PEAT FORMATION IN LIMESTONE REGIONS: SOME EXAMPLES FROM THE PENNINES OF NORTH YORKSHIRE, UK

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Abstract

Limestone regions of either lowland or upland character are predominantly associated with non-peat accumulating soils. Nevertheless, a study of the Pennines of North Yorkshire reveals a surprising number of local situations where peat has formed. Some of these peats are typical of those found elsewhere on acid substrates and arise through the local influence of a drift or alluvial cover over the limestone or as a result of outcrops of non-limestone strata. Other occurrences of peat are of a character peculiar to the processes and evolution of limestone terrain.

This paper provides brief documentation of the various types of peat noting their present form, the processes which are believed to have been responsible for their initiation and relevant details of their ecological history. The peats are of diverse origin and evolution, presenting problems of classification and for this reason are grouped according to their landscape context. They represent varying lengths of the Holocene vegetation record but collectively demonstrate their strategic value in a region otherwise limited for palaeoecological studies. Their significance in this respect relates to evidence for relatively early and sustained use of limestone terrain by prehistoric peoples. This in turn has led to the cessation of peat formation at a number of sites.

Keywords: *palaeoecology, limestone, peat formation*

Introduction

The Yorkshire Pennines is an upland region comprising a dissected plateau with major rivers flowing east and south east in broad valleys or 'Dales' (Raistrick and Illingworth, 1949). Elevations, which generally increase towards the west, range from 100m in the valleys to over 600 m on the summits. The climate is cool and moist and above 300 m in areas of acidic rocks there are extensive moorlands with a peat cover. In the limestone areas grasslands are dominant to high levels.

The area of North Yorkshire covered by this present study consists of highland and lowland scenery, all of which has been glaciated. The depositional mantle over the limestone consists principally of glacial till (Clark, 1967) in low-lying areas with a loessal capping (Bullock, 1971; Catt, 1977) particularly evident at higher levels where this is the only covering over limestone bedrock. The almost horizontal Carboniferous strata have been cut and displaced by major faults which bring overlying sandstone and underlying shales into contact with the various beds of limestone (O'Connor,

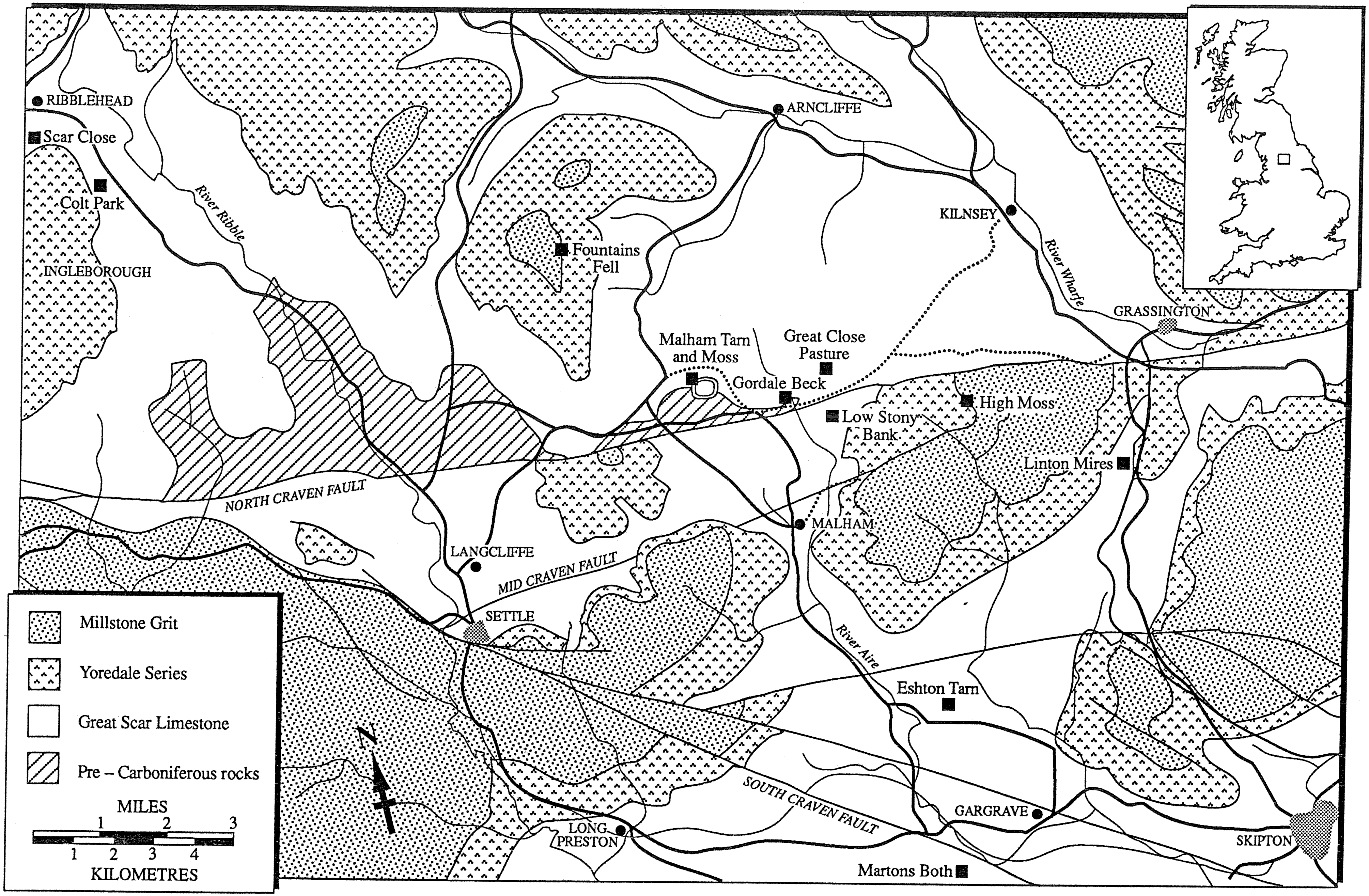


Figure 1: Location and geology map for the North Yorkshire study area

1964; Brumhead and Calloway, 1974). Overlying sandstone also forms the summits of hills in parts of the study area (Fig 1).

Limestone regions are not usually associated with peat formation owing to their well drained conditions and high trophic status. The drainage of limestone soils can arise from porosity of the underlying rock, as in the case of the Cretaceous Chalk, but in this region it is the natural jointing of the crystalline rock, exploited by weathering and solution, which facilitates the downward movement of water. These characteristics tend towards aerobic soil processes of high biological activity and rapid mineralisation of organic matter. Eutrophic brown soils are therefore common although soil properties will depend on what kind of superficial cover overlies the limestone and how thick this is (Crompton and Matthews, 1970; Bullock, 1971; Jarvis, 1984). In many basins where waterlogged conditions occur, the nutrient status of the water is such that anaerobic bacteria maintain decomposition and humification processes whereas in wet acid conditions the latter must cease due to the absence of bacteria and the inactivity of fungi. Ground water conditions too, can be most capricious in limestone regions, with springs issuing from hillsides (sometimes giving rise to a flush peat), rivers disappearing into the rocks below and ground water rising and falling with almost equal rapidity. Not uncommonly, sites which are saturated for most of the winter are too dry in summer to support a marsh habitat.

For these reasons special circumstances are required in order to promote peat accumulation in limestone regions. The first prerequisite is a sealing cover of drift or alluvium then, for primary mire formation, the site must maintain waterlogging so that only temporary periods of low water table occur. Valley or basin situations are therefore suitable candidates, other factors permitting. On flatter or sloping limestone terrain with a drift cover the surface humus can often be raw, especially with a thick drift cover, but true peat formation is often prevented through adequate drainage or occasional flushing from calcareous water. However, where flushing does not occur, drifts can develop peaty gley soils as a result of acidification and a sequence of pedological changes which are described elsewhere by Smith and Taylor (1989).

The following is a review of different situations in which peat occurs and should not be regarded as a complete inventory of peat deposits in the area (see Fig 2 for an overview).

Greater attention is placed upon those peats whose origin is closely related to the evolution of limestone terrain.

1 <u>*Valley mires*</u>

Of all the different types of peat these are possibly the most widespread but at the same time the most concealed. Boreholes taken in Airedale, for example, reveal substantial layers of peats now buried by alluvium and colluvium (Gaunt, 1980). These peats represent varying periods of Holocene time

