THE NORTH SHROPSHIRE MERES AND MOSSES: A BACKGROUND FOR ECOLOGISTS

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I. Introduction

The Meres and Mosses are a series of water- or peat-filled hollows in the glacial drift which covers the Shropshire-Cheshire Plain. These sites tend to occur in clusters in various parts of the region, the most important being the group around Ellesmere and Whitchurch on the border between North Shropshire and the detached part of Flintshire called Maelor Saesneg (Fig. 1). The geology of the area has been described by Pocock and Wray (1925) and the soils by Crompton and Osmond (1954) in the first 1 in. Sheet and Memoir of the Soil Survey; Hardy (1939) has given an account of the vegetational history based on the peat stratigraphy and pollen analysis of certain bogs; and Gorham (1957a) determined the chemical composition of some of the mere waters. The present day ecology has been neglected, however, apart from brief descriptions by Phillips (1884) and Griffiths (1925) of algae in the meres, and by Clapham of the vegetation of Sweat Mere (in Tansley, 1939). Comparable sites in Cheshire have received rather more attention, e.g. in the works of Gorham (1957b), Lind (1945, 1949, 1951), Hincks and Shaw (1954), and Poore and Walker (1959).

In recent years the scientific importance of the North Shropshire Meres and Mosses has become increasingly evident: they bridge a wide gap, both geographically and ecologically, between better-known sites in East Anglia and the Southern counties on the one hand, and in the North and West of Britain on the other. The Nature Conservancy and Preston Montford Field Centre have now launched an extensive programme of ecological study to which specialists in several fields are contributing. The present paper is in the first place a summary report on the results of reconnaissance surveys, but at the same time it aims to provide a background (much of it gathered from the scattered earlier sources) for future work in the area.

Physical aspects.

Full meteorological data are not available for the Ellesmere-Whitchurch area, nor has a detailed analysis yet been made from the records of the nearest stations. Gorham (1957a) suggests an average annual precipitation of about 70 cm. (c. 28 in.) and an evaporation of about 50 cm., giving a P/E ratio of 1·4; he quotes a range of mean monthly temperature at Shrewsbury from about 4·5° C. (winter) to about 16° C. (summer). These approximate figures reflect North Shropshire's intermediate position between the Lowland and Highland Zones of Britain, approaching both the milder oceanic winters of the West and

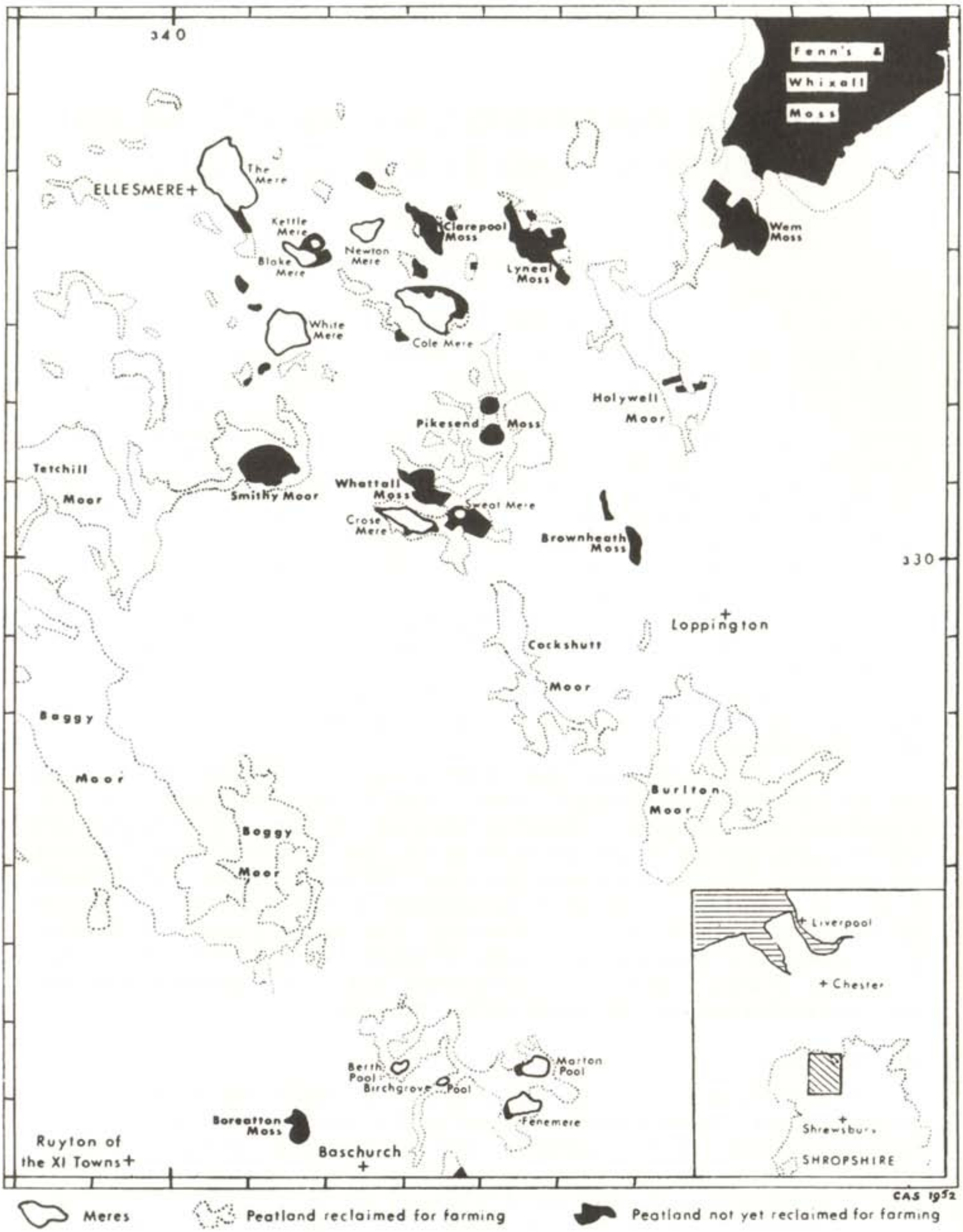

FIG. 1.
Outline Map of The North Shropshire Meres and Mosses.

the more continental low rainfall (and low P/E ratio) of East Anglia. Rainfall is well distributed over the year and the driest period tends to be in the early spring.

Triassic sandstones and marls underlie the region (Pocock and Wray, 1925) but their surface is entrenched at Ellesmere to nearly 150 feet below sea level, where the pre-glacial valleys of the Dee and Upper Severn seem to have joined (Wills, 1912, and recent unpublished borehole data). These irregularities are buried under a thick mantle of glacial drift which masks the outcrop of the solid rocks.

During the last glaciation North Shropshire was occupied by two ice-sheets, the greater of which came down from the Lake District and South-west Scotland by way of the Irish Sea and the Lancashire Plain, while the lesser had its source in the mountains of North Wales. Erratic rocks derived from both source-regions occur in the Ellesmere district and, although the boundary between the two ice-sheets is not well-marked, the North Wales ice appears to have readvanced into Shropshire after the Irish Sea ice had abandoned the area as its front waned northwards at the end of the last glaciation (but see also Peake, 1961). The drifts are extraordinarily varied in their composition and provenance: the finer material is mainly Triassic and Carboniferous, but in this generally reddish ground-mass are embedded fragments of Welsh slate and volcanic ash, Carboniferous sandstone and limestone from the Borderland, granites from the North, and occasional flints (thought to derive from a chalk outcrop on the floor of the Irish Sea) and recent marine shells.

Structurally the glacial drift is of two kinds: (1) a heavy and impervious boulder clay or unstratified drift (Flint, 1957; Charlesworth, 1957) laid down under the sole of the advancing ice-sheet or thrust into a moraine in front of it; and (2) graded layers of sand and gravel or stratified drift, carried and deposited by the streams of meltwater which issued from the ice-sheet during its recession, and forming both featureless outwash plains and abrupt hillocks and ridges (to which such terms as *kame* and *esker* are variously applied). From the decaying ice margin large blocks of dead ice became detached, to lie embedded in the drift like terrestrial icebergs. The melting of these entombed blocks left steep-sided depressions or craters in the drift surface which are known as kettle holes.

The Ellesmere Moraine Belt, which passes in a broad crescent through Ellesmere and Whitchurch, represents a local increase in the accumulation of drift, and probably marks the position of a temporary halt in the waning of the Irish Sea ice front, or a minor readvance (Peake, 1961). Its main feature is an elevated and rather level tract (at about 300 ft. O.D.) of boulder clay, the true moraine, deeply dissected by post-glacial streams flowing northward to join the Dee. From the southern (or outer) flank of this ridge run clusters of conspicuous hillocks (up to 400 ft. O.D.) and hollows in stratified sand and gravel, which pass southwards and eastwards into low-lying (about 275 ft. O.D.) outwash plains, and are separated from one another by gentle swells of boulder clay. The geological details of this area are bewilderingly complex and good exposures are rare. Sections displayed in a gravel pit at Wood Lane (423326) south of Ellesmere, however, suggest a subsequent thrusting and crumpling of the Irish Sea drift by the readvance of Welsh Ice.

North Shropshire is thought to have lain for a time, during the recession of the ice fronts, beneath the waters of an extensive lake (Lake Lapworth—see Pocock and Wray, *loc. cit.*) whose shore line followed roughly the present 300 ft. contour; this feature has left little mark on the modern landscape. The area straddles the present watershed between the Dee and Severn catchments. This seclusion from powerfully erosive streams, coupled with the nature of the glacial drift, has kept the relief almost as fresh, and the drainage almost as disorganized, as Lake Lapworth left them: while erosion and soil creep have no doubt modified the slopes on the impervious boulder clay, the permeability of the sand and gravel hills has enabled water to pass underground and so protected their surface forms. The meres of the Ellesmere group mostly lie cradled in hollows among the sand and gravel hills, though some abut on the boulder clay, and two (The Mere and White Mere) are wholly on it. The deeper and steeper-sided of these hollows are no doubt true kettle holes, but others may be no more than enclosed gaps in the drift ridges. The mosses (i.e. peat bogs) occupy a similar variety of depressions, and some of the large reclaimed peat-flats (e.g. Baggy Moor) fill broad valleys in the subdued landscape of the drift plain. Such surface drainage as exists from the meres and surviving mosses is largely artificial. Cole Mere has a small outflow ditch and Crose Mere is linked through Sweat Mere with the devious network of the river Roden catchment. There are no significant inflows apart from field ditches, and most of the meres are both fed and drained by slow percolation through the drift on which they lie.

There are about three dozen natural meres and pools of more than 200 m. diameter in North Shropshire, the largest being The Mere (Ellesmere) which is about 1 km. long by ½ km. wide; not all have been sounded, but some in the Ellesmere group reach depths of more than 12 m. Few data are yet available on the temperature régimes of the mere waters and the existence or otherwise of thermal stratification, nor have other aspects of the local climate been studied. Wind may be of considerable importance, the exposure and fetch at least of Crose Mere being sufficient to differentiate the shorelines ecologically. Gorham (1957a), in discussing his analyses of the waters from all eight meres of the Ellesmere group, draws attention to the considerable range of concentrations both of total salts and of certain ions. All can be regarded as eutrophic, being well supplied with the ions essential for plant and animal nutrition, and with one exception (Newton Mere: pH 6·8) their untreated waters are on the alkaline side of neutrality; none falls as low in cation content as the most acid Cheshire meres such as Oak Mere (Gorham, 1957b). The richest waters (Crose Mere and Sweat Mere) owe their high total salt figure largely to increased calcium and bicarbonate, other ions varying rather less, but mostly in the same direction. The exception is potassium, which is most abundant—and indeed unusually high—in the least alkaline waters. Magnesium shows a marked and so far unexplained seasonal fluctuation, its concentration falling by as much as one half from the November 1954 to the June 1955 samples, but the other ions analysed show little or no change over this period. Gorham considers that the composition of the various waters may be taken to reflect that of rainwater progressively concentrated by evaporation (by which means the above-average sodium chloride content might be achieved) and modified further by the solution of mineral weathering products. He attempts to correlate the chemical variation from mere to mere with differences in local geology and drainage.

Historical aspects.

The peat stratigraphy and pollen analysis of certain peat bogs in the area, thoroughly investigated by Hardy (1939), reveal a pattern of local climatic and vegetational history broadly similar to those in other parts of England (Godwin, 1956). Stratigraphical data, recording as they do the stages in the development in the mosses themselves, are more directly relevant to the present account than the regional picture drawn from her pollen diagrams. On the latter, which are the main subject of Hardy's paper, there is space for no more than a few comments.* None of them extends back into the Late-glacial period, the longest (from Whattall Moss near Crose Mere) starting early in the Post-glacial (not more than 10,000 years ago) with a pollen spectrum indicating dominant birchwoods and small quantities of pine and willow in the region. This is followed by a brief waxing and waning of the representation of pine, and, in a pattern now regarded as standard for England, a rapid rise in those of elm, oak, alder and lime successively. These changes mark the last stages in the progressive amelioration (mainly warming up) of the climate after the Ice Age, and lead to the long reign of alder and mixed oak forest through the phase known as the Post-glacial Climatic Optimum. Deterioration became rapid about the beginning of the Iron Age (c. 500 B.C.) and continued almost to the present day, but the record of its effect on the regional vegetation is both complicated by a number of transient oscillations back to warmer and drier conditions (see below), and masked by the lengthening shadow of man's influence as his agricultural stature grew.

