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The use of small-scale surface patterns in the classification of British peatlands

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The vegetation and surface patterns of five ombrotrophic mires from northern Britain were surveyed in some detail to determine the relationships, if any, which existed between the various elements of the microtopograpy and the vegetation. A total of 22 noda were recognised for the 5 sites, some of which were widely distributed, others were restricted to one site. The noda were found to be closely linked to six identifiable elements in the microtopography. The distribution of these elements and their significance for classification purposes are discussed.

I. Introduction

There is little difficulty, when studying the majority of habitats, in distinguishing between the soil on which the vegetation grows and the vegetation itself. By and large the former dictates the composition of the latter, although clearly biotic factors also play an important part. However this is not the case for peatlands, particularly ombrotrophic systems. Here the whole process is turned on its head — the effective "ground surface" (i.e. the mire surface) is instead a product of the vegetation. The unusual nature of such mire surfaces, in particular their distinctive microtopography, has been recognised since earliest times, and a considerable volume of literature exists concerning the development and hydrology of these features (Tansley 1939, Pearsall 1956, Ratcliffe & Walder 1958, Ruuhijärvi 1960, Goode 1970, Pakarinen & Uotila 1971, Moore 1977, Boatman *et al.* 1981, Smart 1982).

Surprisingly, this interest in the origins of patterning has not, in general, extended to the relationships which exist between these surface features and their corresponding vegetation. At one time, before the more structured approaches of phytosociology and "objective" techniques of ordination and classification were well established, references to surface patterns and their differing species compositions were a common feature of mire descriptions (Pearsall 1956, Ratcliffe & Walker 1958). Today, at least in Britain, many of the terms established in the early years are now in effect redundant as accepted descriptive systems. Modern techniques which rely purely on the vegetation for classifying mire systems inevitably tend to ignore the phenomenon of surface patterning as a source of variation which can aid classification. A widespread feature of recent British accounts of mire vegetation is the added afterthought: "pools and hummocks are a characteristic feature of this vegetation type" (e.g. Ratcliffe 1977).

This appears to be a waste of potentially useful information and, perhaps worse, has given rise to unfortunate confusion in the understanding of many such long-established terms.

A classification system should reveal order within apparent chaos. It should also provide a common language whereby an understanding of ideas is shared by those who use the system. However, because early accounts give only limited definitions of features such as "hummock", "hollow", "pool", "flat", "lawn" etc., while the modern approach does not recognise their existence at all, the confusion which now surrounds these terms more resembles a confused babble of tongues than a single harmonious language, especially when different countries use different terms for the same element (e.g. "rimpi", "hollow" or "flark").

Importance of surface patterns

Clearly, if the mire water table is a critical factor in determining species composition, then an undulating mire surface which is not a fixed distance from the water table, can provide a much wider range of niches for groups of species to inhabit. Two of the present authors have investigated the relationship between pattern and vegetation in some detail on a site in the Inner Hebrides, and have established a link between specific vegetation noda and various elements of the microtopography (Lindsay *et al.* 1983). Precise definitions, in terms of structure and vegetation, are given for these elements, and from these definitions tentative relationships with mires described by other authors are proposed.

The remainder of this paper summarises some results taken from a more wideranging study of ombrotrophic peatlands throughout Britain, using the same techniques, to establish whether it is possible to use both vegetation *and* microtopography to compare between sites.

II. Methods

Although a wide range of sites throughout Britain have been examined in the course of this work, five sites have been selected for the present paper to show the effect of regional variation. These are 1) Butterburn Flow, Cumbria, 2) Claish Moss, Argyll, 3) Baddanloch, Sutherland, 4) Strathy Bog, Sutherland, 5) Blar nam Faoileag, Caithness (See Fig. 1.). All these sites are listed by Ratcliffe (1977) as nationally important for nature conservation.

