ECOLOGY AND TAXONOMY OF MONTANE LICHEN VEGETATION IN THE BRITISH ISLES

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Dedication

TO JOZEFA and AMELIA

This work is dedicated to my partner, Jozefa, for her constant support, both emotionally and financially, during the writing of this thesis, and to my daughter, Amelia, who has only ever known a daddy who is 'thinking'.

I don't mind mountains as scenery; but this passion for clambering about over piles of rock, that's what beats me! ...... Mountains should be abolished. At least that'd stop all these aeroplanes bumping into every other peak.

Captain Haddock in *Tintin in Tibet,* Hergé, 1962

Oh the water, Oh the water, Oh the water.
I hope it don't rain all day.

Van Morrison.

The illustration on the title page is of *Catolechia wahlenbergii*, a rare montane lichen photographed on Aonach Mor (Ben Nevis range) where it is locally abundant.

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Summary

Factors influencing lichen distribution, principally climate and geology, are discussed. The extreme oceanicity of the British climate is identified as the most influential factor in the development of a distinctive lichen vegetation in the area.

Twenty-four species of lichen are recorded for the first time from the British Isles along with, approximately, 50 unidentified taxa. Draft descriptions are provided for 18 undescribed taxa. Keys are provided to difficult groups and genera, i.e. sterile crustose saxicolous and terricolous lichens, *Lecidea, Porpidia, Rimularia* and *Rhizocarpon* subgenus *Phaeothallus*.

Lichens having the centre of their British distribution in montane areas are listed and assigned to a montane sub-zone. Using this list, a comparison is made between the lichen vegetation of three oceanic areas of the British Isles. The importance of the saxicolous lichen vegetation of the oceanic mountains of western Scotland is emphasised and shown to be important in its own right rather than a species-poor outlier of the Scandinavian flora.

The lichen vegetation of those National Vegetation Classification communities in which lichens form a significant part is described. In general, terricolous macro-lichens are shown to correspond with NVC communities but terricolous micro-lichens and saxicolous species do not and need to be treated separately from NVC.

Lichen data from areas of prolonged snow-lie are analysed by TWINSPAN and three un-named, apparently endemic, lichen communities identified. One is restricted to areas of prolonged snow-lie throughout the Scottish Highlands whereas the other two are more widespread in the western mountains but confined to snow-beds in drier, eastern parts of the country. Their composition and affinities are discussed.

Grazing animals are shown to have a devastating effect on upland/montane lichen vegetation, although this is less pronounced at higher altitudes. Grazing is shown to have a qualitative, as well as a quantitative, effect.

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CHAPTER 1

INTRODUCTION

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1•1 REASONS FOR THIS STUDY

The resurgence of interest in lichenology which has occurred in the British Isles over the past few decades has concentrated mainly on epiphytic species and communities with the result that these are now widely used as bio-indicators of pollution levels (Hawksworth & Rose 1976) and the ecological continuity of woodlands (Rose 1976, 1992). Saxicolous (epilithic - growing on rocks) and terricolous (epigaeic - growing on the ground) lichens have received less attention - the only major work on the phytosociology of British lichens (James *et al.* 1977) is very weak when dealing with non-epiphytic communities. More recently additional habitats have been focused on by individual lichenologists (e.g. maritime rocks, church-yards, etc.) but montane areas, although receiving some attention, remain a severely neglected habitat, being the reserve of a few dedicated workers (Coppins 1978, 1979; Gilbert (and co-workers) 1982 onwards; Fryday 1989 onwards). This can be attributed to a number of factors, the most important of which are:-

a) the remote and difficult working conditions. Many workers have commented upon the problems which arise from working in inhospitable and remote areas (McVean & Ratcliffe 1962; Gilbert 1986; Rothero 1991b; Fryday 1995) as these can have a serious effect on the completeness and accuracy of the data collected. Inhospitable weather is a major consideration often making meaningful recording impossible either through persistent rain, low clouds (Fig 1•1) or strong winds, all of which are frequent occurrences in the Scottish mountains during the summer months.

b) the relatively high proportion of undescribed taxa. Many recent publications on British montane lichens either list a number of problematic collections or describe new species (Gilbert *et al.* 1988; Gilbert & Coppins 1992).

c) the specialized nature of the flora. The many rare species, along with the morphological variation and superficial similarity of some of the more frequent ones, means that a high degree of specialized knowledge is required before any useful work can be carried out.

d) many species are difficult, or impossible, to identify in the field with any degree of certainty, even by an experienced worker.

e) the ecology and variability of many species is still poorly understood.

To some extent these problems are self-perpetuating; the montane lichen vegetation remains poorly studied because it is difficult but it is only difficult because it is poorly studied.

Figure 1•1. Goat Fell, Isle of Arran, in poor weather. In such conditions, survival takes precedence over collecting data.

Montane lichens are worthy of study for both academic and applied reasons.

Academic Reasons Over 700 lichen taxa have been recorded from montane regions of the British Isles (393 specialists) compared with 121 vascular plants (Ratcliffe 1991). Lichens are particularly well adapted to the harsh montane environment for a number of reasons:-

a) lower cell specialization renders them less likely to fatal damage
b) they inhabit the area closest to the ground where conditions are most stable
c) they are better able to cope with rapid fluctuations in water availability due to their poikilohydric nature (i.e. they do not maintain a constant water level but dehydrate in drought conditions and quickly rehydrate when moisture becomes available).

Fifty-two species of montane lichens are included in the Red Data Book for Lichens (Church *et al.* 1997). This is approximately 13% of the specialist montane lichen flora and 29% of the total Red Data List of 177 species. There are two possible interpretations of this apparent richness of the montane zone for rare lichens:-

a) the lichen vegetation of the montane zone is poorly understood and many of the species considered rare are, in fact, more widespread.

b) the montane zone does support a far greater number of rare species proportionate to its size than other habitats.

Either case is sufficient justification for further study but it is most probable that there is some truth in both propositions. Certainly some species considered rare until very recently are now known to be fairly widespread or locally frequent in the montane zone, e.g. *Miriquidica complanata, Rimularia mullensis, Stereocaulon tornense* but, equally, others have remained rare in spite of there being apparently suitable habitat available e.g. *Catolechia wahlenbergii, Lecanora achariana, Nephroma arcticum.* It is, however, true that most species are rare because the habitat they require is scarce; either because they have very precise ecological requirements or because that particular habitat is genuinely rare. In particular, a high percentage of rare montane lichens are calcicoles and their rarity is due largely to the very limited extent of high-level calcareous rocks and soils in the British Isles. This also extends to some usually calcifuge species which are on the extreme edge of their range in the British Isles as these appear to require a higher pH substratum here than elsewhere in their range, e.g. *Caloplaca nivalis, Micarea crassipes, Nephroma arcticum.* Even among montane calcicoles there are widespread species, e.g. *Collema glebulentum, Koerberiella wimmeriana* while others are extremely rare, e.g. *Buellia papillata* and *Rinodina mniarea* - both fairly distinctive species but recorded in the British Isles only from the summit heath on Beinn Eighe. It is possible that the more widespread montane calcicoles only require basic flushing (many grow on damp seepage rocks) whereas the rarer ones occur in drier habitats, growing directly on basic rocks or overgrowing bryophytes.

Applied Reasons. Montane eco-systems are extremely fragile and take a long time to recover from any disturbance. However, they are under threat from four main sources, global warming, increased recreational use, over-grazing by red deer and sheep and, at least in the case of snow-bed vegetation, air-borne pollution. Lichens are often confined to very specialized micro-habitats and will be even more susceptible to these disturbances than other plants and, being notoriously slow-growing, will take even longer to recover.

Initiatives to date have identified a number of areas in need of attention:-

a) **General Survey of the Resource** It is a pre-requisite of any ecological research or conservation action that the nature and extent of the resource is well understood. The inadequacy of lichen data in seminal works such as 'A Nature Conservation Review' (Ratcliffe 1977) is now recognised as a serious weakness as, in many montane habitats, lichens are major contributors to the bio-diversity of the eco-system. A more extensive knowledge of this group would greatly improve the assessment of sites for the importance of their vegetation. However, the number of montane lichen taxa which have been discovered in recent years, and which are either new to the British Isles or new to science, clearly indicates that the montane lichen vegetation of the British Isles is far from perfectly understood.

   Despite their importance to the bio-diversity of montane vegetation lichens are usually omitted from plant community studies as the surveyors are unfamiliar with the group. The recently published National Vegetation Classification (Rodwell 1990, 1991, 1992, ~~[illegible]~~) contains very limited lichen data and where these are included the taxonomy and nomenclature are seriously out of date. A better understanding of montane lichen communities will lead to a more thorough appreciation of montane vegetation in general.

b) **Areas of Prolonged Snow-lie** In contrast to vascular plants and bryophytes the lichen vegetation associated with areas of prolonged snow-lie is poorly understood. This habitat is expected to be one of the first affected by global warming and a comprehensive understanding of the distinctive assemblages of lichens associated with this habitat will facilitate the monitoring of future changes in the vegetation.

c) **Effects of Grazing** - There is anecdotal evidence that over-grazing by sheep and red deer is having a detrimental effect on the lichen vegetation of montane areas but there has been no attempt to assess the extent to which this might be occurring.

1•2 AIMS OF THIS STUDY

Recent work in the mountains of the British isles (see section 1•3) has provided us with a great deal of descriptive ecological information but little quantitative data. The present thesis is an attempt to address this as well as attempting to deal with some of the problems outlined above.

For the purpose of this study, 'montane' is taken to include all the land in the British Isles above the potential tree-line. However, as the majority of high ground is in Scotland (98% of ground over 915m - see section 1•4), work has been concentrated on this area. 'Montane' is used in preference to 'Alpine' as the former portrays a much more accurate picure of the British mountains. Some areas, particularly in the west of the country, which clearly fall within the study area, attain only relatively modest altitudes and are generally snow-free due to the effects of the hyperoceanic climate.

In addition to a general study of the resource it deals with some of the problems of identification by including a key to sterile, crustose, saxicolous and terricolous lichens occurring in the study area; these are regarded as a notoriously difficult group. It also gives brief descriptions of all montane species recorded from the British Isles since the publication of *The Lichen Flora of Great Britain and Ireland* (Purvis *et al.* 1992) along with notes on the numerous collections which have eluded satisfactory identification. The most well-known of these are described in detail as a prelude to their formal description as new taxa. New keys are included to genera where the number of montane taxa recognised has increased significantly since 1992.