The sites with which Hardy was principally concerned (Whattall, Whixall and Bettisfield Mosses) are unfortunately of small ecological interest at the present time, since they have suffered such drastic interference as draining, burning and afforestation. Nevertheless, their stratigraphy, by preserving a succession of deposits whose mineral and plant constituents are readily identifiable, provides a record both of their development and of their ecological character at any given stage. Hardy does not give detailed identifications of the plant remains other than pollen, but the general character of typical sites (e.g. Bettisfield) conforms to the normal hydrosere sequence described elsewhere for the wetter parts of Britain (Tansley, 1939; Godwin, *loc. cit.*; Pigott and Pigott, *loc. cit.*; see also p. 129 below): an initial accumulation of lake silt, clay and mud, at first predominantly mineral but with an increasing organic content upwards, leads through reed-swamp and sedge-fen peats to a brushwood layer representing fen carr (wood), culminating in a considerable thickness of *Sphagnum* peat which shows the growth of the final raised bog. Certain sites, however, are anomalous: some (e.g. parts of Whixall and Fenn's Mosses) lack an aquatic stage, passing directly from terrestrial conditions to fen wood and bog; the southwestern corner of Whattall Moss, by contrast, has a layer of

* An admirable example illustrating the methods and interpretation of pollen analysis is the paper on Malham Tarn Moss by C. D. and M. E. Pigott, published in an earlier number of *Field Studies* (1959).

Sphagnum peat 1·5 m. thick immediately overlying an unplumbed depth (more than 12 m.) of watery mud filling a steep-sided basin which is probably a kettle hole. A most interesting feature of Hardy's results is the evidence of several interruptions in the climatic deterioration of the past 4,000 years. The raised bog deposits vary in a regular manner between pale unhumified peat (called "white peat" by the cutters) consisting largely of *Sphagnum* remains, and dark ("black") peat in which cotton-grass and heather are recognizable: the former was laid down in wet periods when bog growth was vigorous; the latter marks drier (and perhaps warmer) spells when a standstill vegetation of heathy character covered the surface, and sometimes includes pine or birch stumps.

A bronze looped palstave of Middle Bronze Age type (roughly 1,000 B.C.) was found in the main pine stump layer at Whixall Moss (492361), and a fine oak dug-out canoe, probably of the early Iron Age (after 500 B.C.) came from the base of the *Sphagnum* peat at Whattall Moss (431311) (Chitty, 1927), when this site still had some open water at least in the kettle hole. Two archaeological sites, both of uncertain age and requiring further excavation, are closely associated with meres and mosses: the Berth near Baschurch (430236) is a fortified hillock standing in a shallow peat-filled basin, and linked with the "shore" by a causeway which later shrinkage of the Berth pool has left high and dry; and a small un-named fort at a place formerly called Stockett (431307) stands on the low ridge separating Crose Mere from Whattall Moss (Peake, 1909) (see p. 108).

Pertinent historical information about the area is still regrettably meagre—we can probably learn more of man's influence on the landscape from the deposits than from the documents, at least up to the 18th century. Eyton (1854) quotes a survey of the Manor of Ellesmere made in 1309 which mentions 8 meres: "The meres (*stagna*) of Ellesmere, Culghmere (Cole Mere), Croulesmere (Crose Mere), Swotlemere (Sweat Mere), Chetelmere (Kettle Mere), Poulesmere (possibly Newton Mere), Blakemere, and Whitemere and other meres, with a weir at Warchet, were worth, in respect of the fisheries thereof, £13 6s. 8d. *per annum*, and not more, because the tenants fished when they pleased, except in the month of May, in Ellesmere-mere."

Forest clearance on the drier soils proceeded at an increasing rate from Neolithic times to the Reformation as more and more land was taken under grazing and the plough; no doubt these changes affected the water and nutrient régimes of the basin sites. But until the second half of the 18th century, when peat cutting, drainage and reclamation became extensive and systematic, the mosses and valley-fens remained largely undisturbed.

At the present day this is an area of fairly prosperous dairy farming, with some arable fields on the well-drained sands and gravels (Howell, 1941). Changes have been made in the levels of several meres, there are ornamental plantations with exotic conifers and rhododendrons about the shores of some, and activities such as fishing and sailing are beginning to have an impact on the bird population. About four-fifths of the peatland acreage of North Shropshire is now wholly reclaimed and under pasture, including a former market-gardening belt on the fringe of Whixall Moss. None of the mosses has escaped at least partial drainage and burning. Of those still waste a few (e.g. Whattall and Pikesend Mosses) are afforested, and the Whixall-Fenn's Moss area is exploited by an efficient peat-cutting industry: the "black" peat, once an important fuel, is now cut for local domestic use only, but the "white" peat, making up for its low calorific value by its high absorbency, finds an expanding horticultural market. It is the few sites which have escaped irreparable human interference, and still preserve something of an integrated and "natural" ecological system, which are singled out for description in the next section of this account.

II. Ecological description

An attractive feature of these North Shropshire sites is their ecological diversity, for between them they still display a full range of stages in the normal succession or hydrosere from open water to acid bog, and several variations on this succession (see p. 129). Most of the sites fall into one or the other of two categories: (1) The lakes (meres) and fens, whose water supply is topogenous, having passed over or through the surrounding 'mineral' soil to become enriched with electrolytes (especially bases) so that its reaction is usually neutral to alkaline; such sites therefore possess a nutrient status for growing plants which is classed as *mesotrophic* (medium) to *eutrophic* (high). (2) The true bogs (mosses), the greater part of whose surface is inaccessible to base-rich ground water, being kept wet by a direct atmospheric (*ombrogenous*) water supply in the form of rain and other precipitation, and thus having a strongly acid reaction; the consequent low nutrient status renders a bog *oligotrophic* or (in extreme cases) *dystrophic*.

The majority of the Ellesmere group of meres, and certain others including Bomere and Betton Pools, are almost devoid of marginal reedswamp and fen through a combination of such factors as steepness of shoreline, recent rise in water level (see p. 129), and overshadowing by planted trees (unfringed meres, see Appendix); their chief botanical interest lies in their algal ecology and in the occurrence of rare aquatics such as *Nuphar pumila* (Blake Mere) and *Elatine hexandra* (Bomere). Others (fringed meres) show varying degrees of colonization by emergent plants, from the narrow interrupted reedswamp fringes of Crose Mere and Cole Mere, through intermediate states as in the Fenemere group near Baschurch, to Sweat Mere whose floating swamp has almost closed over the open pool. A special case (mere fens) is represented by Hencott and Shrawardine Pools: here recent falls in water-level have permitted the more or less complete invasion of the lake floor by luxuriant reedswamp and tall fen, with sallow and alder carr following; *Cicuta virosa*, *Hottonia palustris*, *Carex elata*, and *Calamagrostis canescens* are conspicuous associates.

The best surviving raised bogs (German: *Hochmoore*) belong to the large Whixall Moss complex, and include Wem Moss; probably of this type are many reclaimed or altered sites such as Smithy Moor south of Ellesmere. Of different development, being built in part on a liquid foundation, are the quaking bogs (German: *Schwingmoore*) of Clarepool and Whattall Mosses; an interesting miniature example is the unnamed pool at Lin Can Coppice near Ruyton-of-the-XI-Towns, which has been wholly overgrown by a floating lawn of *Sphagnum recurvum* and *Carex rostrata* within the past half century (c.f. Conway, 1949).

Little can be said about the natural ecology of the wide river-drained peat flats, such as the Weald Moors north of Wellington and the Baggy Moor complex north of Ruyton, classed as valley mires in the Appendix. Originating as temporary ice-dammed lakes at the end of the last glaciation (Peake, 1961), they may never have reached the ombrogenous stage of development: contemporary records suggest that they were fen woods (*Salix* and *Alnus*) at the time of their drainage and reclamation in the 18th century (Plymley, 1803).

Miscellaneous sites include Brown Moss, which is actually a series of small and shallow fringed pools in a tract of heathland; "Venus Pool", another shallow fringed pool of very recent origin and great ornithological interest; two rather disparate fen sites, Brownheath Moss and Berrington Moss, which may be secondary fens produced by the complete cutting-away of bog peat; and Shomere Pool, an unfringed mere lying at one side of a drained and wooded bog.

Before passing on to the detailed description of selected sites, one feature of the meres calls for special mention:

"*The Breaking of the Meres*"

This term is drawn from the local brewing industry, by a happy analogy with the breaking of wort (yeast) on beer-in-the-making, and it describes the most dramatic biological phenomenon to which the meres are subject. At irregular and unpredictable intervals the waters change almost overnight from their usual limpid state to the colour and turbidity of pea soup. A chlorotic scum, leprous and foetid, festoons the surface of every sheltered bight on the lee shore, while fish skulk at the bottom and refuse the angler's bait. The organisms responsible for this change are minute free-floating Cyanophyceae (Blue-green algae), common members of the plankton at all times, which appear suddenly to undergo spells of catastrophic multiplication until they vastly outweigh all their fellow-planktons. These outbreaks of "water-bloom", commonest in late summer and autumn, last for periods of a few weeks to several months before they gradually die away, but they vary in timing and in the species involved from mere to mere and from break to break. Species of *Anabaena*, *Aphanizomenon*, *Coelosphaerium*, *Gloeotrichia*, and *Microcystis* have been recorded as the most frequent agents in the North Shropshire Meres (Phillips, 1884; Griffiths, 1925; and the unpublished lists of the 1961 Preston Montford Algology Course). The physiological cause of breaking is still unknown: temperature and rainfall appear to play no direct part, but it has been suggested that the availability of nutrients in limited supply, particularly phosphate ions, may be critical (*ex ore* Dr. J. W. G. Lund). It is also a matter of some uncertainty whether the sudden onset of a break is due to rapid multiplication alone, or to a more gradual increase followed by an abrupt rising of the entire population to the surface.

(1) *The Crose Mere Complex* (Plates I and II, Figs. 2a and 2b)

A compound peat-lined basin of irregular shape is divided by a low gravel ridge into a northern and a southern arm (Whattall Moss and Crose Mere respectively), which join eastwards, where the ridge dies away, in Sweat Mere and Lloyd's Wood. At one time this must have been a single lake whose surface stood some 2 to 3 m. higher than the present level of Crose Mere (285 ft. O.D.): the ancient earthwork (see p. 106) on the dividing ridge is

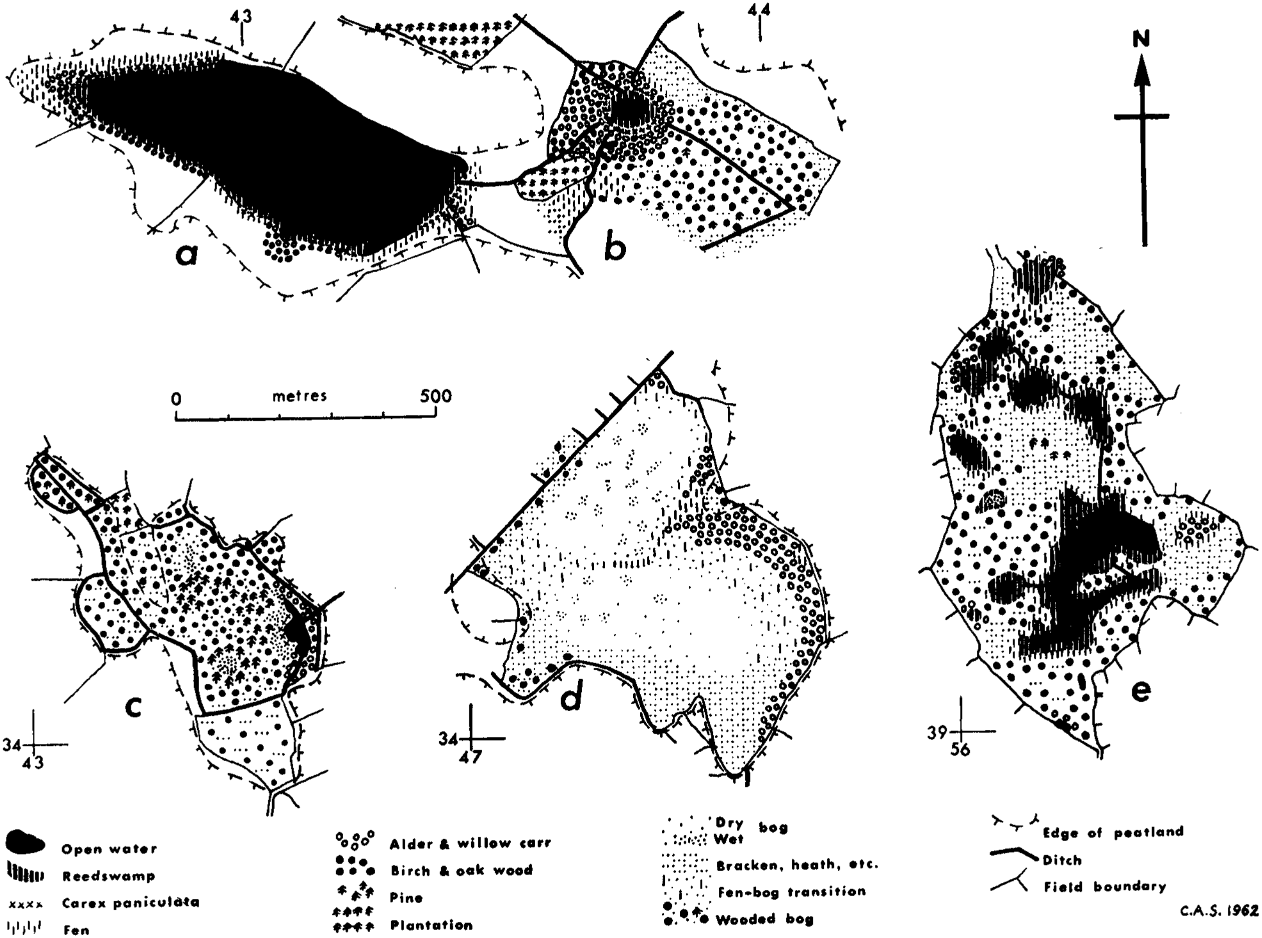

FIG. 2
Ecological sketch-maps of (a) Crose Mere, (b) Sweat Mere, (c) Clarepool Moss, (d) Wem Moss, (e) Brown Moss.

protected to the west by a ditch, containing bedded sand and reed stems, which formerly connected the northern and southern arms of the basin but now stands high and dry (Peake, 1909): drainage operations at Whattall and Sweat Mere in 1864 are said to have lowered the level of Crose Mere by 8-10 ft (Hardy, 1939). The stratigraphical position of the dug-out canoe helps to date the last open-water phase at Whattall, and the 14th century reference to both "Croulesmere" and "Swotlemere" implies that they were separate by that time (see p. 106).