Sampling was based on 10 cm^2 quadrats, to ensure that the sample size was small enough to fall within the various elements of the microtopography. However, these quadrats were sampled in the form of belt transects, measuring 0.5 m x 2 m, each transect thus containing 100 contiguous quadrats of 10 cm^2. Five such transects were taken from each site. (c.f. Lindsay *et al.* 1983). The height of each quadrat was recorded with respect to the water table because this was felt to be the one factor constant to all sites whatever the patterns or vegetation, a mire will always have a water table. To correct for seasonal variation, the

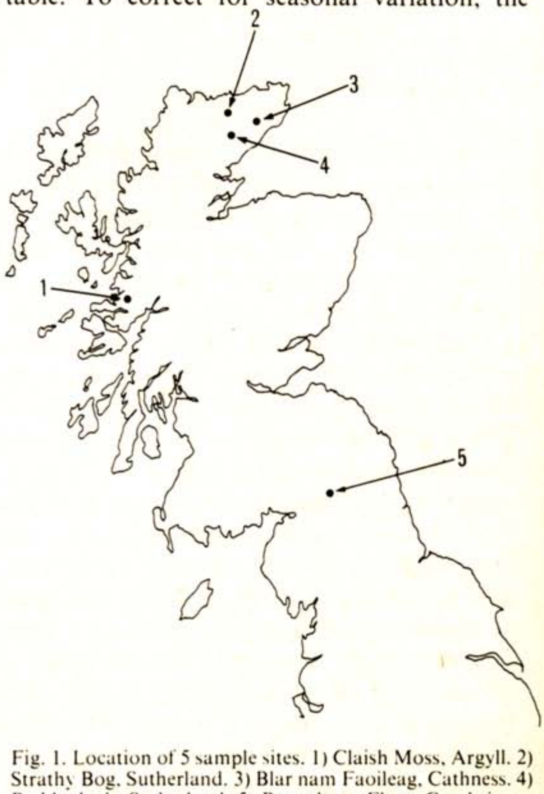

Fig. 1. Location of 5 sample sites. 1) Claish Moss, Argyll. 2) Strathy Bog, Sutherland. 3) Blar nam Faoileag, Cathness. 4) Baddanloch, Sutherland. 5) Butterburn Flow, Cumbria.

highest point of dominant *Sphagnum cuspidatum* was taken to be the height of the average water table. The difference between this and the actual water table at the time of sampling was taken as the correction factor, and all heights adjusted accordingly. Species were recorded on a three point scale within each quadrat: 1 = present, 2 = semi-dominant, 3 = dominant. Bare peat and open water were both recorded on this scale as though they were species, "bare peat" being taken as any part of the mire surface lacking a moss carpet, whether vegetated or not.

Data analysis was by TWINSPAN, a two-way indicator-species analysis developed by Hill (1979), followed by recombination of the resulting "end groups", until the species-groupings represented meaningful noda which could be identified in the field. Using the height datum for each quadrat, a mean height above (or below) the water table was then calculated for each of these noda.

III. Results

1. General vegetation and mire structure*

Butterburn Flow, Blar nam Faoileag, Strathy Bog and Baddanloch are all blanket mires (Ratcliffe 1977), whereas Claish Moss is generally regarded as raised mire (Ratcliffe 1977, Moore 1977).

All five sites fall within the Trichophoreto-Eriophoretum typicum of McVean & Ratcliffe (1962), which is one of the most widespread vegetation types in the western Highlands of Scotland on ground below 450 m and on slopes of less than 15 degrees. Examples can also be found in other parts of western Britain, from Dumfries and Galloway to Dartmoor, in Devon. Much of the ground dominated by this community has suffered considerable damage, particularly from burning, but all five sites are known to have escaped the worst of this. Consequently all five still show, to some degree or other, the pool and hummock patterns which typically, in this association, indicate the areas of deepest peat (Goode 1970).

Of the five, Butterburn has the least well-developed surface patterns, with small linear hollows scattered across the very deepest parts of the site. The patterns bring to mind Tansley's early descriptions of simple hummock/hollow mire surfaces (Tansley 1939). In contrast, Claish Moss is a hyper-oceanic mire with a fantastic maze of pools, ridges, hummocks and hollows — a fine example of Ruuhijärvi's eccentric domed mire (1960). Baddanloch and Strathy are valleyside flows (Goode 1972), with the typical linear patterning of pools and ridges — similar to Claish, but on a more limited scale — while Blar nam Faoileag is an enormous complex of valleyside flow and watershed blanket mire (Goode 1972), with linear patterns on sloping ground and large, very deep pools dominating the watershed plateaux.

