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A PHYTOSOCIOLOGICAL STUDY  
OF  
WIDDYBANK FELL IN UPPER TEESDALE

being a Thesis for the Degree of Doctor of Philosophy  
of the University of Durham

by

Alison V. Jones, B.Sc. (Edin.)



January 1973

## ABSTRACT

The vegetation of Widdybank Fell, Upper Teesdale, was classified, mapped at 1:10,000 and (in parts) 1:2,500 and related to comparable British communities. The phytosociological rôle of the "Teesdale Assemblage" was also investigated.

The methods of Zurich-Montpellier phytosociology were used. Field analysis was followed by a polythetic sub-division and linear ordination of the data.

Thirty-six vegetation units or noda encompassing eleven alliances, and orders of eight classes were found. The complement of noda within each alliance was termed an  $\alpha$ nodal group.

The classes and alliances found are as follows:

<u>Class</u>	<u>Alliance</u>
Asplenieta rupestris	Androsacion vandellii - siliceous rock crevice vegetation
Festuco-Brometea	(Sub-all. Seslerio-Mesobromion - semi-dry calcareous grasslands <sup>s</sup> )
Violetea calaminariae	Thlaspeion calaminariae - heavy-metal mineheap vegetation
Molinio-Arrhenatheretea	Ranunculo-Anthoxanthion - sub-alpine pastures
Montio-Cardaminetea	Cratoneurion - vegetation of calcareous springs
Parvocaricetea	Caricion curto-nigrae - meso-trophic sedge-marsh
	Caricion davallianae - eu-trophic sedge-marsh
Oxycocco-Sphagnetea	Ericion tetralicis - damp heaths
	Erico-Sphagnion - ombrogenous and raised bogs
Nardo-Callunetea	Violion caninae - rough grasslands
	Empetrium nigri - heaths

The  $\alpha$ nodal groups and noda formed the mapping units at 1:10,000 and 1:2,500 respectively. They were identified by dichotomous keys based upon the occurrences of several species. Mapping was carried out on vertical aerial photographs at 1:7,500 and 1:2,500.

Within each alliance, the Widdybank and related British communities were incorporated into an association, either de novo or one previously described. Vegetation unique to this part of Upper Teesdale at or near the sub-association rank occurs in the Seslerio-Mesobromion and Caricion davallianae; distinctive vegetation within the other associations is at a much lower level.

The members of the Teesdale Assemblage are present mainly in communities referable to those syntaxonomic units for which they are characters/differentials in Europe. Sixty percent occur in either the Seslerio-Mesobromion or the Caricion davallianae whose Upper Teesdale communities feature prominently in large-scale limes divergens transition zones between lowland and sub-alpine vegetation.

## ACKNOWLEDGEMENTS

The number of those without whose assistance neither the survey nor this thesis would have been completed is so great that, regretfully, all cannot be mentioned here although grateful thanks is due to each one.

Due recognition must, however, be given to the Teesdale Trust who provided the funds, Dr. Margaret Bradshaw who supervised the project, Professor Donald Boulter who made available laboratory facilities, and Mr. Tom Buffey who gave assistance and hospitality in the field. Valuable discussions were held with several members of the Department of Botany, University of Durham, chief amongst whom was Dr. David Bellamy. Professor Reinhold Tüxen of the Arbeitsstelle für Theoretische und Angewandte Pflanzensoziologie, Todenmann, bei Rinteln, West Germany, gave much advice in the practice of Z-M phytosociology and afforded hospitality.

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Finally, mention must be made of the author's family who assisted in numerous essential ways.

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PART I

INTRODUCTION

and

METHODS

## INTRODUCTION

The Tees Valley and Cleveland Water Act which authorised the Cow Green Reservoir scheme in Upper Teesdale in the north Pennines became law in 1967. Because of opposition to the Act, the chief beneficiary, Imperial Chemical Industries Ltd., donated funds to set up a trust known as the Teesdale Trust. This was to finance a large-scale programme of scientific research in the area which is particularly noteworthy as being the site of many plant species of restricted distribution in the British Isles and representing several geographical elements. Widdybank Fell featured highly in the debate preceding the construction of the reservoir as it supports a large proportion of this flora, part of which was to be lost upon inundation. Although some botanical studies had previously been made in Upper Teesdale, none had concentrated upon the vegetation (as opposed to the flora) of Widdybank Fell nor had any thorough evaluation been made of the extent to which the plant communities are unique in the British Isles. The Teesdale Trust, therefore, agreed to allocate funds for such an investigation the objectives of which were threefold:

- 1) to provide vegetation maps of the whole Fell at 1:10,000 and of those parts of particular phytogeographic interest at 1:2,500;
- 2) to incorporate the vegetational units distinguished into the system of plant community classification used throughout Europe (Oberdorfer 1957, Westhoff and den Held 1969);
- 3) to relate the Widdybank communities to comparable vegetation types described in other British studies.

The resulting survey and its findings are described in this thesis. All the plant communities of Widdybank Fell have been studied and particular attention has been paid to those containing the rare species. The status of these species has been considered also.

This introductory chapter is concerned with the general background to the study, location, climate, topography, geology and soils of Widdybank Fell. It gives a brief overall description of the main vegetation types and mentions land use and certain features of vegetational history.



### Background

Upper Teesdale has been famed for over a century as one of the locations of species rare in Britain. The earliest mention of the discovery of such a species, however, was in 1718 when John Ray found Potentilla fruticosa "by Mickle Force, Teesdale" (Bradshaw 1965). The subsequent records, many made during the first half of the nineteenth century and others made as recently as 1968, are summarised in the accounts by Pigott (1956) and Bradshaw (1965, 1970).

Widdybank Fell has already featured, usually prominently, in the vegetational descriptions of Upper Teesdale made by Pigott (1956), Bradshaw and Clark (1965) and Bradshaw (1970, incorporating Ratcliffe 1966, unpublished). These accounts deal with both the flora and the plant communities, considerable emphasis being placed on the former. The present study, almost entirely confined to Widdybank Fell, is chiefly concerned with the plant communities and considers the flora within this context thus continuing and extending the trend discernible in the earlier works.

### Location

(See Figs. A and B)

Part of the eastern watershed of the north Pennines is drained by the River Tees which lies north of the Swale and south of the Tyne and the Wear. The term "Upper Teesdale" can be broadly applied to that part of the Tees valley between its source at 2,600 ft (793m) on the eastern side of Cross Fell and the town of Middleton in Teesdale at 750 ft (229m) about 20 miles downstream (Johnson 1965). It may, however, be more narrowly defined as that area between and including the Moor House National Nature Reserve at about 1,900 ft (579m) and the hamlet of Newbiggin (850 ft, 259m) about 10½ miles away. This is the region shown in Fig. B; the inset shows the position of Upper Teesdale relative to the British Isles as a whole.

Widdybank Fell lies in the middle of this area on the north bank of a loop in the Tees opposite its confluence with Maize Beck. The Tees forms the south-western boundary of County Durham; to the west lies Meldon Hill in the county of Westmorland and to the south Cronkley Fell in the North Riding of Yorkshire.

The river forms the western and southern boundaries of the 2 $\frac{1}{4}$  sq ml (5 $\frac{3}{4}$  sq km) mapped; the northern is marked by the fence north of Slapestone Sike and south of Peghorn Sike and the eastern boundary by the Fell wall running from Peghorn Sike to Widdybank Farm and thence to the river (Fig. A).

### Climate

Detailed climatological observations have been made on Widdybank Fell only since January 1968. In the unpublished reports of Millar<sup>#</sup> and Buffey<sup>#</sup> (on which this account largely draws) these observations are compared with and discussed in the light of the records gathered since the 1930s by the stations at Moor House (1,825 ft, 556m) and Great Dun Fell (2,779 ft, 847m) which lie respectively 4 $\frac{1}{2}$  and 7 $\frac{1}{2}$  miles to the north-west. The data obtained by the meteorological station at 1,670 ft (509m) on Widdybank show a close similarity to the conditions at Moor House; there are low temperatures for much of the year, high precipitation and near constant winds, thus fulfilling the description of "sub-arctic" often applied to this part of Upper Teesdale.

Air frost is possible in any month of the year and there may be long periods of continuous frost. Minimum air and ground temperatures can reach as low as 0°F (-18°C) and -4.5°F (-20.3°C) respectively and in nine months out of the first two years' observations, the lowest air temperature recorded on Widdybank was lower than that at Great Dun Fell. The growing season, measured as the number of days with a mean temperature above 42.8°F (6°C), is 177 days. This compares with 170 days at Moor House, 145 on Great Dun Fell and 230 at Newton Rigg 561 ft (171m) in the Eden Valley to the west of the Pennine watershed.

The mean annual rainfall on Widdybank is just under 70" (178 cm), 5 to 6" less than at Moor House; the monthly distribution varies greatly from year to year. Although there are often long periods of high humidity, it may sometimes be very much lower than in the lowlands (cf. Smith 1970). Precipitation occurs on almost 300 days per annum

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# Millar (1970); personal communication  
Buffey (1970); personal communication

and there is usually snow cover on more than 100 days; snow can fall at any time between the beginning of October and late April/early May.

The wind speed at the higher parts of the Pennines is about twice that in the eastern lowlands of County Durham; over the ten year period 1957-1968, Smith (1970) records a mean of 13.7 knots at Moor House compared with 7.4 knots at Durham University Observatory lying at 335 ft (102m). The wind speed at Moor House is thought to be near to the limiting value for tree growth in the open in the British Isles<sup>4</sup>; the maximum recorded on Widdybank is a gust of 130+ knots in mid-January 1968. Under anticyclonic conditions the westerly airstreams crossing the Pennines can be channelled down the dales from the higher plateaux (katabatic drainage) thereby producing temperature inversions (Smith 1970) and giving colder temperatures at lower rather than higher altitudes (e.g. the recording on Widdybank of temperatures lower than those on Great Dun Fell mentioned above)

### Topography

(See Fig. A)

The south side of Widdybank Fell is bounded by the the vertical face known as Falcon Clints which rises from about 1,350 ft (411m) and then slopes gradually up to a flat bench of  $\frac{1}{3}$  sq ml (1 sq km) in area lying at approximately 1,650 ft (503m). On the northern edge of this bench a shorter escarpment rises to a flat and plateau-like summit,  $\frac{2}{3}$  sq ml in extent, at 1,700-1,725 ft (518-526m). The east side of this plateau drops relatively sharply (although not as steeply as on the south) to 1,325 ft (404m) but to the west there is a gradual slope down to the Cow Green Reservoir at about 1,600 ft (488m). (This side of the Fell was formerly bounded by the Tees which flowed some 70 ft lower - see below) The northern edge of the Fell merges with its surroundings at 1,650 ft (503m).

Widdybank Fell is drained on all sides, except the north, by sikes (small streams); those on the west and south run directly into the Tees. Immediately above its junction with Maize Beck, opposite the south-west corner of the Fell, the river runs over the Cauldron Snout fall, a drop of 100 ft (31m) in 300; below this it passes through the gorge formed by the cliffs of Falcon Clints and Cronkley Scar.

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<sup>4</sup> Millar (1970): personal communication

The situation above the waterfall was changed during the period September 1967 to September 1970 with the construction of the dam for the Cow Green Reservoir. Prior to this, the river flowed in a broad channel through a wide U-shaped valley; the inundation which followed the completion of the dam 1,000 ft (305m) upstream from the waterfall, led to the formation of the reservoir covering the lower parts of Meldon Hill to the west and Widdybank Fell to the east. When full, the reservoir covers an area of 770 acres and the top water level is around 1,603 ft (489m).

A public right-of-way, the Birkdale Track, runs approximately north-south on the western flank of the Fell. It skirts the summit plateau, drops over the shorter escarpment and passes across the flat bench before traversing the river between the dam and Cauldron Snout.

### Geology

(See Fig. B)

The geological structure (solid and drift) and general soil types of Widdybank and Cronkley Fells have been described by Johnson, Robinson and Hornung (1971) and therefore need only be briefly outlined here. Fig. B is taken from their publication.

Much of Widdybank Fell comprises material laid down during the Lower Carboniferous period, principally the Lower Limestone Group. This is dominated by thick layers of the Melmerby Scar limestone of low carbonaceous content which are separated by thin layers of shale and sandstone. Outcrops of these rocks are found as a band lying towards the west, south-west and south edges of the Fell and also on the north-west of the summit plateau. Farther north-west the Middle Limestone Group outcrops; these limestone strata are dark coloured, having a much higher carbonaceous content.

Following the uplift and doming of the region towards the end of the Carboniferous period, the Great Whin Sill was emplaced across northern England. In this part of Upper Teesdale (i.e. to the west of the faulted monocline known as the Burtreeford Disturbance - see Fig. B) the Sill is at its lowest stratigraphical horizon - close to the base of the Melmerby Scar limestone - and near its maximum thickness. The subsequent erosion (perhaps lasting the 50 million years from the early Tertiary to the present day) has in some places removed the softer rocks overlying the Sill leading to the formation of flat benches

on both Widdybank and Cronkley Fells; their almost vertical faces form Falcon Clints and Cronkley Scar respectively. Other Whin Sill outcrops stand out as projecting "headlands" on the south and east sides of Widdybank. During the Quaternary glaciation, drift was deposited over large parts of the Fells blanketing much of the Lower Carboniferous limestone and parts of the Whin Sill.

In addition to the provision of various structural characteristics, the Whin Sill intrusion has had two other far-reaching effects. The ensuing mineralisation of the surrounding limestone led to the formation of veins of galena and barytes which have been extracted over the last 200 years by drift mining. This has left a visible mark upon the region in the partially vegetated spoil-heaps and trial workings (i.e. horizontal channels), the uneven ground surface and the miners' tracks.

The other consequence of the Whin Sill intrusion was to give a bedrock formation which has led to a "geological setting ..... unknown outside Upper Teesdale in Britain" (Johnson, Robinson and Hornung 1971) due to the formation of thick marble bands in the limestone. The almost-pure beds of the Melmerby Scar limestone were recrystallised by contact with the Whin Sill for a distance of about 82 ft (25m) from its upper surface and for a short distance below. Very little recrystallisation took place in the Middle Limestone owing to the presence of organic material.

All the exposed Melmerby Scar limestone - on the west around Slapstone Sike immediately above the reservoir, forming the escarpment on the south-west and south and part of the Fell top plateau - is in this metamorphosed form. A high proportion of the unvegetated areas of this rock are covered by the fine grains of "rotten" marble known as "sugar limestone" produced by sub-surface weathering followed by erosion of the vegetation, soil and drift cover.

### Soils

These are described in detail in Part II in conjunction with the discussion of the various vegetation types.

Johnson, Robinson and Hornung (1971) note that the presence or absence and thickness of the drift are major factors in determining the rôle of the limestone in the soil formation. Peaty gleyed podsols, peaty gleys or deep peats develop where the drift is over 60 cm (23/2ins) deep, brown earths or brown calcareous soils where it is between 30 and 60 cm and rendzinas where the covering is less than 30 cm.

### Vegetation

The three features of Whin Sill, metamorphosed limestone and drift covered limestone are each clearly visible in their topographical structures and in the nature of the vegetation developed on them. Brief mention must therefore be made of the latter in this introductory section; reference should be made to Fig. A, the vegetation map of Widdybank Fell at a scale of 1:10,000.

The near vertical Whin Sill faces bear a mixture of heath and rock-surface vegetation of the classes Nardo-Callunetea and Asplenietea rupestris respectively. The flat bench above Falcon Clints is largely covered by bog and wet heath communities of the Oxycocco-Sphagnetea as is that (flat or gently sloping) part of the top of the Fell which is drift covered. Surrounding the bogs are other areas of heath and/or rough grasslands (both in the same class).

Lying between these two peat covered areas is the metamorphosed limestone escarpment bearing species-rich grassland vegetation of the Festuco-Brometea. The other metamorphosed limestone exposures, lying on the west and near the Fell summit, are also covered (principally) by Festuco-Brometea communities. The spoil-heaps and trial diggings left by the mining operations are colonised by the specialised vegetation of the Violetea calaminariae. Associated with the drainage water from the limestone are the calcareous flushes and sedge marshes of the Caricion davallianae (Parvocaricetea) whilst the sub-alpine pasture-like grassland plants of the Ranunculo-Anthoxanthion (Molinio-Arrhenatheretea) develop in rather peaty places with calcareous irrigation, in damp hollows and beside streams. Sedge marshes of the Caricion curto-nigrae (also Parvocaricetea) occur where the drainage water is less nutrient-rich.

The reservoir has destroyed between 5 and 10% of each of the Festuco-Brometea and Caricion davallianae communities and 10% of the Ranunculo-Anthoxanthion communities. By contrast, a much smaller proportion of vegetation of the Oxycocco-Sphagnetea and the Nardo-Callunetea, of much less phytogeographic interest, has been affected.

#### Land use

The Upper Tees valley is, in contrast to that of the Wear at the same altitude, largely treeless. The highest conspicuous plantation lies above the Langdon Beck Hotel at 1,400-1,450 ft (427-442m), another near Ettersgill is about 50 ft lower and a larger area is situated around High Force at 1,000-1,100 ft (305-335m). On Widdybank Fell itself on the steep face of Falcon Clints, there are isolated specimens, mostly rather stunted, of Populus tremula, Crataegus monogyna, Juniperus communis, Betula <sup>pubescens</sup> ~~pendula~~ and Sorbus aucuparia. A stunted plant of Pinus sylvestris has been found in the grassland on the limestone escarpment<sup>#</sup> whilst scattered here and there are shoots of Salix repens. A dwarfed Betula nana shrub grows on the bog below the escarpment.

This treeless condition is a result of the past and present land use of the area. The Fell is utilised to-day for sheep farming and grouse shooting and this has been the practice for many decades. The sheep grazing, which continues throughout the year except in extremely hard winters, prevents tree regeneration and assists in promoting the competitive advantage of the less common species of the area. This has been shown by the twofold decrease in species content of flush communities on the south-eastern flank of the Fell which have been enclosed for five years<sup>++</sup>. The constant grazing may also maintain the overall stability of the boundaries between the limestone grassland sensu stricte and a form of it with Calluna. Comparison of aerial photographs taken with a 13-year interval reveals encroachment by the Calluna into the grassland but dead shoots of the shrub have been found below grassy turf from which it is now absent.<sup># #</sup> Grazing by the rabbits which were formerly prevalent in the area would have contributed to this.

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# Bradshaw (1971) : personal communication

++ Bellamy (1970) : personal communication

# # Bradshaw (1972) : personal communication

The effect of rotational burning of the blanket bog to provide young and succulent shoots for the grouse can be seen in the different proportions of certain species in the burned and unburned bog. In several areas examined at least 15 years after burning, there was still a much greater proportion of Eriophorum vaginatum than Calluna compared with originally similar bog dominated jointly by Calluna and Eriophorum and bearing no trace of burning. Working on the Moor House N.N.R., Eddy, Welch and Rawes (1969) have found that the proportions of Empetrum and several bryophyte species also decreased markedly after burning and that complete regeneration takes between 12 years at lower altitudes and 20 years at altitudes above 1,969 ft (600m).

#### Vegetational history

Several factors are considered by Pigott (1956) to have played a part in the maintenance of the phytosociologically important communities of Widdybank Fell. Two of these, climate and geology, have already been discussed, and in the final section of this work various environmental features arising from the unique geological structure are dealt with in detail. The present land use has already been described and it is appropriate to mention at this point some aspects of previous land use and of the vegetational history.

Turner et al (in press) have shown that many of the species for which Upper Teesdale is noted to-day have been present throughout the post-glacial, thus confirming the relict nature of the flora suggested by Pigott (1956). Further, even during the boreal and atlantic forest maximum, the tree canopy was sufficiently open to permit the survival of a rich and varied ground flora.

Bellamy et al (1969) suggest that the particular vegetational units in which these species grow to-day may be a "product of recent land use". This is confirmed and qualified by Turner et al (see also Turner 1970) who have found two clearance phases associated with increases in grass pollen in a diagram constructed from a peat sample taken close to the limestone escarpment. The first clearance, which is not very pronounced, has been dated rather earlier than 5000 B.P. and correlates with archeological evidence that late Mesolithic man was hunting regularly in the area. Following regeneration of the woodland, the

major clearance commenced about 2600 B.P. and the high proportion of grass and heather pollen has continued until the present day. This is associated with the coming of Iron Age man to the Fells and the requirement of wood for burning, building and, later, smelting and with the consequent increase in grazing pressure. The records in the peat samples of several of the rare species, especially those found in present day grassland communities, are concentrated in the period following this major clearance. Turner (1970) therefore stresses the contribution of man over the last five or six thousand years to the specialised and important vegetation of Widdybank Fell; This is supported by Squires' (1971) work on Cronkley Fell.

## METHODS

The techniques employed in this study fall into four categories:

- (i) the phytosociological investigations leading to the definition of mapping categories;
- (ii) the field mapping;
- (iii) the photogrammetric and cartographic work arising from the field mapping;
- (iv) soil profiles and analyses (strictly a part of the field analyses).

Categories (i) and (ii) are considered below; categories (iii) and (iv) were carried out by others working in collaboration and are described in Appendices B3 and C respectively.

### (i) Phytosociological investigations

#### Introduction and background

One of the primary aims of the present undertaking was to produce vegetation maps of Widdybank Fell; thus an analytical technique which would provide the material to enable this to be done on an objective basis was thought desirable. The procedure adopted had also to place the vegetation in the classificatory scheme already developed on the European mainland and to enable the Widdybank communities to be compared with related communities in other parts of Britain.

The European classification has been largely erected by the proponents of the techniques of vegetation analysis and description which originated in the two centres of Zurich and Montpellier and are often referred to as the Zurich-Montpellier (or Z-M) system. This has as one of its primary aims the production of keys to enable mapping to be undertaken and, indeed, this operation provides an opportunity for checking the validity of the vegetation units which have been distinguished in the prior field analysis and laboratory synthesis of the data obtained. Other aspects of the methodology allow objective comparison to be made between sets of vegetational data.

The Z-M techniques have, until comparatively recently, been little used in the British Isles although Moore and his co-workers in Ireland (e.g. Moore 1962, Moore et al 1970) and Shimwell (Shimwell 1968, 1969, 1971a, b and c) have shown them to be applicable to British vegetation. The Widdybank investigation has provided an opportunity for testing this approach in an intensive study involving many vegetation types situated in a relatively small region. It has also enabled some of the results to be incorporated into and compared with a more conventional application of the Z-M system, that of Shimwell's (1968) survey of British calcareous grassland communities some of which are located on Widdybank Fell.

Previous British studies of the vegetation within a circumscribed area have not, in general, used the Z-M techniques although McVean and Ratcliffe's (1962) classic study of the plant communities of the Scottish Highlands follows Poore (1955a, b, c, 1956) and uses an amalgamation of Z-M methods and those practised in Scandinavia. The latter differ from the Z-M techniques in several ways, notably in the status and definition of the basic unit of classification. Poore's procedure has also been used by Edgell (1969), Birks (1969) and in modified form by Eddy, Welch and Rawes (1969).

Throughout the present century, prolonged controversies (reviewed in Shimwell 1971c) have ranged over the nature of the most effective method of "understanding vegetational complexity and its relationship to environmental factors" (Moore et al 1970). Until about 1950 this involved discussion between the proponents of the different analytical and classificatory schemes operating in various parts of Europe (chiefly those in Zurich-Montpellier and in Uppsala). Matters were eventually resolved in favour of the Z-M school to a large extent. More recently, and especially within the last decade, the centre of debate has been between the use of the traditional Z-M methods and the employment of a number of computerised techniques for sorting vegetational (i.e. multivariate) data into either quadrat groups or into groups of species with a related distribution. Linked with this has been discussion centred on the premise that vegetation cannot be classified into discrete units but rather should be regarded as a continuously intergrading continuum which defies the delimitation of discrete boundaries. In this approach any graphic

representation of vegetational data is made in a three-dimensional "ordination" instead of a two-dimensional tabular "classification".

In recent years, however, it has been realised that all these methods have a part to play in achieving the desired vegetational understanding. Schemes of classification and ordination arise out of complementary, rather than mutually exclusive, standpoints and many of the numerical techniques are valuable at a secondary detailed stage of investigation following a primary survey by Z-M phytosociology although the latter can be used in detailed investigations such as the present study. Zurich-Montpellier phytosociology itself combines both classification and ordination in its operation because a polythetic sub-division of the species-site records or Aufnahmen (see below) is followed by a linear ordination of the categories distinguished.

Moore et al (1970) have compared this process with some of the 50 (approximately) numerical techniques available for vegetation analysis. Those used were the monothetic sub-divisive normal and inverse association analyses which are applicable to both classification and ordination, cluster analysis (agglomerative, used in classification) and principal component analysis (used in ordination). The methods of the Z-M school were found to be the most "efficient" in terms of the ratio time taken in input/information emerging. Furthermore, the resulting "clean" table (cf. Moore 1962) combined most of the advantages of the dendrograms or ordination diagrams produced in the other techniques.

The Z-M system has traditionally been operated by hand and eye but Moore and his colleagues (inter alia) have been able to render it amenable to computerised analysis. This is counter to Williams and Lambert's (1966) observation that of the four basic methods of hierarchical classification (divisive mono- and polythetic and agglomerative mono- and polythetic) only divisive monothetic and agglomerative polythetic are practicable even with the aid of a computer.

Zurich-Montpellier phytosociology - general outline

Only a broad outline of the Z-M classification principles and methodology is given here; a full account of all these points is provided by Shimwell (1971c): see also Braun-Blanquet (1964). Field and laboratory details and modifications applicable to the present survey are described in the following section.

The classification is an hierarchical structure, the basic unit involved being the Association<sup>#</sup>, an abstract category compiled from many field analyses. The other ranks, in ascending order, are Alliance, Order and Class; in some cases the Alliance is divided into Sub-alliances. Below the Association lie the Sub-association, Variant, Sub-variant and Facies.

Although these categories are defined according to their floristics (see below) they also correspond with physiognomic, ecological and/or geographic criteria. The class is often described in physiognomic/ecological terms, the order by a more narrow physiognomic and/or ecological range and the alliance according to climatic and/or altitudinal zone. Related associations (known as vicariants) may replace each other in different geographical regions. The species differences which distinguish the sub-associations may be geographically or ecologically based. Variants and facies are characterised by decreasing differences from "type" (cf. Braun-Blanquet 1964).

Each category is named from two genera, or in some cases a single genus, which are particularly prominent in it; the name of the species concerned is added for clarification where necessary. In the ranks from sub-association to class, defined endings are added to the genitive stem of the second, or of the only genus; below the sub-association the name of genus or species is used as it stands. The name of the first person to publish a description and name of the association or a higher unit is appended with the date; if the original definition has been modified the name and year of the first author is retained in brackets. An example of such an

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<sup>#</sup> Hereafter initial capitals are used for these terms only in tables and headings.

arrangement is given below, using the association Festuco-Nardetum of damp, somewhat enriched sub-alpine grasslands.

<u>Rank</u>	<u>Ending</u>	<u>Example</u>
Class	-etea	Molinio-Arrhenatheretea R. Tx. 1937
Order	-etalia	Arrhenatheretalia elatioris Pawl. 1928
Alliance	-ion	Ranunculo-Anthoxanthion Gjaerevoll 1956 emend. Shim. 1968
Association	-etum	Festuco-Nardetum ass. nov. prov.
Sub-association	-etosum	caricetosum pulicaris
Variant	} generic and specific names used	
Sub-variant		
Facies		

The physiognomic/ecological/altitudinal descriptions applicable to these categories are:

- Molinio-Arrhenatheretea - vegetation of hay-meadows, permanent pastures and footpaths
- Arrhenatheretalia - species-rich meadows and pastures
- Ranunculo-Anthoxanthion - sub-alpine meadows and pastures
- Festuco-Nardetum - British (?) sub-alpine pastures
- caricetosum pulicaris - enriched sub-alpine pastures

The associations are recognised through the compilation of a large number of analyses of uniform vegetation. These analyses, for which the correct terms are either the German Aufnahme or the French Relevé, consist of a list of all the species occurring in a defined area of a stand of the vegetation (the Aufnahme may encompass the whole of the stand) with estimates of cover/abundance and sociability together with a short ecological description of the site. These analytical details are then synthesised into a table which, after editing, gives a picture of the range of floristic composition in the vegetation type concerned. This may or may not be an association (hence depicted in an Association Table) depending on the geographical, floristic and ecological range over which the study has been made. Moore (1962) and Shimwell (1971c) each describe the way in which a vegetation type is recognised as being of association rank or of one below.

When the Aufnahmen are grouped together or separated, their total floristic composition is considered. However, some species are of considerably greater value than others in defining associations and subsequently in assigning them to alliances, orders and classes. From the extensive investigations by the followers of Braun-Blanquet (in Montpellier) and Tüxen (the foremost German exponent) over a wide geographical area - the European mainland and beyond - species of restricted ecological amplitude and sociological niche have been cited. These are more or less confined to and/or have their optima in a particular association, alliance, order or class and are termed its "character species" (German "Charakterarten" or, more recently, "Kennarten"). They enable the vegetation unit to be "known" although at the alliance, and more especially at the association, level they are reliably diagnostic only within certain defined geographical limits (Moore 1962, Shimwell 1971c). "Transgressive" character species are those which although characteristic of, for example, an alliance are more likely to be found in only some of its associations (Westhoff and den Held 1969).

Character species are special cases of the differential species ("Differentialarten", "Trennarten") used to distinguish one unit (e.g. association) from the others of equal rank within the same higher unit (e.g. alliance). In contrast to character species, differentials are also plentiful in other associations outside the particular alliance. The categories below the association are distinguished by differential species only. Within this arrangement it is recognised and accepted that an association may have character species of two or more alliances and occupy a transitional position as it cannot be separated into different components.

The character and differential species of the various levels in the hierarchy, i.e. those species whose presence has played a part in the classification of the association, are designated as such in the Association Table. The characters (and sometimes the differentials) of class, order and alliance are listed either above or below the characters of the association and the differentials of its components (sub-associations, variants etc.). Below these are the "companions" ("Begleiter"), species which are either very common in several associations or are of extremely low constancy. Within each group the species are listed in order of decreasing constancy. The

association is characterised and described by the order and alliance characters, the association characters and differentials and the companions of highest constancy. Also shown in the association table are, for each Aufnahme, certain of the site ecological details and its total species number from which the mean species number of each section can be calculated as a further aid to its description.

The association is therefore distinguished from other associations by certain species; its components are also separated from each other by further groups of differential species. This arrangement of vegetation units delimited by the joint occurrences of several species gives rise to a series of "keys" for the field identification and, if required, mapping of these types in stands other than those recorded by the Aufnahmen. Moore (1962) and Shimwell (1971c) both stress that this procedure should be undertaken because it confirms, or otherwise, the validity of the units distinguished by the tabular operations.

Zurich-Montpellier phytosociology - field and laboratory methods of present survey.

The general Z-H principles of selection and description of uniform stands or parts thereof were followed for all the vegetation types represented on the Fell.

Following initial field surveys, stands which appeared to be uniform in both physiognomy and site characteristics were chosen for analysis. Estimations of minimal area (according to species number) of a few vegetation types, mainly different kinds of grassland, indicated that the small-scale variation could be adequately studied with Aufnahmen between 2 and 4 sq m in extent. Some analyses were made at the larger size but many were made at the smaller after trial observations gave approximately the same number of species. The area of the Aufnahme was usually increased for vegetation of coarser detail, such as bogs and heaths. It had to be reduced in other places where the variation in community composition is on a very small scale as, for instance, in some flush complexes, and also where an intensive study was made of the vegetation immediately surrounding some of the rare species, chiefly those on the limestone escarpment.

The use of Aufnahmen of somewhat smaller size than is generally recommended was considered to be justified in an area such as Widdybank Fell where the detailed vegetational pattern is of particular interest (cf. Shimwell 1971c).

Following delimitation of the Aufnahme, details were recorded of general physiognomy, approximate heights of the vegetation layers, percentage cover of Phanerogams and Cryptogams (separately) and total cover, total size of the stand where it exceeded the Aufnahme, contact communities and topography, aspect and degree of slope of the site.

A complete list of all species present was made and specimens were removed for laboratory identification where necessary. To each was given a visual estimation of cover/abundance (proportion of ground covered by the vertical projection of their parts) and sociability, both of which are invaluable in giving a "picture" of the vegetation. The customary 5- point scale was used for sociability but the 11- point Domin scale of cover/abundance replaced the 6-point Braun-Blanquet scale generally used by workers in the Z-M school. This gave finer divisions and facilitated comparisons with the raw material of other British vegetational studies. The scales of both sociability and cover/abundance are reproduced in Appendix A.

In places of hummock/hollow topography where initial visual observation suggested that the communities of the two elements are of different composition, they were recorded separately. However, in almost all cases, the subsequent tabular comparison of the Aufnahmen revealed that these differences are quantitative not qualitative and therefore the members of each pair of analyses were amalgamated.

In a further departure from standard Z-M practice, soil analytical details were not obtained for each Aufnahme; instead, following the synthesis of the floristic data to give the vegetational mapping units (see below), soil analyses were made at representative examples of the various vegetation types. Further details are given in Appendix C.

The technique of the synthetic treatment of the Aufnahmen (that is, their aggregation into floristic tables which are representative of the vegetation units present) followed, broadly, the standard Z-M technique as outlined above and described by Shimwell (1971c). Because the Aufnahmen - about 570 in number - were from many different vegetational types, an initial sub-division based on formation and dominance was made for ease of handling. The Aufnahmen of each group were treated together in one table within which rearrangement of Aufnahmen and grouping of species enabled the tentative delimitation of abstract vegetation units, i.e. a number of Aufnahmen differentiated

from other such units by certain species' occurrences. In this process, the total species composition of each Aufnahme was considered. Further Aufnahmen were added from other tables when appropriate.

This preliminary arrangement of the vegetation units was followed by their allocation to the classes, orders and alliances of the central European phytosociologists. As there has not yet been any comprehensive survey and classification of British vegetation according to Z-M principles, it was necessary to obtain most details of character and differential species from continental accounts although Shimwell's (1968) study of British calcareous grasslands and their contact communities gave invaluable information for several classes and Moore's (1968) account of European bog and wet heath vegetation included the British Isles. The other principal works consulted were Oberdorfer (1957 and 1962) which refer particularly to southern Germany and Westhoff and den Held's (1969) account of the plant communities of the Netherlands. Since those species' lists were not drawn up with reference to British vegetation, they were carefully evaluated in terms of the ecology and distribution of the species in this country; further details are given in the general consideration of each class in Part II.

To facilitate the allocation of the vegetation units the constancies of the character species within each were evaluated according to a 5-point scale. In this, the presence of a species in 81-100% of the Aufnahmen gives a constancy of V, a presence of 61-80% a constancy of IV etc.; a constancy of I is here taken to embrace all presence values up to 20% but this may if desired be sub-divided to give r (rare) for less than 1% presence and I for 1-20% presence. Where there are fewer than five Aufnahmen, however, the constancy is given as the actual number of occurrences of the species, an Arabic numeral being used. As well as enabling the vegetable <sup>tion</sup> units to be regrouped into alliances, orders and classes, this process also afforded an opportunity for the sub-division of any which appeared intermediate between two alliances and for the further refinement of them in general.

The resulting classification of the vegetation units and the constancies of character and differential species are shown in Table I.

As already stated, inspection and comparison of the total species' complement of the vegetation units assigned to each alliance was made through a calculation of species' constancies. This led to the separation of the units by a series of dichotomies, several species, termed "differential species groups", being used wherever possible to characterise each division. In addition, further species were extracted to differentiate the group of vegetation units as a whole. In general, these species were not widespread as an entity in other such groups of units. As far as was practicable the members of these differential species groups, at whatever level, were of constancy III or greater, thereby giving at least 50% possibility of their being found in a stand of this category. Constancies of II or even I were, however, accepted for certain of the rare species.

The differential species group formed the criteria for mapping the vegetation just as the character and differential species of the association and its sub-units do in a conventional geographically extensive phytosociological study. As will have been clear from the preceding discussion, however, the same terminology, i.e. of association, sub-association etc., with its implications of wide-ranging validity could not be used in this survey made over a restricted area. The terminology chosen could be relevant only to this particular investigation although not precluding the possibilities that the same vegetation types would be found outside this area and that the classification could be incorporated within the conventional Z-M one.

The nomenclature adopted is based on that suggested by Poore (1955b). The basic "vegetation unit" extracted by the synthesis of the field data has been termed a "nodum" which is defined as "an abstract vegetation unit of any category"<sup>#</sup>. Poore's terminology has been adapted as follows: the group of noda falling within each alliance and which have a combination of differential species that distinguishes them from all other such groups of noda, is termed an

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\* It should be noted that in the present and the customary examples of the use of "nodum", reference is made to a unit at a lower rank than the alliance.

"C nodal group". This is then sub-divided by a series of dichotomous divisions based on groups of species' occurrences to give further groups of noda and/or individual noda. The designations "B and X nodal groups" are given to the groups of noda formed by the successive divisions which continue until all the noda are keyed out. (It was found that division of the X nodal group always gave the noda, but this need not necessarily be so for it depends on the complexity of the vegetation and the scale of the sub-division.) The nodal groups and noda are nomenclaturally distinguished by appending the names of one or two frequently occurring and conspicuous differential species (nodum with ...) or by the designation "typicum" where no such species can be found.

The hierarchical structure of nodal groups and noda is represented in the floristic tables in Part V, Vol. II, and forms the basis for the vegetational descriptions of Part II. The tables are arranged in similar fashion to an association table and encompass all the noda (occasionally a single nodum) of each alliance. Each table is headed by the C nodal group differentials; these are followed by differentials of B and X nodal groups and noda. Any class, order and alliance characters not already included are then given and, finally, the companions. It should be noted that some Aufnahmen whose composition places them in a position intermediate between noda or nodal groups have been retained in the tables. This is to give as complete a range of floristic variation as possible; in a less intensive survey they would be discarded. Nevertheless, in accordance with the Z-M principle of obtaining clear vegetation "types" about 15% of the Aufnahmen had to be removed from the tables because they were intermediate or fragmentary in composition.

The production of vegetation maps of Widdybank Fell at the scales of 1:10,000 and 1:2,500 has already been mentioned as being one of the major aims of this study. The nodal group/nodum arrangement provided the two levels of related mapping units suitable for the two map scales: the C nodal groups being the mapping units at 1:10,000 and the noda those at 1:2,500. The 1:10,000 mapping units, therefore, encompassed all the vegetation of their alliance on the Fell and where only a single nodum of an alliance was to be shown this formed, when size permitted, the mapping unit at 1:10,000. Both ranks of mapping units were given reference numbers; those mentioned in Parts II and V are of the 1:2,500 scale.

Field keys were constructed from the floristic tables to provide the necessary information for objective field mapping at both scales. The arrangement of such keys is illustrated by the schematic example below. Those actually used in the field are reproduced in conjunction with the descriptions of the vegetation types in Part II.

Diagrammatic field key

Field key to $\alpha$ Nodal group with . . . . .						
$\alpha$ Nodal group	List of differential species					
$\beta$ Nodal groups	Differential species			Differential species		
$\delta$ Nodal groups	Differential species			Differential species		
$\gamma$ Noda	Diff. spp.	Diff. spp.	Diff.spp.	Diff. spp.	-	-
Mapping Unit No.	-	-	-	-	-	-

The field key depicts an alliance whose  $\alpha$  nodal group is divisible into two  $\beta$  nodal groups. One of these has a  $\delta$  nodal group with two noda and a third nodum whilst the second  $\beta$  nodal group has two  $\delta$  nodal groups each with two noda. It should be noted that one of these  $\delta$  nodal groups is distinguished merely by the absence of those species differential for the other. Clearly the more species which can be included in the differential groups the better as, although species have ecological and sociological tolerances and preferences thus allowing vegetation units to be distinguished, it cannot be denied that there is overlap and transgression between phytosociological units. This is especially noticeable in a large-scale survey of a small area.

It was observed in the field that further divisions of some noda, which had not been apparent from the table, could be made owing to the transgression of one or more species from a related one. In general, however, this was not done since the principle of division to produce homogeneity can be carried to absurd lengths. Such cases are mentioned in the text.

The field mapping and checking of the noda did, nevertheless, lead to some redefinition. One pair of noda had to be combined as the occurrences of the species (two sets of three) which appeared from the tabular comparisons to act as differentials frequently overlapped in the field. In another alliance, the existence of a nodum which had not already been distinguished became apparent; the investigation of its full range of floristic composition necessitated the making of further Aufnahmen. Both these instances are mentioned in the text.

(ii) Field mapping

The boundaries of the vegetation units defined by means of the keys were drawn on to vertical aerial photographs. Two sets were used, one at the scale of 1:2,500 in natural colour and the other at 1:7,500 in black and white. These were designed for the 1:2,500 and 1:10,000 maps respectively. The nodal groups were delimited at the smaller scale and their constituent noda at the larger.

An account of the practical field details is given in Appendix B1, and the end product of the field work can be seen from Figs. C and D Vol. II, which are copies of one photograph from each set. Fig. C is at the scale of 1:2,500 and Fig. D at 1:7,500. The central part of Fig. C appears at the top (north) of Fig. D and shows the northern part of the Fell-top limestone plateau and the ground lying west of the Birkdale Track and south of Slapstone Sike. The same areas of vegetation have been marked on both photographs.

The identification numbers of the mapping units in Fig. C are those referred to in Part II but the letter code in Fig. D is used here only for clarity in cross-reference; the corresponding mapping units in Fig. A are numbered. A vegetational mosaic is shown by two figures/letters separated by a comma and a hummock/hollow complex by a "fraction" wherein the upper number refers to the hummocks.

The amount of generalisation needed in mapping at the smaller scale is indicated by a comparison of Figs. C and D; it had also to be borne in mind that the smaller scale was to be reduced by another third in map production. The mapping units on the figures correspond as follows:

<u>Fig. C</u>		<u>Fig. D</u>	
m.u.	4,5,6	limestone grassland noda, part of m.u.	B
"	20,21	sub-arctic grassland noda,	" " C
"	28	blanket bog nodum,	" " G
"	29	rough grassland nodum,	" " H
"	26,31,32	heath noda,	" " J

It had originally been intended that following field surveying and mapping of parts of the Fell, the remaining areas should be mapped in the laboratory using pairs of photographs in a folding mirror stereoscope. The mapping categories for this process were to be defined by correlation between the field mapping units and the colour/texture/shade differences in the photographs. It was, however, found that this technique proved to be of limited value at either scale. It is likely that the vegetational boundaries were being confounded with topographic and/or drainage features.

This was particularly apparent at 1:2,500 where the various noda of each nodal group tended to fall within a single colour/texture type and the boundaries between the nodal groups themselves did not give sharp colour or texture differences. Close field inspection with single photographs (the use of pairs with a hand stereoscope was not practicable on account of the climatic conditions) enabled markings to be distinguished on them which corresponded to the vegetational discrimination possible on the ground. At the 1:7,500 scale, a somewhat greater proportion of the mapping could be done in the laboratory, in addition to the re-working of those areas that had already been done at 1:2,500. Considerable field investigation was also required since discrepancies were again found between some of the field vegetation boundaries and those of shade and/or texture detectable by means of stereoscopic vision.

A similar difficulty in defining vegetation boundaries on aerial photographs is described by Goodier and Grimes (1970) from work in upland north Wales. A greater, and confusing, amount of intra-community complexity was found with increasing photographic scale - from 1:10,000 to 1:5,000 - (cf. also Grimes and Hubbard 1969). Goodier and Grimes note that in general the units delimited in aerial photograph interpretation following vegetation classification "are often the result of a complex interaction between the visual effects of geomorphology, soil type and moisture content and the vegetation".

They therefore suggest that for photo-ecological studies there should be developed a special plant ecological-geomorphological classification which is linked with a conventional phytosociological classification. A similar suggestion has been made by Mew and Ball (1972) in connection with upland soil mapping, and Ward et al (1970) look forward to the development of photographic keys for the identification of British vegetation. If this approach could be linked with a vegetational classification based upon Z-M principles it could have a vital bearing on such studies as the present by reducing the amount of time spent in the field.

A brief outline of the processes involved in the production of the printed vegetation maps from the field data is given in Appendix B3. Figure A, Vol. II, is a copy of one of these maps - that covering the whole Fell at the scale of 1:10,000.

Outline of the material treated in Parts II to V

Part II

The vegetation present on the Fell is systematically treated class by class, the order being based upon the arrangement given in Westhoff and den Held (1969). Descriptive and distributional details of each class, on a broad European scale, are followed by a syntaxonomic review. The character, and in some cases differential, species are then given and their value for the British Isles discussed, with special reference to Upper Teesdale, in terms of their abundance and ecological preferences. This procedure is repeated for each order and alliance represented on the Fell.

The  $\mathcal{L}$ ,  $\beta$  and  $\gamma$  nodal groups and noda assigned to each alliance are dealt with in a similar hierarchical arrangement. Each is described in terms of differential species, general physiognomy, habitat occupied and relationship with other units of the same and of different alliances.

The syntaxonomy of the  $\mathcal{L}$  nodal groups and noda has been treated in some detail to establish their positions vis-à-vis the Z-M association. Following the lead given by Shimwell (1968) and Moore (1968) who have described associations confined to the British Isles, although closely related to associations on the continent, the literature survey necessitated by the syntaxonomic study has been largely but not entirely confined to British vegetation. The principal works consulted, in addition to Shimwell (1968) and Moore (1968), are:

- McVean and Ratcliffe (1962) - Scottish Highlands
- Birks (1969) - Isle of Skye
- Birse and Robertson (1967) - southern Scotland
- Eddy, Welch and Rawes (1969) - Moor House, National Nature Reserve,  
Westmorland
  
- Ratcliffe (1966) - Widdybank Fell
- Ratcliffe (1959) )
- Tallis (1969) ) North Wales
- Edgell (1969) )
- Ivimey-Cook and Proctor (1965) - Burren, Ireland.

The nodal groups and noda, their syntaxonomic equivalents (where found) and related vegetation are grouped together within each alliance to give associations for which character and differential species are given. The associations have been divided to give sub-associations, variants, sub-variants and facies where appropriate.

The description of each class, and of the second order where two are present, is prefaced by a synoptic classification of all parts discussed with particular reference to the Widdybank vegetation. This classification is also shown in conjunction with the keys used in field identification. Included in most discussions of syntaxonomy is a full summary of the association with its synonymy.

The synsystematic placing of each  $\alpha$  nodal group is then considered in relation to the classes, orders and alliances represented in it by character species. Finally, the soil profiles and analytical results obtained by ~~Horning~~ are described and discussed. Schematic soil profiles are presented.

### Part III

This is a general discussion covering two fields:

- (1) the distribution of the members of the "Teesdale Assemblage" within the higher units of classification (classes - alliances) both on Widdybank Fell and in Europe as a whole;
- (2) the extent to which the vegetation of Widdybank Fell is unique in the British Isles.

### Part IV

<sup>References,</sup>  
The/Bibliography and Appendices A, B, C and D covering the field and laboratory techniques of the vegetation analyses, field mapping and map production, soil analyses and a list of the tables in Part V are placed here.

### Part V, Volume II

This consists of floristic tables, in full and as constancies, of  $\alpha$  nodal groups and associations; soil analytical details; maps of the vegetation and geology of Widdybank Fell and specimen aerial photographs.

Authorities and Terminology

The authorities for the species are as follows (except where noted otherwise in the text):

Phanerogams: Clapham, Tutin and Warburg (1962), the only differences being that Euphrasia officinalis agg. is used for all members of subsection Ciliatae unless otherwise stated and that Deschampsia caespitosa follows the spelling of Hubbard (1954).

Cryptogams:

Mosses: Warburg (1963) with the exception that the subspecies of Hypnum cupressiforme are abbreviated throughout:

ssp.  $\chi$  filiforme Brid. to Hypnum filiforme  
ssp.  $\epsilon$  ericetorum B.S. & G. to Hypnum ericetorum  
ssp.  $\eta$  lacunosum Brid. to Hypnum lacunosum

Liverworts: Paton (1965)

Lichens: James (1965)

The term "community" has been used to refer to vegetation in the field of which concrete examples or "stands" may be analysed to give abstract descriptions known as "community types" or "vegetation types" (Shimwell 1971c, cf. McVean and Ratcliffe 1962, Whittaker 1962, Poore 1964, McIntosh 1967)

The "constant" and "near constant" species of a vegetation type have constancies of V and IV respectively, i.e. are present in 81% to 100% and 61% to 80% of the Aufnahmen.

A "differential" species usually has a constancy of III, IV or V but in certain cases it may only be II or I.

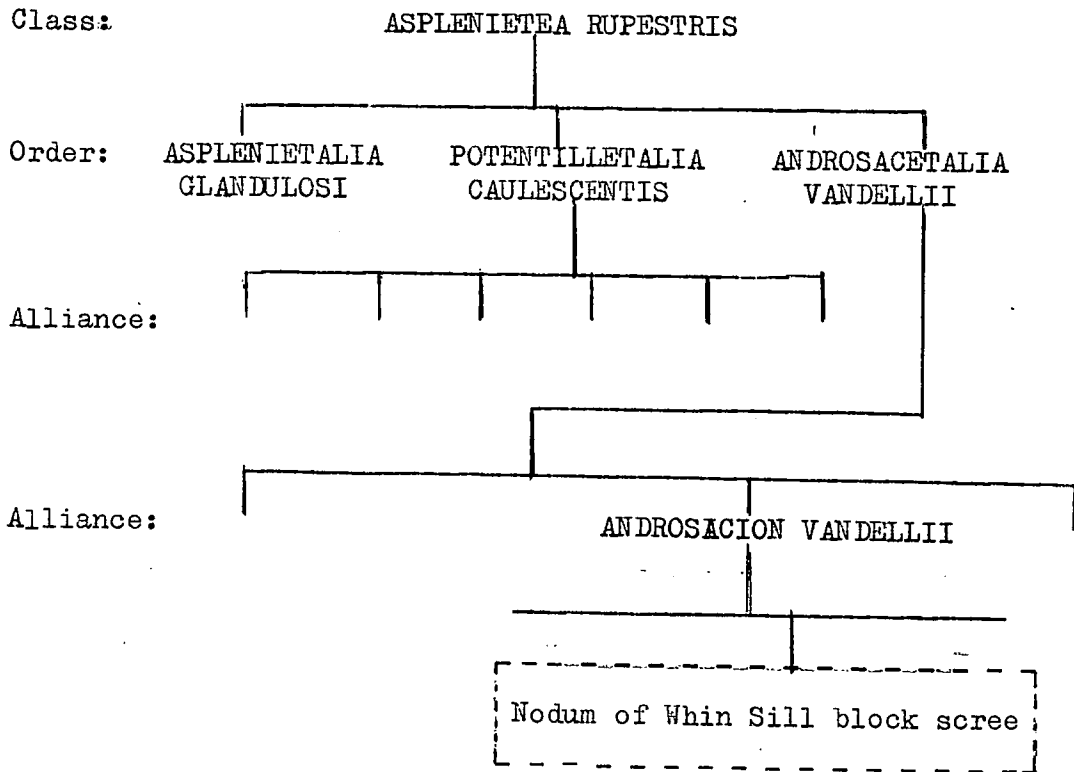
A species may be a differential for vegetation units of the same or other ranks in different nodal groups; the use of the term "differential species groups" emphasises that it is the combination of species which is concerned in the floristic separation.

The term "mapping unit" refers to the units delimited at 1:2,500 (unless stated otherwise) and is synonymous with "nodum".

PART II

THE VEGETATION OF WIDDYBANK FELL  
CLASSIFIED ACCORDING TO THE  
ZURICH-MONTPPELLIER SYSTEM

SYNOPTIC CLASSIFICATION OF PARTS OF THE ASPLENIETEA RUPESTRIS  
WITH PARTICULAR REFERENCE TO WIDDYBANK FELL



Key

[ - - - ] Vegetation present  
 on Widdybank Fell

Class: ASPLENIETEA RUPESTRIS Br.-Bl. 1934

The classification of those parts of the class referred to in the text is summarized on ~~the~~ facing page.

The communities of this class are extremely specialised for they play a pioneer rôle in the colonisation of walls and rock crevices. It is chiefly boreal-montane to arctic-alpine in distribution, and the species-rich nature of the communities of the Alps and the other European mountain ranges contrasts with the more impoverished vegetation of the British Isles and the neighbouring parts of north-west Europe.

Character species

Seven are given by Oberdorfer (1957), but only two - Asplenium trichomanes and Polypodium vulgare (sensu lato) - are widespread in Great Britain. Of the others, Ceterach officinarum and Sedum dasyphyllum are restricted to the southern parts of this country, Saxifraga rosacea to Ireland, Hieracium amplexicaule, an introduction, is found only on the walls of the Oxford Botanic Garden, and Valeriana tripteris is absent altogether.

The vegetation found during the present survey which may belong to this class occurs chiefly on the near vertical cliffs and block screes of the Great Whin Sill (quartz-dolerite) igneous intrusion outcropping in several places on the Fell. Only two of the character species are in this locality: Asplenium trichomanes, although not figuring in any Aufnahme, was found on Falcon Clints in similar vegetation to that studied and Polypodium vulgare is believed to be present there also<sup>#</sup>. The latter species is included by Pigott (1956) in a like community from Cronkley Scar on the other bank of the Tees.

Passarge (1964) lists three orders, two of which are probably represented in the Upper Teesdale area. The third is the mediterranean Asplenietalia glandulosi Br.-Bl. et H. Meier 1934.

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# Bradshaw (1971): personal communication

The others are present in central, eastern and northern Europe and require different levels of base status in their substrates.

Order: POTENTILLETALIA CAULESCENTIS Br.-Bl. 1926

This comprises communities of crevices in calcareous rocks and those of limestone walls and cement fillings. Passarge (1964) lists six alliances from different parts of Europe - Norway, western France and north-west Spain, south-east Europe, the Pyrenees and Ireland.

It is possible that the order is represented in the Upper Teesdale area, although not in the region of the present investigation. Asplenium viride, one of its character species, is included by Pigott (1956) in his species lists from ledges on limestone cliffs in the Upper Maize Beck valley and from limestone on Cronkley Scar, both of which are suitable topographical locations for the order.

Order: ANDROSACETALIA VANDELLII Br.-Bl. (1931) 1934

These communities grow on and between silicious rocks in south-west, central and south-east Europe and in Scandinavia. The distribution of the order in the British Isles is, as in the case of the Potentilletalia, difficult to evaluate. Only two of the four character species given by Oberdorfer (1957) are found in these islands. They are Sedum telephium, a widespread but local species, and the rare Asplenium septentrionale. The former occurs in Upper Teesdale, near the weighbridge above High Force<sup>#</sup>.

Four alliances have been erected covering vegetation in Norway, south-east, south-west and central Europe (Passarge 1964). This latter, the alpine

All. Androsacion vendellii Br.-Bl. 1926

is the one to which that on Widdybank is tentatively assigned pending the further investigation of these communities in the British Isles. One of the four character species given by Oberdorfer (1957), Primula hirsuta, is absent from Britain, but Veronica fruticans, Hieracium schmidtii (H. pallidum Biv. in Oberdorfer) and Woodsia ilvensis all occur locally (or rarely) in

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# Bradshaw(1971) : personal communication

mountainous regions from Wales northwards. The mention of Woodsia ilvensis is especially interesting, for this formerly grew on those cliffs on Widdybank Fell which to-day seem to be one of the chief localities of the communities of the alliance.

These have been placed in the

Nodum of Whin Sill block scree

Table II

which does not occur in those parts of the Fell mapped at a scale of 1:2,500 and is therefore shown only on the 1:10,000 scale map where it forms mapping unit 1.

It develops on the ledges of the Whin Sill, and on the scree which results therefrom. This quartz-dolerite rock outcrops most extensively on the south-west and south edges of the Fell facing the Tees, where it forms the cliffs known as Falcon Clints. The nodum is found on the cliffs themselves but is much more extensive on the expanse of block scree below. Smaller (about 30' to 40' high) "headlands" of the Whin Sill project on the south-west, south and east parts of the Fell and the nodum is present here and on the scree below.

Its composition can be seen in Table II. To the two Aufnahmen from Widdybank Fell have been added five made in the identical habitats of the block scree at the Moor House N.N.R. (Eddy, Welch and Rawes 1969).

The species given are not only those growing adpressed to the rock - the lichens and many of the bryophytes, e.g. Andreaea rupestris and Rhacomitrium fasciculare - but also those of the crevices between them. However, the table reveals that many of the differentials are species which grow on rocks directly, or on top of only a thin layer of humus, for instance those of Cladonia and of Rhacomitrium etc. Species such as Cryptogramma crispa, Lycopodium selago, Deschampsia flexuosa, Vaccinium myrtillus, and Galium saxatile form part of the flora of the damper crevices.

The 1:10,000 map shows that over much of its distribution the nodum does not occur in areas large enough to be shown separately, and that it is intermixed with heath communities of the Empetrium (mapping unit 9 at the 1:10,000 scale). The interchange

of species between these two types of vegetation is shown in the presence of Vaccinium myrtillus, Galium saxatile, Calluna vulgaris etc. in the scree nodum (cf. Table II). This is reminiscent of Leach's (1930) account of the manner in which heath plants colonise scree slopes that are becoming stabilised. The result is the formation of areas of heath which run vertically downhill, eventually to be cut off by the screes fanning outwards as appears to be happening on the south and south-west edges of the Fell. Also, on the near vertical faces of Falcon Clints, there are small-scale mosaics formed by the patches of heath vegetation occurring on the ledges and the moss-lichen community on the actual rock face.

There is very little reference to similar communities in the literature for the British Isles. Tansley (1949) describes the colonisation of upland scree; his list of species present at the end of the process resembles that of the nodum, and Pigott's (1956) list from the Whin Sill blocks of Cronkley Scar is similar to the composite one derived from the seven Aufnahmen of Table II.

It must be stressed that the correct synsystematic placing of the nodum is not at all defined. With the complete absence of all the character species of the class, order and alliance to which it has been assigned, this is the most tentatively classified of all the noda which have been encountered and named in the investigation. This classification is based on species which may occur, or have occurred, on dolerite rock ledges and between scree blocks in the vicinity forming similar communities and on the descriptions of class, order and alliance in the (continental) literature. It has not been possible to make any use of the lichen flora growing on the blocks since the information necessary for comparison has not been given in the phytosociological accounts published to date.

Class :

Order :

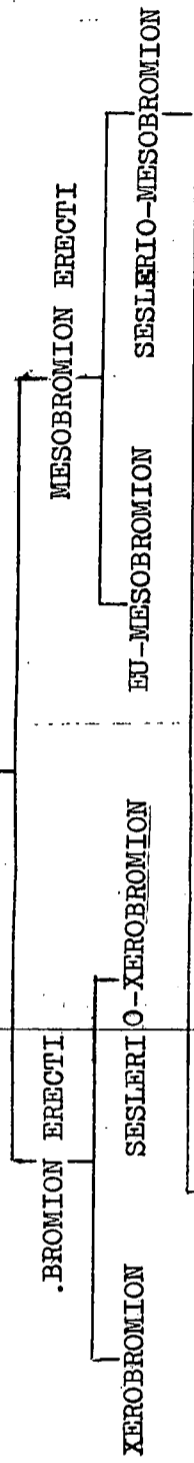
Alliance :

Sub-Alliance :

FESTUCO-BROMETEA

FESTUCETALIA VALLESIAEAE

ERU-METALIBROMETALIA ERECTI



Nodal group with *Sesleria caerulea* and *Koeleria cristata*  
 syn.: *Seslerio-Caricetum pulicaris* Shim. 1968 emend., sub-ass. typicum p.p.

$\beta$  Nodal group with *Minuartia verna*

$\delta$  Nodal group with  
*Carex ericetorum*  
 syn.: sub-ass. typicum-  
*Carex ericetorum* var.

Nodum with *Kobresia* Nodum with *Rhytidium*  
 syn.: *Kobresia* syn.: *Rhytidium*  
 sub-var. sub-var.  
 (m.u. 1) (m.u. 2)

Nodum with  
*Plantago lanceolata*  
 syn.: sub-ass. typicum  
 typical var. p.p.  
 (m.u. 3)

Nodum with  
*Calluna*  
 syn.: sub-ass. typicum  
*Calluna-Empetrum* var.  
 (m.u. 4)

$\beta$  Nodal group with *Carex pulicaris* and *Polygonum viviparum*

$\delta$  Nodal group with bryophytes

$\delta$  Nodal group with *Kobresia*  
 syn.: sub-ass. typicum-*Kobresia* var.

Nodum typicum  
 syn.: *Kobresia* var.-  
 typical sub-var.  
 (m.u. 6)

Nodum with  
*Primula farinosa*  
 syn.: *Kobresia* var.  
*Carex lepidocarpa*  
 sub-var.  
 (m.u. 7)

Key

Vegetation present on  
 Widdybank and Cronkley  
 Fells

Class: FESTUCO-BROMETEA Br.-Bl. et R. Tx. 1943 em. R. Tx. 1961

The status and inter-relationships of those parts of the class to which reference is made in the text are shown on the facing page.

In this class are placed lowland thermophilous open or closed species-rich grassland communities on dry or semi-dry soils which are normally base-rich but in some cases are weakly acidic. The communities are usually secondary being very much influenced by man's activities in clearing, burning and cultivation but in extreme habitats, e.g. rocky areas, they are generally of primary origin - relicts of a formerly wider distribution.

The chief area of distribution of the class is sub-atlantic - sub-mediterranean; large tracts of vegetation in the southern euro-siberian region and in the northern mediterranean lands are referable to it, but a micro-climate permitting its development is only found in isolated parts of the temperate lands of north-central and north-west Europe. In the higher altitudes of the Pyrenees and the Alps there is infiltration by alpine species of the class Elyno-Seslerietea (Shimwell 1968). Coupled with this, in southern Germany there is the west to east gradient of reduction in sub-mediterranean species and addition of sub-continental ones (Oberdorfer 1957).

#### Syntaxonomy

The vegetation of heavy-metal spoil-heaps (order Violetalia calaminariae) was originally in this class but was placed in a separate one - the Violetea calaminariae by Tüxen in 1961 (Westhoff and den Held 1969). The older classificatory schemes, e.g. Oberdorfer (1957) show the order Festuco-Sedetalia as a component of the Festuco-Brometea, but in the early 1960s this was removed to form part of another class; Oberdorfer et al (1967) placed it in the Sedo-Scleranthetea and Westhoff and den Held (1969) in the Koelerio-Corynephoretea.

The two orders remaining in the Festuco-Brometea after its amendment are the Brometalia erecti and the Festucetalia vallesiaca. The distribution of the latter borders that of the Brometalia to the north (in southern Scandinavia) and especially to the east and south-east in the continental steppe lands. Our interest, therefore, lies with the

Order: BROMETALIA ERECTI Br.-Bl. 1936

of dry and semi-dry grasslands on base-rich soils with a little humic material. The present day aspect is very much a secondary one because of man's effect on the natural vegetation in the destruction of forests and in pasture management, and the British distribution of the order extends from the sub-continental regions of south and east England through north England to the atlantic coasts of Wales and Ireland (Shimwell 1971a). On its eastern boundary (on the continent of Europe) species of the Festucetalia vallesiaca infiltrate and, similarly, in the alpine lowlands as well as on the northern flank through north-east England there is intermixing of the Elyno-Seslerietea species - relicts of the late Ice Age (Oberdorfer 1957).

#### Syntaxonomy

The component communities of the order were split up by Doing (1963) to form the Xerobrometalia and the Origano-Mesobrometalia. In the latter, the Mesobromion of the Festuco-Brometea was combined with the Trifolion medii (Trifolio-Geranietea). These orders were placed in different classes, the Xerobrometo-Sedetia (of dry open communities on skeletal soils) and the Mesobrometo-Arrhenatheretea (of closed semi-dry damp pastures on rich soils) respectively.

The latter class included much of the vegetation formerly placed in the Molinio-Arrhenatheretea, including the Arrhenatherion of the Arrhenatheretalia. This reclassification reflected the affinities of the Mesobromion and Arrhenatherion seen in the frequent occurrence of the transitions between them, particularly noticeable in the Netherlands. Westhoff and den Held (1969) describe this intermingling and remark that a reduction in the intensity of grazing, mowing and manuring of Arrhenatherion communities can increase their proximity to those of the Mesobromion. Nevertheless, they do not agree with Doing's (provisional) classification and return these alliances, and also the Trifolion medii and the Xerobrometalia, to their previous classes. This older classification is followed in the present study.

#### Character species

Shimwell (1971a) gives a list of nineteen character species for the order in the British Isles and, as it is the only one of the class to be represented here, they are also class character species. Of these, only the following ten are found in the Widdybank - Cronkley Fells region (Perring and Walters 1962):

Anthyllis vulneraria, Gentianella amarella, Helianthemum canum,  
H. chamaecistus, Helictotrichon pratense, Hippocrepis comosa,  
Koeleria cristata, Scabiosa columbaria, Poterium sanguisorba and  
Viola hirta ssp. calcareo (recorded only to the specific level by  
Perring and Walters). All except the last two have been recorded in  
the present survey, mainly in Brometalia communities, although  
Koeleria is also found in ones closely allied to them. Poterium is  
not known closer to Widdybank than four miles down river, near  
Wynch Bridge<sup>†</sup>

Of the two alliances of the order, the Bromion erecti Br.-Bl.  
(1925) 1936 of open dry thermophilous, chiefly primary, communities  
on rocky/usually limestone ground has a centre of distribution in  
central and southern Europe and is restricted in the British Isles to  
a small number of localities in Somerset and Devon (Shimwell 1971a).

The other alliance is the

Alliance Mesobromion erecti Br.-Bl. & Moor 1938 emend. Oberd. 1949.

The grassland communities placed here are closed, usually more  
mesophilous than those of the Bromion, and secondary in nature.  
Oberdorfer (1957) suggests that they are derived from forests of the  
Fagetalia (Quercus Fagetea) and Westhoff and den Held (1969) give as  
their precursors both the Carpinion betuli of this order and the  
Berberidion of the Prunetalia spinosae in the class Rhamno-Prunetea.  
The soils are moderately dry, loamy and vary from chalk-containing  
to chalk-rich or base-rich.

Westhoff and den Held (1969) describe the alliance as having  
its optimal development in the sub-mediterranean regions but reaching  
also into the sub-atlantic and atlantic zones and, therefore, extending  
from southern Scandinavia to Spain as well as into England and Ireland.  
In the northern part of its range, its occurrence is usually limited  
to warm places such as south-facing slopes, river valleys and sand dunes.

#### Syntaxonomy

The communities now in this alliance were formerly in the sub-  
alliance Mesobromion Br.-Bl. & Moor 1938, one of the three sub-divisions  
of the Bromion, but in 1957 Oberdorfer raised the sub-alliance to the  
alliance level on account of the distinctive species composition,

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<sup>†</sup> Bradshaw (1971) : personal communication

ecological and physiognomic features of the vegetation. At the same time, he sub-divided each alliance to cater for those communities at higher altitudes transitional between the Festuco-Brometea and the Elyno-Seslerietea. This gives the sub-alliances Seslerio-Xerobromion (of the reconstituted Bromion) and Seslerio-Mesobromion (of the Mesobromion), the accompanying lowland sub-alliances being the Xerobromion and Eu-Mesobromion, respectively.

#### Character species

Only two of Shimwell's (1971b) 27 Mesobromion character species are found in the Widdybank - Cronkley Fells region. One, Carex ericetorum, figures prominently in the Aufnahmen from two noda of the alliance but the other, Thalictrum minus, was not found in the survey and it is only known from the banks of the Tees as far west as High Force three miles downstream<sup>#</sup>. This might raise doubts as to the correct classification of these communities but it must be borne in mind that they lie on the extreme margin of the distribution of the alliance (and class), being outside the geographical range of many character species. Furthermore, several of the species cited by Shimwell (1971b) as differentials of the Mesobromion from the sub-alliance of the Bromion found in Britain, the Xerobromion, are present in Aufnahmen of this nodal group: Briza media, Carex caryophyllea and C. flacca are constant in many of the noda, and Plantago lanceolata and Succisa pratensis occur with lower constancies.

Both sub-alliances are represented in Britain, but the lowland Eu-Mesobromion Oberdorfer 1957 lacks the pre-alpine species of the other and reaches only as far north as Wales and Derbyshire (Shimwell 1971b). However, the

Sub-alliance Seslerio-Mesobromion Oberd. 1957 forms a zone extending across northern England, including Upper Teesdale, and into western Ireland (Shimwell 1968). It is the montane sub-alliance, floristically close to the Elyno-Seslerietea. Oberdorfer (1957) describes how the correct classificatory position of similarly transitional communities in the alpine lowlands is very difficult to estimate.

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<sup>#</sup> Bradshaw (1971): personal communication

Class : FESTUCO-BROMEIPEA  
 Order : BROMETALIA ERECTI  
 Alliance : MESOBROMION Sub-Alliance : SESLERIO-MESOBROMION

$\infty$  Nodal group with Sesleria caerulea and Koeleria cristata  
 a) Field key to communities on Widdybank and Cronkley Fells

$\infty$ Nodal group Sesleria caerulea, Koeleria cristata, Sieglingia decumbens, Gentianella amarella, Helianthemum chamaecistus, Plantago maritima, Cladonia subrangiformis, C. pocillum, Cetraria islandica, Cornicularia aculeata, Tortella tortuosa, Rhacomitrium canescens, Ditrichum flexicaule (Viola rupestris, Antennaria dioica, Helictotrichon pratense)	Minuartia verna		Carex pulicaris, Polygonum viviparum, Carex capillaris, C. caryophyllea, Gentiana verna, Cladonia arbuscula					
	Carex ericetorum		Rhytidadelphus squarrosus Pleurozium schreberi Hypnum ericetorum		Kobresia simpliciuscula			
$\beta$ Nodal groups Kobresia simpliciuscula	Rhytidium rugosum	Carex capillaris C. caryophyllea Gentiana verna Cladonia arbuscula	Plantago lanceolata Hieracium pilosella Thuidium tamariscinum	Calluna vulgaris Polygala serpyllifolia Agrostis stolonifera Rhytidadelphus loreus				
					Primula farinosa Carex hostiana C. lepidocarpa			

Mapping Unit 1 2 3 5 4 6 7  
 b) Classification of  $\infty$  Nodal groups and Nodal

Association Seslerio-Caricetum pulicaris Shim. 1968 emend.  
 Sub-ass. typicum p.p.  
 Syn.:  $\infty$  Nodal group with Sesleria caerulea and Koeleria cristata

Carex ericetorum var. Syn.: $\delta$ Nodal group with Carex ericetorum	Typical var.	Calluna- Empetrum var.	Syn.: $\delta$ Nodal group with Kobresia
Kobresia sub-var. Nodum with Kobresia	Nodum typicum of $\delta$ Nodal group with Minuartia	Nodum with Calluna	typical sub-var. Nodum typicum of $\delta$ Nodal group with Kobresia

Mapping Unit 1 2 3 5 4 6 7  
 Syn.

The sub-alliance differential species (Shimwell 1968) - Sesleria caerulea<sup>#</sup>, Galium sternerii, Gentiana verna<sup>#</sup>, Epipactis atrorubens, Dryas octopetala, Polygala amara<sup>#</sup>, Rhytidium rugosum, Viola rupestris<sup>#</sup> and Cornicularia aculeata - all occur in Aufnahmen of the  $\mathcal{L}$  nodal group, cf. Table III.

$\mathcal{L}$  Nodal group with Sesleria caerulea  
and Koeleria cristata (Mapping units 1-7)  
Table III

Syn: Seslerio-caricetum pulicaris Shim. 1968 sub-ass. typicum p.p  
and sub-ass. kobresietosum

The floristic differentiation of the seven noda is based upon Table IV which summarises Table III. The key-card used in the field is given in Fig. 1a).

The grasslands of this  $\mathcal{L}$  nodal group present a coarse appearance because of the abundance of the differentials Sesleria and Sieglingia together with the companions Briza (a constant), Carex panicea and C. flacca (both constant in three noda) whose leaves tend to mask the finer ones of Koeleria (a differential) and Festuca ovina (a companion) also present in large quantities. Varying amounts of such forbs as Campanula rotundifolia, Euphrasia officinalis agg., and the differentials Gentianella amarella, Plantago maritima, Viola rupestris and Antennaria dioica form part of the dense vegetation mat which is often underlain by Thymus drucei and Helianthemum chamaecistus. A variety of Cryptogams isopresent in the turf: Cladonia subrangiformis, C. pocillum, Cornicularia aculeata, Cetraria islandica, Tortella tortuosa, Ditrichum flexicaule, Hypnum lacunosum, Frullania tamarisci, Scapania aspera, Racomitrium canescens, R. lanuginosum and Ctenidium molluscum (all differentials except the last two) being the most prominent.

Although some members of the differential species group occur in mapping units of other alliances, especially nos. 8, 21, 32 and 33, its composition as a whole reflects the highly calcareous nature and low humic content of the soils. These range from dry immature rendzinas (mapping units 1 and 2) to deeper and damper brown calcareous soils and brown earths usually on flat ground or on ground sloping up to about 10°. The aspects most usually encountered are west facing or have a westerly component (i.e. are north-west or south-west). This is probably a reflection of the geological structure of the area in that suitable soils have been developed only on the west facing metamorphosed limestone escarpments. An occasional Aufnahme was made on an east facing slope

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# Character species in Shimwell (1971c)

on Widdybank Fell, and a few more on Cronkley where the limestone exposure has this aspect.