Crose Mere is an open lake about 38 acres in extent (800 m. long × 300 m. wide) and at least 9 m. deep. With Sweat Mere, which it feeds, it is the richest in bases of the Ellesmere meres (pH 8·1, Ca^{++} 3·55 m. equiv./l.). Its formerly greater extent is marked by a strip of flat peat land up to 150 m. wide around all its shores but the north-eastern, where its waters still lap against the gravel ridge. It is fed by three or four very small field ditches along its southern shore, presumably augmented by general seepage through the surrounding drift and possibly by submerged springs, and there is a fairly strong outflow (about 1 m. wide × 30 cm. deep) at the eastern end. The nearest house is at Kenwick more than ¼ mile to the west, and no pollution is apparent. Its banks are quite free from planted woodland, the fields to the north being under medium-quality pasture and those to the south mainly arable.

The exposed eastern sector of the north shore is stony and clear of reedswamp and fen, and the conspicuous stilt-roots of a row of old alders standing high on this bank may indicate that they were established here before the water level was lowered a century ago. The other shores are bordered in varying degrees by a zone of reedswamp up to 10 m. wide, the succession being best developed at the sheltered western end. The bottom material ranges from stones and coarse gravel through sand and silt (often shelly) to dark organic mud (*gyttja*). Aquatic flowering plants so far recorded include *Nuphar lutea*, *Nymphaea alba*, and *Potamogeton crispus* at the western end, while *Zannichellia palustris* is frequent on the extensive strip of shelly silt in shallow water around the eastern end. Offshore from the reedswamp in most parts of the northern and south-western shores the bottom falls away steeply from a depth of about 1 m.: this must be an obstacle to further invasion by emergent plants, and the narrowness of the successive zones may be the result of their telescoping against the arrested reedswamp front. The reedswamp is dominated, often exclusively, by *Phragmites communis*, but at the western end of the north shore (and locally elsewhere) this is preceded by an offshore belt of *Scirpus lacustris* followed by one of mixed *Phragmites* and *Typha angustifolia*; *Scirpus tabernaemontani*, usually a maritime species and rare inland, occurs at two points well inshore from *S. lacustris* (it was recorded from White Mere by Phillips in 1880).

Where the succession is best developed *Cladium mariscus* follows the *Phragmites* or *Typha* zone and introduces a fen community dominated by tussocks of *Carex paniculata*, which may lead directly into alder carr (extreme W. and E. ends) but is more often bordered by short fen meadow (Fig. 3). Similar to that at Sweat Mere (see below) but much less impressive, the carr community nevertheless includes *Ranunculus lingua* and *Eurhynchium speciosum*. Most of the short fen meadow is heavily grazed and trampled, and it grows on a completely humified base-rich peat in which shell-fragments (freshwater molluscs) are

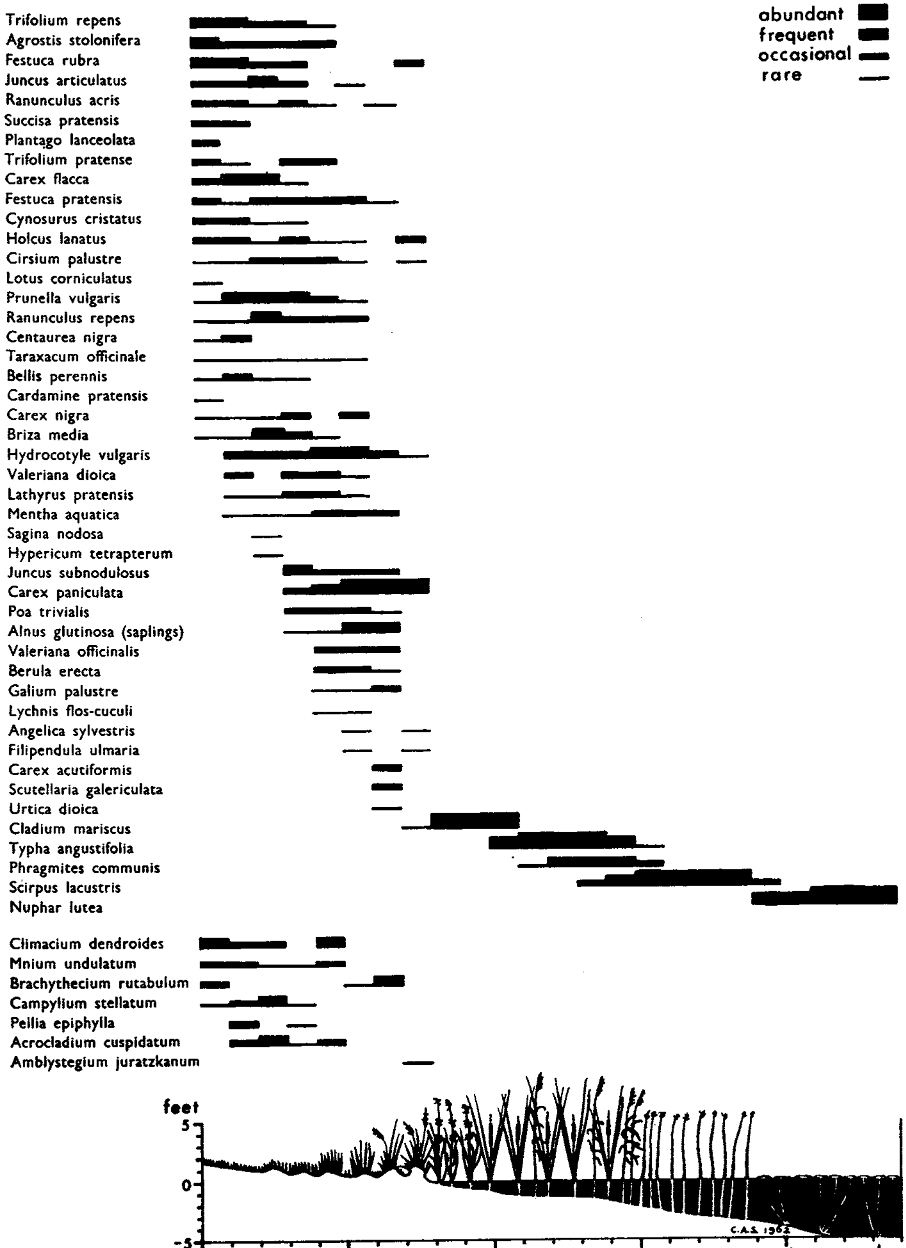

FIG. 3.

Belt transect (one yard wide) of vegetation at western end of Crose Mere, north shore, July, 1960.

common; its general floristic composition can be seen from the list in Fig. 3, to which may be added such species as *Ranunculus sceleratus*, *Stellaria alsine*, *Bidens cernua*, *Carex panicea*, *C. pulicaris*, and *Mnium seligeri*. An ungrazed fragment of fen adjoins the outflow stream; here the short fen list is augmented by *Parnassia palustris*, *Galium uliginosum*, *Epipactis palustris*, *Carex lepidocarpa*, and *Campylium elodes*, but the rapid spread of alder scrub may soon reduce the floristic interest of this patch unless it is controlled. Crose Mere in fact displays richer examples of the early hydrosere stages (especially open fen) than any other Shropshire site, making an interesting comparison with the East Anglian fens.

The hydrobiology of Crose Mere was included in a brief survey of the meres made by Dr. R. O. Brinkhurst in July, 1960, and (with Sweat Mere) was the subject of a special study by Mr. C. R. Kennedy in July, 1961; a collection of

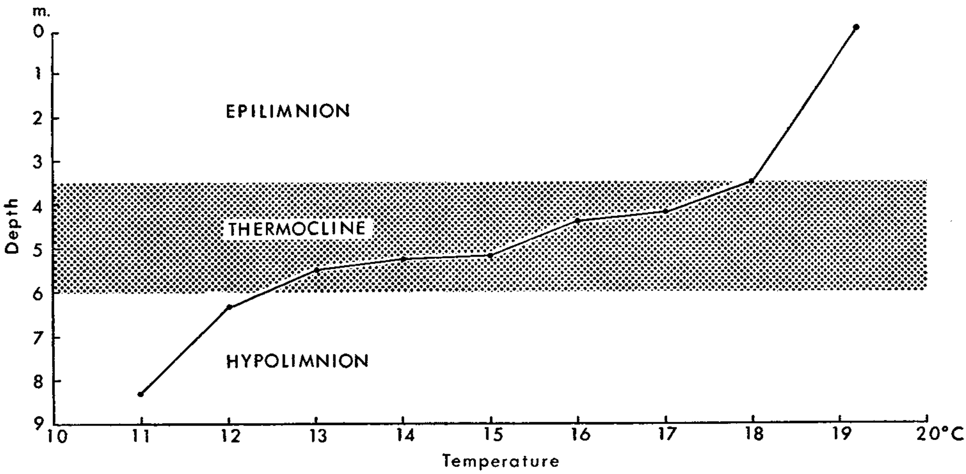

FIG. 4.
Depth/temperature graph showing thermal stratification of Crose Mere, 3rd July, 1961.

its phytoplankton (free-floating algae) was also made at the latter date by the Algological Course under the direction of Dr. J. W. G. Lund; Dr. T. T. Macan has examined the Corixids and other insect groups from both meres, and the Triclads have been listed for these and other sites by Dr. T. B. Reynoldson. While it would be improper to quote in detail findings which I hope will appear in later accounts, a few summary comments on them may be permitted. Crose Mere was not observed to "break" in 1961, but at the time of the collection mentioned above *Ceratium hirundinella* was overwhelmingly dominant in the phytoplankton associated with substantial numbers of *Fragilaria crotonensis*, *Anabaena solitaria* forms, *Dinobryon divergens*, *Pediastrum duplex*, and *Closterium aciculare* var. *subpronum*; a well-marked thermal stratification was evident at the time (see Fig. 4). Brinkhurst and Kennedy record *Helobdella stagnalis*, *Hydrobia jenkinsi*, *Asellus aquaticus* and *Gammarus pulex* as the commonest members of the littoral fauna, while the population of the deeper bottom muds is dominated by

Tubificid worms and Chironomid larvae; the most interesting rarities were *Euilyodrilus bavaricus*, *Asellus meridianus*, and *Gammarus lacustris*. A variety of coarse fish are caught in the mere, but local anglers consider the fishing to have deteriorated in recent years.

The other Shropshire sites most closely comparable with Crose Mere are Cole Mere, Fenemere, and Marton Pool (near Baschurch). Cole Mere's shoreline is largely overshadowed by planted woodland, but Brinkhurst and Reynoldson found its fauna richer than that of any other mere; it may be significant that the Shropshire Union Canal, passing close above the north shore, has an overflow weir into the mere (Twigg, 1959): this could be the source of such exotic species as *Dreissena polymorpha* and *Dugesia tigrina*. Phillips (1884) describes "hedgehogs" of plant debris and "moss-balls" from here and from White Mere. He failed to connect the two, but referred the latter to the alga *Cladophora aegagropila*; though none have been seen in recent years, they may possibly have been identical with the *Cladophora sauteri* balls found in Malham Tarn (Holmes, 1956; Lund, 1961).

Sweat Mere was described by Tansley (1939) from information supplied by Professor (then Dr.) A. R. Clapham who had visited the site in 1938. It was regarded at that time as perhaps the most complete example in this country of a hydrosere leading from reedswamp to alderwood and beyond. More than 20 years later this view is still tenable, although Clapham's two final stages (the birch and oak of Lloyd's Wood) should probably not be considered part of the primary succession for reasons outlined below.

Sweat Mere is now by far the smallest of the Ellesmere meres, its open water reduced to 75 m. length by the encroachment of reedswamp and luxuriant alder carr. In this open part the peaty bottom is nowhere more than 2 m. deep. Wide tracts of peat completely surround it, and its shrinkage has been notably rapid in recent times: the modern O.S. 6 in. and 2½ in. maps (Provisional Editions), on which this feature has probably not been revised for at least 50 years, show the mere with a diameter of about 150 m. including reedswamp; there is also a clearly visible difference in the width of the open water between aerial photographs taken by J. K. St. Joseph in July, 1954 and May, 1960. Its high base status (pH 7·4, Ca^{++} 3·66 m. equiv./l.) is sustained by a radial system of artificial channels: one from Crose Mere (pH 7·6), one from the Whattall basin (pH 7·2), and two from Lloyd's Wood and the fields to the south, all importing topogenous water; a well-kept outlet to the north-east (pH 7·0) ensures a slow but regular through-flow. This base supply persists at the soil surface, though in decreasing amounts, right to the back of the carr zone (see below); the somewhat raised surface of the peat in Lloyd's Wood, however, is dry and very acid (pH 3·7).

The central pool contains two large patches of *Nuphar lutea*, and is fringed on all sides with reedswamp up to 25 m. in width (Fig. 5a). Apart from a short stretch of rooted *Carex acutiformis*, this reedswamp consists of a floating raft of *Typha angustifolia* rhizomes unattached to the bottom; in this respect it is unique in Shropshire. Associated with the dominant there are small quantities of *T. latifolia* and *Phragmites communis* locally, occasional plants of *Solanum dulcamara* and *Galium palustre*, and a sparse seasonal bryophyte flora on the emergent *Typha* litter. In summer the *Typha*-rhizome raft is strong and buoyant enough to support a man's weight (provided he keeps moving) almost to the water's edge, and it rises and falls with changes in water level; in winter, however, when the rhizomes are heavy with stored carbohydrate reserves and deprived of their supply from the living shoots, the raft sinks beneath the water surface. Towards its landward margin the *Typha* thins out and the raft is depressed beneath the weight of the *Carex paniculata* tussocks that dominate the next zone, where they attain considerable size (more than 1 m. tall and *c.* 2 m. girth at the crown) as they mature. *Sparganium erectum* and *Carex pseudocyperus* appear in the deepening surface water, while the older sedge tussocks bear a distinctive epiphytic flora including *Angelica sylvestris* and *Valeriana officinalis*, so that the community as a whole has a mosaic character. Sallow seedlings (*Salix cinerea*) also become established at this stage, often on sedge tussocks which topple over and die as the bushes grow; but the local groves of swamp carr developing here hardly constitute a distinct zone before their supersession by alder, and the associated flora (with occasional *Ranunculus lingua*) is transitional between the sedge and alder stages.