*Plant nomenclature follows Clapham *et al.* (1962), Warburg (1963) and Paton (1965) *Sphagnum subsecundum* agg. follows Eddy (1977).

2. Account of noda and surface patterns

The complete analysis produced a total of 22 noda from five sites. The species composition of all 22 noda is summarized in Table 1, while the general relationships shown by these noda to previosly-described vegetation types can be seen in Table 2. It is perhaps informative to divide the descriptions of the 22 noda into groups which correspond with the main structural elements of the microtopography. These divisions are derived largely from Sjörs (1948) and Lindsay *et al.* (1983). Fig. 2 shows the distribution of the present noda in relation to the mean water table, together with a summary of at least some of the other terms and divisions which have been used by previous authors.

Hummock Level

This is found at least 10 cm above the mire water table, but may rise as high as 75 cm. Higher than this, the vegetation is likely to be more akin to the hagg tops of erosion com-

Table 1a. Percentage abundance of species within 22 noda derived from 5 sites in Scotland and N England. Both noda and species are ordered with respect to mean height above or below the average water table. Terrestrial noda.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13
Rhacomitrium lanuginosum	87			38		1	9		3				
Cladonia pyxidata	1			8									
Dicranum scoparium		1											
Rhytidiadelphus loreus		1											
Plagiothecium undulatum		2											
Hylocomnium splendens		1											
Rhytidiadelphus squarrosus		3											
Empetrum nigrum	4	19		69	7	13							
Aulacomnium palustre		4							1				
Dry bare peat	2	41	13	19	23	65	6		16		26		
Cladonia fimbriata				11									
Hypnum cupressiforme		26		32	2	28	15					1	
Sphagnum inbricatum					52							1	
Cladonia arbuscula						41							
Molinia caerulea	19						47		6		7		
Arctostaphylos uva-ursi		10				5			1	3			
Cladonia impexa	9	3			3	15	63		7				
Cladonia uncialis	3			3			6		2				
Calluna vulgaris	19	88	1		31	65	4		28	3	34	9	
Pleurozium schreberi		4							3				
Eriophorum vaginatum	13	14	86	19	15	1	27		18	24		8	9
Sphagnum rubellum	1	28		3	38	2	2		29	27		11	1
Drosera rotundifolia		1			14	1		16	6	3		3	2
Odontoschisma sphagni		1			5		1		4		39	1	
Erica tetralix	1	8	33		15	26	20		33	5	21	23	
Tricophorum cespitosum	4				5	2	2	23	13			3	
Myrica gale									2				
Pleurozia purpurea					2				3			3	
Campylopus atrovirens									1				
Sphagnum fuscum									1				
Narthecium ossifragum		12		11	6	5			31	5	6	18	6
Lepidozia setacea							1		1		12		
Rhynchospora alba							1		8			1	3
Betula nana									1			1	
Sphagnum subnitens								78	1			1	
Drosera anglica					3				4	1		4	3
Sphagnum tenellum		2		1	6			4	14	1	28	16	4
Sphagnum papillosum		3	62		3				18	99	6	28	
Andromeda polifolia			1					26				9	
Vaccinium oxycoccus											5		
Eriophorum angustifolium	7	8	9	19	19	60	3	16	22	23	97	27	8
Sphagnum magellanicum			12					38	4		12	58	1
Sphagnum pulchrum													82
Sphagnum cuspidatum												15	3
Sphagnum auriculatum													
Drosera intermedia													1
Rhynchospora fusca									1				
Menyanthes trifoliata									2	3		1	2
Wet bare peat (mud-bottom)												2	2
Utricularia vulgaris												1	
Open water													
Carex limosa													
Utricularia minor													
Eleocharis multicaulis													

Table 1b. Percentage abundance of species within 22 noda derived from 5 sites in Scotland and N England. Both noda and species are ordered with respect to mean height above or below the average water table. Aquatic noda.