The noda fall into two groups; the  $\beta$  Nodal group with Minuartia verna and the  $\beta$  Nodal group with Carex pulicaris and Polygonum viviparum. Mapping units 1 to 3 are in the former group and 4 to 7 in the latter, but 3 is of an intermediate composition and forms a link between the two  $\beta$  nodal groups, as shown in Tables III and IV.

Minuartia verna is the sole differential for its nodal group and only the two named species are absolute differentials for the other. Several of the additional differentials for this latter  $\beta$  nodal group - Galium sternerii, Viola riviniana, Carex capillaris and C. caryophyllea - are constant in mapping unit 3, and the others - Gentiana verna and Cladonia arbuscula - are also present although with lower constancies.

$\beta$  Nodal group with Minuartia verna (Mapping units 1 - 3)

Syn.: Seslerio-Caricetum pulicaris Shim. 1968 sub-ass. typicum p.p.

This is composed of the Nodum typicum (mapping unit 3) and the

$\delta$  Nodal group with Carex ericetorum (Mapping units 1 and 2)

Syn.: Ditrichum - Rhytidium variant of Seslerio-Caricetum pulicaris Shim. 1968 sub-ass. typicum.

Carex ericetorum is the only differential species for this nodal group. The two component noda are those on the driest soils of any of the  $\delta$  nodal group. They are very similar floristically and physiognomically and are separated only on the presence or absence of the two species - their differentials. The Aufnahmen are mostly very small in area,  $\frac{1}{4}$  to  $\frac{1}{2}$  sq m, for they were made as part of an investigation into the composition of those communities with some members of the "Teesdale assemblage" such as Rhytidium rugosum, Carex ericetorum and Viola rupestris. The last species was initially considered to be a second differential for the  $\delta$  nodal group but subsequent observations showed it to be present throughout the  $\delta$  nodal group and it is designated as a differential for this although it is of low constancy in the group considered as a whole.

Nodum with Kobresia (Mapping unit 1)

Nodum with Rhytidium (Mapping unit 2)

These are considered together because of their close affinities.

The eroding sugar limestone edges are the most frequent habitats of these noda, where up to 40% of the ground may be of exposed sugar

limestone (in situ or wind blown) although 10% to 20% is a more usual proportion. However, both noda occur also as dense turf with 100% vegetation cover above or below the eroding areas. Phanerogam cover is generally about 75% to 90% and that of the Cryptogams 50% to 75% except in the very open sites where the values may be 50% and 20% to 40% respectively. The turf is often on flat or slightly undulating ground but angles of slope of up to  $10^{\circ}$  are common.

The high cover of Sesleria tends to give the vegetation a very coarse appearance especially when Carex ericetorum is also present. The leaves of Thymus and Helianthemum often form a very dense mat close to the ground but Minuartia verna may be locally dominant, particularly in the more open places. The mean numbers of species are 22 (mapping unit 1) and 23 (mapping unit 2), reflecting the extreme nature of the habitat.

The two noda occur in close juxtaposition to one another and often could not be mapped separately owing to the formation of a small-scale mosaic. Areas with tufts of Kobresia were assigned to mapping unit 1 and those without it to mapping unit 2. The thick shiny shoots of Rhytidium were sometimes to be found in the latter.

Nodum typicum of  $\beta$  Nodal group with Minuartia verna (Mapping unit 3)

As described above, this forms a floristic link between the other noda of this  $\beta$  nodal group and the  $\beta$  nodal group with Carex pulicaris and Polygonum viviparum since it has six of the eight differentials for the latter.

The nodum occurs as part of the limestone grassland complex which is not immediately adjacent to the eroding sugar limestone edges, and develops on flat ground or, more commonly, on banks sloping at angles of up to  $10^{\circ}$ . Physiognomically, as well as floristically, it is of an intermediate appearance. The patches of exposed sugar limestone or small rocks may total 30% of the area but are more likely to range from 10% to 20%, or there may be complete vegetation cover. Phanerogam and Cryptogam cover/are <sup>values</sup> around 80% to 90% and 70% to 75% respectively although the latter can be as low as 30%. Occasionally there is a hummock-hollow aspect with Rhacomitrium lanuginosum forming the basis of the hummocks and the hollows having much exposed soil.

The general appearance is, as with mapping units 1 and 2, of a very coarse turf, the tufts of Carex capillaris, C. panicea and C. flacca contributing to this effect. Dense patches of Minuartia verna are occasionally seen and the general Phanerogam aspect is much less concentrated than <sup>in</sup> mapping unit 5. The average species number is 33, intermediate between mapping units 1 and 2 and mapping unit 5.

β Nodal group with Carex pulicaris and Polygonum viviparum  
(Mapping units 4 to 7)

Carex pulicaris and Polygonum viviparum are the only absolute differentials, the others - Galium sternerii, Viola riviniana, Carex capillaris, C. caryophyllea, Gentiana verna and Cladonia arbuscula - are shared with mapping unit 3.

The β nodal group is divided into two δ nodal groups each with two noda. All occur on deeper and more humus-rich soils than do mapping units 1 and 2.

δ Nodal group with bryophytes (Mapping units 4 and 5)

Syn.: Seslerio-Caricetum pulicaris Shim. 1968 sub-ass. typicum

The two noda of this nodal group are often adjacent, intergrading to such an extent that on several occasions they have been mapped as a mosaic. The three species of differentiating bryophytes - Rhytidiadelphus squarrosus, Pleurozium schreberi and Hypnum ericetorum - are all indicative of damp, somewhat base-poor conditions.

Nodum with Plantago lanceolata (Mapping unit 5)

Syn.: Typical variant of Seslerio-Caricetum pulicaris Shim. 1968  
sub-ass. typicum

The vegetation is usually dominated by Sesleria caerulea and Festuca ovina and Carex capillaris often has high cover also. In some places Briza media or the glaucous sedges (Carex panicea and C. flacca) may be very apparent and Thymus drucei sometimes forms a close mat. Rosettes and clumps of plants of the differential species group of Plantago lanceolata, Hieracium pilosella and Thuidium tamariscinum play a part in the overall appearance of the turf which is further diversified by species normally associated with grazing and manuring such as Cerastium holosteoides, Bellis perennis, Achillea millefolium, Trifolium repens and Lotus corniculatus. The presence of this group shows the affinity of the nodum to the Ranunculo-Anthoxanthion. A study of Table III shows that these companion species and a number of others occur principally in this nodum or only here and in mapping unit 4.

The mean number of species per 2 sq m is 42 which is higher than any other mapping unit of the sub-alliance although a value that is very closely followed by mapping unit 7.

The turf is often moderately or very dense with 100% cover; in this form the nodum occurs along and near the sheep tracks. However, close but not adjacent to the sugar limestone edges, the turf may be rather hummocky with up to 40% (more usually only 10%) of exposed soil. The nodum is generally found on flat or slightly sloping ground but has been recorded on terrain inclined at up to 30°. In an area of (apparently) old molehills the nodum shows two different aspects; on top of the molehills amongst the patches of Sesleria and Festuca ovina there is much Cladonia arbuscula, whilst between the hummocks the Phanerogam cover is complete and has considerably more Carex capillaris.

This habitat type approaches that of the limestone "pavement" of the Fell-top where mapping unit 5 is present on the thinner soil above the pieces of limestone and mapping unit 21 (Ranunculo-Anthoxanthion) with its larger proportion of broad-leaved herbs on the deeper soil between them. These two mapping units also occur as a mosaic on ground which is only slightly undulating, where the two different vegetation aspects enable the components to be recognised. A similar physiognomic separation can be made in the Slapestone Sike area and on the Fell-top where the slightly domed expanses of mapping unit 5 dominated by Sesleria and Carex capillaris stand out from, and are separated by, the channels with the fine-leaved mapping unit 33 of the Empetrium with which it has floristic affinities. The nodum with Plantago lanceolata differs by only a few species (see Table III) from mapping units 4 and 6 of the same nodal group with both of which it may form a mosaic. Overall, mapping unit 5 covers the largest total area of limestone grassland on Widdybank Fell.

Nodum with Calluna (Mapping unit 4)

Syn.: Calluna-Empetrum variant of Seslerio-Caricetum pulicaris Shim.1968  
Sub-ass. typicum

This is the other component of the nodal group and most frequently occurs adjacent to the nodum with Plantago lanceolata and also to mapping unit 32 of the Empetrium which may be a floristically impoverished successor of mapping unit 4.

The differential species group comprises Calluna vulgaris, Agrostis stolonifera, Polygala serpyllifolia and Rhytidiadelphus loreus. Very many of the differential species of the  $\mathcal{L}$  nodal group, such as Gentianella, Plantago maritima, Ditrichum flexicaule, Tortella tortuosa, Helianthemum chamaecistus and Scapania aspera, are virtually absent from this nodum due to the different micro-environment created by the Calluna bushes, and the mean species number drops to 34. Sanguisorba officinalis makes its only important contribution to the vegetation of the  $\mathcal{L}$  nodal group in this nodum and Thalictrum alpinum occurs sparsely both here and in mapping unit 7.

Calluna is the floristic dominant, the bushes often being 10 to 15 cm tall and covering 60% to 75% of the area, except in those places where its colonisation of mapping unit 5 is still at an early stage. (Comparison of aerial photographs taken in 1953 and 1956 with those taken in 1969 suggests that Calluna slowly spreads into the adjacent grassland.) Other Phanerogams have a cover of about 80% and Cryptogams of 30% to 50%. Total cover is frequently 100% but there may be from 10% to 20% of exposed soil due, probably, to the activity of moles. The nodum rarely develops over flat ground, slopes of up to 5° facing north-west to south-west being favoured.

In addition to forming a mosaic with mapping unit 5, this nodum also forms one with mapping unit 7 which is found in damper environments than the other mapping units of the sub-alliance. Occasionally the nodum with Calluna forms the hummocks in a complex with mapping unit 9 (Caricion davallianae) which grows on ground almost continually irrigated with highly calcareous water. This complex has been seen only in the Fold Sike area.

$\mathcal{L}$  Nodal group with Kobresia (Mapping units 6 and 7)

Syn.: Seslerio-Caricetum pulicaris Shim. 1968  
Sub-ass. kobresietosum

Kobresia simpliciuscula is the sole differential species for this nodal group. Mapping unit 7 shows affinities with the noda of the Caricion davallianae and mapping unit 6 often intergrades with mapping unit 5.

Nodum typicum of  $\delta$  Nodal group with Kobresia (Mapping unit 6)

This has no differential species additional to that of the nodal group although the sub-alliance differential Polygala amara shows a preference for the nodum. The differential species of the  $\mathcal{L}$  and  $\beta$  nodal groups are well represented and the mean species number is 33.

The most usual aspect is of a turf having 80% to 100% Phanerogam cover dominated jointly by Kobresia, Sesleria and Festuca ovina with frequent tufts of Carex capillaris. Where the Phanerogam carpet is broken, Rhacomitrium spp., Tortella tortuosa, Ditrichum flexicaule, Cetraria islandica or other species of the 30% to 50% cover Cryptogam layer are exposed. In places, soil or sugar limestone may account for about 10% of the area. The nodum is often encountered forming flat or only slightly hummocky patches in close proximity to the eroding sugar limestone edges with a NSW to NW aspect and a slope of about 5°. It is one of the communities which develops in areas of calcareous seepage and also adjacent to the sikes. Occasional dense patches of Kobresia forming a slightly raised portion in mapping unit 5 have been mapped as this nodum or as a complex with mapping unit 5. Similar treatment was applied where Kobresia and other species of its  $\beta$  nodal group occur in mapping unit 3.

Nodum with Primula farinosa (Mapping unit 7)

This is floristically very closely related to mapping unit 8 of the Caricion davallianae and the two are often contiguous. The differential species are Primula farinosa and the sedges Carex lepidocarpa and C. hostiana. These, together with Kobresia, Sesleria, Festuca ovina and, less frequently, Carex capillaris, have prominent rôles in the general physiognomy. Occasionally also conspicuous are Tofieldia pusilla and Pinguicula vulgaris both differentials for mapping unit 8. The mean species number is 41 which is greater than in mapping unit 6 and reflects the addition of Caricion davallianae species to the  $\delta$  nodal group.

Cover is usually 100%, that of the higher plants being about 90% to 95% - greater than in the other noda - and that of the lower 40% to 60%. Where the Phanerogam cover is broken, the mosses Ctenidium molluscum and/or Tortella tortuosa may be exposed. Occasionally, instead of a flat topography a hummock-hollow complex is developed, probably over old molehills, the height difference ranging from 3 to 30 cm. As with

Aufnahmen later assigned to mapping unit 8, the two components were initially recorded separately because they are of differing physiognomy. The hummocks are dominated by Sesleria with sometimes high Carex panicea and C. hostiana, and the hollows have a greater proportion of Carex spp. and sometimes a lower total Phanerogam cover. However, the species differences were not sufficiently great to enable the hummocks and hollows to be placed in different mapping units and the records were subsequently amalgamated.

The nodum has a limited occurrence as a mixture with mapping unit 4 where it has been mapped as a mosaic, but chiefly it is found in damp, highly calcareous places such as on the banks immediately adjacent to and above the Sikes where there is periodic inundation. In more low-lying areas which may be more frequently irrigated, mapping unit 8 often develops and in places which are dryer, mapping unit 6 is present.

The syntaxonomy and classification of the  $\mathcal{L}$  Nodal group

Table V and Fig. Ib)

The problems of the classification and syntaxonomy of the nodal group are greatly reduced when reference is made to Shimwell's (1968) study of the limestone grasslands of the British Isles. He provides a framework within which can be placed both those Teesdale communities described above and the similar ones studied by Pigott (1956) and by Ratcliffe (1966). The classification of the  $\mathcal{L}$  nodal group and the noda given in Fig. Ib) is that of Shimwell 1968, together with some amendments; the scheme is discussed more fully below. The complete synonymy of the noda can be summarised as:

$\mathcal{L}$  Nodal group with Sesleria caerulea and Koeleria cristata

- Pasture with Alpine plants     Lewis 1904
- Festuco-Seslerietum     Balme 1954
- Sugar limestone turf - tussocky and smooth types     )     Pigott 1956
- Grassland on unaltered limestone p.p.     )
- Limestone grassland     Sinker 1965
- Seslerieto-Festucetum     )     Ratcliffe 1966
- Festuceto-Callunetum     )
- Seslerio-Caricetum pulicaris     Shim. 1968
- Sub-ass. typicum - typical variant
- Calluna-Empetrum variant
- Ditrichum-Rhytidium variant
- Sub-ass. kobresietosum

In the text accompanying his maps of the distribution of the vegetation of the basins of the Rivers Eden, Tees, Wear and Tyne, Lewis (1904) describes a "pasture with Alpine plants" which forms part of the "Alpine moorland". He gives the habitat of this vegetation as being chiefly on limestone and sandstone bands and the list of rare species occurring in it includes many of those found in the  $\mathcal{L}$  nodal group. Although his lower limit of the Alpine moorland is at 2,000 ft (610m) and the highest point of limestone grassland on Widdybank Fell is only about 1,650 ft (503m), Lewis' "pasture" seems to include those communities described here.

The Association Seslerio-Caricetum pulicaris has been erected by Shimwell (1968) to include the damp limestone grasslands dominated in the typical variant of the sub-ass. typicum by Sesleria caerulea, Carex pulicaris and Festuca ovina. The communities are found in suitable localities in an area of the Pennines extending from the Craven district to Westmorland. Shimwell has included in his table Aufnahmen from that vegetation in the Craven to which the names of Balme (1954) and Sinker (1965) refer, as well as some from Widdybank and Cronkley Fells and several from the other localities of the association.

Both Ratcliffe's (1966) Sesleriето-Festucetum and Festuceto-Callunetum and the noda of the  $\mathcal{L}$  nodal group can be accommodated within the Seslerio-Caricetum pulicaris although some re-arrangement of the component Aufnahmen, especially of the Sesleriето-Festucetum, is required (see Table V). This summary shows only constancies of class, order and alliance character species, of association, sub-association, variant and sub-variant differentials, and of companions with constancy V. The Aufnahmen of the typical and Filipendula-Geranium variants of the sub-ass. typicum, the sub-ass. dryadetosum and the sub-ass. of Saxifraga and Cochlearia come from a more extensive area of the central and north Pennines than those of the other components of the association which come solely from Widdybank and Cronkley Fells.

The picture of the Seslerio-Caricetum pulicaris given in Table V is, therefore, an amplified version of Shimwell's original work and, whereas his presented an overall view of the association, this table is weighted in favour of the vegetation of Widdybank and Cronkley Fells since all the additional information comes from that area alone. Nevertheless, the communities found here form a phytosociologically important part of the association. A number of species was recorded almost exclusively in this region and some "tidying up" of Shimwell's association table is

SUMMARY, AMENDMENTS AND SYNONYMY OF THE  
SESLERIO-CARICETUM PULICARIS SHIM. 1968

. ASSOCIATION SESLERIO-CARICETUM PULICARIS Shim. 1968 emend.

SUB-ASS. typicum

typical variant Shim. 1968

syn.: Nodum with Plantago lanceolata p.p.  
Sesleriecto-Festucetum Ratcliffe 1966 p.p.  
Nodum typicum p.p. of  $\beta$  nodal group with Minuartia verna

Calluna-Empetrum variant Shim. 1968

syn.: Nodum with Calluna  
Festuceto-Callunetum Ratcliffe 1966 p.p.

Carex ericetorum variant

Rhytidium sub-variant

syn.: Ditrichum-Rhytidium var. Shim. 1968  
Nodum with Rhytidium

Kobresia sub-variant

syn.: Nodum with Kobresia  
Sesleriecto-Festucetum Ratcliffe 1966 p.p.

Kobresia variant

typical sub-variant

syn.: Sub-ass. Kobresietosum Shim. 1968 p.p.  
Nodum typicum of  $\delta$  nodal group with Kobresia  
Sesleriecto-Festucetum Ratcliffe 1966 p.p.

Carex lepidocarpa sub-variant

syn.: Sub-ass. kobresietosum Shim. 1968 - Carex lepidocarpa facies  
Nodum with Primula farinosa  
Sesleriecto-Festucetum Ratcliffe 1966 p.p.

Filipendula-Geranium variant Shim. 1968

SUB-ASS. dryadetosum Shim. 1968

syn.: Nodum with Plantago lanceolata p.p.  
Nodum typicum p.p. of  $\beta$  nodal group with Minuartia verna

SUB-ASS. of Saxifraga and Cochlearia Shim. 1968

achieved when the two Aufnahmen from Widdybank and/or Cronkley are extracted from each of the sub-associations typicum and dryadetosum. However, the values of the mean constancies of occurrence of these species - Carex capillaris, Cladonia arbuscula, Polygonum viviparum, Ditrichum flexicaule and Viola rupestris - are about III and do not provide sufficient grounds for the erection of a sub-association. The subdivisions which have been made are, therefore, based on other floristic criteria.

A further complication in a classification which results from a small-scale survey is revealed by a comparison of Figs Ia) and Ib). Some of the groupings of nodes shown in Fig. Ia) are no longer considered to be valid for inclusion in the scheme of Fig. Ib). In particular, the differentiation into  $\beta$  nodal groups has no counterpart in Shimwell's data for Minuartia verna and several differentials of the other  $\beta$  nodal group are widespread throughout the various facets of the association. (Other modifications made at the  $\delta$  nodal group level are discussed below.) This reappraisal of differential species and groupings which is a consequence of placing a detailed and small-scale survey in the context of one at a larger scale does not invalidate the former and, as explained below, the process also gives rise to reconsideration of the value of some of the differentials of the latter. The resulting amendments of the association together with its synonymy are given in the summary on the facing page.

The Sub-association typicum of Shimwell (1968) has a number of variants of which the typical (col. A) is the most widespread. Several other vegetation types may be placed within this category. These include the Nodum with Plantago lanceolata - except for one Aufnahme - (col. J), two very similar lists from Ratcliffe's Seslerieto-Festucetum (col. R), and the Nodum typicum of the  $\beta$  Nodal group with Minuartia verna, except for two Aufnahmen (col. N), together with three allied lists from the Seslerieto-Festucetum (col. S). With the rejection of Minuartia verna as a  $\beta$  nodal group differential, this unit becomes divided and the close floristic similarity of the nodum typicum (mapping unit 3) to the nodum with Plantago lanceolata (mapping unit 5) takes precedence over the affinity of the former to the  $\delta$  nodal group with Carex ericetorum. The "sparse turf dominated by Sesleria caerulea ssp. caerulea, Festuca ovina, F. rubra and Koeleria gracilis" of the "grassland on unaltered limestone" (Pigott 1956) also belongs to the typical variant. The Sesleria facies of the Agrost-Festucetum found in the Moor House N.N.R. by Eddy, Welch and Rawes (1969) is not of the same type (although one list, AS5, comes near to it) but is of the Ranunculo-Anthoxanthion.

The Calluna-Empetrium variant of the sub-ass. typicum (col. B) is reported only from Widdybank and Cronkley Fells by Shimwell (1968). The Nodum with Calluna (col. K) and three of the four lists of Ratcliffe's Festuceto-Callunetum (col. W) belong to this variant, the other list being allied to the Empetrium nigri, cf. mapping unit 32. It should be noted that this reclassification of the data from the present study results in the raising of the nodum with Calluna to a rank of equivalent status to that of the  $\delta$  nodal groups cf. that with Carex ericetorum. This comes about because the differentials of the  $\delta$  nodal group with bryophytes are no longer valid; Hypnum ericetorum and Rhytidialphus squarrosus occur more widely than in this nodal group alone and Pleurozium schreberi is more narrowly confined to the Calluna-Empetrium variant than the results of the present survey indicated.

Shimwell (1968) describes the Ditrichum-Rhytidium variant (col. C) of the sub-ass. typicum from the eroding sugar limestone edges of Widdybank and Cronkley Fells. These are habitats identical with most of those of the  $\delta$  Nodal group with Carex ericetorum (cols. O and P) which has a similar community structure and species composition to that of the variant and thus the two types are synonymous. However, the present survey has shown that there must be some revision of nomenclature and of differential species.

The communities of the variant would be more accurately described by re-naming it the variant with Carex ericetorum because Ditrichum flexicaule is also present in the other noda of the  $\delta$  nodal group and Rhytidium rugosum is found in only one of the two noda of the  $\delta$  nodal group. By contrast, Carex ericetorum is of constancies III and IV in these noda although it only occurs in one Aufnahme of Shimwell's Ditrichum-Rhytidium variant. Two of the other species used by him as differentials for this variant - Viola rupestris and Hieracium pilosella - are also located in other parts of the  $\delta$  nodal group, the former especially, and so cannot serve as differentials. The variant is divisible into two sub-variants each synonymous with a nodum, i.e. the sub-var. with Rhytidium (syn.: Nodum with Rhytidium mapping unit 2) differentiated also by the mosses Entodon concinnus and Barbula fallax as shown by Shimwell's work, and the sub-var. with Kobresia (syn.: Nodum with Kobresia mapping unit 1), cf. Table V. One of the lists (col. T) of the Seslerieto-Festucetum (Ratcliffe 1956)

belongs to the latter sub-variant and both the smooth and tussocky types of sugar limestone turf described by Pigott (1956) are referable to the former, although the list he gives from Cronkley Fell to illustrate the tussocky type (p. 564) resembles mapping unit 3 now placed in the typical variant.

Communities of the association from Widdybank Fell in which Kobresia simpliciuscula is co-dominant with Sesleria and Festuca ovina were placed in the Sub-ass. kobresietosum (cols. E and F) by Shimwell (1968) who also described a damper facies of the sub-association where Carex lepidocarpa is prominent (col. F). These two vegetation types have obvious affinities with the  $\gamma$  Nodal group with Kobresia (cols. L and M) and its Nodum with Primula farinosa (mapping unit 7 - col. M).

The additional information concerning the Seslerio-Caricetum pulicaris which has been obtained in the present study has enabled the status of the kobresietosum to be re-appraised. Many differentials of the noda on Widdybank and Cronkley Fells also occur in other, dissimilar, communities of the association and thus in the wider context can no longer be used to differentiate its components. Nevertheless the distribution of these species within the association helps to establish the degree of affinity of its parts. Using the results of the Widdybank survey in this manner, it is suggested that the sub-ass. kobresietosum Shim. 1968 be reduced to the status of a variant of the sub.-ass. typicum because of the generally close floristic similarities of these Kobresia communities to those of the typical and Calluna-Empetrum variants. This similarity is evident from the list of species that serve as differentials for the relevant  $\beta$  nodal group, cf. Fig.1a) and Tables III and IV.

Two sub-variants can be distinguished. The first is a typical to which belong the Nodum typicum of the  $\gamma$  Nodal group with Kobresia (col. I), three Aufnahmen from Shimwell's sub-ass. kobresietosum (col.E), and most of the Kobresia containing lists from Ratcliffe's Seslerieto-Festucetum (col. U). The second is a Carex lepidocarpa sub-variant in which are placed Shimwell's two Aufnahmen from the Carex lepidocarpa facies (col.F), the Nodum with Primula farinosa (col. M) and two lists from the Seslerieto-Festucetum (col. V).

No communities referable to either the Filipendula-Geranium variant of the sub-ass. typicum or the sub-ass. of Saxifraga and Cochlearia have been found by the present author. However, three Aufnahmen were made whose counterpart is the Sub-ass. dryadetosum (col. G). They were not

TABLE A  
THE PHYTOSOCIOLOGICAL AFFINITIES OF THE NODAL GROUP  
WITH SESLERIA AND KOELERIA

Nodum (Mapping unit) No.	1	2	3	5	4	6	7
<u>Festuco-Brometea and Brometalia character species</u>							
Koeleria cristata	V	IV	V	V	V	V	V
Gentianella amarella	I	III	IV	IV	I	IV	III
Helianthemum chamaecistus	V	V	III	II	I	III	II
Helictotrichon pratense	II	I	I	I	I	I	II
Helianthemum canum		II					
Hippocrepis comosa		I					
Anthyllis vulneraria		I					
Scabiosa columbaria				I			
<u>Mesobromion character species</u>							
Carex ericetorum	IV	III		I	I		
<u>Seslerio-Mesobromion differential species</u>							
Sesleria caerulea <sup>#</sup>	V	V	V	V	V	V	V
Cornicularia aculeata	III	V	V	IV	I	II	II
Galium sternerii	I	II	V	V	V	V	V
Carex capillaris		I	V	IV	I	V	V
Gentiana verna			III	III	III	III	IV
Primula farinosa <sup>#</sup>		I					V
Viola rupestris	V	III	I	I		I	I
Rhytidium rugosum	I	III					
Polygala amara <sup>#</sup>			I	I		II	
Dryas octopetala		I	I	I			
Epipactis atrorubens				I			
<u>Elyno-Dryadetalia (O.) and Kobresio-Dryadion (All.)</u> <u>(Elyno-Seslerietaea) character species in Scotland</u>							
O. Sesleria caerulea (rare)	V	V	V	V	V	V	V
O. Potentilla crantzii			I	I	II	II	
All. Dryas octopetala		I	I	I			
<u>Character species of the equivalent Order in C. Europe</u>							
Gentiana verna			III	III	III	III	IV
<u>Differential species of Kobresio-Dryadion (from Seslerio-Mesobromion)</u>							
Polygonum viviparum		I	III	III	III	III	III
Saxifraga aizoides				I			
<u>Character species of Tofieldietaea and Caricion davallianaë (Parvocaricetea)</u>							
Carex lepidocarpa					I		III
C. hostiana						I	III
Tofieldia pusilla							II
Drepanocladus revolvens							II
Campyllum stellatum							I
Fissidens osmundioides				I			
Equisetum variegatum					I		

# Character species (Shimwell 1971c)

sufficiently distinctive to be assigned a separate position in the  $\alpha$  nodal group, but now have been extracted from their noda (two Aufnahmen from the Nodum typicum of the  $\beta$  Nodal group with Minuartia verna and one from the Nodum with Plantago lanceolata) and are given in col.Q. As with the sub-association, all three are characterised by the physiognomic dominance of Dryas octopetala in the sward. A fourth has, in addition, Carex ericetorum and so has been left in the nodum (sub-variant) with Rhytidium.

In Fig. 1b) the most recent synonymy of the  $\alpha$  nodal group and noda (i.e. that based upon the work of Shimwell 1968) is given. Together with the modifications described above, this gives their classification according to the principles of the Z-M school.

The synsystematic placing of the  $\alpha$  nodal group

Table I and Table A

Table I gives the class, order and alliance character species of those higher syntaxonomic units into which the mapping units described in this thesis are considered to fall. Many of those for the class Festuco-Brometea, order Brometalia and alliance Mesobromion are localised in the seven noda of the  $\alpha$  nodal group with Sesleria and Koeleria. Only Koeleria and Gentianella amarella are found elsewhere - in mapping units 21 and 32 - none of which is a typical representative of its alliance. Similarly, five of the eleven sub-alliance differentials (after Shimwell 1968\*) occur only in the nods of this  $\alpha$  nodal group. The occurrences of these character and differential species are shared amongst the noda and their constancies fall off appreciably only in those two with pronounced links with other alliances.

Mapping unit 4 (the nodum with Calluna of the  $\beta$  nodal group with Carex pulicaris and Polygonum viviparum) has affinities with the Empetrium nigri (heath communities) of the Nardo-Callunetea, having high constancies of Calluna vulgaris and Hypnum ericetorum. It also has Polygala serpyllifolia of the Violion canina.

The presence of the last two of these reflects the particular micro-environment created by the Calluna bushes, also shown by the reduction in constancy of Brometalia and Mesobromion species.

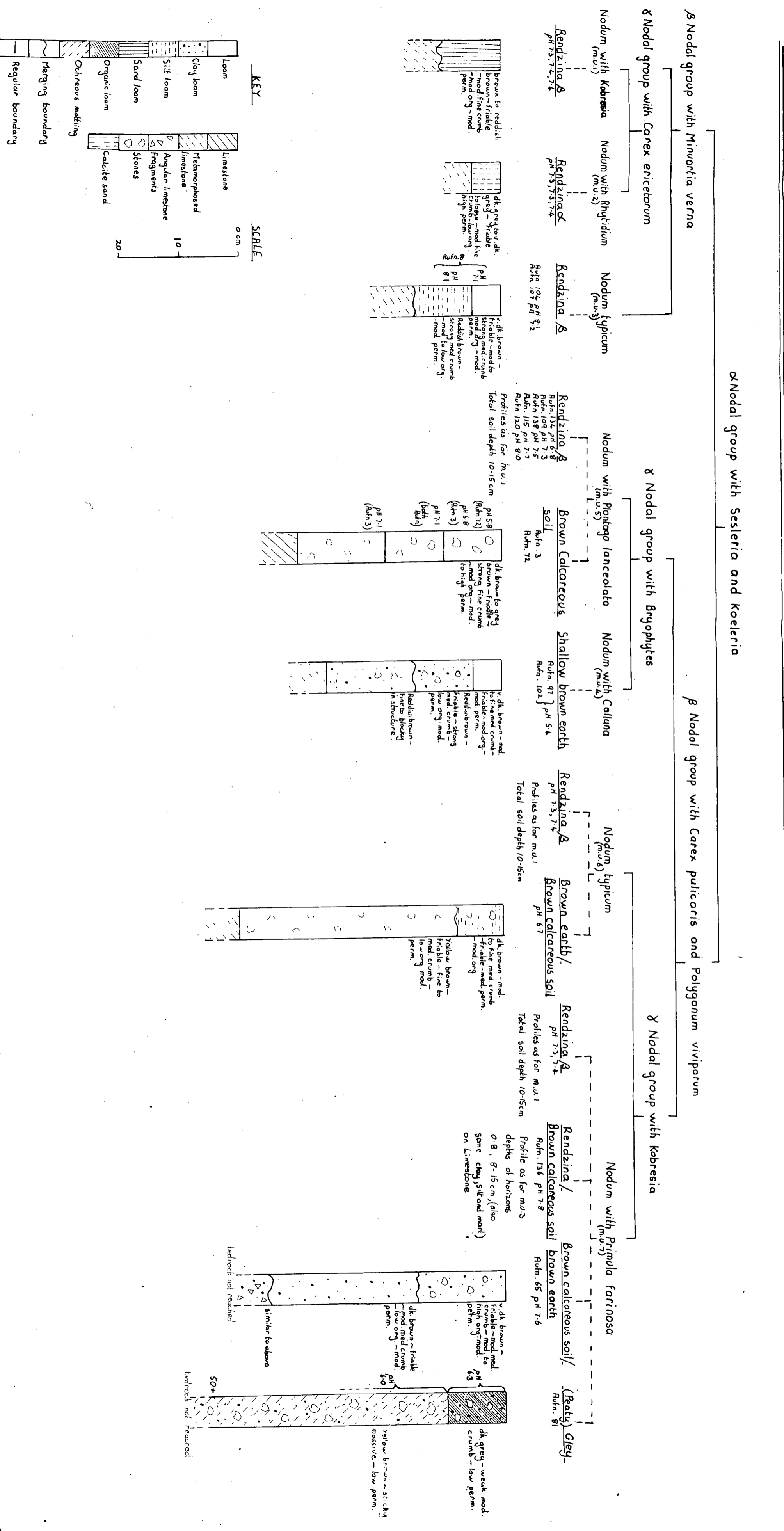
Reference has already been made to the links of mapping unit 7 with the Caricion davallianae. The damper, highly calcareous environment permits the occurrence of such order and alliance character species as Carex lepidocarpa, C. hostiana, Tofieldia pusilla, Drepanocladus revolvens and Campyllum stellatum. The last three species have constancies

\* Four are given as characters in Shimwell (1971c).

in mapping unit 7 of less than III. This is also the case for several of the Ranunculo-Anthoxanthion species of mapping unit 5 - Taraxacum officinale, Trifolium repens, Cerastium holosteoides and Achillea millefolium. Only Plantago lanceolata attains a constancy of III. The links of this mapping unit with the Ranunculo-Anthoxanthion are therefore present but of no great significance.

However, in addition to the relationships already described, there is a more fundamental link which affects the placing of the whole of the  $\mathcal{L}$  nodal group. This is its affinity to the class of the arctic-alpine grass-heaths, the Elyno-Seslerietea Br.-Bl. 1948, and in particular to the alliance and order occurring in the British Isles, the Kobresio-Dryadion Nord. (1936) 1943 emend. McVean and Ratcliffe 1962 of the Elyno-Dryadetalia Br.-Bl. 1948 (Shimwell 1969). In the British Isles this has received most extensive treatment by Shimwell (1969). He describes the occurrence of the class in northern and north-western Scotland, reaching down to sea-level in the extreme north-west, and in more restricted localities in Snowdonia, the Lake District and County Sligo in Ireland, as well as at suitable altitudes in the Alps, Pyrenees, Scandinavia and Iceland. The three out of the thirteen alliance and order character species given by him which have been recorded on Widdybank and Cronkley Fells are given in Table A together with the two order differentials and one character species of the Seslerietalia caeruleae Br.-Bl. 1926, the equivalent order in the Alps and the Pyrenees. Shimwell considers that the communities of the Seslerio-Caricetum pulicaris in northern England and of other associations of the Seslerio-Mesobromion in western Ireland form a phytogeographic link between the classes Festuco-Brometea and Elyno-Seslerietea and that, although a few of his Aufnahmen from Cronkley Fell could have been placed in the latter class, the Seslerio-Caricetum pulicaris shows greater floristic, geographic and edaphic affinities with the sub-alliance Seslerio-Mesobromion of the class Festuco-Brometea.

One of the points he gives in favour of this is that the southernmost stands of the association in the Craven district of the Pennines, have a more typical complement of Mesobromion character species than those further north which complete the total range of variation within the association. The present survey is confined to stands in the northern (although not the most northerly) part of the association's range but, even so, the closer affinities to the Seslerio-Mesobromion can be seen from the constancy estimates in Table A. Study of this also reveals that there is a slight concentration of Festuco-Brometea species in mapping units



4 to 7, i.e. Gentiana verna and Polygonum viviparum. These two groups of nodal have the same composition as the two  $\beta$  nodal groups obtained by the primary division of the data and reflect the closer affinity of mapping units 4 and 5 with 6 and 7 in contrast to that suggested by initial comparison with Shimwell's (1968) work from which 4 and 5 would be allied with 1 to 3. Mapping units 1 and 2 are the most xeric of the  $\alpha$  nodal group, occurring in habitats that appear closest to those suitable for the other Brometalia alliance, the thermophilous Eu-Mesobromion (cf. the occurrence of Carex ericetorum in Eu-Mesobromion communities of the Breckland), but are retained within the Seslerio-Mesobromion because of the presence of several differential species of this sub-alliance.

This intermixing of Festuco-Brometea and Elyno-Seslerietea species is similar to that described by Oberdorfer (1957) and by Shimwell (1968) for the upper altitudinal boundaries of the Festuco-Brometea in the Alps and the Pyrenees respectively. The former author considers this intermixing to be a relic of the changes in distribution of vegetation types that have taken place since the last Ice Age.

#### The soils of the $\alpha$ Nodal group with Sesleria and Koeleria

The diagrammatic soil profiles are shown in Fig. II and the soil analyses in Table VI. The terminology of Rendzina  $\alpha$ ,  $\beta$  and  $\gamma$  is that developed by Hornung and described in Johnson, Robinson and Hornung (1971).

Almost all the soils associated with the  $\alpha$  nodal group have high values of pH and exchangeable calcium; the only exceptions are those of the Nodum with Calluna in which the accumulation of raw humus from the Calluna bushes increases the soil acidity (cf. Welch and Rawes 1969).

The mapping units have been described in the preceding account, following the sequence 1, 2, 3, 5, 4, 6, 7 which reflects the changing composition of the communities of the  $\alpha$  nodal group as individual and groups of species are added and removed. Mapping units 1 and 2 are sufficiently floristically similar to one another and to mapping unit 3 to enable these positions to be reversed in the arrangement of Fig. II without destroying its significance. The ordination in this revised order (mapping units 2, 1, 3, 5, 4, 6, 7) of the soil-types associated with the mapping units has three features:

- (1) an increase in soil depth;
- (2) a slight increase in humus content;
- (3) greater diversity in the soil-types of a particular nodum

although the special nature of the vegetation of mapping unit 4 causes its soils to be likewise somewhat "out of step".

It was observed in the field that the communities of the Nodum with Rhytidium (mapping unit 2), always situated on the eroding sugar limestone, were subjected to extremely xeric conditions. Hornung has found that Rendzina  $\alpha$  is always associated with this mapping unit (cf. Fig. II). Johnson, Robinson and Hornung (1971) remark that of all the rendzinas on the Fell, this contains the least amount of humic material (cf. Table VI) and is the shallowest, having formed where the overlying drift has been completely removed.

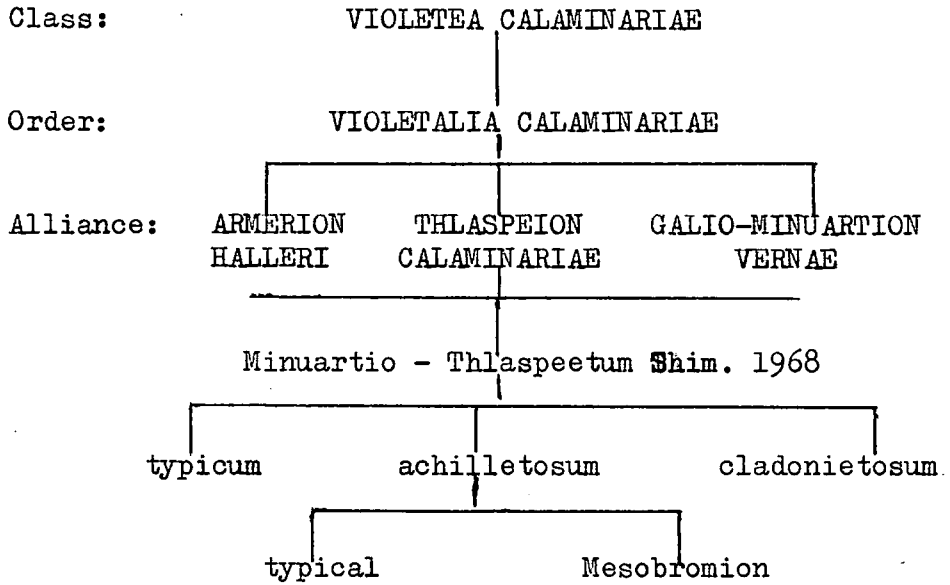
They also describe the formation of Rendzina  $\beta$  in places where the drift is less than 30 cm deep and mention that it is much more widespread than Rendzina  $\alpha$ . It is a striking feature of Hornung's findings that the  $\beta$  rendzinas support both the communities of mapping units 1 and 3 and also some of those of mapping units 5, 6 and 7 (Fig. II). Variation in colour and texture of the surface layer of this soil sub-type and its gradation into the soils developed over unaltered Carboniferous limestone is described by Johnson, Robinson and Hornung. The chemical properties of the  $\beta$  rendzinas also show variability: for example, the calcium contents of those of mapping unit 1 are lower than those of mapping unit 5 (Table VI). This suggests that several forms of the rendzina may exist, each with a distinctive chemical composition and associated with a different nodum. However, it is apparent from Table VI that the brown calcareous soils of mapping unit 5 are less calcareous than the  $\beta$  rendzinas of mapping unit 1, showing that in the association of nodum with soil-types, factors additional to that of calcium content are operative.

The depths of the brown earths/brown calcareous soils, shown in Fig. II, range from 30 to 45+ cm (the bedrock at Aufnahme 65 of mapping unit 7 was not reached); this is in accordance with the observation of Johnson, Robinson and Hornung (1971) that these soils develop where the drift is 30 to 60 cm deep and is thus sufficiently shallow to allow the limestone bedrock to exert an influence on the soil chemistry. The peaty gley of Aufnahme 81 (mapping unit 7) has formed in an area flushed

with lime-rich water and the topographic aspect is one of a hummock-hollow complex with apparent differences in the vegetation of the two elements. However, the profiles of the soils of both are the same and the hummock-hollow height difference of from 3 to 6 cm is not sufficient to produce variation in the composition of the flora but only in the proportions of its constituents.

Mapping units 5, 6 and 7 differ from the others in that the soils underlying their communities may belong to one of a number of types. The soil differences within each nodum, however, cannot be linked with any substantial changes in the composition of the accompanying Aufnahmen. An instance of this is seen when comparisons are made between the compositions of Aufnahmen nos. 112, 136, 65 and 81 of mapping unit 7 (Table III) whose soils are Rendzina $\beta$ , Rendzina/brown calcareous soil, brown calcareous soil/brown earth and (peaty) gley respectively. Although the floristics of the Aufnahmen are not identical, they are all valid members of mapping unit 7. It is apparent from Table III that the floristic composition of mapping unit 3 and, especially, that of mapping units 1 and 2 is much less diverse than that of the other mapping units. It is therefore suggested that the communities of the former noda, formed by the association of a small number of species, require more rigorously defined soils than those of mapping units 5, 6 and 7 where a greater number of permutations of species' composition is possible, thus enabling a range of soils to be colonised.

SYNOPTIC CLASSIFICATION OF PARTS OF THE VIOLETEA CALAMINARIAE,  
WITH PARTICULAR REFERENCE TO WIDDYBANK FELL



Nodum with *Minuartia verna*  
and  
*Trifolium repens*  
syn.: *Minuartio-Thlaspeetum*  
Shim. 1968  
sub-ass. *achilletosum* -  
Mesobromion variant

Key  
┌ - - - - ┐ Vegetation present  
└ - - - - ┘ on Widdybank Fell

Class: VIOLETEA CALAMINARIAE R. Tx. 1961

A synoptic classification of those parts of the class to which reference is made in the text is given on the facing page.

The class comprises those communities which develop on soils rich in heavy metals - principally zinc, but also lead and copper - and is recorded throughout central Europe as far south as the Alps.

Syntaxonomy

They were formerly, as the alliance Violion calaminariae Schwick. 1933, placed in the Festuco-Brometea, but were subsequently separated out on account of their distinctive floristic and ecological nature (Tixen 1962).

The single order of the class is the

Order: VIOLETALIA CALAMINARIAE Br.-Bl. et R. Tx. 1943

Character species

Ernst (1965) names two, valid for both class and order; Silene cucubalis var. humilis (Wibel) Schwick (S. vulgaris in Clapham, Tutin and Warburg (1962)) and Minuartia verna ssp. hercynica (L.) Hiern. At the specific level both are found in Britain, their habitats including those of old mine workings; Minuartia verna occurs in Upper Teesdale. Shimwell (1968) regards them as being of doubtful status for each is an endemic race developed in response to stresses imposed by the substrate. (Similar considerations apply to the alliance character species.)

The original single alliance, Violion calaminariae, was split by Ernst (1965) into three with both geographic and floristic distinctions. These are the Armerion halleri, of central Germany, the Thlaspeion calaminariae occurring in western central Europe and the alpine Galio-Minuartion vernae.

All: Thlaspeion calaminariae Ernst 1965 .

Its distribution on the European mainland forms a zone extending from the south and south-west of France to north-west Germany and including Belgium and the Netherlands (Ernst 1968a, Westhoff and den Held 1969). Recent work in Britain by Ernst (1968a) and by Shimwell (1969) has extended the range to include the Mendips, Derbyshire and northern England, but Ernst stresses that because the

British vegetation is on the north-western boundary of the alliance it gives only an impoverished picture of communities of heavy-metal areas.

Character species

The only one is Thlaspi alpestre ssp. calaminare (Lej.) O. Schwarz (Ernst 1965). a sub-species which is not recognised in the British Isles although Ernst (1968a) assigns to it the British populations of Thlaspi alpestre growing in heavy-metal areas. Clapham, Tutin and Warburg (1962) describe four "types" for this polymorphic species and equate them with named continental taxa, whilst remarking that this process is not very satisfactory. These authors refer the type occurring in Derbyshire and also in the Inner Hebrides, to T. calaminare Lej. Court. (synonymous with the character species (Tutin et al 1964)), but the one present in Teesdale is allied to T. sylvestre Jord.. However, both these species are classified as variants of T. alpestre ssp. alpestre by Tutin et al who do not give their individual distributions, describing merely the occurrence of the sub-species (and the species) often on metal-mineheaps in the upland regions of south, west and central Europe. It is therefore probable that the T. alpestre in Teesdale is a sub-species other than ssp. calaminare, but this remains to be verified. There is no published report of a population of Thlaspi alpestre on Widdybank Fell, although there is a verbal record of one on an abandoned spoil-heap there. Riley (1956) describes its occurrence at Greenhurth mine on Herdship Fell (2½ miles to the north-west) and on igneous rock at Wynch Bridge (4 miles to the south-east, along the Tees).

Only one nodum belonging to the alliance has been distinguished :

Nodum with Minuartia verna and Trifolium repens (Mapping unit V)

Table VII

These communities usually develop along the sides (sloping at up to 20°) of the channels left after the trial excavations for galena, i.e. the opencuts, and on the resulting spoil-heaps. These features are frequently smaller than the minimum size that could be delimited at the 1:2,500 scale (about 25 sq m), and in these instances the vegetation has been indicated by an overprinted "V". Larger communities have been outlined, and also shown on the 1:10,000 map if of sufficient extent.

The total cover varies from 50-80%, that of the Phanerogams ranging from 40-70% and that of the Cryptogams from 10-40%. The unvegetated ground is frequently covered with limestone and barytes fragments. Aufnahme 100 was rather different from the others for it was made on the flat top of an old spoil-heap that had become almost completely covered with vegetation. Phanerogam cover was only 65% but there was an underlying carpet of Rhacomitrium lanuginosum with 95% cover.

The differential group of species includes many of those of the node of the Festuco-Brometea, e.g. Koeleria cristata, Cornicularia aculeata and Galium sternerii and, in addition, Viola lutea and Trifolium repens are present. The latter is also a differential for the  $\mathcal{L}$ nodal group of the Ranunculo-Anthoxanthion. Two of the companions, Plantago lanceolata and Taraxacum officinale s.l., are differentials for the  $\mathcal{L}$  and  $\delta$  nodal groups respectively of this other alliance.

Dominance is shared between Koeleria cristata and the constant companions Festuca ovina and Thymus drucei, shoots of the latter forming an open network beneath the others. Trifolium repens, Viola riviniana, Cornicularia aculeata and Gladonia subrangiformis, all differentials, have high constancy and appreciable cover. Tufts of the only character species present - Minuartia verna - play an important part in much of the turf.

The syntaxonomy and classification of the Nodum  
Table VIII

The only association of the Thlaspeion calaminariae described for the British Isles is the Minuartio-Thlaspeetum Shim. 1968; this provides a basis for the classification of the nodum (as did the Seslerio-Caricetum pulicaris for the  $\mathcal{L}$ nodal group with Sesleria and Koeleria). In addition, three of the six lists recorded by Eddy, Welch and Rawes (1969) on the "made ground" of the Moor House N.N.R. are akin to the Widdybank vegetation and can also be included in the association. (The Moor House unit comprises lists made on all the types of ground which has been disturbed by mining and quarrying and is consequently rather heterogeneous.) Pigott (1956) also refers to this type of vegetation for he describes how Thlaspi alpestre and Minuartia verna are often associated on old heaps of lead-mine spoil

SUMMARY AND SYNONYMY OF THE MINUARTIO-THLASPEETUM

ASSOCIATION MINUARTIO-THLASPEETUM Shim. 1968

SUB-ASS. typicum

SUB-ASS. achilletesum

typical variant

Mesobromion variant

syn.: Nodum with Minuartia verna and Trifolium repens

SUB-ASS. cladonietosum

syn.: made ground p.p. Eddy, Welch and Rawes 1969

in the Upper Teesdale area. In summary form, the synonymy of the nodum is:

Nodum with Minuartia verna and Trifolium repens:

Minuartio-Thlaspeetum Shim. 1968

sub-ass. achilletesum - Mesobromion variant

"Made ground" p.p. Eddy, Welch and Rawes 1969

That of the amplified association is given on the facing page.

The Nodum with Minuartia and Trifolium (col. E) is placed in the Mesobromion variant of the sub-ass. achilletesum (col. C) even though some of the differential species of both sub-association and variant are virtually absent (e.g. Anthoxanthum odoratum, and three of the Mesobromion species) and Cornicularia aculeata, a differential of the sub-ass. cladonietosum, is present with frequency V. However, the nodum is classified in the manner stated because

- 1) the general floristic and physiognomic appearance of the communities of the nodum is one of vegetation which is similar to that of the Seslerio-Mesobromion, although differing from it to such a degree that a separate classificatory position is sought, and
- 2) the altitude of the Widdybank Aufnahmen is within the range of that of the sub-ass. achilletesum in this part of the Pennines, and lower than that of the sub-ass. cladonietosum.

Shinwell (1968) describes the occurrence of the latter sub-association at higher altitudes than that of the other; in Derbyshire the transition takes place at 1,000-1,100 ft (305-335m). He includes in the sub-ass achilletesum-typical var. (col. A) one Aufnahme made on Widdybank Fell at an altitude of 1650 ft (503m) and, in the sub-ass. cladonietosum, three made at Moor House at 1850 ft (564m). The altitudes of the Aufnahmen of the Widdybank nodum and of the lists made at Moor House by Eddy, Welch and Rawes (1969) (col. F) are in the ranges 1600-1650 ft (488-503m) and 1788-1870 ft (545-570m) respectively. The latter group clearly belongs to the sub-ass. cladonietosum, although it is not without achilletesum influence with the occurrence therein of Rhytidialphus squarrosus. It would therefore seem that in this region of the Pennines, the transition from sub-ass. achilletesum to sub-ass. cladonietosum takes

place between about 1650 and 1790 ft (503-548m) and that the communities on Widdybank Fell are in the zone of transition.

The habitats of the sub-ass. achilletosum are given by Shimwell (1968) as "older spoil heaps or ones with a high proportion of limestone debris", conditions more or less fulfilled on Widdybank Fell. Mining was carried out near the point where the Birkdale track crosses Slapestone Sike as recently as the 1950s, but the operations over the other parts of the Fell were undertaken in the previous century. Aufnahme 100, referred to above, was made on the escarpment above Red Sike, an area which was probably mined in the early 1800s and the soil profile of this Aufnahme, described in detail below, contains a small amount of free calcium carbonate. It is likely that this is also the case for other localities of the nodum.

It is interesting to note that the surface of the Seslerio-Mesobromion grassland on the southern bank of Nameless Sike near its source (at the top of the escarpment above Red Sike) is extremely uneven and shows evidence of mining having taken place - perhaps during the early 1800s. Draba incana is scattered throughout this turf; although it was not recorded in any of the Aufnahmen, it is nevertheless found on some spoil-heaps on the Fell. It seems possible, therefore, that after the disturbance caused by the mining operations, communities of the sub-ass. achilletosum-Mesobromion var. developed, and that with the subsequent immigration of additional Mesobromion species, communities typical of this alliance have evolved. (See also the discussion on the presence of Mesobromion species within the nodum with Minuartia and Trifolium in the following section.)

The association has been described by Shimwell only from Britain but Ernst (1965) mentions the floristically distinct (Shimwell 1968) Ass. Thlaspeeto-Minuartietum Koch 1930 (from the Osnabrück region of western Germany) as a fragment of the Violetum calaminariae Schwick 1931. The latter, found in north-west Germany, Belgium and the Netherlands (Westhoff and den Held 1969) has in addition to the sub-ass. typicum the sub-associations achilletosum, cladonietosum and cardamin-opsidetosum (Ernst 1965), the floristic differences being related to those in age and nature of the soils. The sub-ass. cladonietosum

with differentials Cladonia rangiformis, C. chlorophaea and Calluna vulgaris (cf. the sub-ass. cladonietosum of Shimwell 1968) is found on more acid soil (pH 6.4) than the others and has a zinc content intermediate between those of the achilletosum and typicum which are respectively lower and higher. The sub-ass. achilletosum resembles the sub-association of the same name of the Minuartio-Thlaspeetum in England (Shimwell 1968) in that its differentials are Achillea millefolium and Plantago lanceolata and it is found on older, more humus-rich soil. Furthermore, it also has a variant with the Mesobromion species Koeleria cristata and Scabiosa columbaria which forms a mosaic with Mesobromion communities.

The synsystematic placing of the Nodum with Minuartia and Trifolium

Table B:

In preceding sections, reference has been made to the presence of both Festuco-Bromatea and Molinio-Arrhenatheretea species within communities of the nodum. Table B shows the constancies in the nodum of the character species of these classes and of the order and alliance of each represented on the Fell. The values for the nodum as a whole are given and, because of slight floristic differences within the nodum (cf. Table VII), two groups are shown - Group a (Nos. 100, 557 and 560) and Group b (Nos. 556, 558 and 559).

It is evident from Table B that only Minuartia verna out of the three character species named by Ernst (1965) for communities of the Thlaspeion calaminariae is present in the nodum. Soil analyses (Table IX) described in the following section show that the spoil-heaps of Upper Teesdale differ in composition from the true heavy-metal soils of both western Germany and Britain investigated by Ernst (1965 and 1968a respectively). A negligible amount of zinc is present in Teesdale and the concentration of lead in at least one of the sites sampled is not abnormal. Nevertheless, because of their floristic differences from the nodum of the other classes on the Fell, their often open nature, the presence of Minuartia, the distinctive nature of the substrate and their relationship to the Minuartio-Thlaspeetum Shim. 1968, it is considered that the communities of the nodum are most accurately classified in the Thlaspeion calaminariae of the Violetea calaminariae.

TABLE B

THE PHYTOSOCIOLOGICAL AFFINITIES OF THE  
NODUM WITH MINUARTIA AND TRIFOLIUM

	All Aufnahmen	Group a	Group b
<u>Violetea calaminariae and</u>			
<u>Violetalia calaminariae character species</u>			
Minuartia verna	IV	2	2
<u>Festuco-Brometea, Brometalia and</u>			
<u>Seslerio-Mesobromion character and</u>			
<u>differential species</u>			
Koeleria cristata	V	3	3
Cornicularia aculeata	V	3	3
Galium sternerii	IV	1	3
Gentianella amarella	III	1	2
Carex capillaris	III		3
<u>Molinio-Arrhenatheretea and</u>			
<u>Arrhenatheretalia character species</u>			
Plantago lanceolata	III		3
Taraxacum officinale s.l.	III		3
Climacium dendroides	II		2
Achillea millefolium	I	1	
Cerastium holosteoides	I		1

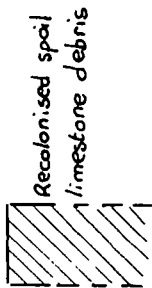
Key

- Group a - Aufnahmen nos. 100, 557 and 560  
Group b - Aufnahmen nos. 556, 558 and 559

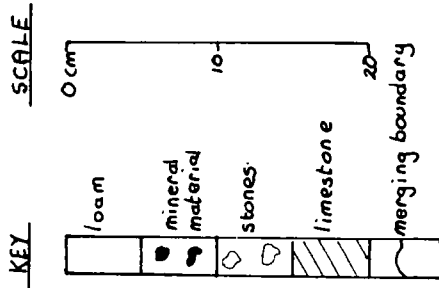
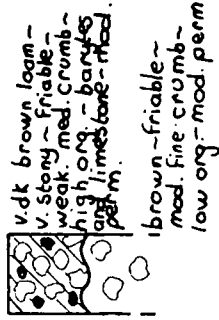
FIG. III DIAGRAMMATIC SOIL PROFILES OF THE NODUM WITH MINUARTIA AND TRIFOLIUM

Nodum with Minuartia and Trifolium

1. Rendzina initiale  
pH 7.8



2. Rendzina (on tip)  
pH 6.6  
A<sub>1</sub>m. 100



The spoil-heaps are generally only a few square metres in extent and the opencuts tend to be at most two to three metres deep. As a result, these communities are of a very small size, usually much less than those of the Mesobromion, amongst which the nodum is often situated. Along the bases of the opencuts there is frequently a narrow strip of vegetation of the Ranunculo-Anthoxanthion (mapping units 19, 20 or 21). The influence (seen from Table B) of these two alliances upon the nodum is not, therefore, particularly remarkable; the close proximity of other kinds of vegetation is an additional factor which inhibits the full development of the Thlaspeion communities. The three Aufnahmen of Group b (Nos. 556, 558 and 559) show most clearly the transition to the Ranunculo-Anthoxanthion, an alliance which is also only weakly represented on the Fell.

#### The soils of the Nodum

The two diagrammatic soil profiles are given in Fig. III and the results of the soil analyses in Table IX.

Both come from localities which are believed to have been mined during the last century. Profile 1 was made on the recolonised side of an opencut and profile 2 on a spoil-heap most probably deposited in the early 1800s and before the other was worked. This age difference is reflected in the types of substrate and the amount of vegetation cover at the two places. The material of profile 1 can scarcely be termed a "soil" for it is merely spoil composed of limestone débris, for which the name "Rendzina initiale" has been suggested by Hornung. The soil of profile 2 is a little more mature being a rendzine formed on material (containing much barytes and lead) dug out from the adjacent opencut. The values of plant cover recorded for the two profiles were 80% and 95% respectively.

The low humus and nitrogen contents are comparable to those of the Seslerio-Mesobromion communities to which the nodium is floristically related. Similarly, the pH of 7.6 from profile 1 could have been obtained from one of these soils. The higher lead concentration at Aufnahme 100 is a reflection of the galena found in the mining waste. However, the values for zinc are within the range of those obtained for many other vegetation types on the Fell and bear no comparison with

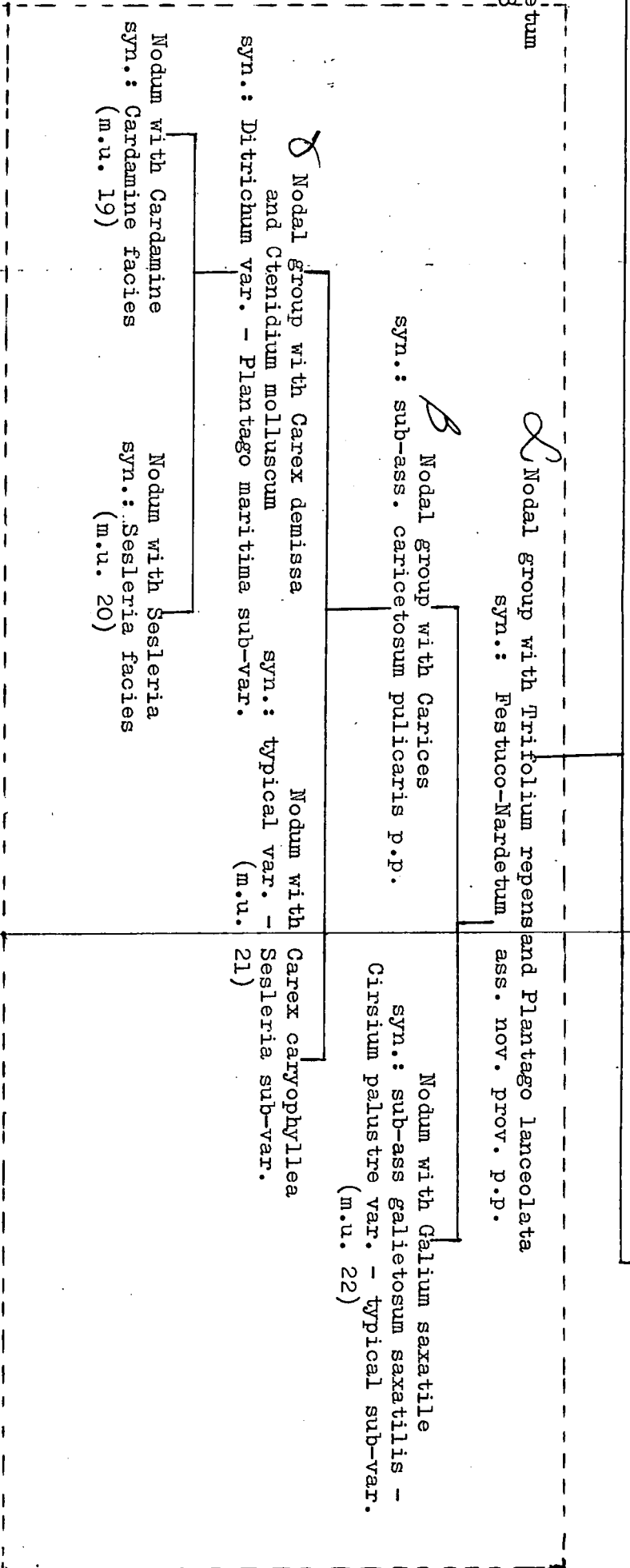
those quoted by Ernst (1965 and 1968b) for the sub-associations typicum, achilletosum, cladonietosum and cardaminopsidetosum of the Violetum calaminariae in Germany: about 5,700, 1,500, 3,000 and 6,000 p.p.m. respectively. Comparable values have been recorded (Ernst 1968a) for heavy-metal areas in the Mendips and the Pennines which support communities of the Minuartio-Thlaspeetum. This bears out the point made above that the communities on the opencuts and spoil-heaps of Widdybank Fell are not the most typical representatives of the class of communities of heavy-metal soils.

SYNOPTIC CLASSIFICATION OF PARTS OF THE MOLINIO-ARRHENATHERETEA  
 WITH PARTICULAR REFERENCE TO WIDDYBANK FELL

65-a

Class: MOLINIO-ARRHENATHERETEA  
 Order: HOLOSCHOENETALIA MOLINETALIA ARRHENATHERETALIA  
 Alliance: ARRHENATHERION POLYGONO-TRISEPTION CYNOSURION POION ALPINAE RANUNCULO-ANTHOXANTHION

Festuco-Poetum  
 Shim. 1968



Key

Vegetation present on Widdybank Fell.

Class: MOLINIO-ARRHENATHERETEA R. Tx. 1937  
(The "Neutral Grassland" of Tansley (1949) pp. 559-576)

Those parts of the class to which reference is made in the ensuing account are summarised on the facing page.

The class comprises the semi-natural vegetation of mires and river banks, and the anthropogenic communities of meadows and pastures. Herbs are preponderant and the moss layer is little developed. Suitable soils range from moist to wet, although superficially drying out in the summer, and vary from moderate to very nutrient-rich and from mildly acidic to basic in status. The class occurs throughout Europe from the euro-siberian to the mediterranean regions, at altitudes ranging from the lowlands to those of the mountains, wherever the ground is sufficiently moist due to precipitation or to topographic causes. The centre of its distribution is in the valleys or mid-mountain regions of western Europe.

#### Syntaxonomy

When he established the class (as the Molinio-Arrhenathereteas) Tuxen (1937) included within the Molinietalia the base-rich sedge-marshes of the Caricion davallianae, but subsequently this alliance was returned to its parent class and it is now part of the Tofieldietalia (cl. Parvocaricetea). The Molinio-Arrhenatheretea was later divided to give the classes Molinio-Juncetea Br.-Bl. 1947 and Arrhenatheretea Br.-Bl. 1947, but most recent authors (e.g. Lohmeyer et al 1962, Oberdorfer et al 1967, Westhoff and den Held 1969) have reconstituted the class and given them the rank of order (Molinietalia and Arrhenatheretalia respectively) within it. This move has been made in view of the considerable number of character species which they have in common and the occurrence of others transgressive between their orders and alliances (Westhoff and den Held 1969). Nevertheless, some (e.g. Soó 1957, Kovačs 1962) have retained the Molinio-Juncetea and added to it the Tofieldietalia. Westhoff and den Held remark that this continuing difficulty in classification results from the occurrence of communities which are transitional from the Molinio-Arrhenatheretea to the Parvocaricetea, and add that similar problems occur with ones allied to the Nardetalia (cl. Nardo-Callunetea).

Character species

Shimwell (1968) and O'Sullivan (1968) have both studied the class in the British Isles and the following list of character species for western Europe is a composite one drawn from their works:

Holcus lanatus <sup>#</sup>	Festuca rubra <sup>#</sup>
Poa trivialis	F. pratensis
P. pratensis	Alopecurus pratensis <sup>#</sup>
Helictotrichon pubescens	Cerastium holosteoides <sup>#</sup>
Rumex acetosa	Ranunculus acris <sup>#</sup>
Cardamine pratensis <sup>#</sup>	Rhinanthus minor
Lathyrus pratensis <sup>#</sup>	Viccia cracca
Plantago lanceolata <sup>#</sup>	Trifolium pratense
Poa subcaerulea <sup>#</sup>	

Oberdorfer (1957) and Westhoff and den Held (1969) add:

Prunella vulgaris <sup>#</sup>	Climacium dendroides <sup>#</sup>
Rhytidiadelphus squarrosus <sup>#</sup>	

Each of these occurs in the British Isles, most are very widely distributed and all are found in the Upper Teesdale area (Perring and Walters 1962). However, only eleven - those marked with an asterisk - have been found in the area of Widdybank Fell investigated; others grow in the pastures which lie about a mile down the Dale at an altitude of 1,200 ft (366m) where Rhinanthus minor occurs as its ssp. monticola whose exact phytosociological affinities are not given in the literature. Two of these, Prunella vulgaris and Rhytidiadelphus squarrosus, are frequent components of vegetation placed in other classes. Therefore these cannot be considered as character species of the Molinio-Arrhenatheretea on Widdybank Fell, nor perhaps in the British Isles as a whole. Those used as class characters are given in Table I.

Three orders are present in the class. Some authors add the vegetation of regularly flooded grasslands as the order Deschampsietalia caespitosae Horvatič 1956 (Passarge 1964) but these communities are usually contained within the Plantaginetea majoris R.Tx. et Prsg. 1950. Of the three orders, the Holoschoenetalia Br.-Bl. 1931 is confined to the north mediterranean region. The second, the Molinietalia caeruleae, is not found on the region of Widdybank Fell covered by the present investigation, although communities belonging to it are found a mile or two lower down Teesdale. This order is composed of the damp vegetation of meadows and pastures characterised by tall herbs and comparatively little affected by man.

The Widdybank communities belong to the

Order: ARRHENATHERETALIA ELATIORIS Pawlowski 1928  
(The "pastures" of Tansley (1949) p.566 et seq.)

This includes the vegetation found in rich agricultural land (cultivated meadows and white clover pasture) and in rough grassland, on nutrient-rich basic to slightly acidic loam and clay soils. It occurs throughout Europe where the climate is suitable, from the warmer and drier plains to the cooler high mountain regions with greater precipitation, but is only fragmentary in the north and the mediterranean regions as it favours a temperate climate.

Synonymy: Class Arrhenatheretea Br.-Bl. 1947 (see above)

Character species

These are chiefly after O'Sullivan (1968) and Shimwell (1968) and are, therefore, modified for the British Isles. They are:

Trisetum flavescens	Bromus mollis
Dactylis glomerata	Arrhenatherum elatius
Daucus carota	Knautia arvensis
Chrysanthemum leucanthemum	Taraxacum sect. vulgaria
Veronica officinalis	Bellis perennis
V. chamaedrys	Achillea millefolium
Trifolium dubium	Heracleum aphondylium

Almost all of these are present throughout the British Isles; a few are absent from northern Scotland. The only ones shown by Perring and Walters (1962) to be absent from Upper Teesdale are Trisetum and Daucus. From Table I it is apparent that only Taraxacum, Achillea, Bellis and Veronica officinalis occur in the Widdybank vegetation.

The four noda described below have been placed in the

All: Rumicula-Anthoxanthion Gjaerevoll 1956 emend. Shim. 1968, of northern, sub-boreal damp meadows and pastures, which corresponds very broadly to the arctic-alpine grasslands of Tansley (1949). This alliance is additional to the four listed by Oberdorfer et al (1967) as components of the order in central Europe. These are: the rich meadow Arrhenatherion, the sub-alpine and alpine meadow Polygono-Trisetion, the lowland pasture Cynosurion and the alpine pasture Poion alpinae.

As erected by Gjaerevoll (1956) the alliance, placed in the Salicetalia herbacea of the Salicetea herbaceae, was described as covering communities growing in areas of late snow-lie which still remained moist after the snow had melted. Shimwell (1968) has placed his association Festuco-Poetum - a damp sub-alpine limestone grassland - in the Ranunculo-Anthoxanthion, but assigned it to the Arrhenatheretalia. Gjaerevoll (1956) listed a number of flowering plants and grasses which are conspicuous in the alliance in Scandinavia, amongst them being Ranunculus acris, Rumex acetosa, Anthoxanthum odoratum, Deschampsia flexuosa and Alchemilla glomerulans (the latter is found in Britain only in certain meadows in Upper Teesdale and on damp rock ledges in north-west Scotland), and commented on the physiognomic dominance of Ranunculus acris. Although only a very few of the species listed in his survey table for the Ranunculo-Anthoxanthion are given as characteristic of either the Molinio-Arrhenatheretea or the Arrhenatheretalia by Oberdorfer (1957), Gjaerevoll's general description of the communities of this alliance as of "late snow-free meadows rich in flowering plants" is in harmony with the type of vegetation placed in this class and order by the Zürich-Montpellier school.

Shimwell (1968), in placing the Ranunculo-Anthoxanthion within the Arrhenatheretalia, has amended the description to include damp montane and sub-alpine meadows and pastures dominated by Deschampsia caespitosa, Festuca ovina, F. rubra, Agrostis tenuis, A. canina or Anthoxanthum odoratum, instead of restricting it to areas of late snow-lie as did Gjaerevoll in Scandinavia. Many Molinio-Arrhenatheretea character species are present, but there is an absence of the grass character species of the other alliances of the order, i.e. :

<u>Arrhenatherum elatius</u>	<u>Bromus mollis</u>
<u>Alopecurus pratensis</u>	<u>Dactylis glomerata</u>
<u>Poa pratensis</u>	<u>Trisetum flavescens</u>
<u>P. trivialis</u>	<u>Festuca pratensis</u>



Nodal group with *Trifolium repens* and *Plantago lanceolata*  
(Mapping units 19-22) Table XIV

Taken together, the four noda of this nodal group approximate to the description of the Ranunculo-Anthoxanthion given above and, accordingly, are placed in this alliance.

Both Balátová<sup>#</sup> and Tüxen<sup>+</sup> have suggested that the noda should be assigned to the Cynosurion. However, in this are placed rich, intensively managed meadows and the Arrhenatheretalia communities of Widdybank Fell are not managed in this manner. Furthermore, the only Cynosurion character species present is Trifolium repens, the grass characters Lolium perenne, Cynosurus cristatus and Phleum pratense being absent.

As a group, the noda show influences from the sub-alliance Seslerio-Mesobromion and from the alliances Caricion davallianae and Violion caninae. This is discussed below.

The floristic differentiation of the four noda is based on the table of constancies, Table XV, which summarises Table XIV. The key-card used in the field is given in Fig. Va.

The turf is closed, soft and rich in grasses, sedges and forbs with, usually, a well developed ground layer. The constant differentials Trifolium repens, Plantago lanceolata and Ranunculus acris play a prominent part in the turf, as do the constant companions Festuca ovina, Agrostis tenuis, Briza media, Prunella vulgaris and Acrocladium cuspidatum. The soils are generally well irrigated with a high water table and have pH values ranging from 5 (mapping unit 22) to 6 - 7 (mapping units 19 and 20).

