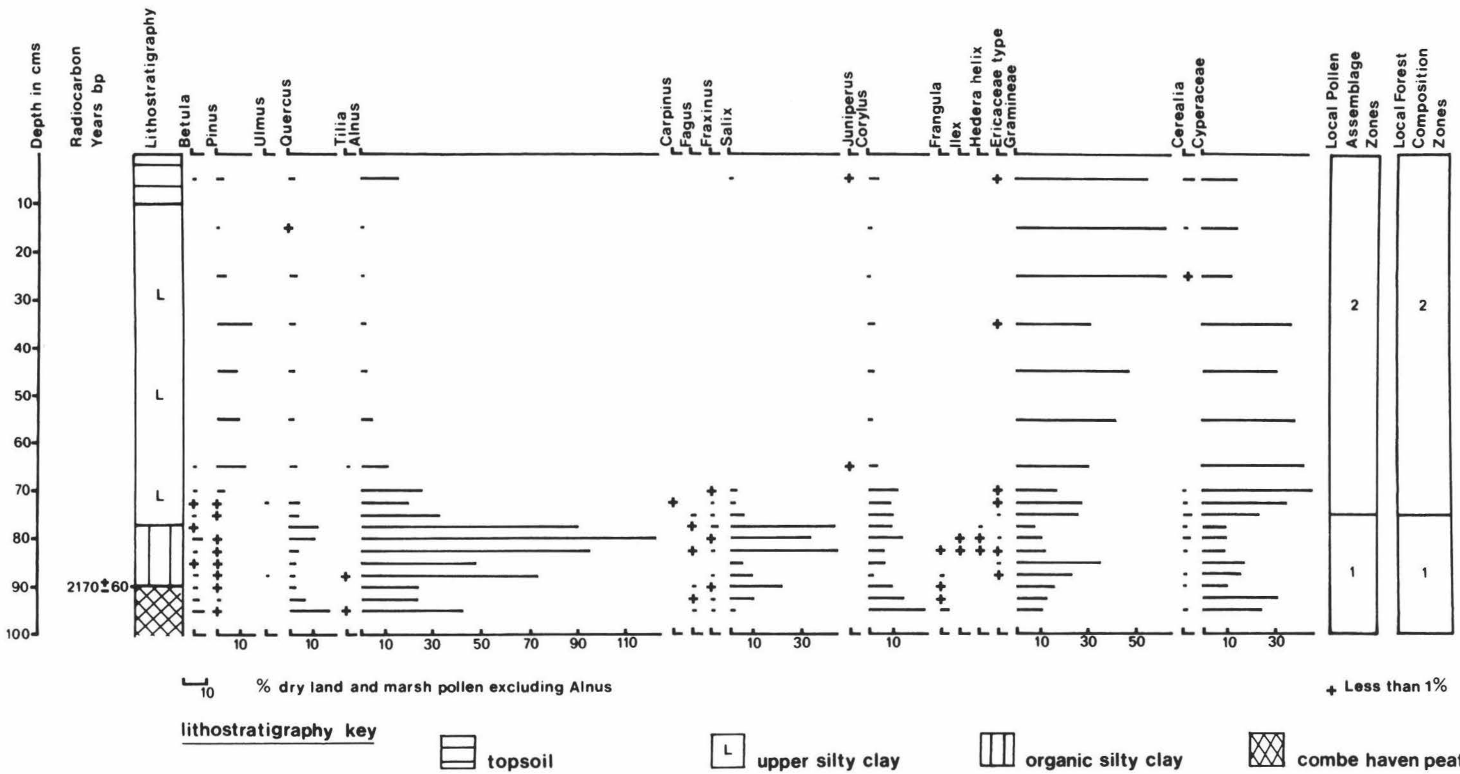

Fig. 7. Radiocarbon dated stratigraphic sequence and relative pollen diagram from Combe Haven 2: arboreal types, Gramineae, Cerealia, and Cyperaceae.