Species	14	15	16	17	18	19	20	21	22
Rhacomitrium lanuginosum									
Cladonia pyxidata									
Dicranum scoparium									
Rhytidiadelphus loreus									
Plagiothecium undulatum									
Hylocomnium splendens									
Rhytidiadelphus squarrosus									
Empetrum nigrum									
Aulacomnium palustre									
Dry bare peat									
Cladonia fimbriata									
Hypnum cupressiforme									
Sphagnum inbricatum									
Cladonia arbuscula									
Molinia caerulea									
Arctostaphylos uva-ursi									
Cladonia impexa									
Cladonia uncialis									
Calluna vulgaris									
Pleurozium schreberi									
Eriophorum vaginatum	13								
Sphagnum rubellum	12								
Drosera rotundifolia									
Odontoschisma sphagni									
Erica tetralix	2								
Tricophorum cespitosum									
Myrica gale									
Pleurozia purpurea									
Campylopus atrovirens									
Sphagnum fuscum									
Narthecium ossifragum	6		3	1					
Lepidozia setacea									
Rhynchospora alba		8	1	1					
Betula nana									
Sphagnum subnitens									
Drosera anglica	4		1	1	1				
Sphagnum tenellum	19		4	3	1				
Sphagnum papillosum	50		3	9	6				
Andromeda polifolia				1					
Vaccinium oxycoccus			1						
Eriophorum angustifolium	11		17	19	24	9	16		
Sphagnum magellanicum	8		25	1					
Sphagnum pulchrum									
Sphagnum cuspidatum	52	20	45	92	63		34		
Sphagnum auriculatum	6	33	3	10	29	7	4		
Drosera intermedia									
Rhynchospora fusca		16							
Menyanthes trifoliata	6			2	12	1			
Wet bare peat (mud-bottom)		47	39	2	28	98	68	99	99
Utricularia vulgaris			1			3	1	6	
Open water	15	70	60	40	99	99	84	99	99
Carex limosa						60			
Utricularia minor						9			
Eleocharis multicaulis			1	2				81	

Table 2. Possible correlation of the 22 vegetation noda with nomenclature of other authors.

<table>
<tr><th rowspan="2">Noda</th><th colspan="3">Wheeler (1975)</th><th rowspan="2">Eddy, Welch & Rawes (1969)</th><th rowspan="2">Eurola & Vorren (1980)</th><th colspan="2">Malmer (1968)</th><th rowspan="2">Sjörs (1948)</th><th rowspan="2">Daniels (1978)</th><th rowspan="2">Ratcliffe & Walker (1958)</th></tr>
<tr><th>Class</th><th>Order</th><th>Alliance</th><th>Alliance</th><th>Association</th></tr>
<tr><td>1</td><td rowspan="13">Oxycocco - Sphagnetea</td><td rowspan="10">Sphagnetalia - Magellanici</td><td>Erico-Sphagnion</td><td>Tricophoreto-Eriophoretum</td><td rowspan="7">High hummock
Southern-Boreal Zone (Norway)</td><td rowspan="14">Erico - Sphagnetalia</td><td rowspan="2"></td><td rowspan="5">Calluna-Cladonia-Sphagnum fuscum ass.</td><td rowspan="2">Calluna - E. vag.
Calluna - E. tet.</td><td>Tall hummock</td></tr>
<tr><td>2</td><td rowspan="3">Sphagnion fusci</td><td>Calluneto-Eriophoretum</td><td rowspan="3">Medium hummock</td></tr>
<tr><td>3</td><td rowspan="20">Tricophoreto - Eriophoretum</td><td>E.vag-Clad.</td><td>E. tet. - E. vag.</td></tr>
<tr><td>4</td><td rowspan="7"></td><td rowspan="3">Calluna-Narthecium</td></tr>
<tr><td>5</td><td rowspan="6">Erico - Sphagnion</td><td rowspan="3">Dry flat</td></tr>
<tr><td>6</td><td rowspan="4">E. vaginatum-Scirpus-Sphagnum rubellum-balticum-cuspidatum ass.</td></tr>
<tr><td>7</td><td>Molinia</td></tr>
<tr><td>8</td><td rowspan="5">Lower hummock
S.B. Zone (Norway)</td><td>E. tet. - Andromeda</td><td rowspan="5">Sphagnum flat</td></tr>
<tr><td>9</td><td rowspan="2">Calluna-Narthecium</td></tr>
<tr><td>10</td><td rowspan="3">Scirpus-Carex pauciflora-Sphagnum tenellum-papillosum</td></tr>
<tr><td>11</td><td>Ericetalia tetralicis</td><td>Ericion-tetralicis</td><td>E.vag-S. ten.</td><td>E. tet. - Tricophorum</td></tr>
<tr><td>12</td><td rowspan="2">Sphagnetalia magellanici</td><td rowspan="2">Erico-Sphagnion</td><td rowspan="3"></td><td rowspan="11">Calluna - Narthecium</td></tr>
<tr><td>13</td><td rowspan="6">Bog hollows
S.B. Zone (Norway)</td><td></td><td rowspan="6">Shallow pools</td></tr>
<tr><td>14</td><td rowspan="9">Scheuchzerietea</td><td rowspan="9">Scheuchzerietalia palustris</td><td rowspan="5">Rhynchospora alba</td><td rowspan="9">Scheuchzeria-Rhynchospora alba-Carex limosa-Sphagnum cuspidatum-Dusenii ass.</td></tr>
<tr><td>15</td><td>Scheuchzerietalia</td><td>R.alba-Cladop.</td></tr>
<tr><td>16</td><td rowspan="2">Erico-Sphagnetalia</td><td rowspan="2"></td></tr>
<tr><td>17</td></tr>
<tr><td>18</td><td rowspan="5">Scheuchzerietalia</td><td>Meny. trif.-S. inundatum</td></tr>
<tr><td>19</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4">Deep pools</td></tr>
<tr><td>20</td></tr>
<tr><td>21</td></tr>
<tr><td>22</td></tr>
</table>