Nodum with *Galium saxatile* (Mapping unit 22)

The differential species are Galium saxatile, Anthoxanthum odoratum and Agrostis canina but A. tenuis and Festuca ovina play a greater part than do the differentials in the dense, close-cropped turf which also contains a variable proportion of forbs. Cerastium holosteoides and Luzula campestris are constants, both contributing to the physiognomic appearance of the turf, but they are also found in mapping unit 21. The mean number of species is 26, considerably fewer than in the other noda.

# Balátová (1970) : personal communication

+ Tüxen (1970) : personal communication

The nodum is found on alluvial flats of several square metres beside the Tees and also adjacent to the Sikes and is one of a number of noda occurring in the channels between areas of blanket bog or heath where sheep tend to congregate.

The other three noda have very close floristic affinities and together form the

B Nodal group with Carices (Mapping units 19-21).

The constant differentials are: Carex pulicaris, C. flacca, C. panicea, Euphrasia officinalis, Viola riviniana, Galium sternerii, Bellis perennis, Deschampsia caespitosa, Agrostis stolonifera and Hylocomium splendens. Each nodum has a greater variety of species than the one already described. The soils are more calcareous and have a greater humic content.

The nodal group is divisible into a  $\delta$  nodal group and the

Nodum with Carex caryophyllea (Mapping unit 21).

The general aspect is of a fine-leaved grassland having a prominent under-mat of forbs with patches of Sesleria caerulea and scattered tufts of Nardus stricta. Differential species include Sieglingia decumbens, Carex caryophyllea, Campanula rotundifolia, Viola lutea, Achillea millefolium, Koeleria cristata, Alchemilla glabra and Carex pilulifera. Cerastium vulgatum and Luzula campestris are constant in the nodum with Galium saxatile as well as in this, and, similarly, Sesleria, Nardus and Linum are constant here and in the nodum with Sesleria. Total cover is 100%, although where the nodum is present on steep slopes it may be only 60-75%. In the other localities, the cover of the Phanerogams is about 90% and of the Cryptogams 50% although ranging from 10-90%. The mean number of species per 2 sq m is 43, the highest of any of the four noda and reflecting the variability of the turf.

The nodum occurs in several types of habitat. Some of the most extensive areas are the slightly undulating well-irrigated and drained expanses forming part of the vegetation complex on the slopes above Sand Sike and alongside the upper part of Fold Sike. Smaller sized patches occur in the concavities by the public footpath, with other noda between hummocks of blanket peat, and the nodum often forms the sheep tracks. This type of turf occurs on alluvial terraces beside calcium-rich streams and in similarly highly basic

environments on the steep banks (slopes of up to 40°) above Sand and Moss Sikes which are irrigated by drainage water from calcareous boulder clay. Vegetation of the nodum may colonise the hollows of a hummock-hollow complex in an area of molehills or sub-surface limestone pavement where the other component of the vegetation mosaic is usually mapping unit 5 of the sub-all. Seslerio-Mesobromion. (The floristic affinity of mapping unit 5 with this nodum (m.u. 21) shows how vegetation of the Seslerio-Mesobromion approaches that of the Ranunculo-Anthoxanthion on Widdybank Fell.) In some places where the ground surface is only slightly undulating, m.u. 21 colonises both hummocks and hollows; the physiognomic differences between them are due to varying proportions of species rather than to distinctive floristics. In the hummock-hollow complexes the other component is sometimes m.u. 33 (of the Empetrium) / As described for the class Violetea calaminariae, m.u. 21 is often to be found on the bases of the opencuts, the nodum with Trifolium repens and Minuartia verna of that class being along the sides.

The other component of the  $\beta$  Nodal group is the

$\delta$  Nodal group with Carex demissa and Ctenidium molluscum  
(Mapping units 19 and 20).

Festuca and Agrostis species are again the dominant grasses whilst species of Carex and the constant differential Ctenidium molluscum impart a characteristic appearance to the dense turf which may be slightly hummocky. Other constant differentials are Festuca rubra, Carex capillaris, C. demissa, Leontodon autumnalis, Plantago maritima, Taraxacum officinale, Bryum pseudotriquetrum, Fissidens adianthoides and Ditrichum flexicaule.

Communities of the nodal group may be found on the banks of streams or on deep soils rich in organic material on flat or gently sloping ground receiving calcareous drainage, e.g. near Slapstone Sike below the access road (now covered by the reservoir).

The  $\delta$  nodal group is composed of two noda :

Nodum with Sesleria (Mapping unit 20).

Campylium stellatum is the differential species. Sesleria, Nardus and Linum are constant and differentiate it from the other nodum of the nodal group but are similarly present in the nodum with Carex caryophyllea. Where m.u. 20 occurs amongst stones or boulders on steep slopes of up to 20-30°, Saxifraga aizoides is often one of the components of the vegetation tufts. This facies of the nodum is often to be found above Moss Sike and also above Sand Sike. Here, the usual 100% cover is reduced to less than 75%. Generally, however, Phanerogam cover is about 90% and Cryptogam ranges from about 5 to 75%, usually being around 50%. The nodum is present most frequently as a pure tract but below the sugar-limestone escarpment above Tinkler's Sike it is found between hummocks (perhaps old molehills?) covered with the dampest nodum of the Seslerio-Mesobromion (m.u. 7). With an average species number per Aufnahme of 39, this nodum is a little more floristically rich than the remaining one, the

Nodum with Cardamine (Mapping unit 19)

which has an average species number of 36.

Cardamine pratensis, Climacium dendroides and Drepanocladus revolvens are all constant, but the first two are also of high constancy in mapping unit 22. Thalictrum alpinum is sometimes present in the turf and then makes a striking contribution to the patchwork of Carex species and Ctenidium molluscum. Cover is consistently about 100% in toto - the higher plants about 80% and the others 50% or above.

This dampest component of the  $\beta$  nodal group often has the water table at, or near, the surface. By far its largest area is now inundated by the reservoir for it lay near to Slapestone Sike below the access road. Smaller patches of the nodum remain in places kept very moist throughout the year, e.g. where calcareous ground water emerges just below the summit limestone, below the Tinkler's Sike/escarpment and along the bases of the opencuts (replacing m.u. 21). Hummocks of mapping unit 8 (the nodum of the Caricion davallianae which is closest to the Seslerio-Mesobromion) may be set in a carpet of m.u. 19, as by Tinkler's Sike (cf. a like complex of mapping units 20 and 7 in the same locality).

SUMMARY AND SYNONYMY OF THE FESTUCO-NARDETUM

## ASSOCIATION FESTUCO-NARDETUM ass. nov. prov.

## SUB-ASS. caricetosum pulicaris

Ditrichum variantPlantago maritima sub-variantCardamine faciessyn.: Nodum with CardamineSesleria faciessyn.: Nodum with Sesleria

Grass-rich Caricetum Ratcliffe 1966

## typical sub-variant

Thalictrum faciessyn.: Thalictrum-Ctenidium provisional nodum  
McV. & R. 1962Saxifraga faciessyn.: Saxifrageto-Agrosto-Festucetum  
McV. & R. 1962

## typical variant

## typical sub-variant

syn.: Agrosto-Festucetum (species-rich) Birks 1969Sesleria sub-variantsyn.: Nodum with Carex caryophylla

## SUB-ASS. galletosum saxatilis

Carex pilulifera variantCarex pulicaris sub-variantsyn.: species-poor Agrosto-Festucetum p.p.  
McV. & R. 1962

## typical sub-variant

syn.: species-rich Agrosto-Festucetum McV. & R. 1962Cirsium palustre variant

## typical sub-variant

syn.: Nodum with Galium saxatilePotentilla sterilis sub-variant

syn.: Basic grassland Ratcliffe 1959

Ptilidium sub-variantsyn.: Basic grassland - herb-rich Agrostis-Festuca  
association Edgell 1969Ptilidium ciliare variant

## typical sub-variant

syn.: Basic grassland - dry facies Edgell 1969

Deschampsia flexuosa sub-variantsyn.: Festucetum p.p. E. W. & R. 1969

Syntaxonomy and classification of the  $\mathcal{L}$  Nodal Group

Table XVI and Fig. Vb

Vegetation types allied to the  $\mathcal{L}$  nodal group are shown in Table XVI and the classification of the Widdybank communities according to the principles of the Z.M. school is given in Fig. Vb.

The present survey has established that there are no exact syntaxonomic equivalents for the communities of the  $\mathcal{L}$  nodal group; those most closely related differ at least at the sub-variant level. Tabulation of this information has enabled the author to erect a provisional association which is described below; it is summarised and its synonymy is given on the facing page.

Association Festuco-Nardetum ass. nov. prov.

Two species - Nardus stricta and Sieglingia decumbens - differentiate the association from the Festuco-Poetum Shim. 1968, the other member of the Ranunculo-Anthoxanthion. However, as both of these occur with equally high constancies in other classes, neither can be used as a character species, and therefore the association can only be erected on a provisional basis. Nevertheless it is hoped that a more extensive phytosociological study of the British Isles will enable the status of the association to become definitively established. The variation within it and links with the Festuco-Poetum are shown in Table XVI where Shimwell's (1968) table for the latter association (cols. A and B) is amplified by material obtained by Eddy, Welch and Rawes (1969) from the Moor House National Nature Reserve (cols. D, E and F). This is in order to facilitate their comparison with the vegetation types included within the Festuco-Nardetum, an operation especially necessary in the cases of the Agrostu-Festucetum-Sesleria facies and the Carex panicea-Ctenidium molluscum nodum (cols. E and F) which have been likened by Eddy, Welch and Rawes and by McVean and Ratcliffe (1962) to communities, shown in cols. N and P, of the Scottish Highlands.

The association is composed of a range of "basic grassland" communities which vary from "species-rich" to "species-poor".

It occurs on soils of differing moisture status at altitudes of between 100 ft (31m) and 2,700 ft (823m) although chiefly between 1,000 ft (305m) and 2,000 ft (610m) over a region extending, at least, from North Wales through the North Pennines (Widdybank Fell) to the Scottish Highlands and Skye. The dominant Gramineae are Festuca ovina (sometimes with F. rubra), Agrostis tenuis and, in many cases, Anthoxanthum odoratum. Intermingled with these, are a number of flat leaved forbs of which Plantago lanceolata, Ranunculus acris, Trifolium repens and Prunella vulgaris are especially prominent. Several of these are class and order characters and also show the stresses imposed upon the communities by the anthropogenic pressures of grazing, trampling and manuring. The floristic variation within the association extends from the vegetation of upland limestone pastures of the Festuco-Poetum sub-ass. sub-alpinum and recorded by Shimwell (1968) to the south, west and north of Widdybank Fell (compare cols. F and K of Table XVI), to that developed in areas of intermittent irrigation, /sometimes also associated with snow-beds and which is classified in the Nardeto-Caricion bigelowii (rigidae) Nord. 1936. The two sub-associations of the Festuco-Nardetum are the caricetosum pulicaris and the galietosum saxatilis. Communities of the former show affinities with the Festuco-Poetum whilst those of the latter form the series leading in to the Nardeto-Caricion bigelowii.

Sub-ass. caricetosum pulicaris

The differential species are Carex pulicaris, Selaginella selaginoides and Linum catharticum. The last two have similar high constancies in the Festuco-Poetum, whilst Carex pulicaris might serve as a differential for one of the variants (found in the Moor House N.N.R.) into which, it is suggested, the sub-ass. sub-alpinum of this association could be divided (cols. E and F).

The Ditrichum variant, differentiated by Ditrichum flexicaule, Carex demissa, C. capillaris and Leontodon autumnalis, comprises those communities of the association receiving the greatest amount of calcareous irrigation. Two sub-variants which can be differentiated on a geographical as well as a floristic basis can be recognised. A similar direction of variation within each allows two pairs of facies to be distinguished.

The Plantago maritima sub-variant has only been recorded on Widdybank Fell and is synonymous with the δ Nodal group with Carex demissa and Ctenidium molluscum. Each of its facies is differentiated by a single species and is identical with a Widdybank nodum. They are the Cardamine facies (syn. Nodum with Cardamine, mapping unit 19, col. K) which occurs on the wettest soils which have standing water for much of the year, and the Sesleria facies (syn: Nodum with Sesleria, mapping unit 20, col. J). The two lists termed "grass-rich Caricetum" by Ratcliffe (1966) are placed in this facies (col. L), although having neither differential species; they appear to have been made in a part of Widdybank Fell from which the Sesleria facies has been recorded.

Ratcliffe has remarked upon the similarities of the Caricetum to the Saxifrageto-Agrosto-Festucetum (col. O) described by McVean and Ratcliffe (1962) from the Scottish Highlands. This is acknowledged by the present author who would, however, because of the virtual absence of Plantago maritima, prefer to place this latter vegetation type in the typical sub-variant of the Ditrichum variant where it forms the Saxifraga facies. Its counterpart on damper, more humus-enriched soils is the Thalictrum facies (col. P) which is McVean and Ratcliffe's Thalictrum-Ctenidium provisional nodum. It would seem that both these facies are confined to the Scottish Highlands. The similar communities at Moor House and on Widdybank Fell are allied but not identical.

The typical variant is composed of two sub-variants. The typical sub-variant (col. Q) is the Agrosto-Festucetum (species-rich) recorded by Birks (1969) from the Isle of Skye, on shallow soils receiving periodic irrigation over limestones and basalts. The Sesleria sub-variant (col. H) is differentiated by Sesleria caerulea, Viola lutea, Koeleria cristata, Luzula campestris and Carex pilulifera. The last two species are both present in some components of the sub-association galietosum saxatilis and illustrate the affinity of this sub-variant with the second sub-association. The Sesleria sub-variant is reported only from Widdybank Fell; it is synonymous with the Nodum with Carex caryophyllea (m.u. 21) - the "ordinary" limestone grassland of Ratcliffe (1966), although he regards it as synonymous with the

species-rich Agrost-Festucetum of McVean and Ratcliffe (1962) - a member of the other sub-association (col. N) - and <sup>with</sup> Pigott's (1956) "grassland on unaltered limestone". Two of the lists (nos. 1 and 2) given by Tansley (1949) for "grassland on the older limestones", pp. 554-6, may include the sub-variant as a part of the vegetation from which they were made.

Sub-ass. galietosum saxatilis

Galium saxatile, Luzula campestris, Polytrichum alpinum and Thuidium delicatulum are the differentials, and reflect a lower level of nutrient enrichment than is present in the other sub-association. Three variants are recognisable, each with a number of sub-variants.

The Carex pilulifera variant is differentiated only by this species and is composed of communities described by McVean and Ratcliffe (1962) from the Scottish Highlands. The Carex pulicaris sub-variant (col. N) is closest to the sub-association caricetosum pulicaris and is formed from the species-rich Agrost-Festucetum mentioned above. Selected lists (Nos. 1, 4, 7, 10, 11, 14, 16, 18, 19 and 20; the others belong to the Nardo-Callunetea) have been extracted from the species-poor Agrost-Festucetum to give the typical sub-variant (col. M). This is found on soils of lower base status than those of the species-rich type; both may be in situations where they receive intermittent irrigation, but there is a difference in nutrient content of the water.

The Cirsium palustre variant has three sub-variants. The typical (col. G) is a rather weak member of the association as both differential species are absent. The presence of both Carex capillaris and Cardamine pratensis in two out of the three Aufnahmen shows a link with the sub-association caricetosum pulicaris. The sub-variant is composed of the three Aufnahmen of the Nodum with Galium saxatilis (m.u. 22) from Widdybank Fell and it would seem that further analysis of this vegetation type is required. The other sub-variants are described from North Wales; that with Potentilla sterilis (col. T) is Ratcliffe's (1959) basic grassland from the Carneddau, and the Ptilidium ciliare sub-variant (col. S) is the basic grassland herb-rich Agrostis-Festuca socation from Cader Idris in Snowdonia (Edgell 1969).

This last vegetation type is clearly close to the Ptilidium ciliare variant whose typical sub-variant (col. R) is Edgell's basic grassland-dry facies, on soils with lower amounts of irrigation than the Agrostis-Festuca sociation. The final step in this sequence is the Deschampsia flexuosa sub-variant formed from twelve lists (nos. 1-3, 5-7, 9, 11-15) of the Festucetum of Eddy, Welch and Rawes (1969). This vegetation type has, however, low values of class and order character species; furthermore, only one association differential - Nardus stricta - is present and is of low constancy. Its inclusion in the association is, therefore, questionable, but such affinities as it possesses link it to the Arrhenatheretalia.

Carex bigelowii is present in the Deschampsia flexuosa sub-var. with a constancy of III and may indicate the starting point of variation comprising a series of communities associated with late snow lie, and referable to the Nardeto-Caricion rigidae (bigelowii). This alliance was originally placed by Nordhagen (1936) in the Salicetalia herbaceae but Dahl (1956) prefers to restrict this order to communities of solifluction soils, and to place the Nardeto-Caricion bigelowii in the Deschampsieto-Myrtilletalia believing its communities to be related to the dwarf shrub heaths of the other alliances of that order. None of the vegetation types here included in the Festuco-Nardetum has been placed by their authors in the Nardeto-Caricion bigelowii, but McVean and Ratcliffe classify both the Saxifrageto-Agrosto-Festucetum (provisionally) and the Thalictrum-Ctenidium nodum in the Ranunculo-Anthoxanthion which in its original form was placed in the Salicetalia herbaceae by Gjaerevoll (1956).

The synsystematic placing of the  $\mathcal{L}$  Nodal group  
Table I

These four noda form a recognisable group atypical of the Widdybank communities of the Seslerio-Mesobromion and of the grass ones of the Empetrium to each of which individual noda show affinities, cf. Table I, where the occurrence of both Seslerio-Mesobromion and Empetrium species in the nodum with Carex caryophyllea (m.u. 21) is evident. In addition, Caricion davallianae character species are present in both mapping unit 19 and (especially) 20. However, the abundance of character species of the Molinio-Arrhenatheretea and the Arrhenatheretalia justify the placing of the  $\mathcal{L}$  nodal group in this class and order.

At this point, its possible affinity to the Cynosurion which comprises the rich pastures of the lowlands and lower-montane regions has to be further considered. The only Cynosurion character species present in the nodal group is Trifolium repens, although the others - Cynosurus cristatus, Phleum pratense, Lolium perenne and the alien Veronica filiformis - are found locally, and Cynosurion communities probably occur around the (now abandoned) Widdybank Farm buildings which lie immediately south-east of the area studied at the slightly lower altitude of 1,300 ft (396m). The  $\mathcal{L}$  nodal group has been described by Tüxen<sup>#</sup> and by Balátová<sup>+</sup> as a very poorly developed Cynosurion, perhaps originating as vegetation somewhere between that of the Nardo-Callunetea and the Parvocaricetea. They suggest that this became altered as a result of grazing pressure which allowed the herbs of the Molinio-Arrhenatheretea, with their flat leaves and extensive rooting system parallel to the ground surface, to gain entry, although the pressure was not sufficient to permit the development of "good" Cynosurion communities. However, the extreme environment of Upper Teesdale hardly seems suitable for the establishment of a "rich pasture"; this term and the description of the alliance is more applicable to the "pastures" of Tansley (1949, p. 566).

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<sup>#</sup> Tüxen (1970) : personal communication

<sup>+</sup> Balátová (1970) : personal communication

Gjaervoll's alliance Ranunculo-Anthoxanthion included areas of comparatively late snow-lie. Much of the vegetation of the nodal group, especially mapping units 21 and 22, occurs in depressions, around hummocks of blanket bog and heath, and between areas of Mesobromion grassland, in which the snow lies longer and into which it is often blown. The absence in the nodal group of the grass character species of class and order - Poa trivialis, P. pratensis, Alopecurus pratensis, Festuca pratensis, Trisetum flavescens, Bromus mollis, Dactylis glomerata and Arrhenatherum elatius - is very noticeable and is in accordance with one of Shimwell's criteria for the Ranunculo-Anthoxanthion (Shimwell 1968).

He gives a table for the alliance which summarises the associations and noda from the works of McVean and Ratcliffe (1962) and King and Nicholson (1964) dealing with the Scottish Highlands and the whole of Scotland respectively. This shows variation from base-rich to base-poor vegetation, includes some damp communities and also one allied to the Cynosurion. The data from McVean and Ratcliffe for the species-poor and species-rich Agrostu-Festuceta and the Saxifrageto-Agrosto-Festucetum included in Table XVI of the present work figure in Shimwell's table. All the other associations and noda summarised in Table XVI, i.e. from the Isle of Skye, North Wales, the Moor House N.N.R. and McVean and Ratcliffe's Thalictrum-Ctenidium nodum, show sufficient general similarity and presence of Molinio-Arrhenatheretea character species (apart from the grasses) to be included in the Ranunculo-Anthoxanthion.

Other noda described from Scotland - the Festuca-Agrostis grassland complex in part of the Cheviots (King 1962) and the Agrostis-Festuca basic and acidic (p.p.) grasslands of Birse and Robertson (1967) - can be placed in the Cynosurion. They are at altitudes of less than 1,500 ft (457m) and 1,750 ft (533m) respectively, and have many of the grass character species of the Molinio-Arrhenatheretea and the Arrhenatheretalia.

DIAGRAMMATIC SOIL PROFILES OF THE α NODAL GROUP WITH TRIFOLIUM AND PLANTAGO

α Nodal group with Trifolium and Plantago

β Nodal group with Carices

Nodum with Carex demissa and Clenidium molluscum

γ Nodal group with Gardamine  
Nodum with Gardamine  
(m.u. 19)

Calcareous peaty gley  
Aufn. 168. 58

Gley  
Aufn. 172 pH 6.0  
Aufn. 159 pH 6.6

Nodum with Selseria  
(m.u. 20)

Calcareous gley  
pH 6.7, 7.4

Nodum with Carex coryphyllea  
(m.u. 21)

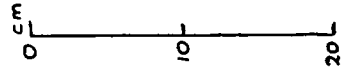
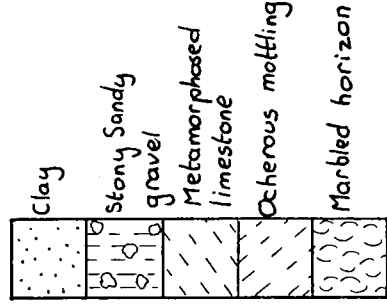
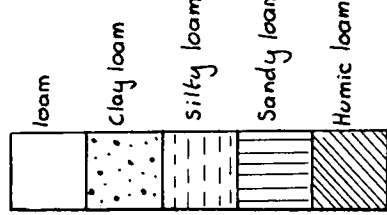
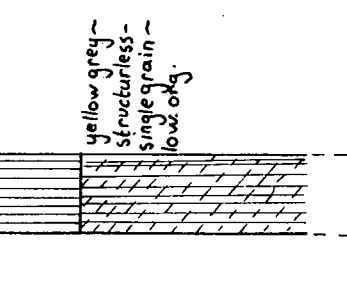
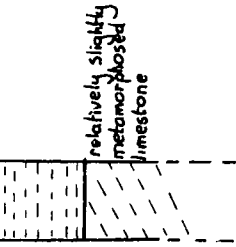
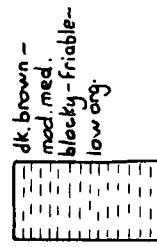
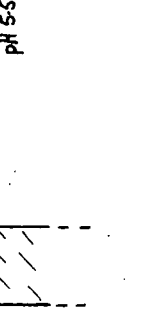
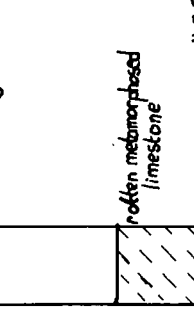
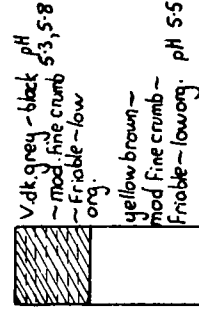
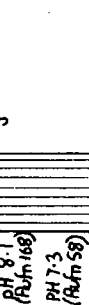
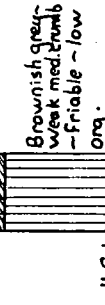
Rendzina β  
Aufn 121  
pH 6.2, 6.7

Brown earth with gleying  
Aufn. 397

Nodum with Galium saxatile  
(m.u. 22)

Alluvial gley  
pH 6.6

(Flushed) Gley  
pH 5.0



The soils of the  $\alpha$  Nodal group  
with *Trifolium repens* and *Plantago lanceolata*

Fig. VI (diagrammatic profiles) and Table XVII (soil analyses)

The  $\beta$  nodal group with *Carices* (mapping units 19, 20 and 21) is distinctly separated from mapping unit 22, the other component of the  $\alpha$  nodal group, by a large number of differential species (Table XIV); within the  $\beta$  nodal group there is a sequence of changes in floristic composition. These two phenomena are reflected in the natures of the associated soil types which also form a series with a disjunction between mapping units 21 and 22. This commences with the calcareous peaty gleys of mapping unit 19 and the gleys of some of the stands of mapping unit 20, all having a greater content of organic material than the calcareous gleys of mapping unit 20 and gleyed brown earths of mapping unit 21 which, again, are more organic than the rendzinas of mapping unit 21. The pH values vary within as well as between these nodes but are all higher than those of the moderately organic alluvial and flushed gleys of mapping unit 22.

The pair of mapping units with the greatest amount of floristic similarity are nos. 19 and 20 which comprise the  $\delta$  nodal group with *Carex demissa* and *Ctenidium molluscum*; the pH values and calcium contents of their soils show a comparable degree of affinity and the presence in mapping unit 19 of *Cardamine*, *Drepanocladus* and *Climacium* (its differentials) is reflected in its much higher humus content.

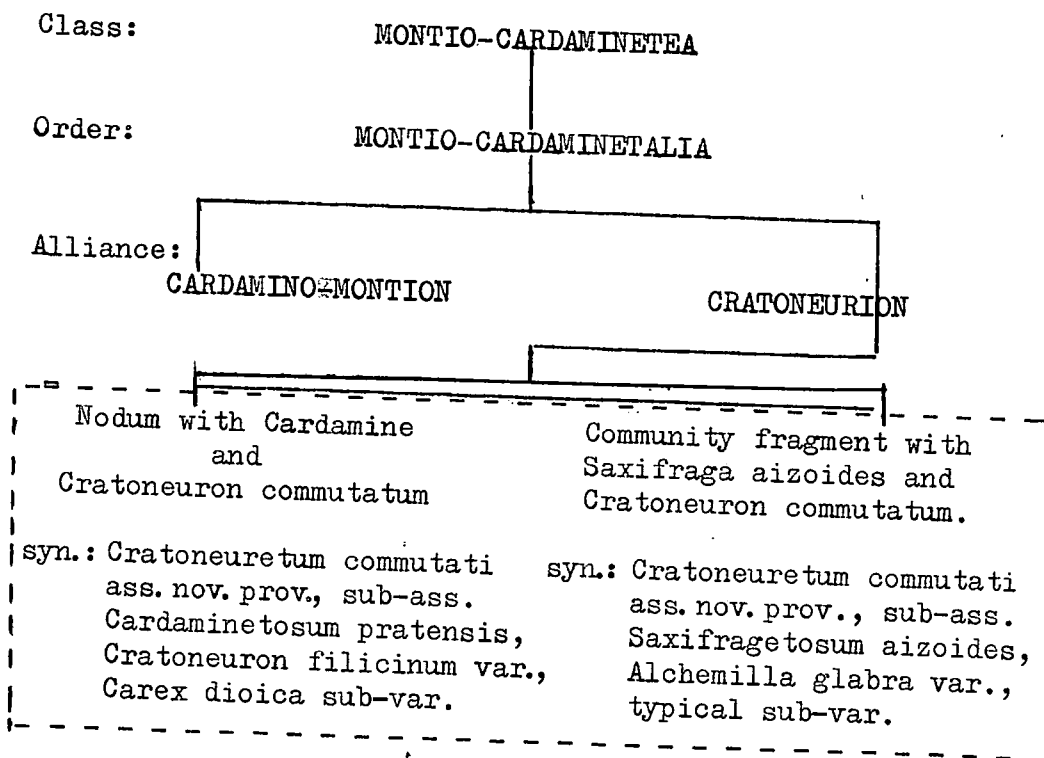
Aufnahme no. 121 (mapping unit 21) was made in an area of undulating topography where there is a physiognomic disparity between the vegetation of the hummocks and that of the hollows; the composition of these two spatio-floristic elements was therefore recorded separately and two soil profiles were examined. Subsequent inspection of the phytosociological data has shown that the continued separation of hummocks and hollows cannot be justified because their respective species' complements are almost identical, the apparent differences being due solely to the relative proportions of the species. This conclusion is substantiated by the results of the soil analyses. Both sets of pH values and humus contents are

nearly the same and although there is considerable difference in the amount of exchangeable calcium, the two values are within the range for the mapping unit as a whole.

A comparison of the soils of mapping unit 21 with those of mapping unit 5 (Seslerio-Mesobromion) is useful since their floristic compositions show a considerable similarity. Those of mapping unit 5 are either  $\beta$  rendzinas or brown calcareous soils (Fig. I) with ranges of surface pH of 6.8-8.0 and 5.8-6.8 and of available calcium of 29.2-61.5 and 20.6-24.2 m eq/100g respectively (Table VI). From these figures and Table XVII it is evident that the  $\beta$  rendzinas of mapping unit 21 have a lower pH status and, usually, calcium content than those of mapping unit 5, and that they resemble the brown calcareous soils of mapping unit 5 in these properties. It should be mentioned that although the gleyed brown earths of mapping unit 21 have a still lower pH and calcium content, they support communities which are as typical of the nodum as are those of the  $\beta$  rendzinas. There is an almost complete absence of free calcium carbonate in the soils of mapping unit 21. The large amount found in those of mapping unit 5 is striking and is of the same order as the quantities of carbonate in the soils of the other members of the Nodal group with Sesleria and Koeleria. It would appear that this difference in calcium carbonate, and hence in pH, between the soils of mapping units 21 and 5, provides a clue to the factors influencing the distributions of these closely related Ranunculo-Anthoxanthion and Seslerio-Mesobromion communities.

In a number of places on the Fell, these two mapping units have developed in an area of hummock-hollow topography - mapping unit 5 on the hummocks and mapping unit 21 in the hollows. This would suggest that another factor influencing their general distributions may be irrigation of the soils and that its increase favours the establishment of communities of mapping unit 21. However, no determinations of soil moisture content have been made as yet.

SYNOPTIC CLASSIFICATION OF PARTS OF THE  
MONTIO-CARDAMINETEA WITH PARTICULAR  
REFERENCE TO WIDDYBANK FELL



Key

[ - - - - ]

Vegetation present on  
 Widdybank Fell.

Class: MONTIO-CARDAMINETEA Br.-Bl. et R. Tx. 1943

Those parts of the class to which reference is made in the text are summarised on the facing page.

The class is formed from the moss-rich pioneer vegetation developed around springs, or in shallow and more strongly flowing water. Its establishment and existence is favoured by well-oxygenated water at more or less constant temperatures throughout the year. Colonisation may take place on the rocks themselves, both on those rich in silicates and on limestones, or on the fine soil around the springs (Oberdorfer 1957, Westhoff and den Held 1969).

The centre of distribution of the class is the boreal-montane euro-siberian region. It occurs only rarely on the plains being chiefly in the upland and alpine zones.

#### Syntaxonomy

Maas (1959) suggested that the existing sub-division of the class into a single order with three alliances encompassing calcifuge, calcicole and alpine vegetation, should be abandoned in favour of a division into two orders - one calcifuge, the other calcicole. However, Oberdorfer et al (1967) restored the former single order for they considered that Maas' sub-division was not floristically sound. Westhoff and den Held (1969) agree with this latter view whilst retaining Maas' sub-divisions of the original calcifuge alliance, the Cardamino-Montion, on account of its heterogeneity. They make the division, however, at the sub-alliance level which is a less fundamental division than the two alliances suggested by Maas.

Order : MONTIO-CARDAMINETALIA Pawlowski 1928

Syn. : Montio Cardaminetalia Pawl. 1928 em Maas 1959 +  
Cardamino-Cratoneuretalia Maas 1959 (cf. above)

All the spring vegetation of temperate Europe is classified within this order.

#### Character species

Since there is only a single order, they are the same for both class and order and are (Oberdorfer 1957, Westhoff and den Held 1969):

*Caltha palustris* var. *minor*  
*Cardamine amara*  
*Fohlia wahlenbergii*  
*Brachythecium rivulare*

*Epilobium alsinefolium*  
*Cratoneuron decipiens*  
*Philonotis fontana*

None has been found in communities of this order on Widdybank Fell although Philonotis is occasionally present in those of the Ranunculo-Anthoxanthion, and the Parvocaricetea (cf. Table I) and Cardamine occurs in a flush on Cronkley Scar<sup>#</sup>. It would seem that the use of Caltha palustris var. minor as a character species will have to be revised for it is not now considered by taxonomists to be a separate variety (Tutin et al 1964).

All the species are found in Britain; Caltha is widely distributed and is recorded by Perring and Walters (1962) for the vicinity of Widdybank Fell, as is Epilobium which occurs in springs and at stream sides in north England, central and north-west Scotland. Cardamine is present in similar habitats in much of Britain although not in Wales, north-west Scotland or south-west England. Its absence from Widdybank Fell (spot-height 1727 ft (5265m)) is no doubt a consequence of its altitudinal limit of about 1500 ft (460 m) (Clapham, Tutin and Warburg 1962). At 650 ft (213 m), however, it is found immediately to the east of Middleton in Teesdale which is about 11 miles (18 km) lower down the valley<sup>#</sup>. The only habitat details available for Cratoneuron decipiens are that it is very rare and grows in "wet places" in the Scottish Highlands and in Yorkshire (Dixon 1954); it is therefore of limited value as a character species.

The remaining three species - Philonotis fontana, Brachythecium rivulare and Bohlia wahlenbergii - appear to act as valid Montio-Cardaminetalia characters in the British Isles. Watson (1966) reports that the first two are often associated together and with Bryum pseudotriquetrum in the "moss flora which develops in bog springs on mountains". It is extremely interesting to note that whilst Maas (1959) gives Bryum pseudotriquetrum ssp. pseudotriquetrum as a class and order character, Westhoff and den Held (1969) point out that the species (sensu lato) has its optimum in Tofieldietalia communities, since a similar situation was found during the present investigation. On Widdybank Fell Bryum pseudotriquetrum is abundant in vegetation of the Caricion davallianae (Tofieldietalia), Caricion curto-negrae and of the Ranunculo-Anthoxanthion (cf. Tables XXV, XVIII and XIV respectively) as well as in that of the Montio-Cardaminetea.

<sup>#</sup> Bradshaw (1972) : personal communication

Pohlia wahlenbergii (Mniobryum albicans in Oberdorfer 1957) is a prominent component of some moss spring-head communities in the Scottish Highlands, although under its synonym of Pohlia albicans var. glacialis<sup>4</sup> (McVean and Ratcliffe 1962).

The silicate-loving

All: Cardamino-Montion Br.-Bl. 1925  
has not been found on Widdybank Fell. However, the Bryophyte flushes of Pigott (1956) on the upper slopes of Dun, Mickle and Dufton Fells, the Philonoto-Saxifragetum stellaria<sup>5</sup> and the Poa annua-Montia fontana nodum in the Moor House area (Eddy, Welch and Hawes 1969) may all belong to it.

The vegetation of the present study belongs to the

All: Cratoneurion W. Koch 1928  
of chalk and limestone springs.

It appears to be distributed throughout Europe and has previously been reported from France, Switzerland, Austria, Czechoslovakia, Germany, the Netherlands, Ireland and Norway (Westhoff and den Held 1969) and from Scotland (McVean and Ratcliffe 1962).

#### Character species

Four of the five given by Oberdorfer (1957) - Cratoneuron commutatum, C. filicinum, Philonotis calcarea and Saxifraga aizoides - are constituents of spring-head communities on Widdybank Fell although, apart from Philonotis, this relationship is not exclusive for they are also present in vegetation of other alliances (cf. Table I). Watson (1966) describes the other species - Eucladium verticillatum - as a "characteristic tufa-forming species of wet limestone rocks" and it would seem to be a valid character species in the British Isles although absent from Teesdale.

Two types of vegetation have been placed in this alliance; the more widely occurring will be described first.

#### Nodum with Cardamine and Cratoneuron commutatum Table X

The differential species group is Cardamine pratensis, Cratoneuron commutatum, Juncus articulatus, Carex dioica, C. lepidocarpa and Triglochin palustris. They all occur in other noda, especially those of the Parvocaricetea, with equally high

<sup>4</sup> Pohlia albicans var. glacialis (Schleich.) Lindb.

constancies, or nearly so, but they do not form a distinct species group in any other nodum or nodal group.

The nodum is found as a very dense mass developed around a spring-head or as patches growing just above the normal water level (although frequently irrigated) of calcareous streams. It may develop in stony places and in one locality, near Widdybank Farm, an interrupted mat has formed amongst a strip of Whin Sill fragments through which calcareous water percolates. In general, the angle of slope is perceptible but slight (up to  $3^{\circ}$ ) and may be of any aspect. The moss cover - chiefly Cratoneuron commutatum - is 90-100% and the higher plants occur as scattered individuals, most frequently having only 10-20% cover.

On the 1:2,500 scale maps where 2mm represents 5m, the position of the nodum is indicated by a solid triangle for its very small-sized communities (often under 1 sq m) could not be outlined. It has not been possible to show this type of vegetation at the 1:10,000 scale at all.

Community fragment with Saxifraga aizoides and Cratoneuron commutatum

Table XI

The other constituent of the Cratoneurion on Widdybank Fell is a mere community fragment represented by the three Aufnahmen of Table XI. These were made close together in a very small area of vegetation, about 3m x 4m, underneath an overhang on the dolerite cliffs of Falcon Clints. At this point there is the obvious influence of calcareous drainage water leading to the formation of this fragmentary rock ledge community markedly different in composition from the surrounding vegetation which is chiefly of the Empetrium (class Nardo-Callunetea). The patches of calcareous vegetation are scattered between the rocks, both those in situ and the weathered fragments derived from them; the relief varies but approaches  $90^{\circ}$  in places. This part of Falcon Clints has a southerly aspect and therefore receives the highest amount of solar radiation possible.

The higher plant cover is only about 60-70%; that of the Cryptogams varies from 20-80% of which hummocks of Cratoneuron commutatum form the chief component although there are also large areas of Ctenidium molluscum. Scattered in and between these patches is a variety of higher plants of which Festuca rubra, Carex flacca, C. pulicaris, C. lepidocarpa, Primula farinosa and Saxifraga aizoides are amongst the more abundant.

This vegetation does not appear on the maps at either scale for it is too small in extent to be represented on the only one covering Falcon Clints - that at the 1:10,000 scale. The data presented here is very incomplete for a description of a community type, especially as the three Aufnahmen were from the one locality. Therefore only tentative comparisons can be made with the material available from other areas.

The syntaxonomy and classification of  
the communities of the Cratoneurion

Table XII

Both the Nodum with Cardamine and Cratoneuron commutatum and the community fragment with Saxifraga aizoides and Cratoneuron commutatum are considered together in this discussion.

The Widdybank communities now included within the nodum are directly referred to in the literature. Pigott (1956) mentions the occurrence of Cratoneuron commutatum (var. falcatum) in the vicinity of springs on the Fell, although he gives no details of the associated species, and Ratcliffe (1966) notes the presence of "moss communities of calcareous springs dominated by Cratoneuron commutatum" and likens them to the Cratoneuron-Saxifraga aizoides nodum of McVean and Ratcliffe (1962).

However, it may now be suggested that the only exact synonym is the type of vegetation occurring in calcareous flushes in the Moor House N.N.R. (Eddy, Welch and Rawes 1969). Even this suggestion gives rise to some difficulties in directly equating the two types and these difficulties are discussed below. The synonymy is, therefore :

~~Nodum with~~ Nodum with Cardamine and Cratoneuron commutatum  
Cratoneuron-Carex nodum Eddy, Welch and Rawes 1969.

The other member of the Cratoneurion on Widdybank Fell has not been described previously nor is it exactly synonymous with any other community found in Britain. However, the broad affinities in both floristics and physiognomy of the community fragment with Saxifraga and Cratoneuron and of the Nodum with Cardamine and Cratoneuron and the Cratoneuron-Carex nodum to one another and to a number of others, i.e., the "communities of calcareous springs" described by Ivimey-Cook and Proctor (1965) from the Burren, Co. Clare, Ireland, the Cratoneuron-Saxifraga aizoides nodum, the Saxifragetum aizoidis and its mixed

SUMMARY AND SYNONYMY OF THE CRATONEURETUM COMMUTATI

ASSOCIATION CRATONEURETUM COMMUTATI ass. nov. prov.

SUB-ASS. cardaminetosum pratensis

Cratoneuron filicinum variant

typical sub-variant

syn.: communities of calcareous springs I-C. &amp; P. 1965

Carex dioica sub-variantsyn.: Cratoneuron-Carex nodum E, W. & R. 1969Nodum with Cardamine and Cratoneuron commutatumSaxifraga aizoides variantsyn.: Cratoneuron-Saxifraga aizoides nodum McV. & R. 1962

SUB-ASS. saxifragetosum aizoidis

Drepanocladus revolvens variantsyn.: Cratoneuron commutatum-Saxifraga aizoides nodum  
Birks 1969Alchemilla glabra variant

typical sub-variant

syn.: community fragment with Saxifraga aizoides and  
Cratoneuron commutatumSaxifraga oppositifolia sub-variantsyn.: Saxifragetum aizoidis McV. & R. 1962  
Saxifragetum aizoidis - mixed Saxifrage facies " "  
Saxifragetum aizoidis McV. & R. 1962 (Birks 1969)

Saxifrage facies of McVean and Ratcliffe (1962) and the Cratoneuron commutatum - Saxifraga aizoides nodum and Saxifragetum aizoidis of Birks (1969), are sufficiently great to enable them all to be incorporated into a provisional association, namely, the

Association Cratoneuretum commutati ass. nov. prov.

A summary of the components of the association together with their synonymy is given on the facing page and its composition is shown in detail in Table XII.

The association comprises communities which have developed under the influence of highly calcareous irrigation, both where the topography is almost level and where it is very steeply sloping. In northern England, the central Highlands and north-west Scotland it occurs principally at altitudes from 1,500 ft (457m) to 3,000 ft (914m), although in the Burren district of western Ireland (where the hills barely reach 1,000 ft (305m) and on Skye, the communities reach almost down to sea-level.

Cratoneuron commutatum and Festuca rubra are both association differentials. It has not been possible to find a good character species, for although the alliance character Cratoneuron commutatum can be suggested for this, it is also present - sometimes with equal abundance - in Caricion davallianae (class Parvocaricetea) communities. Therefore the association can only be erected provisionally meantime. The physiognomic dominants are Cratoneuron and/or Saxifraga aizoides; total cover is frequently 100% and is rarely below 80%. Two sub-associations can be distinguished, the floristic differences between them being paralleled by differences in habitat, in degree of slope and, to some extent, in altitude.

Sub-ass. cardaminetosum pratensis

These communities form around spring-heads on ground with only a small degree of slope at altitudes ranging from nearly sea-level in Ireland to 3,000 ft (914m) in Scotland, although they are found in the north Pennines from around 1,600 ft (488m) to 2,200 ft (671m) and in Scotland usually about the 1,700 ft (518m) contour.

Large hummocks of Cratoneuron commutatum, sometimes jointly with either Cardamine pratensis or Saxifraga aizoides, make a dominant contribution to the cover which is usually complete. The number of other species present is consequently rather low, about 20 per stand, and much less than in the saxifragetosum. The communities may attain a few square metres in size but are often less than one. Cardamine is the only sub-association differential; two variants are recognised.

The Cratoneuron filicinum variant comprises the vegetation in Ireland and that in northern England. The other differential species are Sagina nodosa, Epilobium palustre, Juncus articulatus, Philonotis calcarea and Leontodon autumnalis.

The typical sub-variant is synonymous with Ivimey-Cook and Proctor's (1965) "communities of calcareous springs" (cols. A and B). Although their table (No. XIII; see also pp. 233-4) has been split up because of floristic dissimilarities as indicated in the key to Table XII (another list - from a calcareous waterfall - has been discarded), the sub-variant has not been further divided notwithstanding the fact that the communities of column B have a greater variety of forbs and grasses.

The Carex dioica sub-variant is found on Widdybank Fell (syn.: Nodum with Cardamine and Cratoneuron commutatum - col. D) and in the Moor House N.N.R. (syn.: Cratoneuron-Carex nodum, Eddy, Welch and Rawes 1969 - col. C). The differential species are Carex dioica, C. nigra and Triglochin palustris. Nevertheless, there are floristic differences between the components of the variant. The Moor House nodum has a greater mean species number (40) than that on Widdybank (13) and many more which are constant. Eddy, Welch and Rawes (1969), commenting on the high number of species in their nodum, particularly in comparison with the average of 13 for McVean and Ratcliffe's (1962) Cratoneuron-Saxifraga aizoides nodum, suggest that it is due to the heavy grazing pressure by sheep on the Moor House flushes. When making this type of Aufnahme on Widdybank Fell, however, it was noted that great care had to be taken to avoid the outer parts of the moss-hummock which had become invaded by a number of species otherwise associated with the Caricion davallianae communities into which those of the Cratoneuron pass with increasing distance from the spring-head.

Even so, a number of "invaders" growing in the middle of the moss-hummock had to be recorded in the Aufnahmen. It is therefore suggested that the Moor House Cratoneurion vegetation is in the process of evolving into that belonging to another class - perhaps the Parvocaricetea. As it is probably not typical of its alliance, it has not been separated into a distinct facies. It is possible that in the central parts of the hummocks there might be found "typical" Cratoneurion vegetation for it is noted from Table XII of Eddy, Welch and Rawes (1969) that very many of the "atypical" species are only present as isolated individuals.

The Saxifraga aizoides variant (col. F) is transitional between the two sub-associations; Saxifraga aizoides, one of the two differentials for the sub-ass. saxifragetosum aizoidis is its sole differential. It is formed from the Cratoneuron-Saxifraga aizoides nodum of McVean and Ratcliffe 1962 and reaches the highest altitude of any of the communities of the sub-association for it is recorded from 3.000 (914m) in Scotland.

Sub-ass. saxifragetosum aizoidis

The habitats of the vegetation of this sub-association contrast strongly with those of the other for the saxifragetosum communities develop on steep ground, from 25° to 85° in slope, instead of on almost flat terrain. They may be on irrigated cliff faces or steep banks but are also associated with calcareous springs as is the cardaminetosum. According to the available evidence, the sub-association is confined to Scotland, apart from the small patch of vegetation on Falcon Clints. Its altitudinal range is similar to that of the other sub-association extending from near sea-level in Skye to 3,000 ft (610m) in the central Scottish Highlands, but in central and northern Scotland the stands usually occur above those of the cardaminetosum, lying chiefly between 1,850 and 2,600 ft (504-793m).

Cover is generally about 100%, the main component being Saxifraga aizoides, although Cratoneuron commutatum may be co-dominant. The mean number of species per Aufnahme (4 sq m) of the Drepanocladus revolvens variant is only 19, very similar to that for the cardaminetosum, but for the Alchemilla glabra variant it is 37.

The sub-association differentials are Saxifraga aizoides, Pinguicula vulgaris, Ctenidium molluscum and Blindia acuta.

The Drepanocladus revolvens variant (syn.: Cratoneuron commutatum - Saxifraga aizoides nodum Birks 1969, col. J) is differentiated only by this species. It is confined to Skye at altitudes ranging from 75 to 350 ft (23 to 107m), which are lower than those of any other component of the sub-association. Amongst the members of the saxifragetosum it is unique in being associated with calcareous springs, in which respect it resembles the communities of the cardaminetosum. As well as differing from the latter floristically, however, it develops on cliffs sloping at 50° to 80° and not on almost flat ground.

The Alchemilla glabra variant, differentiated also by Carex pulicaris, is found on plentifully irrigated calcareous cliff faces and steep rocky terrain. The two sub-variants are differentiated geographically as well as floristically.

The typical sub-variant has, to date, been reported only from Widdybank Fell and is the community fragment with Saxifraga aizoides and Cratoneuron commutatum (col. E).

The Saxifraga oppositifolia sub-variant (syn.: Saxifragetum aizoidis McVean and Ratcliffe 1962, cols. G and K, and its mixed Saxifrage facies, col. H) is present both in central and northern Scotland (McVean and Ratcliffe 1962) and in Skye (Birks 1969). The differential species are Saxifraga oppositifolia, Alchemilla alpina and Thalictrum alpinum; the first may be co-dominant with Saxifraga aizoides (col. H). Although no quantitative floristic separation can be made between the Saxifragetum aizoidis (col. G) and its mixed Saxifrage facies (col. H) of the Scottish Highlands, the latter usually occurs at higher altitudes than the former, reaching to 3,000 ft (610m). McVean and Ratcliffe refer to a similar Saxifrage community in the Lake District; without detailed floristic analyses, however, it is impossible to assess its relationship to the association.

Although some of the members of the association (cols. C, F and G) have many more character species of class, order and alliance than the others, all components include at least one such in their floristic complement and it is considered that the association is adequately classified within the Cratoneurion.

The synsystematic placing of the Nodum with  
Cardamine and Cratoneuron  
and of the community fragment with Saxifraga and Cratoneuron  
Table I

The development of Cratoneurion communities on Widdybank Fell is only weak. Both vegetation types classified within it are infiltrated by species characteristic of other classes and three of the Cratoneurion character species are frequently found outside it, e.g. Cratoneuron commutatum occurs throughout the Caricion davallianae communities and Philonotis fontana is completely absent from those of the Cratoneurion whilst being present in vegetation of the Caricion curto-nigrae.

This is related to the phenomenon that suitable habitats for the establishment of Cratoneurion vegetation - calcareous springs and other places receiving similar irrigation - only occur over small areas so that merely restricted growth is possible.

The Nodum with Cardamine and Cratoneuron normally develops amidst Caricion davallianae communities and Riccardia pinguis, Carex dioica and C. lepidocarpa which are characters of this alliance or one of its associated higher units, are present in the nodum with moderately high frequencies. However, on account of the presence of the Cratoneurion characters Cratoneuron commutatum, C. filicinum and Philonotis calcarea together with the general physiognomy and habitats of the communities, the classification of the nodum within this alliance would seem to be valid with the proviso that it is a somewhat atypical example.

Similarly, although Campylium stellatum and Carex lepidocarpa of the Caricion davallianae and Helictotrichon pratense of the Festuco-Brometea occur in the community fragment with Saxifraga and Cratoneuron commutatum, the presence of these two Cratoneurion character species and the physiognomy and habitat of the vegetation justify its being placed in the latter alliance.

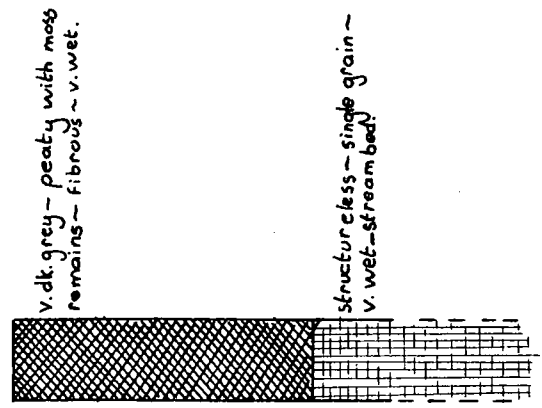
FIG IV DIAGRAMMATIC SOIL PROFILES OF THE NODUM WITH CARDAMINE AND CRATONEURON

Nodum with Cardamine and Cratoneuron  
(mu. 4)

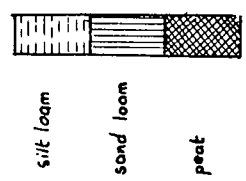
2. mosshummock  
pH 6.7

mosshummock directly on  
bedrock of metamorphosed  
Limestone.

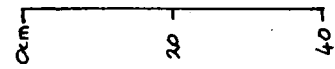
1. mosshummock  
pH 7.2



KEY



SCALE



The soils of the Nodum with Cardamine and Cratoneuron

A diagrammatic profile is shown in Fig. IV and selected features in Table XIII.

The moss-hummock communities of this nodum can develop both on drift subjected to calcareous flushing (profile 1) and directly on metamorphosed limestone (profile 2).

For each profile the analyses have been made on the material composing the interior of the hummocks; its highly organic nature (moss remains) and the tendency to tufa formation observed at other sites are features described also for the Cratoneuron-Saxifraga aizoides nodum McVean and Ratcliffe 1962, and the Cratoneuron-Carex nodum Eddy, Welch and Rawes 1969, which are both components of the same sub-association. A very striking feature shown by the bryophytes (which form the basis of the material analysed) of profile 1 is their capacity to extract zinc from the spring water and their tolerance to this element. This is paralleled only by the analyses of some noda of the Caricion davallianae whose "soils" are also chiefly composed of bryophyte remains.

SYNOPTIC CLASSIFICATION OF THE SCHEUCHZERIETEA AND THE PARVOCARICETEA WITH PARTICULAR REFERENCE TO THE CARICION CURTO-NIGRAE COMMUNITIES OF WIDDYBANK FELL

Class: SCHEUCHZERIETEA  
 syn.: Scheuchzeria Caricetea fuscae p.p.  
 Order: SCHEUCHZERIETALIA  
 Alliance: RYNCHOSPORION ? ERIOPHORION GRACILIS  
 ALBAE

PARVOCARICETEA  
 syn.: Scheuchzeria Caricetea fuscae p.p.  
 Order: CARICETALIA NIGRAE  
 Alliance: ERIOPHORION CARICION CURTO-NIGRAE  
 SCHEUCHZERI

TOFIELDIETALIA  
 CARICION DAVALLIANAE  
 CARICION BICOLORIS-ATROFUSCAE

α Nodal group with Carex nigra and Carex pulicaris  
 syn.: Violo-Epilobietum palustris ass. nov., sub-ass. Caricetosum pulicaris

β Nodal group with Carex flacca and bryophytes  
 syn.: variant with bryophytes  
 Nodum with Cratoneuron filicinum and Equisetum variegatum  
 syn.: Carex-lepidocarpa sub-var. (m.u. 15)  
 Nodum with Ranunculus flammula and Carex echinata  
 syn.: typical sub-var. (m.u. 16)

β Nodal group with Juncus effusus and Cerastium holosteoides  
 syn.: Juncus effusus var.  
 Nodum with Viola palustris  
 Trifolium repens  
 syn.: typical sub-var. (m.u. 18)  
 Nodum with Potamogeton polygonifolius  
 syn.: Potamogeton var. (m.u. 17)

Key  
 [ - - - - ] Vegetation present on Widdybank Fell

Class : PARVOCARICETEA (Westhoff 1961 mscr.)  
den Held and Westhoff cl. nov. 1969

The status and inter-relationships of those parts of this class, and of the related Scheuchzerieta, to which reference is made in the following account are shown on the facing page and immediately prior to the section dealing with the Tofieldietalia.

The terms "mire" and "fen" are used in the ensuing description and discussion in the sense of McVean and Ratcliffe (1962): both apply to vegetation which is usually dominated by monocotyledons and exists under the conditions of a high water-table, but "mires" develop where the water is soligenous in origin and "fens" where it is topogenically determined. (It should also be noted that the latter, lowland, vegetation type belongs to another class.) Furthermore, oligo-trophic, meso-trophic and eu-trophic are given their older meaning and refer to the nutrient level of the substrate and not to the productivity of the communities. Therefore, those said to be oligo-trophic grow on nutrient-poor substrate whilst eu-trophic vegetation is found in nutrient-rich conditions.

The Parvocaricetea, created by the division of the Scheuchzerio-Caricetea fuscae (Nordh. 1936) R. Tx. 1937, includes the low-growing vegetation typical of mires - the "central European "Flachmoor".

The herb layer is principally composed of members of the Cyperaceae, Gramineae and Juncaceae, whilst Sphagnum spp. and/or such pleurocarpous mosses as Scorpidium and Drepanocladus predominate in the ground layer. The surrounding water, which is at a high level during both winter and summer, is nitrogen-poor, may be oligo-, meso- or eu-trophic, and varies between mildly base-poor and base-rich.

The class is found throughout the whole of the euro-siberian region, but is most widespread in the north where its altitudinal range reaches down to sea-level. In the south, it is principally in the montane and alpine zones and its distribution extends also to the mountains of the mediterranean region.

### Syntaxonomy

The difficulty of developing a satisfactory classification for inter-related communities of acidic and basic mires, those on their margins and those of hummock and hollow and lawn complexes was mentioned by Nordhagen (1936) when describing the two orders - the Scheuchzerietalia of communities in channels in Sphagnum bogs, and the Caricetalia fuscae Koch 1926 of oligo- to meso-trophic mires - from which (broadly speaking) Tüxen formed the class Scheuchzerio-Caricetales<sup>a</sup> (syn: Scheuchzerio-Caricetea fuscae) in 1937. This problem is also referred to by Dahl (1956) and by Malmer (1968) who both list a number of ecological features, e.g. position of the water-table, nutrient status and velocity of flow of the water, which promote the variability of the vegetation, and by Segal (1968) who mentions the additional complications imposed by successional changes. Closely related to (different) parts of the Scheuchzerio-Caricetea fuscae are the communities of blanket bogs and wet heaths, usually placed in the Oxycocco-Sphagnetea, and those of tall-herb vegetation (Molinietalia) and reedswamps (Phragmitetea). A detailed bibliographic coverage of the various schemes which have been proposed to cover this wide range of vegetation types is given by Westhoff and den Held (1969) and it is, therefore, only necessary to make a brief mention of some of them in the present account.

The affinities of the base-rich mires of the Tofieldietalia to the Molinietalia have been emphasised in the classificatory schemes of a number of authors; a few of these treatments are described in the later section of this work concerned with such mires.

The arrangement of Duvigneaud (1949), which largely followed that of Vlieger (1937), was much more drastic. It resulted from a study of mire and bog communities over terrain extending from the most continental to the most atlantic parts of Europe during which Duvigneaud had become very much aware of the numerous transitions from the oligo-trophic bogs to the soligenous mires. This caused him to erect the class Sphagno-Caricetea fuscae (syn.: Caricetales uliginosae, Br.-Bl. et Vl. apud Vl. 1937) to cover all the vegetation of "bogs and wet heaths" and "mires". Nevertheless, within it Duvigneaud retained as orders these two broad divisions (although transferring the Scheuchzerietalia - as the Scheuchzerio-Rhynchosporion albae - from the "mires" to the "bogs") which had formed separate classes in older publications and which were retained as such in later ones. The orders were the Molinio-Caricetalia fuscae, combining all the alliances of the Caricetalia fuscae and of the

Molinietalia, and the Erico-Sphagnetalia, composed of the Oxycocco-Sphagnetea and the Scheuchzerietalia. A number of species were proposed as class characters, but Westhoff and den Held (1969) do not feel that they can be retained in central Europe as a distinct group whose members have similar ecological tolerances (a requirement for such an assemblage); neither do they appear to be valid for the British Isles.

The provisional arrangements of Malmer (1968) are similar to Duvigneaud's in that the oligo- to meso-trophic mires are classified with the bog communities, but the eu-trophic mires and the Sphagnum dominated vegetation of blanket bog channels are each placed in separate classes. However, Malmer extends this class of bogs and mires to include the eastern European wooded blanket bogs which are usually assigned to the Vaccinio-Piceetea; this interpretation has not yet been supported by others.

Westhoff and den Held believe, in company with most of those working since Duvigneaud (1949), that the inter-related communities of bogs and mires are best described and classified by a return to the older system in which his orders once more become separated at the class level. However, after removing the Molinietalia from the Molinio-Caricetalia, the Dutch authors differ from most of the others in that they do not return the Scheuchzerio-Rhynchosporion (syn.: Rhynchosporion albae) to the same class as the rest of the mire communities. They feel that the resulting class - the Scheuchzerio-Caricetea fuscae - would be of an unsatisfactory composition: they can find no species which could act as class characters for they would have to be components of both the acidophilous, species-poor communities of the Rhynchosporion and the species-rich chalk-swamp vegetation.

As a consequence, they have split the Scheuchzerio-Caricetea into the Parvocaricetea (syn.: Caricetalia fuscae Koch 1926) and the Scheuchzerietea (syn.: Scheuchzerietalia Nordh. 1936) which has a single order. In central Europe, the latter is more closely allied to the Oxycocco-Sphagnetea than to the Parvocaricetea, but in Scandinavia the converse relationship is found.

Contemporaneously with this reclassification, Tüxen and his collaborators, who are surveying the plant communities of the whole of Europe, have come to the same decision regarding the status of the Scheuchzerio-Caricetea fuscae, although using the synonym Caricetea nigrae for the Parvocaricetea (Tüxen 1971); the present account follows this current thinking.

Character species

Westhoff and den Held (1969) list five species which differentiate the two related classes - Parvocaricetea and Scheuchzerietea - from all others; two of them, Menyanthes trifoliata and Sphagnum teres, are named by Oberdorfer (1957) as characters of the "parent" class - the Scheuchzerio-Caricetea fuscae.

The Dutch workers point out that some of the species which they use as class characters also occur in communities of other classes, e.g. in those of the Magnocaricetalia (Phragmitetea) and are therefore only weak indicators; although these comments cannot be directly applied to Britain because of the paucity of such phytosociological investigations here, they are shown in the list of character species below.

<u>Pedicularis palustris</u>	<u>Carex diandra</u>
<u>Stellaria palustris</u>	<u>C. demissa</u>
<u>Calamagrostis stricta</u>	<u>C. lasiocarpa</u> (weak)
<u>Riccardia pinguis</u>	<u>Potentilla palustris</u> (weak)
<u>Acrocladium cordifolium</u>	<u>Hydrocotyle vulgaris</u> (weak)
<u>Drepanocladus exannulatus</u>	<u>Epilobium palustre</u>
<u>D. sendtneri</u>	

All are found in the British Isles, and at least some of the habitat types described for them by Clapham, Tutin and Warburg (1962) and by Jermy and Tutin (1968) are suitable ones for the class. Many are widely distributed, both geographically and altitudinally; only Calamagrostis, Carex lasiocarpa and Drepanocladus sendtneri are geographically, although not altitudinally, rather restricted, and both Carex diandra and Stellaria palustris occur widely but usually below 1,000 ft (305m) (Perring and Walters 1962). Carex demissa, Pedicularis palustris, Riccardia pinguis and Drepanocladus exannulatus have all been found, chiefly in communities of the Parvocaricetea, during the present investigation (cf. Table I) and Potentilla palustris is present in Widdybank Pastures which lie immediately to the south-east of the Fell. All the other Phanerogams are shown by Perring and Walters to be absent from the Upper Teesdale area; no such data <sup>are</sup> is available for the remaining two bryophytes. Before the value of these species as characters of the Parvocaricetea in the British Isles can be accurately assessed, further phytosociological investigations of the communities in which they occur must be made.

Westhoff and den Held list also a number of species which differentiate the Parvocaricetea from the Scheuchzerietea. Several of these; Equisetum palustre, Triglochin palustris, Cardamine pratensis,

Succisa pratensis and Potentilla erecta, are present on the Fell in communities of each order of the Parvocaricetea. Another, Salix repens, has been found in one nodum (mapping unit 17) of one of the orders - the Caricetalia nigrae.

They divide the class into two orders: the Caricetalia nigrae and the Tofieldietalia. The authors of most of the classificatory schemes published since 1950 (e.g. Oberdorfer 1957, 1962, Lohmeyer et al 1962, Passarge 1964) have had the same conception of the status of the Caricetalia, but Oberdorfer et al (1967) reduced its rank to that of an alliance - the Caricion canescenti-fuscae - and combined it with the Rhynchosporion albae and the Eriophorion gracilis (both considered by most other workers to form the Scheuchzerietalia) to give the Scheuchzerio-Caricetalia fuscae; the Scheuchzerio-Caricetea fuscae was composed of this together with Tofieldietalia. Westhoff and den Held's separation out of the Scheuchzerietalia communities forming the Scheuchzerietea and leaving only the Caricetalia nigrae and the Tofieldietalia in the Parvocaricetea is followed in this account.

Order : CARICETALIA NIGRAE W. Koch 1926 em. Nordh. 1936  
denuo. em. R. Tx. 1937

### Syntaxonomy

The work of Koch (1926) and Klika (1934) in central Europe led to the erection of the Caricetalia fuscae which was composed of three alliances: the Caricion davallianae, the Caricion fuscae and the Rhynchosporion albae. Nordhagen (1936) removed the last and placed it, as the Scheuchzerion palustris, in the Scheuchzerietalia palustris whose centre of distribution was in north and north-east Europe. From the basis of his work in Norway, he considered that the Caricetalia fuscae (syn.: Caricetalia nigrae) still had three alliances: the Schoenion ferruginei (equivalent to the Caricion davallianae of central Europe) of calcareous, eu-trophic conditions, the Caricion bicoloris-atrofuscae, in similar habitats at higher altitudes, and the Caricion canescentis-Goodenowii (syn.: Caricion fuscae) of acidic to neutral, oligo- to meso-trophic habitats. Although Tüxen removed the Caricion davallianae from the Caricetalia fuscae in 1937, it was some years before the order became recognised in its present form since the alliance was returned to it on a number of subsequent occasions, e.g. Vlieger (1937) and Dahl (1956). To-day, it is usually considered to be composed only

of the Caricion curto-nigrae (syn.: Caricion fuscae) but Doing (1963) suggests that some Molinion communities should also be included and the order renamed the Junco-Caricetalia nigrae. The alpine Eriophorion scheuchzeri Hadač 1939 is thought by some to be a second component of the Caricetalia nigrae; however, both Oberdorfer et al (1967) and Westhoff and den Held (1969) regard it as of uncertain status.

All.: Caricion curto-nigrae W. Koch 1926 em. Nordh. 1936  
(sub-nom. Caricion canescentis-Goodenowii)

The communities of the alliance are found in oligo-trophic to meso-trophic oxygen-rich water around springs and streams and in soligenous mires. Its area of distribution is the same as that of the class, but if the Eriophorion scheuchzeri is considered to be a valid alliance, this takes the place of the Caricion in the alpine regions.

#### Synonymy

The alliance has been recognised under a number of names, all with approximately the same floristical-ecological interpretation. The differences in nomenclature which have occurred over the years are partly a result of the changes in the validity of the specific names of the taxa used to designate it. These are (giving the currently accepted term first): Carex curta Good. (syn.: C. canescens auct. non L.) and Carex nigra (L.) Reichard (syn.: C. fusca All. and C. Goodenowii Gay).

The original name of Caricion fuscae Koch 1926 was altered (and the alliance amended - see below) by Nordhagen (1936) to Caricion canescentis-Goodenowii, a move which highlighted two of the species having their ecological optima in it. However, because of the change in nomenclature of Carex Goodenowii, Dahl (1956), Oberdorfer (1957) and Lohmeyer et al (1962) use Caricion canescentis-fuscae. The more succinct (and taxonomically correct) Caricion curto-nigrae is preferred by Westhoff and den Held (1969) and it is followed here.

#### Syntaxonomy

These authors point out that the modern conception of the Caricion curto-nigrae differs from that of Koch's (1926) original Caricion fuscae, for the latter included some of the vegetation now assigned to the Caricion davalliana. In addition, they feel that it is unnecessary to split the alliance into two sub-alliances; this was done by Passarge (1964) in order to cater for the floristic differences between those communities in contact with communities of the Oxycocco-Sphagnetum and

and those adjacent to communities of either the Molinio-Arrhenoratheretea or the Phragmitetea, and also by Hadač and Váňa (1967) to allow for dissimilarities between vegetation of the sub-alpine regions and that at lower altitudes. Westhoff and den Held incorporate within the Caricion curtonigrae part of the Eriophorion gracilis Preisg. apud Oberd. 1957 (syn.: Caricion lasiocarpae Vanden Berghen 1948), which had been placed by Oberdorfer (1957) and some later authors in the Scheuchzerietalia where it formed a link with the Caricion curtonigrae.

#### Character species

All but one of those given by Westhoff and den Held for the order and alliance are found throughout most of the British Isles (a few are absent from the Midlands and south-west England) in oligo- to eu-trophic mires, and figure in Aufnahmen from similar habitats on Widdybank (Table I). These species are: Carex nigra, C. echinata, Ranunculus flammula, Viola palustris, Epilobium palustre and Sphagnum recurvum ssp. amblyphyllum Russ., although as the last taxon is not recognised in this country, the occurrence of the species has had to be used instead. The other member of the group - Juncus filiformis - has a very restricted distribution; it is chiefly found in the Lake District on "stony lake shores" (Clapham, Tutin and Warburg 1962).

#### α Nodal group with Carex nigra and Carex pulicaris (Mapping units 15-18) Table XVIII

The key card used in the field is given in Fig. VIIa. The differential species groups of the α and β nodal groups and noda are summarised as Table XIXb together with those of the noda of the Caricion davallianae (Table XIXa) thus enabling a comparison to be made between the two groups of noda. The constancy ratings for those species used as differentials for nodal groups and noda are outlined for clarity.

In addition to the four noda used as mapping units, another - the Nodum with Potamogeton (which is not represented in a sufficiently large area to map) - is placed in this nodal group. The occurrence of some member of the differential species group both here and in mapping unit 17 is rather weak.

The four noda employed as mapping units can each be loosely described by the term "sedge marsh". In addition to Carex nigra and C. pulicaris, C. dioica and C. demissa are part of the differential species group, and the companion C. panicea is of high constancy throughout. Shoots of the other differential species - Eriophorum angustifolium, Equisetum palustre, Juncus articulatus and Nardus stricta - contribute to the usually dense,

Class : PARVOCARICETEA  
 Order : CARICETALIA NIGRAE  
 Alliance : CARICION CURTO-NIGRAE

L Nodal group with Carex nigra and Carex pulicaris

a) Field key to communities on Widdybank Fell

<u>L</u> Nodal group	Carex nigra, C. dioica, Eriophorum angustifolium, Carex pulicaris, Nardus stricta, Carex demissa, Equisetum palustre, Juncus articulatus.			
<u>B</u> Nodal groups	Ctenidium molluscum, Fissidens adianthoides, Carex flacca, Campylium stellatum, Riccardia pinguis, Drepanocladus revolvens.	Juncus effusus, Rhytidiadelphus squarrosus, Cerastium holosteoides, Thuidium tamariscinum, Mnium punctatum, Luzula campestris, Juncus squarrosus, Anthoxanthum odoratum, Cirsium palustre.		
Noda	Cratoneuron filicinum, Equisetum variegatum, Carex lepidocarpa.	Ranunculus flammula, Carex echinata, Juncus kochii.	Trifolium repens, Holcus lanatus, Pseudoscleropodium purum, Mnium undulatum, Sagina nodosa, Ajuga reptans.	Viola palustris, Acrocladium stramineum, Polytrichum commune, Galium saxatile, Polygala serpyllifolia.
Mapping Units	15	16	18	17
				Potamogeton polygonifolius

b) Classification of L and B Nodal groups and Noda

Association <i>Violo-Epilobietum palustris</i> ass. nov. Sub-ass. <i>caricetosum pulicaris</i> Syn.: <u>L</u> Nodal group with <i>Carex nigra</i> and <i>Carex pulicaris</i>				
Variant with bryophytes Syn.: <u>B</u> Nodal group with <i>Carex flacca</i> and bryophytes		Juncus effusus var. Syn.: <u>B</u> Nodal group with <i>Juncus effusus</i> and <i>Cerastium holosteoides</i>		Potamogeton var.
<i>Carex lepidocarpa</i> sub-var.	typical sub-var.	typical sub-var.	<i>Polygala serpyllifolia</i> sub-var.	
Syn.: Nodum with <i>Cratoneuron filicinum</i> and <i>Equisetum variegatum</i>	Syn.: Nodum with <i>Ranunculus flammula</i> and <i>Carex echinata</i>	Syn.: Nodum with <i>Trifolium repens</i>	Syn.: Nodum with <i>Viola palustris</i>	Syn.: Nodum with <i>Potamogeton polygonifolius</i>
Mapping Units	15	16	18	17

often tall (30 to 50 cm) vegetation. Constant and near constant companions include Festuca ovina, Agrostis stolonifera, Potentilla erecta, Prunella vulgaris, Bryum pseudotriquetrum and Acrocladium cuspidatum. The mean species numbers only range from 30 to 36; that of the other nodum is 15.

Communities of the nodal group develop in areas of tolerably eu-trophic status but rarely with a pH greater than 6.3. Habitats include the flood plains of the sikes and also the boulder clay channels between hummocks of blanket bog where there is continuous irrigation although not necessarily in the form of a rivulet.

The  $\mathcal{L}$  nodal group consists of two  $\beta$  nodal groups, each with two noda, and of the nodum with Potamogeton. Table XVIII shows that the separation into noda is not completely clear cut; for example, several Aufnahmen of the  $\beta$  nodal group with Carex flacca and bryophytes also have species of the other  $\beta$  nodal group.