The areas of prolonged snow-lie have been studied using transects and quadrats. This has allowed their lichen vegetation and the changes in the community composition which occur as the snow-bed is approached to be described.

Relevés have been collected from the major montane NVC communities in all parts of the Scottish Highlands. From these it will be possible to ascertain whether it is necessary to describe any new communities (or sub-communities) based on lichen data.

The effect of grazing has been studied by collecting lichen data from inside and outside exclosures in upland and sub-montane areas of Northern England and Scotland. Lichen biomass and species composition and diversity were recorded.

1•3 HISTORY OF LICHEN RECORDING

It is outside the scope of this thesis to provide a comprehensive review of the investigation of the montane lichen vegetation of the British Isles. Although this would be a fascinating study and much of the literature has been reviewed, it would also require an extensive herbarium search as much work is undocumented and known only from preserved herbarium specimens. The outline given here is intended only as an introduction to the present study, to provide it with a starting place. A general review of the history of lichenology in the British Isles is given in Hawksworth & Seaward (1977) and to individual montane areas by Gilbert and co-workers in a series of papers dealing with those areas (e.g. Coire Cheap, Ben Alder - Gilbert *et al.* 1982; The Cairngorms - Gilbert & Fox 1985; Ben Lawers, Gilbert *et al.* 1988; Ben Nevis range - Gilbert *et al.* 1992; Caenlochan - Gilbert & Coppins 1992; The Lake District - Gilbert & Giavarini 1992; The West of Ireland - Gilbert & Fryday 1996 and to North Wales by Pentecost 1987). The following account is based on these sources.

North Wales appears to have been the first montane area in the British Isles from which lichens were recorded. *Cladonia furcata* was reported by Ray (1696) as having been collected from Carnedd Llewelyn by Edward Lhuyd. Other records made by Lhuyd, who died in 1709, were reported by Dillenius (1742) and by Gibson (Camden 1789). Dillenius visited North Wales in 1725 and collected on Snowdon and Cadair Idris in the company of Brewer, a local man who had previously sent Dillenius lichens from the area. An account of this visit is is given in Brewer's diary (BM; Druce & Vines 1907). Lightfoot made a similar journey in 1773 (Riddelsdell 1905) but added little to the flora.

Lightfoot is the first name to appear in connection with lichen recording in the Scottish mountains. He mentions the Breadalbane Mountains on several occasions in his *Flora Scotica* (1777,1789) but it was Dickson (1790-93) who first discovered the richness of Ben Lawers recording, among other species, *Brigantiaea fuscolutea* and *Cetraria nivalis*. The early 19th century saw activity in the mountains of both Scotland and Wales. Borrer and

Hooker were active in Scotland (Hooker 1821) visiting Ben Lawers, the Cairngorms and, probably, Ben Nevis while the main workers in Wales were Griffiths and Turner who visited Snowdon and the Carneddau respectively (Turner & Dillwyn 1805). Turner, with Dillwyn, also visited the Lake District and recorded several lichens (including *Cornicularia normoerica* and *Thamnolia vermicularis*) from 'the summits of the mountains' (Turner & Dillwyn 1805). Towards the middle of the century Gardiner recorded from Ben Lawers and Caenlochan in Scotland and we obtain the first glimpse of the Irish montane lichen flora with the work of Moore who recorded a number of species from Brandon Mountain in Kerry. These included *Solorina crocea, Umbilicaria arctica* and *U. hyperborea* - although the last two are now generally discounted.

The second half of the 19th century was the most intense period of lichenological activity seen in the British Isles. All the main montane areas were visited although the Lake District and Ireland were less well served than Scotland and Wales. Johnson (1881) and Martindale (1886-90) were active in the Lake District and Larbalestier in Connemara in the West of Ireland but they mostly confined their efforts to low ground and rarely ventured into the mountains. In North Wales, between 1856 and 1879, Leighton undertook the first detailed systematic survey of the mountainous area. He concentrated on the crustose, saxicolous lichens and recorded numerous species for the first time from the British Isles and described several as new to science. In Scotland the newly constructed railway network made the previously remote mountainous areas more accessible with the result that, from around 1860, a number of lichenologists visited the area, mainly the Breadalbane and Cairngorm mountains. The most important of these were Holl (who also visited Wales), Jones & Carroll, Crombie (many of whose records are now considered extremely dubious), Lindsay, Stirton and, in Angus, Ferguson. Between them these workers added numerous species to the British flora and described many new species, amassing a comprehensive knowledge of the lichen vegetation of the Scottish Highlands which has only recently been equalled.

This period of intense activity lasted for around 30 years after which there was a general decline in interest in lichenology with only occasional work being carried out. Wheldon & Wilson (1915) visited Scotland and North Wales, and in Ireland Knowles (1929) and Praeger

(1934) carried out some work. The most important figure, however, was Watson who worked in Scotland, Wales and Ireland and was the first person to attempt to describe the ecology of montane lichens (Watson 1925).

Interest in lichens revived in the early 1960's and the mountains of Scotland were occasionally visited by James, Swinscow, Duncan, Topham and Coppins among others. Unfortunately, although some of this work was published (e.g. James 1965), much of it remained undocumented or only appeared as unpublished reports (James 1976; Coppins 1978 & 1979). James and Coppins also visited North Wales but the main worker in that area in recent times was Clayden whose records from acidic montane rocks are included in Pentecost (1987).

The first person in recent times to pay particular attention to montane lichens was Dr Oliver Gilbert who, with various co-workers, visited and published accounts of many of the most important sites in Scotland, i.e. Coire Cheap in the Ben Alder range (Gilbert *et al.* 1982), the Cairngorms (Gilbert & Fox 1985), N-W Sutherland (Gilbert & Fox 1986), Ben Lawers (Gilbert *et al.* 1988), Ben Nevis (Gilbert *et al.* 1992) and Caenlochan (Gilbert & Coppins 1992) as well as the Lake District (Gilbert & Giavarini 1993) and the West of Ireland (Gilbert & Fryday 1996), describing the lichen vegetation and making numerous ecological observations.

Gilbert concentrated on the potentially most rewarding sites, in particular those with base-rich rocks. It was then necessary to put this information into a context of the overall Scottish montane lichen vegetation. The present author joined Gilbert on his last two surveys and subsequently undertook intensive investigations while carrying out short-term contracts for SNH's predecessors NCC and NCCS (Trotternish, Beinn Eighe, Breadalbane), the NTS (Glen Coe, Kintail, Ardmeanach, Torridon, etc.) and privately (Knoydart, Southern Cairngorms, Sutherland, Creag Meagaidh, etc.).

1•4 FACTORS AFFECTING THE BRITISH MONTANE LICHEN VEGETATION

1•4•1 General nature of the British Mountains

Judged purely on height and extent the montane areas of Britain are, on a world or even European scale, fairly inconsequential. However, they possess certain characters which give them a significance in excess of their height or extent. The most importance of these is the oceanic climate (Ratcliffe & Thompson 1988) which produces a number of plant communities which are either found nowhere else in the world or reach their best development in the British Isles. Although these plant communities, *Calluna vulgaris* and *Racomitrium lanuginosum* heaths and blanket bogs, are of only limited interest for their lichen flora this is, nevertheless, circumstantial evidence that unique or rare lichen communities can be expected in the British mountains. This is also suggested by the development of other plant communities rich in cryptogams, e.g. bryophyte and fern rich communities, as a consequence of the damp, oceanic climate.

Britain is also unusual in possessing a sub-montane zone (i.e. above enclosed farmland but below potential tree-line) which, although derived from woodland, is almost totally treeless and anthropogenic in character. It consists primarily of grasslands for the grazing of domestic animals and deer forest. In Norway the vegetation of this sub-montane zone is composed of *Betula* and *Salix* scrub and medium shrubs but in Britain these communities are confined to inaccessible cliffs and ledges. The effects of grazing by sheep and deer on the lichen flora of this sub-montane zone has not been studied but anecdotal evidence suggests it may be considerable.

A third unusual character of the British mountains is the limited extent of snow-cover - again due to the oceanic climate. This results in a more extreme environment when compared with continental areas where plants are protected from the harshest effects of the winter climate by a thick snow cover. The specialized lichen flora that develops around late snow-beds is of great importance as it is likely to be among the first affected by global warming. The concentrating effect of snow upon acidic deposition means that these communities are also in danger from air-borne pollution.

At a national level the montane areas are important as, although land over 915m (3000 ft) comprises only 0•2% of the land surface, of which 98% is in Scotland (Ratcliffe & Thompson 1988) they are the main remaining area of natural vegetation in the British Isles.

1•4•2 Climate

The general nature of montane climates has been well summarized by Barry 1992. 'Local contrasts of slope angle and orientation give rise to such large variations in local climatic conditions that it seems doubtful whether the concept of a "regional mountain climate" has much validity or value. It is more meaningful to describe the typical range of climatic elements produced in particular topographic situations according to the type of air-flows that occur, bearing in mind the major controls of altitude, latitude and continental location.'

This statement is particularly relevant when considering the effect of climate on vegetation and especially so when dealing with lichens which, being low-growing, are particularly susceptible to small, local variations in climate. An example of this is the contrast in temperature between the exposed, sunny southern slopes of a ridge and the shaded northern ones only a few meters away. This are often far greater than can be experienced over hundreds of miles in a more uniform habitat; a fact well illustrated by the work of Wolfe *et al.* 1949 which is considered in more detail below. It is, however, useful to understand the basic weather pattern upon which the topography acts to produce the local climatic conditions which prevail in any area. Consequently, this section will first give an overview of the climate of the northern part of the British Isles (i.e. Scotland) where most of the mountainous areas are situated. This will be followed by a consideration of the special problems and conditions of the climate of montane areas with brief notes on how the climate of the other major montane areas of the British Isles differ from that of Scotland. It will also give a brief outline of some of the meso- and micro-climatic effects brought about by the topography of the mountains and discuss the Bio-climatic regions of the Scottish Highlands.