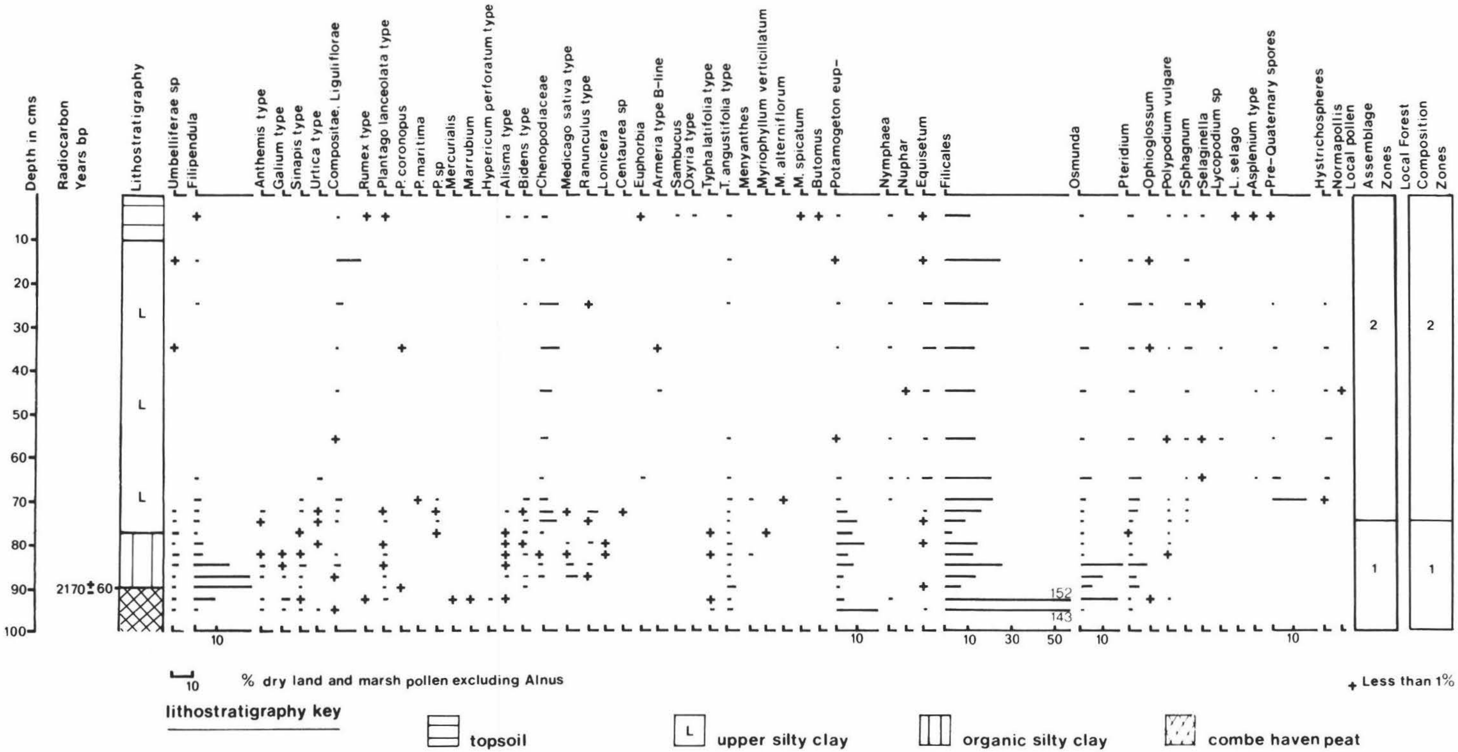

Fig. 8. Radiocarbon dated stratigraphic sequence and relative pollen diagram from Combe Haven 2: herbaceous and aquatic pollen and spores.

centre for pre-Roman iron working.

Quercus could have been used as a source of fuel. Alternatively, large areas of woodland may have been cleared for more extensive agriculture, possibly to serve the growing iron industry. Evidence for agricultural activity is the slight increase in the frequencies of Gramineae and the greater range of herbaceous pollen. *Salix* values increase within LFCZ 4 and may be explained either by a rising water-table, as indicated by the concurrent increase in *Filipendula,* Cyperaceae and *Osmunda,* or by the greater availability of light following the clearances.