$\beta$  Nodal group with Carex flacca and bryophytes (Mapping units 15 and 16)

The differentiating bryophyte species are Ctenidium molluscum, Fissidens adianthoides, Campylium stellatum, Drepanocladus revolvens and Riccardia pinguis; species indicative of meso- to eu-trophic conditions. Thalictrum alpinum, Molinia caerulea and Eleocharis quinqueflora occur only in this nodal group, but are each of very low constancy. A few Aufnahmen of both noda are transitional to mapping unit 13 of the Caricion davallianae. The soils have a higher pH and a greater humus content than do those of the other  $\beta$  nodal group.

Nodum with Cratoneuron filicinum and Equisetum variegatum  
(Mapping unit 15)

Cratoneuron filicinum, Equisetum variegatum and Carex lepidocarpa are the differential species; the first is the sole transgressor into mapping unit 16. Plantago maritima is present only in this nodum of those in the alliance, but is of low constancy. The species of the  $\mathcal{L}$  and  $\beta$  nodal groups are well represented.

The general appearance of vegetation of the nodum is usually of a low mat of Carex species (panicea, flacca, demissa) and Ctenidium molluscum. Superficially, these communities appear close to mapping unit 20 of the Ranunculo-Anthoxanthion but closer examination reveals the absence of Bellis perennis, Trifolium repens and Plantago lanceolata, all of which are differentials of the  $\mathcal{L}$  nodal group of that alliance. In other places, the taller Eriophorum angustifolium, Equisetum palustre and

Carex nigra are more evident; occasionally, Eleocharis, Blysmus compressus and tufts of Juncus effusus are also present, although Blysmus is in the Sand Sike region only. The species of this taller form of the nodum are about 20 to 30 cm in height except for the Juncus which may be 50 cm. The total cover of the vegetation is about 100%; the contributions made by Phanerogams and bryophytes being 80 to 90% and 25 to 100% (more usually 60 to 75%) respectively. Ctenidium plays the greatest part in the lower layer, but occasionally there is a large amount of Drepanocladus revolvens.

The communities of the nodum are most often found forming part of the complex on the (more or less) flat flood plains of the sikes; the scale of the mosaic is such that the patches of mapping unit 15 are rarely more than 25 to 50 sq m in size. The adjacent communities are, most commonly, either the floristically related mapping units 12 and 13 (Caricion davallianae) or, where the ground level is slightly higher, mapping unit 16 or 18 (of the same alliance) or mapping unit 21 of the Ranunculo-Anthoxanthion. Such complexes occur along Sand Sike and by the lower part of Slapestone and the central part of Nameless Sikes. The last two areas are now inundated. The nodum may develop on the hummocks of a complex in which mapping unit 16 is present in the hollows lying about 10 cm below.

Nodum with Ranunculus flammula and Carex echinata (Mapping Unit 16)

The low growing and less easily seen Juncus kochii is the third member of the differential species group of this nodum. The vegetation is rich in sedges - Carex nigra, C. dioica, C. pulicaris, C. demissa and C. panicea being prominent throughout, together with Nardus stricta and Eriophorum angustifolium. Occasional plants of Kobresia and Carex hostiana reveal localised affinities with the Caricion davallianae. Juncus effusus and some of the other species of the nodal group with Juncus effusus and Cerastium holosteoides are sometimes present. Total cover is about 100% and, as with the previous nodum, that of the Phanerogams is 80 to 90% but here the bryophyte cover is much lower, rarely being greater than 50% and generally within the range of 30 to 40%.

The floristic composition, principally as shown by their companion species, of six Aufnahmen of this nodum links it with two noda of the Caricion davallianae: nos. 140, 184 and 186 are transitional to mapping unit 12 and nos. 139, 141 and 146 to mapping unit 13. These relationships are discussed more fully in the section dealing with the noda of this other alliance.



The nodum occurs as one of a number by the sikes where there is slow-moving ground water, the terrain sloping in any direction at angles of only 1 or 2°. Stands, sometimes of one or two hundred square metres in extent, have been mapped beside the lower part of Slapestone Sike, in the mid-part of Nameless Sike and in the Middle Flush region. All these are now inundated but there remain some areas of the nodum by Sand Sike, beside the River Tees below Falcon Clints, and on rather steeply sloping ground (up to 25°) near Widdybank Farm and in the Sand Sike valley where there is soligenous enrichment of the boulder clay. In suitably irrigated areas similar vegetation may also develop between blanket bog hummocks. In a small part of the Middle Flush region, the nodum grew in the hollows of a hummock-hollow complex; the nodum with Cratoneuron and Equisetum being on the hummocks. Aufnahme 179 was made in this area, and although there is some infiltration by species of the β nodal group with Juncus and Cerastium, the floristic differences of hummocks and hollows are evident. This was one of the few occasions in which the separation into hummocks and hollows made in the field could be sustained upon the subsequent examination of the data.

β Nodal group with Juncus effusus and Cerastium holosteoides  
(Mapping units 17 and 18)

The other members of this differential species group are: Rhytidiadelphus squarrosus, Thuidium tamariscinum, Mnium punctatum, Luzula campestris, Juncus squarrosus, Anthoxanthum odoratum and Cirsium palustre. All except Cerastium and Luzula are present in the other β nodal group, but their frequencies are low and they reach their optima in the present one. As a whole, the species content of the nodal group reflects the greater acidity of the substrata.

Nodum with Trifolium repens (Mapping unit 18)

Although Trifolium repens is recorded for some of the Aufnahmen of mapping unit 16, it is the most conspicuous member of this differential species group. The others are Holcus lanatus, Pseudoscleropodium purum, Mnium undulatum, Sagina nodosa and Ajuga reptans; almost all are scattered throughout the previous nodum (mapping unit 16) and its differential - Ranunculus flammula - just attains a frequency of III in the present one. The α nodal group differential, Juncus articulatus, is hardly present in the vegetation but the others are well represented and Carex nigra, C. demissa, Nardus stricta and Equisetum palustre each has an important rôle in the general physiognomy, as has the companion

Festuca ovina. Juncus effusus, J. squarrosus and Deschampsia caespitosa all give the vegetation a "tufted" appearance. The dense herb layer is about 30 cm tall, although the Juncus effusus shoots reach 50 cm and <sup>this</sup> species contributes about 80% to the 100% (approximately) total cover. Bryophyte cover is normally 50%; occasionally the clumped habit of the other species enables this layer to become exposed. The activities of moles produces heaps of soil which are uncolonised and may account for 5% of the area.

Communities of the nodum do not have the water-table above the surface but they apparently require some water movement. Stands of several hundred square metres were mapped in the main part of Middle Flush (immediately below the access road) where the angle of slope was 2° to 3° and near the lower part of Slapstone Sike. In the latter region, the flat ground supporting the nodum was slightly raised above the surrounding vegetation whose dissimilar species complement portrayed the influence of calcareous drainage water. A large area remains as part of the Fold Sike drainage complex and much of the valley side above the north bank of Sand Sike is covered with this vegetation, growing on boulder clay below the flat ground where peat has developed. Near the Fell wall, this nodum is extensively represented. Small areas of it may be present in the complex vegetation patterns associated with natural channels, in which the percolating water is somewhat enriched, cut through the peat surface.

#### Nodum with Viola palustris (Mapping unit 17)

The members of the differential species group are more localised within this mapping unit than are the differentials of mapping units 16 and 18. Viola palustris, Polytrichum commune, Galium saxatile and Polygala serpyllifolia all contribute to the appearance of the vegetation; Acrocladium stramineum is also a differential. There is a definite reduction in the constancies of the nodal group differential species since Carex dioica, Juncus articulatus, Equisetum palustre and Eriophorum angustifolium are often absent. However, Carex nigra and Nardus stricta together with Juncus effusus and J. squarrosus play a prominent part in the physiognomy. Although it figures in only two Aufnahmen, Sphagnum recurvum is frequent in many areas mapped as the nodum and Aulacomnium palustre is locally common. Cover of the vegetation is complete; that of both Phanerogams and Cryptogams is high, being 80-90% and about 75% respectively. The vegetation again varies from 30-50 cm in height. As is explained in more detail below, this nodum is considered to be that most "typical" of the Caricion curto-nigrae on the Fell.

Communities of the nodum are principally found as a band of only a few metres in width separating calcicolous vegetation of the Caricion davallianae or the more eutrophic noda of the Caricion curto-nigrae from those of the Violion caninae or the Oxycocco-Sphagnetea. In many cases this intermediate zone is associated with a channel and therefore with water movement. However, the largest stand of mapping unit 17 (measuring several hundred square metres) was in the Middle Flush region, a large part of which became irrigated in and after wet periods when the ground water bubbled up in many places producing conditions similar to those in the channels. The nodum formed bands extending almost the whole of the distance between the access road and the river, bordering the large stand of mapping unit 18 on its north-west and south-west edges. The other communities adjacent to mapping unit 17 were mapping units 27 and 29 of the Violion caninae; the nodum with Viola palustris is floristically related to both of these.

#### Nodum with Potamogeton polygonifolius

These communities are too small in size to be shown even on the 1:2,500 map for they have developed in the slow-moving water of some sikes which are usually only about a metre wide. This results also in a rather weak development of the nodum as no part of it is very far away from the different types of vegetation on the stream banks. An Aufnahme of similar species composition made on a Camptothecium nitens hummock is also included here. The floating leaves of Potamogeton are usually the most conspicuous feature of the vegetation and may contribute much towards the 75-100% cover, but that of both Phanerogams and Cryptogams varies widely, i.e. from 10-60% and 5-100% respectively. Carex nigra, Eriophorum angustifolium, Equisetum palustre and Juncus articulatus, all nodal group differentials, are frequent. The nodum was chiefly encountered below the access road in some of the meanders of Slapestone Sike, but it is also present in suitable places in the streams on the top of the Fell.

## SUMMARY AND SYNONYMY OF THE VIOLO-EPILOBIETUM PALUSTRIS

## ASSOCIATION VIOLO-EPILOBIETUM PALUSTRIS ass. nov.

## SUB-ASS. caricetosum pullicaris

Potamogeton variantsyn.: Nodum with Potamogeton

## variant with bryophytes

## typical sub-variant

syn.: Species-rich Juncetum squarrosi sub-alpinum ) McV. & R. 1962Hypno-Caricetum alpinum )Nodum with Ranunculus flammula and Carex echinataJuncus-Festuca rubra-Mnium punctatum nodum Eddy 1967Carex lepidocarpa sub-variantsyn.: Nodum with Cratoneuron filicinum and Equisetum variegatumHypno-Caricetum Ratcliffe 1966Juncus effusus variant

## typical sub-variant

syn.: Nodum with Trifolium repensSpecies-rich Nardetum sub-alpinum McV. & R. 1962Species-rich Juncetum effusi Eddy, Welch & Rawes 1969Polygala serpyllifolia sub-variantsyn.: Nodum with Viola palustris

## SUB-ASS. sphagnetosum

Sphagnum palustre variant

## typical sub-variant

syn.: Sphagneto-Juncetum effusi McV. & R. 1962Sphagneto-Juncetum effusi McV. & R. 1962 (Birks 1969)Carex-Sphagnum recurvum nodum Birks 1969Carex rostrata sub-variantsyn.: Carex rostrata-Sphagnum warnstorffianum nodum McV. & R. 1962Carex rostrata-Sphagnum warnstorffianum nodum McV. & R. 1962

(Eddy, Welch &amp; Rawes 1969)

Juncus acutiflorus sub-variantsyn.: Juncus acutiflorus-Acrocladium cuspidatum sociation Edgell 1969Juncus acutiflorus bog Ratcliffe 1959Juncus acutiflorus-Acrocladium cuspidatum nodum p.p.

McV. &amp; R. 1962

Sphagnum papillosum variant

## typical sub-variant

syn.: Sphagneto-Caricetum alpinum Eddy, Welch & Rawes 1969Sphagnum russowii sub-variantsyn.: Sphagneto-Caricetum sub-alpinum ) McV. & R. 1962Sphagneto-Caricetum alpinum )Carex aquatilis sub-variantsyn.: Carex aquatilis-rariflora nodum McV. & R. 1962

The syntaxonomy and classification of the  $\mathcal{C}$  nodal group  
Table XX and Fig. VIIb

A survey of the literature concerning the types of vegetation found in various parts of the British Isles has revealed at least one syntaxonomic equivalent for each of three of the four noda of the  $\mathcal{C}$  nodal group with Carex nigra and Carex pulicaris which have been used as mapping units; nothing comparable either to the nodum with Viola palustris or to that with Potamogeton has been discovered. The author considers that all these vegetation types are sufficiently similar in floristic composition, physiognomy and the nature of their habitats to be grouped together to form one sub-association of a new association - the caricetosum pulicaris of the Violo-Epilobietum palustris. The sub-ass. sphagnetosum has been erected from data relating to communities which, although not directly equivalent to any of the Teesdale vegetation, are nevertheless sufficiently similar to form part of the same association. This is summarised and the synonymy of its components given on the facing page.

Association Violo-Epilobietum palustris ass. nov.

The communities of this association are soligenous mires of any nutrient level which have developed where the angle of slope is usually less than  $15^{\circ}$  and only rarely greater than  $20^{\circ}$ . The association has, so far, been described from Skye, the Scottish Highlands, the northern Pennines and North Wales but it is probable that both sub-associations are also present in the southern uplands of Scotland (McVean and Ratcliffe 1962). Its altitudinal limits extend from sea-level on Skye to 3,500 ft (1068m) in central Scotland, but are chiefly between 1,000 and 3,000 ft (305 to 914m) roughly corresponding to the sub- and low-alpine zones (McVean and Ratcliffe 1962).

The permutations of physiognomic dominants in the herb and the ground layers of the components of the association has led earlier workers to erect a number of associations and noda to encompass the variation; the current treatment of the data has caused each to be demoted to the rank of a sub-variant of the association. These dominant species are such members of the Cyperaceae, Juncaceae and Gramineae as: Carex echinata, C. pulicaris, C. nigra, C. demissa, C. panicea, C. rostrata, C. aquatilis, C. rariflora, Juncus effusus, J. acutiflorus, J. articulatus, Festuca ovina, Nardus stricta and Anthoxanthum odoratum; and of the Sphagnaceae as: Sphagnum recurvum, S. palustre, S. warnstorffianum, S. teres, S. papillosum and S. russowii.

The character species of the Violo-Epilobietum palustris are: Viola palustris, Carex echinata, Epilobium palustre and Juncus kochii; the first three are also Caricion curto-nigrae character species. The sub-associations caricetosum pulicaris and sphagnetosum comprise the vegetation of eu- to meso-trophic and of meso- to oligo-trophic mires, respectively.

Sub-association caricetosum pulicaris

The nature of, and variation between, the communities of the caricetosum pulicaris is amply illustrated by the five nodes of the Nodal group with Carex nigra and C. pulicaris; the differential species are Carex pulicaris, Equisetum palustre and Carex demissa. Three variants have been found.

In addition, to those described from Widdybank Fell, these communities have been reported only from the Moor House, N.N.R. in the North Pennines (Eddy, Welch and Rawes 1969), and from the central and northern Scottish Highlands by McVean and Ratcliffe (1962). The range in altitude encountered so far is from 1000 to 3200 ft (305 to 976m).

The Potamogeton variant is composed solely of the nodum of the same name from Widdybank (col. E, Table XX); nothing comparable is mentioned in the literature of the British Isles.

The variant with bryophytes is differentiated by Riccardia pinguis, Campylium stellatum, Fissidens adianthoides and Ctenidium molluscum. The typical sub-variant is composed of the Nodum with Ranunculus flammula and Carex echinata (mapping unit 16, col. B), two associations described by McVean and Ratcliffe (1962) - the Hypno-Caricetum alpinum (col. M) and the species-rich Juncetum squarrosi sub-alpinum (col. C) - together with the Juncus-Festuca rubra-Mnium punctatum nodum (col. G) in the Moor House N.N.R. (Welch 1967). The last was indeed likened by its author to the Scottish species-rich Juncetum squarrosi sub-alpinum. Species of the Juncus effusus variant transgress into all the members of the sub-variant.

Ratcliffe (1966) described a Hypno-Caricetum (col. F) for Widdybank and likened it to the Scottish Hypno-Caricetum alpinum but it would now appear that the former is more correctly a constituent of the sub-variant with Carex lepidocarpa.

The Nodum with Cratoneuron filicinum and Equisetum variegatum (mapping unit 15, col. A) also belongs here. The differentials are Carex lepidocarpa and Cratoneuron filicinum.

The Juncus effusus variant is differentiated also by Thuidium tamariscinum, Holcus lanatus and Trifolium repens; Anthoxanthum odoratum and Galium saxatile are also prominent. There are again two sub-variants. The members of the typical sub-variant are the Nodum with Trifolium repens (mapping unit 18, col. C), the species-rich Nardetum sub-alpinum McVean and Ratcliffe 1962 (Col. N) and the species-rich Juncetum effusi Eddy, Welch and Rawes 1969 (Col. H). The last two associations were not classified in the Caricion curto-nigrae when they were established. The species-rich Nardetum, and the species-rich Juncetum squarrosi (Col. L) of the variant with bryophytes were assigned by McVean and Ratcliffe (1962) to the Arctostaphyleto-Cetrarion nivalis in which Dahl (1956) had placed the oligo- to eu-trophic moss and lichen heaths of the Rondane district of Norway. However, the habitats of the Scottish types are those of sloping ground which received calcareous drainage and their close floristic affinities with the Hypno-Caricetum alpinum (classified in the Caricion curto-nigrae) are noted by McVean and Ratcliffe. Since both the species-rich Nardetum and Juncetum squarrosi also have many Parvocaricetea and Caricion curto-nigrae character species (cf Table XX) it is suggested that both should be placed in this alliance.

Nevertheless, the species-rich Nardetum of McVean and Ratcliffe (1962) is cited by Shimwell (1968) as a component of the Ranunculo-Anthoxanthion because of the presence of several Arrhenatheretalia and Molinio-Arrhenatheretea character species such as Ranunculus acris, Holcus lanatus, Trifolium repens, Cerastium holosteoides and Taraxacum officinale agg. at moderate constancies. Some of these are present to the same extent in the other two components of the typical sub-variant and indicate its affinity to the Ranunculo-Anthoxanthion. Also, it may be noted that the species-rich Juncetum effusi was placed by Eddy, Welch and Rawes (1969) in the Molinietalia of the Molinio-Arrhenatheretea. In spite of this, when the total floristic composition of these members of the Juncus effusus variant - typical sub-variant is considered, it seems correct to place them in the Caricion curto-nigrae.

The Polygala serpyllifolia sub-variant is composed solely of the Nodum with Viola palustris (mapping unit 17, col. D); Polytrichum commune and Acrocladium stramineum are both present with constancy V and,

therefore, since these species are two of the differentials of the sphagnetosum, the sub-variant forms a link from the caricetosum pulicaris to this second sub-association.

Sub-association sphagnetosum

The sphagnetosum comprises communities of meso- to oligo-trophic mires and is differentiated by Sphagnum recurvum in addition to Acroclodium stramineum and Polytrichum commune. It is found in a region extending from the Isle of Skye and the Scottish Highlands to northern England and North Wales at altitudes ranging from 500 ft (152m) to 3500 ft (1068m). Two variants are present.

The Sphagnum palustre variant is differentiated only by this species; it has three sub-variants. The typical sub-variant has been erected from the Sphagneto-Juncetum effusi McVean and Ratcliffe 1962 (col. O) and two vegetation types described by Birks (1969) - the Sphagneto-Juncetum effusi (col. U) and the Carex-Sphagnum recurvum nodum (col. V).

Although McVean and Ratcliffe equate their Sphagneto-Juncetum with the Juncus effusus mires of North Wales, the Pennines and other parts of England, the present author does not consider that these other community-types are members of the Violo-Epilobietum palustris. However, a study of the floristics of the mires (described by Ratcliffe (1969) and Edgell (1969) from North Wales and by Eddy, Welch and Rawes (1969) from the northern Pennines)) shows that despite there being a very poor representation of Violo-Epilobietum character species in them, affinities to the Sphagnum palustre variant are evident. Nevertheless, they are more closely related to other Juncus effusus dominated communities of Widdybank Fell which contain species characteristic of several classes and which it has proved impossible to classify. This group of mires is described in a later section.

The two other sub-variants both have species which are strongly represented in the communities of the caricetosum, and are found in more meso-trophic conditions than is the typical sub-variant. The Carex rostrata-Sphagnum warnstorffianum nodum McVean and Ratcliffe 1962 (col. P) and the vegetation type of the same name described by Eddy, Welch and Rawes (1969) (col. J) comprise the Carex rostrata sub-variant. The differential species are Carex rostrata, Sphagnum warnstorffianum and S. teres. The Juncus acutiflorus sub-variant is found in the Scottish Highlands (as the Juncus acutiflorus-Acrocladium cuspidatum nodum McVean and Ratcliffe 1962 p.p. col. Q) and in North Wales (the Juncus acutiflorus-Acrocladium cuspidatum

sociation Edgell 1969, col. W, and the Juncus acutiflorus bog Ratcliffe 1959, col. X). Inspection of the companion species lends support to the observation that the Juncus acutiflorus sub-variant is allied to the caricetosum: a number of species (Cirsium palustre, Ranunculus acris, Festuca rubra and Mnium punctatum) found in the caricetosum occur in only this sub-variant of the sphagnetosum.

The Sphagnum papillosum variant is differentiated jointly by this species and by Carex curta; it is described from the Scottish Highlands and from the north Pennines. The typical sub-variant is apparently present only in the latter locality. Detailed floristic analyses of its synonym, Sphagneto-Caricetum alpinum (col. K), are given by Eddy, Welch and Rawes (1969) for the Moor House N.N.R., and Ratcliffe (1966) mentions the occurrence of a Sphagneto-Caricetum McVean and Ratcliffe 1962 on Widdybank Fell. However, he does not give sufficient detail of its floristic composition to allow it to be included in this study of the Violo-Epilobietum palustris and nothing comparable has been found by the present author.

Ratcliffe's reference, according to its page number, is to the Sphagneto-Caricetum sub-alpinum of McVean and Ratcliffe; this has been included (col. R) with the Sphagneto-Caricetum alpinum (col. S) of these authors in the Sphagnum russowii sub-variant of the Sphagnum papillosum variant. The differentiation of the sub-alpine and alpine vegetation is made chiefly upon position relative to the 2000 ft (610m) contour, but is also based to some extent on their floristic compositions. However, it does not seem that this separation can be maintained with the present arrangement of the data, since the species given by McVean and Ratcliffe to distinguish the alpine vegetation are also present with frequencies of III in the other.

The Carex aquatilis sub-variant (syn.: Carex aquatilis-rariflora nodum McVean and Ratcliffe 1962, Col. T), differentiated by Carex aquatilis and C. rariflora is found at the upper altitudinal limit of the association. Its range of from 2400 to ~~3500~~ 3500 ft (305-976m) is approached only by the Sphagneto-Caricetum alpinum (2000-3150 ft, 610-960m) and by the Hypno-Caricetum alpinum (1700-3200 ft. 519-976m).

A number of the vegetation types included in the Violo-Epilobietum were placed in the Caricion-curto nigrae when they were initially erected. These are: the two described by Birks (cols. U and V), the Carex rostrata-Sphagnum warnstorffianum noda of both McVean and Ratcliffe and

Eddy, Welch and Rawes (cols. P and J), the Juncus acutiflorus-Acrocladium cuspidatum nodum (col. Q) of the former and the Sphagno-Caricetum alpinum (col. K) of the latter. The classification of the species-rich Juncetum and Nardetum (cols. L and N) within the Arctostaphyleto-Cetrarion nivalis has already been mentioned. Eddy, Welch and Rawes (1969) have placed the Juncus-Festuca rubra-Mnium punctatum nodum (col. G) and the species-rich Juncetum effusi (col. H) in the Tofieldietalia and the Molinietalia, respectively. However, each has a sufficiently large complement of Caricion curto-nigrae species to enable it to be classified in this alliance whilst still being transitional to another order. Ratcliffe (1959) and Edgell (1969) make no attempt to incorporate their vegetation types into the phytosociological hierarchy.

The remaining members of the sphagnetosum (cols. O, R, S and T) are placed by McVean and Ratcliffe (1962) in the Leuco-Scheuchzerion Nordh. 1943. This forms part of the Rhynchosporion albae W. Koch 1926 which has been removed by Westhoff and den Held (1969) from the Scheuchzerio-Caricetea fuscae to form the Scheuchzerietea (see above). In Table XX a comparison has been made of the relative affinities of the components of the Violo-Epilobietum palustris to the Parvocaricetea and to the Scheuchzerietea. From this it is apparent that the Sphagnum palustre variant, and especially its typical sub-variant (col. K), forms a transition from the Caricion curto-nigrae to the Scheuchzerietea: Sphagnum papillosum itself is a differential of the latter from the Parvocaricetea, and two of the Scheuchzerietea character species - Sphagnum cuspidatum and Cladipodiella fluitans - are present in the sub-variant. Despite the reduction in Caricion curto-nigrae character species in the variant, the weight of its affinity lies with this alliance of the Parvocaricetea.

#### The Synsystematic placing of the $\mathcal{L}$ Nodal group.

The concentration of Parvocaricetea and Caricion curto-nigrae character species in the group of noda is clearly seen from Table I although the rôles of two of them - Carex nigra and C. echinata - in the British Isles are in need of clarification. From left to right within the  $\mathcal{L}$  nodal group there is an increase in affinity to the Caricion curto-nigrae, the nodum with Viola palustris (mapping unit 17) being the most typical of the alliance. Not only does this nodum have the greatest number and constancy of occurrence of character species, but

those given by Westhoff and den Held (1969) as differentiating the Caricetalia nigrae from the Tofieldietalia, i.e. Polytrichum commune, Acrocladium stramineum, Aulacomnium palustre and Sphagnum plumulosum, are almost completely confined to it. The virtual absence of any Tofieldietalia character species from this nodum is very noticeable.

The nodum with the greatest concentration of Tofieldietalia species - that with Cratoneuron filicinum and Equisetum variegatum (mapping unit 15) - is the one showing the least affinity to the Caricion curto-nigrae. Table XIX, which compares the differential species of the two Cl nodal groups of this class, indicates the proximity of this nodum to mapping units 13 and (especially) 12 although mapping unit 15 cannot be classified in the Cl nodal group with Carex dioica and Clepidocarpa because it lacks some of the differential species required. The nodum with Ranunculus flammula and Carex echinata (mapping unit 16) and that with Trifolium repens (mapping unit 18) show progressively a reduction in the Tofieldietalia influence.

There is a noticeable concentration of Molinio-Arrhenatheretea and Arrhenatheretalia character species in mapping unit 18, and Shimwell's (1968) classification in the Ranunculo-Anthoxanthion of similar vegetation from the Scottish Highlands has already been referred to. However, the total species complement and physiognomy of this nodum on Widdybank are similar to those of the other Caricion curto-nigrae noda and distinctly different from those of the Ranunculo-Anthoxanthion in the same area and therefore mapping unit 18 is retained in the former alliance.

The nodum with Potamogeton polygonifolius chiefly occurs in slow-moving streams, and its overall floristic composition relates it to the other noda of the Caricion curto-nigrae. There is an influence, however, of Tofieldietalia/Caricion davallianae character species (cf. Table I): the nodum is the only location for Camptothecium nitens and one of the few for Mnium pseudopunctatum, both also members of the "Teesdale assemblage". Although the nodum has the only occurrence of the Parvocaricetea character Drepanocladus exannulatus, and one of the two for Carex curta - a Caricion curto-nigrae character - these single occurrences do not serve to make the nodum very "typical" of its alliance.

FIG VIII DIAGRAMMATIC SOIL PROFILES OF THE  $\alpha$  NODAL GROUP WITH CAREX NIGRA AND CAREX PULICARIS

112-a

$\alpha$  Nodal group with Carex nigra and Carex pulicaris

$\beta$  Nodal group with Carex flacca and bryophytes

$\beta$  Nodal group with Juncus effusus and Cerastium holosteoides

Nodum with Cratoneuron and Equisetum

Peat  
Aufn. 157 pH 5.8

Massive -  
Fibrous -  
Greasy.

Peat  
Aufn. 167 pH 6.4

Wet-greasy  
massive - high  
amorphous - high  
org. - mod. perm.

Peaty-gley  
Aufn. 132 pH 5.6

v. dk. grey -  
greasy - v. wet  
structureless to  
massive - high  
org.

dk. grey -  
structureless to  
single grain -  
low org.

grey - wet -  
structureless to  
single grain -  
low org.

Nodum with Ranunculus and Carex echinata

Peaty-gley  
Aufn. 179 pH 6.3 (hummocks)  
Aufn. 180 pH 6.8

hummocks  
pH 6.0  
hollows  
pH 5.7

(Flushed) Peat  
Aufn. 139 pH 5.7  
100+ cm

Black - friable  
- weak med. crumb  
high org.

Nodum with Trifolium

Peaty-gley  
Aufn. 181 pH 5.3  
Aufn. 183 pH 6.1  
Aufn. 185 pH 5.2

peaty horizon 20-40 cm  
All profiles as for m.u.16

Nodum with Viola

Peaty-gley  
Aufn. 188 pH 5.1  
Aufn. 189 pH 5.0  
Aufn. 217 pH 4.5

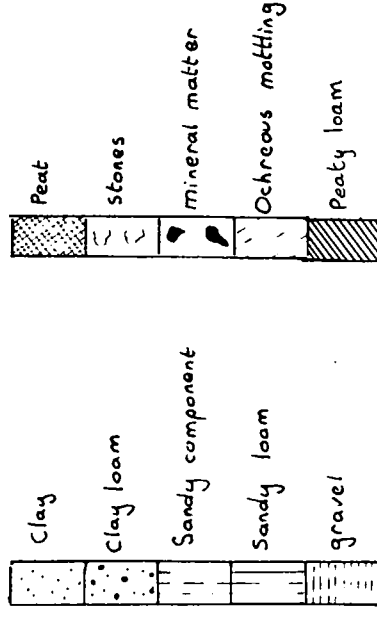
All profiles as for m.u.16  
peaty horizon 5-15 cm

Both profiles as for m.u.15  
(Aufn. 142)

yellow grey -  
structureless to  
massive - low org.

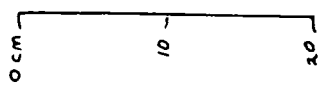
bluish grey -  
wet - plastic -  
structureless to  
massive.

As for m.u.16



KEY

SCALE



The soils of the  $\mathcal{C}$ Nodal group with *Carex nigra* and *Carex pulicaris*

Profile descriptions and soil analyses are available for the four noda used as mapping units and are given in Fig. VIII and Table XXI respectively.

The properties of the soils which can be most usefully discussed are those of humus content (as measured by the loss on ignition - L.O.I), exchangeable calcium and pH. When the mean values of these factors for each nodum are considered, the arrangement and grouping of the noda follows that obtained when only their floristic composition is used (cf. Table XVIII); there is a sequence following the order: mapping units 15, 16, 18, 17 and in two characteristics a greater disjunction occurs from mapping unit 18 to 17 than between any others.

The principal types of substrate associated with the  $\mathcal{C}$ nodal group are peats and peaty-gleys; they support communities of one of three or four noda respectively. A high organic matter content, either throughout the whole profile or confined to the upper horizon in those which are stratified, is a notable feature of all four noda. The mean values of loss on ignition for the upper parts of the profiles are, excluding any that appear abnormally low:

mapping unit 15	62.2%
" 16	49.4%
" 18	46.9%
" 17	34.9%

Soil analyses of other noda show that these large amounts of peaty material are exceeded only by those of mapping units 24 and 28<sup>4</sup> (sp Erico-Sphagnion) L.O.I. 93%; mapping unit 23 (Ericion) L.O.I. 85.7%; mapping unit 26 (Empetrion nigri) L.O.I. 68.6%; mapping unit 13 (Caricion davallianae) L.O.I. 67.4%; and mapping unit 29 (Violion caninae) L.O.I. 67.3%.

Arrangement of the mean values of pH for the upper layers of the soil in decreasing order of magnitude gives the sequence

mapping unit 15	pH 6.1
" 16	pH 5.8
" 18	pH 5.5
" 17	pH 4.9

This order is repeated when the amounts of available calcium are considered; again, that for mapping unit 17 is much lower than the others. The rather distinctive nature of this nodum in these respects parallels its floristic separation from mapping units 15, 16 and 18 since it has a poor representation of several of the  $\mathcal{C}$  nodal group differentials. Its pH and calcium status approaches those of the floristically related

<sup>4</sup> Further data are needed for this nodum.

mapping units 27 and 29 (Violion caninae) for which mean pH values of 3.2 and 4.0 and calcium content of 3.6 and 2.8 m eq/litre have been obtained, respectively.

Some comments can be made concerning the variation between the soils of different examples of both mapping units 16 and 18, these differences being reflected floristically in each case. The soils of Aufnahmen nos. 183 and 161 of mapping unit 18 have markedly greater content of exchangeable calcium than those of the other two Aufnahmen (nos. 181 and 185). Inspection of Table XVIII shows that the first pair are notable in having some of the differential species of mapping unit 16 (and/or the B nodal group with Carex flacca and bryophytes) whose calcium content is similar. Two soil types are associated with mapping unit 16, peaty gleys and (flushed) peats, supporting Aufnahmen nos. 184, 186, 179 and nos. 139, 146 respectively. Reference has already been made to the floristic affinity of nos. 184 and 186 to mapping unit 12 and of nos. 139 and 146 to mapping unit 13. These relationships are borne out by those of soil type and soil humus content since the soils of mapping unit 12 are peaty gleys and those of mapping unit 13 are (flushed) peats which have a greater humus content (cf. Table XXVII).

The links of the soils of mapping units 16, 12 and 13 are part of a general affinity between the substrates of the C nodal group with Carex nigra and C. dioica and the D nodal group with Carex nigra and Equisetum palustre (mapping units 11 to 13) of the C nodal group with Carex dioica and C. lepidocarpa. Again, there are parallel floristic affinities. In pH, content of organic matter and nitrogen the soils of the D nodal group with Carex nigra and Equisetum palustre approach those of mapping units 15 to 18 and differ sharply from the substrates of the other noda of their C nodal group in having a lower pH and higher humus and nitrogen content. The D nodal group is floristically distinguished by the presence of Carex nigra, Equisetum palustre and Eriophorum angustifolium, all differentials of the C nodal group with Carex nigra and C. pulicaris and mapping unit 12 has Nardus stricta and Carex demissa which are also differentials of this C nodal group (cf. Table XIX). Therefore, it is suggested that the differences in species content between the C nodal groups of the Parvocaricetea are related to the amounts of humic material and pH status of the soils. Exchangeable calcium plays little or no part in this inter-alliance differentiation for the values for all the noda (except mapping unit 17) are substantially similar.

Soligenous mires dominated by *Juncus effusus* and/or *Carex rostrata*

Reference has already been made to the difficulty of drawing district boundaries between vegetation placed in the Parvocaricetea, especially in the Caricion curto-nigrae, and that assigned to the Molinietalia of the Molinio-Arrhenatheretea. It has been observed too that whereas the present author wishes to include the species-rich Juncetum effusi of the Moor House N.N.R. in the Violo-Epilobietum palustris, sub-ass. caricetosum pulicaris of the Caricion curto-nigrae, Eddy, Welch and Rawes (1969) place it in the Molinietalia. The soligenous mires dominated by *Juncus effusus* and/or *Carex rostrata* on Widdybank Fell are further examples of communities falling into this zone of transition, so much so that it has proved impossible to classify them.

The six Aufnahmen made in this type of vegetation are given in Table XXII. The group has been split to give mapping unit *Carex rostrata* dominated extremely species-poor mires, and mapping unit III *Carex rostrata* and/or *Juncus effusus* dominated vegetation with a greater variety of a species. It was considered that mapping unit II could not be further divided, but with additional material it might be found that Aufnahmen nos. 204 and 206 form the basis of a separate sub-group. The mapping units are (jointly) differentiated by *Carex rostrata*, *Polytrichum commune*, *Sphagnum recurvum*, *Eriophorum angustifolium* and *Acrocladium stramineum*. Cover is complete; the bryophytes form a very dense layer of 75-90% through which the shoots of the Phanerogams protrude with 50-60% cover. *Juncus effusus* reaches a height of 60-80 cm and the other Phanerogams attain 30-40 cm.

*Carex nigra*, *Holcus lanatus* and *Galium saxatile* are differentials of mapping unit III in which tussocks of *Deschampsia caespitosa* are often prominent. Dominance of the ground layer is either shared between *Sphagnum recurvum* and *Polytrichum commune* or is by *Rhytidiadelphus squarrosus* alone as in Aufnahmen nos. 204 and 206. It is evident from Table XXII that this sub-type of the mapping unit is also characterised by the absence of several of the joint differentials for mapping units II and III and by the presence of *Festuca rubra*, *Rumex acetosa*, *Lophocolea bidentata* and *Stellaria graminea*. It is likely that these changes in floristic composition within mapping unit III may be due to the infiltration of species from the adjacent and different communities.

All the Aufnahmen were made on a 7000 sq m mire expanse (now inundated by the reservoir) which was intermittently flooded by the Tees and extended from the mouths of Slapestone Sike to that of Middle Flush and lay between a tract of blanket bog (mapping unit 28 - Oxycocco-Sphagnetea) and a strip of damp grassland (mapping unit 22 - Ranunculo-Anthoxanthion). Aufnahmen nos. 201 and 202 were made in vegetation which stood out distinctly from the rest because of the dominance of Carex rostrata; the distinctive composition of 204 and 206 is probably a consequence of their proximity to the damp grassland.

These were the only places in which mapping unit II was found but a narrow strip (10m wide) of mapping unit III also extended beside the Tees from Middle Flush to about the present position of the dam. Along the river bank the blanket peat had broken away and receded from the river; periodic inundation by the Tees of the ground about 1m below had deposited a layer of alluvial material on which the mire had developed. Some areas of this mapping unit still remain in places, usually associated with embryonic streams, of slow rather acidic water movement, e.g. at the head of Sand Sike.

The synsystematic position of the mapping units is best considered next on account of its distinctive nature; this is preferable to the customary arrangement of following a discussion of their syntaxonomic relationships.

The Juncus effusus/Carex rostrata mires present an extreme example of the phenomenon, touched upon in previous systematic sections, that even although a vegetation type may be satisfactorily placed within one alliance it may also contain species of another which are at sufficiently high constancies to cause it to constitute a group linking the two. An example of this has been described for the nodal group of the Seslerio-Mesobromion where several Caricion davallianae species are present in mapping unit 7.

By contrast, within the Juncus effusus and Carex rostrata mires, character species of two classes and their sub-groups are present with equal constancy; the occurrences of Caricion curto-nigrae and Molinietalia species are shown in Table XXII in which some affinity to the Violion caninae is also apparent. It may be noted also that both Stellaria graminea and Juncus squarrosus are found in Nardetalia communities on the continent. Nevertheless, the basic choice of their classification is between the Caricion curto-nigrae and the Molinietalia and although the mires cannot be assigned definitely to either, the

occurrence of increasing numbers of Molinietalia species at the right-hand side of Table XXII, especially in the last two Aufnahmen, suggests the direction to which their systematic position may be tending.

These communities were observed in the field to integrate with those of mapping unit 17 (the nodum with Viola palustris) of the Caricion curto-nigrae which are best differentiated from the mires of mapping units II and III by the presence of Viola palustris, Epilobium palustre, Carex pulicaris and Equisetum palustre and by increased frequencies of Carex echinata and Ranunculus flammula. However, there are differences in the habitats occupied by the two types; the nodum with Viola is usually found either in a channel forming a narrow border around blanket bog or associated with a sike as in the Middle Flush region, whereas mapping units II and III were chiefly on periodically irrigated alluvial material adjacent to, but at a lower level than, the blanket peat.

The close relationship of the Juncus effusus mires to the nodum with Viola palustris is an important factor in the consideration of the syntaxonomy of the mires. The nodum has been incorporated into the Violo-Epilobietum palustris to form the Polygala serpyllifolia sub-var. of the Caricetosum pulicaris, Juncus effusus var. (cf. Table XX). From Table XX the floristic proximity of the sub-variant to the Sphagnum palustre var. typical sub-var. of the sphagnetosum is apparent. Included in the latter sub-variant (as col. 0) is the Sphagneto-Juncetum effusi of McVean and Ratcliffe (1962) to which reference is made by Ratcliffe (1966) in his description of "flush bogs in areas of pronounced water seepage". He does not, however, give detailed floristic analyses of the vegetation and although he mentions the presence of Sphagnum palustre it is not clear whether he is describing vegetation equivalent to that of McVean and Ratcliffe, to the nodum with Viola palustris or to the Juncus effusus mires of mapping unit III. Communities of dominant Carex rostrata within an almost pure carpet of Sphagnum recurvum are mentioned also by Ratcliffe; they seem to be equivalent to mapping unit II. He relates them to the Sphagneto-Caricetum (sub-alpinum) of McVean and Ratcliffe which form part (col. R) of the sphagnetosum-Sphagnum papillosum var. and not the Sphagnum palustre var. as does the Sphagneto-Juncetum effusi. There are two further references to the latter in the literature but, on the basis of their floristic composition, they do not both refer to the same type of vegetation. That described by Birks (1969) from Skye is synonymous with the

communities from the Scottish Highlands and is placed with them in Table XX (col. U) but the Sphagneto-Junctum effusi typicum and Carex rostrata facies from the Moor House N.N.R. (Eddy, Welch and Rawes 1969) are too poor in character species of the Violo-Epilobietum palustris to be incorporated into the association. The Juncus effusus-Sphagnum recurvum sociation Edgell 1969 and the Juncus effusus bog of Ratcliffe (1959) fall into the same category. All this vegetation, including that on Widdybank, which is atypical of the Violo-Epilobietum palustris is shown in Table XXIII. The frequencies of three of the association characters (Viola palustris, Epilobium palustre and Carex echinata) are given in the list of Parvocaricetea and Caricion curtonigrae character species; the fourth, Juncus kochii, has not been recorded at all but the "Juncus bulbosus" which occurs with a frequency of I in both kinds of vegetation in the Moor House N.N.R. may refer to this species since the two are often indistinguishable.

In spite of there being some floristic similarity between the vegetation types of Table XXIII, the group cannot be given association status since character species are lacking. However, the table is somewhat heterogeneous and therefore it is not considered that any of its components is an exact syntaxonomic equivalent of the Widdybank vegetation.

The ~~syn~~systematic position of the mires is complex for they are again intermediate between the Molinietalia and the Caricion curtonigrae. Because of their relationship to the Violo-Epilobietum palustris, classification of their position must await further investigation of the floristic limits of this association. Matters are still more aggravated by the probable connection of dominant Juncus effusus with disturbance by man and animals (Ratcliffe 1964, cf. Westhoff and den Held 1969) although Eddy, Welch and Rawes (1969) are of the opposite opinion that these communities have been little grazed and are hardly changed from the natural vegetation.

The soils of the Carex rostrata/Juncus effusus  
mires on Widdybank Fell

Table XXIV

There are two striking features of the analyses presented in Table XXIV: 1) the much higher proportion of organic matter in the soils of the floristically impoverished mapping unit II compared with those of the more species-rich mapping unit III and 2) the overall similarities of the soils underlying the two floristic forms (exemplified by Aufnahmen nos. 203 and 206 of mapping unit III. In addition, the pH values and amounts of humic material associated with each mapping unit strongly resemble those of the adjoining (and different) communities.

The pH levels, which range from 4.4 to 4.6, are very close to that of the adjacent Ranunculo-Anthoxanthion vegetation (Aufnahme 210 of mapping unit 22) which is 5.0 (Table XVII); both the mires and this damp grassland were periodically flooded by the Tees. The humic content of the soils of mapping unit III is similarly akin to that of Aufnahme 210 which has a loss on ignition of 11.62%, whereas that of mapping unit II (88.15%) is almost equal to the 90% of mapping unit 28 to which the vegetation alongside Aufnahme 201 belonged. However, between the blanket bog and the mire there was a small drop in height of about half a metre and both examples of mapping unit II were in places which could have been receiving organic material from the bog. This suggestion is supported by the difference in pH of the two types of vegetation. That of the blanket bog was only 3.7; it would not have received the enrichment given to the mire by the overflowing of the Tees.

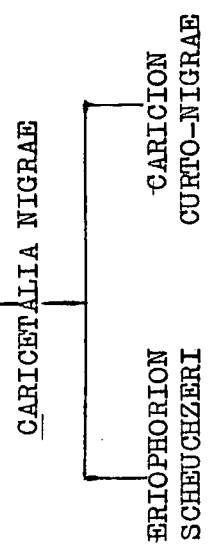
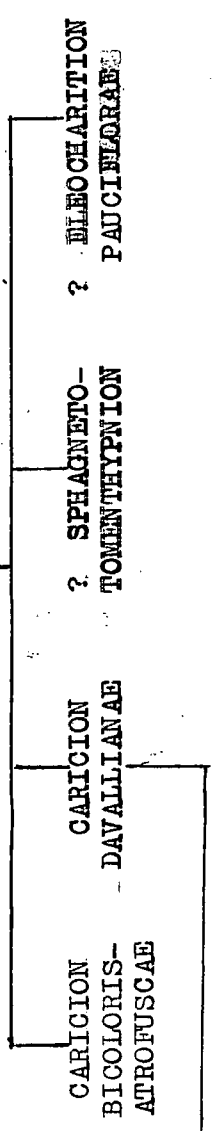
A comparison with the data given in Table XXI for mapping unit 17 shows that both its pH and content of organic matter are higher than those of mapping unit III, although not greatly so, thus reflecting their floristic proximity.

119-a.

SYNOPTIC CLASSIFICATION OF THE SCHEUCHZERIETEA AND THE PARVOCARICETEA  
WITH PARTICULAR REFERENCE TO THE CARICION DAVALLIANAE COMMUNITIES OF WIDDYBANK FELL

Class : SCHEUCHZERIETEA  
 syn.: Scheuchzerio-Caricetea fuscae p.p.  
 Order : SCHEUCHZERIETALIA  
 Alliance : RHYNCHOSPORION ? ERIOPHORION  
 ALBAE GRACILIS

PARVOCARICETEA  
 Scheuchzerio-Caricetea fuscae p.p.  
 TOFIELDIETALIA



α Nodal group with Carex dioica and Carex lepidocarpa  
 syn.: Pinguiculo-Caricetum dioicae ass. nov. p.p.

β Nodal group with Kobresia and Ctenidium molluscum

δ Nodal group with Equisetum variegatum  
 syn.: sub-ass. equisetosum variegati p.p.

Nodum with Sesleria Nodum with Juncus triglumis  
 syn.: Sesleria var. syn.: Juncus triglumis -  
 (m.u. 8) Gymnostomum var.,  
 Juncus triglumis sub-var.  
 (m.u. 9)

Nodum with Molinia  
 and Eriophorum latifolium  
 syn.: Scorpidium var. p.p.,  
 Succisa sub-var. p.p.,  
 Juncus acutiflorus facies  
 (m.u. 11)

with Carex nigra and Equisetum palustre  
 syn.: sub-ass. eleocharetosum p.p.

Nodum with Nardus Nodum typicum  
 syn.: typical var. p.p., syn.: typical var. p.p.,  
 Nardus sub-var. typical sub-var.  
 (m.u. 12) (m.u. 13)

Nodum with Gymnostomum  
 syn.: sub-ass.  
 equisetosum variegati p.p.,  
 Juncus triglumis -  
 Gymnostomum var.,  
 Gymnostomum sub-var.  
 (m.u. 14)

Key

Vegetation present  
 on Widdybank Fell.

Order : TOFIELDIETALIA Preising apud Oberd. 1949

The area of distribution of these nutrient and base-rich mires is identical to that of the class.

#### Syntaxonomy

The alliances of the order were originally placed in the Caricetalia fuscae Koch 1926, but in 1937, Tüxen added them to the Molinieta of the Molinio-Arrhenatheretales (syn.: Molinio-Arrhenatheretea). Later workers (e.g. Vlieger 1937, Dahl 1956) have returned them to the Caricetalia fuscae (either in whole or in part, with or without the communities of the Molinion), but Braun-Blanquet (1949a) gave them the status of an independent order with the name Caricetalia davallianae. Subsequently the term Tofieldietalia became used instead on account of the absence of Carex davalliana from this type of community in Scandinavia.

In recent years other schemes have been drawn up which emphasise the proximity of the Tofieldietalia and the Molinieta: for example, Soó (1957) and Kovačs (1962) place both within the Molinio-Juncetea Br.-Bl.1947 and Malmer (1968) suggests that the Molinion and the Calthion might form part of the Tofieldietalia (or Tofieldietea). However, the most generally accepted arrangement is that of the Tofieldietalia as a member of the Parvocaricetea (the Scheuchzerio-Caricetea fuscae in older publications). This procedure is followed by Oberdorfer 1957, 1962, Lohmeyer et al 1962, Oberdorfer et al 1967 and by Westhoff and den Held who recommend its acceptance in the absence of reliable data for the whole of Europe, the presence of which might enable the situation to be definitively established.

#### Character species

The following are given by Shimwell (1968):

<u>Carex flava</u> agg.	<u>Juncus alpinoarticulatus</u>
<u>C. dioica</u>	<u>J. triglumis</u>
<u>Bartsia alpina</u>	<u>Equisetum variegatum</u>
<u>Campylium stellatum</u>	<u>Eleocharis quinqueflora</u>
	<u>Scorpidium scorpioides</u>

Drepanocladus revolvens s.l. and Campylium chrysophyllum (syn.: Chrysohypnum stellatum) can be added from the lists of Oberdorfer (1957) and Westhoff and den Held (1969). Nordhagen (1936), working in northern Europe, included Carex capitata and C. microglochin in the character species of the Caricion bicoloris-atrofuscae, the upland alliance of the order. However, Oberdorfer uses them as Tofieldietalia characters for he does not consider that this alliance is present in southern Europe.

Others of his group of character species are believed by Shimwell to be differentials in Britain of either the order or its lowland alliance (Caricion davallianae - see below). One of the two remaining, Sesleria uliginosa is non-British and Bryum Nimum is a variety of B. pseudotriquetrum. The latter is named by Westhoff and den Held as a Tofieldietalia character but its ecological tolerance appears to be too wide for this in Britain. (On Widdybank Fell it occurs abundantly in communities of the Caricion fuscae and the Ranunculo-Anthoxanthion as well as in those of the Tofieldietalia) However, Bryum Nimum is "not uncommon in bogs and pools" (Dixon 1954) and is therefore a probable order character.

The altitudinal range of the order in Europe is from sea-level to the alpine regions and in Britain, as in the Netherlands, communities of the Caricion davallianae are present in the dune-slacks. However, three of Shimwell's character species (Juncus triglumis, J. alpinoarticulatus and Bartsia alpina) have a predominantly sub-alpine distribution in the British Isles (Perring and Walters 1962), all three occurring in central Scotland and northern England at altitudes over 2,500 ft (762 m) and 1,000 ft (305 m) respectively. In addition, Juncus triglumis occurs in north Wales and north-west Scotland and J. alpinoarticulatus in the south of Scotland as low as 600 ft (198 m) (Corner 1972). Since Nordhagen (1936) suggests Juncus triglumis as a Caricion bicoloris atrofuscae character, it is treated as such in the present account, but both Juncus alpinoarticulatus and Bartsia alpina are retained, with reservations, as Tofieldietalia characters. All the remaining Phanerogams are found throughout the whole of the altitudinal range of the order although Carex flava is of limited value as a character species as it is found in only two localities - near Morcambe Bay and in the Craven district of the north Pennines - and C. dioica is not very frequent in coastal districts, unlike Equisetum variegatum and Eleocharis quinqueflora. Little information on the distribution of the bryophyte characters is available but habitat descriptions are given by Watson (1966). His remark concerning the association in mountain bogs of Drepanocladus revolvens, Scorpidium scorpioides and Campyllum stellatum is particularly apposite, but the note that C. chrysophyllum is found in somewhat drier places (although calcareous) raises some doubt as to its value as an order character. The Phanerogams occur in

damp to wet places which often have base-rich irrigation (Clapham, Tutin and Warburg 1962, Jermy and Tutin 1968), i.e. they are suitable habitats for the order.

The group of Tofieldietalia character species in the British Isles is therefore amended to read:

Carex flava (local)	Juncus alpinoarticulatus
C. dioica	Eleocharis quinqueflora
Bartsia alpina	Equisetum variegatum
Campylium stellatum	Scorpidium scorpioides
C. chrysophyllum	
Drepanocladus revolvens s.l.	
Bryum bimum	

Shimwell lists four order differential species:

Selaginella selaginoides	Thalictrum alpinum
Pinguicula vulgaris	Parnassia palustris

However, Selaginella and Thalictrum are also present in Caricetalia nigrae communities inter alia both on Widdybank Fell and in the Scottish Highlands (McVean and Ratcliffe 1962), and are therefore disqualified from acting as Tofieldietalia differentials. This does not apply to Pinguicula and Parnassia which occur throughout the whole of the British Isles, especially in the north and west, over the whole altitudinal range of the order.

All the character and differential species (except Carex flava) are members of the flora of base-rich mires on Widdybank Fell; although Carex dioica is also present in some of the Caricetalia nigrae nodes, it is abundant only in those which are most eu-trophic.

Four alliances have been recognised within the Tofieldietalia but only the two already mentioned - the Caricion davallianae Klika 1934 and the Caricion bicoloris-atrofuscae Nordh. 1936 - are generally accepted as distinct entities. The Sphagneto-Tomenthypnion was erected by Dahl (1956) to include the eu-trophic or calcicolous communities which often formed a zone between mires with Sphagnum spp. and ericaceous shrubs and vegetation of the Caricion bicoloris-atrofuscae in the Rondane district of Norway. The fourth alliance, the Eleocharition pauciflorae Passarge 1964, separated out pioneer, open, chalk-swamp communities. Dahl followed the older system of classification and included both the Sphagneto-Tomenthypnion and the Caricion bicoloris-atrofuscae in the Caricetalia nigrae, but the arrangement of Malmer (1968) places both in the Tofieldietalia. This procedure for the Caricion bicoloris-atrofuscae follows that of Oberdorfer et al (1967)

All. : Caricion bicoloris-atrofuscae Nordh. 1936

It is necessary to make only a brief mention of this alliance; it is not represented in Upper Teesdale but the Caricion davallianae communities on Widdybank Fell show some floristic influences from this upland alliance.

The Caricion-bicoloris-atrofuscae replaces the Caricion davallianae (described below) in the sub-arctic and sub-alpine to alpine regions of central and northern Europe. The alliance is described by Nordhagen (1936) who mentions that some of its character species overlap with those of the lowland alliance. It may be noted, however, that Nordhagen did not recognise the Tofieldietalia and included both these alliances within the Caricetalia nigrae; therefore, with the subsequent erection of the Tofieldietalia, his "overlapping character species" became included in those of the order. These rather weak Caricion bicoloris-atrofuscae characters are Equisetum variegatum and Carex capillaris which, in Britain, are cited by Shimwell (1968) as a Tofieldietalia character (see also above) and a Caricion davallianae differential, respectively.

Character species

Eight of the thirteen given by Nordhagen occur in Britain. They are:

<u>Juncus triglumis</u>	<u>Carex atrofusca</u>
<u>J. castaneus</u>	<u>C. microglochin</u>
<u>Salix arbuscula</u>	<u>C. saxatilis</u>
<u>Minuartia stricta</u>	<u>C. capitata</u>

All are generally confined to land above 1,000 to 1,500 ft (305 to 457 m) and occur principally well above this altitude in places receiving base-rich irrigation in the central Highlands and north-west of Scotland, although Juncus triglumis is also present in Upper Teesdale, the Lake District and north Wales, and the only British station for Minuartia stricta is on Widdybank Fell (Clapham, Tutin and Warburg 1962, Perring and Walters 1962). It will be remembered that the two Tofieldietalia characters Juncus alpinoarticulatus and Bartsia alpina (which may in fact be Caricion bicoloris-atrofuscae characters in Britain) have a similar distribution to that of Juncus triglumis when the occurrence in north Wales of the latter is discounted. Three of the species listed above - Minuartia stricta, Carex microglochin and C. capitata - are each found in only one locality in Britain and are therefore of little value as alliance characters.

The only British vegetation so far described whose emplacement in the Caricion bicoloris-atrofuscae can be justified upon the presence of such character species is the Caricetum saxatilis Poore 1955 (Poore 1955 c) which is described by McVean and Ratcliffe (1962) as occurring chiefly in the central Highlands and in a few localities further north. The alliance character species present are Carex saxatilis, Juncus triglumis and J. castaneus. Some of the Caricion davallianae communities on Widdybank Fell, and the related Cariceto-Saxifragetum aizoidis McV. and R. 1962, are floristically close to this upland alliance; these relationships are discussed in the later sections dealing with the syntaxonomy and the synsystematic placing of the Widdybank vegetation.

All.: Caricion davallianae Klika 1934

The altitudinal range of the alliance is from sea-level to the sub-alpine regions but its optimal expression is found in the montane parts of Europe and Scandinavia. The vegetation, which may be either primary or secondary in origin, develops under the influence of base-rich irrigation in such places as soligenous mires, dune-slacks, and adjacent to spring-head communities on valley sides. Carex species and pleurocarpous mosses play prominent rôles in the physiognomy of the species-rich turf.

Synonymy and Syntaxonomy

Nordhagen (1936) expressed a preference for the synonym Schoenion ferruginei because of the presence of Schoenus ferrugineus in parts of the euro-siberian region, and the apparent absence of Carex davallianae from Scandinavia, but, as in the case of the Tofieldietalia versus the Caricetalia davallianae, the central European term Caricion davallianae (which, in any case, has priority over the other) has come to be used instead.

A third name which is preferred by many authors to-day is the Eriophorion latifolii Br.-Bl. et R. Tx 1943. However, it is not now used with their original sense, which was to separate out those communities of the Caricion-davallianae lacking sub-alpine and alpine species and having only a small proportion of those of the class as a whole. The resulting composition of the Eriophorion latifolii was such as to cause it to be referable to the Molinietalia. The modified Caricion

davallianae was retained with the Caricetalia fuscae, the Tofieldietalia not having been erected at that time.

A few authors still use both these terms although with different interpretations from those of Braun-Blanquet and Tüxen. The interpretation of Soó (1957, 1964) and Kovačs (1962) is exactly the converse and Passarge (1964) divides the Eriophorion latifolii on a geographical basis to give two (provisional) sub-alliances - the Caricion davallianae in central and southern Europe and the Eriophorion gracilis Preisg. apud Oberd. 1957 in Fennoscandia, which are also characterised by the addition of sub-mediterranean and boreal-continental species respectively. <sup>however,</sup> The greatest usage to-day of the name Eriophorion latifolii is as a synonym for the Caricion davallianae. The present account follows the practice of Westhoff and den Held (1969) who give precedence to the prior name of Caricion davallianae. The Dutch authors do not feel justified in subdividing the alliance even although they believe it to be somewhat heterogeneous but, if they were to do so, ecological criteria would be used rather than the floristic geographical ones of Passarge. This would result in the formation of one syntaxon for communities in calcium-poor conditions with a constantly high water-table and another for those in calcium-rich conditions with a fluctuating water-table.

It may be remarked that the treatment of the Eriophorion gracilis by Passarge differs from that of Westhoff and den Held who place the greater part of its communities in the Rhynchosporion of the Scheuchzerietalia. This is the order to which the Eriophorion (syn.: Caricion lasiocarpae Vandén Berghen 1948) is assigned in many classificatory schemes including those of Oberdorfer (1957, 1962) and that of Lohmeyer et al 1962 although the latter authors have reservations about this arrangement.

#### Character species

These are most of the remaining members of the group given by Westhoff and den Held (1969) as characters of both Tofieldietalia and Caricion davallianae (the only alliance present in the Netherlands). A few are also cited by Oberdorfer (1957) and by Shimwell (1968) from whose work a further two can be added. The species are:

Sagina nodosa	Eriophorum latifolium
Dactylorhiza incarnata	Tofieldia pusilla
Carex lepidocarpa	Epipactis palustris
C. hostiana	Liparis loeselii
Acrocladium giganteum	Camptothecium nitens
Drepanocladus lycopodioides	Bryum marratii
D. vernicosus	Mnium rugicum
Campylium elodes	M. seligeri
C. polygamum	M. pseudopunctatum
Catoscopium nigratum	M. cinclidioides
Riccardia multifida	Cinclidium stygium
R. sinuata	Sphagnum contortum
Pellia endiviifolia	S. contortum var. platyphyllum
P. neesiana	Fissidens osmundioides

Oberdorfer also includes Taraxacum limnanthes, Tofieldia calyculata and Carex davalliana. The first two of these are absent from Britain and the third is no longer present; it used to grow on a bog near Bath but was lost by drainage some time after the 1830s (Jermy and Tutin 1968). Fissidens adianthoides and Pterogoneurum ovatum are listed by Westhoff and den Held but their British habitats are unsuitable for the alliance, that of the former being too diverse and that of the latter being restricted to walls and banks (Dixon 1954).

Stirling's (1966) description of the habitat of Catoscopium nigratum - "sub-alpine flushes and damp calcareous dune-slacks" - exemplifies the altitudinal range of the alliance and over half the character species are found throughout the whole of this compass. Of the others, Tofieldia is alone amongst the Phanerogams in being confined to the sub-alpine to alpine regions (above 1,000 ft (305 m) in north England and usually over 2,500 ft (762 m) in central and north-west Scotland) whilst Epipactis and Liparis are lowland and coastal plants, the former chiefly in Wales, south and east England and the latter in only south Wales and East Anglia (Perring and Walters 1962). The liverworts are quite widespread but a number of the mosses are rare and are also restricted altitudinally: Drepanocladus vernicosus, Campylium elodes, Camptothecium nitens, Mnium pseudopunctatum, M. cinclidioides and Cinclidium stygium occur in bogs and marshes chiefly in the sub-alpine regions and Bryum marratii is confined to sandy seashores (Dixon 1954, Watson 1966). The complete complement of character species, all plants of damp, base-rich conditions, is retained in its entirety pending further phytosociological investigations throughout the British Isles. It will be appreciated from the above discussion that a number are only of restricted value.

Shimwell (1968) gives three alliance differential species: Carex capillaris, C. pulicaris and Primula farinosa, but the further investigations made since these suggestions have shown that Carex pulicaris is quite frequent in mesotrophic communities of the Caricion curto-nigrae both in north England and in central and north-west Scotland (cf. the preceding description of the Violo-Epilobietum palustris caricetosum pulicaris) and thus may not be a valid Caricion davallianae differential. The other species seem to be more or less confined to the damp calcareous habitats required by communities of the latter alliance. Carex capillaris is chiefly in upland parts of central Scotland, north England and north Wales although reaching sea-level in north Scotland and Primula farinosa, confined to north England and south Scotland, is usually but not always above 1,000 ft (305 m) (Perring and Walters 1962).

The probable geographical extent of the Caricion davallianae can be deduced from a study of the distribution of its character species (as above). Little published work concerning its lowland communities is available but Ivimey-Cook and Proctor's (1965) survey of the Burren includes accounts of some communities of the alliance at altitudes as low as 100 ft (31 m) and representatives from sea-level are described by Ranwell (1960) from the dune-slacks at Newborough Warren, Anglesey. Although she makes no attempt to utilise the Zurich-Montpellier system, the following character and differential species of class, order and alliance from Ranwell's lists (made in open to closed, damp to wet stands) show the affinity of this vegetation to the Caricion davallianae:  
Parvocaricetea character spp: Hydrocotyle vulgaris, Drepanocladus sedtneri;  
Tofieldietalia character spp: Equisetum variegatum, Campyllum stellatum,  
Drepanocladus revolvens;

differential spp: Pinguicula vulgaris, Parnassia palustris;  
Caricion davallianae character spp: Sagina nodosa, Drepanocladus lycopodioides, Campyllum elodes, Pellia endiviifolia.

In striking contrast to the Caricion davallianae communities of the lower altitudes, those of the upper have been much more extensively studied. The appropriate vegetation-types from the areas which have been investigated so far - the highlands of Scotland, the Isle of Skye and north England - are described in the section dealing with the syntaxonomic relationships of those on Widdybank Fell.

These base-rich soligenous mire communities on the Fell contain an appreciable number of alliance character species (cf. Tables I and XXV):

Class : PARVOCARICETEA  
 Order : TOFIELDIETALIA  
 Alliance : CARICION DAVALLIANAE

ℒ Nodal group with Carex dioica and Carex lepidocarpa

a) Field key to communities on Widdybank Fell

ℒ Nodal group	Carex dioica, Riccardia pinguis, Drepanocladus revolvens, Carex lepidocarpa, Campyllum stellatum, Juncus articulatus, Primula farinosa, Pinguicula vulgaris, Plantago maritima.					
⊘ Nodal group	Kobresia simpliciuscula, Ctenidium molluscum, Carex pulicaris, C. hostiana, Tofieldia pusilla.					
⊘ Nodal group	Equisetum variegatum		Eriophorum angustifolium, Eleocharis quinqueflora, Carex nigra, Equisetum palustre, Juncus kochii			
Noda	Rhacomitrium lanuginosum Thymus drucei Carex capillaris Sesleria caerulea Dittrichum flexicaule Scapania aspera Galium sternerii Tortella tortuosa	Juncus alpinoarticulatus Triglochin palustris Juncus triglumis	Molinia caerulea Succisa pratensis Eriophorum latifolium Juncus acutiflorus J. alpinoarticulatus Parnassia palustris	Nardus stricta Carex demissa		Gymnostomum recurvirostrum Minuartia verna Sagina nodosa Thymus drucei Carex capillaris
Mapping units	8	9	11	12	13	14

b) Classification of ℒ, β and ⊘ Nodal groups and Noda

Association Pinguiculo-Caricetum dioicae ass. nov. p.p. syn.: ℒ Nodal group with Carex dioica and C. lepidocarpa.						
Sub-ass. equisetosum variegati p.p. syn.: ⊘ Nodal group with Equisetum variegatum		Sub-ass. eleocharetosum p.p. syn.: ⊘ Nodal group with Carex nigra and Equisetum palustre		Sub-ass. equisetosum variegati p.p.		
Sesleria var.  syn.: Nodum with Sesleria	Juncus triglumis-Gymnostomum var.-Juncus triglumis sub-var.  syn.: Nodum with Juncus triglumis	Saxifraga-Scorpidium var. p.p. Succisa sub-var. p.p. Juncus acutiflorus facies syn.: Nodum with Molinia and Eriophorum latifolium	typical variant		Juncus triglumis-Gymnostomum var. Gymnostomum sub-var.  syn.: Nodum with Gymnostomum	
			Nardus sub-var.	typical sub-var.  syn.: Nodum typicum		
Mapping units	8	9	11	12	13	14

all the Phanerogams except Epipactis, Liparis and Dactylorhiza are present (the latter is, however, found in Widdybank Pastures<sup>#</sup>) together with Catoscopium nigratum, Fissidens osmundioides, Camptothecium nitens, Cinclidium stygium, Pellia endiviifolia, Mnium pseudopunctatum and M. seligeri although the last was not found in any of the Aufnahmen.

ℒ Nodal group with Carex dioica and Carex lepidocarpa (Mapping units 8-14)  
Table XXV

The key-card used in the field is given in Fig. IX a). The differential species groups of ℒ, β and γ nodal groups and noda are summarised in Table XIX a) and a comparison is made with those of the Caricion curto-nigrae which are shown as Table XIX b).

The nodal group encompasses vegetation of widely differing physiognomies for contained here are the damp grasslands of mapping unit 8, very similar to mapping unit 7 of the Seslerio-Mesobromion, the sedge marshes of mapping units 12 and 13 and the various types of flush community of mapping units 9, 11 and 14.

The differential species group comprises Plantago maritima, Juncus articulatus and several class, order and alliance characters and differentials (cf. Table I): Riccardia pinguis, Drepanocladus revolvens, Campylium stellatum, Pinguicula vulgaris, Primula farinosa, Carex lepidocarpa and C. dioica. Juncus articulatus and the last species are also members of the differential species group of the ℒ nodal group with Carex nigra and Carex pulicaris (cf. Table XIX a), b)). Carex panicea is the only companion which is of high constancy throughout the ℒ nodal group: various combinations of this species, the differentials and the companions Carex flacca and Festuca ovina are prominent in the individual noda. Three, 8, 9 and 14, develop under conditions of highly base-rich irrigation, often on calcareous gleys; the others are on flushed peaty material of somewhat lower pH (cf. Fig. X).

The ℒ nodal group is divided into a β nodal group and the nodum with Gymnostomum (m.u. 14). From Tables XIX a) and XXV the marked discontinuity between them is apparent despite the presence in mapping unit 14 of some of the differentials of mapping unit 8.

<sup>#</sup> Bradshaw (1972): personal communication.

β Nodal group with *Kobresia simpliciuscula* and  
*Ctenidium molluscum* (Mapping units 8-13)

The differential species are *Kobresia*, *Ctenidium*, the alliance characters *Carex hostiana* and *Tofieldia pusilla* and the alliance differential *Carex pulicaris*. A number of these are not well represented in either the nodum with *Juncus triglumis* (m.u. 9) or the nodum typicum (m.u. 13). There are no constant companions. *Carex flacca*, *Potentilla erecta*, *Linum catharticum* and *Euphrasia officinalis* are possible constants/near constants but cannot be used as such because they are absent from mapping units 9 and 13. The difficulties in classification result from the necessity of representing a multi-dimensional structure (vegetation) in only two dimensions and these noda (9 and 13) are considered to be valid members of both the  $\mathcal{C}$  nodal group and their respective  $\mathcal{D}$  nodal groups on account of the good representation in them of the differential species concerned.

The two  $\mathcal{D}$  nodal groups of the  $\beta$  nodal group are not separated by clear-cut species distinctions; some of the differentials of mapping unit 8 occur with low constancies in mapping units 11 and 12 and vice versa. This illustrates the concept of the Zurich-Montpellier system that a scheme for the emplacement of a stand of vegetation into a defined category should be based upon the greatest possible number of species.

The floristic differences between the two  $\mathcal{D}$  nodal groups are correlated with differences of soil type and pH. Communities of the  $\mathcal{D}$  nodal group with *Equisetum variegatum* develop on soils which are less peaty and have a higher pH than those of the  $\mathcal{D}$  nodal group with *Carex nigra* and *Equisetum palustre* (cf. Table XXVII).

$\mathcal{D}$  Nodal group with *Equisetum variegatum* (Mapping units 8 and 9)

*Equisetum variegatum* is the only differential species. Both noda occur in places receiving highly calcareous irrigation and the pH of each is above 7. There are, however, distinct floristic differences between them symbolised by the most frequent manner of occurrence of each - as a complex of hummocks of the grassy mapping unit 8 set amidst a calcareous flush of mapping unit 9.

Nodum with Sesleria (Mapping unit 8)

syn.: Caricetum lepidocarpae-hostianae  
Shim. 1968 sub-ass. kobresietosum

The differential species are Rhacomitrium lanuginosum, Thymus drucei, Carex capillaris, Sesleria caerulea, Ditrichum flexicaule, Scapania aspera, Galium sternerii and Tortella tortuosa. They portray the affinity of this nodum to the  $\mathcal{L}$  nodal group with Sesleria and Koeleria, and especially to its  $\beta$  nodal group with Carex pulicaris and Polygonum viviparum since all are also members of the differential species groups of one of these nodal groups and Sesleria, Galium sternerii and Carex capillaris are Seslerio-Mesobromion differentials. This nodum is the chief location within the  $\mathcal{L}$  nodal group for Thalictrum alpinum, but it is of low frequency.

Dominance is usually shared between Kobresia, Sesleria and the constant companions Festuca ovina, Carex panicea and C. flacca. In the Sand Sike region (chiefly) a facies occurs with prominent Nardus and, occasionally, Parnassia and Blysmus also; this is clearly related to mapping units 11 and 12 although lacking most of the differentials of these nodes and of the  $\mathcal{O}$  nodal group with Carex nigra and Equisetum palustre. The facies was not differentiated from mapping unit 8 on account of its merely localised occurrence. The mean species number of 38 is the highest in the  $\mathcal{L}$  nodal group.

Phanerogam cover is usually within the range 80% to 90%. Tufts of Rhacomitrium lanuginosum, the dominant bryophyte, are frequently exposed by the breaks in cover of the herb layer and Ctenidium molluscum also contributes much towards the 60% to 75% Cryptogam cover. The turf is commonly differentiated into hummocks and hollows and these two species are each prominent in a different component. Rhacomitrium is abundant on the former, together with Cladonia pocillum, C. subrangiformis, C. arbuscula and Cornicularia aculeata, whilst Ctenidium colonises the damper intervening hollows which have greater proportions of Carex panicea, C. flacca, Primula farinosa and Plantago lanceolata. The difference in height between these two elements is usually from 3 to 10 cm but can be as much as 70 cm. Exposed soil may account for about 10% of the ground of the hollows and sometimes the hummocks appear to be breaking up in the centre, also exposing the ground surface. Saxifraga aizoides is occasionally present in both components, either around the hummock bases or in the depressions

in the hummocks themselves. Separate records were made of the vegetational composition of the hummocks and hollows on account of the physiognomic differences between them but, as in many of the other instances in which this distinction was made in the field, it could not be maintained subsequently. The hummocks and hollows fell into the same nodum since the differences are quantitative and not qualitative.