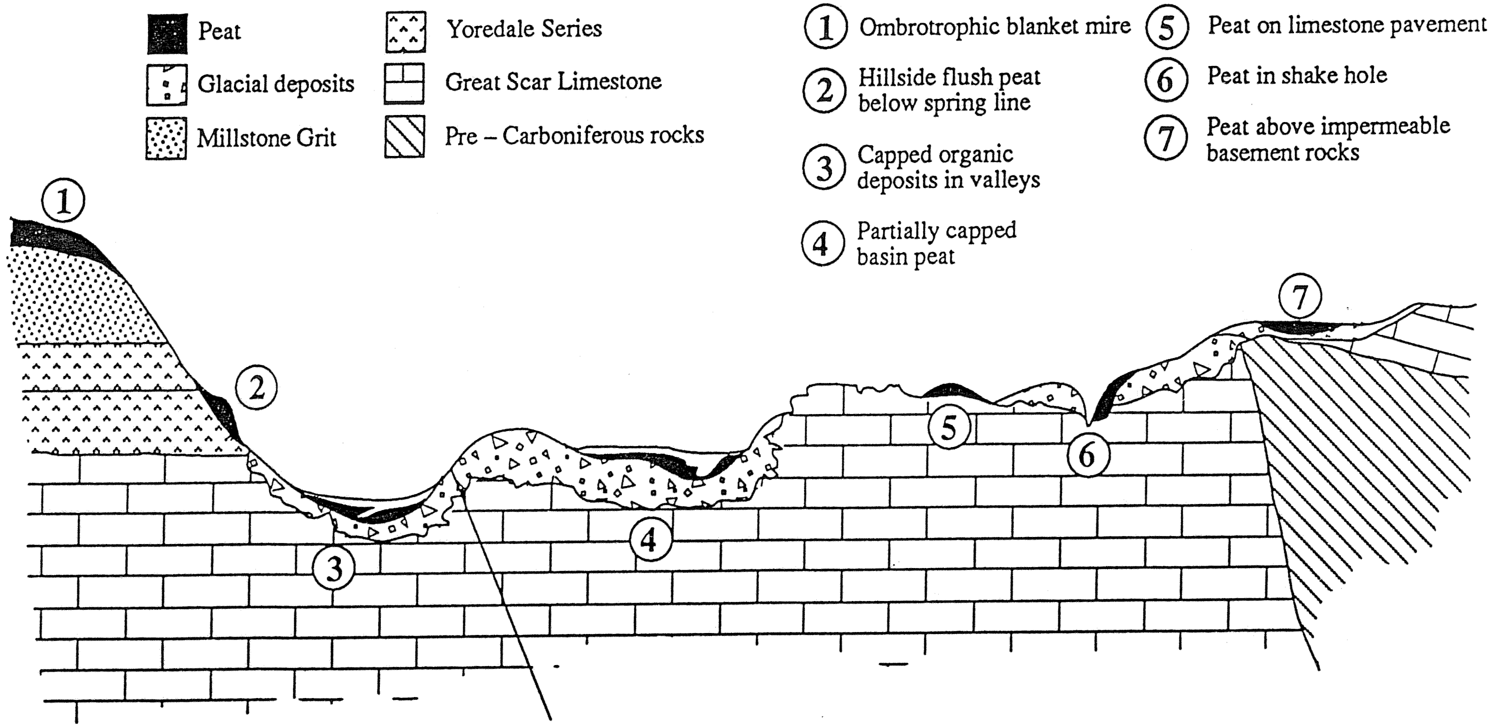


Figure 2: Schematic diagram to illustrate a range of peat types found in Limestone districts of the Yorkshire Pennines

TABLE 1

Site	*Onset of Organic Deposition (C14 or Estimated)*	*Organic Deposition Status*
Wharfedale/Airedale buried peats	***Late glacial***	***Ceased Neolithic/Bronze-Age/Iron Age/RB***
Linton Mires	***Late glacial***	***Ceased 3500-4000 BP***
Martons Both	***10,090 ± 140 BP (SRR-2485)***	***Ceased 4500-5000 BP***
High Moss	***9,940 ± 130 BP (Birm-1154)***	***? Truncated***
Eshton Tarn	***c.10,000 BP***	***Ceased c.3000-2500 BP (locally continues to present)***
Malham Tarn and Moss	***Late glacial***	***Continues to present***
Great Close Pasture	***10,070 ± 140 BP (Birm-1156)***	***Continues to present***
Gordale Beck	***c.8000 BP***	***Continues to present***
Fountains Fell	***5000 ± 100 BP (Birm-1079)***	***Continues to present***
Low Stony Bank	***1690 ± 60 BP (Birm-1157)***	***Continues to present***
Scar Close	***c.3000 BP***	***Degenerating***

in basins or riverside swamps. The capping deposits represent the product of deforestation, agriculture and the altered depositional regime of the river through prehistoric and historical times (Table 1).

Linton Mires at 190m may be an example of this kind. It occupies an area of 3x1.5 km where glacial till and moraine overlies limestone in a broad valley. Here, an early Holocene lake developed through reedswamp and fen, towards raised moss (Bartley, Jones and Smith, 1990). The low tree pollen contents throughout, suggest much of the surrounding landscape from earliest times was kept in a semi-cleared state while high frequencies of pine and hazel pollen indicate the relative success of these quick regenerating species in a Mesolithic disturbance regime involving fire (Smith, 1982). The peat deposit has been terminated at a level equivalent to about 4000 BP and the 30 cm of silty capping represents the distal end of a fan of debris from a side valley (Fig 3). This would indicate that flooding, perhaps related to human landscape changes, was the cause here of the cessation of peat accumulation during the Middle Bronze Age, for examination of the summary pollen diagram shows a dramatic reduction in woody plants prior to peat cessation.

A further valley site is that of Gordale Beck near Malham (Smith, 1986). The Gordale stream rises in springs on Malham moor. As it leaves the latter and proceeds down its gorge-like valley much of the stream water disappears into the limestone. A peat deposit is located north of a fault (the North Craven Fault) which brings up a wedge of impermeable Silurian rocks (Fig 1). This allows a stretch of Gordale Beck to have a higher water table and 2.75 m of peat has accumulated in a back marsh as the river has continued to build up its valley floor. Basal calcareous muds are succeeded by a principally sedge (monocotyledonous) peat with increasing Sphagnum towards the surface. The peat is a narrow tongue of relatively organic deposition sandwiched between river and valley side, both of which generate silty facies. It is about 30m long and at maximum about 5 metres wide. Its origin appears to relate to the development of forested hillsides some 7000 years ago which facilitated build up of organic deposits through reduced sediment delivery to the stream. We can see from Fig 4 that during the Early Bronze Age (C14 date 4780 # 120 BP) increasing mineral content of the peat coincides with reduction of woodland and presumably greater extremes of runoff.

2 Basin Peats

These peats are distinguished from valley mires by virtue of their circular rather than linear form and their association with open, drift-covered terrain. Two such peat deposits in lowland Craven are at Eshton Tarn and Martons Both (Bartley, Jones and Smith, 1990). Eshton Tarn is the remnant of a once larger lake possibly centred on a kettle hole within drift overlying limestone. The basin has been subject to continuous siltation on its margins but particularly near the entry of its principle inflow stream. As a result most of the peat, consisting of fen, reedswamp and sedge remains, is now covered by mineral deposits and the pollen record for the most part terminates at about 3000 BP when it is very clear that agriculture was being widely practised. While standard pollen zones are