The next zone is one of the finest undisturbed examples of alder-dominated fen carr known in this country. It completely surrounds the pool and swamp in a belt varying from 5 m. to 50 m. wide. Although the carr is floored with a fluid and treacherous humified peat it is not actually afloat, nor is there standing water on the surface at most seasons except where the sedge-sallow swamp leads into it. Alder (*Alnus glutinosa*) maintains complete dominance throughout the zone, from the younger edge where it rapidly shades out the sallows to the older where it is gradually replaced by birch and occasional oak; its seral character is marked both by the increasing height and girth of the trees from mereward to landward, and by the parallel change in the balance of fen to woodland species with the consolidation and elevation of the ground. *Carex paniculata* survives longer under the shade of the alders than the sallows do, but as it dies the epiphytic flora on the very persistent tussocks (and on those of the rarer *C. elata*) undergoes an interesting succession of its own: the early colonists mentioned above, often associated with such woodland plants as *Oxalis acetosella* and *Geranium robertianum*, give place to ferns (*Dryopteris dilatata* and *D. lanceolato-cristata*), and eventually to mosses such as *Mnium hornum* as the tussock finally decays. The general flora of the alder carr can be gathered from the following list:

Agrostis canina o.
Angelica sylvestris o.
Calamagrostis canescens l.f.
Caltha palustris f.
Cardamine flexuosa f.
Carex acutiformis l.a.
Carex remota o.
Cirsium palustre o.
Epilobium hirsutum o.
Epilobium parviflorum f.
Filipendula ulmaria l.f.
Galium palustre f.
Holcus lanatus l.f.
Iris pseudacorus o.
Juncus effusus l.f.
Lychnis flos-cuculi r.
Lycopus europaeus f.
Lysimachia vulgaris o.
Lythrum salicaria r.
Mentha aquatica f.
Myosotis caespitosa o.
Poa trivialis l.a.
Ranunculus repens l.a.
Rubus fruticosus o.
Rumex conglomeratus o.
Scutellaria galericulata o.
Solanum dulcamara f.
Sparganium erectum r.
Stellaria alsine o.
Thelypteris palustris l.f.
Urtica dioica f.
Valeriana officinalis l.f.
Veronica beccabunga r.

On the landward margin of the carr, alder gives way to birch (*Betula pubescens*) and the flora takes on the character of a damp acid woodland with *Oxalis*, *Lonicera*, and abundant *Dryopteris dilatata*. But this zone is narrow and impersistent, for in the eastern sector the ground rises rather abruptly behind it in a distinct bank about 1 m. high which leads up into Lloyd's Wood. Here the trees (mostly *Betula pubescens* and *Quercus robur*) grow on an acid but dry and humified peat quite free from the influence of ground water. They are well spaced, and the open canopy permits the general dominance of bracken (*Pteridium aquilinum*) beneath it. On other sides the birch carr occupies the periphery of the site: to the north and west it is bounded by open ground (mostly meadow), and to the south, beside the Crose Mere outflow stream, by a small tract of *Molinia* fen (Lloyd's Moss) which has recently been planted with conifers.

For want of full stratigraphical data the history of this site cannot yet be reconstructed in detail. The bank at the western edge of Lloyd's Wood seems to mark an abrupt break not only in ground level but also in the hydrological and ecological sequence—the latter is well shown by the floristic table in Tansley (*loc. cit.*, p. 466): furthermore, it curves neatly round to join the perimeter of the site to the north and south, thus closing a ring which is roughly concentric with the present shrunken mere. It is tempting to suggest that this ring may be the pre-1864 shoreline of the mere: age-data on the outer birch and alder trees would help to confirm that the full succession we see today is hardly a century old. A peat-boring made by Mr. D. J. Bellamy just above the bank showed the following rough sequence downwards:

Depth (cm.)	
0– 30	Mixed wood peat with *Rubus idaeus* fruit and *Pteridium* (both present on surface), *Sphagnum palustre*
30– 70	Similar mixed wood peat
70–100	Pale brown *Sphagnum recurvum* peat
100–170	Ditto (?)
170–270	Darker fairly humified peat with *Alnus* leaves, *Betula* twigs, *Carex* remains, *Sphagnum plumulosum*
270–300	Lake mud (gyttja) with *Carex* remains
300–400	Lake mud
400–430	*Phragmites* remains
430–440	Lake muds and red sands

This suggests a normal base-rich hydrosere, leading to alder birch carr, up to 170 cm., followed by more acid but still topogenous conditions until the possibly artificial onset of the present woodland phase; allowance should, of course, be made for contraction in the peat thickness as a result of drainage.

The algal flora of the pool seems to represent an attenuated sample of the Crose Mere phytoplankton brought in by the connecting ditch, rather than a well-developed endemic population. Kennedy found no clear correlation between the freshwater faunal elements and the vegetation zones, but Macan (collecting in February, 1962) observed a very full suite of *Corixa* species whose distributions tied up well with the accumulation of fresh organic debris.

WHATTALL Moss is a raised bog, with a small area of quaking bog over a probable kettle hole at the western corner. Its stratigraphy is dealt with by Hardy (see p. 105 above), who briefly describes its modern vegetation. At the

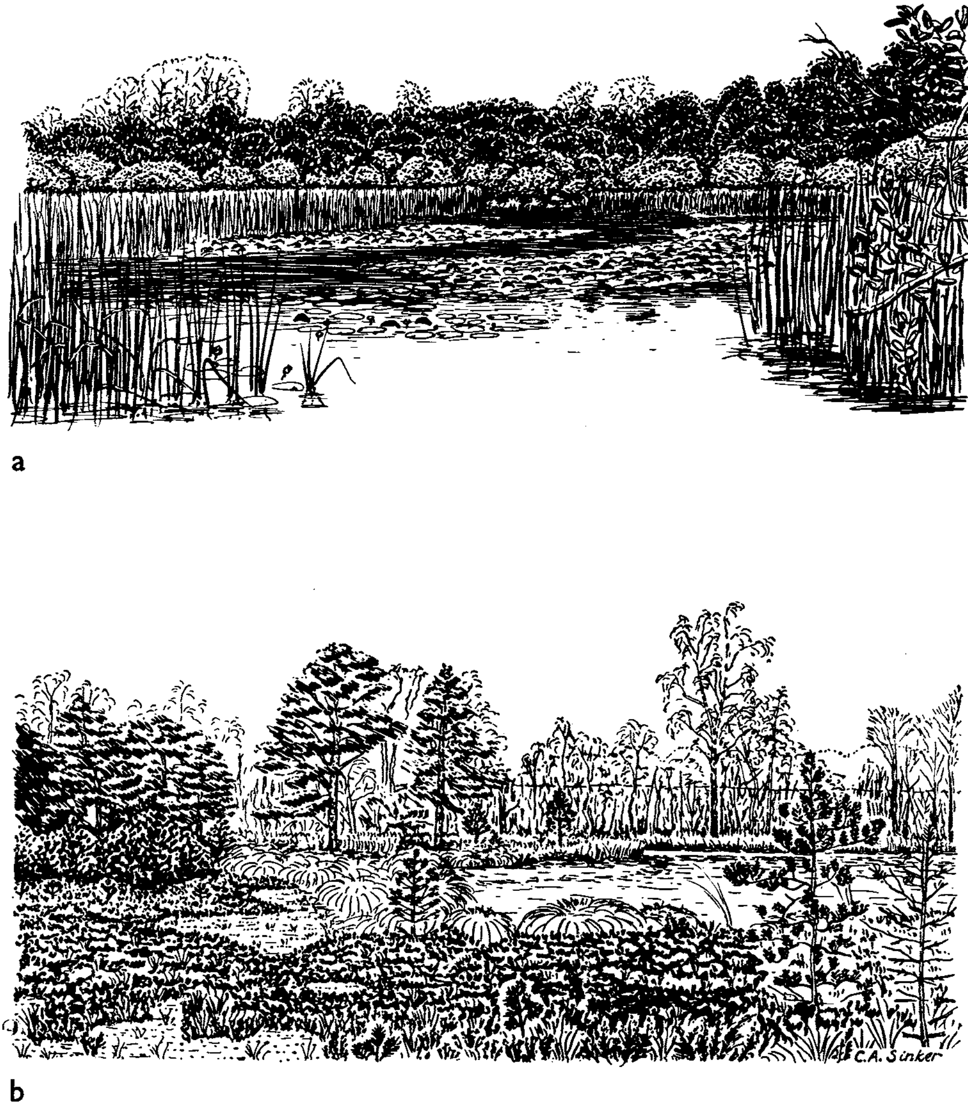

FIG. 5.
Ecological sketches of (a) Sweat Mere (August, 1958), and (b) Clarepool Moss (February, 1958).

PLATE I. Crose Mere (W. end) May, 1960.

PLATE II. Sweat Mere (looking E.) May, 1960.

Photo by J. K. St. Joseph. Crown copyright reserved

PLATE III. Clarepool Moss (looking W.) May, 1956.

present time it is largely under plantation, but the quaking bog still carries a pine-and-birch-dominated bog wood whose main constituents in the field layer are:

Calluna vulgaris l.d.	Myrica gale l.a.
Deschampsia flexuosa a.-l.d.	Vaccinium oxycoccos l.f.
Dryopteris dilatata co-d.	Sphagnum recurvum l.d.
Dryopteris lanceolatocristata co-d.	Sphagnum magellanicum l.f.

(2) *Clarepool Moss*

(Plate III and Fig. 2c)

This site is a small wooded bog complex with a pool close to its eastern edge (Fig. 5b). Almost unknown to naturalists until it came recently to the attention of the Nature Conservancy, it is proving to be of quite unusual character and in an excellent state of preservation. Since Clarepool Moss is still under active investigation by Dr. F. Rose and his colleagues, no more than a brief and tentative account may be given here of its stratigraphy, but the ecology of the present surface merits description.

The entire peat basin is no more than 800 m. (north to south) long by 400 m. wide. Its irregular shape and topography suggest a nest of minor kettle holes in the stratified drift. A tiny detached basin (Towery Moss) lies to the north-east, and a narrow arm (Hampton Moss), partly separated by a low rib of sand and gravel, extends to the northwest of the main area (Clarepool Moss proper). Towery Moss, Hampton Moss, and the southernmost third of Clarepool Moss itself are thoroughly drained and bear open birch wood with *Dryopteris* spp., bracken, or *Holcus mollis* beneath; the drift rib carries well-grown oak trees, and a conifer plantation at the northern end. The site is surrounded mainly by arable fields. The surviving portion of the moss is so small (about 400 m × 300 m.) that it must be rather sensitive to indirect influence and edge effects from the maintenance of the neighbouring agricultural land: but apart from the marginal ditches and a group of small abandoned peat cuttings near the northern end, there is very little trace of direct human interference.

The pool near the eastern edge is about 125 m. long (north to south) by 50 m. wide, and unexpectedly deep (more than 8 m.) for its area. There is apparently no surface outlet, but a *Sphagnum*-filled soakway runs into its northern end, and two cut channels join it, one at the southern end and one on the eastern side. None of these shows any appreciable flow at normal times, but the eastern ditch links the pool with the neighbouring fields and its existence may have greatly modified the hydrology of the site. The water of the pool is more acid than that in the bigger meres (pH 5·2, Ca^{++} 0·98 m. equiv./l., according to Bellamy's determinations in July, 1959), though certainly not markedly base-deficient at the present day; no higher aquatic plants grow in it, and reedswamp is absent. Nothing is known about its hydrobiology, but quite large flocks of wildfowl (mallard) visit it and may help to raise its nutrient status especially round the shores.

The eastern shore of the pool has a narrow border of fen with *Potentilla palustris*, *Solanum dulcamara*, and *Juncus effusus*. This leads back rapidly into alder-birch carr, presumably a development of the old lagg (see p. 132), which occupies the rest of the strip between the pool and the boundary ditch and fence on this side, extending to the south of the pool as well. The carr is poor floristically, with *Molinia* dominant beneath its more open parts and *Dryopteris dilatata* under the dense alder canopy, but it includes *Dicranum rugosum* as a rare associate with the first and *Osmunda regalis* with the second. The presence of *Sphagnum* species (*S. recurvum* locally in the fen zone, *S. palustre* in the carr) suggests acid but not seriously base-poor conditions.

The much-indented western shore is of a more unusual character: it is fringed by a row of large floating *Carex paniculata* tussocks, beyond which a strip of pure *Sphagnum recurvum* lawn leads into a patchwork area of wet and dry bog further diversified by small hummocks and hollows. This abrupt transition is matched by a steep gradient in base-status across the sedge and lawn zones to the oligotrophic conditions in the bog (pH 3·40, Ca^{++} 0·0925 m.equiv./l. in *Sphagnum* areas). The wettest parts of the bog are still dominated by *S. recurvum* (with *S. cuspidatum* in a few shallow pools), but low hummocks of *S. rubellum* become increasingly abundant away from the lake with *Vaccinium oxycoccos* and *Drosera rotundifolia* as frequent associates (Fig. 6). In less wet parts Calluna is dominant with some *Aulacomnium palustre* and occasional cushions of the rare *Dicranum bergeri*. Throughout this zone there is vigorous pine regeneration (*Pinus sylvestris*), the young trees being healthier and more numerous among the heather than on the *Sphagnum*.

Farther away from the pool the rather treacherous open bog gives place to firmer peat, and the scrub of young pines to mature and close-grown trees up to about fifty years old. There is much bare needle-litter under these pines, but *Empetrum nigrum* is locally abundant and *Eriophorum vaginatum* frequent. The pinewood is fairly localized, however, more than half the site being covered by birch (*Betula pubescens*) woodland and scrub with *Molinia*, *Calluna*, and *Erica tetralix* on dry acid peat.