The vegetation around the hummocks sometimes give the appearance of a Kobresia dominated flush which is very like the communities of mapping unit 9, but detailed examination has shown that these areas are much richer in species than are the "Kobresia lawns" of that nodum. However, over an area of several thousand square metres in the Fold Sike region, the nodum with Sesleria colonises hummocks set amidst a carpet of the nodum with Juncus triglumis (mapping unit 9). Identical complexes are found in the flushed ground irrigated by Red Sike east of the Birkdale Track and in the large flushed area draining into Sand Sike.

Mapping unit 8 also occupies the hummocks of a complex with mapping unit 19 of the Ranunculo-Anthoxanthion. Considerably less common than the other, it is found below the main sugar limestone escarpment and was formerly near Slapestone Sike. It may be remembered that the mapping unit of the Seslerio-Mesobromion which has pronounced Caricion davallianae affinities, no. 7, has been described in a similar topographic complex with mapping unit 20 which is also a member of the Ranunculo-Anthoxanthion but one which occurs in drier situations than mapping unit 19.

The pure nodum with Sesleria (mapping unit 8) is also found in smaller sized patches and less frequently than its complex with mapping unit 19. It forms a narrow band, less than 5 metres wide, beside the calcium-rich sikes (e.g. Slapestone and Sand Sikes) where it forms an intermediate zone between the lower lying flush communities of mapping units 9 and 14 on one side and those of either mapping units 4 to 7, 18, 20, 21 or 25 on the other. The amount of slope, if present at all, is very slight and may be in any direction although above Sand Sike several hundred square metres of the nodum occur on both north and south facing slopes of 10 and 20 degrees.

Nodum with Juncus triglumis (Mapping unit 9)

syn.: gravel flushes Pigott 1956 p.p.

The species which differentiate this nodum from that described above are Juncus alpinoarticulatus, J. triglumis and Triglochin palustris; the first is also a differential of mapping unit 11 from the others of its  $\delta$  nodal group. The communities of the nodum are usually very poor in species and the mean of 17 is the lowest in the  $\mathcal{L}$  nodal group. The total complement consists chiefly of those differentials (including those of  $\mathcal{L}$ ,  $\beta$  and  $\delta$  nodal groups) which are present; companions are virtually absent.

Under the heading "gravel flush", Pigott (1956) describes a type of vegetation which is considered by the present author to be a composite unit referable to two nodum. When applied solely to the open vegetation between the Gymnostomum hummocks, it is an apt description of one of the forms of mapping unit 9 and is directly synonymous with it. Total cover is only 50% to 75% (Phanerogam 50% to 60% and Cryptogam 10% to 30%) and mud and porcelainite chips are exposed between the tufts of Kobresia and Carex hostiana. In other places, the nodum exists as an almost pure sward or "carpet" of Kobresia interspersed with Carex dioica, Juncus articulatus, Plantago maritima and other species - often of reduced vitality. Drepanocladus revolvens and/or Cratoneuron commutatum are prominent in the ground layer although their shoots are often coated with mud. In these instances, total cover can reach 100%, the Phanerogams having 75% and the Cryptogams about 50% cover in marked contrast to the other form of the nodum. Only rarely does it exist in hummock-hollow form, an example of this (Aufnahme 84) being found in the Fold Sike area where the height difference between the two components ranges from 10 cm to, surprisingly, 50 cm.

Communities of the nodum develop in places where the small amount of slope (only  $2^{\circ}$  -  $3^{\circ}$ ) is, nevertheless, sufficient to promote constant irrigation and, except in times of drought, the water-table is above the ground surface. It occurs in its pure form comparatively rarely, for example associated with Fold and Red Sikes where it forms a band of only a few metres in width following a seepage line. Much more commonly it provides the low-lying component in which are set hummocks colonised by another nodum which may be mapping unit 8 (described above), mapping units 11 (rarely), 12 or 14 of the same alliance and, most often of all, mapping unit 25 of the Violion caninae. This last

mapping unit is notable for its floristic affinity to the Caricion davallianae. Following upon increased distance from the zone of highest irrigation the pure nodum with Juncus triglumis frequently passes into one of the complexes. These are chiefly found in the Fold and Red Sike drainage areas and in the latter, mapping unit 4 (Seslerio-Mesobromion) occasionally colonises the hummocks. In these places and in the Sand Sike region mapping unit 9 may complex with mapping unit 14 as a small-scale mosaic which is not associated with a hummock-hollow topography.

Ø Nodal group with Carex nigra and Equisetum palustre  
(Mapping units 11 -13)

Three of the differential species - Carex nigra, Equisetum palustre and Eriophorum angustifolium - are amongst those also differential for the ∞ nodal group with Carex nigra and Carex pulicaris (cf. Table XIX b)). The others are Eleocharis quinqueflora and Juncus kochii. Both sedge marshes (mapping units 12 and 13) and the more floristically varied mapping unit 11 which corresponds to the "turfy marshes" described by Pigott (1956), belong to the nodal group. The inclusion of mapping unit 13 presents some problems since the ∞ nodal group differentials are almost absent. Those of the Ø nodal group are, however, well represented. Furthermore, it is very similar in physiognomy to mapping unit 12 and is quite unlike the Gymnostomum hummock vegetation of mapping unit 14 which also lacks ∞ nodal group differentials. Each nodum is rather restricted in either the extent of its distribution or the size of its representative stands (or both). Mapping units 12 and 13 principally occur as a narrow band forming part of a flush complex which may sometimes be in the channels between isolated blanket bog hummocks.

Nodum with Molinia caerulea and Eriophorum latifolium  
(Mapping unit 11)

syn.: Turfy marshes Pigott 1956

The differential species group of Molinia caerulea, Eriophorum latifolium, Succisa pratensis, Juncus acutiflorus, J. alpinoarticulatus and Parnassia palustris together with such ∞ and ∞ nodal group differentials as Kobresia, Carex hostiana and Primula farinosa play a large part in the appearance of the communities of the nodum. The class character Pedicularis palustris and the order character Bartsia

alpina are occasionally present (this nodum is their sole location on the Fell) and are also prominent as are the companions Trichophorum cespitosum, Saxifraga aizoides and Erica tetralix although all are of low constancy.

The nodum is comparable with mapping units 8 and 12 in having a good representation of species of  $\mathcal{L}$  and  $\beta$  nodal groups and of the companions Carex panicea, C. flacca, Euphrasia officinalis, Linum catharticum and Festuca ovina. The turf is often tufted, some of the species which infiltrate from mapping unit 8 - Sesleria caerulea, Carex capillaris and Rhacomitrium lanuginosum - contributing to this. Total cover, sometimes 100%, may be as low as 60%, the unvegetated portion being rich in stones. Phanerogam cover is usually about 75% but that of the Cryptogams ranges from 30% to 80% although since the data are incomplete the variation may be greater; in some places there is prominent Cratoneuron commutatum and/or Drepanocladus revolvens. The mean species number of 38 is, jointly with mapping unit 8, the highest of the  $\mathcal{L}$  nodal group.

Extensive tracts of the nodum are restricted to the south-eastern side of the Fell. Several thousand square metres occupy the stony flushes lying to the west of Widdybank Farm and are present in those between the Farm and Fold Sike although in the latter the nodum often forms a small-scale mosaic with mapping unit 25. The angle of slope of these flush systems ranges from 5° to 15° and they face east and south-east respectively. Smaller patches of the nodum extending to only a few hundred square metres form part of the vegetational complex in the flushed area to the south of Sand Sike where they lie, both in the horizontal and the vertical planes, between the heavily flushed channels colonised by mapping units 9 and 14 and the more elevated parts which often have mapping units 12 and 25. Much smaller strips of the vegetation are associated with other seepage lines in the Sand Sike valley and within the flushes below the main north-west to south-west facing sugar limestone escarpment. In a very few places in this region mapping unit occupies the hummocks in a carpet of mapping unit 9 on almost level terrain.

Nodum with Nardus stricta and Carex demissa (Mapping unit 12)

Nardus and Carex demissa are the only differentials and both aid in the visual discrimination of this mapping unit from numbers 11 and 13 although Molinia, Succisa and other species of mapping unit 11 are occasionally prominent in the turf. Kobresia, Nardus, Carex flacca, C. hostiana, C. pulicaris, C. panicea and Eriophorum angustifolium are the principal dominant species of this sedge marsh, their general height being about 20 to 30 cm. Cover is usually complete (Phanerogams 80% and Cryptogams 30%) but occasionally up to 50% of the ground is unvegetated and the plants set amidst stones and mud. The mean species number 30 which is about the average for the  $\mathcal{L}$  nodal group.

There are distinct floristic similarities between this nodum and that with Ranunculus flammula and Carex echinata (m.u. 16) of the Caricion curto-nigrae (cf. Table XIX a) and b)). Some of the differentials of the  $\mathcal{L}$  nodal group with Carex nigra and Carex pulicaris are also differentials of the  $\mathcal{C}$ ,  $\beta$  and  $\delta$  nodal groups to which mapping unit 12 belongs (the numbers of such species are 2, 1 and 3 respectively). Carex demissa and Nardus stricta complete this group of differentials for the  $\mathcal{L}$  nodal group and Juncus kochii (a  $\delta$  nodal group differential of mapping unit 12) is one of the differentials of mapping unit 16 itself. A few Aufnahmen (nos. 140, 184, 186) made in the Middle Flush region and in the ground between Red and Nameless Sikes west of the Birkdale Track have been placed in mapping unit 16 (cf. Table XVIII) but are transitional to mapping unit 12 for, although they have the correct species complement for the nodum with Ranunculus flammula and Carex echinata, many  $\mathcal{C}$ ,  $\beta$  and  $\delta$  nodal group and nodal differentials of mapping unit 12 are also present. They have not been included within it, however, as Primula farinosa, Plantago maritima, Tofieldia pusilla and Eleocharis quinqueflora are absent.

The nodum is widely spread over the Fell and forms part of the gently sloping flush complexes associated with a number of the sikes (Slapstone, Red, Tinklers, Sand and, to a lesser extent, Fold) and is amongst the mapping units found between the Tinkler's Sike bog and the sugar limestone escarpment above. Although developing in irrigated places, the mapping unit does not occur in those with the greatest water flow which are colonised by mapping units 9, 14 and, sometimes, 11. Where mapping unit 12 is adjacent to those others, it

is slightly raised above them (cf. the soil analyses below, which show the greater content of humic material in those of mapping unit 12).

Mapping units which are adjacent to, but in drier places than, mapping unit 12 are 8 (occasionally), 25 and 18, the last combination occurring chiefly on the south facing bank of Sand Sike. Mapping unit 12 is set in an irrigated area developed within mapping unit 18 and passes below into mapping unit 20 (Ranunculo-Anthoxanthion). The slope of this bank is similar to the 15° to 30° encountered between Fold Sike and Widdybank Farm for communities of the nodum.

The nodum with Nardus stricta and Carex demissa has been found in hummock-hollow complexes with two others. In the Slapestone, Red and Fold Sike flushes it occupies hummocks surrounded by mapping unit 9. Occasionally there is immigration on to the higher component of Calluna vulgaris, indicating a possible initiation of transition to mapping unit 25. This is the second mapping unit to occur in complexes with mapping unit 12 and in these instances the hummocks are conspicuous in having Erica, Calluna and Trichophorum with an absence of Primula, Pinguicula and other Tofieldietalia species. This combination is found principally in the Fold and Red Sike regions and, in common with the other combinations, it is usually contiguous to pure areas of the nodum comprising it.

#### Nodum typicum (Mapping unit 13)

This is characterised by an absence of the species differential for the other members of the  $\delta$  nodal group. The paucity of  $\beta$  nodal group differentials indicates something of a divergence of this nodum from the others of the  $\beta$  nodal group.

Eleocharis quinqueflora is the most frequently dominant Phanerogam. Also prominent in this layer may be Carex nigra, C. dioica, C. panicea, C. flacca, Juncus articulatus, Eriophorum angustifolium and Equisetum palustre. The only constant/near constant companions are Carex flacca, Bryum pseudotriquetrum and Cratoneuron commutatum in addition to Carex panicea. The mean species number of 21 is the lowest of the  $\delta$  nodal group. The height of the vegetation, about 15 cm, is less than that of mapping unit 12. Total cover, which is at most 90%, is similarly smaller than that of the other nodum. The Phanerogam cover - about 75% - is the same and the Cryptogam, often 60% to 75%, is greater. This layer is chiefly composed of Drepanocladus revolvens and Cratoneuron commutatum.

There is some affinity between this nodum and the nodum with Ranunculus flammula and Carex echinata (m.u. 16) although it is less than that between mapping unit 12 and the other since Carex demissa and Nardus stricta, two of the nodal group differentials for mapping unit 16, are absent from mapping unit 13. Nevertheless, Aufnahmen nos. 139, 141 and 146 of mapping unit 16 lack many of the companion species of that nodum (hence being of a considerably lower species number than its mean) and are of a suitable composition to be transitional to the nodum typicum. In addition, two of the three records obtained for the Caricion davallianae character Cinclidium stygium were made in Aufnahmen 139 and 146.

In common with the nodum with Nardus and Carex demissa, the nodum typicum is widespread over the Fell and is again part of the complex of flush vegetation types associated with several of the sikes or, occasionally, with the narrow channels on the exposed mineral substrate between isolated hummocks of blanket bog. In both situations, the angle of slope is either imperceptible or very small.

The patches of mapping unit 13 are usually less extensive than those of mapping unit 12. One of the largest which, incidentally, has the only record to be made in any Aufnahmen for the order character Scorpidium scorpioides is of several hundred square metres. It lies adjacent to the Tinkler's Sike blanket bog (mapping unit 24 - Oxycocco-Sphagnetea) and is bounded also by mapping units 12 and 18. The nodum typicum usually lies adjacent to a heavily irrigated zone, bearing mapping units 9 or 14, above which it is slightly raised on a more peaty substrate. It often forms a buffer between the highly calcareous flushes and the somewhat more elevated mapping units of the Violion caninae. In the Slapestone Sike flushes and in the large one in the Sand Sike valley, there is an interdigitation of Gymnostomum hummock vegetation (m.u. 14) and the Eleocharis-Cratoneuron-Drepanocladus dominated communities of the nodum typicum. The only vertical complex in which the nodum has been encountered was in a very small part of Middle Flush where it colonised hummocks within the nodum with Juncus triglumis (m.u. 9); this is now covered by the reservoir.

Nodum with Gymnostomum (Mapping unit 14)

Syn.: gravel flushes Pigott 1956 p.p.

This physiognomically very distinctive final member of the  $\infty$  nodal group is differentiated by Gymnostomum recurvostrium, Minuartia verna and Sagina nodosa. The 10 cm high (approx) hummocks of Gymnostomum are almost always dominant although Aufnahme 458, which is dominated by Eleocharis, has been included here since it lacks the other species of the  $\beta$  and  $\delta$  nodal groups whose presence would lead to its classification within mapping unit 13. The vegetation is usually open: a total cover of between 60% and 75% is most common. A variety of other species is set amidst the mud and stones (often porcelainite, i.e. baked marl); the companion Carex panicea and the  $\infty$  nodal group differentials Carex dioica, C. lepidocarpa and Drepanocladus revolvens are some of the most conspicuous. Thymus drucei and Carex capillaris which are differentials of mapping unit 8 frequently grow on and between the hummocks as do the companions Selaginella selaginoides, Agrostis stolonifera, Bryum pseudotriquetrum and Cratoneuron commutatum. Phanerogam cover is only about 40% but Cryptogam cover is 75%.

Several members of the "Teesdale assemblage" are found in this nodum which is one of the chief habitats for Minuartia stricta (cf. Pigott 1956). Although it also occurs in skeletal forms of the nodum with Juncus triglumis (m.u. 9), Catoscopium nigratum and Anoetangium aestivum, other hummock forming mosses may be present and half of the four records for Armeria maritima made during the survey were in this nodum. The mean species number is 18, only one more than that of the nodum with Juncus triglumis.

Mapping unit 14 develops in slightly sloping places receiving highly calcareous irrigation where there is little deposition of humic material. It is one of the vegetation types associated with many of the sikes and usually lies between the fast-flowing rivulet beds with no, or only very scanty, vegetation, and other mapping units, e.g. 11, 12 and 13, on more humic substrates. By far the largest areas of the nodum are in the flush complex above Sand Sike where in three places it occurs in stands each over 1,000 sq m in size, but in general the pure nodum rarely occurs in patches greater than a few hundred square metres. It is also present in complexes such as with mapping unit 9 where there may or may not be a definite separation into hummock/hollow

SUMMARY AND SYNONYMY OF THE PINGUICULO-CARICETUM DIOICAE  
ASSOCIATION PINGUICULO-CARICETUM DIOICAE ass. nov.

## SUB-ASS. molinietosum

syn.: Caricetum lepidocarpae-hostianae molinietosum Shim. 1968

## SUB-ASS. equisetosum variegati

Sesleria variant

syn.: Caricetum lepidocarpae-hostianae kobresietosum Shim. 1968  
Nodum with Sesleria  
Kobresieto-Caricetum Ratcliffe 1966 p.p.

Juncus triglumis-Gymnostomum variant

syn.: Gravel flushes Pigott 1956

Juncus triglumis sub-variant

syn.: Nodum with Juncus triglumis  
Gymnostometo-Caricetum Ratcliffe 1966 p.p.

Gymnostomum sub-variant

syn.: Nodum with Gymnostomum  
Gymnostometo-Caricetum Ratcliffe 1966 p.p.

SUB-ASS. ~~thalictro-~~saxifragetosum

syn.: Cariceto-Saxifragetum aizoidis McV. & R. 1962  
Carex-Saxifraga aizoides nodum Birks 1969

## SUB-ASS. eleocharetosum

Saxifraga-Scorpidium variant

## typical sub-variant

Acrocladium trifarium facies

syn.: Carex demissa - C. panicea nodum  
Carex hostiana - C. demissa nodum } Poore 1955

Breutelia facies

syn.: Carex panicea - Campyllum stellatum ass.  
McV. & R. 1962 emend. Birks 1969

Succisa sub-variant

## typical facies

syn.: Carex panicea - Campyllum stellatum nodum  
McV. & R. 1962 p.p.

Juncus acutiflorus facies

syn.: Nodum with Molinia and Eriophorum latifolium  
Turfy marshes Pigott 1956

Drosera - Schoenus facies

syn.: Cariceto-Saxifragetum aizoidis  
McV. & R. 1962 low-level facies  
Eriophorum latifolium - Carex hostiana ass. Birks 1969

## typical variant

Nardus sub-variant

syn.: Nodum with Nardus and Carex demissa  
Carex panicea - Campyllum stellatum nodum  
McV. & R. 1962 p.p.

## typical sub-variant

syn.: Nodum typicum  
Carex panicea - Campyllum stellatum nodum  
McV. & R. 1962 p.p.

topography and with mapping unit 13 where there is such a division (see above). These combinations are usually a little more extensive than the nodum alone.

The syntaxonomy and classification of the  $\alpha$  nodal group

Table XXVI and Fig. IX b)

The "gravel flushes" and "turfy marshes" described by Pigott (1956) under the general term "calcareous marshes" are directly equivalent to mapping units 9 and 14 (together) and to mapping unit 11 respectively; the Caricetum lepidocarpae hostianae kobresietosum Shim. 1968 is synonymous with mapping unit 8. McVean and Ratcliffe (1962) and Birks (1969) have commented on the similarities of some of their vegetation types to those depicted by Pigott but, with a few exceptions, these Scottish types have not been found to be synonymous of the Widdybank communities. However, the seven noda described above and the related vegetation portrayed in the accounts of McVean and Ratcliffe (1962), Birks (1969) and Shimwell (1968) have been drawn together by the formation of the association described below. Its composition is given in Table XXVI, the resulting classification of the Widdybank noda is shown in Fig. IX b) and the complete synonymy of the association is on the facing page.

Association Pinguiculo-Caricetum-dioicae ass. nov.

The Caricetum lepidocarpae-hostianae Shim. 1968, erected during that author's extensive survey of calcareous grasslands, has been incorporated within the Pinguiculo-Caricetum dioicae which is of a wider floristic, and hence geographical and altitudinal, compass than the other.

The Pinguiculo-Caricetum encompasses a range of flush and mire communities on substrates whose pH rarely falls below 6.0 and which may be stony and silty muds (sometimes highly organic), peaty gleys and flushed peats. Cover is usually lower than 100% and may not be much above 50%; a figure of 80% is about average. The terrain is commonly either flat or sloping at less than 5° although some communities can tolerate up to 30° of inclination. The orientation is variable but the east-south-west sector, which receives the greatest amount of insolation, is most frequent.

The association has developed in suitable localities in the north of England (Pigott 1956, Ratcliffe 1966, Shimwell 1968), central and north-west Scotland (Poore 1955c, McVean and Ratcliffe 1962) and Skye (Birks 1969). McVean and Ratcliffe, Ratcliffe (1966) and Birks (1969) all refer to the occurrence of similar vegetation to that (now) included in the Pinguiculo-Caricetum dioicae, especially to the Thalictro-saxifragetosum, in the southern uplands, the Cheviots, the Lake District and north Wales. However there are no detailed floristic analyses available for these localities (the accounts by Ratcliffe (1959b, 1960) of the mountain flora of the Moffat hills and of Lakeland are not sufficient) and thus the exact floristic relationships of these communities to the association cannot be established.

In Skye, in north-west Scotland and on Rhum the association has been recorded near sea-level but the most favoured altitudes lie between 1,000 and 2,500 ft (305 and 762m). In central Scotland and northern England its representatives lying around and below 1,000 ft are transitional to the Schoenetum nigricantis, of the same alliance. At 1,700 ft (518 m) in northern England, 2,900 ft (884 m) in central Scotland and 2,500 ft (762 m) on Skye, transitions to the Caricion bicoloris-atrofuscae are apparent. These affinities are discussed more fully when describing the appropriate part of the association.

The Pinguiculo-Caricetum dioicae is distinguished by a number of species from the other British Caricion davallianae communities: the vegetation of dune-slacks (Ranwell 1960), of the Irish lowlands (Braun-Blanquet and Tüxen 1952, Ivimey-Cook and Proctor 1965), of the association group Schoenetum nigricantis W. Koch 1926 (Shimwell 1968, see also Braun-Blanquet and Tüxen 1952, McVean and Ratcliffe 1962, Ivimey-Cook and Proctor 1965) and of the Carex rostrata-brown moss provisional nodum McV. and R. 1962. However, since detailed phytosociological investigations (sensu Zurich-Montpellier) have yet to be made in most representatives of these other vegetation types, the following group of character and differential species may need to be modified when this deficiency is remedied. The suggested character species are the order character Carex dioica, the alliance characters Tofieldia pusilla and Carex lepidocarpa together with Triglochin palustris and Kobresia simpliciuscula. Kobresia and Carex lepidocarpa are local characters only, the former for Widdybank and Cronkley Fells

and the latter for the English communities as a whole. Carex pulicaris and Plantago maritima, which are both plentiful in vegetation of other alliances, are differentials of the association.

Dominance is shared between Carex lepidocarpa and the companions C. hostiana, C. panicea and Pinguicula vulgaris in the herb layer; the order characters Campyllum stellatum and Drepanocladus revolvens are prominent in the ground layer. Four sub-associations can be distinguished, each of which has a reasonable complement of character species of the class and, especially, order and alliance.

Sub-ass. molinietosum

This sub-association, not represented on Widdybank Fell, is Shimwell's Caricetum lepidocarpae hostianae molinietosum (col. A, Table XXVI). Molinia is the only differential given by this author but, as a consequence of the present more extensive treatment, Succisa pratensis, Eriophorum latifolium and Parnassia palustris have each been found to have this status also.

Since this sub-association and the kobresietosum (col. B) have already been described by Shimwell, only brief details are necessary in the present account. The molinietosum may develop on either flat or steeply sloping (40°) ground with a pH of between 6.8 and 7.8; the mean species number of 33 is near the top of the range for the association.

Shimwell found that the Caricetum lepidocarpae-hostianae was the first stage in the transition from calcareous grassland to flushes and that communities of the Schoenetum nigricantis came next in the dry-to-wet sequence. Evidence to support the first part of this observation is presented later but, with the wider survey now undertaken, it has become apparent that altitude is a much more important factor influencing the change from Caricetum lepidocarpae-hostianae to Schoenetum nigricantis.

The Schoenetum nigricantis described by Shimwell and the related vegetation found by McVean and Ratcliffe (1962) and by Birks (1969) are generally situated below 600 ft (183 m) and near the sea; the only exceptions are some communities described by Birks from as high as 750 ft (229 m) on Skye and those of Shimwell's Aufnahmen made near Sunbiggin Tarn in Westmorland at about 850 ft (259 m). These findings are in accordance with Sparling's (1968) upper latitudinal limit for Schoenus nigricans of about 600 ft (183m). Although its range extends to

over 1,200 ft (366m) in western Ireland, it is present there as a member of the blanket bog flora.

The upper part of the range of the Schoenetum overlaps that of the molinietosum which, at 750 to 1,250 ft (229 to 381m) is one of the lowest for a component of the Pinguiculo-Caricetum. This ~~spatial~~ transition is mirrored in the floristics of the vegetation since, in addition to the over-all similarities between the two associations, two differentials of the molinietosum - Molinia and Succisa - are also prominent in the Schoenetum. It therefore seems that the transition from the Schoenetum to the molinietosum takes place between 750 and 1,250 ft (387m). The only locality so far described where both vegetation types exist in close proximity is Sunbiggin Tarn (Shimwell 1968). Shimwell's Caricetum lepidocarphae-hostianae kobresietosum (col. B) which is incorporated into the Pinguiculo-Caricetum dioicae equisetosum variegati Sesleria var. (see below) occurs from 1,300 to 1,500 ft (396 to 457m) and does not show this floristic affinity to the Schoenetum. The other low-level members of the association show links with both the Schoenetum and the molinietosum which are discussed below.

The virtual absence of Schoenus nigricans from land above 600 ft (183m) may be directly connected with altitude. Sparling (1968) suggests that the species may be frost sensitive since its world distribution is confined to regions south of the  $-2^{\circ}\text{C}$  ( $28.4^{\circ}\text{F}$ ) January isotherm. All the English localities are within, and strongly correlated with, the  $3.9^{\circ}\text{C}$  ( $39^{\circ}\text{F}$ ) isotherm although those in north Scotland show that the species is there able to tolerate a mean January temperature of  $37-38^{\circ}\text{F}$ ; the Welsh and Irish localities lie well above these limiting temperatures (Perring and Walters 1962).

Sub-ass. equisetosum variegati

Equisetum variegatum is the sole differential species of this sub-association which has been recorded only on Widdybank Fell at altitudes between 1,300 and 1,700 ft (396 and 518 m). The soils are calcareous gleys (pH 7.3 or above) and have developed on more or less flat terrain.

The Sesleria variant, also differentiated by Rhacomitrium lanuginosum and Ditrichum flexicaule, has been formed from the Caricetum lepidocarpae-hostianae kobresietosum Shim. 1968 (col. B) the Nodum with Sesleria (m.u. 8, col. C) and seven of the nine lists of the Kobresieto-Caricetum Ratcliffe 1966 (col. J) in these damp grasslands have been adequately described in each of the accounts concerned. Total cover is about 90% and the mean species number is 33; both values are very different from those of the other members of the sub-association. Ratcliffe notes the similarity of the Kobresieto-Caricetum to the Carex panicea-Campyllum stellatum nodum McV. and R. 1962 shown in columns N, O and P of Table XXVI. The affinities of these vegetation types are acknowledged in the present work in so far as they have been united in the one association but the differences between them are of sufficient magnitude to necessitate their emplacement in different sub-associations. The Scottish nodum has species of much damper and somewhat less base-rich conditions than the Kobresieto-Caricetum (cf. Table XXVI).

The other member of the sub-association is the Juncus triglumis-Gymnostomum variant. The variation within this is spanned by ten of the eleven lists which comprise Ratcliffe's (1966) Gymnostomato-Caricetum (col. K), a vegetation type previously described by Pigott (1956) as "gravel flushes". However, it may be re-iterated that, as a consequence of the present study, it is apparent that these are heterogeneous units whose components occur separately as well as together, although the composite type may be more extensive than either of the other two. The variant has therefore been sub-divided to give the Juncus triglumis sub-variant (syn.: Nodum with Juncus triglumis, m.u. 9), (col. D) and the Gymnostomum sub-variant (syn.: Nodum with Gymnostomum, m.u. 14 and Gymnostometo-Caricetum Ratcliffe 1966 p.p.) (cols. H and L). The bulk of Ratcliffe's Gymnostometo-Caricetum (col. K) has been included in each sub-variant since it contains some elements of both.

The variant itself has no differentials; those of the first-named sub-variant are Juncus triglumis and J. alpinoarticulatus and of the second Gymnostomum recurvirostrum, Sagina nodosa and Minuartia verna. The mean species numbers of the sub-variants are 17 and 18 respectively; cover of the Juncus triglumis sub-var. varies between 50% and 100% whereas that of the other is 50% to 75%. This sub-alpine vegetation shows some affinity to the Caricion bicoloris-atrofuscae. This relationship is discussed below in the section dealing with the systematics of the nodal group; it is not sufficiently great to warrant the variant being removed from the Caricion davallianae.

Sub-ass. thalictro-saxifragetosum

The differential species show that this sub-association of flush communities is intermediate in composition between the equisetosum variegati and the eleocharetosum. They are, in addition to Thalictrum alpinum, Juncus triglumis (mentioned above), Carex demissa, Scorpidium scorpioides, Saxifraga aizoides and Blindia acuta, all differentials of either the eleocharetosum or its Scorpidium variant (cf. Table XXVI); the mean species number is 30. Cover varies from 40% to 80%, the underlying substrata of peaty mud or silty sand and gravel being thus exposed. This may be inclined in any direction. The mean angle of slope is 10° but it may be as much as 30°. The pH range of 5.6 to 7 is intermediate between that of the eleocharetosum and the other sub-associations.

The sub-association is, marginally, the most high-level member of the association. It has been described by McVean and Ratcliffe from central and north-west Scotland at 1,100 to 2,900 ft (335 to 884 m) and by Birks from Skye at 800 to 2,500 ft (244 to 762 m). The vegetation types from these regions are the Cariceto-Saxifragetum aizoidis (col. M) and the Carex-Saxifraga aizoides nodum (col. T) respectively. Both McVean and Ratcliffe and Birks link their vegetation with some present on Widdybank Fell and involve the eleocharetosum Saxifraga-Scorpidium var. Succisa sub-var. Juncus acutiflorus facies and the equisetosum variegati Juncus triglumis-Gymnostomum var. respectively, emphasising the floristically intermediate position of this sub-association. Although Ratcliffe (1966) has likened the Juncus triglumis-Gymnostomum var. to the Cariceto-Saxifragetum aizoidis McVean and Ratcliffe 1962, it now seems that these similarities must be given a wider interpretation

than may have been done in the past.

Parallel with the links of the equisetosum variegati to the Caricion bicoloris-atrofuscae, the highest representatives of this other sub-association are also strongly influenced by the alpine alliance. McVean and Ratcliffe note the presence of Carex atrofusca, C. microglochin, Kobresia simpliciuscula, Juncus biglumis and J. castaneus in the Cariceto-Saxifragetum at altitudes over 2,500 ft (763 m) in the Breadalbane district of Perthshire. Both Carex species and Juncus castaneus are Caricion bicoloris-atrofuscae characters and Kobresia occurs in vegetation of this alliance in central Europe. Juncus triglumis, a sub-association differential, is a further alliance character. The only true member of the alpine alliance described to date is the Caricetum saxatilis McVean and Ratcliffe 1962 (syn.: Carex saxatilis sociation (Poore 1955) from restricted localities in central and north-west Scotland between 2,500 and 3,200 ft (763 and 976 m) although lists nos. 11 and 15 of the Cariceto-Saxifragetum aizoidis are probably also referable to it.

Sub-ass. eleocharetosum

This sub-association is considerably more wide-ranging in floristic, altitudinal and geographical terms than any of the others described above. It includes both flush and mire communities with from 50% to 100% cover at altitudes extending from near sea-level to 2,650 ft (808 m) in Scotland and at 1,500 to 1,700 ft (457 to 518 m) in England. The pH range from 5.7 to 6.5 is lower than that of any other sub-association. The differential species are the order character Eleocharis quinqueflora with Eriophorum angustifolium, Carex nigra, Juncus kochii, Equisetum palustre and the class character Carex demissa.

The foregoing descriptive remarks also apply to the mires and flushes of the Saxifraga-Scorpidium variant whose differentials are Scorpidium scorpioides, Saxifraga aizoides, Blindia acuta, Erica tetralix and Carex echinata. The variant is composed of a number of sub-variants each with a number of facies.

The typical sub-variant embraces a group of mire communities which occur only in central Perthshire and on Skye. The Acrocladium trifarium facies has been formed from the Carex panicea-Carex demissa and Carex hostiana - Carex demissa noda (cols. R and S respectively) described by Poore (1955c) from Breadalbane, Perthshire. Acrocladium trifarium is the only differential; the mean species number of 17 is

the lowest for the sub-association and cover is only between 50% and 80%. The facies develops on very wet peaty mud overlying a stony silt and the pH is in the range 6.2 - 6.4; the ground slopes only slightly, if at all. Although occurring from 1,500 to 2,650 ft (457 to 808 m), there is some altitudinal separation of the components of the facies, the Carex hostiana - C. demissa nodum being present at the lowest elevations and slightly overlapping with the Carex demissa - C. panicea nodum which occurs between 1,600 and 2,650 ft (488 and 808 m). Poore's tentative separation into two nodes is also doubted by McVean and Ratcliffe when the vegetation over the whole of the Highlands is considered and, in the light of the present survey, his separation is further seen to be untenable since the floristic differences between the nodes are not distinctive within the context of the association as a whole. McVean and Ratcliffe feel that the Carex demissa - C. panicea nodum can be accommodated within their Cariceto-Saxifragetum aizoidis (col. M) but it is apparent from Table XXVI that the rather different floristics of these vegetation types places them in separate, although allied, sub-associations.

The Breutelia facies (syn.: Carex panicea - Campylium stellatum association McVean and Ratcliffe 1962 emend. Birks 1969), (col. U) is differentiated by Breutelia chrysocoma and Juncus squarrosus. In common with the facies described above, it is a closely grazed sedge sward with a small number of species (its mean value is 23) on moist silty muds which may be highly organic, but it differs in that it occurs at much lower altitudes - up to 1,100 ft (335 m) and on the more oceanic Isle of Skye only. Birks considers that this vegetation type is sufficiently close to McVean and Ratcliffe's Carex panicea - Campylium stellatum nodum (cols. N, O and P) to give it the same name. When their floristic compositions are compared in detail with each other and with the rest of the Pinguiculo-Caricetum, however, it is apparent that different types of vegetation have been described.

Both mires and flushes are included within the Succisa sub-variant which is represented in England (Widdybank Fell) as well as in Scotland. Its altitudinal range is very much less than that of the typical sub-var. being from sea-level to only 1,700 ft (518 m) instead of between sea-level and 2,650 ft (808 m). Succisa pratensis, Molinia caerulea and the alliance character Eriophorum latifolium are the differentials.

Ten lists from the rather heterogeneous Carex panicea - Campyllum stellatum nodum of McVean and Ratcliffe are included within the typical facies (col. N) which is present in central and north-west Scotland between, principally, 1,000 and 1,600 ft (305 and 488 m). These mire communities develop on silty muds with variable humus content and a pH of 5.9 - 6.3 in places which are often sloping at up to 25°. There is almost complete cover; the mean species number of 34 is the second highest of the sub-association and of the association.

The English representative of the sub-variant is the Juncus acutiflorus facies (syn.: Nodum with Molinia and Eriophorum latifolium, m.u. 11) (col. E) from Widdybank Fell. Its edaphic conditions resemble those of the preceding facies, but with a mean species number of 38 it is even more floristically diverse and has the highest value for any of the members of the association. The facies is also synonymous with Pigott's (1956) "turfy marshes" and although vegetation in other parts of Britain have been likened to Pigott's type (McVean and Ratcliffe 1962, Birks 1969), it is probable that the facies is represented on Widdybank Fell only.

The final members of the sub-variant are the flushes of the Drosera-Schoenus facies whose differentials are Drosera anglica and Schoenus nigricans. The total cover lies chiefly within the range 50%-80%; the mean species number of 24 is the lowest of the sub-variant. The facies develops on moist silt, sand or gravel with a low humus content sloping at up to 10-15°. It is composed of McVean and Ratcliffe's Cariceto-Saxifragetum aizoidis low-level facies (col. Q) and Birks' Eriophorum latifolium - Carex hostiana association (Col. V) also described as low-level vegetation. The chief altitudinal compass of the facies is well below that of any other member of the association; on Skye it extends only up to 150 ft (229 m) and in north-west Scotland it is mainly between 100 and 600 ft (31 and 198 m). Although present at up to 1,400 ft (427 m) in the latter region, Schoenus itself is absent from these higher elevations and the vegetation grades into the thalictro-saxifragetosum (syn.: Cariceto-Saxifragetum aizoidis McV. & R. 1962, cf. McVean and Ratcliffe 1962).

Between sea-level and 600 ft (198 m) the Drosera-Schoenus facies is co-extensive with the Schoenetum nigricantis mentioned above and to which it is closely related. Eleocharis, Eriophorum angustifolium and Carex nigra (differentials of the eleocharetosum) and the three

differentials of the Succisa sub-var. are all present with at least moderate frequencies in the Schoenetum (from north England, Scotland and Skye). The Schoenetum develops in drier situations which are also of a higher pH than those of the Drosera-Schoenus facies.

Birks likens one list from his Eriophorum latifolium - Carex hostiana ass. to Pigott's "turfy marshes" on Widdybank Fell (syn.: Juncus acutiflorus facies) (col. E) to vegetation near Sunbiggin Tarn (Holdgate 1955) and to some in Great Close Mire, Malham, Yorkshire (Sinker 1965). As a consequence of the work of Shimwell (1968) it would seem reasonable to surmise that in the last two localities Birks is referring to the Pinguiculo-Caricetum dioicae molinietosum (syn.: Caricetum lepidocarpae-hostianae molinietosum Shim. 1968) (col. A) which has a number of features in common with the Drosera-Schoenus facies (cf. Table XXVI and see above). Although fewer than with the Juncus acutiflorus facies, McVean and Ratcliffe note the resemblances of their Cariceto-Saxifragetum aizoidis to Pigott's turfey marshes also, but this comment is made in general and not with specific reference to the low-level facies.

The facies appears to be confined to Scotland but Bradshaw<sup>‡</sup> has recorded a community with Schoenus nigricans, Primula farinosa, Carex hostiana X lepidocarpa, C. panicea, Molinia caerulea and Chara vulgaris in a small flush in Cote Gill, Littondale, Yorkshire. At an altitude of 1,250 ft (381 m), this is the highest record (known to the author) for Schoenus in Britain; the community may represent an outpost of the Drosera-Schoenus facies or may be a very high-level member of the Schoenetum nigricantis. It may be noted that Cote Gill is one mile from Yew Cogar Scar, Cowside Beck, Littondale, and two miles from Great Close Mire, Malham, from where Shimwell (1968) has recorded communities of the molinietosum.

The second variant of the eleocharetosum is the typical variant which comprises a group of mire communities described so far only from Rhum, central Scotland and Widdybank Fell, chiefly in the sub-alpine zone.

The Nardus sub-variant, differentiated only by this species, is shown in col. F (the Nodum with Nardus and Carex demissa, m.u. 12) and col. O (a further six lists from the Carex panicea-Campylium stellatum nodum McV. and R. 1962). The mean species number is 30 and cover varies from 75% to 100%. The usual substrata are silty muds

<sup>‡</sup> Bradshaw (1972) : personal communication

and flushed peats with pH values between 5.7 and 6.0 on terrain which may be flat or sloping at up to 30°. Although the sub-variant is present at 100 ft (31 m) on Rhum, it is chiefly found between 2,000 and 2,400 ft (610 and 732 m) in central Scotland and from 1,500 to 1,700 ft (457 to 418 m) in north England (Widdybank Fell).

Widdybank Fell is the principal locality for the typical sub-variant (syn.: Nodum typicum, m.u. 13) (col. G), although also included here is a single list from the Carex panicea - Campyllum stellatum nodum McVean and Ratcliffe 1962 (col. P) made in Inverness-shire at 1,350 ft (411 m). The mean species number of 22 is one of the lowest for the sub-association; cover is between 75% and 95%. The underlying soils are very similar to those of the previous sub-variant although the ground is usually flat and only slopes at 15° at most.

Some of the flush and mire communities of the Pinguiculo-Caricetum dioicae frequently exist in close juxtaposition in a single locality. The flushes of the Juncus triglumis - Gymnostomum var. of the equisetosum may be bordered by a narrow zone of the eleocharetosum Saxifraga-Scorpidium var. Juncus acutiflorus facies or eleocharetosum typical var. on Widdybank Fell; the thalictro-saxifragetosum and Drosera-Schoenus facies by the Saxifraga-Scorpidium var. Succisa sub-var. typical facies or typical sub-var. Breutelia facies in Scotland.

The synsystematic placing of the ∞ Nodal group  
Table I

The ∞ nodal group comprises both flush and mire communities and thus embraces the two physiognomic components of the Caricion davallianae. It is bound together by a variety of differential species, several of which are also characters for the higher units of classification.

Each nodum, distinguished and included within the nodal group on the basis of its total floristic composition, is rich in character species of the Tofieldietalia and the Caricion davallianae; in addition, almost all the nodum have two of the four Parvocaricetea characters present on the +Fell. Although there are some links with other alliances (both of the same and of different classes), they are not so great as to disturb the unity of the group.

In the preceding section allusion was made to the connection of these sub-alpine representatives of the Caricion davallianae with the sub-alpine - alpine Caricion bicoloris-atrofuscae. Juncus triglumis, a

character of the latter, is present with constancy IV in mapping unit 9 and Minuartia stricta, a European character of the upland alliance but of too restricted a distribution to be very useful as such in Britain, has single occurrences in mapping units 9 and 14. Furthermore, Juncus alpinoarticulatus and Bartsia alpina which may, on account of their sub-alpine distribution in Britain, be Caricion bicoloris-atrofuscae characters here (although used at present for the Tofieldietalia - see above), are each present on Widdybank Fell. The former appears in mapping unit 9 with constancy IV and both in mapping unit 11 with constancies IV and II respectively. Mapping unit 9 - the nodum with Juncus triglumis - is, therefore, in common with other Caricion davallianae communities at high altitudes in different parts of Britain, thought to be transitional to the Caricion bicoloris-atrofuscae.

Some connections are apparent between several nodum and alliances of different classes. The nodum with Sesleria (m.u. 8) has a number of differentials (nota bene - not characters) of the Seslerio-Mesobromion at moderate constancies, including Sesleria caerulea (IV) and Galium sternerii (III). Characters of the Oxycocco-Sphagnetea - Erica tetralix, Trichophorum cespitosum, Narthecium ossifragum and Drosera rotundifolia - are found in the nodum with Molinia and Eriophorum latifolium (m.u. 11) at constancies of II, I, I and I respectively. With these properties, only a very slight affinity to this class is indicated. Nardus stricta is present with constancy IV in the nodum with Nardus (m.u. 12); the species is a character of the Nardetalia of the Nardo-Callunetea but this is the only such link of the nodum with the order.

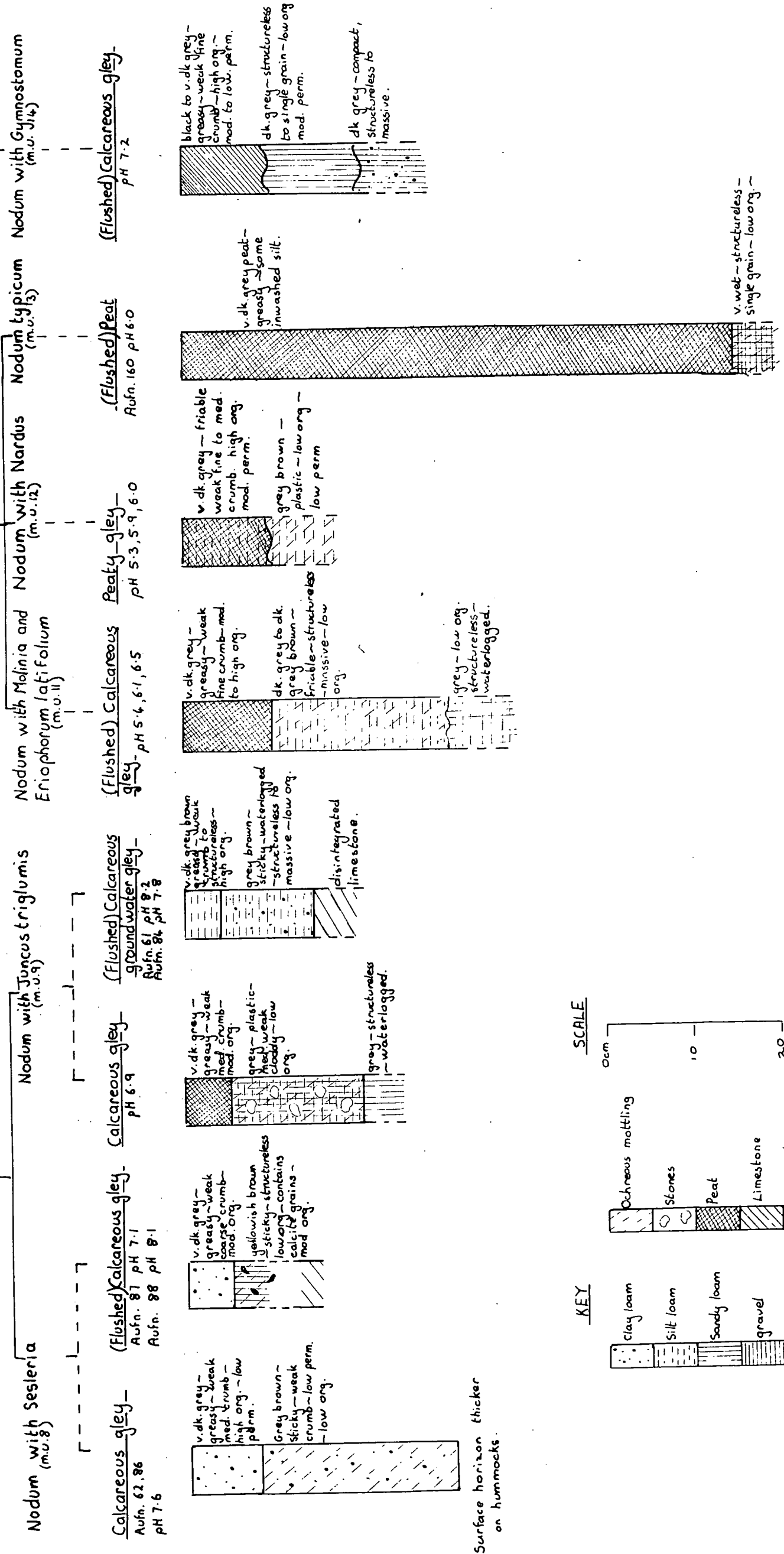
In reciprocity to this intrusion of species of other alliances etc. into the nodal group, both the nodum with Primula farinosa (m.u. 7) of the Seslerio-Mesobromion and the nodum with Carex dioica and Erica tetralix (m.u. 25) of the Violion caninae (Nardetalia) each have a number of Tofieldietalia and Caricion davallianae character species and are thus, to some extent, synsystematically differentiated from the other members of their nodal groups. The exact relationship of mapping unit 7 have already been discussed; those of mapping unit 25 are described, in context, below.

FIG. X DIAGRAMATIC SOIL PROFILES OF THE  $\alpha$  NODAL GROUP WITH CAREX DIOICA AND CAREX LEPIDOCARPA

$\alpha$  Nodal group with Carex dioica and Carex lepidocarpa

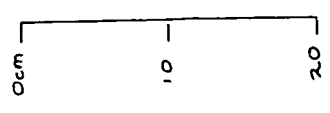
$\beta$  Nodal group with Kobresia and Ctenidium molluscum

$\gamma$  Nodal group with Carex nigra and Equisetum palustre

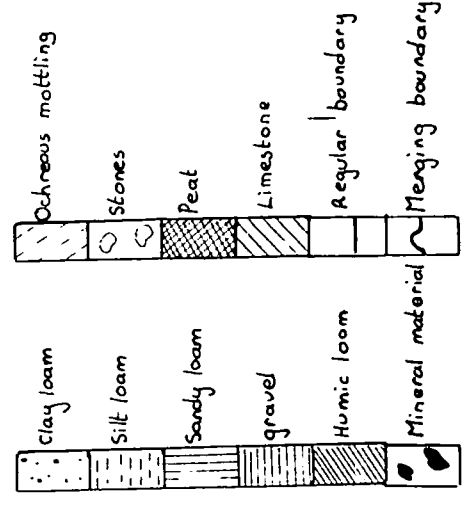


Surface horizon thicker on hummocks.

SCALE



KEY



The soils of the  $\mathcal{L}$  Nodal group with *Carex dioica*  
and *Carex lepidocarpa*

Table XXVII and Fig. X

When considered with reference to the vegetation on Widdybank Fell alone, the noda of the  $\mathcal{L}$  nodal group were arranged to give a  $\beta$  nodal group of five noda, plus mapping unit 14 (Table XXV). However, as a result of the study of this vegetation within the context of related types in other parts of Britain, this mapping unit has been included, with nos. 8 and 9, in the equisetosum variegati, despite some floristic differences between them; mapping units 11 to 13 remain as a group and have been placed in the eleocharetosum of Fig. IX b).

Parallel with this floristic arrangement of the noda, their soils show sufficient similarity in a number of factors within each sub-association and dissimilarity from those of the other sub-association to enable them to be taken together also. The range of values for each characteristic is evident from Table XXVII. The means of those for which the data are most complete are given below (excluding the hollows):

	pH	L.O.I.	Ca <sup>2+</sup>	N
Mapping units 8, 9 and 14	7.5	7.5	45.5	0.51
" " 11, 12 and 13	5.9	46.4	35.8	1.31

Furthermore, the soils of each nodum of the equisetosum variegati are more diverse than those of the eleocharetosum in which there is only one soil-type per nodum (cf. Fig. X; three sites were investigated for each of mapping units 11 and 12).

The floristics of mapping units 8 and 9 show considerable divergence both in absolute species-number and in species-variety (see Table XXV). However, at first sight, their soils seem remarkably similar: both noda may develop on either calcareous gleys or the somewhat wetter (flushed) calcareous gleys, each with a high value of pH. Nevertheless, closer inspection of Table XXVII reveals two differences: the concentrations of free calcium carbonate (calcite crystals) are 11.82% and 55.4% and the losses on ignition (giving a measure of humus content) are 9.46% and 3.55% for mapping units 8 and 9 respectively. In addition, it was noted in the field that the soils of mapping unit 9 have a much higher water-table than those of the other. The factors of soil moisture, humus and free carbonate

contents are, therefore, amongst those influencing the change from the nodum with Sesleria (m.u. 8) to the nodum with Juncus triglumis (m.u. 9).

The nodum with Sesleria is one of those which often shows floristic - physiognomic separation into hummock and hollow components; the soils of these were analysed separately and the analyses are distinguished in Table XXVII. The only qualitative difference is that the surface horizon is thicker on the hummocks (cf. Fig. X) but there are striking quantitative differences in the amount of calcite present. This has a slight effect on pH, presumably due to the proximity of the hollows to the limestone bedrock; this horizon was reached in the (flushed) gleys. The other quantitative soil characteristics are approximately equal and reflect the findings that the floristic differences between the components are quantitative and not qualitative.

Reference has already been made to the floristic connection between the nodum with Primula (m.u. 7) of the Nodal group with Sesleria and Koeleria and the nodum with Sesleria (m.u. 8). This affinity is exemplified by the differential species of the noda (Tables III and XXV) since those of mapping unit 7 emphasise its damper nature in comparison with the rest of the Nodal group and vice versa. Accordingly, a comparison has been made of the nature and selected features of their soils. As in the case of mapping units 8 and 9, pH and calcium concentrations are about the same but, again, differences can be seen for loss on ignition - 19.48% and 9.46% - and free calcium carbonate content - 30.22% and 11.82% - in mapping units 7 and 8 respectively. More striking are the dissimilarities in soil moisture content as reflected by the soil nature: mapping unit 7 develops on  $\beta$  rendzinas, rendzinas/brown calcareous soils, brown calcareous soils/brown earths and, occasionally, on (peaty) gleys; whereas mapping unit 8 forms on calcareous gleys or (flushed) calcareous gleys, both of which are damper than the soils of the other nodum.

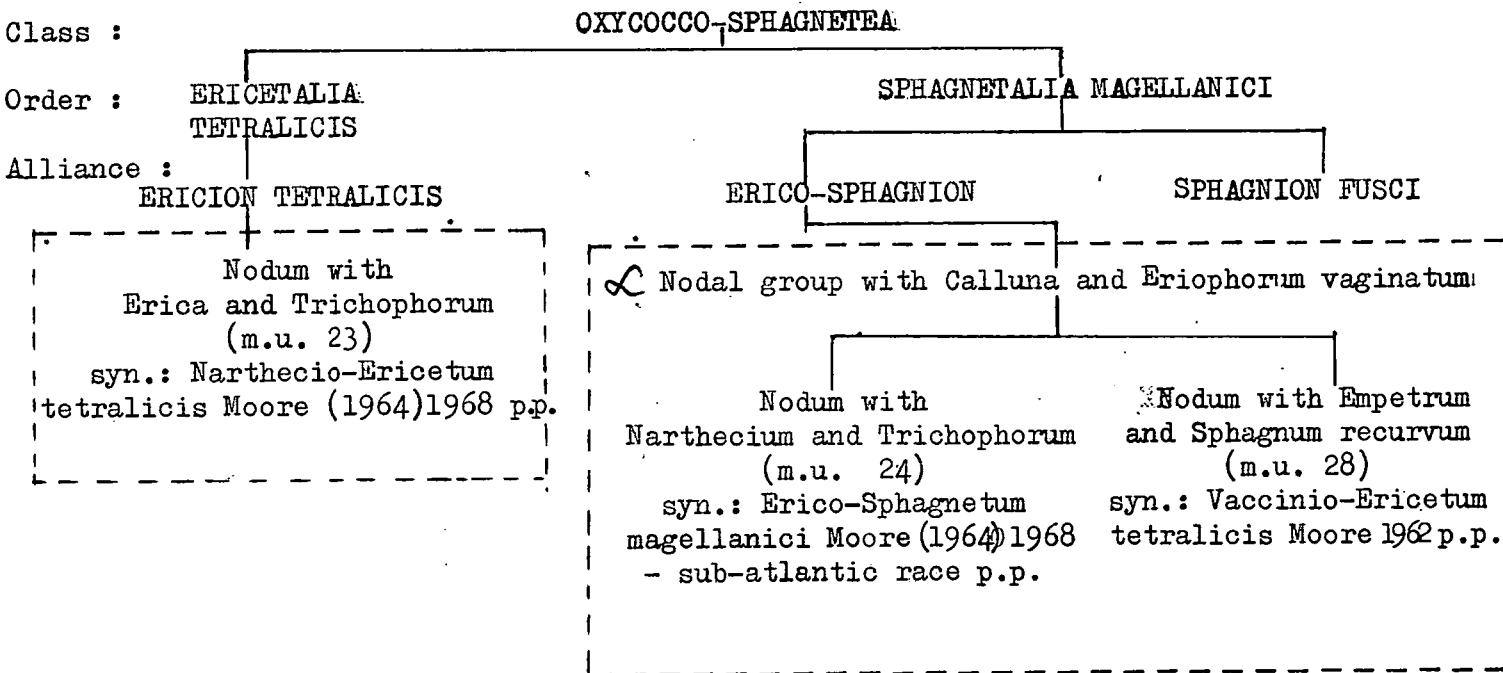
The substrates of mapping unit 14 are barely distinguishable from those of mapping unit 9, although the Gymnostomum hummocks may develop directly on the limestone <sup>and when</sup> of the stream bed. As noted with reference to the moss hummocks of the nodum with Cardamine and Cratoneuron commutatum (Cratoneurion), there is occasional accumulation by the bryophyte tissue of very high levels of zinc (cf. also the analyses for 9/1 and 11/1 of the Caricion davallianae).

The soils of the three nodal (mapping units 11, 12 and 13) of the δ nodal group with Carex nigra and Equisetum palustre form a group distinguishable from those already described. By reference to the mean figures quoted earlier and to Table XXVII, it is apparent that there is an absence of free calcite, a lower calcium concentration and a reduction in pH. The values for loss on ignition are strikingly greater and, coupled with this increase in humic material, additional amounts of nitrogen are present.

These nodal form a floristic series in which mapping unit 11 is closest to the δ nodal group with Equisetum variegatum and nos. 11 and 12 approach nos. 15 and 16 of the β nodal group with Carex flacca and bryophytes of the ℓ nodal group with Carex nigra and C. pulicaris. The same direction of variation is followed by the soils of mapping units 11, 12 and 13: the (flushed) calcareous gleys of mapping unit 11 have no free calcite, are more acidic and are more humus-rich than those of mapping units 8 and 9 whilst the peaty gleys and (flushed) peats of nos. 12 and 13 (respectively) have less humic material and are often shallower than those of mapping units 15 and 16 (cf. Table XXI and Fig. VIII). The single profile and set of analyses for mapping unit 13 is taken to be representative of that nodum since the profiles of Aufnahmen nos. 139 and 146 (m.u. 16) which have strong affinities with mapping unit 13, are very similar both in nature and in chemical composition.

The frequent occurrence in the field of a hummock-hollow complex of mapping units 12 and 9 (respectively) has been mentioned in an earlier section. Their soils are peaty gleys of pH 5.7 with no calcite crystals (m.u. 12) and (flushed) calcareous gleys of pH 7.6 (m.u. 9) resting on limestone or calcite sand and irrigated by calcareous ground water.

SYNOPTIC CLASSIFICATION OF PARTS OF THE OXYCOCCO-SPHAGNETEA  
WITH PARTICULAR REFERENCE TO WIDDYBANK FELL



Key

vegetation present on  
Widdybank Fell

Class : OXYCOCCO-SPHAGNETEA Br.-Bl. et Tx. 1943

The summary on the facing page shows the part of the class mentioned in the text.

Communities of ombrophilous bogs (Bellamy 1967) and of damp heaths are both included within the class. Dwarf shrubs, eg. Calluna vulgaris, Erica tetralix, Empetrum nigrum and/or Ledum palustre are often dominant, although members of the Cyperaceae may be prominent also; the ground layer, in which Sphagnum species are plentiful, is well developed. The extent of the peaty substratum ranges from quite shallow to very deep, it is highly acidic and extremely to moderately oligo-trophic in nature. Four broad topographic types are encompassed by the class and, from west to east, <sup>across Europe</sup> these are: relatively nutrient-rich oceanic blanket bogs, sub-oceanic flat bogs or Flachhochmooren, sub-continental-continental raised bogs or eigentliche Hochmooren, wooded raised bogs or Waldhochmooren (Westhoff and den Held 1969).

Vegetation of the class is chiefly found in the eurosiberian region but its distribution may be circumpolar; Oberdorfer (1957) and Westhoff and den Held (1969) believe that it may be represented in North America although the latter consider that the vegetation of this region may be more clearly described if placed in another class, and Miyawaki (1968) reports its presence in Japan. Within the eurosiberian region its optimal development is in the north-western part; although the class reaches the mediterranean region, it is here confined to the alpine zones.

#### Syntaxonomy

The classification of the bogs and wet heaths is complicated by the widespread occurrence of transitions between them and other types of vegetation. The intermingling with soligenous mires (already mentioned in the discussion of the syntaxonomy of the Parvocaricetea) has caused some authors to include all these kinds of vegetation in a single class, i.e. the Sphagno-Caricetea fuscae Duvigneaud 1949 and the Vaginato-Sphagnetea Malmer 1968 prov. In addition, the wooded raised bogs, which are at the eastern edge of the range of the Oxycocco-Sphagnetea, have affinities with the forests of the sub-all. Eu-Vaccinio-Piceion (class Vaccinio-Piceetea)

Tüxen (1969) mentions the extremely high number of classificatory schemes which have been proposed for this class. Westhoff and den Held provide a detailed bibliographic coverage of these and favour - and use - that proposed by Moore (1968) which in many respects cuts ~~at right angles~~ across most of the others.

Originally, Nordhagen (1936) placed all the communities of the present Oxycocco-Sphagnetea in a single order - the Ledetalia palustris. This practice has been repeated on numerous later occasions, e.g. Tüxen (1937), Braun-Blanquet et Tüxen (1943), often with a change of name; Erico (Ericeto)-Sphagnetalia Schwick, 1940 (Tüxen 1969, Doing 1963), Oxycocco-Ledetalia palustris Dahl 1956, Trichophoro-Sphagnetalia Malmer 1968. Other authors, whilst still placing all the Oxycocco-Sphagnetea communities in a single order, have added to them vegetation (usually placed in the Scheuchzerietalia of the Scheuchzerietea, syn.: Scheuchzerio-Caricetea fuscae pp.) of the channels in ombrophilous bogs and of the lagg zone around the bogs. In these schemes, the order names Scheuchzerietalia Vlieger 1937 and Erico-Sphagnetalia Duvigneaud 1949 have been used. A similar conception was held by Du Rietz (1954) but at the class level under the term Ombro-Sphagnetea.

Most of the divisions of the class into two orders have been on a geographic-floristic basis. This has given the Ledetalia palustris Nordh. 1936 emend. (Braun-Blanquet 1949b) syn.: Sphagnetalia fusci Tx. 1955 (Oberdorfer 1962, Lohmeyer et al 1962, Oberdorfer et al 1967) of northern, central and eastern Europe with isolated outposts in the sub-arctic regions and in the alpine parts of southern Europe, and the Erico-Sphagnetalia Schwick, 1940 (amended by Oberdorfer 1962, by Lohmeyer et al 1962 and by Oberdorfer et al 1967), syn.: Sphagno-Ericetalia, Braun-Blanquet 1949, of south-west Europe and the atlantic region.

Moore (1968) goes against this general trend and subdivides the class on an ecological-floristic basis in line with the treatment given to most other classes. This gives the Ericetalia tetralicis for damp heaths on shallow peat in the atlantic sector and the Sphagnetalia magellanici for bogs with dominant Sphagna on deeper peat present in both the atlantic and the continental parts of Europe. His arrangement is followed by Westhoff and den Held without modification but Tüxen (1969), whilst in broad agreement with the premise that classification should be on ecological grounds,



Order : ERICETALIA TETRALICIS Moore (1964) 1968

Syntaxonomy

The order was first recognised as a separate entity in 1957 when Oberdorfer amended Schwickerath's (1940) conception of the Erico-Sphagnetalia (originally intended to encompass all the vegetation of the present-day class) to produce a grouping synonymous with the Ericetalia tetralicis. Subsequently, however, the Erico-Sphagnetalia has been further amended to include the communities of atlantic and sub-atlantic bogs (Oberdorfer 1962, Lohmeyer et al 1962, Oberdorfer et al 1967) and Tüxen (1969) has reverted to Schwickerath's original conception of it (see above).

The Ericion tetralicis is the only alliance currently recognised within the order but in 1957 Oberdorfer separated out the Scirpion caespitosi comprising an association containing a group of communities which were more widely spread over western Europe than the, therefore amended, Ericion tetralicis which he believed to be confined ~~purely to the~~ atlantic regions. After being down-graded to a sub-alliance by Oberdorfer in 1962, the association became included within the Ericion by Oberdorfer et al (1967). Westhoff and den Held believe that the contents of a third alliance - the Narthecion Vanderm Berghen 1958 - should be divided between the Ericion and the Erico-Sphagnion (see below).

Since the order has only the one alliance, the general descriptions and character species' complements of each are the same.

All: Ericion tetralicis Schwick. 1933

These damp dwarf-shrub heaths are rather more species-rich than the vegetation of the Sphagnetalia and are notable for the prevalence of Erica tetralix and Trichophorum cespitosum ssp. germanicum. The moss layer is not as dense as in the other order and unvegetated peaty areas are common. The alliance is floristically close to the dry heaths of the Calluno-Ulicetalia from which it is distinguished by the peat bog species, and Duvigneaud (1949) mentions the abundance of Caricion curto-nigrae and of Molinion species. The peat substrata are less oligo-trophic and are shallower (only 25-100 cm deep) than in the Sphagnetalia. The level of the groundwater fluctuates from winter to summer but damp conditions are always maintained (Westhoff and den Held 1969).

Class : OXYCOCCO-SPHAGNETEA  
 Order : ERICETALIA TETRALICIS  
 Alliance : ERICION TETRALICIS

Nodum with Erica and Trichophorum

Order : SPHAGNETALIA MAGELLANICI  
 Alliance : ERICO-SPHAGNION

∞ Nodal group with Calluna and Eriophorum vaginatum

a) Field key to communities on Widdybank Fell

Nodum & ∞ Nodal Group	Calluna vulgaris, Eriophorum angustifolium, Erica tetralix		
∞ Nodal Group alone	Eriophorum vaginatum, Sphagnum papillosum, S. capillaceum/rubellum, Mylia anomala		
Noda	Trichophorum <sup>#</sup> cespitosum Narthecium ossifragum Sphagnum tenellum Juncus squarrosus Nardus stricta Cladonia uncialis C. arbuscula C. furcata	Trichophorum <sup>#</sup> cespitosum Narthecium ossifragum Sphagnum tenellum S. cuspidatum Carex rostrata Cladonia imp <sup>o</sup> xa	Empetrum nigrum Sphagnum recurvum Calypogeia trichomanes Lp <sup>h</sup> ozia ventricosa Plagiothecium undulatum Aulacomnium palustre Hypnum ericetorum Ptilidium ciliare Polytrichum commune Rhytidiadelphus loreus Pleurozium schreberi Pohlia nutans, Carex nigra Campylopus flexuosus
Mapping units	23	24	28

b) Classification of Noda

Narthecio-Ericetum tetralicis Moore (1964) 1968 p.p.  syn.: Nodum with Erica and Trichophorum	Erico-Sphagnetum magellanici Moore (1964) 1968 sub- atlantic race p.p.  syn.: Nodum with Narthecium and Trichophorum	Vaccinio-Ericetum tetralicis Moore 1962 p.p.  syn.: Nodum with Empetrum and Sphagnum recurvum	
Mapping units	23	24	28

<sup>#</sup> ssp. germanicum

The alliance is principally present in the extreme atlantic and atlantic regions - from Denmark and North Germany to Spain and including the British Isles - although there are outliers in sub-atlantic regions, e.g. the Alps.

### Syntaxonomy

This type of vegetation has been described separately from the bog communities since 1933 when Schwickerath erected the Ulicio-Ericion tetralicis (syn.: Trichophoro-Ericion tetralicis Duvign. 1947) although Vlieger (1937) placed them in the Rhynchosporion which was included, along with the Sphagnion fusci of ombrophilous bogs, in the Scheuchzerietalia (cf. above). Another classification was suggested by Passarge (1964) who placed the Ericion, and the Scirpion caespitosi Oberd. 1957, in the new order Juncetalia squarrosi which comprised the damp wet oligotrophic communities of the Nardo-Callunetea; this has not come into general use. More common (Lohmeyer et al 1962, Oberdorfer 1962, Oberdorfer et al 1967) has been the classification of bogs in the atlantic sector within the Ericion which was the only alliance recognised in the amended Erico-Sphagnetalia Schwick. 1940. These bog communities now form part of the Erico-Sphagnion of the Sphagnetalia magellanici (see below).

### Character species

To Moore's (1968) group of

Erica tetralix  
Trichophorum cespitosum ssp. germanicum  
Juncus squarrosus  
Sphagnum compactum

may be added Gymnocolea inflata and Zygonium ericetorum from Westhoff and den Held (1969).

It is apparent from Moore's Table I that both Erica and Trichophorum are also widespread through the communities of the Erico-Sphagnion of the Sphagnetalia, and that several of the differentials of this alliance are equally frequent in the Ericion tetralicis. As a consequence, Moore describes the difficulty of determining whether the point of major division of the class should be to separate out the two orders Ericetalia and Sphagnetalia as he has done, or to include within the same order all the atlantic vegetation (i.e. both wet heath, Ericion, and bog, Erico-Sphagnion) leaving the true continental bog communities in the other (cf. Lohmeyer et al 1962, Oberdorfer et al 1967). The chief

considerations influencing Moore's subdivision of the class have already been mentioned. The allocation of a group of Aufnahmen to the Ericion may, however, present some problems. A decision will be influenced by the number of Ericion/Ericetalia characters present, the necessity of almost complete absence of Sphagnetalia characters (Moore's table shows only a little overlap of these into the Ericion) and the general physiognomy (wet heath or bog) of the vegetation. In addition, peat depth can provide confirmatory evidence.

All the species listed above are common <sup>on</sup> bogs and wet heaths throughout Britain and are absent only where suitable habitats are lacking (cf. the class character species) but Gymnocolea is also found on moist gravel, silt and sand.

All except Zyggonium are known to be present in Upper Teesdale and have been recorded during the present study; Erica, Trichophorum, Juncus squarrosus and Sphagnum compactum occur in vegetation of the Ericion but are also in that of the Erico-Sphagnion; Gymnocolea is in the latter only (cf. Table I).

The only nodum of the Ericion tetralicis which has been distinguished on Widdybank Fell is the

Nodum with Erica and Trichophorum (Mapping unit 23)  
Table XXVIII, Fig. XI a)

The inter-relationships between the Ericion and Erico-Sphagnion already described on a north European scale are also shown by the analyses from Widdybank Fell. The constancies of the differentials of the three Oxycocco-Sphagnetea nodi are given in Table XXIX and the field key shown in Fig. XI a) also incorporates all three nodi.<sup>4</sup> From this table and figure is seen the common possession by mapping units 23 and 24 (in particular) of a number of differentials, several of which are also alliance character species: Erica and Trichophorum for the Ericion, Narthecium for the Erico-Sphagnion (cf. also Table I).

<sup>4</sup> This treatment differs from that given to the other classes in which two alliances are represented on the Fell, but it is felt to be more meaningful than the use of separate field keys.

The Phanerogam members of the differential species group - Erica tetralix, Trichophorum cespitosum ssp. germanicum, Juncus squarrosus (all alliance characters), Narthecium ossifragum, Calluna vulgaris, Eriophorum angustifolium and Nardus stricta - all feature prominently in vegetation of the nodum; Trichophorum is usually fairly evenly dispersed whereas the others occur as clumps or rosettes of various sizes. The differentials Sphagnum tenellum (a class character), Cladonia uncialis, C. furcata and C. arbuscula and the companion Rhacomitrium lanuginosum, are the chief components of the ground layer. The shoots of Trichophorum are about 30 cm tall and those of Erica and Calluna are between 5 and 20 cm in height. The mean species number of 15, the lowest for any nodum on the Fell, is only fractionally lower than those for the noda of the Erico-Sphagnion. Total cover is 80% to 90%; a partially exposed peat surface is one of the characteristic features of the alliance. Phanerogam cover (50% to 75%) is usually less than that of the Cryptogams (30% to 90%).

The nodum is of somewhat restricted occurrence and its total area is very much less than that of the bogs of the Erico-Sphagnion. Where present, it is often a member of a small-scale mosaic, chiefly with vegetation of mapping unit 28 of this other alliance. The ground surface is usually slightly sloping - up to 10°.

Large hummocks of mapping unit 28 (the nodum with Empetrum and Sphagnum recurvum), dominated by Calluna and Eriophorum vaginatum, were formerly present on the western side of the Fell adjacent to the Tees with the nodum with Erica and Trichophorum between them on the Whin Sill. A small area of a similar complex remains above top water level on the south-west corner of the Fell; further small patches are in the main area of blanket bog on the Fell and around the edges of Red and Tinkler's Sike bogs/ <sup>below the limestone escarpment.</sup> In all these places small-scale erosion has broken up the continuous vegetation cover on deep peat and mapping unit 23 has developed on the thin peat over the Whin Sill. Comparable mosaics are sometimes formed between this mapping unit and no. 31 of the Empetrum nigri in similar habitats where the blanket bog has become sufficiently dried out to be replaced by dry heath. The thinning out of the peat cover which takes place at the margins of the blanket peat (mapping unit 28) covering the top of the Fell may also provide suitable conditions for

mapping unit 23, either on its own or as a complex with no. 26 of the Empetrium.

The separation in the field of these two mapping units - the wet heath in the Oxycocco-Sphagnetea and the wet heath of the normally dry heath vegetation of the Empetrium - is not always straightforward but usually Narthecium and Juncus squarrosus prove good differentials for mapping unit 23 against Molinia for no. 26. Their general physiognomy and topographic locations also provide aids to their separation. The flat rather open communities of mapping unit 23 most frequently colonise the peat between the blanket bog hummocks (m.u. 28) whilst mapping unit 26 forms either free-standing hummocks itself or else a heathy border around those of mapping unit 28.