1•4•2•1 Overall Climatic Conditions

Of Barry's three 'major controls' the first two - altitude and latitude - are of only minor importance when considering the climate of the British Isles, the British mountains being of relatively low altitude and latitude when considered on a world (or even European) scale. The third factor, 'continental position', is what gives the British climate its special character and, consequently, is of paramount importance to the climatic conditions which prevail in the montane regions of the British Isles.

Oceanicity The British climate is overwhelmingly influenced by the proximity of the large, relatively warm, mass of the North Atlantic Ocean, the prevailing westerly winds giving rise to a climate of extreme oceanicity which decreases across the country from west to east (Fig 1•2). The west coast of Norway does not experience a climate of such extreme oceanicity because above about 60° latitude the prevailing westerly winds give way to prevailing easterly winds due to the rotation of the earth (Kimble 1951). Consequently the hyperoceanic regions of western British Isles experience a climate which, if not unique, is extremely rare elsewhere in the world (Figs 1•3 and 1•4). This can be quantified using Kotilainen's Index of Oceanicity:-

$=Ndt/100\Delta$ where:- N = precipitation (mm)
dt = number of vernal and autumnal days (mean temperature 0-10 C)
Δ = difference between mean temperatures of warmest and coldest months

This was modified by Poore & McVean (1957) who replaced N (precipitation) by $N_{0.0}$ (Number of days with <0•1mm of rainfall) so that the Index becomes:-

$$K_{0.0} = N_{0.0}dt/100\Delta$$

Unfortunately, values for $N_{0\cdot0}$ do not exist in ~~Scandinavian~~ British meterological data and so Poore & McVean used N to compare their degrees of oceanicity. They found that most areas of Scotland have a higher degree of oceanicity than all but the extreme western seaboard of Norway. However, because of the use of 'vernal and autumnal days' this index is applicable only in temperate regions of the world.

More recently Averis (1991) devised a series of oceanicity indices based on annual rainfall divided by temperature range which correlated with oceanic bryophyte distribution (Figs 1•2 - 1•4). He found that the most suitable rainfall value was the number of wet days per annum (i.e. days with more than 1mm precipitation) and the best temperature range the difference between the highest monthly mean daily maximum temperature and the lowest monthly mean daily minimum temperature (Fig. 1•2). Unfortunately these two parameters are only available for the British Isles and so these were replaced in other areas by the number of rain days per annum (i.e. days with more than 0•1mm precipitation) and the difference between the highest and lowest monthly mean daily temperatures (Figs 1•3 and 1•4). This index gives excellent correlation for temperate areas but also gives high oceanicity values for some tropical areas with little variation in temperature but which are very hot and provide a poor environment for oceanic bryophytes. To compensate for this a temperature range value of the maximum deviation of monthly mean daily temperature from 10 C was used.

The main features of the British climate are all due to its extreme oceanicity. These are:-

a) a low seasonal variation in cloudiness and temperature.

b) high atmospheric humidity and precipitation (mostly falling as rain).

c) high winds.

d) high altitudinal temperature lapse-rate.

The other major character of the British climate is its extreme changeability. This is due to the position of the islands mid-way between two semi-stable weather systems, the 'Iceland low' and the 'Azores high', where the alternation between high and low pressure is most rapid; the 'perturbation duct'. This zone, which lies across the Central Atlantic Ocean and extends into the British Isles, results in an average of between 160 and 180 depressions and 110 frontal systems passing over the islands every year. The main track of these systems is between Scotland and Iceland and the British mountains, being situated mainly in the north-west of the country, are exposed to their full effects. The location of the British mountains also results in their being more influenced by polar air than that from the tropics.

Figure 1·2 Map showing increasing degree of oceanicity across the British Isles from east to west. (from Averis 1991).

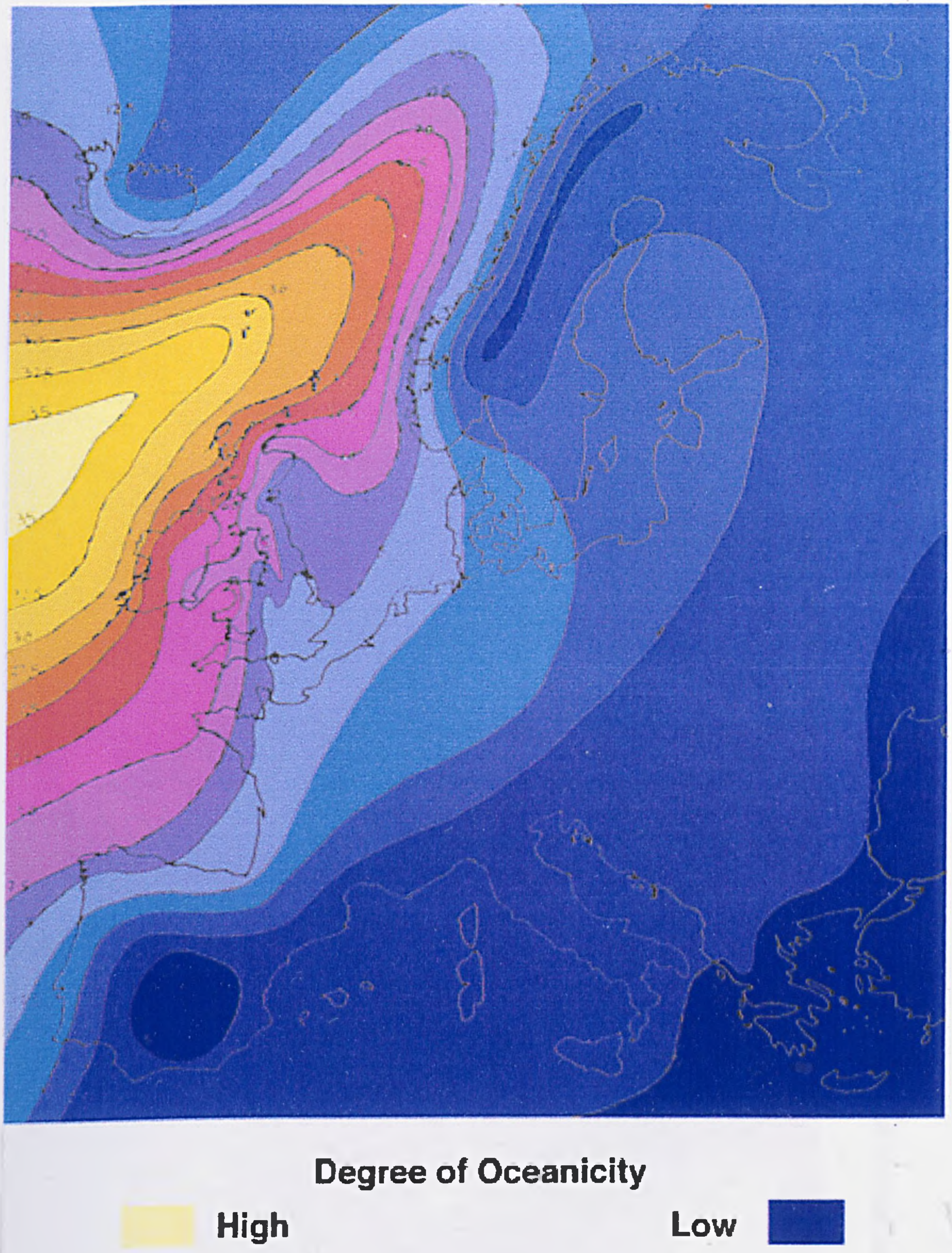

Figure 1·3. Map showing degree of oceanicity of different areas of Europe. The unique position of western areas of the British Isles is clearly indicated (from Averis 1991).

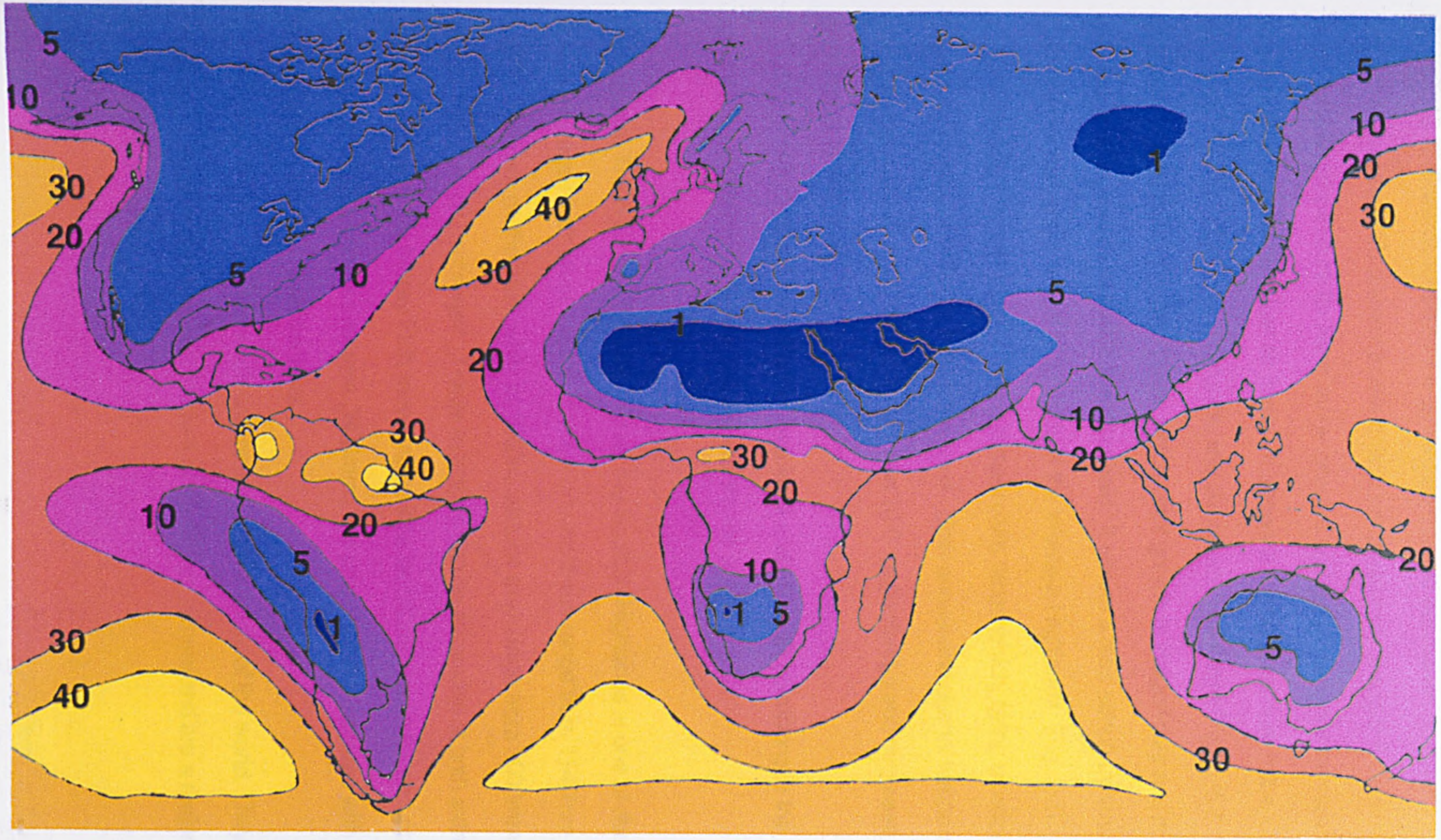

Figure 1-4. Map showing oceanic areas of the world (from Averis 1991).