The clearances which had begun in LFCZ 3 continued and intensified during LFCZ 4. However, it should be noted that there is little minerogenic sediment in the lithostratigraphy of this zone. An explanation for such an anomaly lies in the location of the cleared areas. It is argued later in this paper that colluvium was not extensively reworked by the river and remained *in situ*. Therefore, unless the clearances were on the slopes adjacent to the pollen site, there may be no lithostratigraphic evidence for them. Thus, a lag between the pollen and lithostratigraphic records would result. Only if clearances were local to the pollen site would they be recorded by both the lithostratigraphy and biostratigraphy.

LFCZ 5 (110–50 cm. at CH. 1) *Alnus-Salix-Corylus-Quercus*
LFCZ 1 (95–75 cm. at CH. 2) *Alnus-Salix-Corylus-Quercus*

The recovery of AP in LFCZ 5 may indicate a regenerative phase. The exception is *Tilia* pollen which disappears from both diagrams. At CH. 1 the demise of *Tilia* corresponds with a silty clay deposit. *Ulmus* has a low and rather sporadic occurrence, but *Fagus* is by now continuously present, and *Carpinus* (hornbeam) is first recorded. Thus a secondary succession of trees is indicated on the valley slopes and floor. The latter situation is well illustrated by the substantial recovery of *Alnus* frequencies at both sites, and of *Salix* at CH. 2 (Figs. 5,7,9,10). *Betula* (birch) is present in higher values at both sites and it may have re-colonised some of the cleared areas.

A number of plant communities associated with anthropogenic influences are suggested by the pollen data. The development of a heathland habitat is indicated by an increase or appearance of Ericaceae and other acid-loving plants such as Cyperaceae, *Osmunda,* and *Sphagnum.* Meadow and arable pollen increase, especially Cerealia (cereals), *Plantago* sp., *Artemisia, Galium* sp. (bedstraw/cleavers) and *Filipendula.* Additionally, at both sites there is a further decline in *Quercus* values, for example at the 83 cm. level on the CH. 1 diagram, and is probably a consequence of anthropogenic activity. On the CH. 2 diagram the sediments become more minerogenic during this phase, but this is not evident at CH. 1.

Despite a secondary succession of woodland, anthropogenic influence upon the vegetation in LFCZ 5 is considerable and usually associated with a change in valley sedimentation. Organic deposits are replaced finally by minerogenic sediments of the Upper Silty Clay when all trees have declined to very low values in the upper part of the forest composition zone (Figs. 9 & 10). In their place an abundant and diverse herbaceous vegetation flourished. Such an association suggests that the effects of major anthropogenic clearances in the Combe Haven valley resulted in the erosion of the soils and the colluviation of material onto the valley bottom. Similar results from other valleys in Britain have been obtained by Shotton (1978), Bell (1982), Brown (1982), Robinson and Lambrick (1984) and Brown and Barber (1985).

LFCZ 6 (50–0 cm. at CH. 1) Deforestation
LFCZ 2 (75–0 cm. at CH. 2) Deforestation

The formation of a minerogenic floodplain at both sites correlates with the dramatic decline and subsequent destruction of the forest, as shown by the AP/NAP ratio on Figs. 9 & 10. At CH. 1 there is a decline in AP from 40 per cent to 13 per cent. Concurrent with this is pollen representative of a greater diversity of meadow herbs and an increase in Gramineae and