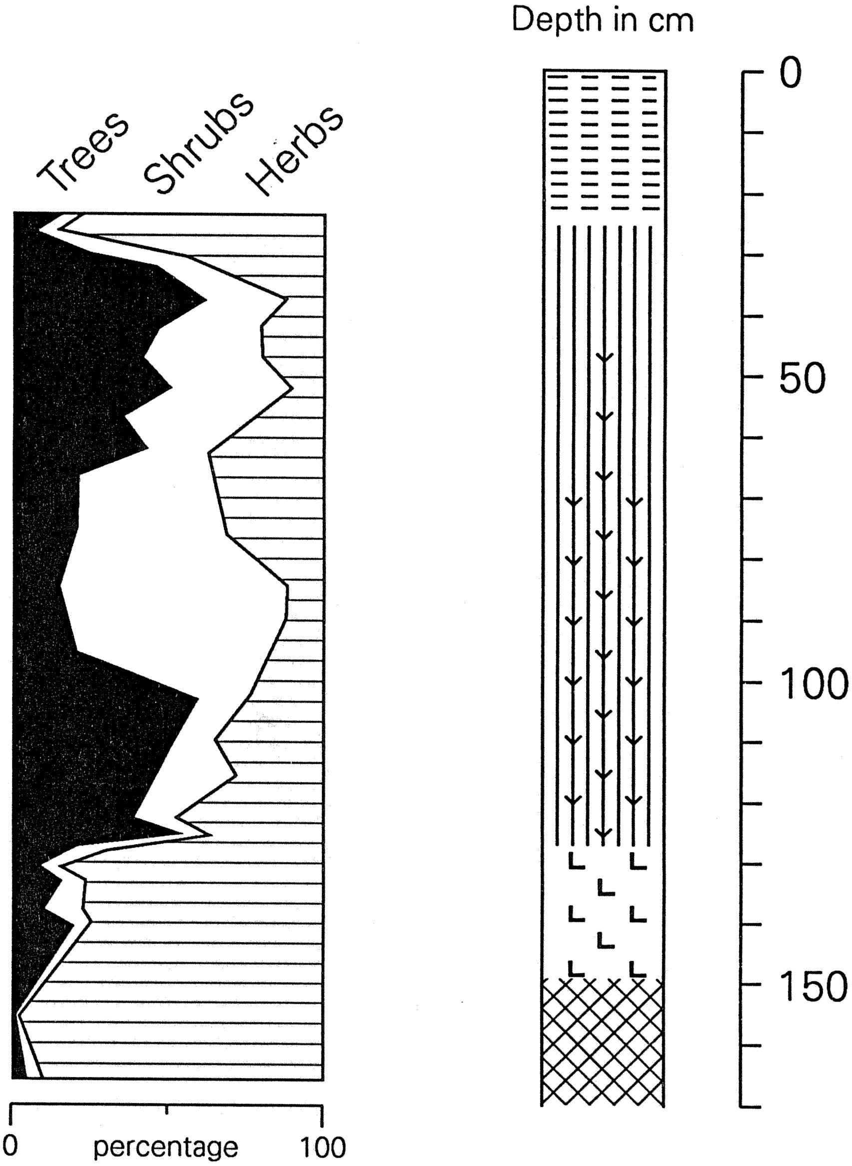


Figure 3: **Linton Mires**
Summary pollen diagram and stratigraphy

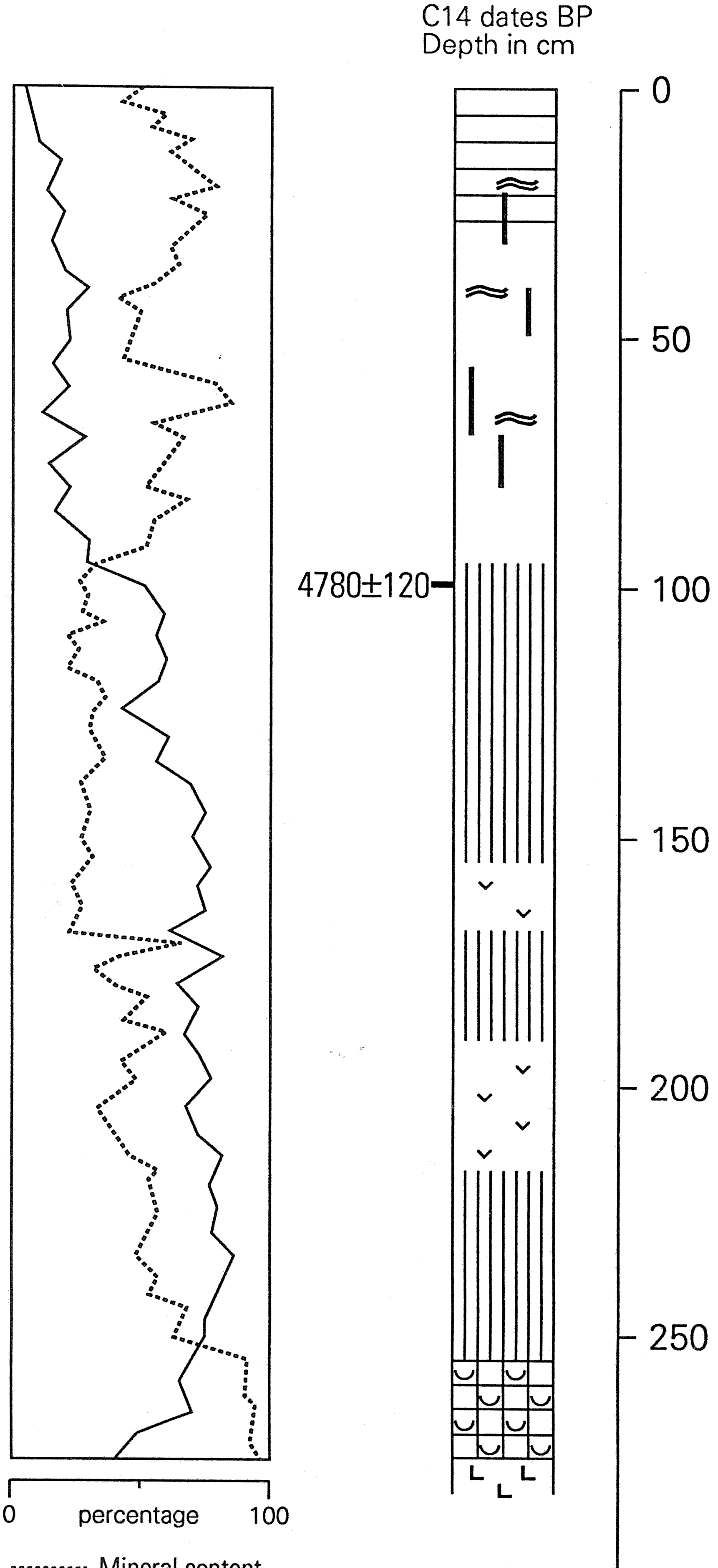


Figure 4: **Gordale Beck**
Summary pollen diagram and stratigraphy

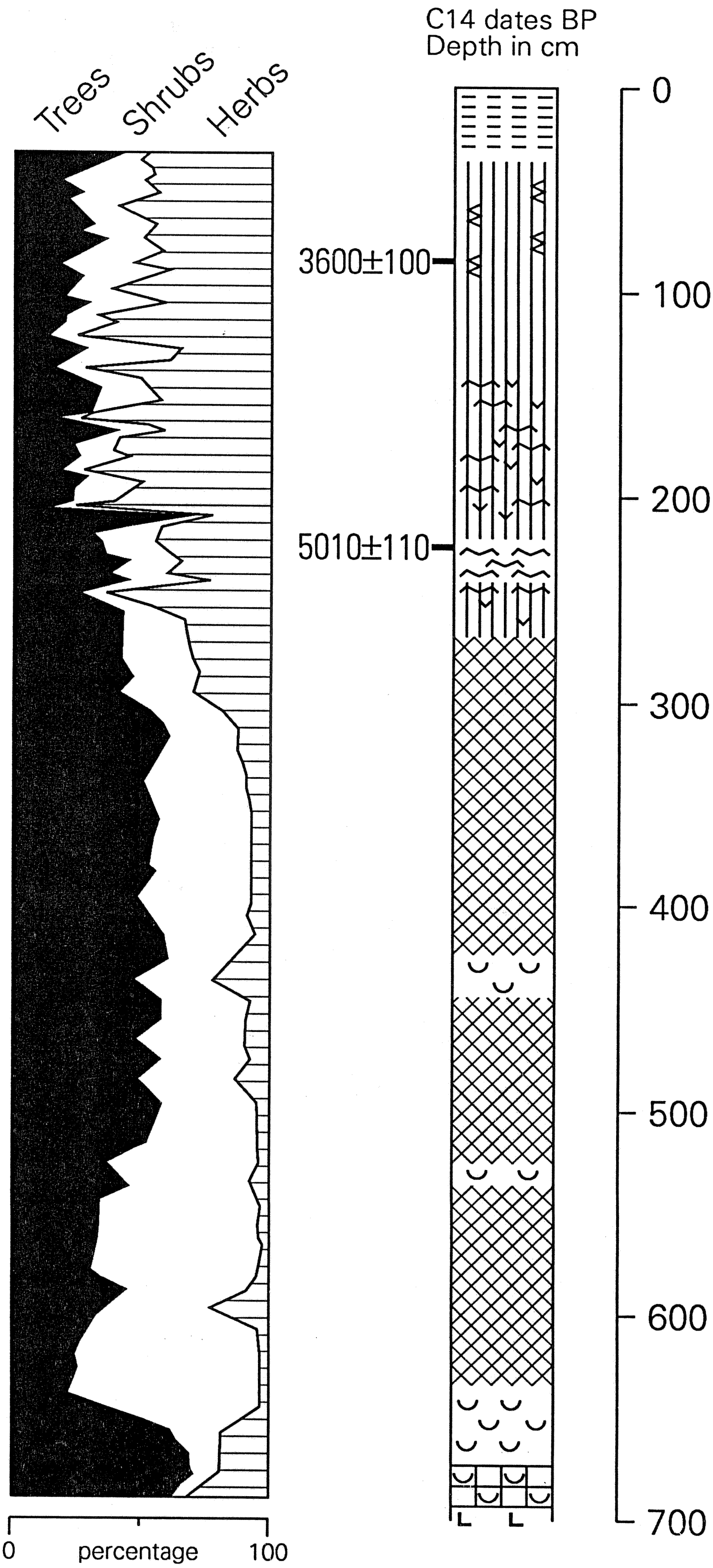


Figure 5: **Eshton Tarn**
Summary pollen diagram and stratigraphy

discernible at this site, the pollen record (Fig. 5) nevertheless shows a comparatively low tree pollen content for much of the Holocene with secondary shrubs, characteristic of woodland disturbance, featuring early on and being represented strongly throughout.

At Martons Both, also on till-covered limestone, an early Holocene lake with aquatic vegetation developed into sedge and moss peat with the passage of time. The pollen record ceases at the Atlantic/Sub-Boreal transition around 5000 BP with the peat again being sealed by a layer of mineral inwash (Fig 6). Reduction of elm pollen prior to cessation of peat formation suggests that Neolithic activities brought organic deposition to a close over most parts of this basin.

Other basin peats are found in highland Craven on Malham Moor. Perhaps the best known of all sites in this area is that of Malham Tarn and Tarn Moss. This classic site has been studied by several workers including the Pigotts, Sinker and Proctor (Pigott and Pigott, 1963; Sinker, 1960; Proctor, 1974). Malham Tarn, though surrounded by limestone is underlain by impermeable Silurian shales which are covered by glacial drift, while the lake is impounded by glacial kame deposits. Reedswamp and fen developed early on the side of the lake nearest to the inflow stream and this developed through the Holocene into a raised moss. The moss peat extends to 10 metres while a more limited stratigraphy has been recorded from the sediments of the tarn. Peat formation continues to this day on the raised moss (see Table 1). The pollen diagram (Fig. 7) has been reprocessed from the data of Pigott and Pigott (1963) which originally displayed only percentages of tree pollen. The diagram shows again that tree pollen representation is comparatively modest throughout the Holocene and that the pollen of shrubs, mainly hazel, is substantial. At this site the large herb pollen values probably also reflect the extensive wetland habitat of the moss and adjacent fen. That Malham Tarn represented an important locus of prehistoric human activity is evidenced by the large number of Mesolithic remains in the area (Raistrick and Holmes, 1962). The pollen data appear to corroborate this picture.

Great Close Pasture was probably the site of a small meltwater lake which quickly drained. Peat formation starts here in the early Mesolithic period (10070 # 140 BP) when pollen and charcoal remains indicate the local destruction of a pine wood (Smith, 1986). Very large numbers of flint microliths have also been found in this area in the vicinity of Malham Tarn. No doubt the loss of trees in the area around the basin altered the water balance in favour of increasing wetness for it is from this time that some 3m of almost entirely monocotyledonous peat has formed. Once again it is to be noted that throughout the pollen record from this site (Fig. 8) the tree component is only weakly represented which suggests a predominance of open or parkland habitats over the adjacent fells for long periods of prehistoric time. Compared with Malham Tarn Moss the earlier record shows higher tree and herb pollen which probably indicates the local existence of copses of trees with open areas between, whereas on the extensive Malham Tarn wetland hazel and willows (classified as shrubs) were much more important and true forest lay further away.