It is apparent from both Table XXIX and Fig. XI a) that there are also floristic resemblances between the nodum with Erica and Trichophorum and mapping unit 24 of the Erico-Sphagnion. Six species attain high constancies in each and they share the same dominants. However, each nodum (or  $\alpha$  nodal group in the Erico-Sphagnion) has a number of individual differentials, e.g. Juncus squarrosus and Nardus stricta for mapping unit 23 and Eriophorum vaginatum and Sphagnum papillosum for no. 24. In addition, different topographic locations are occupied because although both develop in places with some water movement, the small patches of the nodum with Erica and Trichophorum in the mosaics described above contrast vividly with the large flat tracts of the nodum with Narthecium and Trichophorum (m.u. 24).

The syntaxonomy and classification of the nodum  
Table XXX, Fig. XI b)

Moore's (1968) reclassification of the Oxycocco-Sphagnetea includes details of species frequencies and brief descriptions of the associations of each of the three alliances. The Nodum with Erica and Trichophorum falls on both floristic and descriptive grounds within the Association Narthecio-Ericetum tetralicis Moore (1964) 1968 one of the three associations described for the Ericion tetralicis. The Widdybank nodum and Moore's details of the association are compared in Table XXX together with other analyses of closely related British vegetation which have become available since Moore's study. The designations of association character and differential species and companion species are taken from Moore's table. A list of

SUMMARY OF THE COMPONENTS OF THE  
NARTHECIO-ERICETUM TETRALICIS

ASSOCIATION NARTHECIO-ERICETUM TETRALICIS

Moore (1964) 1968

Nartheccio-Sphagnetum acutifolii exatlanticum  
Duvign. 1949 (Moore 1968)

Trichophoreto-Callunetum McV. & R. 1962)(McV. & R. 1962,)

Molinieto-Callunetum McV. & R. 1962 } ( Birks 1969 )

Trichophorum cespitosum nodum Edgell 1969

Nodum with Erica and Trichophorum

the components of the association is given on the facing page.

Moore notes that the Narthecio-Ericetum tetralicis is "abundant in the extreme atlantic regions on shallow, wet peat". Column 4 in Table I of his paper (col. A in Table XXX of the present study) is composed of analyses from the west and central Scottish Highlands (McVean and Ratcliffe 1962), Normandy (Duvigneaud 1949) and Ireland (Moore, unpublished). The geographical extent of the association can now be extended to Skye (cols. D and E, Birks 1969) north Wales - Cader Idris (col. C, Edgell 1969) and north England where Widdybank Fell (col. B) is its only locality; it is absent from Moor House, (cf. Eddy, Welch and Rawes 1969). Widdybank and the eastern Cairngorms (cf. McVean and Ratcliffe 1962) provide some of the most easterly situations of the association. Although Birse and Robertson (1967) have described from the Lammermuirs a "wet Calluna moor", which is undoubtedly a member of the Ericion tetralicis, this lacks the characters and differentials of the Narthecio-Ericetum tetralicis. It may be noted that these Ericion communities reach much farther north and west than Bridgewater's (1970) Erica tetralix heaths (a grouping of equivalent rank to the Ericion tetralicis) which were recorded only south of a line from mid-Wales to east Yorkshire. With the present state of British phytosociological knowledge, however, such details of distribution as well as the following information on altitudinal range can be regarded as only approximate. On Cader Idris and on Widdybank Fell the association occurs between 1,300 and 2,500 ft (396 and 762 m) and 1,500 and 1,700 ft (457 and 518 m) respectively, but this range is substantially increased in Scotland where the association is found from sea-level to 3,000 ft (914 m).

The variation in physiognomy of the association as a whole is not much different from that of the Widdybank nodum. Trichophorum, Calluna, Erica, Narthecium and, in some cases, Molinia are all prominent in the vegetation the height of which is between 15 and 30 cm. Rhacomitrium lanuginosum and various Sphagnum species (papillosum, tenellum, plumulosum) are also plentiful and total cover lies between 80% and 100%. The ground is usually sopping - often up to 15° and in some parts of Scotland to 30° - and thus does not allow the development of the deep peat required by the communities of the Erico-Sphagnion occurring in the same locality. The abundance in the

association

/of Erico-Sphagnion character and differential species previously mentioned as a feature of Ericion tetralicis communities, is evident from Table XXX; the inclusion of some Caricion curtonigrae species, e.g. Viola palustris, Carex nigra, in the association characters is illustrative of the occurrence of water movement through the vegetation.

The communities of the Narthecio-Ericetum tetralicis on Skye are transitional to the Pleurozia purpurea - Erica tetralix association Br.-Bl. et Tx. 1952 emend Moore (1964) 1968 whose character species are also given in Table XXX. This association is an atlantic member of the Erico-Sphagnion. Moore notes its affinity to the Ericion and gives a number of differentials which it shares with the associations of that alliance. The Pleurozia purpurea - Erica tetralix association, however, has many more Sphagnetalia and fewer Ericion differentials than the Skye members of the Narthecio-Ericetum tetralicis.

The synsystematic placing of the Nodum with Erica and Trichophorum

Table I

The nodum fulfils the general criteria outlined above for membership of the Ericetalia and Ericion tetralicis despite the paucity of character species of the Oxycocco-Sphagnetea. Four of the five order and alliance characters are present, three with high constancies, and Sphagnetalia characters are virtually absent. Although several Erico-Sphagnion characters occur within the nodum, only Narthecium is of high constancy (IV) and such occurrences are in keeping with communities of the Ericion in general. The nodum develops on peaty substrata which are less than one metre in depth (see below), another of the features of the alliance described by Moore. Character species of other higher units of classification are rare; mention may be made of the Nardetalia character Nardus stricta and the Caricetalia nigrae/Caricion curtonigrae character Carex echinata with constancies of III and II respectively.

The soils of the nodum with Erica and Trichophorum  
Table XXXIII and Fig. XII

These are discussed below in conjunction with the soils of the ∞ nodal group with Calluna and Eriophorum vaginatum; the schematic profiles and tabulated features of both types are shown together.

Order : SPHAGNETALIA MAGELLANICI (Pawl. 1928 p.p.)  
Moore (1964) 1968

The order is composed of hummock and hollow forming blanket and raised bogs which have almost always developed on oligo-trophic and very deep peat. They are characterised by abundant Sphagna in the ground layer and by such species as Eriophorum vaginatum, Andromeda polifolia and Vaccinium oxycoccus in the field layer. Westhoff and den Held point out that there are close successional relationships in both build up and decay between these communities and those of the Scheuchzerietea in which is placed the vegetation of soligenous blanket bog channels.

It is currently believed (Westhoff and den Held 1969) that the order is confined to the eurosiberian region with its "centre of gravity" in the sub-atlantic to continental parts. Miyawaki (1968), however, has speculated that the Japanese raised bog vegetation should also be placed in this order, although he recognises that ultimately it may come to be assigned to a different one within the class.

Syntaxonomy

The complex syntaxonomy of this order which cuts right across very many other classificatory schemes is very intelligibly given by Westhoff and den Held who cite the Ledetalia palustris Nord. 1936 as amended by Oberdorfer (1957) as its only exact equivalent. The Dutch authors note that the alliance names for the vegetation of bogs, sensu lato, used before 1957 and in some cases after that date (e.g. Oberdorfer et al 1967) - Sphagnion fusci Br.-Bl. 1915, Sphagnion europaeum Schwick. 1940 and Vaginato-Sphagnion europaeum Duvign. 1949 - are not synonymous with the Sphagnetalia magellanici since some of the communities placed by Moore in the Erico-Sphagnion of this order were included under these other systems in the Ericion tetralicis or its equivalent (see above). This was a

consequence of the close relationship between the Ericion and the Erico-Sphagnion.<sup>#</sup>

Character species

The following list taken from Moore's paper is substantially the same as that of Westhoff and den Held. Sphagnum fallax is given by the latter authors only and they regard Eriophorum vaginatum and Sphagnum rubellum as transgressive class characters, believing that only within the Netherlands are these species valid Sphagnetalia characters. This is not substantiated by Moore's data and so they are retained as order characters. The species are:

<u>Eriophorum vaginatum</u>	<u>Sphagnum magellanicum</u>
<u>Vaccinium oxycoccus</u>	<u>S. rubellum</u> /
<u>Andromeda polifolia</u>	<u>S. recurvum</u> /
<u>Carex pauciflora</u>	<u>S. fallax</u>
<u>Polytrichum alpestre</u>	<u>Cephalozia connivens</u>
<u>Pohlia nutans</u>	<u>C. macrostachya</u>
<u>Mylia anomata</u>	<u>Calypogeia sphagnicola</u>

Only Sphagnum fallax is unsuitable for use in the British Isles since it is not recognised in this country. All the others are, more or less exclusively, members of the flora of bogs and boggy moorland. Eriophorum vaginatum, found in Scotland, north England, Wales and central Ireland, is one of the most widely distributed members of the group; Vaccinium and Andromeda are chiefly confined to the central part of this range whilst Carex pauciflora is predominantly in north-west and central Scotland with only scattered occurrences in south-west Scotland and north England. Several of the bryophytes - Sphagnum rubellum, S. recurvum, Pohlia nutans and Mylia anomala - are particularly common in suitable habitats.

Moore divides the Sphagnetalia into two alliances: the Erico-Sphagnion for the atlantic regions where snow lies on the bogs for only a short time in winter, and the Sphagnion fusci of the continental and boreal parts with their more harsh winters.

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<sup>#</sup> A similar lack of synonymy is also true for the order, the Sphagnetalia fusci Tx. 1955, containing the Sphagnion fusci Br.-Bl. 1915 since it is the only alliance present, cf. Bohmeyer et al 1962, Oberdorfer et al 1967.

/ Sphagnum recurvum ssp. recurvum var. parvulum Warnst. in Westhoff and den Held - not distinguished to this level in Britain.

All.: Sphagnion fusci Br.-Bl. (1915) 1920 em. Moore (1964) 1968

This alliance is widespread in the boreal-continental zone, including much of Siberia, but extends in a species-poor form into atlantic Europe and is represented in the Netherlands, Denmark and north Germany (Westhoff and den Held 1969) as well as in Scotland. Its communities are more oligo-trophic than those of the Erico-Sphagnion.

#### Syntaxonomy

As a result of Moore's work, the syntaxonomy of the alliance is, as with most other parts of the class, complex. It originally encompassed a greater floristic variety of bog vegetation types from a larger geographical area and, as such, was synonymous with the later terms of Sphagnion europaeum Schwick. 1940 and Vaginato-Sphagnion europaeum Duvign. 1949. Moore's amendment of the alliance gives a classificatory unit which is even more restricted in scope than the continental sub-alliances erected by Schwickerath and by

Duvigneaud - Sphagnion continentale Schwick. 1940 and Sphagnion medio-fusci Duvign. 1949 respectively - since he places in the Erico-Sphagnion some of the vegetation which is included in these alliances. The complete synonymy is given by Westhoff and den Held (1969) who note that the only exact equivalents of Moore's conception of the Sphagnion fusci are the Oxycocco-Empetrium hermaphroditum Nordh. 1936 sensu R. Tx. 1937 and the Eu-fuscium Du Rietz 1950.

#### Character species

Moore lists the following:

Ledum palustre	Sphagnum fuscum
Rubus chamaemorus	Dicranum undulatum
Vaccinium microcarpum	Cephalozia media
Empetrum hermaphroditum	Calypogeia neesiana
Chamaedaphne calyculata	Cetraria islandica
Trichophorum cespitosum	C. alpestris
ssp. cespitosum	

Most of these are repeated by Westhoff and den Held who also include Ledum groenlandicum. The value in Britain of the character species is as yet difficult to decide; a few are absent altogether but several are much more widespread than the general description and distribution of the alliance (given above) would seem to indicate.

Sphagnum fuscum and Rubus chamaemorus are often abundant in upland bogs (Rubus in moors also) in Scotland, north England and

north Wales; Vaccinium microcarpum and Empetrum hermaphroditum are present in bogs in the east Scottish Highlands and on moors, usually above 2,000 ft (610m) in central and north-west Scotland and in the Lake District. The distribution of Trichophorum cespitosum ssp. cespitosum is imperfectly known since it has only rarely been separately identified from the other sub-species. Ledum palustre is said to grow on Flanders Moss, a raised bog near Stirling (Clapham, Tutin and Warburg 1962, Martin 1965) but others have named this population as L. groenlandicum<sup>#</sup>; both species are occasionally present elsewhere as escapes. The habitats of Dicranum undulatum<sup>†</sup>, Cephalozia media, Calypogeia neesiana, Cetraria islandica, Cladonia alpestris and C. squamosa include peat bogs; Calypogeia and Cladonia alpestris are both very rare (McVicar 1926, Dixon 1954, Watson 1966, Duncan 1970); Chamaedaphne is non-British.

Several species act as differentials of the Sphagnion fusci from the Erico-Sphagnion. They are: Empetrum nigrum, Betula nana, Vaccinium uliginosum, V. vitis-idaea, Cladonia rangiferina and C. arbuscula. All occur in Britain, chiefly in central and north-west Scotland but the Phanerogams and Cladonia arbuscula extend into north England and in many cases into north Wales and Ireland also (Perring and Walters 1962). Their habitats include mountain bogs; but several species are found in moors, woods and heaths in addition but this variety in habitat is a feature of differential species.

The value of Moore's character and differential species for the Sphagnion fusci is strikingly reinforced by Ratcliffe's (1964b) description of the upland Scottish Calluna-Eriophorum bogs and especially in their separation from those in the lowlands with the same dominants. Mention is made of the presence of Vaccinium microcarpum, Empetrum hermaphroditum (both characters), Vaccinium vitis-idaea, Empetrum nigrum, Betula nana, the Cladonia arbuscula - C. rangiferina group (all differentials) and the absence of Myrica gale, an Erico-Sphagnion character. Ratcliffe also places

<sup>#</sup> Tüxen(1968) : personal communication

<sup>†</sup> syn.: Dicranum bergeri Bland. in Westhoff and den Held

the emphasis on Sphagnion fusci species (although not under this heading) in his portrayal of the mountain Empetrum - Eriophorum bog (cf. also the earlier descriptions of these vegetation types as Calluneto - Eriophoretum and Empetreto - Eriophoretum respectively in McVean and Ratcliffe (1962)).

These are the only definite members of the Sphagnion-fusci in Britain but, even so, they have affinities with the Erico-Sphagnion (cf. Moore 1968). The upland blanket bogs of north England and north Wales are related to the Sphagnion fusci whilst being members of the other alliance. These relationships are discussed below in connection with the affinities of the Sphagnetalia vegetation of Widdybank Fell.

All.: Erico-Sphagnion Moore (1964) 1968

The bog communities of this alliance extend from the sub-atlantic into the boreo-atlantic regions, i.e., from west Ireland to west Germany and south Sweden.

Syntaxonomy

The formation of this alliance has involved a division both of alliances which covered a greater variety, floristically and geographically, of bog communities (e.g. the Sphagnion europaeum Schwick. 1940, Vaginato-Sphagnion europaeum Duvign. 1949 and the Andromedo-Sphagnion europaeum Doing 1963), and alliances which included wet heaths as well as bogs in the atlantic regions (e.g. Oxycocco-Ericion Nord. 1936, Ericion tetralicis Schwick. 1933 emend. (Oberdorfer 1962, Oberdorfer et al 1967)). The alliance does not correspond with the sub-alliance for atlantic bogs of either Schwickerath or Duvigneaud. It is equivalent to much of the sub-all. Sphagnion atlanticum Schwick. 1940 plus part of the sub-all. Sphagnion continentale Schwick. 1940 and similarly to the greater part of the sub-all. Sphagnion pupilloi Duvign. 1949 plus some of the sub-all. Sphagnion medio-fusci Duvign. 1949 (Westhoff and den Held 1969). It also includes part of the Nartheccion Vanden Berghen 1958; the rest is placed in the Ericion (Westhoff and den Held 1969).

Character species

Moore suggests the following:

Myrica gale	Sphagnum papillosum
Narthecium ossifragum	S. plumulosum
Drosera intermedia	S. imbricatum
	Odontoschisma sphagni

However, the only alliance character given by Westhoff and den Held is Sphagnum papillosum and these authors note that although Sphagnum imbricatum is a valid Erico-Sphagnion character in the truly atlantic regions, it is present in vegetation transitional between this alliance and the Caricion curto-nigrae in the sub-atlantic lowlands of the Rhineland, Westphalia and part of the Netherlands.

Nevertheless Sphagnum imbricatum appears to act as a character in Britain and, as with Drosera, Myrica and Sphagnum plumulosum, is found principally in the north and west parts of the country especially in Scotland and Ireland (Proctor 1954, Perring and Walters 1962). All occur chiefly in damp peaty places as do Sphagnum papillosum and Campylopus flexuosus which are both more definite bog species and are widespread in Britain (Proctor 1954, Clapham, Tutin and Warburg 1962, Watson 1966). Each character except Drosera intermedia and Myrica gale is present on Widdybank Fell in vegetation of the Erico-Sphagnion.

There are several species which, whilst not confined to the alliance, differentiate it from the Sphagnion fuscii (Moore 1968); some of their British habitats are suitable for the alliance (Clapham, Tutin and Warburg 1962, Watson 1966, Duncan 1970).

These differential species are:

Erica tetralix	Campylopus flexuosus
Molinia caerulea	Hypnum cupressiforme
Rhynchospora alba	Leucobryum glaucum
Eriophorum angustifolium	Cladonia impexa

All are present in bog vegetation (inter alia) of Widdybank Fell with the exception of Rhynchospora which is absent from the area altogether having a somewhat oceanic distribution pattern.

Leucobryum, not recorded in this survey, occurs in mapping unit 24 west of Tinkler's Sike<sup>#</sup>.

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<sup>#</sup> Bradshaw (1972) : personal communication

Two noda belonging to the Erico-Sphagnion have been distinguished on Widdybank Fell. Together they form the

∞ Nodal group with Calluna and Eriophorum vaginatum  
(Mapping units 24 and 28)  
Table XXXI, Fig. XII a)

The key-card used in the field is given in Fig. XII a) facing the description of the Nodum with Erica and Trichophorum, and the relationships of the nodal group to the nodum with Erica and Trichophorum is shown in Table XXIX.

The differential species group comprises Calluna vulgaris, Eriophorum angustifolium, Erica tetralix (all also present in mapping unit 23), the class character Sphagnum rubellum, the order characters Eriophorum vaginatum and Mylia anomala and the alliance character Sphagnum papillosum. The mean species number is low, below 20, and cover is generally complete. Two noda are included in the group; both develop on terrain which is almost flat.

Nodum with Narthecium and Trichophorum (Mapping unit 24)

The nodum differentials Narthecium and Trichophorum are constant; the other members of this group - Sphagnum tenellum, S. cuspidatum, Carex rostrata and Cladonia impexa - are less frequent but are locally abundant. The usual appearance of the vegetation is an open patchwork of these differential Phanerogams and of the nodal group differentials with the occasional total dominance of one of these species. Sphagnum papillosum is dominant in the ground layer; in addition to the hummock forming species, e.g. Sphagnum rubellum shown in Table XXXI, there are occasional hummocks of Sphagnum imbricatum and S. fuscum (although always associated with the latter are species of mapping unit 28); Cladonia arbuscula is occasionally prominent. Two of the hummock formers, Sphagnum magellanicum (an order character) and S. plumulosum (an alliance character), are confined to this mapping unit as are the companions Cladipodiella fluitans and Cladonia uncialis. The shrubs are between 10 and 20 cm high and the Sphagnum hummocks vary between 10 and 40 cm above the general ground level. The cover of the ground layer, mostly Sphagnum spp. is about 80% and is usually greater than that of the shrub-herb layer which is only 50% to 60%. The differentiation of this nodum from mapping unit 23 is not always straightforward; the criteria employed are described above.

The nodum covers several thousand square metres of ground in the bog expanse on either side of Tinkler's Sike below the sugar limestone escarpment. A much smaller area formerly existed near the Tees immediately north of the dam. Another small patch of a few hundred square metres is present on Widdybank Moss which lies in the midst of the blanket bog covering of the Fell. In all these places the terrain is almost flat and the nodum is often bounded by mapping unit 28 or by a complex of this and no. 31 in an area of erosion; the last combination occurs particularly on the Tinkler's Sike bogs.

All the sites of this nodum have been palynologically investigated<sup>#</sup>; at each, peat formation in a basin in the underlying bedrock commenced before the spread of blanket peat in Atlantic times. These are not the only places on the Fell where peat growth started early. The present vegetation of the other sites is either a type of sedge marsh or the nodum with Empetrum and Sphagnum recurvum where drying out of the peat surface has commenced. The correlation of mapping unit 24 with former basins which have remained extremely wet is striking and complements the occurrence of mapping unit 28 on the general body of deep peat on the Fell.

Nodum with Empetrum and Sphagnum recurvum (Mapping unit 28)

syn.: *Eriophoretum vaginati* Tansley 1939

A large group of species, almost entirely all bryophytes, differentiate this nodum from the other. Of these, only Empetrum nigrum, Polytrichum commune and, occasionally, Carex nigra, play any part in the physiognomy of the vegetation. The other species are:

<i>Calyptogeia trichomanes</i>	<i>Hypnum ericetorum</i>
<i>Lophozia ventricosa</i>	<i>Pleurozium schreberi</i>
<i>Sphagnum recurvum</i>	<i>Ptilidium ciliare</i>
<i>Plagiothecium undulatum</i>	<i>Pohlia nutans</i>
<i>Aulacomnium palustre</i>	<i>Campylopus flexuosus</i>
<i>Rhytidiadelphus loreus</i>	

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<sup>#</sup> Turner (1971) : personal communication

The nodal group differentials Calluna vulgaris and Eriophorum vaginatum and, to a lesser extent, Erica tetralix are foremost in establishing the structure and physiognomy of the vegetation. The Eriophorum shoots may be dispersed amongst the others or this species can be in its tussocky form with hummocks up to 20 cm high. The order characters Cephalozia connivens, Vaccinium oxycoccus and Polytrichum alpestre occur in this nodum alone and the companions Dicranum scoparium, Cladonia squamosa and Rubus chamaemorus are found only in this nodum of the nodal group; the last species is occasionally prominent. The nodum may be very rich in lichens; the chief species is Cladonia arbuscula together with C. chlorophaea and C. squamosa. The height of the shrubs is between 20 and 30 cm; the shoots of Eriophorum vaginatum sometimes reaching 35 cm.

The cover is complete, Phanerogams and Cryptogams each occupying about 75% of the surface except after burning when the underlying peat is exposed. The lowest values of total cover recorded in such localities were 75% and 80% for Aufnahme nos. 505 and 429 respectively. Other Aufnahmen (nos. 246, 466, 234, 215) made where regeneration is taking place following burning several years previously, are included in Table XXXI; apart from being, in some cases, of a lower species number, they are not substantially different from the others of the nodum.

Mapping unit 28 covers a very high proportion of the surface of the Fell. It is the predominant bog type; most of the Fell top is covered by this nodum as are the outer parts of the bogs below the sugar limestone escarpment and, before the construction of the dam, it occupied much of the land between the Birkdale Track to the east and the Tees to the west. The terrain is either flat or gently sloping. Occasional hummocks of the nodum are situated on peat amidst the Seslerio-Mesobromion vegetation of the limestone escarpment. Here, as around the edge of the Fell top blanket bog, the nodum with Empetrum and Sphagnum recurvum is usually surrounded by an uneven rim of either mapping units 26 or 31 of the Empetrium or of no. 23. In places of erosion on both the Fell top and Tinkler's/Red Sike bogs the extreme edges of the channels which cut into mapping unit 28 are occupied by mapping unit 31, a dry member of the Empetrium. The mosaic of mapping units 28 and 23 is mentioned above.

The syntaxonomy and classification of the  $\alpha$  nodal group  
Table XXXII Fig. XI b)

Moore (1968) distinguishes three associations within the Erico-Sphagnion: the Pleurozia purpurea - Erica tetralix association Br.-Bl. et Tx. 1952 emend Moore (1964) 1968 of lowland blanket bogs, usually below 1,000 ft (305m), in west Scotland and west Ireland; the Erico-Sphagnetum magellanici Moore (1964) 1968 comprising west European raised bogs (a topographical description which can now be enlarged); and the Vaccinio-Ericetum tetralicis Moore 1962 of upland blanket bogs in Ireland, England, Wales and south Scotland. The last two associations are represented on Widdybank Fell by mapping units 24 and 28 respectively. In Table XXXII these nodes, the relevant data from Moore (1968) and details of related British vegetation not included by him are shown. Also included in Table XXXII (col. F) is the Scottish vegetation already mentioned which is a member of the Sphagnion fusci although closely related to the Vaccinio-Ericetum tetralicis.

No character species for either the Erico-Sphagnetum magellanici or the Vaccinio-Ericetum tetralicis are given by Moore. In Table XXXII several species have been designated as differentials of each of these associations in order that the differences between them can be more clearly appreciated. Narthecium, Drosera and Sphagnum magellanicum are also abundant in the Pleurozia purpurea - Erica tetralix ass. and all those listed as differentials of the Vaccinio-Ericetum tetralicis except Juncus squarrosus, Vaccinium vitis-idaea and V. myrtillus are named by Moore as characters of the Scottish Sphagnion fusci vegetation (col. F) together with Carex bigelowii and Chamaepericlymenum suecicum. As a consequence of the further details concerning the Vaccinio-Ericetum tetralicis now available, it is suggested that all Moore's character species except the last two named above should be used as differentials of both vegetation types, one of which is in each alliance of the Sphagnetalia.

In Moore's original table delimiting the associations of the Oxycocco-Sphagnetea, there is no transgression of these suggested differential species between the Erico-Sphagnetum magellanici and the Vaccinio-Ericetum tetralicis. This can be seen by a comparison

of cols. A, B, C and D with col. E in Table XXXII since this data is taken from Moore's paper. With the addition to the table of the extra data concerning the associations, however, this clear-cut definition is lost.

Association : Erico-Sphagnetum magellanici Moore (1964) 1968

Moore (1968) describes this association as comprising the "hummock-hollow vegetation of the typical raised bogs of western Europe". The communities he now includes in it were formerly distinguished as four separate associations defined principally according to the identity of the dominant Sphagna in the ground layer but Moore has combined them in the belief that the overall floristic composition of each is broadly similar. The association extends from central Ireland and Great Britain to north-west Germany and Belgium and variation within it is accommodated by distinguishing a number of geographical races: extreme atlantic (col. A), sub-atlantic (col. B) and sub-continental (cols. C and D). Westhoff and den Held (1969) and Dierschke (1969) follow Moore's belief in the validity of a broad association but Tüxen (1969) reverts to the opinion that there should be division into four hummock-building associations and restores the Sphagnetum imbricati, Sphagnetum papillosum, Sphagnetum medii and Sphagnetum fuscum as individual associations for, broadly, the atlantic, atlantic central and nordic-alpine parts of Europe respectively. He is able to identify the first three of these associations in the original table of the Pheurozia purpurea - Erica tetralix association in Ireland (Braun-Blanquet and Tüxen 1952) as well as within the Erico-Sphagnetum magellanici. It would nevertheless seem advisable to follow Moore's recent interpretation of the classification of this vegetation since it is part of an extensive survey of the class.

The geographical races of the Erico-Sphagnetum magellanici are correlated with the presence, absence and relative abundance of Sphagnum species and of various Phanerogams. The extreme atlantic race (col. A) found in the central Irish lowlands is characterised by a comparatively high frequency of Sphagnum imbricatum, the presence of isolated hummocks of Sphagnum fuscum and the absence of S. recurvum. The only other British vegetation included by Moore in the association is from west Wales and is referred to the sub-atlantic race (col. B) also found in coastal parts of north

SUMMARY OF THE COMPONENTS OF THE  
 ERICO-SPHAGNETUM MAGELLANICI - SUB-ATLANTIC RACE  
 ASSOCIATION ERICO-SPHAGNETUM MAGELLANICI (Moore 1964) 1968

Sub-atlantic race

syn.: Sphagnetum Godwin & Conway 1939

Type A moss, Type B moss Pearsall 1941

Type 1 bog, Type 2 bog Chapman 1964

Lowland Calluna-Eriophorum bog Ratcliffe 1964

Calluneto-Eriophoretum Sphagnum facies

McV. & R. 1962 emend. Ratcliffe 1966

Calluna-Eriophorum vaginatum-Trichophorum bog s.l.

Birse & Robertson 1967

Rhacomitrium-Cladina nodum Tallis 1969 +

Drosera-Narthecium nodum Tallis 1969

Trichophoro-Eriophoretum-Erica facies ) McV. & R. 1962

Trichophoro-Eriophoretum typical facies ) emend.  
 E.W. & R. 1969

Nodum with Narthecium and Trichophorum

Germany and Holland in which Narthecium is quite common and Sphagnum recurvum is present, often abundantly. In the sub-continental race, from north Germany and Belgium (cols. C and D), Narthecium is absent and both Sphagnum papillosum and Trichophorum cespitosum ssp. germanicum are absent or rare. The data from Widdybank Fell and from other parts of Britain which may now be added to the association fall within the sub-atlantic race, a list of whose components is given on the facing page.

The British vegetation placed in this race by Moore is the Sphagnetum of the coastal Tregaron bog which lies at 50 ft (15m) above sea-level (Godwin and Conway 1939). The other communities which are most "typical" of the race - i.e. have an abundance of Drosera, Narthecium and Sphagnum magellanicum and a lack of Vaccinio-Ericetum tetralicis differentials - are from terrain below 1,000 ft (305m): type 1 and type 2 bogs (col. G) from Coom Rigg Moss in Northumberland (Chapman 1964) and the lowland Calluna - Eriophorum bog (col. H) from around the Solway Firth, the plains of the central lowlands and the land bordering the eastern Scottish Highlands (Ratcliffe 1964a). The Scottish sites include both "raised" (as in Northumberland) and "intermediate" bogs. Ratcliffe (1964) describes the latter as a variable topographic type forming a linking series between typical "raised" and "blanket" bogs. They may exist under climatic conditions intermediate between those of the two end points or be in a régime suitable for blanket bog development when the intermediate bogs are topographically distinguished by having developed following the original fen communities in basins or channels in the underlying bedrock. The latter description applies to both the Trichophoro-Eriophoretum-Erica facies (col. I) from Moor House (Eddy, Welch and Rawes 1969) and the Modum with Narthecium and Trichophorum (col. N) which extend the altitudinal range of the association to about 2,000 ft (610m) and 1,700 ft (518m) respectively. It should be noted that the Widdybank vegetation was initially mentioned (Ratcliffe 1966) as a Sphagnum facies of the Calluneto-Eriophoretum McVean and Ratcliffe 1962. This upland Scottish vegetation, a member of the Sphagnion fusci already referred to, is considered below under the Vaccinio-Ericetum tetralicis.

Pearsall's (1941) analyses from the Stainmore district of the north Pennines (col. P) fall within this altitudinal range since they lie between approximately 1,250 and 1,600 ft (381 and 488m). His Type A moss is found on almost flat ground but Type B moss, which has low frequencies of some of the differentials of the Vaccinio-Ericetum tetralicis and reduced amounts of Drosera and Narthecium, may be on drier and more definitely sloping terrain.

Pronounced affinities to the Vaccinio-Ericetum tetralicis are seen in the remaining three analyses: the Rhacomitrium-Cladina and Drosera-Narthecium noda taken together, (col. Q) from the Berwyn mountains of north Wales (Tallis 1969), the Calluna-Eriophorum vaginatum - Trichophorum bog (col. T) from central and south-east Scotland (Birse and Robertson 1967) and the typical facies of the Trichophoro-Eriophoretum McV. & R. 1962 emend. (col. J) from Moor House. There are at least two possible causes of this intermediacy in floristic composition - increased altitude and/or a lower water table.

This Moor House vegetation lies between 1,650 and 1,800 ft (503 and 549m) and the Berwyn communities at 2,000 to 2,200 ft (610 to 671m) have the highest record for the association. Nevertheless, although both Ratcliffe (1964a) and Moore (1968) note that members of the Erico-Sphagnetum magellanicum are predominantly lowland in distribution, other more typical communities (see above) occur between 1,650 and 2,000 ft (503 and 610m) and the range of the Calluna-Eriophorum vaginatum-Trichophorum bog is only between 50 and 1,525 ft (15 and 465m).

A possibly more significant feature shared by the Moor House and north Wales vegetation is the pronounced hummock-hollow nature of the bog surfaces; similarly, some of the Scottish analyses are from drier parts of the bog. The Rhacomitrium-Cladina and Drosera-Narthecium noda colonise the hummocks and hollows respectively, or a complex which has developed in waterlogged depressions, and the hummock-hollow nature of the typical facies of the Trichophoro-Eriophoretum contrasts with the even-surfaced Erica facies (col. I). It should be mentioned that the complex of two noda from the Berwyns has been left as one unit since, although it is less typical of the Erico-Sphagnetum magellanicum than the Drosera-Narthecium nodum alone, the Rhacomitrium-Cladina nodum is not sufficiently close to the

SUMMARY OF THE COMPONENTS OF THE  
VACCINIO-ERICETUM TETRALICIS

ASSOCIATION VACCINIO-ERICETUM TETRALICIS Moore 1962

Calluna - Eriophorum vaginatum bog Ratcliffe 1959

Calluneto - Eriophoretum McV. & R. 1962 emend. Ratcliffe 1966

<u>Calluna</u> - <u>Eriophorum vaginatum</u>	}	Birse and Robertson 1967
Trichophorum bog - <u>Calluna</u> facies		
Upland <u>Calluna</u> - <u>Eriophorum vaginatum</u> moor		

Eriophorum vaginatum bog - low and high-level facies  
Edgell 1969

Calluneto - Eriophoretum McV. & R. 1962 emend. Birks 1969

Plagiothecium undulatum-Hylocomium splendens nodum

<u>Juncus squarrosus</u> - <u>Deschampsia flexuosa</u> series	}	Tallis 1969
( <u>Campylopus</u> - <u>Diplophyllum</u> and <u>Juncus squarrosus</u> -		
<u>Vaccinium vitis-idaea</u> nod.)		

Trichophoro - Eriophoretum McV. & R. 1962 emend.	}	Eddy, Welch &
<u>Calluna</u> facies		
Calluneto - Eriophoretum McV. & R. 1962 emend.	}	Rawes 1969
typical, <u>Sphagnum recurvum</u> and <u>Empetrum</u> facies		

Eriophoretum - high-level and grazed facies

Nodum with Empetrum and Sphagnum recurvum

Vaccinio-Ericetum tetralicis to be included in it.

Birse and Robertson do not give separate details of each of the three facies they distinguish within the Calluna-Eriophorum vaginatum-Trichophorum bog. Column T gives the composite unit which is formed from a Calluna facies on markedly dry peat (given in col. U and included within the Vaccinio-Ericetum tetralicis); a very wet facies which is possibly identical with Ratcliffe's lowland Calluna-Eriophorum bog (col. H) and whose analyses were probably made over the same geographical area; and an intermediate facies selected from the drier parts of the bogs. Thus the composition of column T is weighted towards the drier bog types.

It may be noted that Eddy, Welch and Rawes describe the Moor House vegetation under the name Trichophoro-Eriophoretum McV. & R. 1962 and that Birse and Robertson equate theirs with this community-type also whereas Moore (1968) has shown this lowland blanket bog type from west Scotland to be a member of the Pleurozia purpurea - Erica tetralix association, the member of the Erico-Sphagnion not encountered in the present survey.

To sum up the preceding discussion: the sub-atlantic race of the Erico-Sphagnetum magellanicum develops on a substratum of more or less level deep peat at altitudes which are usually between sea-level and 1,000 ft (305m) but which may be up to 2,200 ft (671m). Where the hummock-hollow micro-topography is strongly developed, the composition of the vegetation on the hummocks may approach that of the Vaccinio-Ericetum tetralicis. The known British distribution of the race is central and north Wales, north England and south and east-central Scotland; it is possible that further investigations will show that the race is also present on the south side of the Solway Firth and around Morcambe Bay (cf. Ratcliffe 1964).

Association Vaccinio-Ericetum tetralicis Moore 1962

The list of the components of this association is given on the facing page.

Moore has shown that in Britain there are two associations of upland blanket bog dominated by Calluna vulgaris and Eriophorum vaginatum. One is the Vaccinio-Ericetum tetralicis which is a member of the Erico-Sphagnion although with affinities to the Sphagnion fusci and the other is an un-named association composed of McVean and Ratcliffe's (1962) Scottish Calluneto-Eriophoretum and

Empetretum-Eriophoretum, belonging to the Sphagnion fusci but related to the Erico-Sphagnion. Moore's data for these two associations are shown in columns E and F respectively of Table XXXII. The additional analyses of upland blanket bog vegetation have been placed between columns E and F and referred to the Erico-Sphagnion (and therefore to the Vaccinio-Ericetum tetralicis) since, although some Sphagnion fusci differentials - notably Empetrum nigrum and Cladonia arbuscula - are present, the main bulk of these species is not well represented and those of the Erico-Sphagnion are much more frequent. Mention has already been made of the utilisation as Vaccinio-Ericetum tetralicis differentials of Rhytidiadelphus loreus, Plagiothecium undulatum, Ptilidium ciliare and Hylocomium splendens which are all present in these additional Vaccinio-Ericetum tetralicis communities but were included by Moore amongst the character species of the Scottish Sphagnion fusci vegetation. To this group of differentials may be added Vaccinium myrtillus, Juncus squarrosus and the Sphagnion fusci character Rubus chamaemorus and differential Vaccinium vitis-idaea. The last two species emphasise the connection of the association with the Sphagnion fusci and all the differentials are also present in the Scottish vegetation of this alliance (col. F).

The geographical distribution of communities of the association is broadly similar to that of the Erico-Sphagnetum magellanicum since they extend from the mountains of central Ireland, north Wales and north England to upland parts of south Scotland but reach as far north as the Isle of Skye in addition. However, the ecological conditions required by the two associations differ: the water-table of the Vaccinio-Ericetum tetralicis is the lower and this association can develop on ground sloping at up to  $15^{\circ}$  (rarely to  $25^{\circ}$ ) as well as on flat summit plateaux rather than in infilled basins as does the Erico-Sphagnetum magellanicum.

The Vaccinio-Ericetum tetralicis is more closely confined to the sub-alpine regions than is the Erico-Sphagnetum magellanicum since it lies chiefly between 1,250 and 2,500 ft (381 and 762m). The association reaches its highest limits in north Wales; 2,700 ft (823m) on the Berwyns (col. S) (the Campylopus-Diplophyllum nodum of the Juncus squarrosus - Deschampsia flexuosa series Tallis 1969), 2,650 ft (808m) on Cader Idris (col. X) (the high level series of the ...)

high-level facies of the Eriophorum vaginatum bog Edgell 1969), and 2,500 ft (762m) in the Carneddau (col. Y) (Calluna - Eriophorum vaginatum bog Ratcliffe 1959). The maximum altitude is slightly lower in the north Pennines, being 2,450 ft (747m) at Moor House (col M) (p.p. Eriophoretum high-level facies E. W. & R. 1969) and in south Scotland (col. V) (upland Calluna - Eriophorum vaginatum moor Birse and Robertson 1967) it reaches only 50 ft (15m) higher than in north England. The lowest range of the vegetation of the association is on Skye where the Calluneto - Eriophoretum McV. & R. 1962 emend. Birks 1969 occurs from 400 to 1,250 ft (122 to 381m). This is no doubt a reflection of the oceanic climate of the island; all other records came from localities above 1,000 ft (305m), the only exception being some analyses for the Calluna facies of the Calluna - Eriophorum vaginatum - Trichophorum bog in south Scotland (Birse and Robertson 1967 which occurs down to about 700 ft (213m).

No attempt has been made in this account to sub-divide the Vaccinio - Ericetum tetralicis. In the original description of the association, Moore (1962) recognises three sub-associations: a Juncus squarrosus sub-ass differentiated by Juncus squarrosus, Calypogeia trichomanes, Plagiothecium undulatum and Deschampsia flexuosa; a typical sub-ass.; and a Narthecium sub-ass. with the differentials Narthecium ossifragum, Cladonia uncialis, C. arbuscula, Rhacomitrium lanuginosum and Andromeda polifolia. These distinctions, however, are not maintained in the analyses from the Berwyns, Widdybank Fell, Moor House or Skye.

The existence of vegetation transitional between this association and the Erico - Sphagnetum magellanicum is seen from Table XXXII especially in the low-level facies of the Eriophorum vaginatum bog on Cader Idris (col. W) (Edgell 1969) and the Scottish Calluna facies of the Calluna - Eriophorum vaginatum - Trichophorum bog. Both these communities are described by their authors as being transitional to others now placed in the Erico - Sphagnetum magellanicum.

The use, by subsequent workers (Ratcliffe 1966 on Widdybank Fell, Birks 1969, Eddy, Welch and Rawes 1969) of McVean and Ratcliffe's (1962) term Calluneto-Eriophoretum for vegetation now placed in the Vaccinio-Ericetum tetralicis reflects the affinity to the Sphagnion fusci of some communities of this association. In Table XXXII an attempt is made by the arrangement of the components of the Vaccinio-Ericetum tetralicis to show those closest to the Sphagnion fusci; there is an increase from left to right (especially from col. R to col. M) in the number and frequency of the character and differential species of this alliance. A division of the association may possibly be made between columns Z and R where the Sphagnion fusci character Rubus chamaemorus and differential Vaccinium vitis-idaea come in. To the left, the vegetation encompasses the whole altitudinal range of the association and is chiefly from the more atlantic regions of Wales (Cader Idris and the Carneddau) and Skye although including those southern Scottish communities which are atypical of the association and transitional to the Erico-Sphagnetum magellanicum (col. U) whilst on the right of this division all the analyses are from over 1,050 ft (320m) and from less oceanic and/or more northerly places - the Berwyns, Widdybank Fell, Moor House and south-east Scotland.

The synsystematic placing of the  $\infty$  Nodal group with Calluna and Eriophorum vaginatum

Table I

The group of character species of Oxycocco-Sphagnetum, Sphagnetalia magellanicum and Erico-Sphagnion is concentrated as a whole within the  $\infty$  Nodal group with Calluna and Eriophorum vaginatum, although individual species occur in other noda, notably in mapping units 27 and 29 of the Violion caninae. The character species are almost equally well represented in both mapping units 24 and 28 and, also plentiful, especially in the Nodum with Narthecium and Trichophorum (m.u. 24), are character species of the Ericion tetralicis. This, however, is a common feature of Erico-Sphagnion communities (cf. the foregoing and Moore (1968) Table I).

To the group of Erico-Sphagnion characters shown in Table I for mapping unit 24 must be added Sphagnum imbricatum. The following fragmentary Aufnahme was made on a .4 sq m Sphagnum imbricatum hummock which is representative of those on the Red/Tinkler's Sike bogs.

Sphagnum imbricatum	9.5	(E.S.)
Eriophorum vaginatum	5.2	) (S.)
Sphagnum rubellum	4.1	
Erica tetralix	4.1	
Trichophorum cespitosum ssp. germanicum		+
Calluna vulgaris	6.1	
Cladonia impexa	4.2	

E.S. = Erico-Sphagnion character  
S. = Sphagnetalia character

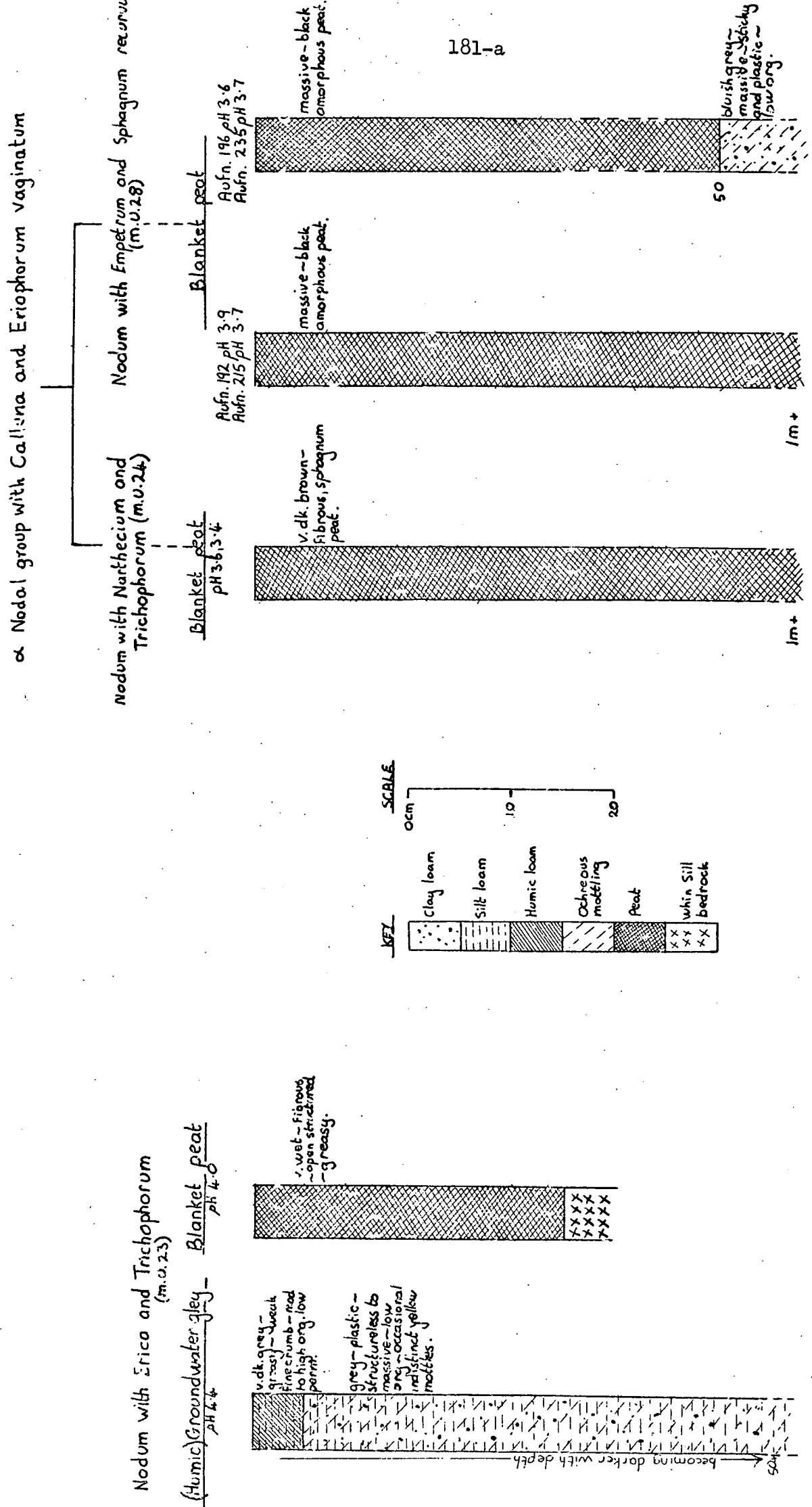
The Modum with Empetrum and Sphagnum recurvum has affinities to the Sphagnion fusci and also to the Violion caninae of the Nardo-Callunetea. The connection with the Sphagnion fusci of many members of the Vaccinio-Ericetum tetralicis, especially those in the north of England, has already been described. The presence in mapping unit 28 of the Sphagnion fusci character Rubus chamaemorus and differentials Empetrum nigrum, Vaccinium vitis-idaea, Cladonia arbuscula and C. squamosa is apparent from Table XXXII. In addition, the character Sphagnum fuscum and differential Betula nana are both present on the Fell in vegetation of this mapping unit; the former occurs on the flat surface of the bogs of mapping unit 24 as isolated hummocks associated with which are species of mapping unit 28 while the latter is found in a single locality which is its only English site. The following two Aufnahmen illustrate the composition of the associated vegetation but were too fragmentary to be included in Table XXXI: Number 247 is from a Sphagnum fuscum hummock of 1 sq m and No. 255 from the Betula nana site.

No. 247		No. 255	
Sphagnum fuscum	10.5	(F.)	
Cladonia arbuscula	4.3	) (F <sup>M</sup> )	{ Betula nana 4.2
Empetrum nigrum	8.3		
Odontoschisma sphagni	+	(E.S.)	
Vaccinium oxycoccus	4.1	) (S.)	Eriophorum vaginatum 7.2
Eriophorum vaginatum	4.2		
Calluna vulgaris	7.3		Calluna vulgaris 8.3
			Erica tetralix 4.1
			Cladonia impexa 4.2
			Hypnum ericetorum +

F<sub>1</sub> = Sphagnion fusci character  
F<sup>M</sup> = Sphagnion fusci differential  
E.S. = Erico-Sphagnion character  
S. = Sphagnetalia character

FIG XII DIAGRAMMATIC SOIL PROFILES OF THE NODUM WITH ERICA AND TRICHOPOPHORUM

AND OF THE α NODAL GROUP WITH CALLUNA AND ERIOPHORUM VAGINATUM



181-a

50

1m+

1m+

Mapping unit 28 is somewhat floristically and physiognomically close to nos. 27 and 29 of the Violion caninae (cf. Table XXXIV) and communities transitional between mapping units 28 and 27/29 occur on the Fell often where there are oligo-trophic seepage zones through the blanket peat covering. However, Nardetalia/Violion caninae character species occur only sparingly in mapping unit 28; those present are Nardus stricta, Polygala serpyllifolia and Galium saxatile, the last two having only single records in the Aufnahmen of Table XXXI. Calluna vulgaris, a Nardo-Callunetea character, is conspicuous in both Erico-Sphagnion mapping units but it is a notably widespread companion of Oxycocco-Sphagnetea communities (Moore (1968) Table I). Similarly, the presence in mapping unit 28 of Hypnum ericetorum and Empetrum nigrum which are Calluno-Ulicetalia and Empetrion nigri characters respectively does not affect the classificatory position of this nodum since these species are also Erico-Sphagnion (Hypnum) and Sphagnion fusci (Empetrum) differentials (see above).

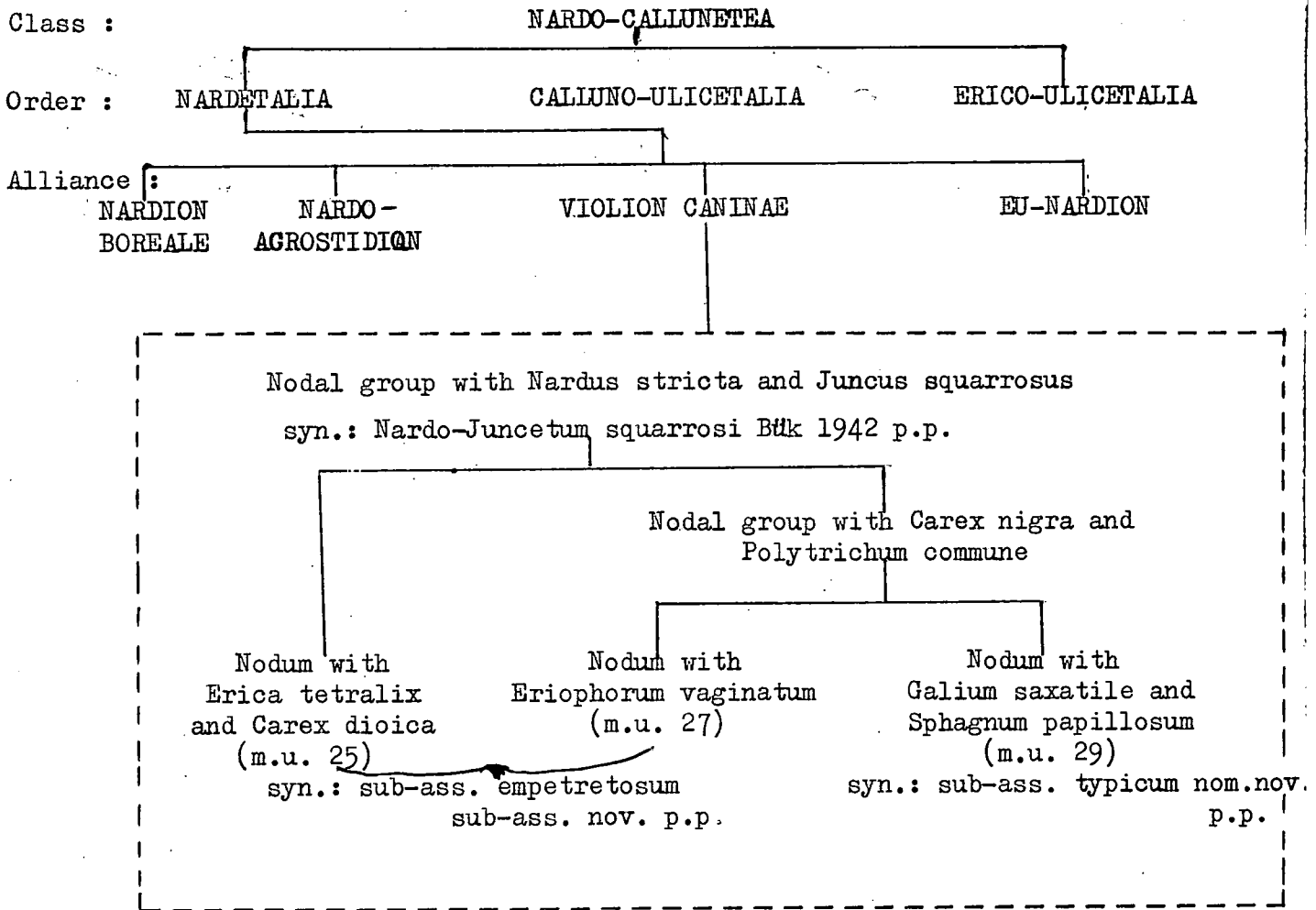
The soils of the nodum with Erica and Trichophorum and of the  
∞ nodal group with Calluna and Eriophorum vaginatum

Table XXXIII and Fig. XII

Although only two profiles have been obtained, the most usual substrata of the Nodum with Erica and Trichophorum (m.u. 23) are thought, from field experience, to be the shallow blanket peats of profile 2). Their depths are in marked contrast to those of the peats underlying mapping units 24 and 28 most of which are over 1 metre. This difference in peat depth between Ericion and Erico-Sphagnion communities is one of the features which aid in distinguishing the alliances (cf. Moore 1968). The peats of the ∞ nodal group are slightly lower in pH and are richer in organic matter than those of mapping unit 23 (all three noda, excluding profile 23/1, have higher values of loss on ignition than any others on the Fell); it is possible that this is correlated with the development of the nodum with Erica and Trichophorum on sloping ground which permits slight aeration and oxidation of the peat and also some nutrient enrichment.

SYNOPTIC CLASSIFICATION OF PARTS OF THE NARDO-CALLUNETEA  
WITH PARTICULAR REFERENCE TO THE VIOLION CANINAE COMMUNITIES OF

WIDDYBANK FELL



Key



Vegetation present  
on Widdybank Fell.

Class : NARDO-CALLUNETEA Preising 1949

The status and inter-relationships of those parts of this class to which reference is made in the following account are shown on the facing page and immediately prior to the section dealing with the Calluno-Ulicetalia.

The class is composed of the communities of poor rough grassland and of heaths. Both types are usually anthropogenic replacements of evergreen and/or deciduous forests (classes Vaccinio-Piceatea/Quercetea robori-petraeae and Quercu-Fagetea respectively) and are maintained by various agricultural practices, i.e. burning, mowing, trampling and light grazing. The communities occur as the primary vegetation only in extreme habitats such as sand-dunes, rocky places and at the upper extremity of the sub-alpine zone. The nutrient-poor mineral soil is somewhat acid, varies from damp to moderately dry and may be strongly podsolised. The class is chiefly found under conditions of cool summers and high precipitation in the atlantic, sub-atlantic and sub-continental parts of the euro-siberian region from the lowlands to the mountains and sometimes reaching to the beginning of the alpine zone. In an impoverished form it reaches more continental parts and is also in the high mountains of the mediterranean region - Spain, Corsica and north Africa (Oberdorfer 1957, Westhoff and den Held 1969).

Syntaxonomy

The west European Calluna and Genista heaths were first described as a distinct unit with the formation of the Calluno-Ulicetalia (Quantin 1935) R. Tx. 1937 and for some years the communities of rough grasslands were also included. In 1943 Braun-Blanquet and Tüxen raised the order to the rank of class, the Calluno-Ulicetea (Westhoff and den Held 1969) but the Calluno-Ulicetalia was later re-established and placed within either the Querceto-Ulicetea Br.-Bl. 1947 (Lebrun et al 1949) or the Betulo-Pinetea Knapp 1942. Both these classes also included woodland vegetation and emphasised the seral relationships mentioned above. Nevertheless, the subsequent removal from the Calluno-Ulicetalia of the rough grasslands comprising the Nardetalia Preising 1949 and the formation of the Nardo-Callunetea from these two orders has been much more generally accepted.

Character species

Westhoff and den Held list the following :

Sieglingia decumbens	Cuscuta epithymum
Carex pilulifera	Calluna vulgaris
Potentilla erecta	

and Oberdorfer (1957) adds:

Veronica officinalis	Hieracium pilosella
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Veronica is not an absolute Nardo-Callunetea character since it also acts as such for the Arrhenatheretalia. The above list has to be reduced for British vegetation as both Sieglingia and Potentilla occur here on somewhat base-rich soils which do not support communities of the class as well as on soils which do. This is exemplified by the analyses from Widdybank Fell where Potentilla is abundant in many nodes of the Seslerio-Mesobromion, Caricion davallianae and Caricion curto-nigrae in addition to the Nardo-Callunetea. Similarly, Sieglingia occurs throughout the Seslerio-Mesobromion and is absent altogether from the Nardo-Callunetea.

Calluna, a transgressive character as it is also valid for the Calluno-Ulicetalia (Oberdorfer 1957), and Carex pilulifera are both present on acid soils throughout most parts of the British Isles and are scarce only in the east. Calluna's habitats include bogs and woods in addition to heaths (as is true for Europe as a whole) but Carex pilulifera is much more closely confined to rough upland grassland and heaths (Jermy and Tutin 1968). Veronica and Hieracium are also found throughout much of the British Isles in grasslands and heaths although the latter can occur on rocks and walls also. Cuscuta, encountered chiefly in southern England, is parasitic on plants of Calluna and Ulex (Perring and Walters 1962, Clapham, Tutin and Warburg 1962).

In the light of the above comments, those species which seem suitable as class characters in Britain as a whole are:

Calluna vulgaris (transgr.)	Veronica officinalis (?)
Carex pilulifera	Hieracium pilosella
Cuscuta epithymum	

Only Calluna, Carex pilulifera, Hieracium and Veronica are present on Widdybank Fell; the first is in all Nardo-Callunetea nodes (although also in those of other classes, particularly the Oxycocco-Sphagnetes) and Carex pilulifera is a component of most

Calluno-Ulicetalia noda. Of the other two species, Hieracium has a single record in a nodum of this class but otherwise both are found elsewhere. Hieracium is present in mapping unit 21 (Ranunculo-Anthoxanthion) and in most Seslerio-Mesobromion noda, especially nos. 4 and 5, whilst Veronica is also in mapping units 21 and 5 (and in the community fragment with Saxifraga aizoides and Cratoneuron commutatum of the Cratoneurion). Since Veronica is also a character of the order (Arrhenatheretalia) to which mapping unit 21 belongs and from which mapping unit 5 shows other influences, it appears that on Widdybank Fell it is acting as an Arrhenatheretalia rather than a Nardo-Callunetea character. However, by contrast, both mapping units 5 and 21 contain other species which indicate some Nardo-Callunetea affinity and therefore Hieracium is retained as a character of this class although a doubtful one.

The orders comprising the class are the Nardetalia and various others, the number of which is still under debate, for heath vegetation. The classification used here is that of Rivas-Martinez<sup>4</sup> in which the Calluno-Ulicetalia and Erico-Ulicetalia Br.-Bl., Pinto da Silva and Rozeira 1964 encompass the heaths of north-west and central Europe and of south-west Europe, respectively. In addition, both Passarge (1964) and Westhoff and den Held (1969) mention that two other orders are present in the mountains of the mediterranean regions. Both the Nardetalia and the Calluno-Ulicetalia are represented throughout the British Isles including Widdybank Fell.

Order : NARDETALIA (Oberd. 1949) Preising 1949

This order of rough grasslands, found chiefly in nordic-sub-atlantic Europe and in the central European mountains, is absent from the mediterranean region.

#### Character species

Westhoff and den Held do not distinguish between order and alliance characters since only one alliance is present in the Netherlands. This differentiation is made by Oberdorfer (1957) but his list includes several species which are absent from Britain and two others which are present here in communities of calcareous

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<sup>4</sup> The classification is as yet unpublished and is quoted in Bridgewater (1970).

soils and not in the acid ones characteristic of the Nardetalia. His remaining four species (given also by Westhoff and den Held) appear to be the most suitable for use in Britain. They are:

<u>Nardus stricta</u>	<u>Antennaria dioica</u>
<u>Gentianella campestris</u>	<u>Botrychium lunaria</u> (transgressive)

Nardus and Gentianella are species of neutral to acid grassland and of pastures and dunes respectively; Nardus is found over much of Britain and is only absent from the chalk and limestone outcrops of the south and east whilst Gentianella occurs principally in the north and west as do Botrychium and Antennaria. However, the value of the last two species as characters needs further investigation since on Widdybank Fell both are found in communities of the Seslerio-Mesobromion. Although Botrychium occurs in mapping units 5 and 4 (on the most acidic soils, mean pH 5.7, of the  $\infty$  nodal group) it is also present in Calluna/Nardus and Agrostis/Festuca dominated vegetation<sup>#</sup> referable to the Nardo-Callunetea, whereas Antennaria is in all mapping units of the Seslerio-Mesobromion (cf. Table III) and appears to be confined to it. The Widdybank distribution of the latter species seems to be in accordance with Clapham, Tutin and Warburg's (1962) observation that Antennaria is usually found "over base-rich rock where the surface soil is rather leached" since where separate pH determinations were made of different horizons a lower value was obtained for the upper horizon (cf. Fig. II and Table VI). In more general terms, both Botrychium and Antennaria are said to occur in dry grasslands and the latter in heaths also (Clapham, Tutin and Warburg 1962), habitats at least partially suitable for the order.

Nardus is the only other character found on Widdybank; it is abundant in the noda of this order but is also present in four noda (mapping units 15 to 18) within the Caricion-curto-nigrae and in one (mapping unit 12) of the Caricion davallianae.

Coeloglossum viride and Alchemilla glaucescens are Nardetalia characters in Europe but are also present in acid Mesobromion communities (Oberdorfer 1962); in Britain both are near the edge

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# Bradshaw (1972) : personal communication

of their range and are only found in limestone grassland. It may be noted that Coeloglossum has been found once on Widdybank Fell in mapping unit 4 of the Seslerio-Mesobromion<sup>#</sup>. Non-British Nardetalia characters (Oberdorfer 1957) are:

Dianthus seguieri	Arnica montana
Thesium pyrenaicum	Hieracium gothicum
Alchemilla fallax	H. lactucella
Euphrasia stricta var. subalpina	

Two order differentials named by Oberdorfer are Hypericum maculatum and Carex pallescens. Both are British and occur in damp woods and damp grassy places throughout much of the British Isles.

Four alliances are currently recognised within the order by Westhoff and den Held (1969) although others have been suggested in different classificatory schemes (e.g. Doing 1963, Passarge 1964). These alliances and their distribution patterns are:

Violion caninae	- sub-atlantic
Nardion Br.-Bl. 1926 em. Preising 1949	- upper montane - sub-alpine
(syn.: Nardo-Trifolion alpini Preising 1949)	
Nardion boreale Preising 1949	- northern
Nardo-Agrostidion Sill 1933	- continental

The Nardion, of acid soils, extends into the sub-alpine zone as far as the dwarf-shrub limit. The alliance has occasionally (Ellenberg 1963, Braun-Blanquet 1964) been placed in the Caricetalia curvulae of the Caricetea curvulae, the class which comprises the communities of dry grasslands above the tree line in the alpine/sub-alpine regions. Although not in agreement with this, Oberdorfer (1957) mentions the occurrence below 8,200 ft (2,500m) in the central Alps of transitions between the Nardion and the Caricion curvulae at the beginning of the dwarf-shrub zone. The corresponding zone between the Nardion and the Violion caninae is about 3,280 ft (1,000m) in southern Germany (Oberdorfer 1957) and 4,920 ft (1,500m) in the Fribourg Alps, western Switzerland (Berset 1969).

Although included by Shimwell (1971 c) in his conspectus of the higher vegetation units of the British Isles, it seems doubtful that the Nardion is represented here. Only four of the fifteen possible alliance characters (Oberdorfer 1957) are present and Lycopodium

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<sup>#</sup> Bradshaw (1972) : personal communication

alpinum alone occurs in suitable habitats -moors and mountain grasslands - and reaches sufficient altitudes of up to 4,000 ft (1,220m).<sup>#</sup> Of the other characters, Gnaphalium norvegicum and Ajuga pyramidalis, occurring up to 3,600 ft (1,097m) and 1,750 ft (533m), are members of the flora of rock crevices, and although Leucorchis albida is found in "upland pastures" including some in Upper Teesdale close by and below Widdybank Fell<sup>x</sup>, its range does not exceed 2,000 ft (610m) (Clapham, Tutin and Warburg 1962).

The most widespread, if not the sole, alliance of the order in Britain is the

All.: Violion caninae Schwick (1941) 1944 em. Preising 1949

These herb-rich rough grasslands develop on acidic loams and, sometimes, clays - soils which are rather more nutrient-rich than those of the heath communities of the class. The vegetation is maintained in its secondary state by trampling, grazing and mowing. The alliance occurs at altitudes from the lowland plains to the sub-montane/montane zone and is best developed and most species-rich in the hilly regions of sub-oceanic western Europe, i.e. north-west France, Belgium, the Netherlands, Denmark and western and central Germany. In eastern Germany and north-west Czechoslovakia it is somewhat species-poor and under the "summer warm" conditions of southern central Europe and southern Europe it forms communities which are transitional to the Nardion (cf. above).

#### Synonymy and Syntaxonomy

The alliance has often been known under the name Nardo-Galion saxatilis Preising 1949, e.g. in Lohmeyer et al (1962), but in recent years the older term erected by Schwickerath has come to take precedence although Oberdorfer et al (1967) prefer to use the compromise Violo-Nardion.

Oberdorfer (1957) separated out from the Nardo-Galion the sub-alliance Juncion squarrosi for damp communities differentiated by Juncus squarrosus and Pedicularis sylvatica. This differentiation was carried even further by Passarge (1964) who did not retain the Nardo-Galion but erected two separate alliances: the Violion caninae Schwick. 1944 (thereby returning to Schwickerath's original

<sup>#</sup> Ratcliffe (1966) records its presence in heath on Widdybank Fell.  
<sup>x</sup> Bradshaw (1972) : personal communication.

conception) and the Nardo-Juncion squarrosi Oberd. 1957.

Under this scheme the former alliance was retained within the Nardetalia but the latter became part of a new order, the Juncetalia squarrosi, encompassing Nardo-Callunetea communities in damp to wet conditions, dominated by Juncus and Trichophorum, and short-sedge swamps adjacent to heaths chiefly in the boreal-montane and atlantic-sub-atlantic regions. The alliances of this order were the Trichophorion cespitosi Oberd. 1957 (previously mentioned in the discussion of the syntaxonomy of the Ericion tetralicis), the Ericion tetralicis itself and the Nardo-Juncion squarrosi. The latter comprised "trampled pastures and poor grasslands on damp, humic, poor soil in depressions and at bog edges". Although neither the Juncetalia, Nardo-Juncion squarrosi nor, eventually, the Trichophorion have been retained, they served to bring out vegetation in northern Germany transitional between the Nardetalia and the Ericetalia and, if still in use, might have proved meaningful for Britain. Similar transitional vegetation was found on Widdybank Fell and included in the Violion caninae; the alliance (as such) has been little studied in Britain to date.

#### Character species

As with the Nardetalia characters given by continental workers (Oberdorfer 1957, Westhoff and den Held 1969), some of those used for the Violion caninae are non-British and others are only present here on calcareous soils. The following species appear to be valid for use here:

Meum athamanticum	Galium saxatile
Polygala vulgaris	Centaurea nigra
P. serpyllifolia	Juncus squarrosus
Viola canina ssp. canina	Pedicularis sylvatica
Euphrasia nemorosa	Dactylorhiza maculata ssp.
E. borealis	ericetorum
Luzula multiflora	Gentiana pneumonanthe
	Carex ovalis

The status of the orchid is rather uncertain: Westhoff and den Held cite Orchis (syn.: Dactylorhiza) maculata ssp. elodes (Griseb) Camus var. ericetorum (Linton) as the alliance character (and var. elodes as an Oxycocco-Sphagnetea character) whereas the corresponding taxon in Clapham, Tutin and Warburg (1962) appears to be Dactylorhiza maculata (L.) Vermeul. ssp. ericetorum (E.F. Linton) Vermeul.

Most of these are very widely distributed although many are absent from the chalk and limestone outcrops of the south and east (cf. the Nardetalia character Nardus stricta). Three species of more restricted occurrence are : Meum, predominantly found in upland central and south-west Scotland and occasionally in north England and north Wales; Gentiana, present near York<sup>\*</sup> but principally confined to the southern half of England; and Viola canina ssp. canina which has an upper altitudinal limit of 1,400 ft (1,427m) (Perring and Walters 1962). The ecological descriptions in the literature (Clapham, Tutin and Warburg 1962) and field observations show that the members of the above list are most commonly found in heaths and grasslands and occasionally in dunes and pastures also. Pedicularis and Juncus (both differentials of the Juncion squarrosi - see above) together with Dactylorhiza and Gentiana are present in the damper communities of the alliance. For this reason, Westhoff and den Held describe Pedicularis and Gentiana as "transgressive" characters i.e. more strongly present in one part of the alliance. The two species of Euphrasia are of more restricted occurrence than the main group of character species. Both are found in rough pastures but E. borealis is widespread in Scotland becoming rarer further south whereas E. nemoralis is common in England and Wales but less so in Scotland and Ireland.

Only a few of the character species are present on Widdybank Fell: Juncus squarrosus, Galium saxatile, Polygala serpyllifolia and Luzula multiflora are all found, but not exclusively, in Violion caninae vegetation although the last has not been recorded in the Aufnahmen, probably because of confusion with Luzula campestris. Galium saxatile is prominent in all three nodes. Pedicularis sylvatica occurs immediately south-east of the Fell, in Widdybank Pastures.

Those continental character and differential<sup>†</sup> species which are invalid for Britain since they occur in base-rich habitats are: Galium pumilum var. glabrum, Thymus pulegioides<sup>†</sup>, Platanthera bifolia var. bifolia, Pimpinella saxifraga<sup>†</sup> (Neither variety is

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\* Bradshaw (1972) : personal communication.

Class : NARDO - CALLUNETEA  
 Order : NARDEETALIA  
 Alliance: VIOLION CANINAE

∞ Nodal group with Nardus stricta and Juncus squarrosus

a) Field key to communities on Widdybank Fell

∞ Nodal group	Nardus stricta, Juncus squarrosus, Eriophorum angustifolium, Calluna vulgaris, Agrostis canina, Hypnum ericetorum, Carex echinata, Molinia caerulea, Pleurozium schreberi, Juncus effusus.		
β Nodal group		Carex nigra, Polytrichum commune, Aulacomnium palustre, Sphagnum recurvum, Calypogeia trichomanes, Lophocolea bidentata, Acrocladium stramineum.	
Noda	Carex dioica, C. demissa, C. hostiana, C. pulicaris, Erica tetralix, Polygala serpyllifolia, Narthecium ossifragum, Hylocomium splendens, Trichophorum cespitosum <sup>x</sup> , Selaginella selaginoides, Rhacomitrium lanuginosum, Diplophyllum albicans, Cladonia arbuscula, C. furcata, Thuidium tamariscinum, Juncus ? bulbosus, Succisa pratensis, Thalictrum alpinum.	Eriophorum vaginatum  Deschampsia flexuosa	Galium saxatile, Rhytidiadelphus squarrosus, Plagiothecium undulatum, Sphagnum papillosum, Luzula ? campestris, Anthoxanthum odoratum
Mapping units	25	27	29

b) Classification of ∞ Nodal group and Noda

Nardo - Juncetum squarrosi Buk 1942 p.p. syn.: ∞ Nodal group with Nardus and Juncus squarrosus			
Sub-ass. empetretosum syn.: Nodum with Erica and Carex dioica	AND	sub-ass. nov p.p. Nodum with Eriophorum vaginatum	
Sub-ass. galietosum saxatilis sub-ass. nov. p.p. syn.: Nodum with Galium saxatile and Sphagnum papillosum			
Mapping units	25	27	29

x ssp. germanicum

recognised here; the ecological details (Clapham, Tutin and Warburg 1962) refer to the species). Non-British characters given by Oberdorfer (1957) are Genista sagittalis and Jasione perennis.

Two of Oberdorfer's alliance differentials - Narcissus pseudo-narcissus and Lathyrus montanus - may be applicable for Britain. They are present in damp woods and grasslands in England, particularly in the south and west, and in woods and hedgerows throughout Britain except eastern England, respectively. Festuca tenuifolia, the other differential, is regarded as a sub-species of F. ovina and is not always distinguished from it. Only Lathyrus has been recorded from Widdybank although not in vegetation of the Violion caninae but in communities of the Empetrion and in mapping units 3 and 4 of the Seslerio-Mesobromion.