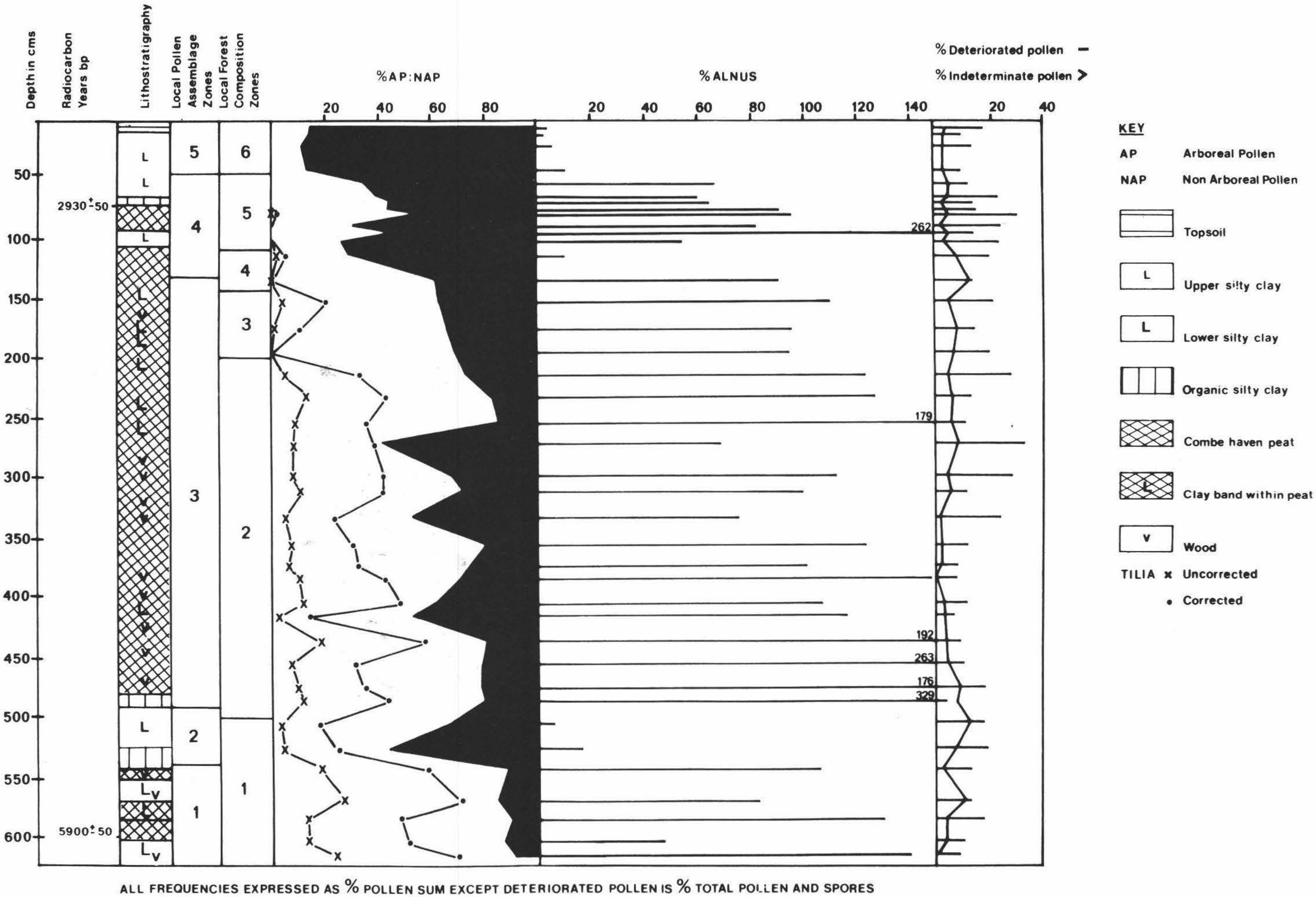

Fig. 9. Composite/summary pollen diagram for Combe Haven 1. Radiocarbon dates and the percentage deterioration and indeterminate are indicated.