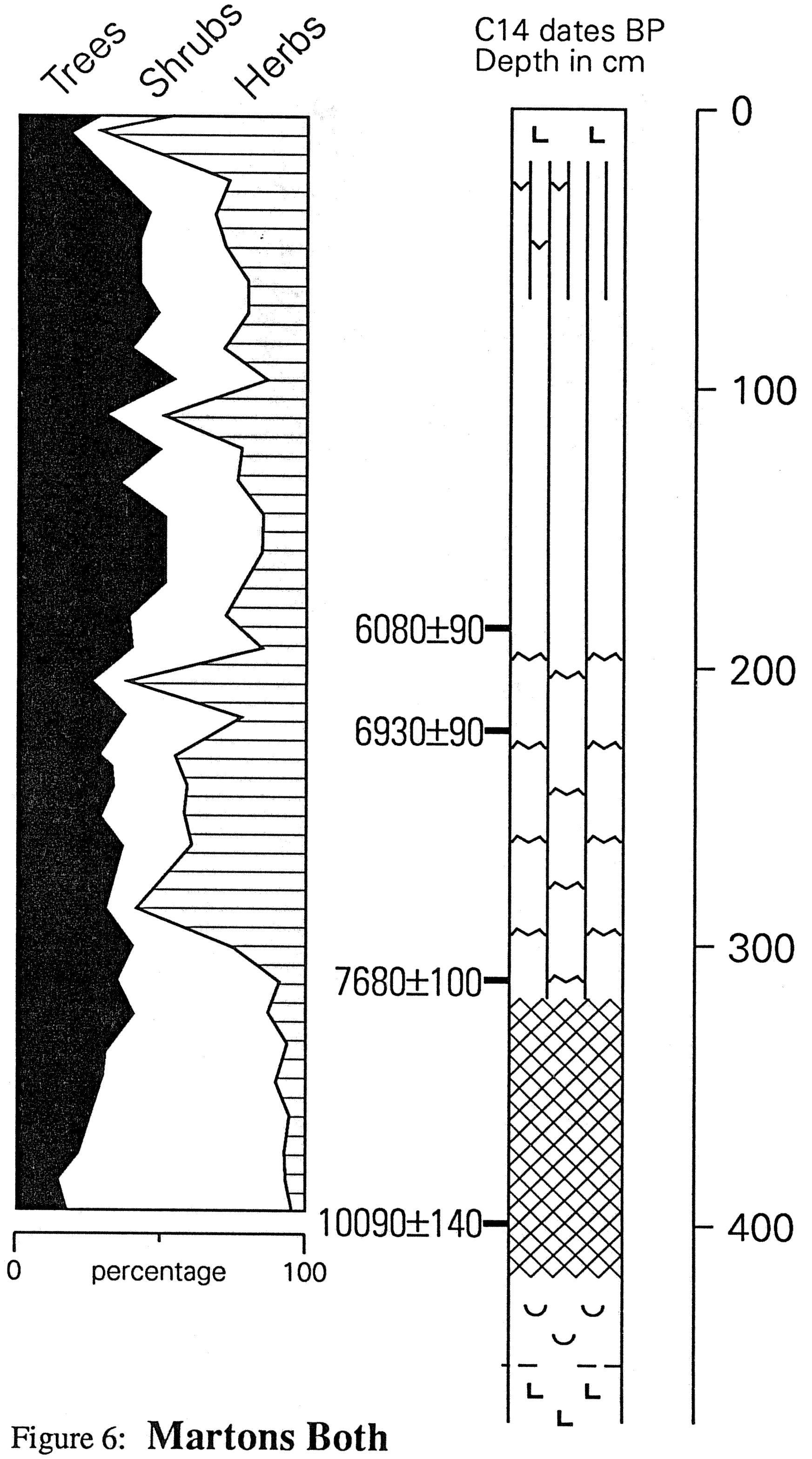


Figure 6: **Martons Both**
Summary pollen diagram and stratigraphy

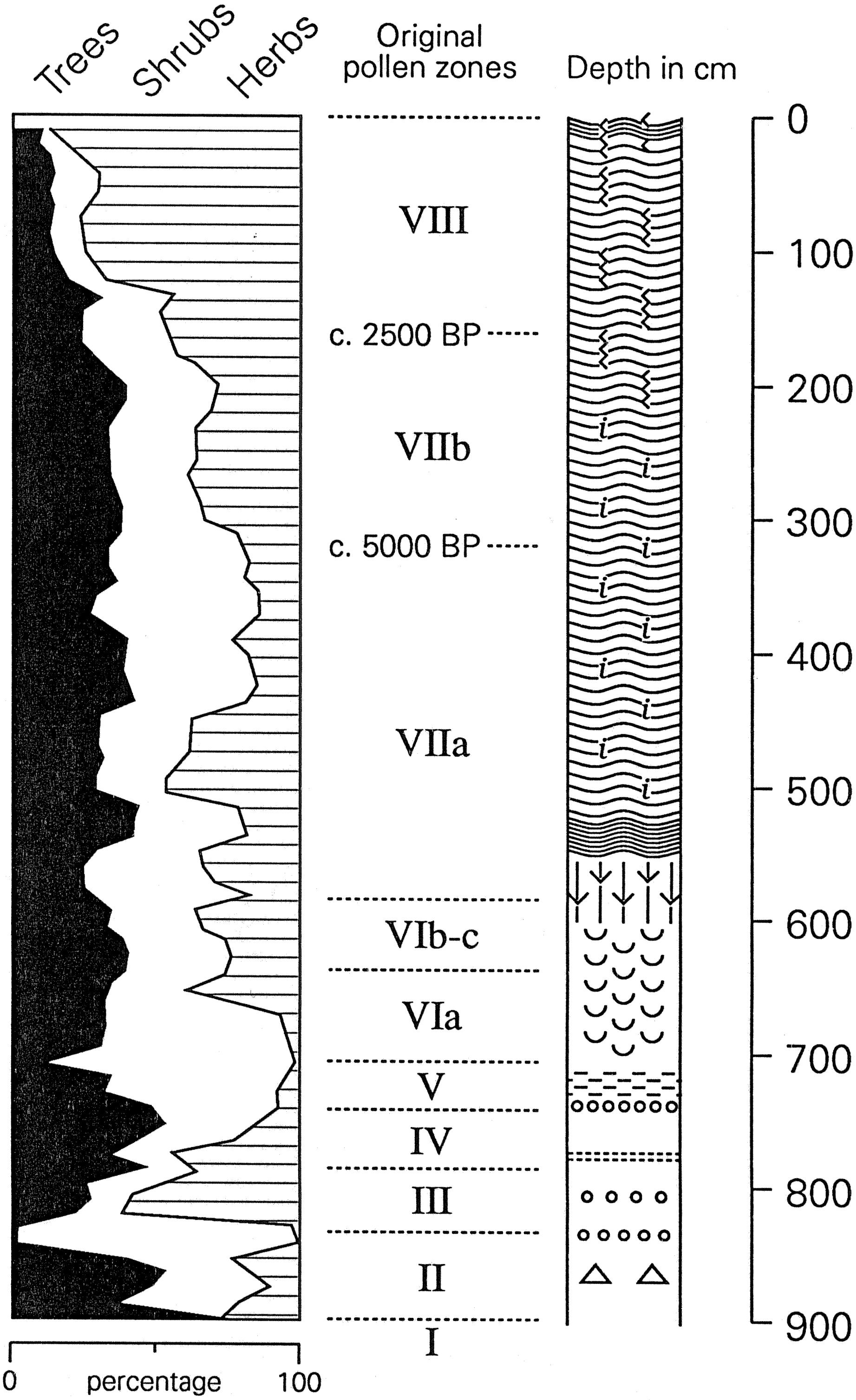


Figure 7: **Malham Tarn Moss**
Summary pollen diagram and stratigraphy (after Pigott and Pigott 1963)