Temperature This is an important factor affecting plant growth and distribution; in general it decreases northwards whereas the temperature range decreases from east to west. It is usually expressed with respect to two critical temperatures; 0 and 5•6 Celsius. The former is the critical temperature for life in many species and is conveniently indicated by the average dates for first and last air frosts. It shows a strong maximum in the Cairngorms, with a lesser one in the N-W Highlands, and decreases westward (Figs 1•5 & 1•6). 5•6 C is generally accepted as the level below which plant growth is insignificant and is indicated by accumulated temperature above this threshold. It shows a less strong minimum in the Cairngorms with one of equal magnitude in the Western Highlands (Fig. 1•7).

An equally important parameter is temperature range which, being ameliorated by oceanicity is greater in the east than the west. Both annual and diurnal temperature ranges reach a maximum in the Cairngorms (11 and 10 C respectively) and decrease towards the west coast (8 and 4 C).

All these figures are corrected for sea-level and although conditions in the montane zone will be much more severe, the general trends will be similar.

Precipitation The basic rainfall pattern over the Scottish Highlands is one of decreasing annual averages from west to east. On low ground these range from 1140mm on the west coast to 760mm on the east, while at 1000m. altitude they range from 3000mm on the Isle of Mull to 1500mm on Lochnagar. These averages can be exceeded at both extremes; the lowland shores of the Moray Firth receiving as little as 560mm while the mountains of Lochaber in West Inverness receive 3800mm. The proportionate increase with altitude is also greater in the west than the east.

All these figures are high when compared to other areas of the world. They are a consequence of the hyper-oceanic nature of the British climate and are a major contributor to its special character.

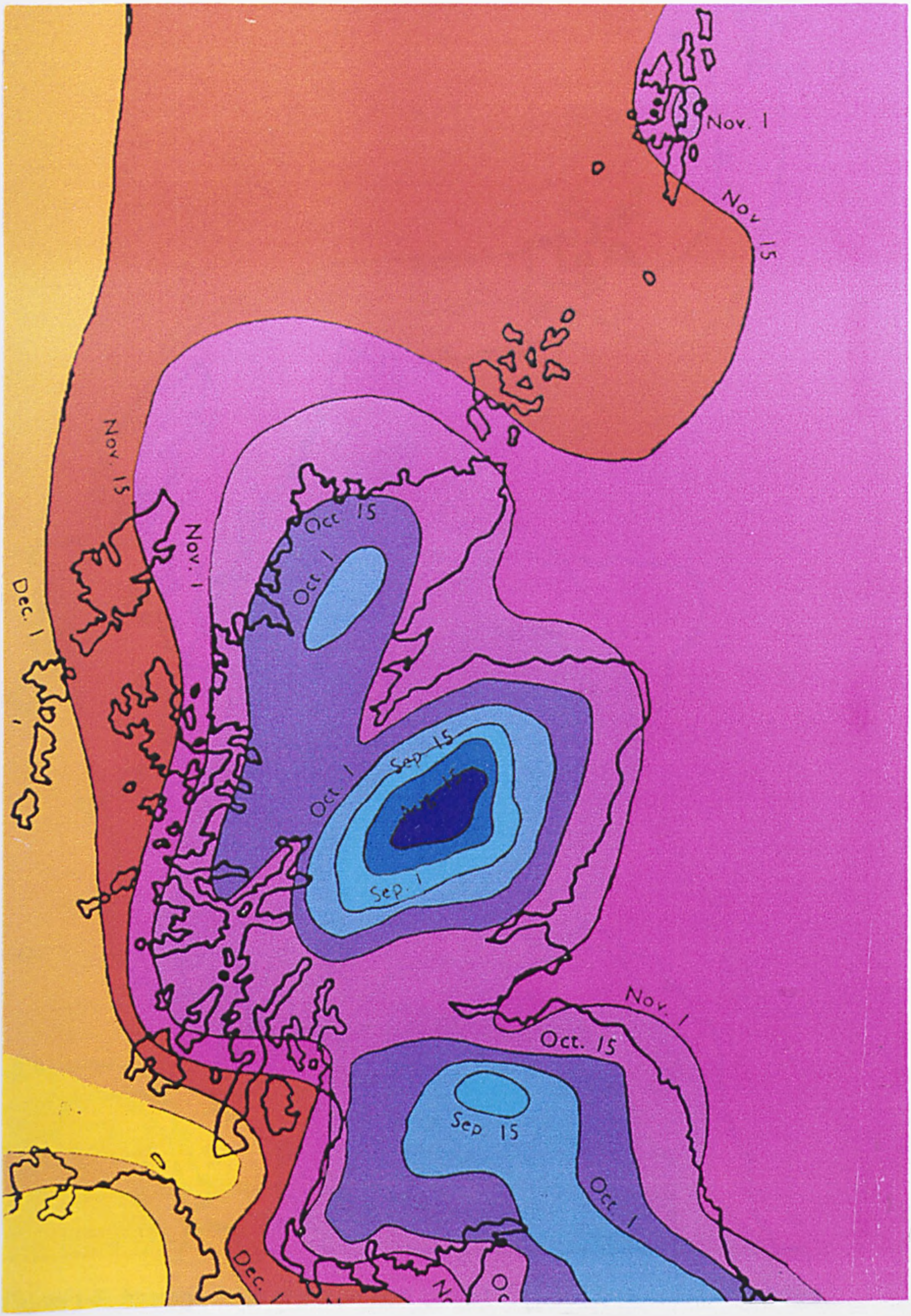

Figure 1•5. Average dates of first air frost (period 1911-1940) recorded in standard thermometer screens (after Meteorological Office 1952).

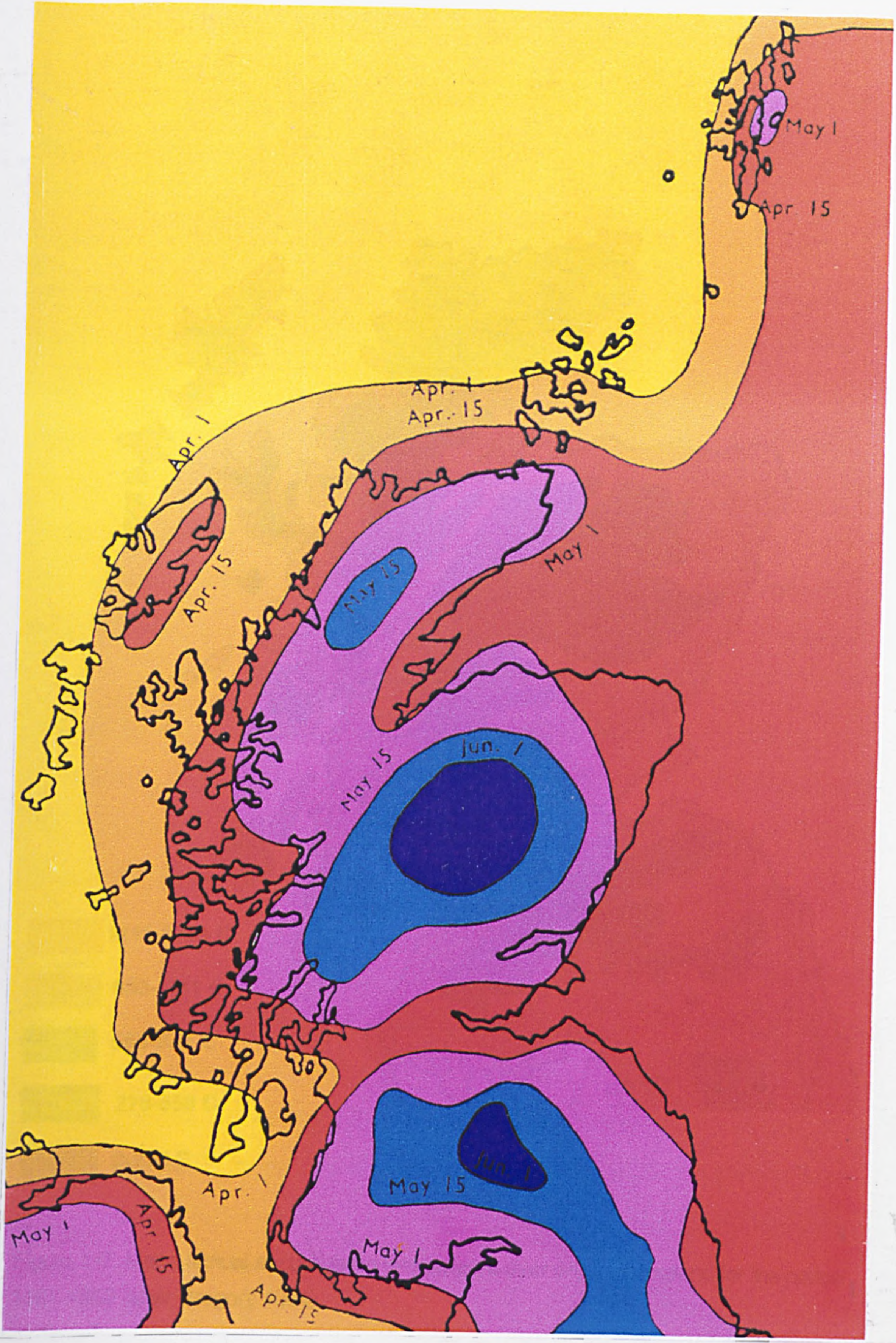

Figure 1·6. Average dates of last air frost (period 1911-1940) recorded in standard thermometer screens (after Meteorological Office 1952).