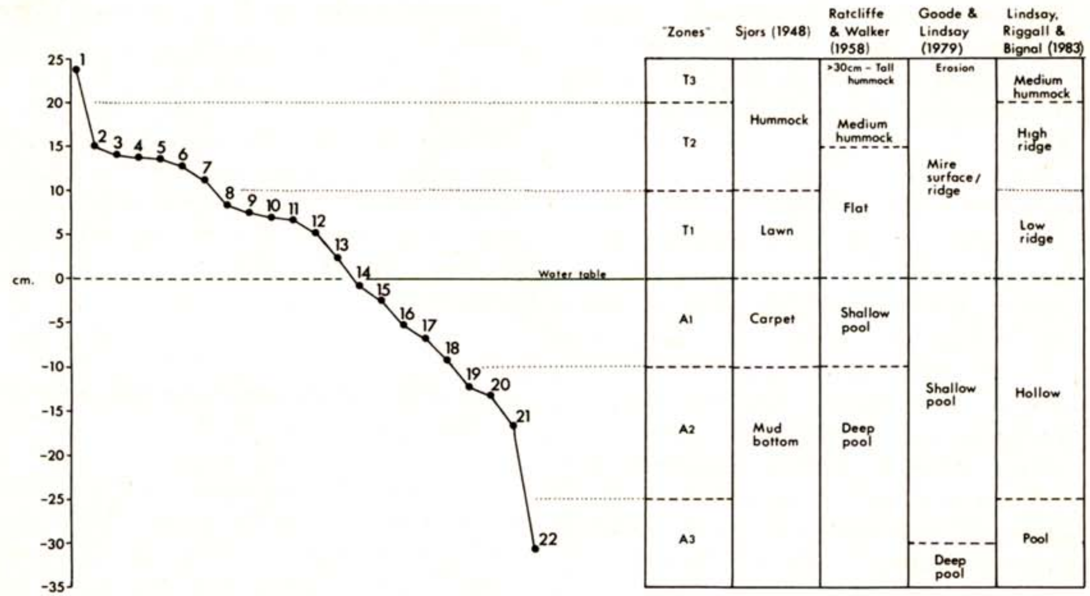

Fig. 2. Profile showing distribution within the microtopography of 22 noda, based on their mean heights relative to the water table. The different terminologies from four sources are related to the profile and compared with the "zone" system as defined in this paper.

plexes (Goode & Lindsay 1979). Hummock level is characterized by a dominance of bryophytes — either *Rhacomitrium* or *Sphagnum* — or else by a vigorous growth of dwarf shrubs. The range of dwarf shrub species found at this level increases towads the north and east of Britain, to produce the *Arctostaphylos-Calluna, Empetrum nigrum* and *Calluna-Erica tetralix* noda (Noda 2, 3 and 6 respectively) which predominate in the three north-easterly sites, whereas *Rhacomitrium* hummocks (Nodum 1) and *Molinia-Cladina* on bare peat (Nodum 7) are more typical of the western Claish Moss.