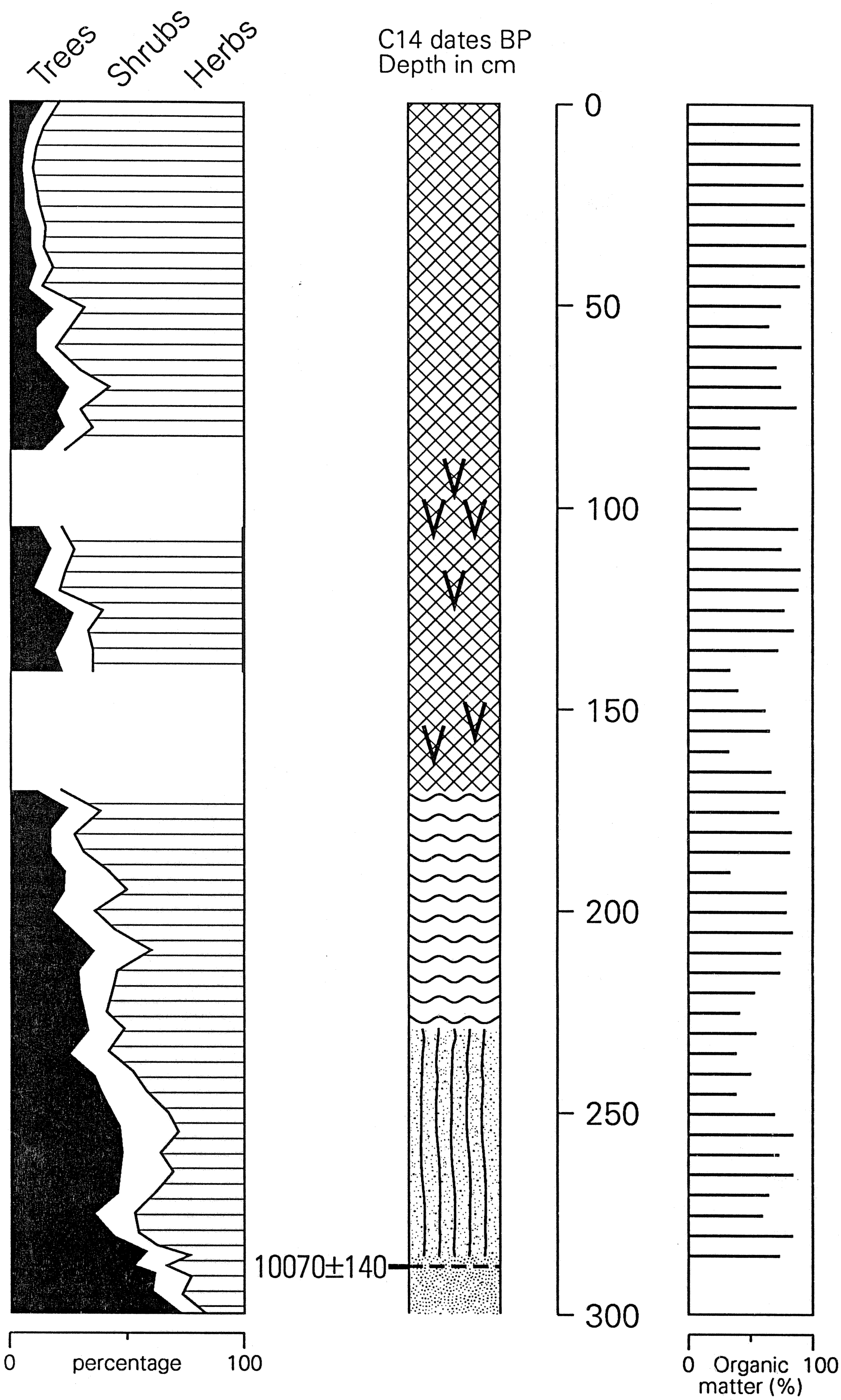


Figure 8: **Great Close Pasture**
Summary pollen diagram and stratigraphy

Great Close is a site characterised by fluctuating water tables. Microscopic evidence reflects this, for the pollen is poorly preserved throughout. Investigations at the site suggest two reasons for this hydrological behaviour. Runoff and seepage from the surrounding catchment tends to flush the site with water high in calcium ions while study of the outflow stream indicates that extreme hydrological events flush out the deposits which build up in the exit area during long periods of average rainfall. The effect of this is to periodically lower the local base level and prevent water backing up in the basin behind.

<u>High Moss</u> has little surrounding catchment and lies on the junction of the Yoredale rocks and the Millstone Grit (Fig 1). It consists of 2.5 m of sedge and Sphagnum mire which at periods of high water forms a floating bog. Organic matter at the junction with basal blue-grey clay is dated to 9940 # 130 BP which together with birch and pine pollen, confirms a further early Mesolithic origin for peat formation. However, the greater part of the peat is of low humification (H2-3) and not only is sampling difficult but pollen content and preservation is too poor for a reliable analysis to be carried out. It is possible that peat cutting has removed an earlier peat following which sedge and Sphagnum regrowth has taken place.

3 <u>Shake hole or doline peats</u>

A further type of basin is produced by the effects of subsidence of drift over limestone. Such features are normally to be found where acid drainage water is plentifully available towards the edge of a thick cover of drift. Known as shake holes, they are often found to have a linear distribution reflecting the juxtaposition of available water and a suitable jointed limestone stratum beneath (Clayton, 1981).

As solution proceeds at major joint intersections in the underlying limestone or as underground fissures and cavern systems are cleared of large amounts of drift, the overlying surface subsides to produce a saucer-shaped depression. The depressions will eventually collapse through erosion of basal drift but according to the length of time taken by this process and the size of the depressions involved, varying amounts of Sphagnum and sedge peats can accumulate. Thicknesses vary from around 2 m below Fountains Fell and at Stump Cross east of Grassington (both about 30-50 m diameter) to less than 1 m at Tattersall Pasture and Low Stony Bank on Malham Moor (5-10 m diameter). At <u>Low Stony Bank</u> the peat stratigraphy shows that a moorland soil with a thin raw humus layer developed a monocotyledonous peat as the basin subsided. At this site, and others of its kind, the surviving peat remains on the side of the conical depression nearest to the main source of surface water inflow. As the basal organic matter is here dated to 1690 # 60 BP (c.260 AD) it indicates that the whole process of collapse can be fairly rapid in geological terms. The pollen record (Fig. 9) indicates an open landscape of grassland around the site throughout the entire period which is in general agreement with post-Roman records of vegetation in these uplands. Furthermore the likelihood of limited tree cover in these areas for much of the prehistoric past raises the probability

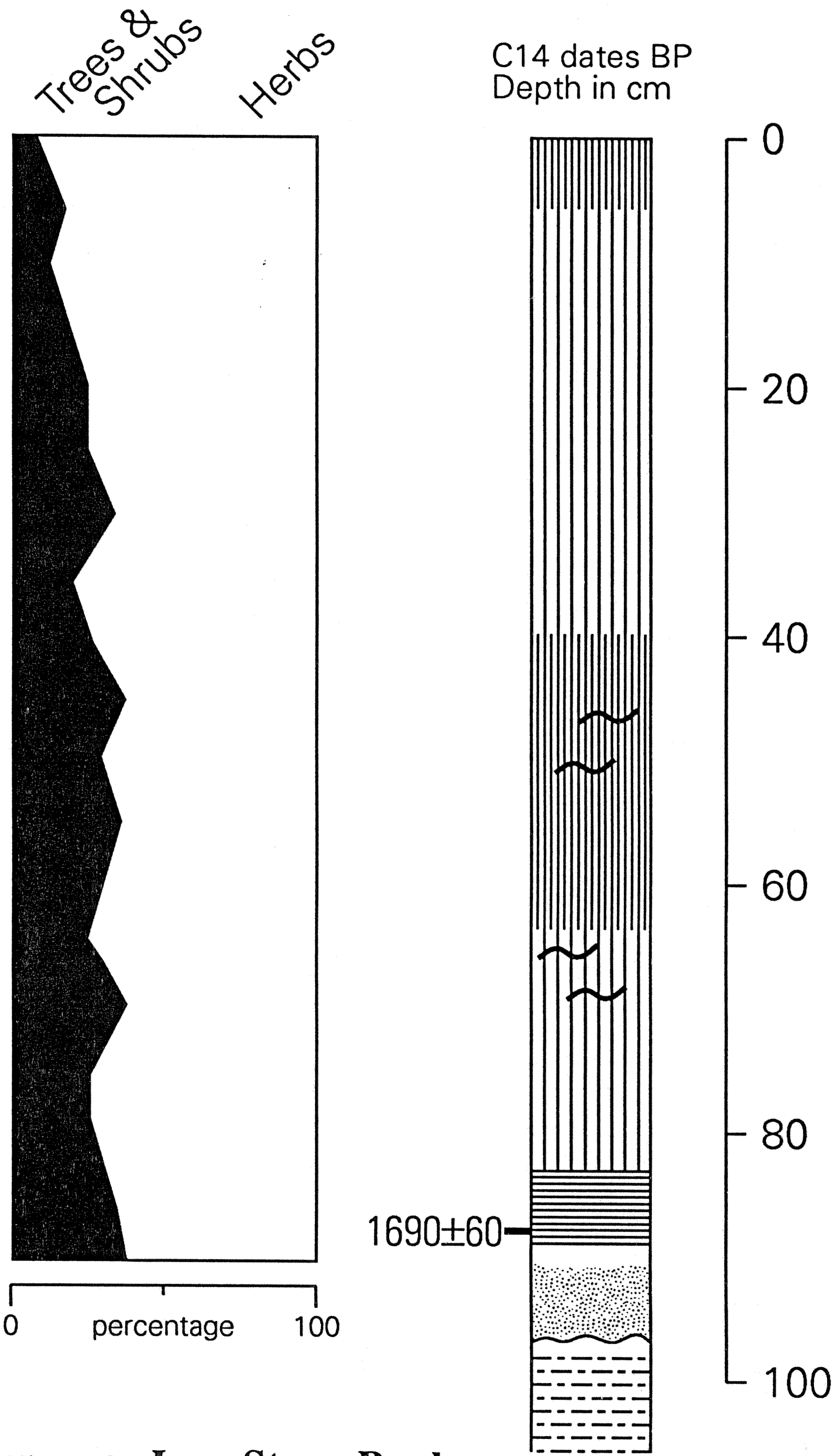


Figure 9: **Low Stony Bank**
Summary pollen diagram and stratigraphy

of faster rates of drift acidification facilitating the widespread development of features resulting from solution. Certainly after the removal of local tree cover one may argue that they would develop more rapidly owing to increased runoff and soil moisture (Moore, 1975).

Peat is no longer to be found in many shake holes owing to the continuing collapse of material from around their steep sides. Figures 10 and 11 show possible sequences of development and degeneration for subsidence peats depending on whether sited on flat or hillside locations. While the lack of residual evidence of peat in many shake holes may be evidence of the brief nature of organic deposition and survival it would be presumptious not to allow that a proportion of enclosed hollows have formed so rapidly that organic accumulation was not possible in the first place. The mechanism envisaged for more rapid surface collapse seems likely to depend on the formation of a cavernous void in the base of the drift. This would result from erosion of drift above the main underground channel in the limestone. Periodic failure in the drift material, akin to faulting, would not only lower the ground surface but concentrate water flow and enhance the drainage. In turn this would accelerate the lowering process.