About 150 m. south-west of the pool there is a roughly circular area of *Sphagnum recurvum* lawn 10-15 m. in diameter with abundant *V. oxycoccos* and *Drosera rotundifolia* and a few plants of *Carex limosa*. 200 m. north-west of this lawn is a larger open area, close to the drift rib, whose dry heather dominated surface is pitted with small and irregular peat-cuttings; each of these now holds a miniature *S. recurvum* lawn on which *Rhynchospora alba* is conspicuously abundant with frequent *Eriophorum angustifolium* and *Drosera anglica*. The three main areas of pinewood are around the western *Sphagnum* lawn, at the southern end of the peat cuttings, and (the largest) to the west and north-west of the pool.

The pattern described above is evidence of the compound structure of the site; furthermore, its ecological history, subject to the vicissitudes of an unstable hydrological system, has not been a simple sequence. The single series of borings so far made by Rose and Bellamy shows that the pool and the western lawn lie over separate deep basins with a pronounced hump in the drift between them. The basins are lined with lake mud which extends thinly over the drift hump as well, indicating a single lake at this early stage. Later the hump seems to have carried a dry wooded bog (German *Waldhochmoor*) rather like the present one, but a rising water table (perhaps climatically induced) eventually covered this and most of the site with wet *Sphagnum* bog. No fen or bog peat, however, overlies the lake mud at the bottom of the pool, which is therefore an original and persistent feature whose area has been

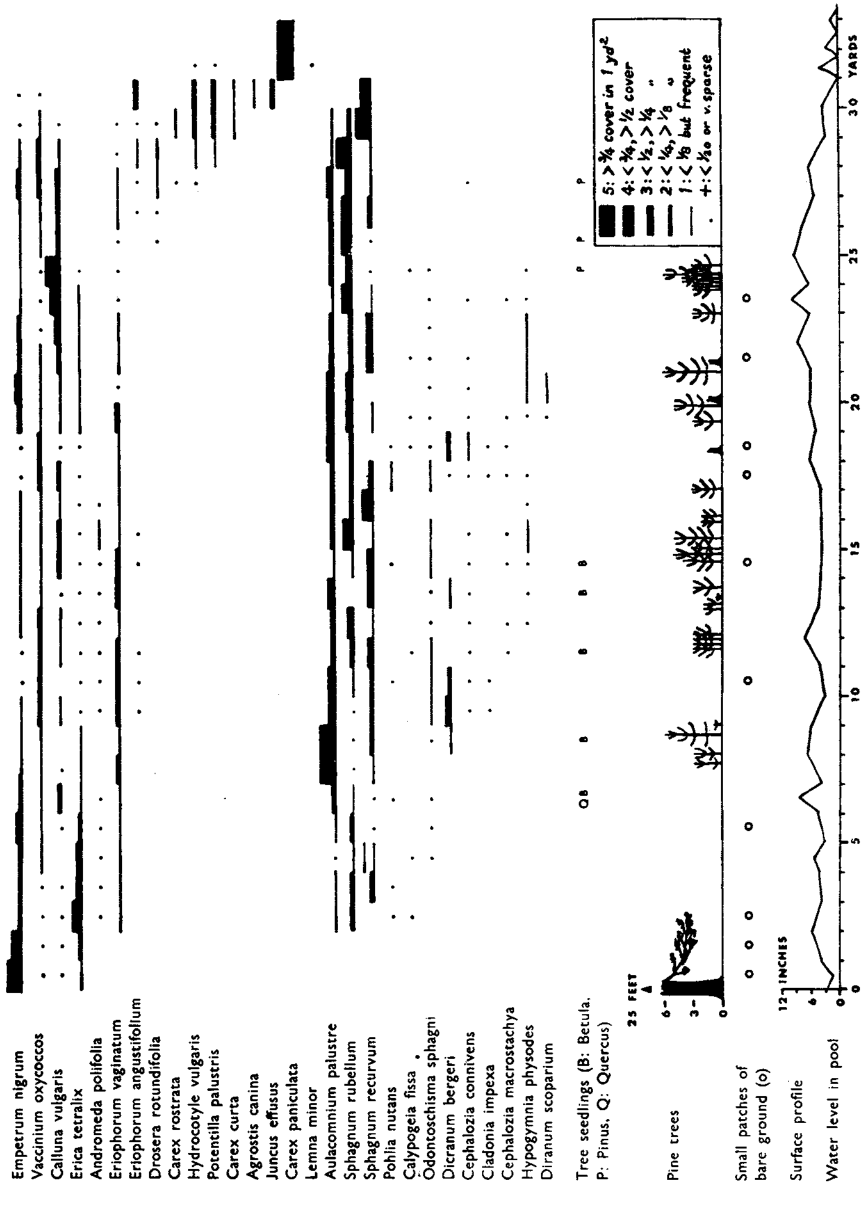

FIG. 6.
Belt transect (one yard wide) of vegetation west of pool on Clarepool Moss (May 1961).

reduced by the slow encroachment of quaking bog from the west. The western lawn is also a quaking bog, though its thin and untrustworthy *Sphagnum* coverlet suggests more recent initiation, and there is no evidence of very deep water beneath it. This tentative interpretation may need modifying, however, in the light of a fuller stratigraphical study.

During the past century or so striking vegetational changes have occurred. In borings on both sides of the pool, from a depth of less than 0·5 m downwards, the peat consists of fresh (unhumified) *Sphagnum* remains with *Eriophorum angustifolium* and *Scheuchzeria* rhizomes below 1 m. The *Sphagnum* is mainly *S. cuspidatum*, but *S. imbricatum*, *S. magellanicum* and probably *S. papillosum* also occur. The topmost 0·25 m., however, shows a rapid transition to strongly humified peat in which ericaceous remains become increasingly abundant. In many places this "retardation layer" (so called because within it the accumulation of peat is progressively slower) directly underlies the present standstill vegetation with dominant *Calluna* or *Empetrum*. But elsewhere it is capped by a thin blanket of fresh *Sphagnum recurvum* or *S. rubellum*, whose active transgression over the formerly drier surface is marked in the profile by a sharp recurrence surface between the older humified and the newer unhumified peat.

These changes are of hydrological origin, and should probably be imputed to human interference. Before they occurred an intact and vigorously growing bog surface covered much of the site and ringed the pool itself, whose water, thus insulated on all sides from base-rich topogenous sources, must have been markedly oligotrophic. Active peat formation ended with a general lowering of the water table, no doubt brought about by the cutting of drains around and on the moss; a downward shrinkage of the upper layers is suggested by the existence of a thin cover of peat draped over the drift rib up to 2 m. above the present bog surface. There followed a phase of expansion of pine and birch woodland which continues to the present day. But there is ample evidence near the pool (and perhaps round the western lawn) that the *Sphagnum* carpet has recently begun to spread again at the expense of the heathy standstill communities, possibly through neglect of the marginal drains. Although the cutting of the eastern ditch opened the pool to topogenous influence again and permitted the growth of fen vegetation round its margins, any small rise in the pool level would be reflected not so much by an efflux of base-rich water into the surrounding bog as by a general backing up of the ombrogenous water table in the bog itself. The Carex tussocks and the adjacent strip of *S. recurvum* lawn might also serve as a buffer zone between pool and bog, by taking up electrolytes from any topogenous water that passes them. Whatever its cause, the net effect has been a recent slight increase in the height of the water table and the wetness of the bog surface unaccompanied by any rise in base status. It is interesting in this context to note that the *Sphagnum* lawns in the old peat cuttings are afloat on fairly deep water, which would be expected if they developed in quaking-bog fashion after the flooding out of the pits.

The brief dry phase was something of a catastrophe from the floristic viewpoint: certain species were eliminated altogether, while others are reduced to very local occurrences. Among the former, *Scheuchzeria palustris*, whose remains are abundant in the peat, was known to grow sparsely at Clarepool Moss as recently as 1866 but had disappeared 20 years later (Sledge, 1949). The

"Cymbifolian" Sphagna of active bog surfaces (*S. imbricatum*, *S. magellanicum*, and *S. papillosum*) have also mostly gone. Curiously disjunct distributions between the three areas of active Sphagnum growth are shown by the species tabulated below:

	Bog. W. of pool	Western lawn	Old cuttings
Drosera anglica	v.r.	—	f.-l.a.
Carex limosa	v.r	v.r	—
Rhynchospora alba	—	o.	a
Sphagnum cuspidatum	l.f.	r.	—

If the present trend continues these plants may well become commoner on the site, and others such as *Narthecium ossifragum* (a surprising absentee throughout the record) may arrive.

Species of the dry phase are behaving rather differently. *Empetrum nigrum* (generally rare on the Shropshire Mosses) is abundant under the pinewood but dying in the newly *Sphagnum*-invaded areas. *Dicranum bergeri*, the most notable surviving rarity of the site, is disfavoured by both extremes and is clearly on the wane, though still frequent in the zone of open but fairly dry bog.

Clarepool Moss has been the only site of its kind in Shropshire since Whattall Moss was drained a century ago, but it bears close comparison with two other bogs in the region. Chartley Moss in Staffordshire (43/020280) is a larger quaking bog complex with several pools and extensive pinewoods, but its flora is less rich than that at Clarepool Moss; its stratigraphy and surface ecology are being investigated by Dr. K. M. Goodway and his colleagues at Keele University. Wybunbury Moss in Cheshire (33/700500) is a very small kettle-hole quaking bog with a rich flora similar to that at Clarepool; it has been described by Poore and Walker (1959).

(3) *The Whixall Moss Complex*
(Plates IV and V, Fig. 2d)

This was the main area investigated by Hardy (1939). It is the largest tract of peat land (*c.* 6 km. long SW to NE by 3 km. wide) not yet to have suffered complete reclamation. Roughly oval in plan with lobed margins, it occupies a comparatively shallow Late-glacial lake basin in drift country whose relief is gentle and subdued. The structure is of conventional raised bog (*Hochmoor*) type, probably with several separate domes. But parts of the bog seem to be of transgressive origin, since their stratigraphy shows a direct passage from terrestrial soil at the base, upwards through brushwood (acid carr or bog wood), to *Sphagnum* peat, no lake sediments being represented.

The Welsh Border passes through the tract, and more than three-quarters of its area lies in Flintshire. The land is parcelled up between four parishes: Fenn's Moss in Bronington, Bettisfield and Cadney Mosses in Bettisfield are on the Welsh side; while Whixall and "Worldsend" Mosses in Whixall and Wem Moss in Wem (Rural) are on the English. This subdivision and nomenclature, together with recent modes of tenure and traces of earlier cuttings, make it likely that the adjacent villages once held turbary rights in common on their respective parcels, but documentary evidence for this view has yet to be found. Piecemeal reclamation and enclosure by neighbouring smallholders have brought a wide strip of peat land round the margins under pasture and other cultivation, and have cut off the southernmost lobe (Wem Moss) from the rest.

Cadney Moss is drained and largely reclaimed, with a small residue of waste-land under *Betula*, *Pteridium*, and *Juncus effusus*. Fenn's Moss is leased to a single peat-cutting company, whose thorough and efficient exploitation for some decades past has left only its northern part uncut, and this has suffered repeated burning. Whixall Moss is also heavily cut over (save for a small triangle of a few acres at the southern end), but here the cuttings were held by local cottagers on an allotment system until they were recently taken over by another local company. Bettisfield and "Worldsend" Mosses are separated from the main area by the the Shropshire Union (Llangollen) Canal, which passes across the peat basin on a rubble embankment; they bear traces of regular cutting in the past, but their surviving parts are now of some interest in showing vigorous and apparently spontaneous regeneration of pine on the rather dry bog surface. Wem Moss alone has escaped systematic cutting and draining; but sporadic digging of peat took place at times in the past, and the small irregular trenches, now filled with fresh *Sphagnum*, show up like swarms of pale bacilli on the aerial photographs.

WHIXALL MOSS, in spite of a long history of extensive exploitation, still bears a flora of considerable diversity and interest. This fact is partly due to the varied topography and drainage conditions brought about by the cutting of the peat, and partly to the wide range of dates of abandonment. Most of the disused "cases" (rectangular areas of cutting) have floors which coincide approximately with the internal water table of the bog. Their condition is wet but oligotrophic, and in the older ones many of the species characteristic of an undisturbed raised bog survive and flourish. The deeper water-filled cuts are dominated by *Sphagnum cuspidatum* and *Eriophorum angustifolium*, with *Utricularia minor*, *Drepanocladus fluitans*, and *Cladopodiella fluitans* as local associates. Surfaces not deeply submerged except after heavy rain bear a patchwork community in which *Sphagnum papillosum* and *S. recurvum* are conspicuous together with *Eriophorum vaginatum*, *Narthecium ossifragum*, *Erica tetralix*, and (on bare patches) *Drosera rotundifolia*. *Calluna* is dominant on the drier parts.

The narrow droves and baulks between the cases stand several feet higher, but their dry and dusty peat surfaces have suffered heavy erosion by the animals and vehicles used for transport. Attempts to consolidate the trackways have included the deliberate seeding of *Molinia* which is now extensively dominant in the neighbourhood of the droves, but the impenetrable tussocks and wiry roots of this grass (called "iron-grass" locally) have become a serious impediment to cutting; bracken is an increasing nuisance in some areas as well. The dumping of rubbish off the sides of the droves has produced slightly more base-rich conditions at certain points, this change being marked by the local occurrence of such species as *Sphagnum squarrosum*, *S. palustre*, and *Salix repens*.

Periodic fires, both accidental and deliberate (usually in an effort to control adders), appear to have initiated and later restricted the spread of birch scrub, which has, however, extended over a large part of the Welsh side in the past thirty years. The Moss was used for a short time during the last war as an incendiary bombing range, and this disturbance was followed by a remarkable increase in the abundance of *Andromeda polifolia*. Scots pine is surprisingly scarce at the present day, though its stumps are almost as common as those of birch in the peat cuttings.

The small uncut area at the southern end is of particular interest, in spite of occasional burning and marginal drainage. Here the vegetation is better integrated, preserving some trace of the hummock-and-hollow pattern which the rest of the bog has lost. Certain species are commoner here than elsewhere, notably *Vaccinium oxycoccos*, *Empetrum*, *Polytrichum alpestre*, and *Sphagnum tenellum* which often colonizes recently burned patches; *Dicranum bergeri* (a new Shropshire record when it was found in 1959) is restricted to this part.