Lawn Level

This occupies the first 10 cm above the water table, and is typically *Sphagnum*- and species-rich. Many of the species found here are generally regarded as the "bog typics", such as *Drosera rotundifolia/anglica, Narthecium ossifragum, Vaccinium oxycoccus* and *Andromeda polifolia*. It is probably the most productive part of the mire surface (Clymo & Reddaway 1971), and frequently seems to form the dominant element where a mire had suffered little or no damage from burning or drainage. The water table in this zone appears to fluctuate more dramatically than in any other zone (present authors, unpublished), which perhaps explains the relative abundance of species such as *Narthecium ossifragum* and *Sphagnum papillosum*.

Nodum 9 (*Erica tetralix – Narthecium – Sphagnum*) appears to be one of the more universal facies, occuring in all four northern sites. Butterburn Flow, however, has instead two noda — *Sphagnum subnitens* (Nodum 8) and *S. tenellum – Eriophorum angustifolium* (Nodum 11) — which look slightly out of place. *Sphagnum subnitens* is more usually associated with fen conditions, whereas Nodum 11 is more of a wet-heath facies. *Sphagnum papillosum – S. magellanicum* lawns (Nodum 12) are common features of most sites, though on the north-eastern Blar nam Faoileag, this is replaced with Nodum 10, where *Sphagnum rubellum* and *Eriophorum vaginatum* take the place of *S. magellanicum*.

At the lawn/carpet transition, *Sphagnum* *pulchrum* (Nodum 13) forms a distinctive boundary, but only in the westerly extreme of Claish Moss. The *Sphagnum pulchrum* facies is very much restricted to the western seaboard of Britain.

Sphagnum carpet, or hollow

Although, to an untrained eye, carpets and lawns may look similar, a simple distinction between them is their differing ability to support any real weight. A lawn will support an observer's weight fairly well, whereas the same observer will immediately sink kneedeep through a carpet. In Britain this carpet almost always consists of *Sphagnum cuspidatum* and *S. auriculatum* in varying proportions, occupying the first 10 cm below the water table. *Sphagnum cuspidatum* carpets (Nodum 17) occur on all five sites, whereas the intimate mixture of *S. cuspidatum – S. auriculatum – Menyanthes* (Nodum 18) is restricted to the numerous small hollows surrounding the watershed pools of Blar nam Faoileag. Indeed carpets appear to be commoner in the north east of Britain perhaps because the greater run-off through oceanic mires results in conditions more akin to poor-fen, in much the same way as snow-melt is thought to form mud-bottom hollows in Scandinavia (Sjörs 1983).

Mud-bottom Hollows

These may occur at depths between 5 cm and 25 cm below the water table. They are generally associated with the nort-west of Britain, as mentioned above, and frequently support highly distinctive vegetation. *Rhynchospora fusca* (Nodum 15) is entirely restricted to this zone, even occupying a similar location in artificially-produced patterns, such as old peat cuttings, or flooded tank tracks. *Drosera intermedia* is more abundant in this zone (and thus in the north-west), as are *Carex limosa – Utricularia minor* (Nodum 19) and *Eleocharis multicaulis* (Nodum 21), and as such, the similarities with oligotrophic valley mires in northern and western Britain cannot be ignored. Only the relatively simple Nodum 20 (bare peat-patchy *Sphagnum cuspidatum*) is found outside Claish Moss.

Deep Pools

The deepest element within the surface pattern, a pool may be anything from 30 cm to 3 metres deep. Generally the pool is devoid of vegetation, apart from scattered stands of *Menyanthes trifoliata*, but their faunal interest is often considerable.

3. Differences in the microtopography between sites

Fig. 3 shows the distribution of the 22 noda between the five sites. From this it can be seen that some mires have a large number of noda within certain elements or zones, yet in other sites this element may be entirely absent.

Fig. 4 shows the approximate scale and distribution of surface patterning in Britain, and from this it is possible to explain much of the variation revealed in Fig. 3. Indeed, as many noda are restricted to certain levels, or zones, it should be possible, having established the range of patterns present on a site (within a broad climatic zone), to make some sort of prediction about the likely presence or absence of particular noda.