In considering what might lead to either slow or rapid evolution of these features it seems reasonable to contrast those sited on preglacial drift-plugged cavern systems as opposed to joint systems freshly exploited by Holocene weathering and solution. The latter would be more likely to generate slow collapse while the former, following subterranean erosion of drift, would potentially lead to very rapid subsidence. Whatever the exact sequence of events, it is clear that peat formation represents an extremely transient and possibly exceptional stage in the formation of most subsidence hollows.

4 Ombrogenous blanket mire

Blanket mire is to be found on the tops of hills capped by Millstone Grit. Much blanket mire in the Pennines has been forming for more than 7000 years (Tallis, 1991). On the edge of Fountains Fell a raw humus soil had developed by 5000 ± 100 BP (Smith, unpublished). This then began to accumulate 1.5 m of sedge and Sphagnum and sedge peat of medium humification. The pollen record (Fig.12) shows local trees and shrubs fairly high in frequency at the onset of peat formation, subsequently declining. Taken together with the evidence of a primitive soil at the base, it is suggested that paludification was caused here by a spread of wet conditions away from areas on the Fountains Fell plateau which had established peat deposits much earlier on. Such a relationship was referred to as Secondary peat by Moore and Bellamy (1973) and is the 'Intermediate' peat type of Smith and Taylor (1989).

5 Peat directly on limestone

Extensive areas of exposed limestone 'pavement' occur in the Malham and Ingleborough districts (Fig. 1). It is now recognised that these barren landscapes with their characteristic microrelief of

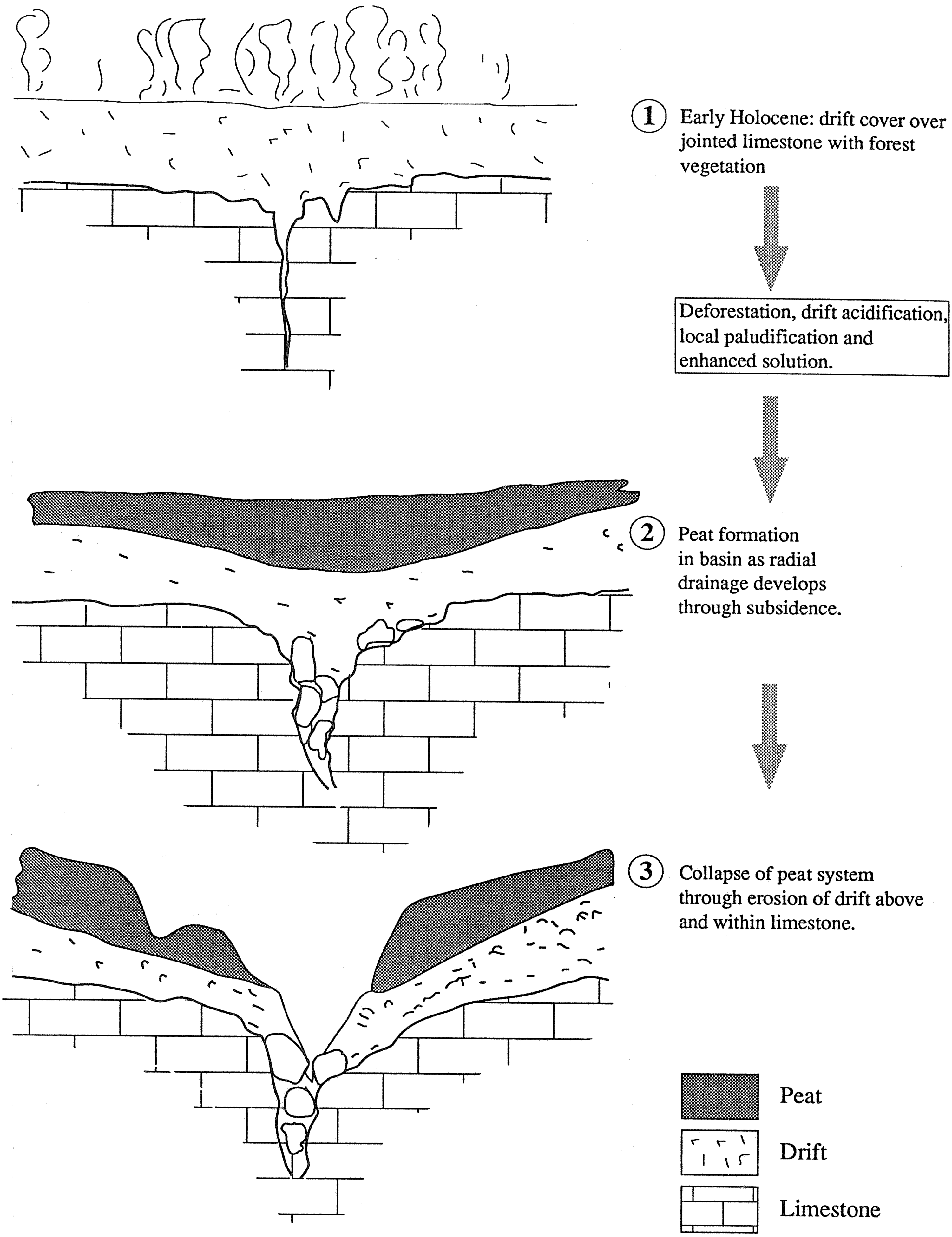


Figure 10: Subsidence peat formation: level sites

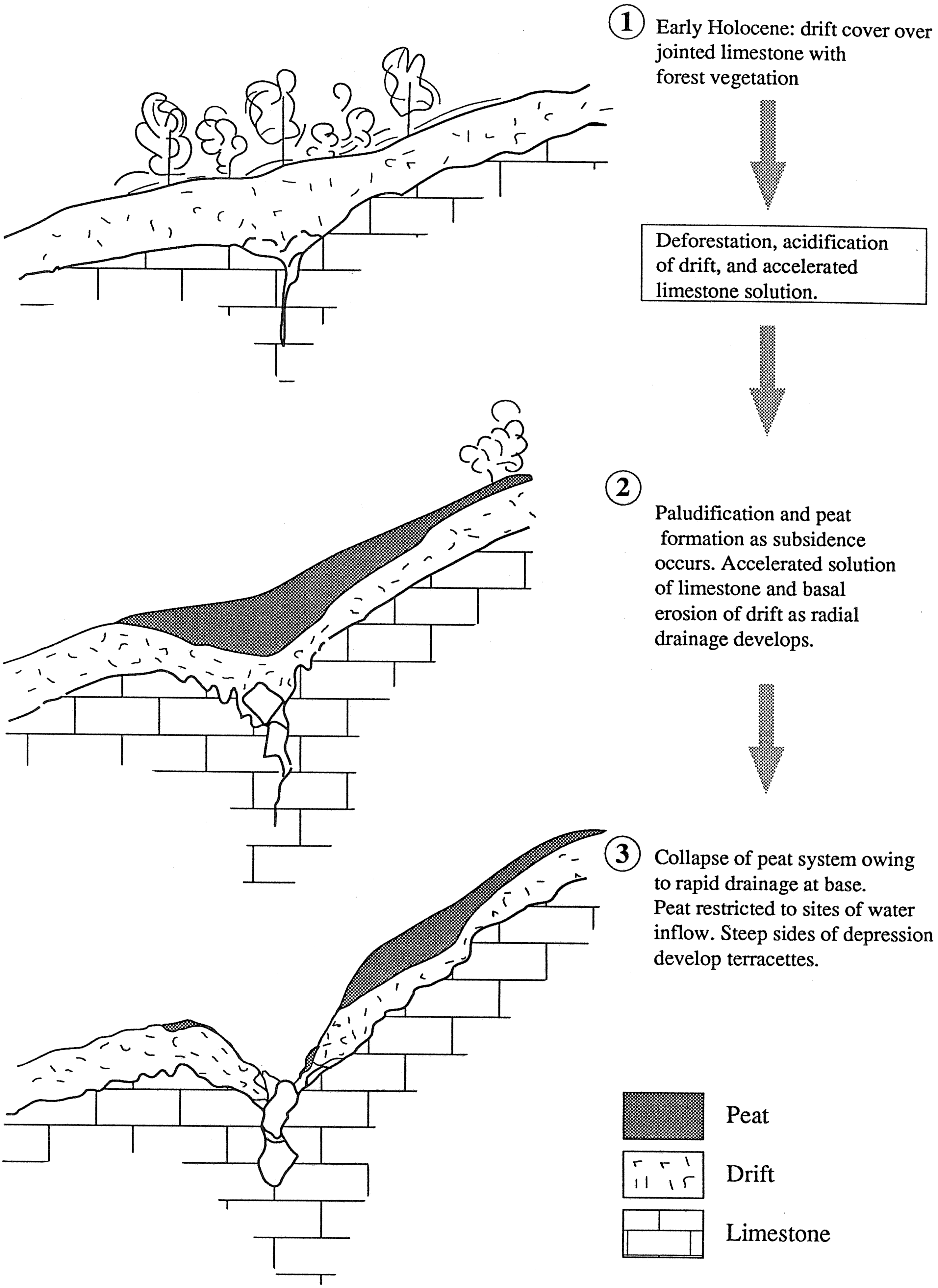


Figure 11: Subsidence peat formation: sloping sites.