Three noda have been recognised within this alliance. Together they form the

∞ Nodal group with Nardus stricta and Juncus squarrosus (Mapping units 25, 27, 29)  
Tables XXXIV and XXXV and Fig. XIIIa)

The ∞ nodal group comprises some of the dampest communities which it is possible to include within the alliance. The key card used in the field is given in Fig. XIIIa).

Several members of the differential species group - Calluna vulgaris, Nardus stricta and Juncus squarrosus, characters of class, order and alliance respectively, - are amongst the species prominent in all noda as are Eriophorum angustifolium, Carex echinata and Molinia caerulea. The other differentials are Agrostis canina, Hypnum ericetorum, Pleurozium schreberi and Juncus effusus. Some of these also figure in the differential species group of the ∞ nodal group with Calluna and Cladonia arbuscula but the species associated with them illustrate the differences between the two ∞ nodal groups (see Table XXXV where the constancies of all differentials of both ∞ nodal groups and their noda are compared). Potentilla erecta and Festuca ovina are the only constant/near constant companions.

Total cover is usually complete, the 50-75% Cryptogam cover which almost equals that of the Phanerogams, playing an important rôle in this. The communities of the nodal group usually develop on more or less flat peaty or gleyed soils and are often subject to irrigation

although some representatives of the nodum with Erica tetralix and Carex dioica are raised above the water flow.

The  $\alpha$  nodal group divides clearly into the nodum with Erica tetralix and Carex dioica and the  $\beta$  nodal group with Carex nigra and Polytrichum commune; each develops in response to different environmental constraints.

Nodum with Erica tetralix and Carex dioica (Mapping unit 25)

Polygala serpyllifolia, alone of the many differential species, is a character for one of the higher classificatory units - the Nardo - Callunetæa - into which the nodum has been placed. Other members of the group are more commonly found in and are characteristic of either the Oxycocco Sphagnetæa (Erica tetralix, Narthecium ossifragum, Trichophorum cespitosum ssp. germanicum) or the Parvocaricetæa especially the Caricion davallianae (Carex demissa, C. dioica, C. hostiana) cf. Table I. The other differentials are Hylocomium splendens, Carex pulicaris, Selaginella selaginoides, Rhacomitrium lanuginosum, Diplophyllum albicans, Cladonia arbuscula, C. furcata, Thuidium tamariscinum, Juncus bulbosus (since this is a species of gravelly flushes, the records may refer to J. kochii more often than is indicated), Succisa pratensis and Thalictrum alpinum. The nodum is further distinguished from the other Violion caninae communities by the presence at low constancies of another group of species which are more or less confined <sup>here</sup> within the  $\alpha$  nodal group. These species, some again representative of a number of different vegetation types, are: Sphagnum subsecundum var. auriculatum, Acrocladium cuspidatum, Taraxacum officinale s.l., Riccardia pinguis, Campyllum stellatum, Ctenidium molluscum, Prunella vulgaris, Sphagnum plumulosum, Breutelia chrysocoma, Euphrasia officinalis and Sieglingia decumbens. Others, e.g. Kobresia, Tofieldia, occur with very low constancies. The only constant companion is Carex panicea.

The physiognomy of the communities is very variable; the dwarf shrubs Calluna and Erica (10 to 20 cm high) are much in evidence but may either be much interspersed throughout the other species or quite densely clumped together. Also prominent are Nardus, Molinia, Trichophorum, Narthecium, Carex hostiana, C. pulicaris, C. dioica and, occasionally, Juncus effusus, Tofieldia, Kobresia and Primula farinosa. Phanerogam cover is only about 80%; Rhacomitrium lanuginosum, Cladonia arbuscula and C. furcata are the most frequent

members of the Cryptogam flora whose cover is around 60%; total cover is just under 100%. The mean species number of 30 is the highest for any nodum in the class and illustrates the variety of micro habitats available for species of different ecological tolerances within communities of the nodum.

Mapping unit 25 forms part of the calcareous flush complexes which are barely perceptibly sloping. Although slightly raised above the percolating water, the nodum is clearly under its influence since the pH values and calcium contents of its soils are much higher than for any other member of the *Caricion davallianae* nodal group. Patches of the nodum occur in, and often bordering, the flushed expanses at the head of Fold Sike, the flushes associated with Red Sike on both sides of the Birkdale Track and those along Sand Sike. The adjacent nodum on the non-flush terrain is often either the calcareous heath, mapping unit 4, or the damp acidic heath of mapping unit 26, whilst the flush nodum are usually mapping units 9, 12 or 8 of the *Caricion davallianae*. The nodum with *Erica* and *Carex dioica* sometimes forms part of a small-scale hummock/hollow complex with mapping unit 9 (occasionally with mapping unit 12) when mapping unit 25 colonises the hummocks; in a similar complex near Widdybank Farm the flushed unit is mapping unit 11. Occasionally this topographic differentiation is less pronounced (under 10 cm) and both elements are colonised by mapping unit 25 with an increase in the proportion of calcicoles in the hollows. It is interesting to note that a comparable situation where quantitative, not qualitative, floristic differentiation is associated with hummocks and hollows has been observed with mapping unit 8 of the *Caricion davallianae* (see above).

The most closely related mapping units of other alliances are two members of the *Caricion davallianae*. These have the normal species complement for the alliance but mapping unit 11 includes amongst its differentials *Trichophorum*, *Erica* and *Warthecium*, whilst mapping unit 12 has *Nardus* and *Carex demissa*. Table XVIII shows the full details. In contrast, however, mapping unit 25 lacks many *Caricion davallianae* species and has all the differentials of mapping units 11 and 12 listed above together with abundant *Calluna vulgaris* and several *Sphagnum* species. This floristic affinity is paralleled - especially between mapping units 25 and 12 - by affinities of soil type and composition (see below).

B Nodal group with Carex nigra and Polytrichum commune  
(Mapping units 27 and 29)

The composition of the differential species group - Carex nigra, Polytrichum commune, Aulacomnium palustre, Sphagnum recurvum, Calypogeia trichomanes, Lophocolea bidentata and Acrocladium stramineum - exemplifies the somewhat oligo-trophic soligenous habitats in which the nodal group occurs. Although there are definite species differences between them, its constituent nodes are physiognomically very similar. They are usually dominated by clumps of Nardus and Juncus squarrosus with scattered Juncus effusus shoots whilst between them there is a carpet of Sphagnum recurvum, Polytrichum commune and Atrichum undulatum giving 100% cover. Viola palustris, which is under-recorded in the Aufnahmen, is occasionally scattered in communities of each nodum and contributes to the difficulty sometimes encountered of distinguishing them from mapping unit 17 of the Caricion curto-nigrae. The differentials of this other nodum include, in addition to Viola palustris, Polytrichum commune and Acrocladium stramineum; Sphagnum recurvum and Aulacomnium palustre are locally common. Another differential, Galium saxatile, is also a differential for mapping unit 29 (see below).

Nodum with Eriophorum vaginatum (Mapping unit 27)

The differentials of the nodum are Eriophorum vaginatum and Deschampsia flexuosa. The first plays an important part in the structure of the communities as do Calluna vulgaris, Carex nigra and those species mentioned above for the B nodal group. The shoots of Juncus effusus may reach 60 cm whilst the Calluna bushes, only about 5 cm tall, are rather dwarfed; the other Phanerogams are usually 20 to 30 cm in height. The nodum is physiognomically somewhat intermediate between mapping units 29 and 28 and this is paralleled by their spatial proximity (see below). Phanerogam cover is fairly generally near to 75% but the Cryptogam ranges between 20% and 80%, the mean being 60%. The mean species number of 18 is the lowest of the L nodal group.

Mapping unit 27 often forms a transition zone between nos. 28 (Oxyocco-Sphagnetea) and 29. An example may be seen on the north side of the Fold Sike flushes where the nodum with Eriophorum

vaginatum occurs on flat ground adjacent to the large expanse of blanket bog (mapping unit 28) and is replaced by mapping unit 29 where the slope becomes greater. In general, mapping unit 27 is found in sites with a higher water table than is mapping unit 29. Several dozen square metres of the former occurred below the access road near both Slapestone Sike and Middle Flush and also on the north side of the Red Sike flush to the west of the Birkdale Track. Nodum with Galium saxatile and Sphagnum papillosum (Mapping unit 29)

Various members of the differential species group of Galium saxatile, Rhytidiadelphus squarrosus, Plagiothecium undulatum, Sphagnum papillosum, Luzula ? campestris and Anthoxanthum odoratum, together with the other species mentioned above in reference to the  $\beta$  nodal group, are prominent between the rosettes and shoots of Juncus squarrosus, J. effusus and Nardus stricta. The  $\alpha$  nodal group differentials Molinia caerulea and the companions Trichophorum, Festuca ovina and Carex panicea may also be conspicuous. Species of low constancy but more or less confined to this mapping unit are Sphagnum capillaceum, Barbilophozia floerkei, Mnium hornum and Equisetum palustre. The vegetation is slightly taller than the previous nodum described: Juncus effusus is between 40 and 70 cm, Calluna reaches 15 cm and the other Phanerogams range from 20 to 40 cm. Phanerogams cover, at 75%, is the same as in the other nodum but the Cryptogam varies between 20 and 100% with a mean of 70%. The mean species number is 23.

The most common topographical location for this mapping unit is as part of the sloping rim around the edge of a hummock or large expanse of the nodum with Empetrum and Sphagnum recurvum (mapping unit 28) where the peaty substrate has become much shallower. Around the main blanket bog covering of the Fell, this juxtaposition principally occurs on the eastern side where areas of the nodum, each rather less than a hundred square metres in extent, separate the blanket bog from the dry heath communities (mapping unit 31) of the Empetrium. On the north bank of Sand Sike several hundred square metres of mapping unit 29 are followed, lower down the slope, by mapping unit 18 of the Caricion curto-nigrae; a similar juxtaposition of mapping units, although on less steeply sloping ground, occurred on the north-west part of the Fell associated with Slapestone Sike and with Middle Flush. Also in

the latter region, mapping unit 29 (and occasionally 27) had colonised a wide trackway running through the blanket bog just above the Tees. The association of the nodum with places of water movement is further shown by two other situations in which it is found: together with mapping units 26 and 31 between the Seslerio-Mesobromion vegetation of the Fell top and the slightly lower-lying blanket bog adjacent to it, and in the sink holes in the blanket peat itself where mapping unit 29 forms a rim around the communities, usually mapping units 21 or 22 of the Ranunculo-Anthoxanthion, on the exposed limestone.

It can be deduced from Table XXXIV and from details given above that the nodum with Galium saxatile and Sphagnum papillosum cannot always be clearly differentiated from the nodum with Eriophorum vaginatum; the occasional floristic proximity of both noda, especially the latter, to mapping unit 17 (Caricion curtonigrae) has already been noted. Under somewhat drier conditions, around some of the blanket bog hummocks on drift amidst the Seslerio-Mesobromion grassland, patches of Carex binervis are present within mapping unit 29. This is a companion species of the adjacent mapping unit 31 and has presumably invaded from there. Conversely, occasional Juncus squarrosus rosettes occur in this Empetrion nodum.

The syntaxonomy and classification of the nodal group  
Table XXXVI and Fig. XIII b)

Descriptions of various rough grassland types, both dry and wet, can be found in the vegetation accounts from each of several parts of the British Isles; only a few such units are directly relevant to the present discussion. These are the communities which are directly referable to the Nardo-Juncetum squarrosi Btk 1942. Two sets of floristic analyses of this association were available to the author - those by Duvigneaud (1949) and by Oberdorfer (1957). Since the former come from parts of Europe which are geographically closer to Britain than the latter and its floristic composition is more akin to that of the British vegetation, it alone is included in Table XXXVI to give a point of reference. Also placed in the table, for comparison, are those analyses of the Nardo-Galietum saxatilis Preising 1949 from Shimwell (1968) together with a few of the other British analyses

SUMMARY OF THE COMPONENTS OF THE  
 NARDO-JUNCETUM SQUARROSI IN BRITAIN

ASSOCIATION NARDO-JUNCETUM SQUARROSI Bük 1942

SUB-ASS. empetretosum sub-ass. nov.

Nodum with Erica tetralix and Carex dioica

Nodum with Eriophorum vaginatum

Juncus squarrosus nodum Edgell 1969

Juncus squarrosus bog

Juncus - Eriophorum vaginatum bog )

} Ratcliffe 1959

SUB-ASS. galietosum saxatilis sub-ass. nov.

Nodum with Galium saxatile and Sphagnum papillosum

Nardeto - Juncetum squarrosi McV. & R. 1962 emend.

Birks 1969

Species-poor Juncetum squarrosi sub-alpinum )

Species-poor Nardetum sub-alpinum - typical )

and Juncus facies )

Eddy,

Welch &

Rawes

) 1969

Festuca - Nardus and/or Juncus squarrosus grasslands

Ratcliffe 1959

which are referable to the second association; some of these have previously been likened to the vegetation now included in the Nardo-Juncetum squarrosi.

Association : Nardo-Juncetum squarrosi (Nordh. 1920) Btk 1942

A summary of the British components of the association is given on the facing page and the classification of the Widdybank communities is shown in Fig. XIII b).

In its typical form, the association is dominated by rosettes of Juncus squarrosus and tufts of Nardus stricta between which is a wide variety of other species, often typical of the Caricion curto-nigrae or of siliceous grassland (Duvigneaud 1949). This has led to several different classificatory positions for the association. Duvigneaud places it in the Ericion tetralicis although noting that an earlier referral to the Caricion curto-nigrae might, in fact, be more suitable and it was a member of the now discarded Nardo-Juncion squarrosi Oberd. 1957 (cf. Passarge 1964).

Duvigneaud describes the occurrence of the association in the atlantic sector, including its montane zones (Fair Isle, Norway), in the lower mountains of central Europe (in the Ardennes, Black Forest and Lorraine) and in the upland parts of Britain. His analyses come from western central Europe whilst those of Oberdorfer are from the southern part of the range between 1,312 and 4,429 ft. (400 and 1,350m). In the British Isles, the association appears to be confined to parts of the atlantic/sub-atlantic zones occurring in north Wales (Ratcliffe 1959), the northern Pennines (Eddy, Welch and Rawes 1969 and the present study) and the Isle of Skye (Birks 1969) between 1,200 and 3,000 ft (366 and 914 m) on ground which is flat or slightly sloping - usually only up to 10° - and is therefore badly drained.

The various vegetation types referable to the association fall into two groups which have been distinguished as sub-associations. These differ from those suggested by Preising and described by Passarge (1964) - a drier agrostidetosum tenuis, a typicum and a damper eriphoretosum angustifolii although the British Nardo-Juncetum squarrosi approaches the latter in composition. A more exhaustive British and Continental survey is required to give a

unified classification. Passarge mentions a number of vicarious associations in various parts of Europe including the Irish Rhytidiadelpho-Juncetum squarrosi Br.-Bl. et R. Tx. 1952.

The sub-association galietosum saxatilis is distinguished from the sub-association empetretosum by the presence of several species which are also present in the Nardo-Galietum saxatilis. This related member of the Violion caninae comprises acidic grasslands dominated by Nardus, Deschampsia flexuosa, Festuca spp., Agrostis spp., Potentilla erecta and Galium saxatile situated on drier and more freely drained soils (Shimwell 1968).

The Nardo-Juncetum squarrosi can be separated from the other association not only in general physiognomy and the habitat preferences mentioned above, but also by the presence of a number of differential species - Carex nigra, Eriophorum angustifolium, Aulacomnium palustre, Calyptogeia trichomanes, Sphagnum papillosum, S. recurvum, S. capillaceum, Polygala serpyllifolia, Carex echinata and Eriophorum vaginatum. Most members of this group are characters of communities of damp oligo- to meso-trophic conditions and illustrate the earlier classificatory positions for the association mentioned above. The Carex spp. are characters of the Caricion curto-nigrae; Sphagnum cuspidatum and Calyptogeia trichomanes of the Oxycocco-Sphagnetia; Eriophorum vaginatum and Sphagnum recurvum of the Sphagnetalia magellanici; and Sphagnum papillosum of the Erico-Sphagnion. Only Polygala serpyllifolia is a Violion caninae character, although the co-dominants Nardus and Juncus squarrosus are Nardetalia and Violion characters, respectively, and the class character Calluna is plentiful throughout much of the association.

Sub-ass. empetretosum

This is differentiated by Empetrum nigrum, Erica tetralix and Narthecium ossifragum, the last two being characters of the Ericion tetralicis and Erico-Sphagnion respectively. The sub-association is physiognomically and floristically very akin to vegetation of ombrogenous bogs. This has already been mentioned in the description of mapping unit 27 (col. B, and both Edgell (1969) and Ratcliffe (1959) include under this heading their descriptions of the units now placed in the empetretosum - the Juncus squarrosus nodum (col. D) and the Juncus squarrosus and Juncus/Eriophorum vaginatum bogs

(col. F). Since the sub-association has not been further divided, mapping unit 25 (col. A), although it contains many species of constancy III (Carex hostiana, C. pulicaris, C. demissa) which are clearly exclusive to it, is included with these rather different representatives of the empetretosum.

The sub-association has been described only from north Wales (Cader Idris, col. D, and the Carneddau, col. F) and from Widdybank Fell (cols. A and B). The altitudinal range of the Cader Idris and Pennine localities are 1,500 to 1,825 ft (457 to 556m) and 1,500 to 1,700 ft (457 to 578m) respectively, whereas Ratcliffe's analyses from the Carneddau were made between 1,200 and 3,000 ft (366 and 914m). This vegetation has a greater altitudinal overlap with communities of the galietosum which tends to occur at higher levels (see below). This situation is reflected floristically since the empetretosum vegetation from the Carneddau is somewhat intermediate between the two sub-associations. The soil types associated with the sub-associations, as with their altitudinal preferences, are not sharply separated although the empetretosum is frequently underlain by deep peat and the galietosum by peaty gleys, peaty podsols and shallow peat.

Sub-ass. galietosum saxatilis

Although, as mentioned above, the differentials of this sub-association are also present in the Nardo-Galietum saxatilis, this other association is further distinguished by the absence of the Nardo-Juncetum differentials. The sub-association differentials are Galium saxatile, Anthoxanthum odoratum, Luzula multiflora, L. ? campestris, Carex pilulifera, and C. binervis. None of these is a character of another higher unit of classification and, as a further contrast with the empetretosum, Carex pilulifera is a Nardo-Callunetea and both Galium saxatile and Luzula multiflora are Violion caninae characters. The mean species number of the galietosum is slightly greater than that of the empetretosum, 20.

Not only does the galietosum reach higher altitudes than the empetretosum, but it is more widely distributed. The Carneddau (col. G) Ratcliffe 1959 and Widdybank (col. C) records are again at 1,200 to 3,000 ft (366 to 914m) and 1,500 to 1,700 ft (457 to 578m) respectively but the work of Eddy, Welch and Rawes (1969) at Moor House (col. K) extends its North Pennine range to 2,600 ft (792m), and Birks' (1969) analyses from Skye (col. J) show that it is present there between 1,500 and 2,100 ft (457 and 640m).

Notwithstanding the fact that both Birks (directly by name) and Eddy, Welch and Rawes liken their noda to the species-poor Nardetum and Juncetum squarrosi sub-alpinum of McVean and Ratcliffe (1962), this vegetation (col. N) is clearly not a member of the Nardo-Juncetum squarrosi but belongs to the Nardo-Galietum saxatilis, Shimwell's analyses for which are shown in col. O of Table XXXVI. Reference has already been made to the floristic overlap between these associations in the description of the galietosum. This is further seen by an examination of the species' complements of col. G (from the Carneddau) of the galietosum and col. L (from south-east Scotland, Birse and Robertson 1967) of the Nardo-Galietum saxatilis. The former has reduced frequencies of Nardo Juncetum differentials whilst the latter is infiltrated by species of this other association.

Any discussion by this author of the relative regions of the British Isles occupied by these associations must, at the moment, be incomplete since it has to be based on the published material which does not cover the whole of the country. However, it seems that the only locality where they have both been recorded is Cader Idris in north Wales from which Edgell (1969) has described a Festuca ovina - Juncus squarrosus sociation (col. E) referable to the Nardo-Galietum saxatilis in addition to the Nardo-Juncetum squarrosi empetretosum vegetation (col. D) mentioned above. Ratcliffe (1966), although noting the presence on Widdybank Fell of McVean and Racliffe's (1962) species-poor Nardetum and Juncetum squarrosi, does not give any supporting floristic analyses.

Apart from north Wales, the Nardo-Juncetum appears to occur only in the northern Pennines and on Skye since the extensive investigations in the Scottish Highlands (McVean and Ratcliffe 1962) and southern Scotland (King and Nicholson 1964) have revealed vegetation of the Nardo-Galietum alone. These are the species-poor Nardetum and Juncetum squarrosi sub-alpinum (col. N) and the Nardus-Festuca-Deschampsia type 2, Festuca-Deschampsia (Nardus) type 3 and the Festuca-Agrostis (Nardus) type 6 respectively. (No members of the latter group are shown in Table XXXVI). Other British records of the Nardo-Galietum saxatilis are the Nardetum (col. M) from the Craven district of Yorkshire (Williams and Varley 1967) and Shimwell's analyses in col. D. The latter reports the presence of the association in Derbyshire, Breconshire, Yorkshire (Craven and Wharfedale) and Westmorland; this distribution does not as yet overlap with

that of the Nardo-Juncetum squarrosi. It also seems likely that the altitudinal limits of the Nardo-Galietum saxatilis are slightly lower than those of the Nardo-Juncetum squarrosi since the former often occur around 800 ft (264m) and has not been found above 2000 ft (610m) in England or above 2,500 ft (762m) in Scotland and north Wales.

The synsystematic placing of the  $\infty$  Nodal group with Nardus stricta and Juncus squarrosus

Table I

The synsystematic position of this  $\infty$  nodal group is not nearly so clear-cut as that of most other  $\infty$  nodal groups and nodal on Widdybank Fell. Only one class and one order character, Calluna vulgaris and Nardus stricta respectively are present, although other species of each category occur on the Fell. The three Violion caninae characters are concentrated, as a group, within the  $\infty$  nodal group but two are also widespread in the Empetrium communities.

The nodal group is further seen to be somewhat atypical of its class and alliance in the plentiful occurrence of Oxycocco-Sphagnetum, Ericetalia and Sphagnetalia characters. However, it is not assigned to this other class for the following reasons:

(1) there are fewer of these characters in the  $\infty$  nodal group and they occur with lower constancies than in the genuine bog or damp heath vegetation;

(2) the  $\infty$  nodal group would fall somewhere between the two orders of the class (Sphagnetalia and Ericetalia); and, most important of all,

(3) there is a greater number of Nardetalia/Violion caninae species occurrences than in the Oxycocco-Sphagnetum communities.

Mapping unit 25 differs greatly from the other two in the nodal group in that it comprises vegetation transitional to the Caricion davallianae. This is chiefly shown by the constancies (given in brackets) for the following character species all of which are entirely or almost confined within the  $\infty$  nodal group to this nodum:

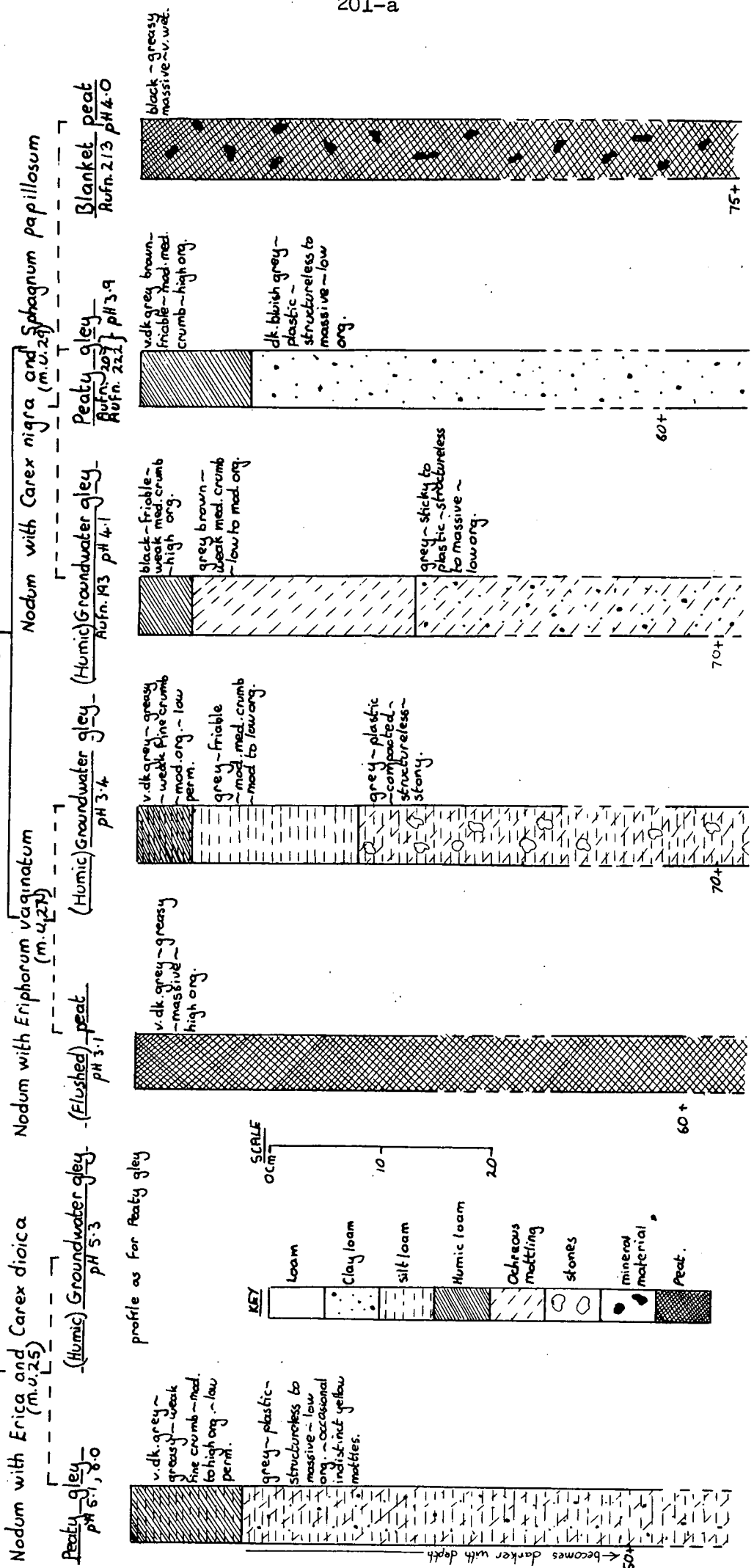
Carex demissa (IV)	)	Parvocaricetea characters
Riccardia pinguis (II)	)	
Carex dioica (V)	)	Tofieldietalia characters
Campyllum stellatum (II)	)	
Carex hostiana (III)	)	Caricion davallianae character

It may be noted that in comparison with mapping units 27 and 29,

FIG. IV. DIAGRAMMATIC SOIL PROFILES OF THE  $\alpha$  NODAL GROUP NARDUS STRICTA AND JUNCUS SQUARROSUS.

$\alpha$  Nodal group with Nardus stricta and Juncus squarrosus

$\beta$  Nodal group with Carex nigra and Polytrichum commune



there is no reduction in the frequency of Nardetalia/Violion caninae characters of mapping unit 25 associated with this addition of Caricion davalliana species.

The Caricetalia nigrae characters Carex nigra and C. echinata are present in all three noda and are a further indication of the damp nature of these communities. This vegetation from Widdybank Fell appears to fall within the Nardo-Juncion squarrosi Oberd. 1957 which was originally erected as a sub-alliance to include the damper communities of the Violion caninae (or Nardo-Galion saxatilis Preising 1949 as it was then known). The sub-alliance was later raised to an alliance by Passarge (1964) who placed it in a new order - the Juncetalia squarrosi (see the discussion above of the syntaxonomy of the Violion caninae). Unfortunately, this division of the Violion caninae has not been retained by later workers such as Oberdorfer et al (1967), Westhoff and den Held (1969).

The soils of the  $\alpha$  nodal group with Nardus stricta and Juncus squarrosus

Table XXXVII and Fig. XIV

The various substrates associated with these three noda form a fairly uniform whole as far as their general nature, i.e. the "soil type" to which Hornung has assigned them, is concerned. Nevertheless, they are divisible, on the basis of their chemical characteristics, into two groups which parallel the separation of the  $\alpha$  nodal group into the Nodum with Erica and Carex dioica (m.u. 25) and the  $\beta$  nodal group with Carex nigra and Polytrichum commune (mapping units 27 and 29). The peaty gleys and (humic) groundwater gleys of mapping unit 25 have a much greater pH (mean 5.5) and calcium content (mean 37.1 m eq/litre) than the peaty gleys (humic) groundwater gleys, flushed peats and blanket peats of the other two mapping units (mean values: pH 3.7 and Ca 3.1 m eq/litre). A similar difference is seen in the mean values for loss-on-ignition:

mapping unit	25	37.0%	
"	"	27	54.2%
"	"	29	67.3%

It would appear likely, therefore, that each of these three factors of pH, calcium content, humus content, in particular the first two, is instrumental in determining the distinctive species composition of mapping unit 25.

This nodum is the member of the Violion caninae which is most closely related to the Caricion davalliana. Conversely, mapping unit 12 is the member of the latter alliance which is closest, although to a lesser degree, to the Violion caninae and mapping unit 11 also approaches that form of the Violion which is represented by mapping unit 25. There is a similar convergence in one or more of pH, calcium content, humus content, between the soils of these three noda as can be seen by a comparison of the relevant parts of Tables XXVII and XXXVII. There is a striking similarity to the substrates of mapping unit 25 in the pH and calcium content of the peaty gleys of mapping unit 12 (means of 5.7 and 37.6 m eq/litre respectively) and the loss-on-ignition (32.5%) of the (flushed) calcareous gleys of mapping unit 11, although these differ in the other factors.

The chief difference between the soils of mapping units 27 and 29 lies in their relative pH values which are 3.2 and 4.0 respectively. The figures for loss-on-ignition in both noda have a high spread and a complete discussion must await further analyses, especially for mapping unit 27. For the present it may, however, be noted that their means are somewhat lower than those for mapping unit 28 (L.o.I. 92.1%) to which both noda are often adjacent and with which they share a number of bryophyte differentials, e.g. Polytrichum commune, Aulacomnium palustre, Sphagnum recurvum. The pH of this nodum (3.7) is almost midway between those of mapping units 27 and 29.



Order : CALLUNO-ULICETALIA (Quantin 1935) R.Tx. 1937

Those parts of the class, and this order in particular, to which reference is made in the following account are shown on the facing page.

The dwarf-shrub-heath communities which comprise the order are rather species-poor although notably rich in lichens and mosses. Only rarely primary in origin, e.g. in rocky places, they are usually replacements of the Vaccinio-Piceetea and of the Quercion robori-petraeae and Luzulo-Fagion of the Quercetalia robori-petraeae and are maintained by grazing, trampling, mowing and, in contrast to the Nardetalia, burning. The soils are usually acidic, nutrient-poor and somewhat dry (Westhoff and den Held 1969).

These heaths are found in the atlantic to sub-continental parts of the euro-siberian region i.e. over an area stretching from north Sweden, Finland and north-west Russia to south-east France, central Italy, Yugoslavia and Hungary and extending to northern France and across the British Isles to western Ireland. Throughout much of this zone the order covers a wide altitudinal range but in the south it is restricted to the montane and sub-alpine parts. In the arctic-alpine regions it is bordered by the dwarf-shrub tundra vegetation of the Loiseleurio-Vaccinietae Egger 1952 emend. Schubert 1960 whose alliances were formerly included in the Vaccinio-Piceetea Br.-Bl. 1939. The southern boundary of the Calluno-Ulicetalia adjoins the mediterranean heaths of the Cisto-Lavanduletea except in the south-west where the heath communities of France (apart from those in the north, the Pyrenees and the Alps) are referred to the Erico-Ulicetalia Br.-Bl., Pinto da Silva and Rozeira 1964 (Schubert 1960, Bridgewater 1970).

Syntaxonomy

The syntaxonomic problems of this order centre on the composition and position of the Ulicion Duvign. 1964 which encompasses the heaths of atlantic Europe. Schubert (1960), who included in this alliance the heaths of Britain and northern France, removed it from the Calluno-Ulicetalia and placed it in the Ulicetalia europaeae Quantin 1935, an order which also contained as the Ericion umbellatae Br.-Bl., Pinto da Silva, Rozeira et Fontes 1952, the heaths of south-west Europe. The Calluno-Ulicetalia thereby confined to northern and central Europe, was re-named the Vaccinio-Gninetalia.

Both Passarge (1964) and Westhoff and den Held (1969) follow this procedure. Their investigations were not, however, primarily concerned with the communities of the extreme west of Europe. Others (Lohmeyer et al 1962, Braun-Blanquet, Pinto da Silva and Rozeira 1964, Oberdorfer et al 1967, Shimwell 1971c) have returned the Ulicion to the northern European grouping for which the order name Calluno-Ulicetalia has again been used (cf. Oberdorfer 1957, So6 1957).

A further development was the formation of the Erico-Ulicetalia Br.-Bl., Pinto da Silva and Rozeira 1964 for the south-west European heaths. Although originally excluded from this order (cf. Bridgewater 1970), the southern affinities of the Ulicion were re-emphasised by Braun-Blanquet (1967) who placed it in the Erico-Ulicetalia. He also modified the original conception of the alliance and removed from it the heaths in the northern half of Britain placing them with the others of northern Europe in a new order - the Erico-Genistetalia. This has not been retained by later workers ~~nor,~~ it may be noted, have Doings' (1963) Genisto-Callunetalia and Ulici (nanae)-Ericetalia cinerea for, respectively, north-west and central Europe.

Bridgewater (1970) who has made an extensive study of the British heath communities, follows Rivas Martinez' unpublished classification which places the heaths of south-west Europe in the Erico-Ulicetalia and those of north-west and central Europe in the Calluno-Ulicetalia. Under this arrangement, the heaths of southern England and northern France, forming the Ulicion constitute part of the Calluno-Ulicetalia and are thus separated from the communities of central and western France and northern Spain which are referred to the other order. This scheme, therefore, assigns all British heaths to the Calluno-Ulicetalia and since Bridgewater has specifically attempted to place them in their European context, his procedure is followed in preference to that of Westhoff and den Held which removes the southern English heaths from this order (cf. above).

Character species

Their small number is doubtless partly due to the difficulty of determining the composition of the order. Those given by Oberdorfer<sup>(1957)</sup> are:

Calluna vulgaris    Hypnum ericetorum    Sarothamnus scoparius.  
Westhoff and den Held (1969) name Calluna, Hypnum and Arctostaphylos uva-ursi as characters of the Vaccinio-Genistetalia (equivalent to the Calluno-Ulicetalia without the Ulicion - see above). Since Arctostaphylos is present in British Ulicion communities (Bridge-water 1970) as well as in others of the Calluno-Ulicetalia, it is considered, with reference to Britain, that this species may be added to Oberdorfer's order characters, pending further investigation.

Calluna is a transgressive class character and it is in this order that it finds its optimum expression. All four species occur in Britain: Sarothamnus, absent from Widdybank Fell although present in the Tees valley, is widespread on waste ground and in woods as well as on heaths; Calluna and Hypnum are also generally common and the occurrence of Hypnum is strongly linked with that of Calluna (Watson 1966); the distribution of Arctostaphylos is rather disjunct since it is abundant on moors north of the Highland boundary fault but otherwise is scattered over the remaining parts of upland Britain. It is present in Upper Teesdale (Perring and Walters 1962). Although not mentioned in Table XXXVIII, it was recorded from Falcon Clints in vegetation similar to mapping unit 31 of the Empetrium and also occurs on Whin Sill cliffs and scree on Cronkley Scar (Pigott 1956) and above High Force<sup>†</sup>. Calluna and Hypnum are also found in the Violion caninae communities on Widdybank but they have much higher cover value in the nodes of the Calluno-Ulicetalia (cf. Tables XXXIV and XXXVIII).

The species named by Oberdorfer (1957) as order differentials vis-à-vis the Nardetalia are Ptilidium ciliare, Dicranum spurium and D. undulatum. Westhoff and den Held also cite these with the addition of Juniperus communis as Vaccinio-Genistetalia differentials and, following the treatment given to the character species, it may be suggested that all four should be used as British Calluno-Ulicetalia differentials.

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<sup>†</sup> Bradshaw (1972) : personal communication.

A survey of the available habitat descriptions (Clapham, Tutin and Warburg 1962, Watson 1966) and distribution maps (Perring and Walters 1962) has shown the probability that in Britain in general (but see below) Ptilidium can act as such a differential and that Juniperus (probably ssp. nana) is also valid in the northern half of the country. Both Dicranum species are rare: D. spurium, present in heaths, chiefly in eastern England, is a suitable differential (Longton 1965) but the use of D. undulatum, an even scarcer plant of bogs principally in north-east Scotland and on the Scottish-English border (Dickson 1966) may not be valid.

Only Ptilidium and Juniperus occur on Widdybank Fell and the present results seem to indicate that the former cannot be used as a differential here since it is present with equal frequency and abundance in both the  $\infty$  nodal group with Nardus stricta and Juncus squarrosus (Violion caninae) and the  $\infty$  nodal group with Calluna and Cladonia arbuscula (Empetrium nigri). Juniperus figures in only two Aufnahmen. These are nos. 411 and 413 made on Falcon Clints and placed in mapping unit 31 of the latter  $\infty$  nodal group.

Four alliances are recognised within the order by Rivas-Martinez:

<u>Empetrium boreale</u> Bøcher 1943	boreal-sub-atlantic
<u>Calluno-Genistion pilosae</u> Duvign. 1944	sub-atlantic
<u>Sarothamnion</u> R. Tx. 1945 apud. Prsg. 1949	
<u>Ulicion nanae</u> Duvigneaud 1944 em. Vanden Berghen 1958	atlantic

The classification employed by Westhoff and den Held differs from this in two ways as they follow, in part, Schubert (1960). The Empetrium nigri is used instead of the Empetrium boreale to give a geographically more widespread alliance and the Ulicion is transferred to the Ulicetalia europaeae.

Schubert and Passarge (1964) have both suggested other modifications in the arrangement of the existing alliances and/or addition of new ones. These have not all been sustained by later workers and only a few points need to be mentioned in the present account. The Calluno-Genistion was divided by Schubert to give the alliances Vaccinion vitis-idaeae Bøcher 1943 em.  $\Rightarrow$  boreal-montane and Genistion pilosae Duvign. 1942 em; the Sarothamnion R. Tx. 1945 became a sub-alliance of the latter. In addition, he erected the Euphorbio-Callunion vulgaris for the species-rich heaths of continental central Europe.

The unity of the Calluno-Genistion has, however, been maintained by later workers (Lohmeyer et al 1962, Passarge 1964, Oberdorfer et al 1967) and, in general, the Sarothamnion has been retained as an alliance although Oberdorfer et al suggest that it might be better included in the Prunetalia spinosae R. Tx. 1952. At that time this was included in the woodland class Querco-Fagetea but has since been placed in the Rhamno-Prunetea Rivas Goday et Borja Carbonell 1961 of woodland-edge scrub communities (Westhoff and den Held 1969, Shimwell 1971c).

The present account follows Bridgewater's (1970) use of Rivas-Martinez' classification with the substitution of the Empetrium nigri for the Empetrium boreale (cf. Shimwell 1971c).

Braun-Blanquet and Tüxen (1952) and Ivimey-Cook and Proctor (1965) have both shown that the Ulicion nanae is present in Ireland and Bridgewater (1970), whose survey of British heaths excluded that country, has found British representatives of the alliances Ulicion nanae, Calluno-Genistion and Empetrium nigri. The distribution patterns of these communities illustrate the European zonation of the alliances, i.e. atlantic, sub-atlantic and boreal-sub-atlantic respectively. The Ulicion occurs in north-west and central Scotland, the Isle of Man, west Wales and south-west England; the Calluno-Genistion is chiefly in eastern and southern England with isolated outposts in south-west England, north Wales, the Isle of Man and south-west Scotland; the Empetrium is found in north-west, central and southern Scotland, northern England and is scattered throughout Wales.

The Widdybank heaths have been placed in the Empetrium nigri although some affinity to the Ulicion is evident.

All.: Empetrium nigri Bøcher 1943 emend. Schubert 1960

The alliance is found in the coastal dunes of sub-atlantic Europe, i.e. south Sweden, south Norway, Poland, Denmark, Germany, the north Netherlands and in the montane-sub-alpine parts of central Europe where it forms a zone between the lowland Calluno-Genistion and the alpine alliances of the Loiseleurio-Vaccinietea (Schubert 1960). Bridgewater (1970) has now extended its distribution to those parts of Britain mentioned above.

### Syntaxonomy

With the formation of this alliance, Schubert has combined the nordic-sub-atlantic communities of the Empetrium boreale Böcher 1943 with the Empetrum heaths of the central European mountains. These two components have been placed in different sub-alliances owing to the absence in the latter region of several of the lowland characteristic species. The sub-alpine vegetation, assigned to the Vaccinio-Empetrium, is noteworthy for the abundance of Empetrum nigrum, Vaccinium uliginosum, V. myrtillus, V. vitis-idaea and Cetraria islandica; the character species are Empetrum and Vaccinium uliginosum. The lowland communities are referred to the Caricio-Empetrium which includes part of the Empetro-Salicion arenariae Doing 1962 (Westhoff and den Held 1969) and have abundant Carex arenaria, C. pilulifera, C. stolonifera, C. panicea with many species of Cladonia and Cetraria. It is not clear to which, if either, sub-alliance the Teesdale vegetation belongs although both floristically and geographically they seem closer to the Vaccinio-Empetrium.

### Character species

Schubert does not give any character species for the alliance as a whole. Those named by Westhoff and den Held are Empetrum nigrum and Salix repens ssp. argentea both of which are present in Britain. Empetrum, found in moors and in drier blanket bogs (it is a differential of the Sphagnion fusci), is widely distributed up to about 2,500 ft (762m) north of a line from the Bristol Channel to the Humber estuary and also occurs in Ireland. Salix repens ssp. argentea is described by Clapham, Tutin and Warburg (1962) as a plant of dune-slacks and sometimes of rocky heaths in northern Scotland also. Many coastal occurrences are given by Perring and Walters (1962) for the species (i.e. not sub-species) but the actual composition of these communities needs clarification since damp "dune-slacks" are not "coastal heaths". However, some of Gimingham's (1964) descriptions of coastal vegetation, i.e. Salix repens heaths and the drier stages of colonisation of the dune-slacks, appear to refer to vegetation of the alliance.

Both species are present on Widdybank Fell. Empetrum is plentiful in some of the Empetrium noda and also in the blanket bogs of the Erico-Sphagnion and Salix repens (not ssp. argentea, illustrating the need for investigation into the actual taxon characterising the alliance) has been found on the sugar limestone escarpment in

Class : NARDO-CALLUNETEA  
 Order : CALLUNO-ULICETALIA  
 Alliance : EMPETRION NIGRI

∞ Nodal group with Calluna and Cladonia arbuscula

a) Field key to communities on Widdybank Fell

Nodal group	Hypnum ericetorum, Galium saxatile, Calluna vulgaris, Dicranum scoparium, Pleurozium schreberi, Cladonia arbuscula, Vaccinium myrtillus, Nardus stricta.			
	Nodal group	Carex pilulifera, Polytrichum formosum, Polygala serpyllifolia		
Nodal group			Campanula rotundifolia, Agrostis stolonifera, Luzula campestris, Briza media, Cladonia subrangiformis, Ptilidium ciliare	
Noda	Empetrum nigrum, Erica tetralix, Trichophorum cespitosum, Molinia caerulea, Campylopus flexuosus, Carex binervis	Deschampsia flexuosa, Pteridium aquilinum, Parmelia physodes, Pohlia nutans, Blechnum spicant	Viola riviniana, V. lutea, Anthoxanthum odoratum, Cetraria islandica, Thymus drucei, Rhacomitrium lanuginosum, Hylocomium splendens, Koeleria cristata, Dicranum bonjeanii.	Sieglingia decumbens, Carex caryophyllea.
Mapping Units	26	31	32	33

b) Classification of ∞ Nodal group and Noda

Vaccinium myrtillus heath Bridgewater 1970 p.p. syn.: ∞ Nodal group with Calluna and Cladonia arbuscula			
Deschampsia flexuosa complex, Empetrum nigrum community, Rhytidiadelphus loreus variant.		Calluna vulgaris complex, Calluna vulgaris community, Festuca ovina variant. syn.: ∞ Nodal group with Galium saxatile and Luzula campestris	
Erica tetralix sub-var. nov. prov. syn.: Nodum with Empetrum and Erica	Carex pilulifera sub-var. nov. prov. syn.: Nodum with Pteridium and Deschampsia flexuosa	typical sub-var. nom. nov. syn.: Nodum with Viola riviniana	Anthoxanthum odoratum sub-var. nov. prov. syn.: Nodum with Sieglingia decumbens
Mapping Units	26	31	33

\* ssp. germanicum

the nodum with Calluna<sup>#</sup> that member of the Seslerio-Mesobromion which is most closely related to the Empetrium.

Four noda falling within the Empetrium have been described from the Fell. Together they form the

∞<sup>\*</sup> Nodal group with Calluna and Cladonia arbuscula  
(Mapping units 26, 31-33)

Table XXXVIII and Fig. XV a)

The key card used in the field is given in Fig. XV a)

The order characters Calluna vulgaris and Hypnum ericetorum are both members of the differential species group. Together with Nardus and Pleurozium schreberi they are also constituents of the differential species group of the ∞<sup>\*</sup> nodal group with Nardus and Juncus squarrosus (cf. Table XXXV where the differentials of all Nardo-Callunetea noda are shown). The other differentials are Galium saxatile, Cladonia arbuscula, Dicranum scoparium and Vaccinium myrtillus. Some species are rare, or even absent altogether, in individual noda thereby emphasising the heterogeneity within the nodal group. Calluna, Cladonia arbuscula and, less frequently, Galium saxatile and Vaccinium myrtillus, are amongst the usual dominants; the constant/near constant companions Festuca ovina, Potentilla erecta and Agrostis tenuis may also be prominent on occasion. The communities included within the nodal group vary from damp heaths, related to the Ericion, on peaty soils to species-poor grass heaths usually on acid brown earths and showing some affinity to the Seslerio-Mesobromion. The mean species number of all noda is low, ranging from 16 (m.u. 26) to 26 (m.u. 32).

The ∞<sup>\*</sup> nodal group is scattered over most of the Fell either on shallow peat in amongst the blanket bog (m.u. 26 only) or as one of the vegetation types associated with the spatial transition from Erico-Sphagnion (blanket bog) to Seslerio-Mesobromion communities. The most extensive tracts of Empetrium nigri vegetation lie on the southern and south-eastern sides of the Fell where, in many places, it is closely associated with the scree vegetation of the Asplenieta rupestris. On the eastern side, between Fold Sike and Widdybank Farm, another large expanse dominated by Nardus occurs.

The ∞<sup>\*</sup> nodal group divides into a ∞<sup>o</sup> nodal group with three noda and the

<sup>#</sup> Bradshaw (1972) : personal communication

Nodum with Empetrum and Erica (Mapping unit 26)

This nodum has a full complement of nodal group differentials, each being present with constancy III or greater; it is further differentiated by the alliance character Empetrum nigrum together with Erica tetralix, Trichophorum cespitosum ssp. germanicum, Molinia caerulea, Campylopus flexuosus and Carex binervis. Sphagnum rubellum occurs only in this nodum of the  $\infty$  nodal group. is usually

Calluna, the dominant Phanerogam, /about 10 to 15 cm tall and extremely dense although in places Nardus may be prominent. Scattered throughout the heather are shoots of Erica, Molinia, Empetrum and, occasionally, Carex echinata. Cover is between 90% and 95%; according to the location of the site either portions of outcropping Whin Sill or peat are exposed. The Phanerogams contribute 75% to 90% to the cover and the Cryptogams about 50%. Cladonia arbuscula and, to a lesser extent, Hypnum ericetorum, are the most abundant species in this category. The degree of slope of the ground colonised lies between 0 and 10°.

It should be noted that since the existence of this vegetation type became apparent only when mapping was being undertaken, its composition and variability had to be established with speed. As a consequence, five of the Aufnahmen in Table XXXVIII are shown on a presence/absence basis only and several habitat details are lacking. Most were made on the south-west facing escarpment above Red Sike where the general angle of slope is about 10° although individual patches of this type of vegetation are on flat ground.

The habitats and contact communities of the nodum with Empetrum and Erica reflect its affinity, already apparent from the floristic description, to the Oxycocco-Sphagnetea, especially with damp heaths of the Ericion. The difficulty occasionally encountered of floristically separating mapping unit 23 of this alliance from mapping unit 26 has already been mentioned in the description of the former. The two nodum sometimes occur adjacent to one another in the midst, or at the edge, of an area of blanket bog where the peat has become much thinner than it is over the general expanse.

Mapping unit 26 is most commonly found as a "buffer zone" between the blanket bog vegetation of the Erico-Sphagnion and those mapping units (31 and 32) which are more typical of the Empetrium and occurs in such a position with mapping units 23 (Ericion) and

29 (Violion caninae) bordering much of the main blanket bog mass over the top of the Fell where there is a distinct gradient off the edge of the drift. At the extreme eastern end of the sugar limestone escarpment where the drift covering the sugar limestone is absent or very thin, mapping unit 26 lies chiefly between the blanket bog and units of the Seslerio-Mesobromion. Further west along the escarpment, above Red and Tinkler's Sikes, raised areas of peats and peaty gleys occur amidst the Seslerio-Mesobromion vegetation. These hummocks, often overlying marl (porcelainite), may be circular in plan but, especially towards the Birkdale Track, are long and narrow with their long axes at right angles to the direction of slope. They are very characteristically colonised by mapping unit 26 alone or by this nodum together with mapping units 31 and 28 (blanket bog) and there is a sharp transition between them and the surrounding limestone grassland.

The other main site type for the nodum with Empetrum and Erica is also as a border but in this case it is adjacent to mapping unit 25 (Violion caninae). These complexes occur alongside regions of calcareous flushing, e.g. in Red Sike west of the Birkdale Track and at the head of Fold Sike. In both these areas and near to Sand Sike mapping unit 26 may abut directly on Caricion davallianae vegetation.

β Nodal group with Carex pilulifera (Mapping units 31 to 33)

The differential species are Carex pilulifera (class character), Polygala serpyllifolia (Violion/caninae character) and Polytrichum formosum. The three noda can be grouped into a β nodal group and the

Nodum with Pteridium and Deschampsia flexuosa (Mapping unit 31)

The members of the differential species group are: Pteridium aquilinum, Deschampsia flexuosa, Parmelia physodes, Pohlia nutans and Blechnum spicant. Several others are confined to this nodum but are of very low presence. They include: Vaccinium vitis-idaea, Sorbus aucuparia, Erica cinerea (all found only on Falcon Clints), Polytrichum piliferum and various Cladonia species. In addition, further field investigations have shown that Carex binervis is a good differential from the other members of the β nodal group. The α nodal group differential Cladonia arbuscula is virtually absent.

Festuca ovina and Agrostis tenuis are the only constant companions.

The nodum has a number of aspects; although it does not appear from the present data that they can be floristically separated, a more detailed investigation of the communities concerned might have enabled this to be done. Over much of the Fell, the nodum has 95% to 100% cover and is characterised either by dense patches of Calluna associated with Deschampsia flexuosa, Festuca ovina, Vaccinium myrtillus and several Cladonia species or as between Fold Sike and Widdybank Farm, by a dense Nardus dominated sward with Calluna, Deschampsia, Galium saxatile, Carex binervis etc. An attempt was made to form separate mapping units from these two types but none of the possible discriminatory species was valid in the field; furthermore, vegetation intermediate between them with co-dominant clumps of Calluna and Nardus is often encountered.

The nodum occurs in this form above and at the western end of the sugar limestone escarpment and similarly around the various calcareous communities associated with Slapstone Sike and the adjacent sugar limestone soils and also those on the Fell top sugar limestone. Where mapping unit 31 forms, with mapping unit 29, a rim on the shallow soil around the edge of a blanket bog hummock set amidst Seslerio-Mesobromion vegetation, rosettes of Juncus squarrosus are occasionally found in mapping unit 31 and tufts of Carex binervis in mapping unit 29. The nodum with Pteridium and Deschampsia flexuosa is one of those forming isolated hummocks in the Seslerio-Mesobromion vegetation - mostly the calcareous heath of mapping unit 4 - on the sugar limestone escarpment where deeper soil, and sometimes peat colonised by mapping unit 28, has formed in the drift overlying the bedrock.

In all the sites mentioned above, the nodum develops on ground with only a small amount of slope, at most  $10^{\circ}$  to  $15^{\circ}$ . Its other chief occurrence is on the steeply sloping ground of and near Falcon Clints; it has been recorded on well vegetated rock ledges as well as from the boulder (Whin Sill) strewn ground where the boulders may occupy 10% to 30% of the area above and below the vertical cliff faces. In this part of the Fell, the nodum is again often dominated by Calluna vulgaris (usually 5 to 15 cm tall) with Deschampsia flexuosa, Vaccinium myrtillus, V. vitis-idaea, Festuca ovina, Agrostis tenuis and A. canina where the Calluna

cover is not quite so dense. Various other species, many indicative of former woodland, have been recorded in this type of community. Mention may be made of Erica cinerea, Sorbus aucuparia, Juniperus communis, Betula pubescens, Crataegus monogyna, Teucrium scorodonia amongst others; Arctostaphylos uva-ursi (not included in Table XXXVIII) is present here also. In some places in this region, Pteridium aquilinum occurs in the Calluna dominated vegetation but elsewhere it has colonised a close-cropped sward of Agrostis/Festuca/Calluna/Galium saxatile grassland. Here Pteridium with shoots up to 50 cm tall may achieve over 80% of cover and as a consequence the number of species in the turf becomes very much reduced e.g. Aufnahmen nos. 401 and 415.

Much of the southern side of the Fell (Falcon Clints) has been mapped as a complex of mapping unit 31 and the nodum of Whin Sill block scree of the Androsacion vandellii. This colonises the boulders and some of the vertical cliff faces around and on which the other nodum occurs. Since it was not always possible to draw a distinct dividing line between the two types some species of the scree community, such as Andraea rupestris, are recorded in some Aufnahmen of mapping unit 31. This complex is also present on the exposed sides of the Whin Sill outcrops on the south-east and east facing sides of the Fell.

♂ Nodal group with Galium and Luzula campestris  
(Mapping units 32 and 33)

The noda of this nodal group are the Calluna heath in Agrostis/Festuca grassland (m.u. 32) and the Agrostis/Festuca grassland itself (m.u. 33). These communities on acid soils correspond to mapping units 4 (Nodum with Calluna "species-rich heath") and 5 (Nodum with Plantago lanceolata) respectively of the Seslerio-Mesobromion. The division of the Aufnahmen into two noda, however, has not been based on the dominance, or even presence, of a single species but on the presence or absence of all those found within the ♂ nodal group to be differentials. This has resulted in the inclusion in mapping unit 32 of Aufnahme no. 123 in which Calluna is absent as it has some of the differentials for this nodum and none of those for mapping unit 33. Conversely, Aufnahme no. 130 although with dominant Calluna, is placed in mapping unit 33.

The  $\infty$  nodal group differentials are Campanula rotundifolia, Agrostis stolonifera, Luzula campestris, Briza media, Cladonia subrangiformis and Ptilidium ciliare. The companions Festuca ovina, Potentilla erecta and Agrostis tenuis are constant and Agrostis canina is present with constancies IV and III in mapping units 32 and 33 respectively. Trifolium repens and Carex hostiana are confined to the nodal group but are of very low constancy. The mean species numbers of 26 (m.u. 32) and 22 (m.u. 33) are the highest in the  $\infty$  nodal-group. Cover is almost always complete; the ground usually slopes at less than  $10^\circ$  although the inclination may be as much as 15 to  $25^\circ$ .

Nodum with Viola riviniana (Mapping Unit 32)

The differential species group is composed of Viola riviniana, Anthoxanthum odoratum, Cetraria islandica, Thymus drucei, Rhacomitrium lanuginosum, Hylocomium splendens, Viola lutea, Koeleria cristata and Dicranum bonjeanii. The  $\infty$  nodal group differentials Vaccinium myrtillus and Nardus are both of very low constancy. The species listed above do not normally play any prominent part in the physiognomy of the vegetation but are part of the general rather species-poor (i.e. compared with the Seslerio-Mesobromion grasslands) Agrostis-Festuca turf within which the Calluna bushes are situated. Galium saxatile and Cladonia arbuscula are the other most prominent species.

The Calluna plants, between 5 and 15 cm high, occur with varying density and often achieve a cover of 85% to 90%; the grassy areas between them may occasionally be colonised by Seslerio-Mesobromion species such as Galium sternerii, Sesleria caerulea, Carex capillaris, C. pulicaris and Polygonum viviparum. In other places the shrubs (Empetrum is sometimes also present) may be so dense as to shade out some species typical of the nodum -  
Aufnahmen 455 and 459. Phanerogam cover, therefore, is generally high, ca. 90%; the Cryptogam is variable although often between 60% and 75%. Bare soil is occasionally exposed by the activity of moles but it never covers more than 10% of the area.

The nodum usually plays a part in the transition from Empetrium to Seslerio-Mesobromion communities (chiefly mapping units 4 and 5) and grades imperceptibly into mapping unit 33 or mapping unit 4. Since all these nodum develop on soils of similar

depth, there is not the marked drop in height that occurs where mapping units 26 and 31 on deeper and usually more peaty soils (cf. Fig. XVI) are adjacent to the Seslerio-Mesobromion vegetation. Such complexes of grass and heath noda occur on several parts of the Fell. They are very common near the tops of the banks above Slapestone Sike and close to Nameless Sike just above the Birkdale Track and isolated patches of mapping unit 32 are found amidst the Seslerio-Mesobromion communities of the escarpment above Red Sike. Adjacent to Nameless Sike west of the Birkdale Track and around the upper part of Fold Sike (inter alia) communities of the nodum occur next to, and slightly raised above, flush and sedge-marsh vegetation of the Caricion davallianae.

Nodum with Sieglingia decumbens (Mapping unit 33)

Sieglingia and Carex caryophyllea are the only differential species. The  $\alpha$  nodal group differential Calluna vulgaris is virtually absent (cf. above) as is the  $\beta$  nodal group differential Polygala serpyllifolia. The dry species-poor turf, rich in Agrostis and Festuca species, Cladonia arbuscula, C. uncialis and Galium saxatile and Vaccinium myrtillus in places and an occasional tuft of Sesleria caerulea. Phanerogam cover varies from 60% to 100% and that of the Cryptogams ranges even more widely - from 10% to 75%. A comparison of the cover values of these two components of Aufnahmen nos. 494 and 438 with those of the other Aufnahmen shows that there is a distinctly inverse relationship between them; this also holds for mapping unit 32.

In common with the other Empetrium units, the nodum occurs between the large and small blanket bog (Erico-Sphagnion) masses and the Seslerio-Mesobromion communities. However, much more frequently, and in distinction from the other Empetrium noda, mapping unit 33 forms complexes with the nodum with Plantago lanceolata (m.u. 5) of the Seslerio-Mesobromion and, less often, with the Nodum with Carex caryophyllea (m.u. 21) of the Ranunculo-Anthoxanthion. The nodum with Sieglingia colonises the hummocks of a hummock-hollow complex with each of the other noda. Such complexes are found principally in the various areas of grassland on either side of the Birkdale Track both before and after it crosses Slapestone Sike and also on the Fell top plateau. It is assumed that both types of complex are caused by the presence of patches

of drift overlying the sugar limestone as the acid brown earths of mapping unit 33 are usually deeper than the gleyed brown earths and rendzinas of mapping unit 21 and the rendzinas and brown calcareous soils of mapping unit 5 (cf. Johnson, Robinson and Hornung 1971).

A different type of mosaic between mapping units 5 and 33 covers a large part of the Fell top plateau and, before inundation, occurred extensively in the Slapestone Sike drainage area away from the facing slopes adjacent to the Sike; between one third and one half of this now remains.

In such places the slightly domed areas of mapping unit 5 dominated by the coarse leaves of Carex panicea, C. flacca, Sesleria caerulea with Carex capillaris stand out from the fine-leaved turf of mapping unit 33 in the channels and depressions between.

The syntaxonomy and classification of the  $\alpha$  nodal group

Tables XXXIX and XL and Figs XV b)

The author believes that a study of the syntaxonomy of the heaths on Widdybank Fell can be most profitably related to the work of Bridgewater (1970) who has made an extensive phytosociological survey of British heath communities (excluding those in Ireland, Orkney and Shetland). His descriptions of British representatives of the Ulicion nanae, Calluno-Genistion and Empetrion nigri and the inclusion of the heaths in northern England (inter alia) in the latter alliance have already been mentioned.

Below the rank of order, Bridgewater does not follow the classical phytosociological terminology of alliance association, sub-association etc. but adopts instead the practice of de Smidt (1966) whereby

Heath all  
Complex  
Community  
Variant  
Sub-variant

are used in a hierarchical arrangement and "heath" is equivalent to the conventional "alliance". Underlying the floristic separation of the complexes by groups of differential species are both ecological (chiefly water and mineral nutrient content of the soil) and geographical factors. These differential species differ from the Kennarten of an association in three ways; they are by no means exclusive to the complex; they do not, in general, reach their

SUMMARY AND SYNONYMY (WITH REFERENCE TO WIDDYBANK FELL)  
OF PARTS OF THE VACCINIUM MYRTILLUS HEATH Bridgewater 1970

CALLUNA VULGARIS COMPLEX Bridgewater 1970

Calluna vulgaris community

typical variant nom. nov.

Festuca ovina variant

typical sub-variant nom. nov.

syn.: Nodum with Viola riviniana

Festuceto-Callunetum Ratcliffe 1966 p.p.

Anthoxanthum odoratum sub-variant nov. prov.

syn.: Nodum with Sieglingia decumbens

Erica tetralix variant

Pohlia nutans variant

Luzula multiflora variant

Leucobryum glaucum sub-variant

Pteridium aquilinum sub-variant

Erica cinerea community

DESCHAMPSIA FLEXUOSA COMPLEX Bridgewater 1970

Rhytidiadelphus loreus community

Empetrum nigrum community

typical variant nom. nov.

Rhytidiadelphus loreus variant

typical sub-variant nom. nov.

Erica tetralix sub-variant nov. prov.

syn.: Nodum with Empetrum and Erica

Carex pilulifera sub-variant nov. prov.

syn.: Nodum with Polytrichum and Deschampsia flexuosa

Juniperus communis variant

Erica cinerea variant

Sieglingia decumbens sub-variant

Pohlia nutans sub-variant

Gymnocolea inflata variant

Juncus squarrosus variant

Deschampsia flexuosa community

Pteridium aquilinum community

optima in it; and they overlap considerably with those of other complexes within the heath unit. This last difference is evident from a comparison of the groups of differentials shown in Tables XXXIX and XL for two complexes within the Vaccinium myrtillus heath.

The communities are usually separated on a geographical basis and the variants according to the soil mineral content. The composition of the differential species groups of these units (communities/variants) is such as to cause considerable overlap between the members of different complexes. In common with the more conventional Zurich-Montpellier schemes, this type of classification can only be erected after the completion of the type of geographically wide-ranging survey which was made by Bridgewater both in the field and in the literature.

The Widdybank noda fall into two complexes of the Vaccinium myrtillus heath - the Calluna vulgaris complex (mapping units 32 and 33) and the Deschampsia flexuosa complex (mapping units 26 and 31).

Vaccinium myrtillus heath - Calluna vulgaris complex  
Bridgewater 1970

These heaths are found on the Pennine hills across northern England from west Yorkshire to Durham and Westmorland. Bridgewater distinguishes two communities: the Calluna vulgaris community whose differentials are given in Table XXXIX; and, in Durham, Northumberland and Westmorland, the Erica cinerea community which is chiefly distinguished by the abundance of Erica cinerea, E. tetralix, Sieglingia decumbens and the virtual absence of Pleurozium schreberi, Plagiothecium undulatum, Lophocolea bidentata and Potentilla erecta.

Calluna vulgaris community  
Table XXXIX

This is restricted to north-west Yorkshire, Durham, Northumberland and Westmorland. There is usually complete Phanerogam cover; the mean Cryptogam is 70% but it varies from 5% to 95%. The mean species number is about 10 except in the Erica tetralix variant and the Festuca ovina variant where it is 12 and 22 respectively. The community chiefly develops on ground sloping between 0 and 25°.

Bridgewater's table (III. 2.a) is summarised in Table XXXIX. To it have been added the constancy lists for the Nodum with Viola riviniana (mapping unit 32), the Nodum with Sieglingia (mapping unit 33) and one list from the Festuceto-Callunetum Ratcliffe 1966.

All five of Bridgewater's variants are included in Table XXXIX in order to give a complete picture of the community but only one is directly concerned in the present discussion. This is the

Festuca ovina variant

Bridgewater's data for this comes entirely from Widdybank Fell (near Slapestone Sike). Although he describes the variant as a "species-rich heather moor", it must be noted that the vegetation most closely conforming to this description is the nodum with Calluna (m.u. 4) of the Seslerio-Mesobromion. Nevertheless, the heather moor of mapping unit 32 (col. A) and the species-poor grassland of mapping unit 33 (col. B) both of whose Aufnahmen come from a greater area of Widdybank Fell, may each be placed within the Festuca ovina variant. Also referable to it is a single Aufnahme (col. C) from the four Ratcliffe (1966) has termed the Festuceto-Callunetum<sup>#</sup>. Bridgewater notes that several species which are occasionally present in the vegetation are not included in his Aufnahmen. This probably accounts for the high number of companion species with constancies V and IV which have now been introduced into his table. Mapping unit 33 has been segregated as the Anthoxanthum odoratum sub-variant (col. B), therefore Bridgewater's original analyses together with Ratcliffe's Aufnahme (col. C) and mapping unit 32 (col. A) have been termed the typical sub-variant.

Vaccinium myrtillus heath - Deschampsia flexuosa complex  
Bridgewater 1970

Bridgewater distinguishes the following four communities within this complex: Rhytidiadelphus loreus community - southern Scotland; Empetrum nigrum community - North Yorkshire moors, Durham, Cumberland; Deschampsia flexuosa community - Brecon and Pembroke to Cumberland and Northumberland; Pteridium aquilinum community - lowland county Durham. The Widdybank vegetation has been placed in the

Empetrum nigrum community  
Table XL

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# The other three Aufnahmen along with mapping unit 4 have been referred earlier in the present work to the Seslerio-Caricetum pulicaris Shim. 1968 emend., sub-ass. typicum, Calluna-Empetrum variant (cf. Table V).

The Phanerogam cover is about 100%; the Cryptogam ranges widely but averages around 70%. The mean species number of 13 is a little higher than in the Calluna vulgaris community; that of the Rhytidiadelphus loreus variant is 18. The angle of slope of the terrain lies between 0° and 75° and often exceeds 20°.

Again, Bridgewater's table (III.3.b) for the whole community is summarised and the Widdybank data added to the relevant variant. This is the

Rhytidiadelphus loreus variant

Although both the Nodum with Empetrum and Erica (m.u. 26, colA) and the Nodum with Pteridium and Deschampsia flexuosa (m.u. 31, col. B) have been placed here, it is apparent from the details of the complete community given in Table XL that the position of mapping unit 31 is not clearly defined as it has one or more differentials, sometimes at high constancies, for a number of other variants. In addition, this nodum is not unlike some variants of the Deschampsia flexuosa community (defined by the presence of Agrostis tenuis and Galium saxatile and the absence of Empetrum nigrum) of the same complex. However, in this case also, the nodum has affinities with several variants, notably the Vaccinium vitis-idaea variant (differentiated by Pohlia nutans and Pteridium aquilinum in addition) which is found in dry exposed situations in the north Yorkshire moors on peat of 5 cm or more in depth. Nevertheless emplacement in the Rhytidiadelphus loreus variant gives a greater degree of "fit" and maintains the relationship with mapping unit 26.

As with the Calluna vulgaris community Festuca ovina variant, Bridgewater's data for the Rhytidiadelphus loreus variant comes only from the Slapestone Sike region. The possession by these two variants from Widdybank Fell of four differentials in common - Rhytidiadelphus loreus, Ptilidium ciliare, Cladonia arbuscula and Festuca ovina - is in keeping with the factor of soil mineral nutrients underlying their differentiation (see above).

To accommodate the mapping units, two sub-variants have been erected - one is the damper Erica tetralix sub-var. (col. A) differentiated by Erica tetralix, Carex binervis, Molinia caerulea and Trichophorum cespitosum ssp. germanicum, and the other is the drier Carex pilulifera sub-var. differentiated only by this species.

Bridgewater's original data has been referred to a typical sub-var.

From the foregoing it is evident that this classification of Widdybank heaths is not entirely satisfactory but it is felt to be the best that can be achieved at the moment, using the available data and whilst the synsystematics of European heaths is under review (Bridgewater 1970).

It will have been realised that the availability of Bridgewater's survey has enabled a fairly narrow approach to be adopted in this particular syntaxonomic study. Mention may also be made, however, of some related vegetation which has either been previously supposed to be represented on Widdybank Fell or which might be expected to be so.

Ratcliffe (1966) refers to the existence there of both a Callunetum vulgaris McV. and R. 1962 and a species-poor Agrostofestucetum McV. and R. 1962 but does not give any detailed vegetation analyses. The first refers, no doubt, to mapping unit 31 now placed in the Vaccinium myrtillus heath-Deschampsia flexuosa complex-Empetrum nigrum community. Bridgewater classifies the Scottish vegetation in the Erica cinerea heath-Vaccinium myrtillus complex-Hylocomium splendens community although remarking that this vegetation is transitional from the Ulicion nanae (in which the Erica cinerea heath is placed) to the Vaccinium myrtillus heath. Part of the vegetation included in the Scottish species-poor Agrostofestucetum has been placed in the Festuco-Nardetum ass. nov. prov. of the Ranunculo-Anthoxanthion as already stated. The remaining lists are sufficiently different from mapping unit 33 and from Bridgewater's Festuca ovina variant not to be grouped with them. This is also true for those Aufnahmen not placed in the Festuco-Nardetum of the Festucetum Eddy, Welch and Rawes 1969.

Pigott's (1956) list from Cronkley Scar of a "dry heather moor" with Arctostaphylos, Calluna and Vaccinium species is similar to some Aufnahmen of mapping unit 31 from Falcon Clints. He also mentions a "grassland on unaltered limestone ... dominated by Festuca ovina and Agrostis spp. with scattered patches of heavily grazed Calluna and Vaccinium myrtillus" which probably refers to vegetation now placed in mapping unit 32.

The synsystematic position of the  $\infty$  Nodal group with Calluna  
and Cladonia arbuscula

Table I

Character species of the Nardo-Callunetea and either the Calluno-Ulicetalia or Empetrium or both, are present in all four mapping units, in most cases with high constancies. In addition to those species listed in Table I, the Calluno-Ulicetalia character Arctostaphylos uva-ursi is present in vegetation of mapping unit 31 on Falcon Clints. (The relevant Aufnahme is given below.) The differentiation of the  $\infty$  nodal group from the noda of the Violion caninae on the basis of character and differential species, however, is not at all sharp. Just as Calluno-Ulicetalia/Empetrium characters feature in the  $\infty$  nodal group with Nardus and Juncus squarrosus, so several Nardetalia/Violion caninae species are abundant in some noda of the  $\infty$  nodal group with Calluna and Cladonia arbuscula. Nevertheless, all members of the latter group of characters, except Galium saxatile, have their optima in the first nodal group and, conversely, the constancies and cover values of Calluna, Hypnum and Empetrum are greater in the  $\infty$  nodal group with Calluna and Cladonia arbuscula.

The problem has been exacerbated by the small number of character species available and by their uncertain status in the British Isles. Therefore, the classification of these four noda into an alliance separate from the other three of the class has been much influenced by the optimal occurrences of the species, the general physiognomy of the communities and, in the case of mapping unit 33, by noting its affinity to another nodum (m.u. 32) more definitely referable to the alliance. Although all noda are more or less strongly referable to the Empetrium each can also be allied, to a greater or lesser degree, to another higher classificatory unit.

Mapping unit 26 shows an affinity to the Ericion tetralicis since it has the alliance characters Erica tetralix, Trichophorum cespitosum ssp. germanicum and Juncus squarrosus with constancies of IV, III and I respectively. The difficulties of distinguishing in the field this mapping unit from mapping unit 23 of the Ericion have already been mentioned. The overall affinities of the one to the Empetrium nigri and of the other to the Ericion tetralicis

can be seen in a comparison of the constancies of the relevant character species in Table I.