IV. Discussion

The difficulties of defining the various elements of surface microtopography are many and various. A standard reference point, a possible constant from which to measure the scale and nature of surface pattern, would seem to be the water table. Unfortunately such a constant is not constant, from month to month or year to year. In the absence of continuous measurements over many years, it is therefore necessary to resort to the vegetation as a guide. In Britain, the rise to dominance of *Sphagnum cuspidatum* is a reasonably good indicator, but is clearly of limited use elsewhere in Europe. Much of the information contained in Fig. 2 concerning the

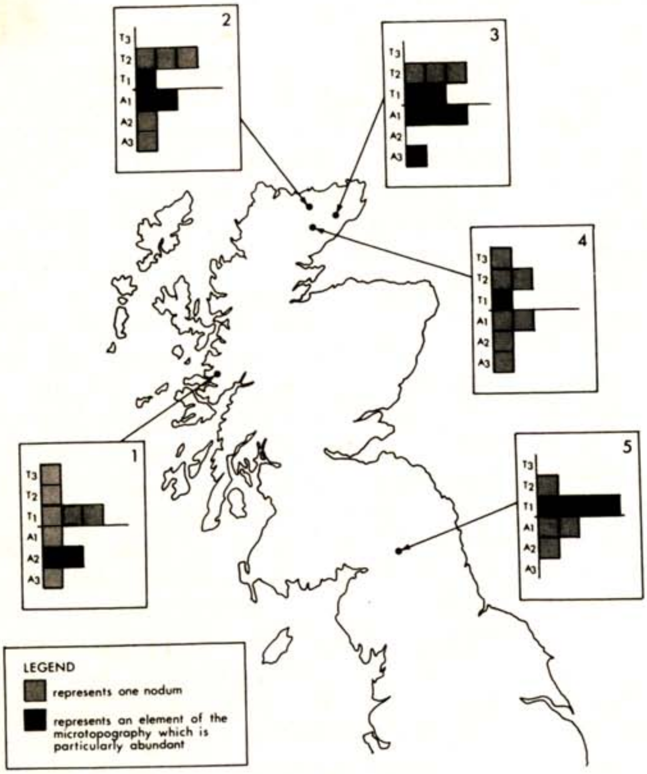

Fig. 3. Variations in the number of different noda recorded for each level (or zone) of the microtopography between the five study sites. 1) Claish Moss, 2) Strathy Bog, 3) Blar nam Faoileag, 4) Baddanloch, 5) Butterburn Flow.

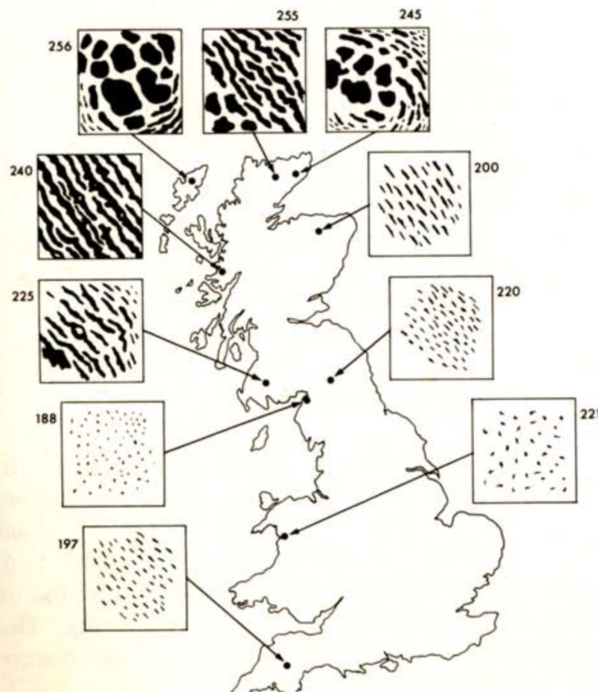

Fig. 4. Distribution and general structure (seen from above) of surface patterns in Britain, taken from ongoing survey work by the Nature Conservancy Council. Pools/hollows are shaded black, ridges and hummocks white. All insets are drawn at a scale of 1:1000.
The figures represent the average number of rain days per year for each site (Times Atlas of the World, 1955).

location of the water table was inferred from the species composition, rather than by direct measurement.