The uncut area is bounded to the south by the line of the Shropshire Union Canal. The canal is carried across the peat on a substantial embankment made of boulder clay: water percolating from the embankment onto the moss has produced an artificial alder-dominated "lagg" (marginal fen or carr), beyond which a strip of the bog some 15 m. wide, apparently cut to a slightly lower level than the natural surface, still shows signs of the influence of this edge-effect. There are prominent hummocks of *Sphagnum plumulosum*, *S. magellanicum*, and *S. rubellum*, with abundant *Erica tetralix*, *Narthecium*, and *Rhynchospora alba*; *Riccardia latifrons* has been recorded here, as well as *Scorpidium scorpioides* and other base-demanding species.

Whixall and Wem Mosses have long been known to entomologists as the southernmost English locality of the Large Heath butterfly (*Coenonympha tullia*) whose principal food-plant is said to be the White Beak-sedge (*Rhynchospora alba*). The local population belongs to the uncommon south-eastern race (ssp. *philoxenus*), darker and more heavily marked than the type, but merging into it both northwards and westwards (Ford, 1945). Conspicuous among the terrestrial invertebrate fauna is the large and handsome spider *Dolomedes fimbriatus*, which in spite of its size is often seen skating over the surface film in watery hollows. Freshwater insect species collected from peat pools (cuttings) and drainage ditches on the Moss by Miss H. M. Twigg in 1957-59 and subsequently by Miss F. N. Arnold are listed below:

Leptophlebia marginata	Hydroporus pubescens
Enallagma cyathigerum	Hydroporus planus
Aeshna sp.	Agabus bipustulatus
Libellula quadrimaculata	Ilybius fuliginosus
Sympetrum sp.	Ilybius aenescens
Gerris gibbifer	Dytiscus sp. (larva)
Nepa cinerea	Acilius sulcatus
Notonecta sp. (nymph)	Gyrinus natator f. substriatus
Corixa castanea	Helophorus (s. str.) aquaticus
Corixa sahlbergi	Helophorus (A.) brevipalpis
Sialis lutaria	Hydrobius fuscipes
Hygrotus inaequalis	Anacaena globulus
Coelambus impressopunctatus	Enochrus affinis
Hydroporus tristis	Tipula sp.
Hydroporus palustris	Phalacrocera replicata
Hydroporus erythrocephalus	Dixa sp.

Wem Moss is the southernmost lobe of the Whixall peat basin, from which it is now separated along its north-western edge by a straight ditch marking the county (and national) boundary. There has been very little marginal reclamation. The site is about 500 m. wide along the boundary ditch and about 600 m.

long in a direction perpendicular to it. The drier parts around the southern side and in a narrow strip bordering the ditch have been invaded by a secondary "heath waste" vegetation, with bracken, gorse and birch scrub, similar to that which covers an unreclaimed part of the neighbouring Cadney Moss. The entire eastern edge is fringed by a natural and presumably primary lagg. More than three-quarters of the central part of Wem Moss is still in a state which renders it the best-preserved area of raised bog in the Midlands.

A small portion of the eastern lagg is polluted by an effluent of domestic sewage from Hornspike Farm. The boundary ditch and its short tributary along the northern edge of the moss are well maintained and accentuate the drainage locally. But these minor factors apart, human interference has not, on the whole, been detrimental to the vegetation: the sporadic peat-cutting of earlier times has provided a large number of damp hollows where the more water-demanding bog species survive; frequent winter burning has at least eliminated a former pine wood (suggested by the presence of several burnt stumps) like that covering Bettisfield and Worldsend Mosses, and holds in check the spread of birch scrub. As far as can be gathered Wem Moss is still a common with rights of turbary (peat-cutting) for the people of Wem Parish, but (owing perhaps to the distance from that town) the rights have not lately been exercised. Cattle, which used to be turned onto the moss in winter for the "early bite" (cotton-grass, etc.), are now confined to certain marginal points because of treacherous pits and adders.

A tongue of willow carr projects westwards from the lagg towards the centre and leads into a "soakway" of fen-like character which cuts the bog into separate northern and southern halves. This soakway, like the lagg itself, is under the influence of base-rich surface water, but its base-status declines progressively from east to west, and its latter end fans out into an indeterminate area hardly distinct from the rest of the bog's surface.

Hardy's two borings on Wem Moss proved the basin to be surprisingly shallow, but showed a normal sequence from fen to raised bog peat; a profile fairly close to the eastern side is summarized below (Hardy, 1939):

Depth m (cm.)	
0–165	Moderately humified Sphagnum peat, roots of *Eriophorum vaginatum*.
165–227	Sedge peat, *Phragmites* and seeds of *Menyanthes*
227–	White sand.

Even when allowance is made for a considerable downward shrinkage of the bog following marginal drainage and burning, there is remarkably little evidence of the "rand" or steep slope which usually leads up from the lagg on to the crown of a true raised bog (*eigentliches Hochmoor*): both the northern and the southern parts of the moss display a very subdued convexity. Furthermore in place of the normal sharp ecological break, there is a broad and ill-defined transition zone (*Zwischenmoor*) between the lagg and the bog proper. In view of these features it may be better to regard Wem Moss as an example approaching the "plane bog" (*Planhochmoor*) in its morphology.

The eastern lagg is disappointing floristically, perhaps because of the edge-effect from the surrounding agricultural land and the farm effluent. Most of it takes the form of a dense willow carr, with *Salix cinerea* dominant (except where

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PLATE IV. Wem Moss (looking S.E.) June, 1960.

PLATE V. Whixall and Fenns Moss (looking N.W.)

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replaced locally by alder) and *Frangula alnus* as a frequent associate; the flora beneath this scrub is sparse and poor in species, *Holcus lanatus* being the main subdominant and *Caltha palustris*, *Cardamine pratensis*, *Galium palustre*, *Juncus effusus*, *Ranunculus flammula*, *R. repens*, *Stellaria alsine*, and *Urtica dioica* common; *Acrocladium cordifolium* is a characteristic moss in wet hollows, but although *Mnium hornum* and *M. punctatum* are abundant on tree-bases there is little development of an epiphytic bryophyte and lichen flora. A patch of open fen north of the projecting tongue of carr has a rather richer flora with dominant *Molinia caerulea* and the following additional associates:

Achillea ptarmica ..	o.	Hydrocotyle vulgaris ..	l.f.
Carex panicea	f.	Juncus acutiflorus ..	l.a.
Dactylorchis incarnata ..	r.	Juncus articulatus ..	l.f.
Drepanocladus aduncus ..	r.	Platanthera bifolia ..	r
Epilobium obscurum ..	o.	Sphagnum subsecundum	f.
Epilobium palustre ..	o.	Viola palustris	l.f.
Equisetum palustre ..	o.		

The central soakway is marked by a narrow strip of similar vegetation extending half-way across the moss, and is notable for the dominance of *Myrica gale* around its eastern end and the local occurrence of *Cirsium dissectum*, *Carex lasiocarpa*, and *Osmunda regalis*, all of which are rare or absent elsewhere in the county. The transition zone, leading almost imperceptibly from base-rich lagg or soakway to acid bog, is still dominated by *Molinia*, but it may conveniently be defined by the association of this dominant with such bog species as *Narthecium* and *Erica tetralix*; the *Molinia* tussocks produce a hummocky relief interspersed with hollows and small pools. The fen/bog mixture of species is augmented by a number of plants confined to the transition zone or at least commoner in it than at either extreme, among them the following:

Aulacomium palustre ..	l.a.	Potentilla palustris ..	l.a.
Carex demissa	l.f.	Sphagnum fimbriatum	f.
Polytrichum commune ..	l.a.	Sphagnum palustre ..	l.a.
Potamogeton polygonifolius	l.f.	Sphagnum plumulosum	l.a.
		Sphagnum recurvum ..	l.f.

The remainder of the bog surface, constituting the two plateau-like bog plains north and south of the soakway, is purely ombrogenous in its water supply and oligotrophic in character. There are local remnants of the natural hummock-and-hollow pattern marked by the survival of such fire-sensitive species as *Sphagnum magellanicum*, *Leucobryum glaucum*, and *Empetrum nigrum*; but most of the surface is more or less uniformly levelled by frequent burning, and broken only by the irregular and abrupt depressions of old peat-cuttings. It is these hollows which contribute to the variety and interest of the flora, for they have provided a haven for the most water-demanding species in a generally desiccated and fire-swept terrain. Particularly noteworthy is the occurrence of all three British species of sundew here: *Drosera rotundifolia*, the commonest, ranges indiscriminately from wet hollows to bare peat, and vigorously recolonizes burned areas; *D. intermedia* occurs locally on wet bare peat but is more abundant in the *Sphagnum*-filled hollows; *D. anglica* is restricted wholly to the latter. It is curious that each hollow tends to be occupied exclusively by one or other species, and no hybrids have yet been recorded. Other species confined to hollows and wet patches, or commoner there, are listed below:

Calypogeia sphagnicola ..	r.	Mylia anomala ..	f.
Cephalozia connivens ..	o.	Narthecium ossifragum	l.a.
Cephalozia macrostachya	o.	Odontoschisma sphagni	f.
Cephalozia media.. ..	r.	Rhynochospora alba ..	a.
Cladopodiella fluitans ..	l.f.	Sphagnum cuspidatum	l.d.
Drepanocladus fluitans ..	o.	Sphagnum papillosum ..	l.d.
Eleocharis multicaulis ..	l.f.	Sphagnum pulchrum ..	l.a.
Eriophorum angustifolium	a.	Vaccinium oxycoccos ..	o.

The drier areas are occupied by plants which regenerate freely after fire:

Andromeda polifolia ..	l.f.	Erica tetralix	l.d.
Calluna vulgaris	l.d.	Eriophorum vaginatum	l.d.
Campylopus flexuosus ..	l.f.	Lepidozia setacea ..	l.d.
Cladonia furcata	o.	Molinia caerulea ..	f.
Cladonia impexa	o.	Pohlia nutans	l.f.
Cladonia macilenta ..	o.	Polytrichum alpestre ..	r.
Cladonia sylvatica ..	r.	Sphagnum rubellum ..	o.
Dicranum scoparium ..	o.	Sphagnum tenellum ..	l.f.

(4) *Brown Moss*

(Fig. 2e)

This site is remote both in distance and in ecological character from those already described, but it is rich and varied enough botanically to merit a brief account here. It lies less than 2 miles south-east of Whitchurch as a roughly elliptical area of unenclosed common land about 1 km. long from N. to S. and up to 600 m. wide, covering some 60 acres apart from the pools. Common rights of long standing permit the grazing and watering of local cattle, but recently enacted bye-laws administered by a joint committee for the County Council are designed to protect the natural beauty and the wild-life of the area.

A tract of hummocky stratified drift (sand and gravel) gives rise to acid podzolic soils on all the drier parts, which consequently support heath or birchwood at the present day. But the relatively shallow and gentle-sided depressions in the drift suffer from impeded drainage and several of them contain pools or mires. The more substantial pools are seven in number, varying in size from about 80 m. to about 370 m. long, and at least four of them are linked by artificial channels. There is a striking contrast between the acid state of the heathland (pH *c.* 4) and the high base status of the pools (pH 6-7·5), the latter being fed by ground water percolating through the drift and probably drained by the same means. Their water levels fluctuate markedly with the weather, but there appears to have been a mean rise (in some of them at least) during recent years.

The heathland is of no great floristic interest, being a closely-grazed patchwork of grass-heath species with *Agrostis tenuis*, *Calluna vulgaris*, *Erica cinerea*, *Festuca ovina*, *Juncus squarrosus*, and *Nardus stricta* co-dominant or abundant; both *Ulex europaeus* and *Ulex gallii* are also common. Among the associated flowering plants are the following:

Aira praecox	l.f.	Luzula campestris ..	f.
Campanula rotundifolia ..	f.	Pedicularis sylvatica ..	o.
Carex pilulifera	o.	Polygala serpyllifolia ..	l.f.
Galium saxatile	f.	Rumex acetosella ..	l.a.
Hieracium pilosella ..	r.	Sieglingia decumbens ..	l.f.

The wooded areas carry both species of birch (*Betula pubescens* and *B. pendula*) with frequent mountain ash and occasional oak and holly, while bracken is dominant beneath. The heathy slopes lead down through marsh into the hollows, and the change in water supply and base status is marked by the sudden appearance of rushes (*Juncus effusus* and *J. acutiflorus*) and sedges (*Carex demissa, C. hirta, C. nigra*) together with such grasses as *Agrostis canina, Anthoxanthum odoratum*, and *Holcus lanatus*, and other mesotrophic marsh species:

Achillea ptarmica ..	o.	Lotus uliginosus ..	l.f.
Anagallis tenella	r.	Luzula multiflora ..	f.
Cirsium palustre	f.	Scirpus setaceus ..	r.
Hydrocotyle vulgaris ..	l.f.	Stellaria alsine ..	f.
Leontodon autumnalis ..	f.	Viola palustris	o.

Towards the pool margins the base status rises still further, and species of more strictly eutrophic requirements come in:

Agrostis stolonifera ..	a.	Mentha aquatica ..	o.
Alopecurus aequalis ..	l.f.	Mentha arvensis ..	l.f.
Cardamine pratensis ..	f.	Myosotis caespitosa ..	f.
Galium palustre	f.	Oenanthe fistulosa ..	l.f.
Glyceria fluitans	l.f.	Rumex conglomeratus ..	o.
Juncus articulatus.. ..	o.	Scutellaria galericulata	l.f.
Lychnis flos-cuculi ..	l.f.	Veronica scutellata ..	o.

Similarly the bryophytes associated with the more acid marsh (*Polytrichum commune, Sphagnum palustre, S. squarrosum*, etc) are replaced by such species as *Acrocladium cuspidatum* and *Climacium dendroides. Alnus, Frangula*, and *Salix cinerea* grow at the edges of some pools, and one is completely overgrown with willow carr.