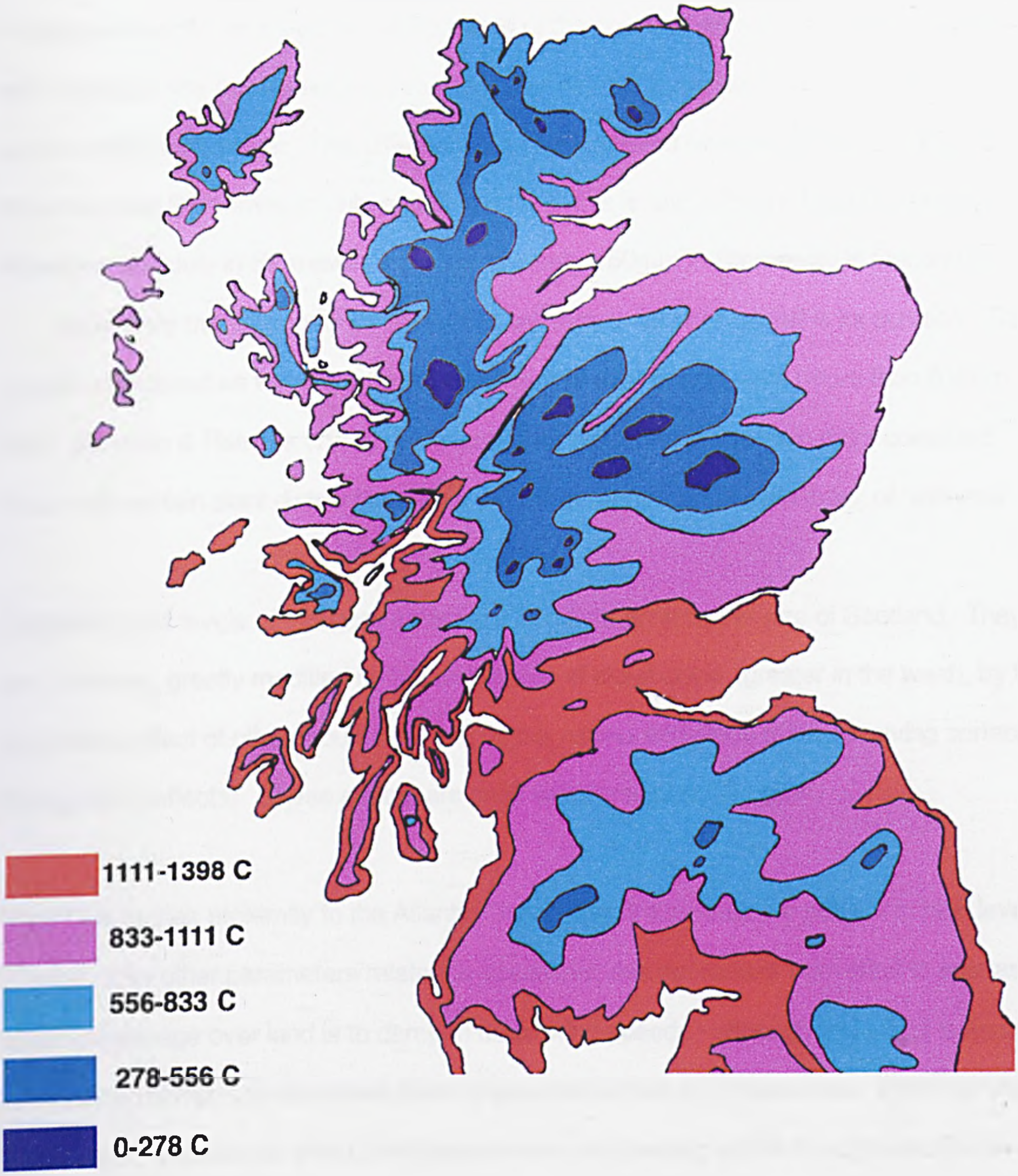

Figure 1•7. Mean annual accumulated temperature over 6•0C in Scotland for the period 1881-1915 (after Gregory 1954).

The seasonal distribution of precipitation is also different between east and west and is again a consequence of oceanicity The west of Scotland has a rainfall distribution corresponding to that over the Atlantic ocean with a distinct minimum in spring and a maximum in winter whereas the eastern side of the country has a more continental pattern with a gradual rise throughout the year from January to December with slight maxima in late summer and early winter. This difference can be illustrated by comparing the rainfall in Aberdeen and Stornaway in July and December; this is about 75mm for both months in Aberdeen and July in Stornaway but rises to nearly 150mm in Stornaway in December.

Apparently more important than total or average amount of rainfall is its duration. This is usually expressed as wet days (more than 1mm of rain) or rain days (more than 0.2mm of rain). McVean & Ratcliffe (1962) discovered that the distribution of rain days coincided better with certain plant distributions than any other readily accessible index of 'wetness'.

Sunshine Input levels of this parameter vary little over an area the size of Scotland. They are, however, greatly modified by the distribution of cloud cover (greater in the west), by the shadowing effect of other mountains, and by the aspect and slope of the receiving surface (topographic effects). These effects are dealt with in more detail below.

Wind Due to their proximity to the Atlantic Ocean, the British Isles are subject to high levels of wind. Like other parameters related to oceanicity, this decreases from west to east as the effect of passage over land is to dampen down wind speeds - although this effect is less pronounced at high altitude where there is less land for the air to pass over. Wind not only has a direct, mechanical effect on vegetation and an abrading action through wind borne dust and ice particles, but also has an indirect effect through increasing desiccation and evaporation, and re-distributing snow in winter.

Potential Water Deficit This is perhaps the single most important factor for assessing the climatic environment. Incoming energy from the sun is dissipated in two main ways; raising temperatures and evaporating water. The ratio between the two is virtually constant at any location but changes with altitude, there being a slight increase in the proportion used to evaporate water with increasing elevation. The potential evaporation (PE) at any location is, consequently, proportional to the accumulated air temperature so although absolute values are not always reliable general trends are well known.

Potential Water Deficit (PWD) is the difference between precipitation and PE and is, therefore, lowest where there is either a high rainfall and/or a low PE . As the former occurs in the west and the latter in the north, the north-west is the area of the country with the lowest PWD (Fig. 1•8). The area of low PWD reaches sea-level in the west but climbs steadily towards the east and is almost absent from the Cairngorms. If these mountains extended any further east the area of low PWD would almost certainly disappear (Fig. 1•9).

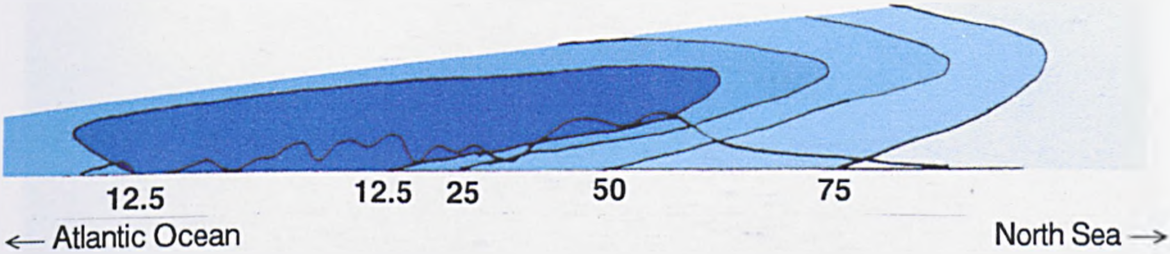

Figure 1•9. Diagrammatic section across Scotland from the Western Isles to near Aberdeen. The isolines are for Potential Water Deficit (in mm) as in Fig. 1•8 (from Green 1964).

These patterns of PWD must be treated with caution as it is only POTENTIAL evaporation that is being considered; ACTUAL evaporation will, like any other climatic character, be influenced by topography. Consequently, deeply shaded, north-facing slopes in the Cairngorms will have a low PWD while sunny, exposed slopes in the west will have a far greater PWD than maps and figures indicate.

In mountainous areas of southern Norway rainfall is lower and PE higher than in Scotland and, consequently, PWD is greater thus further emphasizing the almost unique climatic conditions which prevail in Western Scotland.