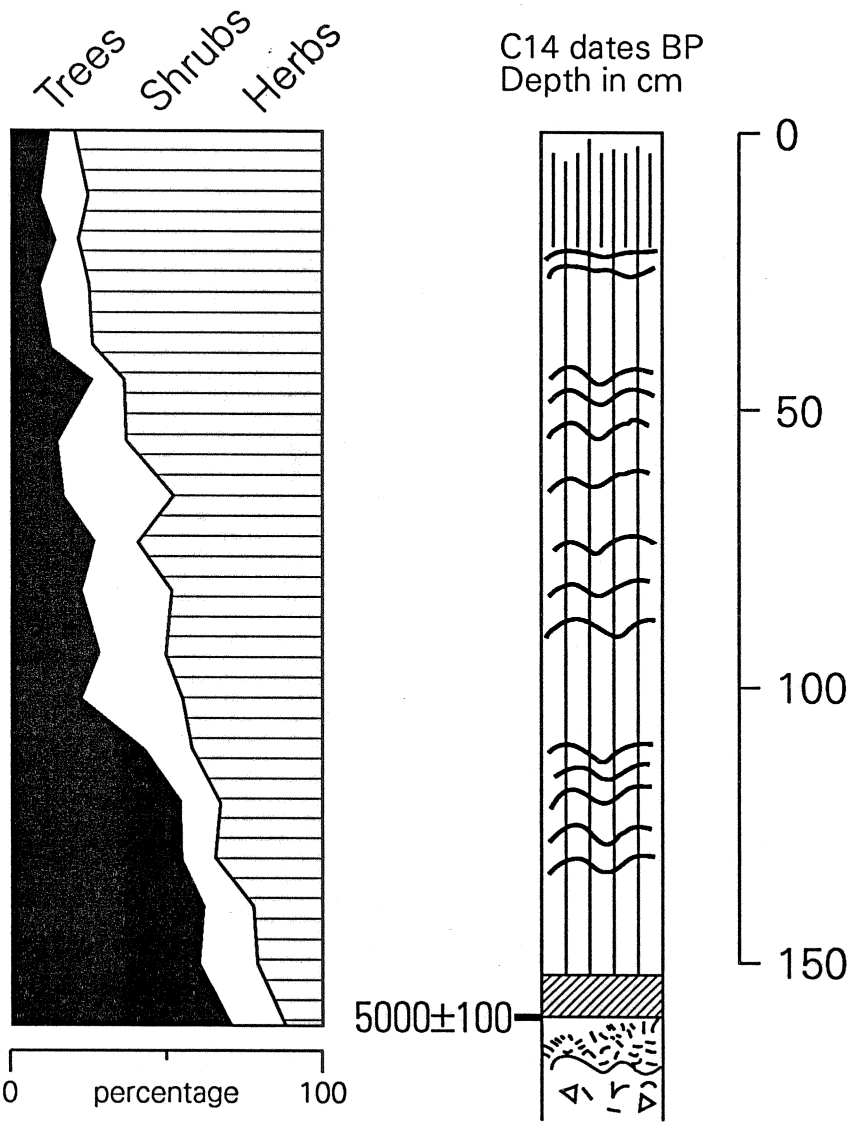


Figure 12: **Fountains Fell 1**
Summary pollen diagram and stratigraphy

elevated (clint) and fissured (gryke) elements have, for the most part, emerged over time as a superficial cover of drift/soil has been lost (Clayton, 1981). Occurrences of peat lying directly on limestone as at Scar Close, Ingleborough, raise significant problems of genesis as the introduction to this paper has outlined. No matter how they were originally formed, these examples of peat are all now residuals, as deep fissures effectively isolate them from any water supply other than atmospheric.

Two possible mechanisms exist to explain such occurrences. The first considers the peat as having formed on an acidified drift cover which originally extended as a continuous sheet and derived a substantial part of its water from lateral, higher level sources. This requires that the basal drift soil is subsequently lost down widening limestone fissures, a process which would have accelerated as the drift became more completely acidified. Support for this view is provided by glacial erratic boulders on the limestone surface, surviving drift on the upland margin of the pavement at Scar Close and small Gritstone pebbles exposed with the degradation of peat 'islands'. Plinths beneath the erratic blocks also demonstrate that the limestone has been substantially lowered since drift deposition.

An alternative hypothesis must visualise micro-successions from open pools or lichen surface, to lime-tolerant moss to acidophile moss followed by other plants such as heather, forming the basis of the build up of organic matter on bare limestone. Such a sequence is most likely to develop from water-filled solutional pits on the limestone surface which are currently colonized by cyanobacteria. However, in this region vulnerability to desiccation is likely to prevent such a sequence unless there is tree cover. Even where there is tree cover, a close spacing of fissures in the limestone tends to frustrate the process of build-up. It is I believe of some significance that superficial organic deposition presently occurs under a tree cover at Colt Park, Ingleborough, where also the tree leaves contribute to the annual organic deposition. Even so, no net accumulation takes place from year to year due to high rates of decomposition and vulnerability to erosion. At Scar Close some of the acid peat survives in an area where tree and shrub cover occurs. It is also worth noting that isolated peat areas at Scar Close which are without the assumed benefits of tree cover appear in most cases to be slightly lower than the general level of the pavement suggesting a more favourable water regime.

All the surviving peat deposits on the limestone pavement are shallow (<50cm) and contain a substantial mineral content up to 40% (Jones, 1965; Smith, unpublished). This would suggest accretion of mineral matter under dry and windy conditions as well as from rainfall. Mineral soil could thus be derived from adjacent grykes, from eroding drift material on adjacent parts of the limestone surface and from exposures of nearby Yoredales and Millstone Grit strata. This process would no doubt contribute to the development of peat soils on limestone in places where a plant cover had already become established.

Nevertheless, the discovery of earthworms at the peat-limestone interface on Scar Close points to current active degradation of what were formerly deeper deposits. We may visualise that as drift soil is lost beneath the peat layer the latter is subject to increased aeration and biological activity. With increasing fragmentation of the peat area one may assume that the transmission of worm eggs would be facilitated. Thereafter, soil movement by worms could effectively mix basal drift soil with the lower peat layers. This would provide a satisfactory mechanism to account for why basal drift soil cannot be seen under the dissected remnants or peat islands but is present on the edge of the pavements adjacent to deeper drift under wetter conditions.

Figure 13 displays two summary pollen diagrams selected from Gosden (1968) where B2 represents peat on the slope of Ingleborough above the dissected limestone pavement while B4 is a site on a peat island. Gosden considered that B4 was a 'truncated' record representing only the later part of the history represented by site B2. This history is that of the most recent Holocene (Gosden, 1968; Swales, 1987) and indicates formation during and after major deforestation and drift acidification in approximately the last 3,000 years. While part of the reason for truncation of the pavement peat may be its later spread onto these lower areas it does seem highly probable that the early basal part of the record has been physically and biologically lost. Furthermore, increasing earthworm homogenisation of the thin surviving peat will have led to over-representation of modern pollen in the organic matter. For these reasons it is highly doubtful that a true stratigraphy exists in the peat survivals on the limestone pavement.

On balance, the development of pavement peats on a former drift cover seems much more likely than the alternative hypothesis but judgements differ on the possible early removal of glacial drift cover towards the edge of Ingleborough (See Gosden 1968; also Jones, 1965; Moisley, 1965; Sweeting, 1966). The rarity of coarse drift material beneath the peat islands may signify primary peat development under originally more favourable circumstances. However, in view of the amount of solution which has taken place, coarse pebbles, had they been of limestone, would now have disappeared by solution. Others, of Gritstone, remain. Moreover, although morainic drift may have been subject to erosion in a meltwater phase, the deposits common on many other Carboniferous limestone uplands are of loessic origin (Bullock 1971; Pigott, 1962), suggesting deposition in a subsequent drier periglacial phase. Such loamy deposits, on removal or incorporation, would leave no stony remains. There is also a further fundamental weakness in the idea of peat forming directly on the limestone. If tree cover has existed on the limestone pavements through the majority of the Holocene and yet field evidence is such that peat did not generally form until late in the Holocene in adjacent areas it suggests that the genesis of peat on the limestone is linked to the deposits and hydrology of the surrounding landscape rather than to special peat forming pathways peculiar to the limestone surface. Though the latter might have achieved convincing effects on the Burren of western Ireland it is doubtful they would have led to stable peat formation in an area of lower and more variable rainfall.