A zone of the greatest interest is that which fringes the more variable pools between high and low water levels (flood and drought respectively), often exposing wide stretches of bare mud on the gently shelving shoreline. The fluctuating water level and the trampling of cattle call for special tolerances on the part of the plants which grow here. Some (e.g. *Bidens cernua, Gnaphalium uliginosum, Juncus bufonius, Ranunculus sceleratus, Rorippa islandica*) are quick-growing and often transitory occupants of the exposed mud, usually killed by prolonged immersal but quickly re-established from seed. Others tolerate changes in water level with little variation in their morphology or performance (*Agrostis stolonifera, Glyceria fluitans, Lycopus europaeus, Mentha aquatica, Scirpus fluitans, Solanum dulcamara*). Others again put up with either extreme, but look very different in their terrestrial and aquatic states (*Apium inundatum, Baldellia ranunculoides, Callitriche stagnalis, Hottonia palustris, Luronium natans, Polygonum amphibium*).

All the pools are being invaded at varying rates by emergent reedswamp species, though the width and composition of this zone varies from pool to pool:

Alisma plantago-aquatica	f.	Eleocharis palustris ..	l.d.
Carex pseudocyperus ..	o.	Equisetum fluviatile ..	l.d.
Carex rostrata	l.d.	Sparganium erectum ..	f.
Carex vesicaria	l.f.	Typha latifolia	l.d.

In part of one pool the reedswamp is replaced by a floating raft of *Menyanthes* *trifoliata*, and several have such aquatic species as *Potamogeton natans* and *Ranunculus aquatilis* in the deeper open water, while *Lemna minor* and *L. trisulca* are frequent among the reedswamp.

The most westerly pool is more acid than the others (pH *c.* 5), and its eastern shore has a narrow strip of *Sphagnum* bog with *Erica tetralix* leading directly into a fen zone dominated by *Juncus effusus* and *Potentilla palustris* with abundant *Hypericum elodes* and *Riccia fluitans*; an *Equisetum* reedswamp stands offshore. A short distance south of this pool lies a small depression, containing a perfect miniature example of a quaking bog no more than 30 m. by 20 m. in extent: a watery moat with *Menyanthes*, *Juncus effusus*, and *Sphagnum cuspidatum* surrounds a floating raft of *S. recurvum* which undulates alarmingly as one walks across it; the following associates are found on the raft:

Aulacomnium palustre ..	a.	Erica tetralix	o.
Betula pubescens (seedlings)	o.	Eriophorum angustifolium	f.
Drosera rotundifolia ..	a.	Polytrichum commune ..	l.a.

Brown Moss poses a number of fascinating problems, especially in regard to its hydrological and ecological history. Why is the name "Moss" rather than "Heath" attached to this almost peatless area, unless the exercise of local turbary rights has stripped a former bog? Why have these shallow and gentle-shored pools not been wholly overgrown long since, unless their basins were once drier and have filled as a result of progressive silting up or a recent rise in the local water table? These questions must remain unanswered until a far more intensive study is undertaken.

III. DISCUSSION

(1) *Hydrology*

In the main group of sites (as at Brown Moss) crucial problems concerning the history of drainage and vegetation changes remain unsolved. It is far from certain what holds up the water in the mere-filled basins: their floors may rest directly on an impermeable foundation of boulder clay; they may be sealed by the progressive accumulation of clay washed out of the surrounding slopes; or they may simply represent the intersection of the water table in a fully

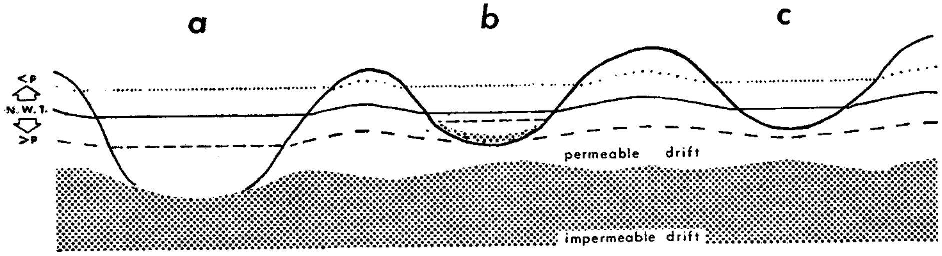


FIG. 7.

The hydrology of closed basin sites (see text). A schematic section showing three possible situations and the effect of changes in precipitation.

N.W.T.—"normal" water table; <P—increase in precipitation; >P—decrease in precipitation.

permeable bed with the land surface (Fig. 7). These possibilities are not mutually exclusive and the situation may vary from mere to mere. Whichever case applies, there is a further point to be considered: a normal lake with a surface outlet can suffer a fall in water level during dry periods, but it is unlikely to rise more than a little way above the level of its outlet lip following an increase in rainfall; a lake in a closed basin with permeable walls, by contrast, is at the mercy of the local water table, and climatic variations may induce drastic changes of level upwards as well as downwards.

It may justly be asked why, when so many of the Late-glacial lake basins of North Shropshire have become filled with peat, any meres should survive at all as bodies of open water. A combination of such factors as size, maximum depth, and steepness of shoreline, together with the very slow rate of silting in a basin not supplied by surface streams, may suggest a plausible impediment to reedswamp invasion. Not all the meres, however, fulfil the necessary conditions, and some have peaty borders which indicate successful invasion arrested at a later stage. Past fluctuations in water level, therefore, may well prove to have played a part in retarding colonization. A fall in level is probably less lethal to most of the stranded plants than the asphyxiating effect of a rise. Whereas the former reduces the water area and depth and may (after an initial pause) actually accelerate invasion, the latter destroys the older zones of vegetation by flooding them, erodes the peat platform they have built, and delays recolonization by making necessary the fresh establishment of plants from other sites.

Poore and Walker (1959) found evidence at Wybunbury Moss in Cheshire for an early rise of about 12 m. in the water level, and there are certain features in the (terrestrial) soil profiles of the Ellesmere area which might be explicable in similar terms. It is tempting to link supposed water table variations with Post-glacial climatic history, and to suggest that in the early part of the Boreal phase, for instance, the meres would have been much shallower and smaller than they are today, while by the middle of the Atlantic phase their surfaces stood somewhat higher than at present. Several of the meres and mosses are known with some certainty to have suffered artificial changes of water level within the past century, and these are indicated on the list in the Appendix.

(2) *The Hydrosere in closed basin sites*

A source of some confusion in the British literature is the lack of universal agreement on a terminology for wet habitats, and especially on a general name to cover all such habitats, whether base-rich or acid, on both mineral and organic substrates; the most widely accepted is probably the word *mire*, which has the virtue of being cognate with the equivalent Swedish *myr* and German *Moor*. Other terms used in the present account are defined in context.

The normal sequence of the hydrosere in a closed basin site is too well-known to call for more than a brief recapitulation. A relatively shallow lake with gently-shelving shores is assumed, and the initial establishment of such aquatic plants as pondweeds and waterlilies on the silted bed is followed by the advance of bottom-rooted but emergent reedswamp from the margins inwards; whereas the accumulation of partly decomposed aquatic plant remains can give rise to little more than an incoherent organic mud (*gyttja*), the more

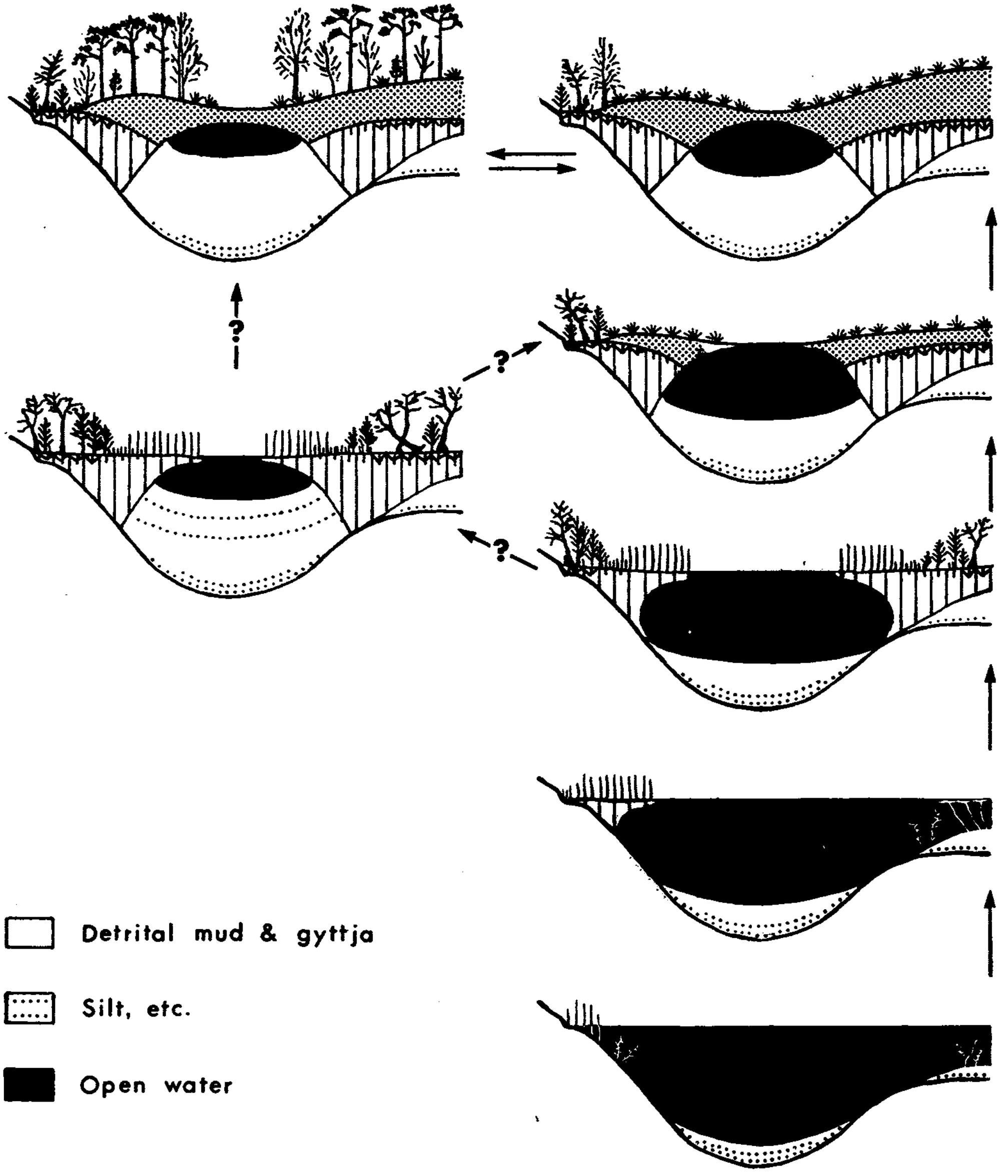
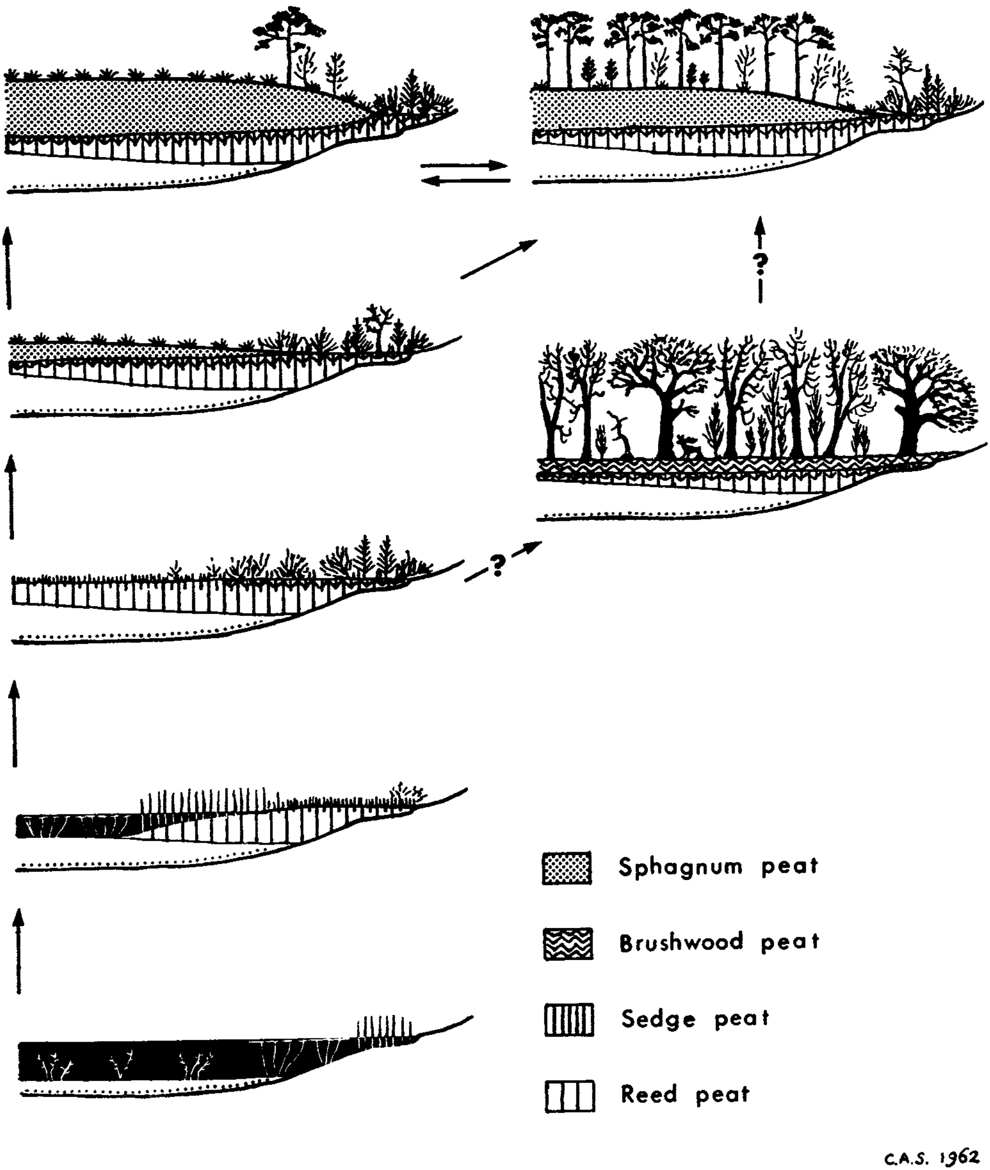


FIG. 8.
The hydrosere in closed basin sites (see text). Serial diagrams showing by means of hypothetical sections the "normal" succession, the succession in deep basins, and some possible variations on these.