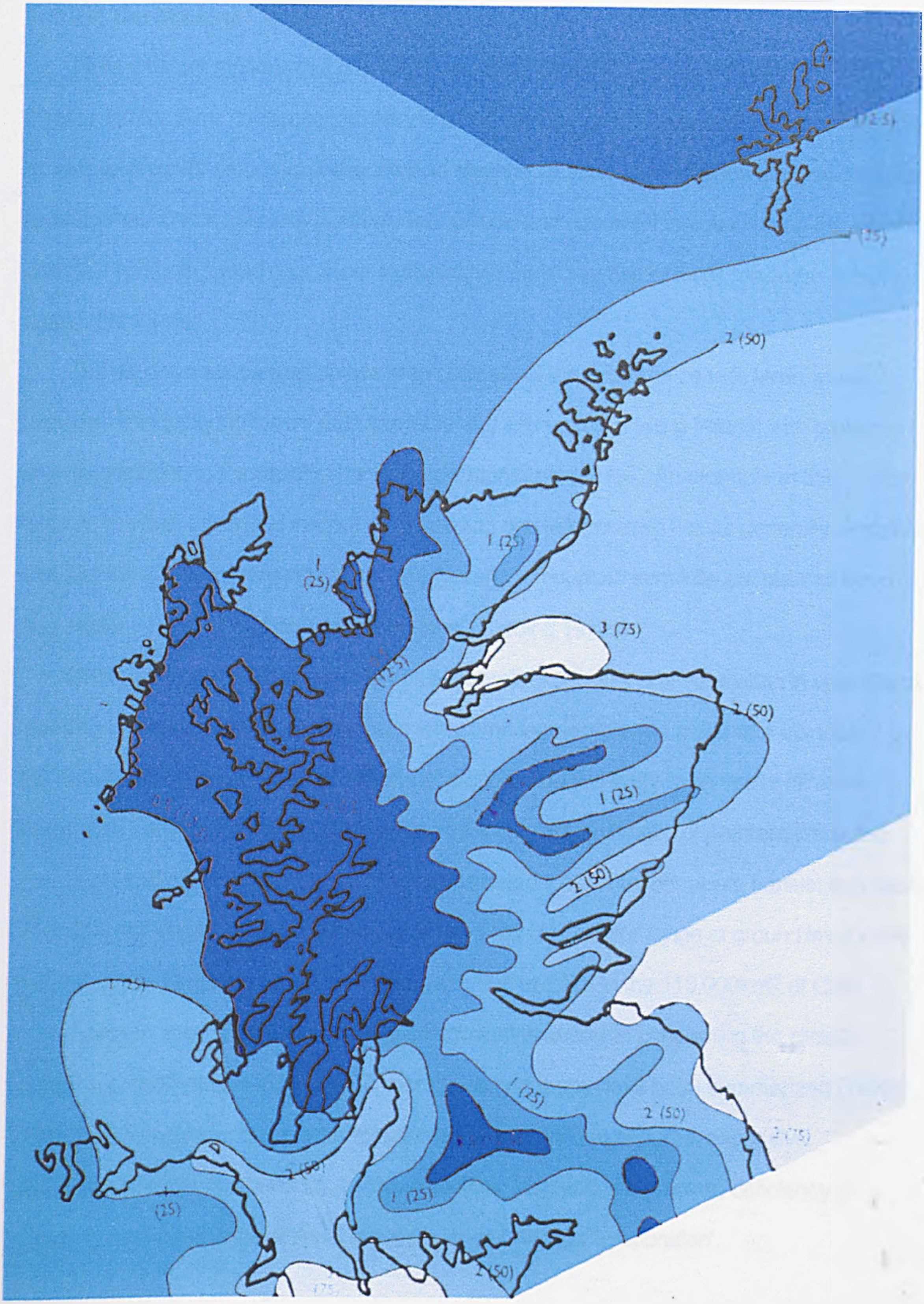

Figure 1·8. Average annual potential water deficit in inches (approximate millimeter equivalents in parentheses) (from Green 1964).

1•4•2•2 The Montane Climate

Most weather stations in the British Isles are situated in the lowlands near the coast (Taylor 1976). As a consequence, nearly all information on the climate at higher altitudes is an extrapolation of data from these lowland stations. Even where stations are present in the uplands they are usually at a relatively low altitude and assumptions concerning the climate at higher levels is based on a linear extrapolation from only two or three readings - a highly suspect process.

The situation concerning details of the climate of the montane zone is even worse, there being virtually no recent data available and extrapolation being fraught with problems and dangers due to the rapidly changing conditions that prevail. An example of this is with respect to cloud cover and insolation. Insolation and temperature values generally decrease with altitude due to increasing cloud cover but when mountain summits are clear of cloud they reach values far higher than at sea-level (Harding 1979a).

When it comes to assessing the actual operating conditions of vegetation in upland and montane regions, a further complication is that measurements are made at a standard 1.5 metres above the ground and conditions at ground level are likely to be vastly different. Wolfe *et al.* (1949) working in Ohio, measured a number of climatic characters (including maximum and minimum temperatures and the dates when they occurred, earliest and latest frost, and the length of the frost-free period) and found a greater range at ground level in the 0.6 km^2 of the Neotoma valley than were recorded at 1.5m in the 113,000km^2 of Ohio.

However, a good deal of scattered information is available concerning the climatic conditions which prevail in the British mountains and these have been summarized (Taylor 1976) as 'a combination of low temperatures, severe wind exposures, excessive precipitation, cloud and humidity, persistent winter frost and snow cover, deficiency of sunshine, poor visibility, continual ground wetness and low evaporation'.

Arctic-Alpine? The term Arctic-alpine is often used to describe the plant communities of many montane regions - including those of Great Britain. However, this is an unsatisfactory description as, although the two regions do have in common a harsh climate of low mean annual temperatures and long periods of snow cover, the factors producing Arctic environments differ in many respects from those which produce alpine ones. This has been stated by Beschel (1970) thus: 'As we do not usually lump ...... non-polar, non-alpine and non-tree-covered vegetation of the remainder of the globe under one heading, one wonders why a collective term should be applied to the vegetation of arctic and alpine regions ...... unless we understand its use as an involuntary expression of our ignorance.'

Arctic and Alpine conditions are the result of Barry's two other major controls upon montane climate, high latitude - which produces an Arctic climate - and high altitude which produces an alpine one. The differences can be summarized as a greater variation in:-

a) Sun and Shade Temperatures - In Arctic areas levels of solar radiation fluctuate on a seasonal level while in alpine regions the fluctuation is diurnal. The difference in the angle of sunlight also affects the amplitude of the temperature range.

b) Winds - Arctic areas are no more or less windy than any other area but alpine regions experience extreme maximum and average wind speeds. This leads to increased abrasion and evaporation as well as a redistribution of snow-cover.

c) Relative Humidity - Due to the increased cloud-cover over mountains, alpine regions tend to have a higher relative humidity than Arctic areas.

d) Soil Moisture - Arctic soils are mostly water-logged for much of the year whereas alpine soils, because of the extreme variations in slope, aspect and exposure are often dry and plants will experience periods of drought in areas which, theoretically, have a high water surplus.

Another difference is in the patterns of snowfall, with much of the Arctic receiving little snow whereas some alpine areas receive among the highest totals recorded anywhere. With respect to topography, Arctic areas are predominately flat with habitats ranging from wet meadow through dry heaths to fellfields often with large expanses of each type whereas Alpine areas are often extremely varied topographically resulting in a small-scale mosaic of climatically induced micro-habitats.

Although it is inappropriate to speak of an arctic-alpine climate or environment it is possible to describe a plant as having an arctic-alpine distribution although, bearing in mind

Beschel' s quote given above, this does display our ignorance of all but the most basic ecological reqirements of that plant.

British montane areas are best considered as part of a continuum from Arctic (high latitude, low altitude) to alpine (low latitude, high altitude) and are thus intermediate between the two extremes having some of the characters of each. Alternatively they may be thought of as outliers of either climatic type. The lichen flora has elements of both environments, with a greater proportion belonging to the Arctic element.

Temperature It is an over simplification to equate increasing altitude with decreasing temperature. The rugged terrain causes rapid fluctuations in exposure to insolation and wind with the result that a small-scale mosaic of meso- and micro-environments is produced, e.g. the vegetation on a south-facing slope will receive much more solar radiation than a north-facing one (*cf.* below).

However, the general decrease in temperature with altitude is evident in the early records from the Ben Nevis observatory (1984-1903) and more recently from the Cairngorms (McClatchey 1996). The data from the summit of Ben Nevis shows a mean annual temperature of -0.3 C with mean hourly temperatures below 0 C from October to early May. Even in July the hourly mean only just exceeds 6 C for a few hours in the middle of the day with the monthly mean remaining at 5 C. The figures from the Cairngorms indicate a mean annual temperature of 2.3 C with 196 days of air frost and a continuous period of 83 days when the temperature was below 0 C.

However, all these measurements were made at the standard meteorological height of 1.5m above ground level and conditions closer to the ground may be radically different. The boundary-layer (a layer of still air a few millimetres thick above smooth surfaces, less above rough ones and in windy conditions) constitutes a formidable barrier to heat and water-vapour transfer between the ground and the air. In this region mixing due to convection by turbulent air cannot take place and, consequently, heat is only transferred by conduction and water-vapour by diffusion through air molecules. Mainly as a result of this, surfaces may experience a temperature far in excess of ambient. Turner (1958) working at the tree-line

(2070m) in the Ötztal region of Austria recorded a temperature of 80 C on bare, raw, dark humus on a south-west facing slope - a temperature over 50 C above ambient air temperature and 57 C higher than on a nearby north-facing slope. The highest temperatures within the boundary-layer are reached under partly cloudy conditions, when the sun is shining through gaps in the clouds and radiation from cloud reflection is also considerable. These are also the conditions under which the most rapid fluctuations in temperature occur; Turner (1958) recorded variations of as much as 10 C within a few seconds. However, as wind speeds, in general, increase with altitude the boundary-layer will become smaller at high altitudes and on very exposed ridges and summits may be virtually absent. In these circumstances the above effects are likely to be less pronounced.

Snow-cover also modifies recorded temperatures as it has an insulating effect with the result that temperatures beneath snow rarely drop more than a few degrees below zero. As snow-beds often form in north-east facing coires which are, under normal circumstances, colder than exposed ridges and south-facing slopes, this ameliorating effect will be particularly pronounced.

Wind The effect of wind at various levels have been summarized by Barry 1992. 'Overall dimensions and orientation of a mountain range with respect to the prevailing winds are important for large-scale processes, relative relief and terrain shape are particularly important on a regional scale, while slope and aspect cause strictly local differences of climate'.

Wind is more influenced by topography than altitude but the two basic altitudinal influences work against each another - vertical compression of the air-flow tending to speed it up and frictional effects tending to slow it down. However, in oceanic regions mountain summits are mostly unaffected by frictional effects and this results in them being extremely windy places. Data from the Ben Nevis observatory over a period of 13 years at the beginning of this century indicate an annual average of 261 gales of force greater than 50 mph (43 kt) compared with only 40 at sea-level (Pearsall 1950) while Dybeck & Green (1955) working in the Cairngorms recorded an increase of days with winds over 20 mph from 4% at Glenmore Lodge (300 m) to 20% at Cairn Lochan on the summit plateau (1100m.) However, winds at ground level may be as little as 15% of those measured at the standard meteorological height of 1.5m (Stocker 1931; Whitehead 1951; Warren-Wilson 1959) whereas wind speeds within vegetation will be even lower (Kreutz 1938; Ramdas 1946; Stocker 1923; Warren-Wilson 1959).