The phytosociological relationships of mapping unit 31 are interesting in two respects. First, there is a connection with another alliance of the Calluno-Ulicetalia. The Ulicion nanae character Erica cinerea has been recorded in three Aufnahmen made on Falcon Clints and it should also be noted that Vaccinium myrtillus, another character of this alliance (Schubert 1960), is most abundant in this mapping unit. This alliance, however, in its true form does not reach as far east as Upper Teesdale; Bridgewater (1970) has found that it is confined to the extreme western parts of Britain, as has already been seen.

The second notable phytosociological feature of this nodum is the occurrence in its communities on Falcon Clints of several species which suggest that this area was formerly wooded. An illustration is provided by the following Aufnahme made amidst the block scree on Falcon Clints. Since the site was rather inaccessible, the probability that the Aufnahme was incomplete was noted in the field and it was later found to be too fragmentary to be included with the other data for mapping unit 31 in Table XXXVIII.

Aufnahme 410

Size of Aufnahme 1 sq m; Total cover 100%; Aspect SW; Slope 90°.

Arctostaphylos uva-ursi	9.5	Populus tremula	(+)
Calluna vulgaris	(+.2)	Sorbus aucuparia	+ (seedling)
Empetrum nigrum	(+)	Teucrium scorodonia	2.3
Vaccinium myrtillus	(+.2)	Deschampsia flexuosa	4.3
Polypodium vulgare	+.2	Festuca ovina	3.3
Galium saxatile	+.2	Agrostis canina	+.2

Polypodium and Teucrium were also recorded on Falcon Clints in Aufnahmen which have been included in this mapping unit and are shown in Table XXXVIII. Additional species recorded are given below; the general distribution in Britain of at least part of them is in woodlands.

Pteridium aquilinum	Blechnum spicant
Dryopteris filix-mas	Juniperus communis
Crataegus monogyna	Betula pubescens
Digitalis purpurea	Solidago virgaurea
Lonicera periclymenum	Hypericum pulchrum
Holcus mollis	Luzula pilosa

(Blechnum is also a component of mapping unit 31 in other parts of the Fell)

Many of these species figure in the lists of characters and differentials given by Westhoff and den Held (1969) for the class, order and alliance of deciduous woodlands of acidic to mildly basic soils and others are present in these communities inter alia. The remaining species of the list from Falcon Clints are representative of various woodland types. The character and differential species are: Quercetea robori-petraeae Br.-Bl. et R. Tx. 1943 and Quercetalia robori-petraeae R. Tx. (1931) 1937 em. 1955 characters: Lonicera periclymenum, Pteridium aquilinum, Hypericum pulchrum plus four other species.

Differentials of Quercetea robori-petraeae and Vaccinio-Piceetea Br.-Bl. apud Br.-Bl., Siss. et Vl. 1939 (pine forest and associated juniper scrub vegetation) from all other classes: Vaccinium vitis-idaeae, V. myrtillus, Sorbus aucuparia, Blechnum spicant plus seven other species.

Quercion robori-petraeae (Malcuit 1929) Br.-Bl. 1932 characters: Holcus mollis, Teucrium scorodonia, Populus tremula (transgressive) plus seven other species

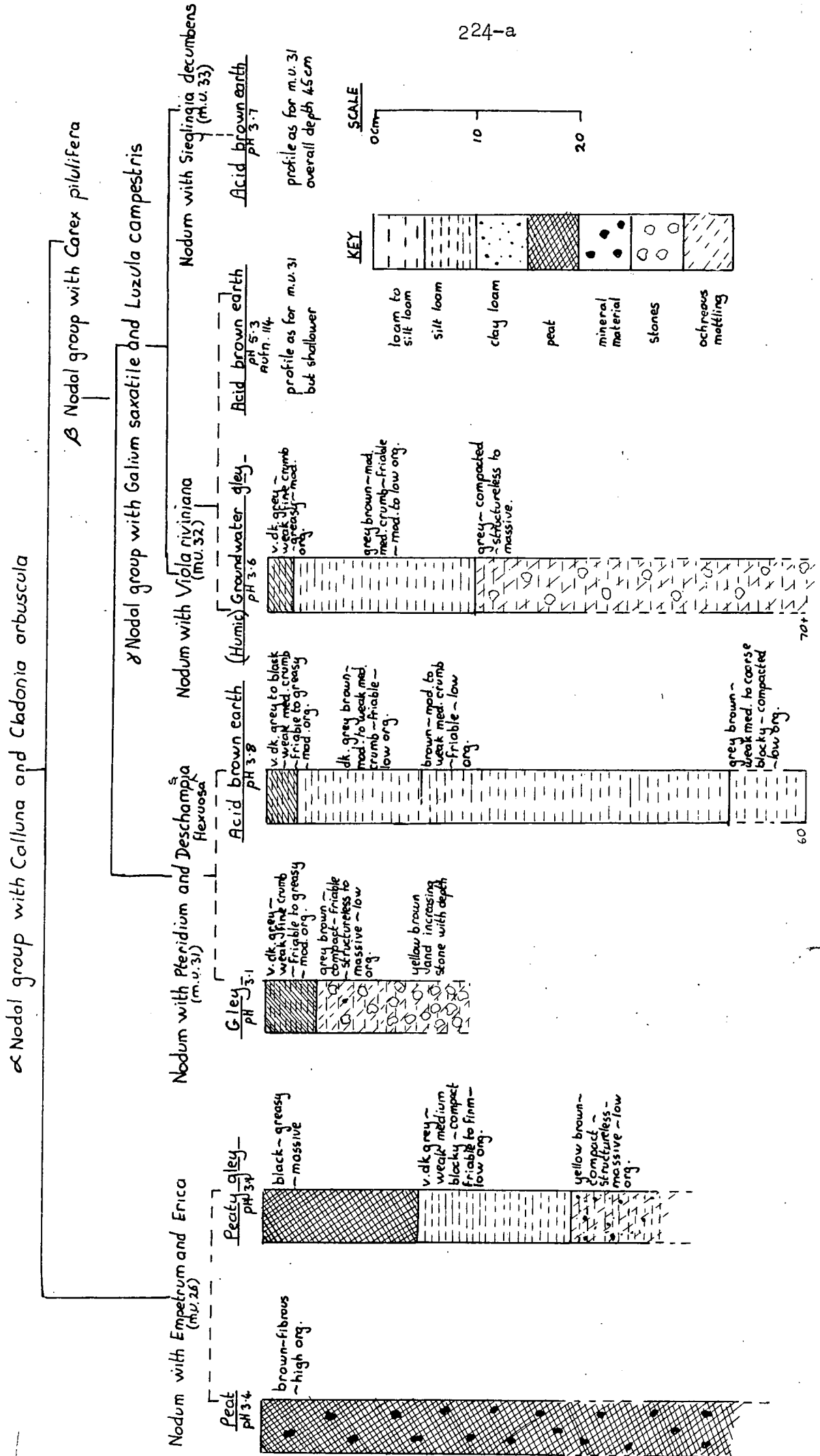
Juniperus communis, Betula pubescens, Solidago virgaurea, Luzula pilosa and Polypodium vulgare are all found in associations of the Quercion robori-petraeae as are many of the heath species e.g. Calluna vulgaris, Empetrum nigrum, Dicranum scoparium etc.

These findings are in striking accordance with the remark of Oberdorfer (1957) that the destruction of communities of the Quercion robori-petraeae gives rise to a secondary development of heaths of the Calluno-Ulicetalia or, occasionally, to rough grasslands of the Nardetalia. This is reiterated by Westhoff and den Held with reference to the Vaccinio-Genistetalia (synonymous with a large part of the Calluno-Ulicetalia) and they also mention a similar secondary development of these heaths following destruction of vegetation of the Vaccinio-Piceetea.

In passing, it may be observed that the Calluno-Ulicetalia and the Quercetalia roboris-petraeae (syn.: Quercetalia roboris-sessiliflorae Tx.) were at one time united to form the Querceto-Ulicetea Br.-Bl. 1947 (Lebrun et al 1949).

A few remarks remain to be made about the phytosociological affinities of the other two nodes in the  $\mathcal{C}$  nodal group. The

FIG. XVI. DIAGRAMMATIC SOIL PROFILES OF THE  $\alpha$  NODAL GROUP WITH *CALLUNA* AND *CLADONIA ARBUSCULA*



communities of mapping unit 32 contain a few species - for example, Koeleria cristata constancy III, Carex capillaris constancy II - which are characteristic of/found in the Seslerio-Mesobromion vegetation. The differences in character species content between this nodum and the nodum with Calluna (m.u. 4), its Seslerio-Mesobromion counterpart with Empetrium influences, can be clearly seen from Table I.

Some reduction in character species constancy is seen in mapping unit 33 (Calluna, Empetrum) and the syntaxonomic position of these degraded heath communities must be elucidated with reference to the related mapping unit 32. In addition to the isolated occurrences shown in Table I of the Brometalia character Koeleria cristata and the Seslerio-Mesobromion differential Cornicularia aculeata, patches of Sesleria caerulea a sub-alliance character, are also found in this grassland.

The soils of the Nodal group with Calluna  
and Cladonia arbuscula

Fig. XVI and Table XLI

The floristic separation of the nodum with Empetrum and Erica (m.u. 26) from the other three noda is substantiated when their soils are considered. The peats and peaty gleys of this nodum have an organic matter content (mean L.o.I. 68.6%) which is strikingly higher than that of any other substrate and is in harmony with the differentiation of this nodum by such species of wet habitats as Erica, Molinia and Trichophorum. The nitrogen content for mapping unit 26 is similarly much higher than the values for the other noda.

The soils of the remaining three noda are united in having much lower and very similar organic matter content. Although the data are rather scanty, it would seem that a constant feature may well be the development of these noda upon acid brown earths despite the greater pH and calcium content those of mapping unit 32 appear to have. From field experience it is felt that this soil type rather than a (humic) groundwater gley is most usually associated with the nodum.

The chemical composition of the acid brown earth recorded for Aufnahme 114 of mapping unit 32 is strikingly similar to those of the shallow brown earths, only about 30 cm deep and developed

over metamorphosed limestone, underlying mapping unit 4 of the Seslerio-Mesobromion (cf. Table VI) and Fig. II whose mean values are: pH 5.4; L.o.I. 19.23%; Ca<sup>++</sup> 10.03 m eq/litre. (The Ca<sup>++</sup> content of Aufnahmen 114 seems abnormally high as it is greater than many of the values for the other Seslerio-Mesobromion noda.) This pedological proximity correlates well with the floristic affinity of the two noda already described.

PART III

GENERAL DISCUSSION

## GENERAL DISCUSSION

These concluding remarks deal with the vegetation of Widdybank Fell as a whole and are concerned with two issues:

- (i) The status of the "Teesdale Assemblage";
- (ii) The status of the vegetation of Widdybank Fell.

### The Status of the "Teesdale Assemblage"

Table XLII

Before proceeding further it is necessary to explain the term "Teesdale Assemblage". An assemblage is generally defined as an unorganised grouping of plants or animals occurring in a particular locality (cf. Poore 1962). The "Teesdale" assemblage refers to those plant species which are present in Upper Teesdale sensu lato (cf. the Introduction) and are of phytogeographical interest since they have a disjunct distribution in the British Isles.

The members of the assemblage shown in Table XLII are taken from the selection of species made by Pigott (1956) and by Bradshaw (1970). Only those found in the present survey have been included in the Table although a few not given in the earlier works have been added. This review of the Teesdale assemblage, therefore, refers only to Widdybank Fell and to the Seslerio-Mesobromion communities on Cronkley. The species are grouped according to their synsystematic affinity (Nordhagen 1936, Oberdorfer 1957, 1962, Moore 1968, Shimwell 1968, 1969, 1971c, Westhoff and den Held 1969) and the majority of these relationships have been mentioned in the preceding text. The information on the Seslerio-Mesobromion characters comes from Shimwell (1971c); his earlier work (1968) does not differentiate between characters and differentials of this sub-alliance.

About 60% of the species shown in Table XLII fall into one of two groups; they are character or differential species or frequently present in communities of either the Seslerio-Mesobromion or the Caricion dayallianae or their relevant orders. Several others are similarly valid for the Kobresio-Dryadion (Elyno-Seslerietea) or the Caricion bicoloris-atrofuseae (Tofieldietalia), two arctic-alpine alliances. Most of the remaining species are characteristic or differential of the Violetea

calaminariae, Cratoneurion (Montio-

Cardaminetea), Erico-Sphagnion or Sphagnion fusci (Oxycocco-Sphagnetea) or Calluno-Ulicetalia (Nardo-Callunetea). Two others, Plantago maritima and Armeria maritima are characters of the Asteretea tripolii (grass and herb-rich salt marsh vegetation) and its alliance Armerion maritimi respectively although they are also known as members of the flora of upland calcareous habitats.

The synsystematic units to which the mapping units have been assigned are repeated for reference at the end of Table XLII. Examination of the table shows that the members of the Teesdale assemblage are concentrated in the orders and alliances for which they are characteristic.

It must be pointed out that the classification has been based as much on comparatively widespread characters as on those belonging to the Teesdale assemblage. For example, a comparison with Table I shows that in addition to the rare Helianthemum canum, Anthyllis vulneraria etc. other Brometalia characters - Koeleria<sup>gracilis</sup>, Gentianella<sup>amarilla</sup>, Helianthemum chamaecistus and Helictotrichon pratense - are present, often abundantly, in mapping units 1 to 7 and are largely confined to them. Similarly, the Tofieldietalia characters Carex dioica, Drepanocladus revolvens, Campyllum stellatum and Pinguicula vulgaris together with the Caricion davallianae characters Carex lepidocarpa and C. hostiana are frequent in mapping units 8 to 14 of this alliance. Two members of the assemblage are characters of some of the acidophilous vegetation: Sphagnum imbricatum, an Erico-Sphagnion and Arctostaphylos uva-ursi, a Calluno-Ulicetalia character, are each occasionally found in noda referable on the basis of many other character species occurrences (cf. Table I) to these units.

The synsystematic units of especial interest on Widdybank and Cronkley Fells are the Seslerio-Mesobromion and the Caricion-davallianae. Each is represented by communities of high species diversity and has a floristic affinity with another alliance - the Kobresio-Dryadion and the Caricion bicoloris-atrofuscae respectively. Other species-rich vegetation - although somewhat less so - is referable to the Thlaspeion calaminariae, Cratoneurion or Ranunculo-Anthoxanthion. None of these alliances is represented in a very 'typical' form since the communities contain species characteristic of other alliances, notably the Seslerio-Mesobromion and/or the Caricion davallianae. The ~~blanket bog~~ Erico-Sphagnion blanket-bog covering provides additional floristic interest

as the occasional occurrence therein of two Sphagnion fusci characters and three differentials causes these communities to form part of a geographically extensive series linking the British blanket bog Erico-Sphagnion and Sphagnion fusci vegetation. In general, however, the communities of the Caricion curto-nigrae, Oxycocco-Sphagnetea and Nardo-Callunetea form the species-poor background to the other vegetation types and contain few members of the Teesdale assemblage.

The various soil types associated with the noda have been described and discussed in the appropriate sections and therefore only their most important features need to be repeated here. It may be remembered that the rendzinas, brown calcareous soils, brown earths, calcareous gleys and moss hummocks of the Seslerio-Mesobromion, Caricion davallianae, Thlaspeion calaminariae, Cratoneurion and Ranunculo-Anthoxanthion are, broadly, of a higher pH, calcium and free carbonate content and lower organic matter content than the flushed peats, peaty gleys, peats and acid brown earths of the other vegetation types. There are, however, transitions between these two groupings in, for example, the occurrence of mapping units 12 and 13 of the Caricion davallianae, on peaty gleys and flushed peats respectively. The members of the soil complex can, therefore, be sequentially arranged along several gradients, the foremost being high-low pH, mineral-organic, high calcium-low calcium and wet-dry.

The occurrence of the distinctive Teesdale flora has been linked with particular characteristics of their soils. Pigott and Walters (1954) note that one of the common features of a number of rare species sites ("localities") including Widdybank Fell, is the presence of base-rich rock or the drainage water therefrom, another being the absence of the naturally dominant woodland. Both Pigott (1956) and Godwin and Walters (1967) cite the peculiar geology (i.e. the presence of metamorphosed pure limestone) in addition to the climate as contributory factors. Welch and Rawes (1969) have found that moisture tensions greater than that at permanent wilting point are experienced in most summers in the bare sugar limestone soil. They point out that this will prevent many species from colonising it until there has been an accumulation of humus with a consequent increase in moisture content. Finally, evidence is provided by Park, Rawes and Allen (1962) and by Jeffrey (1971) that nutrient deficiency has also to be taken into consideration. They particularly cite the low availability of phosphate (cf. Grime 1963 a and b) which may be affected by the presence of heavy metals such as lead (Jeffrey 1971).

Marshall (1971) has shown that the members of the Teesdale assemblage are chiefly concentrated in communities (referable to the Seslerio-Mesobromion and Caricion davallianae) of low primary production. Concurrent with this there is a very low organic matter content of the soil. Related communities, of the Empetrition and Caricion curto-nigrae, on soils richer in organic matter have a greater productivity with which the rarities are unable to compete successfully. To these stresses already mentioned must be added those of grazing and trampling by sheep and rabbits.

Rather than deal with individual species or particular environmental factors, van der Maarel (1971) seeks to explain the rich flora of Teesdale from the viewpoint of various types of community influenced simultaneously by the environmental gradients mentioned above. A similar approach has also been suggested by Bellamy et al (1969) and by Bridgewater (1970).

Some mention must now be made of the theories of pattern (changes in space) and process (changes in time) in vegetation which have been developed by Dutch ecologists over the last few years.

This has led to the definition of four main types of environment (van der Maarel 1966). Two of these are special cases of the other two which are themselves recognised as being but opposite ends of a series (van Leeuwen 1966). The term "boundary zone" is often used instead of "environment" as the regions under discussion are defined according to their differences from those adjacent (cf. van der Maarel 1966). The first of these opposites is the Limas convergens environment or ecotone in which a small number of species, each of a high primary production, is represented by a large number of individuals giving vegetation of a coarse granulation and having sharp boundary lines with the adjacent communities. The habitat is notable for its strong and often irregular fluctuations, e.g. in water-table, the presence of saline and fresh water etc., and there is a consequent instability of the vegetation with time. Characteristic species of such an environment are those of the weed communities of the Plantaginetea majoris.

This environment is in marked contrast to the Limas divergens boundary zone or ecocline in which exist many species, each often of only a few individuals forming a small-scale mosaic which on casual inspection may appear rather homogeneous. This boundary, forming a

transitional zone between two contrasting environments, can be stable for many years. Its occurrence is associated with such environmental gradients as organic-mineral, dry-wet, base-poor - base-rich in which the first of each pair is at the top of a topographic gradient, i.e. "poor dominates rich". These are seen in the lagg zone of bogs on limestone, the slopes on limestone hills where the tops are covered by poor soils and the border between salt marsh and fresh dune valleys (van Leeuwen 1966; Westhoff 1971). A well-known example of such an environment is the Trifolio-Geranietea whose species-rich, often calcicolous, communities form the boundary zones between scrub and grassland. To this, Bridgewater (1970) adds various associations of the Tofieldietalia, a point of special interest to Widdybank Fell. Superimposed on the environmental gradients can be a fluctuating one of, for example, a water-table, giving an unstable form of this environmental type (and mutatis mutandis for the limes convergens).

Bridgewater points out that species which are rare in a given locality can be found in either type of boundary zone as both may provide habitats which do not otherwise occur in the area. However, the limes divergens environment is especially rich in rarities. The diversity in species content is directly associated with the variety in environmental gradients which can include the influence of animals and man (van der Maarel 1966).

Bellamy et al (1969) and Bridgewater (1970), using transects of contiguous 1/16 sq m quadrats, have discovered small-scale limes convergens situations on Widdybank Fell but the present study has not been made in sufficient detail to detect these. Although the limes convergens/divergens concept is usually applied to small-scale vegetation pattern within a defined area, van der Maarel (1971), Bellamy et al and Bridgewater all speculate upon the existence in Teesdale of a large-scale limes divergens situation. The present author would like to expand on this further with particular reference to the vegetation of the Seslerio-Mesobromion and Caricion davallianae each of which may be considered to constitute a limes divergens boundary zone, the first throughout all its geographical range, the second over part.

The Seslerio-Mesobromion was erected by Oberdorfer (1957) to cater for those communities of the Mesobromion lying at higher altitudes than normal and infiltrated by arctic-alpine species of the Elyno-Seslerietea. The sub-alliance occurs in the eastern foothills of the Pyrenees, the

pre-alpine parts of north-central Europe and on the Swedish island of Öland (Shimwell 1971 a and c). In the British Isles it forms a broad zone across northern England and is also present in western Ireland. The British localities differ from the continental ones in that the Seslerio-Mesobromion does not lie adjacent to the arctic-alpine grass heaths of the Elyno-Seslerietea (Shimwell 1968, 1969, 1971a) although these are present in north-west Scotland, northern Ireland and in a single locality in north Wales.

It may therefore be argued that the sub-alliance Seslerio-Mesobromion forms a large-scale transition zone between the lowland, western/central European Mesobromion and the arctic-alpine Elyno-Seslerietea. In the communities of this sub-alliance on Widdybank Fell, there are not only species of the Elyno-Seslerietea and Kobresio-Dryadion which are at the southern limit of their ranges and are rare in the British Isles, but there are such Festuco-Brometea characters as Helianthemum canum, Hippocrepis comosa and Scabiosa columbaria and the Mesobromion character Carex ericetorum at or near their northern extremities and also, in several cases, rare in British Mesobromion grasslands.

A similar situation can be suggested for the calcareous flushes and sedge marshes of the Caricion davallianae. Found in them on Widdybank are Juncus triglumis and Minuartia verna, both characters of the arctic-alpine alliance Caricion bicoloris-atrofuscae which is represented in a few localities in central and north-west Scotland. Widdybank and Cronkley Fells are the only English sites for Kobresia simpliciuscula which is a member of the continental Caricion bicoloris-atrofuscae communities. In these flushes also, however, are several Tofieldietalia and Caricion davallianae characters, e.g. Juncus alpinoarticulatus, Bartsia alpina, Cinclidium stygium, Camptothecium nitens, which are rare in the other British communities of the alliance. Both these Seslerio-Mesobromion and Caricion davallianae communities provide habitats for Plantago maritima, a character of the lowland salt-marsh class Asteretea tripoli. Armeria maritima, a characteristic of the Armerion maritimae of this class, is present in the Widdybank Caricion davallianae communities.

It may be suggested that the occurrence of members of the Teesdale assemblage, other than Plantago and Armeria, in mapping units of classes in which they are not normally found, is due to these nodes being again rather atypical of their class (or order) and being related overall either

to the Seslerio-Mesobromion, i.e. the Thlaspeion calaminariae mapping unit V, nos. 21 and 20 of the Ranunculo-Anthoxanthion, and no. 32 of the Empetrion, or to the Caricion davallianae - mapping units 20 and 19 of the Ranunculo-Anthoxanthion, 15 of the Caricion curto-nigrae and 25 of the Violion caninae. These nodes, therefore, contribute to the transitional nature of the vegetational complex.

The Widdybank Erico-Sphagnion blanket bog vegetation, dominated by Calluna and Eriophorum vaginatum, forms part of another large-scale transition zone as it contains two characters and three differentials of the Sphagnion fusci. (One species of each group is a member of the Teesdale assemblage.) This sequence links the Welsh, northern English and southern Scottish Erico-Sphagnion communities with those of the Sphagnion fusci, also dominated by Calluna and Eriophorum vaginatum, in the Scottish Highlands. The other Erico-Sphagnion nodum on Widdybank provides a suitable habitat for Sphagnum imbricatum, a comparatively rare character of this alliance.

The presence of the various edaphic gradients mentioned above - wet-dry, high-low pH, mineral-organic, high-low carbonate - is considered to provide the necessary environmental conditions for the limes divergens situation on Widdybank and, by analogy, on Cronkley Fells. This has given rise to very varied vegetation which, when compared with that in places of high disturbance such as river shingle, has rather faint boundaries. This phenomenon necessitated the use of as many species as possible to distinguish the mapping units in the field. The blanket peat covering of the Fell with the calcareous grasslands below provide the necessary organic and acid over mineral and calcareous gradient (cf. van der Maarel 1971).

The maintenance of the Dutch semi-natural species-rich communities by the gradient situations mentioned above, by grazing and mowing which keep the standing biomass at a low level and by the absence of any fertiliser addition, is also described by van der Maarel. This is exactly the same situation as that obtaining on Widdybank Fell where sheep and rabbits graze and where, as Jeffrey (1971) has shown, the addition of phosphate caused such an increase in productivity of the "non-rare" species, e.g. Festuca ovina, F. rubra, that Kobresia which was initially dominant was almost eliminated.

Within this large-scale limes divergens pattern are to be found small-scale boundary zones. Most notable, perhaps, are the hummocks of blanket

bog (mapping unit 28 - Erico-Sphagnion) set amidst various calcareous flushes of the Caricion davallianae, an organic-acid-dry over mineral-base rich-wet gradient, noted by van der Maarel (1971) to occur only in arctic-alpine and oceanic limestone areas. The limes convergens situations described by Bellamy et al (1969) and by Bridgewater (1970) also occur within this general limes divergens context.

#### The Status of the Vegetation of Widdybank Fell

The final subject for consideration is the extent to which the vegetation of Widdybank Fell and, where sufficiently known, of Cronkley is unique in Britain.

Almost all the noda described on Widdybank Fell have been assigned, together with related British vegetation, to an association or to a comparable grouping. Some of these have been described previously whilst others are newly defined. Several associations need only be given a brief mention as they are widespread in Britain, although there may be an extreme member on Widdybank Fell. In general, they are very poor in members of the Teesdale assemblage. Other associations are more restricted in their distribution; one is found in the north Pennines alone, whilst a few are either in central and north-west Scotland and Teesdale or in these parts of Scotland, north Wales and more extensively in the north Pennines. In some of these associations the species of the Teesdale assemblage are prominent although any rôle as differentials is usually (but not exclusively) played at the level of variant or below<sup>#</sup>.

The various parts of these associations which are exclusive to Widdybank Fell are listed below and distinguished within the hierarchical arrangement by an asterisk.

Some of the most widespread vegetation falls into the Nardo-Juncetum squarrosum (Nordh. 1920) Bùk 1942 of the Violion caninae (Table XXXVI) although mapping unit 25 is very different from the rest of the association. Similarly, the Empetrium communities have been placed in Bridgewater's (1970) Vaccinium Myrtillus heath Calluna vulgaris complex - Calluna vulgaris community (Table XXX) and Deschampsia flexuosa complex - Empetrum nigrum community (Table XL). In the former, the Widdybank vegetation is referable

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<sup>#</sup> The descriptions and definitions of the associations are compiled from analyses of vegetation which generally encompass a greater geographical area than the ranges of the individual members of the assemblage.

CONSPECTUS OF THOSE ASSOCIATIONS WITH COMPONENTS (\*)  
CONFINED TO WIDDYBANK AND CRONKLEY FIELDS

Class: Festuco-Brometea

Order: Brometalia erecti

Alliance: Mesobromion

Sub-alliance: Seslerio-Mesobromion

Ass: Seslerio-Caricetum pulicaris Shim. 1968 emend. p.p.

Sub-ass. typicum p.p.

\* Calluna-Empetrum var. Shim. 1968

\* Carex ericetorum var.

\* Rhytidium sub-var. Shim. 1968 emend.

\* Kobresia sub-var.

\* Kobresia var. Shim. 1968 emend.

\* typical sub-var.

\* Carex lepidocarpa sub-var.

Class: Molinio-Arrhenatheretea

Order: Arrhenatheretalia

Alliance: Ranunculo-Anthoxanthion

Ass: Festuco-Nardetum ass. nov. prov.

Sub-ass. Caricetosum pulicaris

Ditrichum var. p.p.

\* Plantago maritima sub-var.

\* Cardamine facies

\* Sesleria facies

typical var. p.p.

\* Sesleria sub-var.

Sub-ass. galietosum saxatilis p.p.

Cirsium palustre var. p.p.

\* typical sub-var.

Class: Montio-Cardaminetea

Order: Montio-Cardaminetalia

Alliance: Cratoneurion

Ass.: Cratoneuretum commutati ass. nov. prov.

Sub-ass. cardaminetosum pratensis p.p.

Cratoneuron filicinum var. p.p.

\* Carex dioica sub-var.

Sub-ass. saxifragetosum aizoidis p.p.

Alchemilla glabra var. p.p.

\* typical sub-var.

Class: Parvocaricetea

Order: Caricetalia nigrae

Alliance: Caricion curto-nigrae

Ass.: Violo-Epilobietum palustris ass. nov. p.p.

Sub-ass. caricetosum pulicaris

\* Potamogeton var.

variant with bryophytes p.p.

\* Carex lepidocarpa sub-var.

Juncus effusus var. p.p.

\* Polygala serpyllifolia sub-var.

CONSPECTUS (continued)

Class: Parvocaricetea (contd.)

Order: Tofieldietalia

Alliance: Caricion davallianae

Ass.: Pinguiculo-Caricetum dioicae ass. nov. p.p.

\* Sub-ass. equisetum variegati

\* Sesleria var.

\* Juncus triglumis - Gymnostomum var.

\* Juncus triglumis sub-var.

\* Gymnostomum sub-var.

Sub-ass. eleocharetosum p.p.

Saxifraga-Scorpidium var. p.p.

Succisa sub-var. p.p.

\* Juncus acutiflorus facies

typical var. p.p.

\* typical sub-var.

Class: Nardo-Callunetea

Order: Calluno-Ulicetalia

Alliance: Empetrion nigri

Vaccinium myrtillus heath Bridgewater 1970

Calluna vulgaris complex

Calluna vulgaris community

\* Festuca ovina var.

\* typical sub-var. nom. nov.

\* Anthoxanthum sub-var. nov. prov.

to a separate variant - the Festuca ovina variant - and in the latter, the Rhytidiadelphus loreus variant which is rather more widespread has had to be especially divided to accommodate the Teesdale vegetation.

The three mapping units of the Oxycocco-Sphagnetum have each been accommodated within associations described by Moore for the British Isles and, in the case of mapping unit 24, for western Europe: Narthecio-Ericetum tetralicis Moore (1964) 1968 (Table XXX, m.u. 23 - Ericion tetralicis), Erico-Sphagnetum magellanicum Moore (1964) 1968 - sub-atlantic race (m.u. 24 - Erico-Sphagnion) and Vaccinio-Ericetum tetralicis Moore 1962 (m.u. 28 - Erico-Sphagnion, Table XXXII).

It is probable that elsewhere in Britain there is vegetation closely related to the nodum of Whin Sill block scree (Table II) but these communities have yet to be described.

The associations Violo-Epilobietum palustris ass. nov. (Table XX) and Festuco-Nardetum ass. nov. prov. (Table XVI) have been described to include the Widdybank vegetation of the Caricion curto-nigrae and Ranunculo-Anthoxanthion respectively. Both can be divided into an oligo-meso-trophic and a meso-eu-trophic sub-association and in each association the Upper Teesdale (sensu lato) representatives of the second sub-group, the caricetosum pulicaris, are the only non-Scottish members of the sub-association.

One of the Caricion curto-nigrae noda has been referred to a variant (that with Potamogeton polygonifolius) which appears to be confined to Widdybank but this may be an artefact due to insufficient sampling of other localities. The other four fall into the other two variants (with bryophytes and with Juncus effusus) of the sub-association; each variant has one sub-variant recorded for Widdybank Fell alone (mapping units 15 and 17) and one (the typical sub-var. in each case) which also occurs in the Moor House N.N.R. and in the Scottish Highlands (mapping units 16 and 18).

A similar geographical distribution is seen in the case of the Widdybank representatives of the Festuco-Nardetum caricetosum pulicaris. One sub-variant of each variant of the sub-association is present on the Fell whilst the other is confined to Scotland. The Plantago maritima sub-var. of the Ditrichum var. is represented by two facies (mapping units 19 and 20), the typical sub-var. being present in the Scottish Highlands; the counterpart of the typical var. - Sesleria sub-var. (m.u. 21) being the typical sub-var. found in Skye. Two members of the Teesdale assemblage, Sesleria caerulea and Plantago maritima, are therefore sub-variant or facies differentials and a third, Carex capillaris, is one of the

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differentials of the Ditrichum flexicaule var. (Related vegetation found at Moor House is referable to the Festuco-Poetum sub-ass. sub-alpinum (Shim. 1968). The fourth mapping unit (no. 22) of this alliance has been referred to the oligo-meso-trophic galietosum saxatilis which is well represented in north Wales in addition to the localities mentioned above. Mapping unit 22 forms one sub-variant of the Cirsium palustre var.; the other two sub-variants occur in north Wales.

A similar close relationship with Scottish vegetation is seen in the spring-head and similar communities classified within the Cratoneuretum commutati ass. nov. prov. (Cratoneuron, Table XII) although some from Ireland are also placed here. Both sub-associations are represented on Widdybank Fell. The Carex dioica sub-var. (also present at Moor House) of the Cardaminetosum pratensis, Cratoneuron filicinum var. forms a floristic-geographic link between the lowland Irish typical sub-var. and all the Scottish vegetation of the association. This includes both the Saxifraga aizoides var. of the cardaminetosum, found in the Highlands and on Skye, generally above 1,700 ft (578m), and almost all the communities of the saxifragetosum aizoides. However, three Widdybank Aufnahmen form the Alchemilla var. typical sub-var. of the latter sub-association. Saxifraga aizoides is the only member of the Teesdale assemblage to play a part in the differential species groups.

The single nodum of the Violetea calaminariae on Widdybank Fell comes within the Minuartio-Thlaspeetum Shim. 1968 achilletosum, mesobromion var. (Table VIII) whilst being transitional to the cladonietosum which is found at Moor House and in other parts of the north Pennines. Shimwell (1968) has shown that this variant is not confined to Widdybank Fell since all his analyses for it come from Derbyshire.

The Caricion davallianae noda have been used with analyses from other parts of the north Pennines (Shimwell 1968), the Scottish Highlands (McVean and Ratcliffe 1962) and Skye (Birks 1969) to form the Pinguiculo-Caricetum dioicae ass. nov. (Table XXVI). Of its four sub-associations, one is entirely confined to Widdybank Fell and another is also represented on it. Various members of the Teesdale assemblage are directly concerned in the differentiation of sub-associations, variants and sub-variants; one, Kobresia simpliciuscula, is a local (Upper Teesdale) character of the association.

Mapping units 8, 9 and 14 are placed with the appropriate analyses from Ratcliffe (1966) and Shimwell (1965) in the equisetosum variegati. This is unique to Widdybank Fell and has a Sesleria var. (m.u. 8) and a Juncus triglumis-Gymnostomum var. (syn.: gravel flushes Pigott 1956). The latter is divisible into the Juncus triglumis sub-var. (m.u. 9), also differentiated by Juncus alpinoarticulatus, and the Gymnostomum sub-var. (m.u. 14) whose other differentials are Minuartia verna and Sagina nodosa. The molinietosum is confined to various sub-montane parts of the north Pennines and the thalictro-saxifragetosum to the Scottish Highlands and Skye.

The remaining sub-association, the eleocharetosum, is found in the Highlands, on Skye and on Widdybank, its only English station; both variants are present here. The Saxifraga-Scorpidium var., Succisa sub-var., Juncus acutiflorus facies occurs on Widdybank as mapping unit 11 (and as Pigott's (1956) turfy marshes); the other facies (and members of the variant) are found in the Scottish localities. Each sub-variant of the typical var. - Nardus sub-var. (m.u. 12) and typical sub-var. (m.u. 13) - is present on Widdybank Fell and in central and north-west Scotland, but the English locality is the chief site for the latter.

Certain parts of the Seslerio-Mesobromion association, the Seslerio-Caricetum pulicaris Shim. 1968 emend. (Table V) have been described from Widdybank and Cronkley Fells only. The consideration given to the possibility of erecting a separate sub-association, differentiated by Carex capillaris, Cladonia arbuscula, Polygonum viviparum, Ditrichum flexicaule and Viola rupestris, for this area has already been mentioned. This was, however, rejected as these species' constancies were only about III and with the addition of the analyses from the present survey there was the possibility that Shimwell's overall view of the association was becoming distorted. Nevertheless, it seems clear that certain components of the sub-ass. typicum are confined to these Fells, i.e. the Kobresia (m.u. 1) and Rhytidium (m.u. 2) sub-vars. of the Carex ericetorum var., the Calluna-Empetrum var. (m.u. 4) and the typical (m.u. 6) and Carex lepidocarpa (m.u. 7) sub-vars. of the Kobresia var., several of which have previously been described by Shimwell (1968). The remaining two mapping units (3 and 5) form part of the typical var. which is much more widespread in the north Pennines. The sub-ass. dryadetosum is present on Cronkley but is also in Littondale (Yorkshire); Shimwell mentions the occurrence in a single locality on Widdybank (not covered in the present survey) of the sub-ass. of Saxifraga hypnoides and Cochlearia alpina, chiefly found on the limestone

slopes of Mickle, Little and Great Dun Fells above 2,100 ft (640m). It is seen in this association, also, that some of the Teesdale assemblage are instrumental in differentiating several of its components.

Shimwell (1968, 1969) remarks that the Seslerio-Caricetum pulicaris communities in Teesdale differ on two counts from those in the Craven district (another part of the north Pennines with a distinctive plant assemblage). They are poorer in Mesobromion species and have a richer complement of Kobresio-Dryadion species. Indeed, some of the Teesdale vegetation is more closely related to the latter alliance than are any other representatives of the association. These comments, in conjunction with those above concerning the possibility of erecting a separate sub-association of the Seslerio-Caricetum pulicaris for Teesdale, highlight the distinctive nature of the Seslerio-Mesobromion communities on Widdybank and Cronkley Fells.

The occurrence in Teesdale of communities of the Seslerio-Caricetum pulicaris which has its centre of distribution and is at its most typical further to the south and at lower altitudes, is complemented by the presence of representatives of the Pinguiculo-Caricetum dioicae which is more widespread in the Scottish Highlands, often up to 2,900 ft (884m). In contrast to the abundance of lowland species in the Seslerio-Caricetum pulicaris, two of the five characters of the Pinguiculo-Caricetum (Tofieldia pusilla and Kobresia simpliciuiscula) are arctic-alpine in distribution. Furthermore, the sub-ass. equisetosum variegati which is exclusive to Widdybank (and probably Cronkley) Fell is principally defined by arctic-alpine or montane species.

The distinctive phytogeographic position of Widdybank and Cronkley Fells is further brought out by Bradshaw's (1970) consideration of the distribution in Britain according to 10 km. squares <sup>of the National Grid and</sup> /of twelve members of the Teesdale assemblage, mostly characters of the Brometalia/Seslerio-Mesobromion or Tofieldietalia/Caricion davallianae. Only in 35/82 which includes parts of Widdybank and Cronkley do all twelve occur; seven are found in 35/83 (the northern end of Widdybank) and in the Scottish Highlands there is one square with five and some with four. In most of the British localities of these species, however, only one is present.

The Zurich-Montpellier techniques of phytosociological analysis has provided a firm basis for the comparison with vegetation in other parts of Britain and in Europe as a whole of the communities containing these and the other members of the Teesdale assemblage. It is to be hoped

that further British studies along these lines will be undertaken more readily than has often been the case in the past.

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## REFERENCES AND BIBLIOGRAPHY (i)

### References

- BALME, O.E., (1954). Biological flora of the British Isles:  
Viola lutea Huds. J. Ecol., 42, 234-240.
- BELLAMY, D.J., (1967). Ecological studies on some European mires.  
Ph.D. Thesis, Univ. of Durham.
- BELLAMY, D.J., BRIDGEWATER, P., MARSHALL, C. and TICKLE, W.M., (1969).  
Status of the Teesdale Rarities. Nature, 222, 238-243.
- BERSET, J., (1969). Pâturages, prairies et marais montagnards et  
sub-alpine des préAlpes Fribourgeoises. Edits. Univ. Fribourg.
- BIRKS, H.J.B., (1969). The Late-Weichselian and present vegetation  
of the Isle of Skye. Ph.D. Thesis, Univ. of Cambridge.
- BIRSE, E.L. and ROBERTSON, J.S., (1967). Vegetation. In: The soils  
of the country round Haddington and Eyemouth. Mem. Soil Survey  
of Scotland. H.M.S.O.
- BRADSHAW, M.E., (1965). Upper Teesdale in danger. Countryside, 20, (N.S.)  
193-197.
- BRADSHAW, M.E., (1970). The Teesdale Flora. In: Durham County and  
City with Teesside. (ed.) Dewdney, Durham, pp. 141-152.
- BRADSHAW, M.E. and CLARK, W. A., (1965). Flora and Vegetation. In:  
The natural history of Upper Teesdale. (ed.) Valentine, Newcastle,  
pp. 23-42.
- BRAUN-BLANQUET, J., (1949a) Übersicht der Pflanzengesellschaften  
Rétiens. Part II. Vegetatio, 1, 129-156.
- BRAUN-BLANQUET, J., (1949b). Übersicht der Pflanzengesellschaften  
Rétiens. Part III. Vegetatio, 1, 285-316.
- BRAUN-BLANQUET, J., (1964). Pflanzensociologie. 3rd Ed. Vienna.
- BRAUN-BLANQUET, J., (1967). Vegetationsskizzen aus dem Baskenland mit  
Ausblicken auf das weitere Ibero-Atlantikum. Part II. Vegetatio, 14,  
1-126. (SIGMA Commun. 174).
- BRAUN-BLANQUET, J., PINTO DA SILVA, A.R. and ROZEIRA, A., (1964).  
Résultats de trois excursions géobotaniques à travers le Portugal  
septentrional et moyen. Part III. Landes à cistes et ericacées  
(Cisto-Lavanduletea et Calluno-Ulicetea). Agron. Lusit., 23, 229-313.
- BRAUN-BLANQUET, J. and TUZEN, R., (1952). Irische Pflanzengesellschaften.  
Veröff. Geobot. Inst. Rübel, 25, 224-421.
- BRIDGEWATER, P., (1970). Phytosociology and community boundaries of the  
British heath formation. Ph.D. Thesis, Univ. of Durham.
- CHAPMAN, S.B., (1964). The ecology of Coom Rigg Moss, Northumberland.  
Part I. Stratigraphy and present vegetation. J. Ecol., 52, 299-313.
- CLAREHAM, A.R., TUTIN, T.G., and WARBURG, E.F., (1962). Flora of the  
British Isles. 2nd Ed. Cambridge.

REFERENCES AND BIBLIOGRAPHY (ii)

References (contd.)

- CORNER, R.W., (1972). Juncus alpinoarticulatus Chaix. in southern Scotland. Watsonia, 9, 58.
- DAHL, E. (1956). Rondane: Mountain vegetation in south Norway and its relation to the environment. Diss. Skr. Norske. Vidensk. Akad. 1. Mat. Naturv. Kl. 3, 1-374, Oslo.
- DICKSON, J.H., (1966). Dicranum undulatum Brid.; Distribution maps of bryophytes in Britain. Trans. Brit. Bryol. Soc., 5, 366.
- DIERSCHKE, H., (1969). Natürliche und naturnahe Vegetation in den Tälern der Böhme und Fintau in Her Lüneburger Heide. Mitt. Flor.-soz. Arbeitsgem., N.F. 14, 377-397.
- DIXON, H.N., (1954). The Student's Handbook of British Mosses. 3rd Ed. Eastbourne.
- DOING, H., (1963). Übersicht der floristischen Zusammensetzung, der Struktur und der dynamischen Beziehungen niederländischer Wald- und Gebüschgesellschaften. Meded. Landb. hogesch. Wageningen, 63, 1-60.
- DUNCAN, U.K., (1970). Introduction to British Lichens. Arbroath.
- DU RIETZ, G.E., (1954). Die Mineralbodenwasserzeigergrenze als Grundlage einer natürlichen Zweigliederung der Nord- und Mitteleuropäischen Moore. Vegetatio, 5/6, 571-585.
- DUVIGNEAUD, P., (1949). Classification phytosociologique des tourbières de l'Europe. Bull. Soc. Roy. Bot. Belg., 81, 59-129.
- EDDY, A., WELCH, D. and RAWES, M., (1969). The Vegetation of the Moor House National Nature Reserve in the northern Pennines, England. Vegetatio, 16, 239-284.
- EDGEELL, M.C.R., (1969). Vegetation of an upland ecosystem: Cader Idris, Merionethshire. J. Ecol., 57, 335-359.
- EHLENBURG, H., (1963). Die Vegetation Mitteleuropas mit den Alpen in kausaler, dynamischer und historischer Sicht. Stuttgart.
- ERNST, W., (1965). Ökologisch-Soziologische Untersuchungen der Schwermetall-Pflanzengesellschaften Mitteleuropas unter Einschluss der Alpen. Abh. Landesmus. Naturkde. Münster., 27, 1-54.
- ERNST, W., (1968a). Zur Kenntnis der Soziologie und Ökologie der Schwermetallvegetation Grossbritanniens. Ber. Dtsch. Bot. Ges., 81, 116-124.
- ERNST, W., (1968b). Das Violetum calaminariae Westfalicum, eine Schwermetallpflanzengesellschaft bei Blankenrode in Westfalen. Mitt. Flor.-soz. Arbeitsgem., N.F. 13, 263-268.
- GIMMINGHAM, C.H., (1964). Maritime and sub-maritime communities in the vegetation of Scotland. (ed.) Burnett, Edinburgh, pp. 67-142.
- GJAEREVOLL, O., (1956). The Plant Communities of the Scandinavian Alpine Snow-beds. Trondheim.

REFERENCES AND BIBLIOGRAPHY (iii)

References (contd.)

- GODWIN, H. and CONWAY, J., (1939). The ecology of a raised bog near Tregaron, Cardiganshire. *J. Ecol.*, 27, 213-363.
- GODWIN, H. and WALTERS, S.M., (1967). The scientific importance of Upper Teesdale. *Proc. B.S.B.I.*, 6, 348-351.
- GOODIER, R. and GRIMES, B.H. (1970). The interpretation and mapping of vegetation and other ground surface features from air photographs of mountainous areas in North Wales. *Photogramm. Rec.* 36, 553-66.
- GRIME, J.P., (1963a). Factors determining the occurrence of calcifuge species on shallow soils over calcareous substrata. *J. Ecol.*, 51, 375-390.
- GRIME, J.P., (1963b). An ecological investigation at a junction between two plant communities in Coombsdale on the Derbyshire limestone. *J. Ecol.*, 51, 391-402.
- GRIMES, B.H. and HUBBARD, J.C.E., (1969). The use of aerial photography in the Nature Conservancy. *Photographic Journal*, 109, 264-267.
- HOLDGATE, M.W., (1955). The vegetation of some springs and wet flushes on Tarn Moor near Orton, Westmorland. *J. Ecol.*, 43, 80-89.
- HUBBARD, C.E., (1954). Grasses: a guide to their structure, identification, uses and distribution in the British Isles. Harmondsworth, Middlesex.
- IVIMEY-COOK, R.B. and PROCTOR, M.C.F., (1965). The plant communities of the Burren, Co. Clare. *Proc. Roy. Ir. Acad.*, 64B, 211-301.
- JAMES, P.W., (1965). A new check-list of British lichens. *Lichenologist*, 3, 95-153, 242-247.
- JEFFREY, D.W., (1971). The experimental alteration of a *Kobresia*-rich sward in Upper Teesdale. In: *The Scientific Management of Animal and Plant Communities for Conservation*. (ed.) Duffey and Watt, Oxford, pp. 79-89.
- JERMY, A.C. and TUTIN, T.G., (1968). *British Sedges*. London.
- JOHNSON, G.A.L., (1965). Geology. In: *The Natural History of Upper Teesdale*. (ed.) Valentine, Newcastle, pp. 12-22.
- JOHNSON, G.A.L., ROBINSON, D. and HORNUNG, M., (1971). Unique bedrock and soils associated with the Teesdale flora. *Nature*, 232, 453-456.
- KING, J., (1962). The *Festuca-Agrostis* grassland complex in south-east Scotland. *J. Ecol.*, 50, 321-355.
- KING, J. and NICHOLSON, I.A., (1964). Grasslands of the Forests and sub-alpine zones. In: *The Vegetation of Scotland*. (ed.) Burnett, Edinburgh, pp. 168-231.

REFERENCES AND BIBLIOGRAPHY (iv)

References (contd.)

- LEACH, W., (1930). A preliminary account of the vegetation of some non-calcareous British screes (Gerölle). *J. Ecol.*, 18, 321-332.
- LEBRUN, J., NOIRFALISE, A., HEINEMANN, P. and VANDEN BERGHEM, C., (1949). Les associations végétales de Belgique. *Bull. Soc. Roy. Bot. Belg.*, 82, 105-199.
- LEEUWEN, C.G. van (1966). A relation theoretical approach to pattern and process in vegetation. *Wentia*, 15, 25-46.
- LEWIS, F.J., (1904). Geographical distribution of the vegetation of the basins of the Rivers Eden, Tees, Wear and Tyne. Part I. *Geogr. J.*, 23, 313-331; Part II. *Geogr. J.*, 24, 267-285.
- LOHMEYER, W., et al, (1962). Contribution à l'unification du système phytosociologique pour l'Europe moyenne et nord-occidentale. *Melhoramento*, 15, 137-151.
- LONGTON, R.E., (1965). *Dicranum spurium* Hedw., Distribution maps of bryophytes in Britain. *Trans. Brit. Bryol. Soc.*, 4, 885.
- MAAREL, E. van der, (1966). Dutch studies on coastal sand dune vegetation especially in the Delta region. *Wentia*, 15, 47-82.
- MAAREL, E. van der, (1971). Plant species diversity in relation to management. In: *The Scientific Management of Animal and Plant Communities for Conservation*. (ed.) Duffey and Watt, Oxford, pp. 45-63.
- MALMER, N., (1968). Über die Gliederung der Oxycocco-Sphagnetea und der Scheuchzerio-Caricetea fuscae in Südschweden. In: *Pflanzensoziologische Systematik - Ber. Int. Symp. 1964* (ed.) Tüxen, Stolzenau/Weser, pp. 293-305.
- MARSHALL, C., (1971). Ecological investigations of some plant communities in the Cow Green area of Upper Teesdale. Ph.D. Thesis, Univ. of Durham.
- MARTIN, W.K., (1965). *The Concise British Flora in Colour*. London.
- McINTOSH, R.P., (1967). The continuum concept of vegetation. *Bot. Rev.*, 33, 130-187.
- McVEAN, D.N. and RATCLIFFE, D.A., (1962). *Plant communities of the Scottish Highlands*. H.M.S.O., London.
- McVICAR, S.M., (1926). *The Student's Handbook of British Hepatics*. 2nd Ed., Eastbourne.
- MEW, G. and BALL, D.F., (1972). Grid sampling and air photography in upland soil mapping: an investigation in the Rhinog mountains of north Wales. *Geogr. J.*, 138, 8-14.

## REFERENCES AND BIBLIOGRAPHY (v)

References (contd.)

- MIYAWAKI, A., (1968). Japanische Hochmoorvegetation. In: Pflanzensociologische Systematik - Ber. Int. Symp. 1964 (ed.) Tüxen, Stolzenau/Weser, pp. 321-324.
- MOORE, J.J., (1962). The Braun-Blanquet system: a reassessment. J. Ecol., 50, 761-769.
- MOORE, J.J., (1968). A classification of the bogs and wet heaths of northern Europe - Ber. Int. Symp. 1964. (ed.) Tüxen, Stolzenau/Weser, pp. 306-320.
- MOORE, J.J., FITZSIMMONS, P., LAMBE, E. and WHITE, J., (1970). A comparison and evaluation of some phytosociological techniques. Vegetatio, 20, 1-21.
- NORDHAGEN, R., (1936). Versuch einer neuen Einteilung der sub-alpinen-alpinen Vegetation Norwegens. Bergens Mus. Aarbok, Nature. Rekke 7, 1-88.
- OBERDORFER, E., (1957). Süddeutsche Pflanzengesellschaften. Bundes. f. Naturschutz u. Landschafts, B 10, Jena.
- OBERDORFER, E., (1962). Pflanzensociologische Exkursionsflora für Süddeutschland und die Angrenzenden Gebiet. 2nd Ed. Stuttgart.
- OBERDORFER, E., et al., (1967). Systematische Übersicht der Westdeutschen Phanerogamen und Gefäßskryptogamen-Gesellschaften. Schriftenr. Vegetationsk. 2, 7-62.
- O'SULLIVAN, A.J., (1968). The Rowland grasslands (Molinio-Arrhenatheretea) of County Limerick. Dublin.
- PARK, K.J.F., RAWES, M. and ALLEN, S.E., (1962). Grassland studies in the Moor House National Nature Reserve, J. Ecol., 50, 53-62.
- PASSARGE, H., (1964). Pflanzengesellschaften des Nordostdeutschen Flachlandes. I. Pflanzensoz. 13, 1-324.
- PATON, J.A., (1965). Census catalogue of British Hepatics. 4th Ed. Ipswich.
- PEARSALL, W.H., (1941). The 'Mosses' of the Stainmore district. J. Ecol., 29, 161-175.
- PERRING, F.H. and WALTERS, S.M., (1962). Atlas of the British Flora. London.
- PIGOTT, C.D., (1956). The Vegetation of Upper Teesdale in the North Pennines. J. Ecol., 44, 545-586.
- PIGOTT, C.D., and WALTERS, S.M., (1954). On the interpretation of the discontinuous distributions shown by certain British species of open habitats. J. Ecol., 42, 95-116.
- POORE, M.E.D., (1955 a, b, c). The use of phytosociological methods in ecological investigations. Parts I, II, III. J. Ecol., 43. 226-244, 245-269, 606-651.

REFERENCES AND BIBLIOGRAPHY (vi)

References (contd.)

- POORE, M.E.D., (1956). The use of phytosociological methods in ecological investigations. Part IV. J. Ecol., 44, 28-50.
- POORE, M.E.D., (1962). The method of successive approximation in descriptive ecology. Adv. in Ecol. Res. 1, 35-68.
- POORE, M.E.D., (1964). Integration in the plant community. J. Ecol., 52 Suppl., 213-226.
- PROCTOR, M.C.F., (1954). A key to the British species of Sphagnum. Trans. Brit. Bryol. Soc., 2, 551-560.
- RANWELL, D., (1960). Newborough Warren, Anglesey. Part II. Plant associates and succession cycles of the sand dune and dune slack vegetation. J. Ecol. 48, 117-141.
- RATCLIFFE, D.A., (1959). The vegetation of the Carneddau, North Wales, Part I. Grasslands, heaths and bogs. J. Ecol., 47, 371-413.
- RATCLIFFE, D.A., (1959b). The mountain plants of the Moffat hills. Trans. Bot. Soc. Edinb., 37, 257-271.
- RATCLIFFE, D.A., (1960). The mountain flora of Lakeland. Proc. B.S.B.I., 4, 1-25.
- RATCLIFFE, D.A., (1964a). Mires and bogs. In: The Vegetation of Scotland. (ed.) Burnett, Edinburgh, pp. 426-478.
- RATCLIFFE, D.A., (1964b). Montane mires and bogs. In: The Vegetation of Scotland. (ed.) Burnett, Edinburgh. pp. 536-558.
- RATCLIFFE, D.A., (1966). A botanical survey of the proposed Cow Green Reservoir site in Upper Teesdale. (unpublished report).
- RATCLIFFE, D.A. and WALKER, D., (1958). The Silver Flowe, Galloway, Scotland. J. Ecol., 46, 407-445.
- RILEY, R., (1956). The influence of the breeding system on the genecology of Thlaspi alpestre L. New Phytol., 55, 319-330.
- SCHUBERT, R., (1960). Die swergstrauchreichen azidiphilen Pflanzengesellschaften Mitteldeutschlands. Pflanzensoz., 11.
- SCHWICKERATH, M., (1940). Aufbau und Gliederung der europäischen Hochmoorgesellschaften. Bot. Jahrb., 71, 249-266.
- SEGAL, S., (1968). Schwierigkeiten bei der Systematik von Moorgesellschaften. In: Pflanzensoziologische Systematik - Ber. Int. Symp. 1964. (ed.) Tüxen, Stolzenau/Weser, pp. 220-229.
- SHIMWELL, D.W., (1968). The Phytosociology of calcareous grasslands in the British Isles. Ph.D. Thesis, Univ. of Durham.
- SHIMWELL, D.W., (1969). The status of the Class Elyno-Seslerietea Br.-Bl. 1948 in the British Isles. Mitt. Flor.-soz. Arbeit gem., N.F. 14, 309-321.

## REFERENCES AND BIBLIOGRAPHY (vii)

References (contd.)

- SHIMWELL, D.W., (1971a,b). Festuco-Brometea Br.-Bl. and R. Tx. 1943 in the British Isles; the phytogeography and phytosociology of limestone grasslands, Parts I and II. *Vegetatio*, 23, 1-28 and 29-60.
- SHIMWELL, D.W., (1971c). Description and Classification of Vegetation. London.
- SINKER, C.A., (1965). The vegetation of the Malham Tarn area. *Proc. Leeds Phil. and Lit. Soc., Sc. Sect.* 8.
- SMIDT, J.T. de, (1966). The inland-heath communities of the Netherlands. *Wentia*, 15, 142-162.
- SMITH, K., (1970). Climate and Weather. In: Durham County and City with Teesside. (ed.) Dewdney, Durham, pp. 58-74.
- SOO, R., (1957). Systematische Übersicht der Pannonischen Pflanzengesellschaften, I. *Act. Bot. Acad. Sci. Hung.*, 3, 317-373.
- SPARLING, J.H., (1968). Biological flora of the British Isles: Schoenus nigricans L. *J. Ecol.*, 56, 883-899.
- SQUIRES, R.H. (1971). Flandrian history of the Teesdale rarities. *Nature*, 229, 43-44.
- STIRLING, A. McG., (1966). Catoscopium nigritum; Distribution maps of bryophytes in Britain. *Trans. Brit. Bryol. Soc.*, 5, 163.
- TALLIS, J.H., (1969). The blanket bog vegetation of the Berwyn mountains, North Wales. *J. Ecol.*, 57, 765-787.
- TANSLEY, A.G., (1949). The British Isles and their Vegetation, Cambridge.
- TURNER, J., (1970). Vegetational History. In: Durham County and City with Teesside. (ed.) Dewdney, Durham, pp. 123-133.
- TURNER, J., HEWETSON, V.P., HIBBERT, F.A., LOWRY, K.H. and CHAMBERS, C. (In Press). The History of the Vegetation and Flora of Widdybank Fell and the Cow Green Reservoir Basin, Upper Teesdale.
- TUTIN, T.C., et al (eds.) (1964). *Flora Europaea*, Vol. I. Cambridge.
- TUXEN, J., (1969). Gedanken über ein System der Oxycocco-Sphagnetetea Br.-Bl. and R. Tx. 1943. *Vegetatio*, 19, 181-191.
- TUXEN, R., (1971). Vorläufige liste von Mitarbeitern am Prodrömus der Europäischen Pflanzengesellschaften. *Vegetatio*, 22, 265-268.
- WARBURG, E.F., (1963). Censüs catalogue of British Mosses. 3rd Ed. Ipswich.
- WARD, S.D., PERKINS, D.F., GOODIER, R., JONES, A.D., (1970). The use of aerial photography for vegetation mapping and vegetation interpretation. In: The Application of Aerial Photography to the Work of the Nature Conservancy. (ed.) Goodier, Edinburgh. pp. 52-65.

## REFERENCES AND BIBLIOGRAPHY (viii)

### References (contd.)

- WATSON, E.V., (1966). British Mosses and Liverworts, Cambridge.
- WELCH, D., (1967). Communities containing Juncus squarrosus in Upper Teesdale, England. *Vegetatio*, 14, 229-240.
- WELCH, D. and RAWES, M., (1969). Moisture regime of soils on metamorphosed limestone in Upper Teesdale. *Trans. Nat. Hist. Soc. Northumberland, Durham and Newcastle-upon-Tyne*. 12 (N.S.)
- WESTHOFF, V., (1971). The dynamic structure of plant communities in relation to the objectives of conservation. In: *The Scientific Management of Animal and Plant Communities for Conservation*. (ed.) Duffey and Watt, Oxford. pp. 3-14.
- WESTHOFF, V. and den HELD, A.J., (1969). *Planten gemeenschappen in Nederland*. Zutphen.
- WHITTAKER, R.H., (1962). Classification of natural communities. *Bot. Rev.*, 28, 1-239.
- WILLIAMS, J.T. and VARLEY, Y.W., (1967). Phytosociological studies of some British grasslands. Part I.: Upland pastures in northern England. *Vegetatio*, 15, 169-189.
- WILLIAMS, W. T. and LAMBERT, J.M., (1966). Multivariate methods in plant ecology. Part V.: Similarity analysis and information analysis. *J. Ecol.*, 54, 427-445.

### Bibliography

- BRAUN-BLANQUET, J. and MOOR, M., (1938). *Verband des Bromion erecti*. *Prodromus der Pflanzenges.* 5.
- BRAUN-BLANQUET, J. and TUZEN, R. (1943). *Übersicht der höheren Vegetationseinheiten Mitteleuropas*. *SIGMA Comm.* 84, 1-11.
- HADAC, E. and VANA, J., (1967). Plant communities of mires in the western part of the Krkonose mountains, Czechoslovakia. *Folia Geobot. Phytotax.* 3, 213-254.
- KOCH, W., (1926). *Die Vegetationseinheiten der Linthebene unter Berücksichtigung der Verhältnisse in der Nordost-Schweiz*. *Jahrb. St.-Gallischen Naturwiss. Ges.* 61.
- KOVACS, M., (1962). *Die Moorzweiden Ungarns. Die Vegetation ungarischer Landschaften* 3, Budapest.
- MAAS, F.M., (1959). *Bronnen, bronbeken en bronbossen van Nederland, in het bijzonder die van de Veluwezoom*. *Diss. Wageningen Meded. Landb. hogesch. Wageningen*, 59, 1-166.

REFERENCES AND BIBLIOGRAPHY (ix)

Bibliography (contd.)

- SCHWICKERATH, M., (1933). Die Vegetation des Landkreises Aachen und ihre Stellung im Nördlichen Westdeutschland. Aachener Beitr. Heimatk. 13.
- SOO, R., (1964). A Magyar flóra és vegetáció rendszertani-növényföldrajzi kézikönyve I (Synopsis systematico-geobotanica florum vegetationisque Hungariae I). Akadémiai Kiadó, Budapest.
- TUXEN, R., (1937). Die Pflanzengesellschaften Nordwestdeutschlands. Mitt. Flor.-soz. Arbeitsgem. 3.
- TUXEN, R. (1962). Zur systematischen Stellung von Spezialisten-Gesellschaften. Mitt. Flor.-soz. Arbeitsgem. N.F. 9, 57-59.
- VLIEGER, J., (1937). Aperçu sur les unités phytosociologiques supérieures des Pays-Bas. Ned. Kruidk. Arch. 47, 335-353.

## APPENDIX A

### SCALES OF SOCIABILITY AND COVER/ABUNDANCE

#### Sociability classes

- |             |   |   |  |
|-------------|---|---|--|
| Sociability | 1 | - | growing once in a place, singly                            |
| "           | 2 | - | grouped or tufted  |
| "           | 3 | - | in troops, small patches or cushions                       |
| "           | 4 | - | in small colonies, in extensive patches or forming carpets |
| "           | 5 | - | in great crowds or pure populations                        |

#### Domin scale of cover/abundance values

- |               |   |   |
|---------------|---|---|
| Class +       | - | a single individual, cover small                            |
| 1             | - | scarce, 1-2 individuals, cover small                        |
| 2             | - | less than 1%  |
| 3             | - | 1 to 4%   |
| 4             | - | abundant, cover 5 to 20%                                    |
| 5             | - | abundant, cover 20 to 25%                                   |
| 6             | - | 25 to 33%   |
| 7             | - | 33 to 50%   |
| 8             | - | 50 to 75%   |
| 9             | - | 75 to 90%   |
| 10            | - | 90 to 100%  |
| (+)           | - | sp. outside area of Aufnahme although in similar vegetation |
| o             | - | of low vitality   |
| (superscript) |   |   |

Cover/abundance is followed by sociability in most analyses, but where a single figure is given it refers to cover/abundance.

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## APPENDIX B-(i)

### PRODUCTION OF THE VEGETATION MAPS

#### 1 Practical field details

Both sets of vertical aerial photographs, each suitable for stereoscopic viewing, were taken in October 1969 by Meridian Airways Ltd. Figs. C and D are copies of one member of each set.

#### Mapping at 1:2,500 (cf. Fig. C)

Each print, at 1:2,500 in natural colour, was enclosed between two sheets of dimensionally-stable plastic whose edges were bound by PVC tape to obtain a waterproof finish. The use of Mars "Staedler" pencils on the semi-matt overlay of "Astrafoil" (manufactured by D.E.P. Ltd.) allowed corrections to be made during work in the field. The semi-matt finish, however, caused some reduction in light transmission.

Each mapping unit was distinguished on the overlays by the number (or, in the case of one, by the letter) referred to in the vegetation descriptions in Part II. A small-scale mosaic of two mapping units of the same or different alliances was shown by two numbers (x, y). Places of hummock/hollow vegetation of different mapping units were indicated by a fraction, the upper figure referring to the unit of the hummock.

Even at this comparatively large scale some vegetational detail had to be omitted. The smallest size which it was cartographically possible to show was 4 sq mm representing an area of 25 sq m on the ground; anything smaller than this had to be included in one of the types of complex mentioned above or slightly enlarged or ignored. As necessary, enlargements were made of vegetation forming a narrow band around another type, e.g. blanket bog hummock, or situated alongside a stream. The combination, found in the channels left by the mining excavations, of one vegetation type along the base with others on the near vertical sides, could not be shown as such but had to be represented by the normal striped complex for a mosaic.

Ten vegetation types, each of limited distribution, could not be assigned to any mapping unit nor, initially, to any syntaxonomic unit. In general they were in places of high disturbance due to fluctuating water-table or trampling. A separate system of numbering was used for

## APPENDIX B - (ii)

these and species lists were made. It was subsequently found that two of these types could be considered with the nodal group of the Caricion curto-nigrae although they were not referable to this alliance only.

### Mapping at 1:10,000 (cf. Fig. D)

The black and white aerial photographs (at 1:7,500) were printed directly on to weather-resistant Projection Durafilm Opal (manufactured by Criterion (Plates, Papers and Films) Ltd.) and thus could be used without protective overlays. Mapping was carried out using an 0.2 mm Rotring Rapidograph pen and waterproof Peliken Special ink which could, however, be removed by the application of water with firm pressure.

The mapping units were the nodal groups except for those alliances represented by only a single nodum, i.e. mapping was at the alliance level. As the smallest size delimitable on the map (2x2mm) represented 21 x 21m on the ground at 1:10,000, large areas of the Fell had to be shown as mosaics and indicated as described below. Even so, a considerable amount of detail was lost at this scale compared with the other, which was four times greater. Some of the effects of this can be seen in a comparison of Figs. C and D; see also Methods - Part I, Section (ii).

### 2 Colouring scheme employed

Because of its relevance to the foregoing, the colouring scheme is described here although, following the sequence of operation, it should come after the next section.

The colours used in both maps are the same and follow the accepted practice in continental Europe. Red/<sup>(pink)</sup>implies dry vegetation; blue, wet vegetation; yellow, man-influenced vegetation; green, woods or wood derived; pastel shades are used throughout. The alliances are, therefore, designated as follows (symbols being employed for vegetation of very small area):

APPENDIX B - (iii)

<u>Colour/symbol</u>	<u>(Sub-) Alliance</u>	<u>Class</u>
pink	Seslerio-Mesobromion	Festuco-Brometea
purple (or 'v')	Thlaspeion calaminariae	Violetea-calaminariae
yellow	Ranunculo-Anthoxanthion	Molinio-Arrhenatheretea
light blue	Caricion curto-nigrae)	Parvocaricetea
dark blue	Caricion davallianae )	
gold-brown	Ericion tetralicis	Oxycocco-Sphagnetea
light brown	Erico-Sphagnion	
dark green	Violion caninae	Nardo-Callunetea
light green	Empetrion nigri	
mid-green	Androsacion vandellii	Asplenieta rupestris
▲	Cratoneurion	Montio-Cardaminetea

A neutral colour at 1:2,500 indicates unclassifiable vegetation and at 1:10,000 a multi-alliance complex.

At both scales, a mosaic of two alliances is shown by a vertical striping of the relevant colours; at 1:2,500 the hummock/hollow mosaics involving two alliances are depicted by dots representing the hummock vegetation upon a background of the colour for the hollows. At 1:10,000 black dots are overprinted on the colour for an alliance occupying only 85 to 90% of the area.

The mapping units at 1:2,500 are each distinguished on the map by their reference numbers since in nearly all cases the same colour is used for more than one nodum. At 1:10,000 there is but a single mapping unit in an alliance and separate identification is necessary only for the complexes of several alliances each of which is distinguished on the map by a letter.

Areas lacking vegetation due to natural or anthropogenic causes are shown at both scales by black stippling.

### 3 Photogrammetric and cartographic procedures

The 1:2,500 photographs with overlays and those at 1:7,500 were passed to the Department of Surveying, University of Newcastle-upon-Tyne, for photogrammetric handling in preparation for the production of the topographic and vegetation maps. The processes were the same for the 1:10,000 map and for the five at 1:2,500. Four of these were based on an area, 1 km sq, of the National Grid and the fifth was a slightly enlarged 1 km sq.

APPENDIX B - (iv)

The material passed through the following photogrammetric and cartographic stages:

- (a) Using a Wild A8 stereo plotter, a base map of the vegetation boundaries, corrected for vertical displacement and other distortions, was drawn on to a dimensionally-stable plastic-based film ("Ozatex"). This corresponded with two similar maps of contours and of rivers and roads on the same material.
- (b) A "guide image", effectively a "negative" was produced. This was a reproduction of the base map on "astra scribe", a film with a coloured coating which was marked with a sapphire-pointed scribing tool.
- (c) A contact process resulted in the formation of a "positive", a black-lined image on clear film. Similar positives were made for the contours and for the roads and rivers.
- (d) Numbering, lettering etc. was added to the positives.
- (e) From each positive several "strip masks" were produced. Their number depended upon the number of strengths of the primary colours - red, blue, yellow - to be used in printing each map sheet. The strip masks were formed in a contact process whereby the vegetation boundaries were etched on to an orange-coated film.
- (f) The coating of the film was removed for those areas which were to be printed in colour.
- (g) A "positive" on a photographic dimensionally-stable film was made by a contact process by which the areas to be printed<sup>were</sup> rendered black. Numbers and letters were added to the areas of vegetation.
- (h) The following printing plates were produced and used in the order given:

sepia - topographic contours, National Grid, lettering;  
black - vegetation boundaries and numbers, "boxes" for key, etc.;

yellow )  
blue ) various strengths - given by line screens  
red )

## APPENDIX C - (i)

### SOIL ANALYSES

The soil analyses were carried out by Dr. M. Hornung of the Nature Conservancy Welsh Office, Bangor, North Wales, who worked in conjunction with the author to obtain representative sets of soil samples from each nodum. Dr. Hornung has provided the field descriptions of the profiles and the results of the physical and chemical analyses which have been discussed in this work. His terminology for the soil types has been based upon the current (1972) publication of the Soil Survey of England and Wales.

#### Field methods

Six 6" by 1" diameter cores were taken at each sample site and bulked for analysis. In some instances pits were dug and deeper samples taken of the mineral horizon below a comparatively humus-rich surface. In cases of hummock/hollow topography, each element was described and analysed separately.

#### Laboratory methods

The samples were bulked for analysis.

pH : samples air dried; 10g mixed with 25ml distilled water for estimation.

Loss on Ignition: (L.O.I.) samples air dried at 105°C; percentage-weight loss determined after ignition for 16 hours at 375°C. At 375°C calcareous material contributes only slightly to the breakdown, therefore the loss can be taken as an indication of the humic content.

Phosphate (P<sub>2</sub>O<sub>5</sub>): "extractable" in acetic acid; expressed as mg P<sub>2</sub>O<sub>5</sub>/100g sample.

Calcium carbonate: equivalent was calculated from the volume of carbon dioxide evolved from calcareous samples on treatment with acid in a Collins Calcimeter.

Calcium : (and other exchangeable cations not cited) extracted by shaking 5g soil with 200 ml neutral N ammonium acetate for one hour, then filtering the extract for analysis. Calcium was determined by atomic absorption spectrophotometry. The quantities are quoted as milli-equivalents per 100g air-dry (35°C) soil.

APPENDIX C - (2i)

Lead and Zinc : 10g soil shaken with 250 ml/N acetic acid for two hours; 50 ml aliquots removed, remainder shaken for further 14 hours. Concentrations of lead and zinc (ppm) determined on EEL 240 Atomic Absorption Spectrometer. Results given (ppm) are those following shaking for 16 hours. Only a selection of samples was analysed.

Total Nitrogen: determined on air-dry soil on a weight percentage basis. The soil was digested with  $H_2SO_4$ ,  $K_2SO_4$ , and  $H_2O$  and the determination carried out by putting the digests through an Autoanalyser using the indo-phenol blue colorimetric reaction.

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APPENDIX D - (i)

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