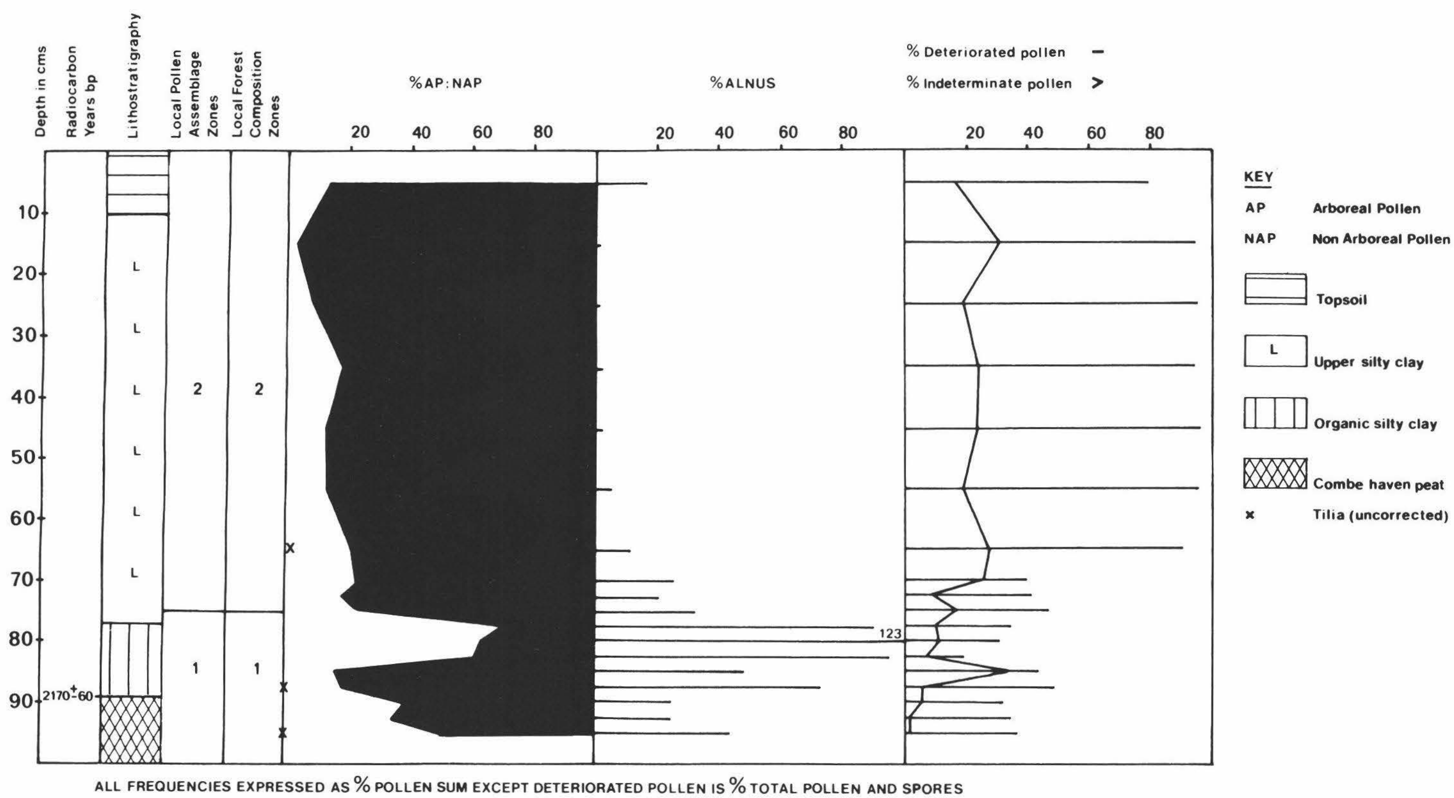

Fig. 10. Composite/summary pollen diagram for Combe Haven 2. Radiocarbon date and the percentage deterioration and indeterminate are indicated.