Passage of air over a summit causes compression of the air-flow with a consequent increase in wind speed. When speeds exceed about 25 knots turbulence causes mobile frictional eddies to form on the lee slopes and wind direction is often reversed, while at slightly lower speeds (20 kt) stationary eddies are formed. This effect which occurs, not only with mountain summits, but also with boulders, stones and soil banks (Warren-Wilson 1959), is important for the development and maintenance of late snow-beds and their resultant plant communities.

At a local level, winds generally tend to travel upslope during the day (anabatic) as the air is warmed and downslope (katabatic) at night as it cools. However, contrasting ground conditions can set up a variety of convectional flows - rising air being generated by relatively warm areas, e.g. bare rock, dry coarse soil, sand, gravel, scree or rock debris; land without snow-cover; and dry ground or vegetation; whereas relatively cool surfaces - which include vegetated surfaces, wet heavy peaty soils, land with snow cover, and wet land or vegetation - will not cause air to rise.

Precipitation The oceanic mountains of the British Isles are extremely wet places. The annual mean rainfall for the mountains of Lochaber in West Inverness is 3800mm. This figure contrasts strongly with those for more continental areas even though the latter are at a higher altitude, e.g. Sonnblick at 3106m in the Hohe Tauern, Austria has an annual mean of 1643mm, Mt Washington at 1917m in New Hampshire, USA receives 1784mm while the Niwot ridge, Colorado, U.S.A at 3749m receives only 634mm.

It appears that British average rainfall gradients increase linearly with altitude, although one study has shown an exponential increase (Harrison 1973). It has been calculated Gloyne (1968) that while the eastern coastlands of Scotland have an average annual duration of 500 hours precipitation, the north-west Highlands have over 2000 hours. As total average rainfall for the two areas differs by a factor of nine, this suggests that the intensity of rainfall in the north-west Highlands is approximately twice that in the east.

Although rainfall is little affected by topography its effects on the environment are linked with variations in rates of evaporation which are strongly related to topography.

Cloud Cover This is, in general, thicker over mountains than over the surrounding lowlands. Mechanical uplift when an airstream encounters a topographic barrier is a primary cause although this may be augmented by convection effects due to slope heating. If an air parcel is forced to rise it expands, due to the lower ambient pressure, and cools with the consequence that water droplets condense from the air and clouds are formed. This assumes no exchange of heat between the parcel and its surroundings, i.e. an adiabatic process. When cloud is already present, the slowing down of air by the mountain barrier also leads to an increase in cloud water content.

Cloud cover is important for assessing the level of insolation which a montane area receives but, unfortunately, data for cloud cover in the British mountains are largely lacking. The early records from the Ben Nevis observatory record a figure of 16% of available sunshine. Most others appear to receive less than 20-25 %, with a gradient of increasing amounts from west to east.

In a cloudless sky there is a 5-15% increase in radiation with every 1000m of altitude but due to increased cloud-cover radiation levels are actually lower over much of the uplands than the surrounding lowlands. This amounts to approximately 10% over the lowest 500m but is probably not significant in limiting plant growth, extreme cold and high winds being more important in this respect. However, ground above 500m may be above cloud level and, consequently, radiation levels are often higher than in the lowlands. Harding (1979a) recorded a mean increase in insolation of 35% over three summer months between the summit of Cairngorm at 1245m and the nearby Glenmore Lodge at 341m, while in the Alps, Sauberer & Dirmhim (1958) indicated that the daily mean values of solar radiation for clear skies are 21% higher at 3000m than at 200m in June and 33% higher in December. Unfortunately this solar radiation maximum occurs too early for vegetation growth as ground conditions delay warming until late summer, although this is probably not as significant for lichens as for vascular plants.. These data also illustrate the similarity in environment between the Alps at 3000m and the Cairngorms at approximately one third the elevation.

Perhaps the most important factor relating to cloud cover is occult precipitation (i.e. that derived from water droplets in fog or low cloud). This is likely to be a major input into the water relations of montane ecosystems and, especially for lichens and other organisms with a poikilohydric nature, possibly plays an important role in determining their distribution. It is unclear whether PWD data take account of occult precipitation, if not, much of the work on climatic zones may need modifying.

Insolation The amount of solar radiation reaching the earth's surface is reduced by passage through the atmosphere due to refraction and reflection by dust and water particles; some wavelengths are affected more than others. These affects will be greater at high latitudes as the radiation has a longer column of air to pass through but lower at high altitude as most of the dust and water vapour is concentrated in the lower atmosphere. Further, due to the lower angle of incidence of the radiation at high latitudes, the effects of scattering are further magnified. When the sun is at 90° to the horizon 92% of energy received at the surface is direct radiation, whereas when the sun is near the horizon (8°) 50% of the energy received is by diffuse radiation (Allee *et al.* 1949). The wavelength composition of reflected light is different from that of direct light being richer in long-wavelengths (infra-red).

A further difference in northern areas is the greater importance of radiation as a means of energy exchange; whereas in tropical and temperate regions convection and conduction are the most important routes. 'It is important to think, not in degrees as measured by a thermometer, but in joules of heat flowing from a source to a receiver or accumulating body.' (Pruitt 1978)

Cloud cover greatly influences the effects of radiation as it is more or less transparent to direct insolation but opaque to the infra-red radiation of reflected light. This reflected, long-wave radiation can be trapped by even thin cloud, greatly increasing the surface temperature although air temperature may remain substantially unaltered.

Altitudinal, temperature lapse-rate The British Isles have among the highest lapse-rates in the world due to the steep temperature gradients inherent in the cold polar air which affects the British climate. However, as lapse-rates are higher in dry air than in moist there is a conflict between the higher incidence of polar air in the west and the lower humidity in the east. The large variations due to topography make meaningful comparisons between areas difficult but lapse-rate vlues appear to be higher in the eastern mountains than the western ones. There is also evidence of an increase from north to south for the same reason.

As very few weather stations are in the montane zone most lapse-rate figure for the British mountains are extrapolations from upland ones and assume a linear relationship with altitude. Work in southern Norway has shown that a linear relationship does exist up to (at least) 2000m. (Det Norske Meteorologiske Institutt 1960), results suggesting an exponential increase (Meteorological Office 1975a, Taylor 1976) are probably due to the lower stations being coastal where there is a horizontal as well as a vertical temperature gradient. The Meteorological Office has adopted a standard lapse rate of 6 C per 1000m rise in elevation for mean temperatures (with 7 C for maximum temperatures and 5 C for minimum). These are lower than actual recorded levels which range from 6.4-7.3 C per 1000m. (Manley 1943; Smith 1950; Oliver 1960, 1964). Harding (1978), using data from weather stations throughout the British Isles, quotes values for maximum temperatures of up to 10.2 C per 1000m with an average of approximately 8.5 C

Like most other aspects of climate, lapse-rates are affected by topography which produces local and regional vertical air flows. Work by Harding (1979b) in the Pennines indicated that the effects on minimum temperatures of the very local topography around a site could be as great as the effects of altitude, whereas the variation in maximum temperatures was primarily accounted for by altitude. Lapse-rates also show seasonal variation with the highest values occurring in spring falling gradually to a minimum in the winter months.

Snowfall This is, in essence, a special form of precipitation but its effects are so different from rain that it is best treated separately. Snow differs from rain in that it persists on the surface after it has fallen and is, consequently, redistributed. Winds blow it away from exposed slopes and it collects in sheltered hollows out of reach of the prevailing winds - usually on the eastern sides of mountains. The thermal insulating properties of snow are well known and prolonged snow lie has a strongly modifying effect on the exposure of plants associated with it, so much so that characteristic communities develop. This aspect will be dealt with in more detail in the section on late snow bed communities.

Late snow lie also has a meso- and micro-climatic effect. Due to its effect on the albedo of the ground much more radiation is reflected back into the atmosphere whereas, because of the latent heat required to melt the snow, less is available for raising air and ground temperatures. Consequently, temperatures in the immediate vicinity of snow beds tend to be lower than in nearby areas. Large areas of snow lie produce their own air currents and micro-climatic systems.

Climate of Other Montane Areas The climate of the other parts of the British Isles with mountainous areas have a similar climate to Scotland with oceanicity being the factor of over-riding importance. The West of Ireland has a more oceanic climate than mainland Scotland (equivalent to the Outer Hebrides) with a difference in mean temperature of the warmest and coolest months of around 8 C (between 9 and 10 C on the west coast of mainland Scotland rising to 11 C in the east). The oceanicity of Northern England (North Pennines and the Lake District) and Wales is slightly lower due to the ameliorating effect of the landmass of Ireland to the west (Pentecost 1987). The other two principal factors affecting climate, latitude and altitude, create similar small differences in the climates of the other areas. In all cases these are lower with the result that the climatic conditions, principally temperature, are less severe. In the mountains of North Wales annual accumulated temperature above 5•6 C is in the region of 825-1325 whereas in Scotland it ranges from 300-500 over much of the high-ground dropping to <300 on the highest ground.

1•4•2•3 Effects of climate on lichen distribution

These are dealt with in detail in Chapter 3, but are summarized here. The main effect on the lichen vegetation of increasing oceanicity is as a consequence of the lower potential water deficit which produces almost permanently water-logged soils in the western regions of the British Isles. This severely restricts lichen growth so that many terricolous lichens are largely restricted to drier eastern regions (e.g. *Alectoria* spp.) whereas saxicolous lichens become much more important in the west. Increasing oceanicity also results in montane species descending to near sea-level in the west (e.g. *Cornicularia normoerica, Pseudephebe pubescens, Stereocaulon tornense*). The same effect is also apparent with increasing latitude with species such as *Brigantiaea fuscolutea* occurring at sea-level on the northern coast of Scotland.

1•4•2•4 Meso- and Micro-climate

As mentioned above, large scale climatic systems are extensively modified by the physical montane environment often producing such a heterogeneous mosaic of small-scale climates that conventional climatic data for an area is likely to be misleading. These can be due to either topography (slope, aspect, etc.) or vegetation and surface features and are much more pronounced in montane environments than in most others due to the lack of ameliorating factors. Although the terms meso- and micro-climate respectively are most often used, topo- and enviro-climate have also been employed (Geiger 1966). The climatic elements most affected are solar radiation, precipitation and wind - the last having a consequent effect on the distribution of late-snow beds.

Turner (1980) considered the factors affecting montane micro-climate to be:-

a) slope irradiation
b) wind exposure
c) depth of snow cover
d) density and height of ground cover

a) & b) being independent variables and c) & d) dependent ones.