Sphagnum peat
Brushwood peat
Sedge peat
Reed peat
C.A.S. 1962

bulky and fibrous seasonal debris from the reedswamp persists and builds up a platform of reed peat. When the reed peat surface reaches the mean water level, the swamp zone is succeeded by a sedge-dominated fen community which the later establishment of sallow and alder seedlings may transform into a shrubby *carr*, and these are marked by the accumulation of sedge peat and brushwood peat in turn. It is important to realize that up to this stage the pattern of invasion is centripetal so that in time it comes to occupy the whole basin, and that all the growing plants are fed by a base-rich or *topogenous* ground water supply.

Under an oceanic climate the building up of the peat does not stop, however, when it reaches the normal water table. There comes a stage when its surface ceases, more or less abruptly, to be accessible to topogenous water; but the effective rainfall (that is, the total precipitation less the water lost by evaporation and transpiration) is high enough to keep the surface wet directly and so to promote its continued upward growth above ground water level. Ombrogenous conditions therefore set in, and the consequent deprivation of the base-supply brings about a total ecological change; fen and carr species disappear, to be replaced by *Sphagnum*-dominated bog communities. The change tends to set in first near the centre of the basin, where the risk is least of occasional flooding by base-rich water off the surrounding slopes; from here the bog spreads centrifugally, and, through the more rapid accumulation of *Sphagnum* peat in the central area than at the edges, it gradually takes on that lens-like convexity which gives the mature raised bog its name. Outside the *rand* or steep edge of this dome the bog is permanently ringed around by a zone liable to base-rich flooding, and this zone, the *lagg*, carries a persistent fen or carr vegetation.

When the sides of the basin have a very gentle gradient, the gradual elevation of the entire peat surface can cause the lagg, followed by the bog itself, to climb slowly up the neighbouring slopes and so to expand laterally over dry land; in such a case the early aquatic and reedswamp stages are bypassed, and the stratigraphical passage from terrestrial soil through sedge and brushwood peat to *Sphagnum* peat identifies an area of transgressive bog; this variant is thus closely related in its origin to the blanket bog of mountain and moorland areas (Pearsall, 1950).

Under a more continental climate the effective rainfall value is lower and the raised bog surface drier, so that heathy communities and eventually birch and pinewood become dominant on the acid peat; the retardation layers mentioned above (p. 106) in the stratigraphy of the raised bogs mark such phases of dry or wooded bog in the past. It is also possible that when sufficiently low values of effective rainfall prevail from an early stage, the change from topogenous to ombrogenous conditions could be postponed indefinitely by aerobic decomposition of organic debris at the surface and by the capillary rise of the ground water table; in these circumstances the carr would mature to an alder-dominated fen woodland, and might even lead in the end to mixed oak-ashwood.

In a deep and steep-sided lake basin the normal hydrosere cannot develop beyond a narrow shoreline fringe, because most of the water exceeds the limiting depth (approximately 2 m.) for bottom-rooted reedswamp. Plant colonization may therefore be arrested until slow silting up of the lake has reduced its depth sufficiently. But in sheltered sites and when other conditions favour really vigorous growth, the outer part of the reedswamp may become detached from the bottom and then its edge is free to advance over the water as a floating raft. As fresh litter accumulates on the top of the raft its base is depressed, until it meets the rising surface of the sloughed-off detritus which is piling up on the lake floor. These combined processes—the centripetal and downward growth of the peat, and the build-up of bottom mud—may ultimately seal off the central area from its ground water supply; the stagnant pool becomes acid as the residual nutrients are absorbed by living and dead plant material, and the mire surface suffers a change analogous to that involved in raised bog formation. Further (and eventually complete) overgrowth of the pool is through the agency of aquatic *Sphagnum* species and such associates as *Eriophorum angustifolium* forming a quaking bog. In sites, however, where natural or artificial surface channels ensure a permanent through-flow of topogenous water, eutrophic conditions may persist until floating reedswamp has closed over the pool or imported silt has filled it.

The various successions postulated above are all illustrated in the accompanying diagrams (Fig. 8). They are also represented by past or contemporary examples in North Shropshire. Comparable sites are found elsewhere in Britain, and there are particularly interesting parallels in the morainic lowlands of North Germany, Poland, and southern Fennoscandia. Many of the terms and concepts derive, indeed, from the classic work of Osvald (1925) whose German nomenclature (quoted in the present account) has become standard, and reference should also be made to the studies of Overbeck (1950) in Lower Saxony.

It will be appreciated that this genetic survey presents an idealized and much-simplified picture: the processes involved in a particular site may vary from one part to another and from stage to stage, while certain complicating factors have been deliberately ignored. Of profound importance are the fluctuations of water level referred to in the section on hydrology—there is, for instance, some reason to believe that the genesis of most quaking bogs may depend on a rising water table. The simple division into topogenous and ombrogenous water supplies must be reconsidered in the light of recent work in this country as well as in Sweden and Poland. No mention has been made of the *soligenous* type where surface water, enriched by its passage over or through the adjacent mineral soil, flows out across the accessible parts of the bog and raises their base status. Nor is base-supply merely a matter of the hydrostatic balance between ombrogenous and topogenous or soligenous waters in the mire: the uptake of nutrients by growing plants and the neutralization of bases by humic and other acids can diminish the concentration of electrolytes in the ground water to an oligotrophic level as it passes laterally through the peat. Moreover, the rate of movement of this ground water may be critical in relation to the supply of nutrient ions diluted to threshold values: in the last resort it is dose rather than concentration which governs the nourishment of plants on poor soils.

(3) *Recent ecological and floristic changes*

A cursory survey leads to the unsurprising conclusion that the North Shropshire mire sites, like most others in Great Britain, are in a secondary or degraded condition. This is, of course, due primarily to human interference, but an uncomputed residue of the recent changes may be attributable to climatic or other natural causes. Direct evidence of the kinds (and to some extent the rates) of changes can be drawn from two sources: (i) the stratigraphical sequence of plant remains, including pollen, preserved in the peat, and (ii) a comparison of species and locality records made by past generations of botanists with distributions found at the present day. The former is the only sure way of determining the full ecological history of a site; but dating methods are crude, the topmost part of a profile (if not damaged or removed by peat-cutting) may be too short to be informative about changes within the historical period, and in general only the commoner plants are likely to be seen in samples from each stage. The latter method, in spite of the scantiness of records and the imprecision of plant identification and localization until very recent times, can tell us much about the unprecedented changes during the past century.

An analysis has been made of records for the Meres and Mosses from Leighton's *Flora of Shropshire* (1841) by tabulating survivals and extinctions in a number of sites. These data are too lengthy to reproduce here, but a number of points may be quoted and tentative conclusions drawn. It is quite clear, for instance, that several raised bogs have deteriorated or disappeared altogether, including marginal ones on the shores of The Mere at Ellesmere and Bomere and Shomere Pools. *Molinia* was a comparative rarity in Leighton's time, while the now uncommon *Anagallis tenella* he records as " . . . covering the mossy sides of all our Shropshire pools, and in boggy ground generally". *Lobelia dortmanna* seems to have gone from the four meres in which he knew it, and *Hypericum elodes* is much reduced in range. But the most notable extinction is that of *Scheuchzeria palustris*, recorded in the mid-nineteenth century from Bomere, Shomere and Clarepool Mosses. *Luronium natans*, by contrast, which may have had its headquarters in the Shropshire Meres, is now more abundant in the Shropshire Union Canal—its highway to other parts of England.

Certain plants not mentioned by Leighton deserve consideration: *Nuphar pumila* in Blake Mere, otherwise unknown south of the Scottish Border, is a probable survivor from early Post-glacial times rather than a recent adventive —if so, it testifies to the constancy of this particular site in a changing landscape; *Dicranum bergeri*, so lately discovered on Clarepool and Whixall Mosses, is a relict of undisturbed raised bog conditions; *Sphagnum imbricatum*, once a dominant of this habitat and a notable peat-former, has apparently gone the way of *Scheuchzeria*.

Burning, cutting, draining, and modern agricultural methods, have dried out the Mosses and raised the base status of the Meres and fens; alterations in mere water levels have modified the shoreline vegetation. But there are certain changes, such as the recurrence surface at Clarepool Moss and the apparent rise in the Brown Moss water table, that human management (or rather neglect) may not fully account for. It is possible that these and other details could point to a climatic shift over the past half-century towards warmer and more oceanic conditions.

(4) *Conclusion*

One fact emerges clearly from this attempt to provide an ecological background to the Meres and Mosses, and that is the need for much more intensive work on all its aspects. The detailed glaciological studies already carried out in neighbouring regions must be extended into North Shropshire to provide a fuller understanding of the sequence, structure, and morphology of the drift features. Pedological work on the terrestrial as well as the peat soils will throw valuable light both on the ecological history and on the chemical properties of the ground water. Climatic and microclimatic data are required. A detailed programme of physical, chemical, and hydrobiological investigations may help to crack the problem of the breaking of the meres and contribute much-needed information on the freshwater biology of eutrophic lowland lakes in Britain. Ecological history and site development may be elucidated by more detailed stratigraphical work and pollen analysis on the various mires, and it would be of particular value to extend this field into the examination of cores from the mere sediments. The building up of the lists of plant and animal species will go on, supported by sociological and population studies, and by experiments on the physiology and performance of selected species. Nor must the archaeological and historical aspects be neglected.

The present account, therefore, is intended to be no more than an introduction—and, it is hoped, a stimulus—to future work in an area whose natural interest is second to none in the country.

Summary

The present work provides a background to the natural history of the water- or peat-filled hollows in the glacial drift of the North Shropshire Plain known as the Meres and Mosses.

After referring to previous published work on the area, an extended introduction deals (under Physical Aspects) with the climate, glacial geology, hydrology, and water chemistry; and (under Historical Aspects) with the contributions of peat stratigraphy, pollen analysis, and archaeological and historical records to the vegetational history of the area, together with the effects of agriculture and other exploitation by man.

An outline of the empirical grouping of natural wet habitat sites in the area as unfringed and fringed meres, mere fens, raised and quaking bogs, valley mires, and miscellaneous, leads into a detailed ecological description (primarily botanical) of the following selected sites:

(1) The *Crose Mere complex*, including Crose Mere, an eutrophic lowland lake with narrow marginal zones of reedswamp and fen; Sweat Mere, a small eutrophic pool almost overgrown by floating reedswamp with marginal alder carr; and Whattall Moss (not described in detail), a drained and afforested raised and quaking bog.

(2) *Clarepool Moss*, a small compound bog, part wooded and part quaking, with an acid pool.

(3) The *Whixall Moss complex*, an extensive tract of raised bog including (with other parts not described in detail) Whixall Moss, mostly altered by peat-cutting; and Wem Moss, a less damaged site with marginal lagg.

(4) *Brown Moss*, a small area of undulating heathland with several shallow eutrophic fringed pools and various mire types.

In the discussion, problems connected with the hydrology of the meres are

considered, various alternative courses for the hydrosere in closed basin sites postulated, and tentative deductions made from recent ecological and floristic changes. The conclusion calls attention to some of the many fields in which more intensive work on this area is needed.

An ecologically classified site list appears as an appendix.

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APPENDIX

A selective list of natural wet habitat sites in North Shropshire, ecologically classified, is given below. Sites where significant changes in water level during the past century are known or may reasonably be inferred are marked ↓ (fall) or ↑ (rise). An asterisk (*) indicates Sites of Special Scientific Interest scheduled by the Nature Conservancy in 1953; it is likely that some of the other areas will be added under the current revision. Full National Grid References are given to approximately the middle of each site or area. All the sites listed lie on the O.S. One-inch Map (Seventh Series) Sheet 118 Shrewsbury, though not all are marked on it by name.

Unfringed meres	
Alkmondpark Pool	SJ 480160
Berth Pool	430234
*Betton Pool	511079
Blake Mere (Ellesmere)	416334
*Bomere Pool ↑	500080
Hardwick Pool	371338
Kettle Mere	419341
Newton Mere	425342
The Mere ↑	407350
White Mere	415330
Fringed meres	
Berrington Pool	525072
*Birchgrove Pool	436232
Blake Mere (Whitchurch)	559426
Cole Mere ↓	434333
Cottage Pond	419182
Crose Mere ↓	430305
*Fenemere	446229
Isle Pool	461170
Llynclys Pool	286244
*Marton Pool (Baschurch)	448234
Marton Pool (Chirbury)	295027
*Oss Mere	567439
Oxon Pool	454139
*Sweat Mere ↓	438305
Top Pool	520072
Mere fens	
Hencott Pool ↓	492160
New Pool ↓	415182
*Shrawardine Pool ↓	398161

Raised bogs	
Boreatton Moss ↑	SJ 417226
Harmer Moss ↓	485220
Lyneal Moss ↓	447340
Pikesend Moss ↓	441319
Rednall Moss ↓	348272
Smithy Moor ↓	413312
Top Moss ↓	570269
Wem Moss	475343
*Whixall Moss ↓	490358
Quaking bogs	
*Clarepool Moss ↓ ↑	434343
Lin Can Moss	376211
Whattall Moss ↓	432310
Valley mires (reclaimed)	
Baggy Moor	390270
Boggy Moor	414257
Burlton Moor	470270
Cockshutt Moor	445285
Holywell Moor	462320
St. Martins Moor	315358
Tetchill Moor	395313
Turf Moor	360190
Weald Moors	670170
Miscellaneous	
Berrington Moss	526067
Brownheath Moss	460302
*Brown Moss ↑	563395
*Shomere Pool and Moss ↓	504079
Venus Pool ↑	550061