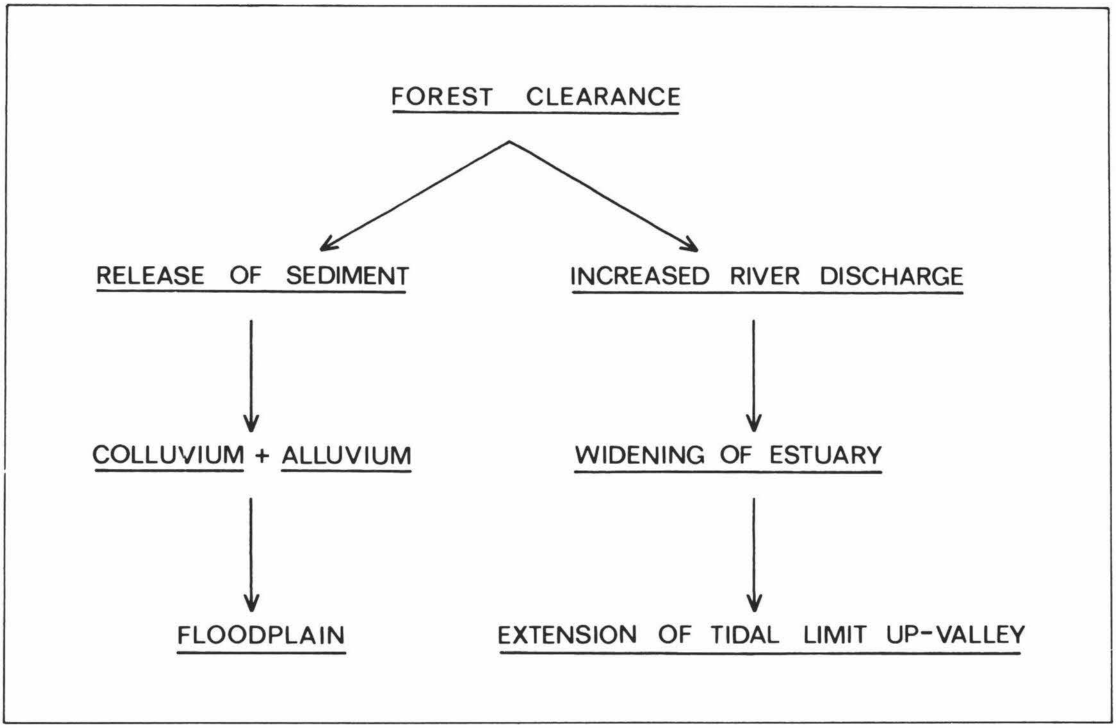

Fig. 11. A model depicting the consequences of major forest clearance in the Combe Haven valley.

Cerealia, which may reflect a wider source area of pollen dispersal. Significantly, *Polypodium*, an epiphyte especially on *Quercus* sp. (Moore, P. D., pers. comm. 1986) declines to low values now that the tree cover is greatly reduced. At CH. 1 the organic-minerogenic boundary has been radiocarbon dated to 2930 ± 50 b.p. (SRR-2684), while down-valley at CH. 2 the same boundary with a similar vegetational history has been dated to 2170 ± 60 b.p. (SRR-2680).

The CH. 2 composite pollen diagram (Fig. 10) mirrors the dramatic decline in AP frequencies (from 72 per cent to 4 per cent), but the occurrence of Chenopodiaceae and Gramineae in the pollen record is evidence for an estuarine environment from the 75 cm. to 25 cm. levels. The assemblage of pre-Quaternary spores, Hystrichospheres and higher *Pinus* values also indicate estuarine conditions (Jennings 1985). The further decline in *Alnus* to very low percentages may also be explained by an increase in salinity. At these depths the sediments contain *Scrobicularia plana* and *Hydrobia* sp. Unfortunately, due to poor preservation, diatom analysis has provided only limited supportive evidence for a marine incursion. The presence, at the 85 cm. level, of *Nitzschia scalaris* (Ehrenberg) W. Smith and *Amphora ovalis* Kutzing var. *libyca* (Ehrenberg) Cleve suggests a brackish to freshwater environment.

At CH. 2 a removal of saline conditions is identified at the 25 cm. level by significant changes in the pollen record. There is no alteration to the lithostratigraphy but the pollen record indicates a decline in the salt marsh taxa. The decrease in Chenopodiaceae and *Pinus* pollen, pre-Quaternary spores and Hystrichospheres and the appearance of Gramineae, Compositae (Daisy) and Cerealia pollen suggests that the estuarine environment had been replaced by a freshwater habitat.

FLOODPLAIN DEVELOPMENT

The Upper Silty Clay unit of the Combe Haven valley represents a switch from a biogenic to a minerogenic floodplain and registers a major palaeoenvironmental change. As already discussed, the change from biogenic to freshwater, minerogenic sedimentation was a direct consequence of anthropogenic forest clearance. Although more complex, the formation of the estuarine facies is also believed to have been due to forest clearance. The model illustrated by Fig. 11 summarises the 'chain of events' that may follow major forest clearance. In the following discussion this model will be applied to the Combe Haven valley.

A feature of the radiocarbon results is the diachronous onset of minerogenic sedimentation associated with the Upper Silty Clay. While the minerogenic floodplain was developing at the mid-valley site (CH. 1), down-valley (CH. 2) peat continued to form for approximately another 760 years. Additionally, at the seaward end of the valley, the Upper Silty Clay is estuarine in nature. This pattern may be explained by the limited distance sediments released by clearance on the valley side were transported. Clearances in mid-valley would have resulted in the movement of material downslope and onto the floodplain, as suggested by the pollen record. In the absence of reworking by the river, this colluvium would have remained in a mid-valley location. It was not until the forest had been cleared down-valley that sediments were colluviated into that area. By this time the extra discharge available to the Combe Haven river, through the reduction in evapotranspiration and greater runoff, may have resulted in a widening of the river mouth allowing the tidal limit to penetrate the lower reaches of the valley.