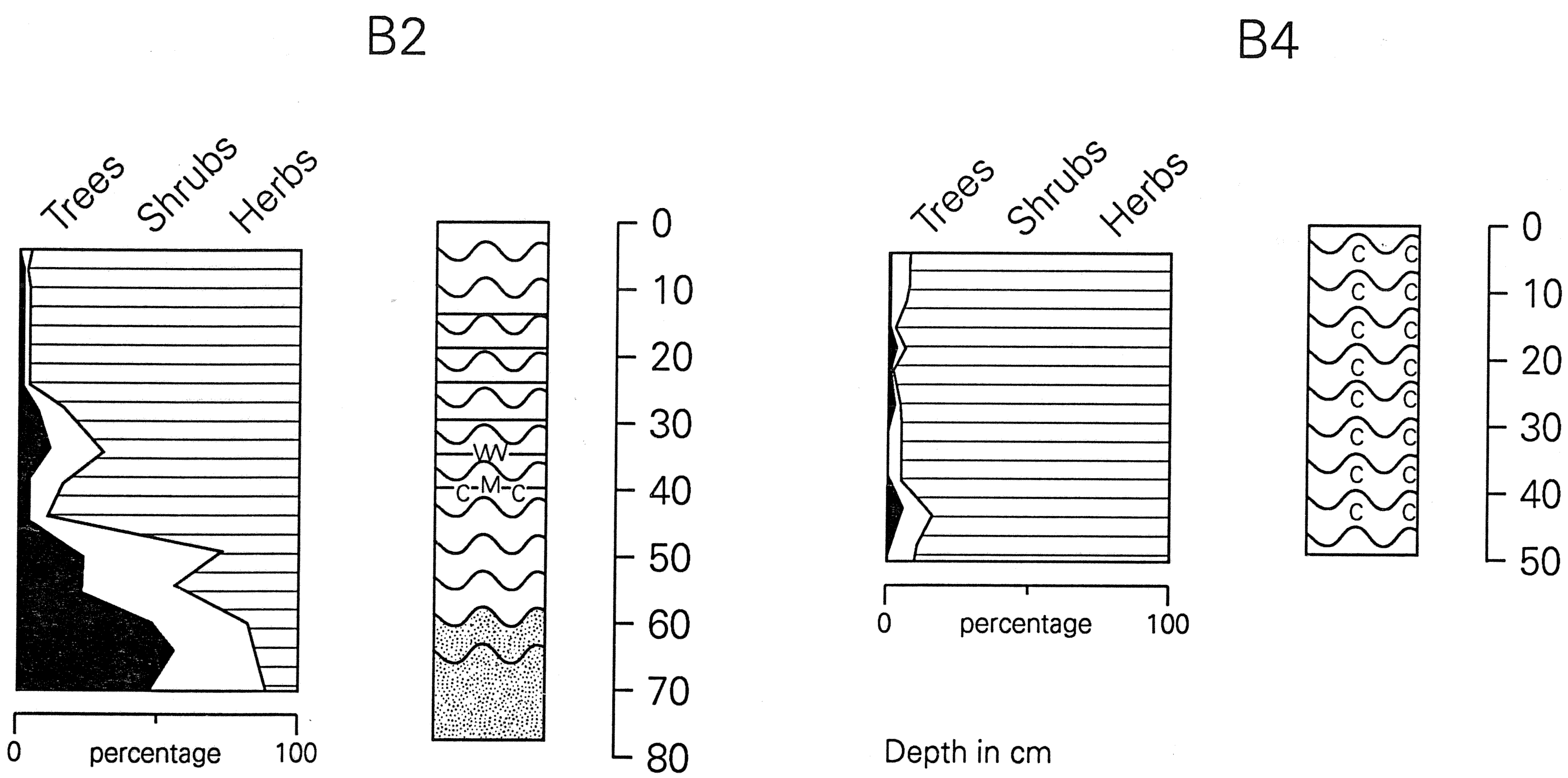
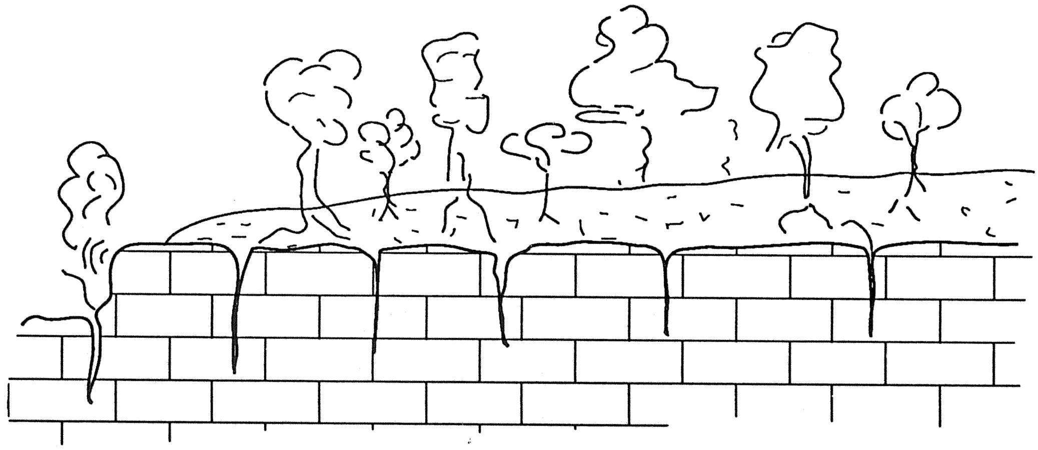
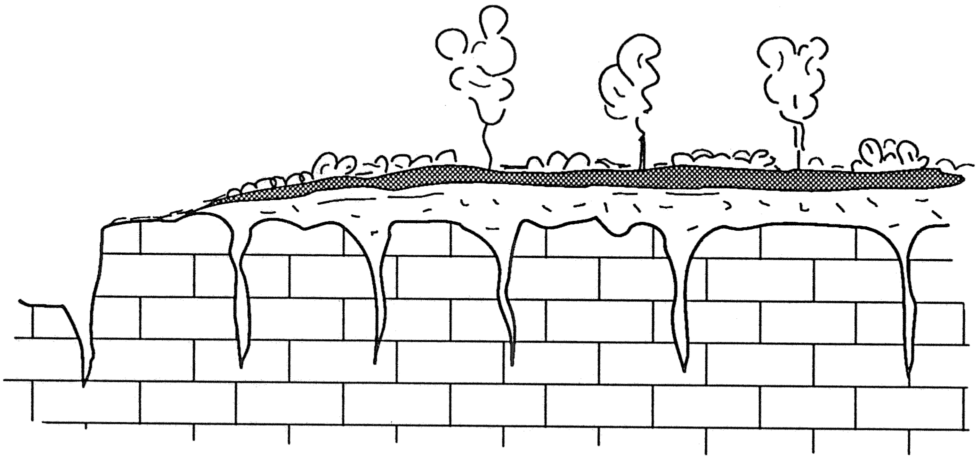


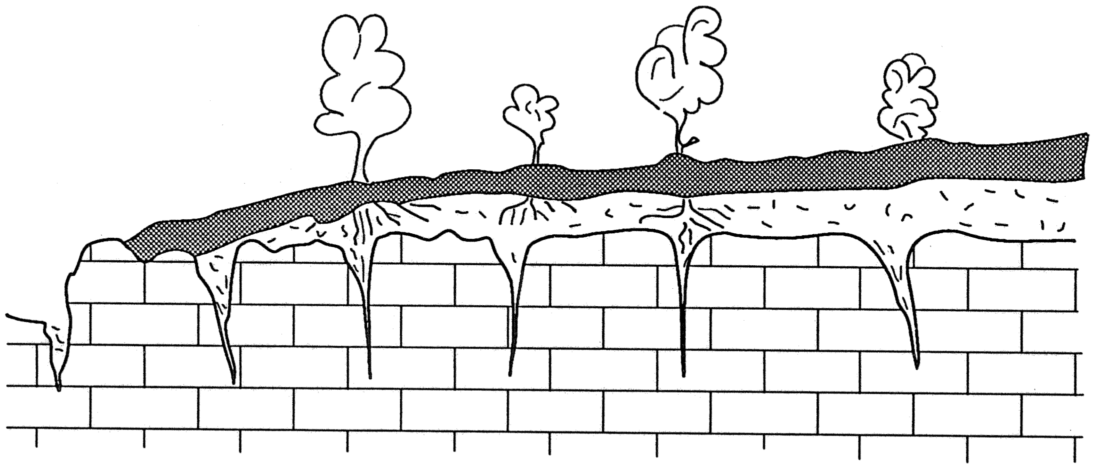
Figure 13: **Scar Close**
Summary pollen diagram and stratigraphy (after Gosden 1968)



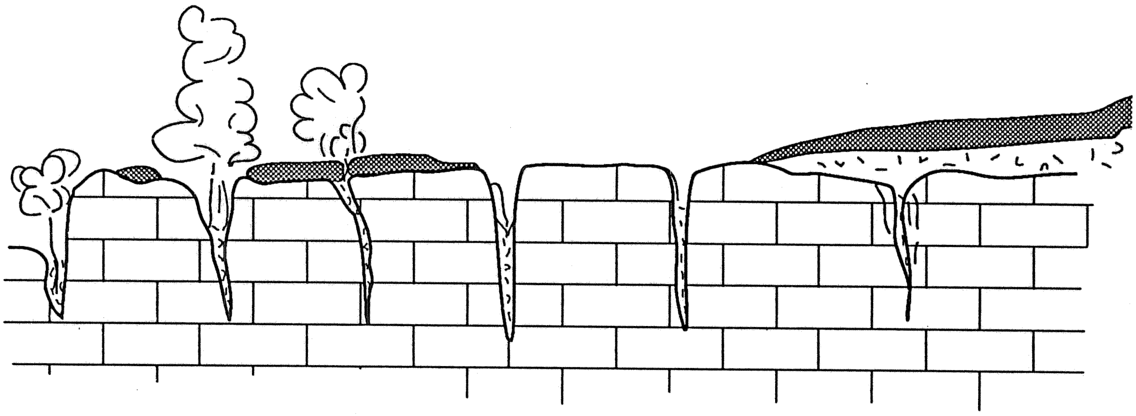
Presumed early Holocene situation with drift covered limestone and variable tree cover.



Later Holocene tree reduction and soil acidification producing surface raw humus 'proto peat'.



Subsequent paludification via acid soil pathway and lateral sources during late Bronze / early Iron Age.



Peat degeneration through tree removal, lowering of drift surface, basal mixing and oxidation.

Figure 14: Proposed sequence of peat development and decline on Scar Close.

Finally, however it was originally formed, the survival of peat over the limestone is very likely to be related to the occurrence of a protective tree and shrub cover. It is this author's view that as a result of soil subsidence, once grykes become too deep to permit the regeneration of trees and shrubs, the microclimate becomes unsuitable, the cycle of organic deposition is broken and the peat suffers irreversible decline. Whether trees were lost simply through cutting or gradually through inability to regenerate, the destabilising effect on the peat system would be the same. Figure 14 attempts to portray the evolutionary sequence considered here to be the most likely.

Summary

A diversity of peats of varying stability has been outlined. Though individually of limited extent these records cover the entire Holocene. A common theme appears to be the action of man in both the initiation and termination of peat formation. Solution of underlying limestone has also played a distinctive part in creating and destroying peats.

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