A further problem is that, even in ombrotrophic mires, the contribution of soligenous flow in the form of run-off can be quite significant. Thus a vegetation type recognised as ombrotrophic in Ireland may be regarded as minerotrophic in Finland, simply because the rainfall is so great in Ireland that run-off across the mire surface provides an almost continuous flow — equivalent to minerotrophic conditions. The problem thus expands from the relatively simple question of vegetation and water table to include rates of water movement. And of course rain, or run-off, varies in its nutrient content . . .

Fig. 5 is an attempt to summarise these three main axes of variation, showing the possible mechanisms behind not only the problems of ombrotrophy/minerotrophy, but also the close relationship between mud-bottom hollows and valley mires proposed above.

In terms of location in the microtopography, a mud-bottom hollow and the central water-track of a small valley mire are probably roughly equivalent; both lie below the water table for much of the year. However what separates them (if anything does) is the rate of water flow, and nutrient content, of that water. However, to describe a valley-mire water-track as a "mud bottom hollow" would be to stretch the terminology too far. Indeed that whole terminology which is used to imply position in relation to the water table hummock, hollow, pool, carpet — is useful only within a narrow range of mire types, whereas the three axes of height, flow and nutrient content are more universal.

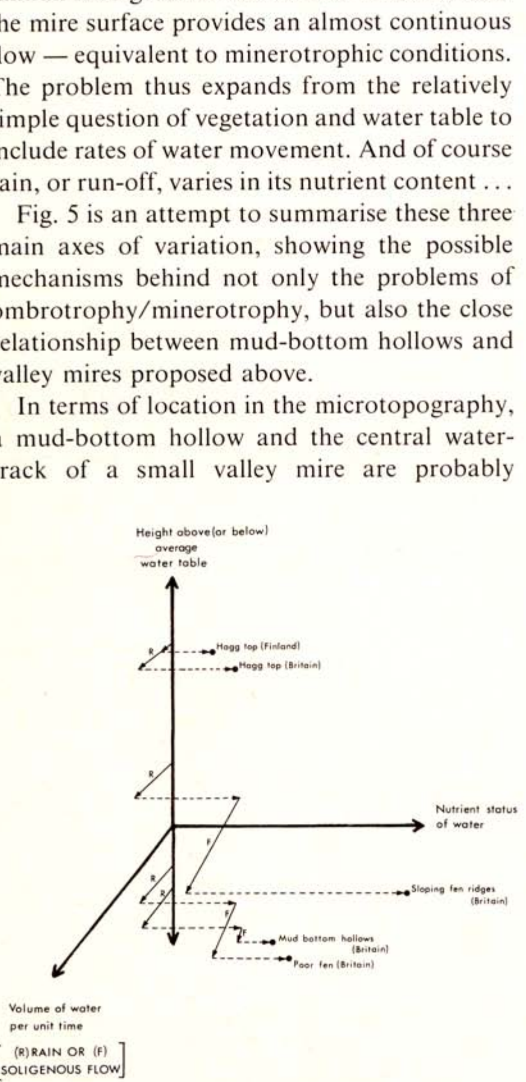

Fig. 5. Generalised 3D graph showing the contribution of physical components to the composition of different types of noda. Solid lines represent the amount of water input to the system; pecked lines show the nutrient status of this water.

It is therefore suggested that a relatively simple set of categories, which have no connotations with past or present terminologies, might be employed to describe a series of "zones" above or below the water table. Such a system is demonstrated in Fig. 2 and Fig. 3. Thus it would be possible to agree that a particular vegetation type occurs at, say T_1 (the lowest terrestrial zone), or A_2 (the aquatic zone which lies between —10 cm and —25 cm), whatever the local names given to than zone, or the rate of flow, or the nutrient status of the water.

Clearly there are still problems with this; perhaps, for instance, the "Aquatic" zone should instead be divided on the basis of "number of days submerged". Nevertheless, it would at least provide a simple universal reference code which could be added to all mire description.

Species taxonomy had to resort to Latin to provide a common tongue; perhaps in this case a simple code may be all that is required.

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