This idea of a 'patchwork' formation of the Upper Silty Clay unit is supported by a number of lines of evidence. First, the composite pollen diagram for CH. 2 (Fig. 10) shows that forest clearance was again concurrent with the change in sedimentation. Therefore the development of the Upper Silty Clay occurred at different times in different parts of the valley. The second line of evidence hinges on the potential of the Combe Haven river to erode its floodplain and transport its load downstream. A horizontal contact between the Combe Haven Peat and the Upper Silty Clay along most of the valley is illustrated in Fig. 3. There is no evidence for an erosion surface at the top of the peat as both the biostratigraphy and the lithostratigraphy exhibit a transitional sequence from peat to silty clay. It is apparent that the Combe Haven valley had a low gradient, as it does today, with reduced river energy. As a result only restricted reworking and transportation of colluvial material has taken place. In addition, the colonisation of the Upper Silty Clay by Gramineae and Cyperaceae (Figs. 5 & 7) may have stabilised the floodplain and further reduced erosion. Trimble (1983) found that fine textured stream banks and floodplains can be highly resistant to erosion especially if protected by vegetation.

In the U.S.A., Costa (1975) and Trimble (1983) have shown that material removed from the valley sides can accumulate locally rather than being removed by the river to the estuary. Costa found that only approximately one-third of material eroded from slopes was removed from the watershed, the bulk of the material was deposited on lower slopes and floodplains. Trimble calculated that less than 7 per cent of sediment released by human activity from the slopes of the Coon Creek basin has been lost from the catchment. The floodplain has acted as a major sediment store. Additional evidence for a local provenance of floodplain sediments is provided by Moffat (1984). He studied the late-Holocene history of the eastern Pevensey Levels in southern England (Fig. 1), immediately to the west of the Combe Haven valley. By minerological analysis he established that the sediment which comprises the surface deposits has been derived from local mass movement.

The development of the Upper Silty Clay floodplain of the Combe Haven valley therefore appears to be a result of anthropogenic forest clearance, but the movement of sediment downslope following the removal of the trees may have been assisted by the climate prevailing during the Iron Age. Gribbin and Lamb (1978) have argued for increasing wetness during this period. Indeed Barber (1982), using evidence from peat bogs, maintains that there was 'A catastrophic decline to a cooler and/or wetter climate around 2850 to 2550 b.p. . . . and some evidence for further decline around 2050 b.p.' (p. 110). The coincidence of forest clearance with a period of climatic wetness would have accelerated colluviation and further increased stream discharge.

CONCLUSION

Detailed biostratigraphic analyses of biogenic and minerogenic sediments, supported by radiocarbon analysis, have been used to study palaeoenvironmental change in the Combe Haven valley since the mid-Holocene. A complex relationship between vegetational change, sedimentation and anthropogenic influence has been revealed by this study. It has also been shown that declines in AP frequencies have a variety of causes and a close inspection of the relationship between pollen frequencies and the lithostratigraphy is necessary in order to identify them.

From these analyses it appears that the major changes to the vegetation of the Combe Haven valley over the last 6000 years are related to anthropogenic factors, but marine incursions have also been influential. The major decline in AP frequencies on both diagrams corresponds so well with the onset of Upper Silty Clay sedimentation that a cause and effect relationship is strongly suggested. Iron Age forest clearance is considered to be the linking mechanism in this relationship, with climatic deterioration encouraging slopewash following removal of the trees. This reinforces the assertion by Bell (1982, 139) that patterns of valley sedimentation in lowland Britain have been principally determined by land-use and that this has tended 'to swamp and mask underlying climatic trends.' If the conclusions regarding anthropogenic forest clearance are correct, then clearly the area around the Combe Haven valley has the potential for stimulating archaeological investigations.

The examination of the Combe Haven valley pollen record is a local study. Accurate regional palaeoenvironmental reconstruction is not possible without prior knowledge of small areas in great detail.

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