Using these variables Turner defined four types of micro-habitat:-

a) sunny windward slope
b) sunny lee slope
c) shaded windward slope
d) shaded lee slope

These four categories are better considered as meso-climatic types and form a basic sub-division of the montane environment upon which other micro-climatic features can be superimposed.

Frank & Lee (1966) showed that, for a latitude of 50° N under clear skies, a 45° south-facing slope received four times as much solar radiation as a similar north-facing one. Presumably, for the higher latitudes of the British mountains (56-58°), these differences would be even more pronounced. Similarly, Turner (1958) reported a surface temperature of 80 C on black humus on a south-west slope of 35° in the Ötztal, Austria compared with only 23 C on a nearby north-east slope while Shreve (1924), working in the Santa Catalina Mountains near Tucson Arizona, found that maximum soil temperatures were more affected by aspect than minimum ones - an effect which was more pronounced at higher altitude. These effects are modified by ground conditions, vegetation reducing them and bare rock increasing them.

Another important micro-environmental effect is that of albedo, the amount of light (and heat) reflected by a surface. This is of greatest importance in the vicinity of late-snow beds (fresh snow can have an albedo approaching 100%) but differences in albedo of other surfaces (due to their colour, texture, wetness, etc.) can have a significant effect on the local climate.

Rocks, boulders and even small stones also greatly modify their immediate environment. Mani (1962) cites diurnal air temperature ranges of 24 C in June at 4000-4500m on the south slopes of the Himalaya compared with only 5-7 C in insect niches beneath rocks where the relative humidity was also rarely below 90%. Air-flow is also modified; Gloyne (1955) indicates that an obstacle will set up eddy currents in its wake up to 15 times its height whereas Warren-Wilson (1959), investigating the flow of air over and around boulders and vegetation barriers, recorded a reduction in wind speed of 80% for a distance three to five times the height of a barrier of 50% density. He also investigated the effects of wind on evaporation and temperature finding that both were closely related to wind speed. However, Oke (1972) has pointed out that areas of increased roughness will disturb the air-flow and increase mixing and, in the case of snow-beds, result in areas of increased warmth occurring down-wind from them. Because lichens are low growing they will usually inhabit the boundary-layer and high wind speeds will often be beneficial by lowering excessively high temperatures.

Areas of late snow lie, while largely the result of small scale climatic effects themselves, also contribute to the micro-climate by reflecting incoming radiation onto adjacent slopes and modifying air-flows.

Lichens are generally extremely specific in their ecological requirements and, as such, their distribution is controlled by the availability of a certain habitat. This applies at all the levels considered here. Many species have a distinct oceanic or continental distribution (macro-climate), others are more or less confined to damp coires or more exposed ridges (meso-climate) while still others are confined to rock faces of a particular aspect (micro-climate). In practice, any or all effects may apply to a single species, i.e. a lichen may usually occur on the north-sides of boulders in damp coires in oceanic areas.

However this makes no allowance for the extreme ecological specialization of lichens, particularly micro-lichens. These may inhabit a very precise ecological niche, e.g. near the top or the bottom of the rock, in a slight depression or on a slight protrusion, in an underhang, associated with bryophytes, etc. All these habitats have their own micro-climates and if we consider the climate produced by the slope and aspect of the side of a boulder as micro-climates then it is perhaps appropriate to describe that associated with the relief and other characters of the boulder face as nano-climates.

1•4•2•5 Climatic Regions in the Scottish Mountains

Altitude alone is an unsatisfactory character to use in determining whether a site is 'montane'. By definition the montane zone starts at the potential tree-line but, as this is rarely immediately obvious, as grazing has extensively modified the natural vegetation, the character most often used is the lower limit of prostrate *Calluna vulgaris*. These two characters are compared in Table 1•1.

The two do not always correspond as there is considerable variation in both factors due to degree of exposure. This is shown by Birse who gives three different altitudinal limits for prostrate *Calluna* from Ben Kilbreck, Sutherland which range from 455-610m depending upon the degree of exposure.

Table 1•1. Comparison of potential tree line with lower limit of prostrate *Calluna vulgaris* (from Birse, 1971 and Birks 1988)

	Potential Tree-line	Prostrate *Calluna*
Cairngorms	700-800m	650-700m
Central Grampians	700-800m	
N.W. Sutherland	550m	300m
Isle of Skye	450m	
Far N.W. Sutherland	350m	
Orkney & Shetland	200-300m	sea-level.

Birse (1971) divided Scotland into a number of bioclimatic sub-regions based on accumulated temperature over 5.6 C, degree of exposure, accumulated frost, and potential water deficit. Using accumulated temperature he defined an oroarctic zone of <675 day C which he further subdivided into a orohemiarctic (676 to 500), a lower oroarctic (500 to 300) and an upper oroarctic (<300) sub-zone. He modified the thermal sub-zones with higher accumulated temperatures (boreal and temperate zones) by taking account of degree of exposure but only did this to a more limited extent for the oroarctic zones. He also divided Scotland into a number of 'humidity zones' based on Potential Water Deficit, three of which occur in the oroarctic sub-zones, perhumid (PWD <-500mm), extremely humid (PWD 0 to -500 mm) and very humid (PWD 0 to +25mm) and three oceanicity sub-sectors based on accumulated frost at sea-level, hyperoceanic (<50 day C of frost), euoceanic (50 to 110) and hemioceanic (>100) these values being calculated from an arbitrary altitude of 180m in central Scotland to allow for variation in altitudinal and latitudinal lapse-rates.

By combining these criteria a theoretical total of 18 climatic regions within the montane zone of the British Isles are obtained. However, only eight are actually present and some of these are of extremely limited extent (e.g. types 1 and 2 in Table 1•2 - which only occur at a few places on Orkney, Shetland and in extreme N.W. Sutherland).

Table 1•2. Climatic regions of Birse 1971 present in the montane areas of the British Isles.

Oceanicity	**Humidity**	**Temperature**	**Code**
1) Hyper-oceanic	very humid	lower oroarctic	(O1H2A2)
2) Hyper-oceanic	extremely humid	lower oroarctic	(O1H1A2)
3) Hyper-oceanic	perhumid	lower oroarctic	(O1P A2)
4) Eu-oceanic	extremely humid	lower oroarctic	(O2H1A2)
5) Eu-oceanic	perhumid	lower oroarctic	(O2P A2)
6) Eu-oceanic	perhumid	upper oroarctic	(O2P A1)
7) Hemi-oceanic	extremely humid	lower oroarctic	(O3H1A2)
8) Hemi-oceanic	extremely humid	upper oroarctic	(O3H1A1)

These zones are calculated for a theoretical, level surface and will, of course, be greatly modified by the topography of an area. In particular the temperature differences between north and south-facing slopes already mentioned will result in the north-facing slope and coires having a much more extreme environment than the more clement south-facing ones. It is probable, therefore, that vegetation representative of each type will be found in areas assigned to one particular zone and that areas with a 'montane' climate and vegetation will be found well below the theoretical altitude.

For the purposes of this study, 'montane' is used as being equivalent to the two oroarctic zones of Birse (1971), although some areas which fall in his orohemiarctic sub-zone are also considered in the western, hyperoceanic sub-sector where degree of exposure is very high.

More recently Brown *et al.* (1993a) divided the Scottish uplands into eight bio-geographical regions by multivariate analysis of plant community data. Three of these are true montane regions - high, South-West Highland; high, North-West Highland plateaux and high, East Highland plateaux, while a fourth, high North-West Highland ridges, also has some montane characters. The montane areas included in these four categories are shown in Table 1•3. In a companion paper (Brown *et al.* 1993b) various environmental variables (aspects of location, topography, climate , geology, geomorphology, climate and land-use) were analysed in a similar manner. It was found that the most important factors were those related to, in decreasing order, oceanicity, altitude and latitude. They specifically mention that geology, except in extreme cases (i.e. the Breadalbane Hills) was of very little consequence in determining the distribution of plant communities. It is expected that lichen communities, which are either saxicolous or, if terricolous, have a more intimate association with the soil, will be more affected by changes in geology.

Table 1•3. Sites (with site numbers) assigned to the four 'montane' regions in Brown et al. (1993a). Only sites where good survey data were available were included in their analysis.

Region 1 (High S-W Highland)
56 Ben Nevis
57 Bidean nam Bian
58 Creag Meagaidh
59 Ben Alder/Aonach Mor
61 Drumochter Hills
68 Meall Buidhe
69 Ben Lawers/Meall nan Tarmachan
70 Meall Ghaordie
71 Meall na Samhna
72 Creag Mhor/Beinn Heasgarnich
73 Beinn Laoigh
74 Beinn Dubhcraig
75 Ben More/Stobinian

Region 2 (High N-W Highland plateaux)
25 Ben More Assynt/Breabag
28 Beinn Dearg
30 Fannich Hills
37 Monar Forest
38 Affric-Cannic Hills

Region 3 (High East Highland plataux)
31 Ben Wyvis
42 Monadliath
48 Eastern Cairngorms
52 Lochnagar
53 Glen Calleter
54 Caenlochan/Clova
60 Coire Bhachdaidh
62 Beinn a'Ghlo
67 Carn Gorm/Meall Garbh
76 Ben Chonzie

Region 4 (High N-W Highland ridges)
7 Cullin
16 Beinn Spionnaidh
17 Foinaven/Meall Hourn
18 Ben Hope
22 Ben Kilbreck
24 Inverpolly/Knockan
27 An Teallach
29 Letterewe Forest
32 Beinn Alligin
33 Beinn Eighe
35 Beinn Bhan
39 Sgurr na Ciche

1.4•3 Geology

1•4•3•1 Introduction

The major factors which determine large-scale plant distribution in montane areas can be attributed to the various effects of climate; i.e. the degree of oceanicity, and the harsher environments due to increasing altitude and latitude. However, the geology of an area is also liable to be of some significance.

The geology of montane Scotland is extremely complex but much of the variation has little bearing on plant distribution; how a rock was formed and how long ago are only botanically significant in so far as they affect the composition of a rock. Ferreira (1959) found that 'there is often as much variation in vegetation within any one geological formation as there is between two relatively contrasting formations. ..... this variation in the vegetation is often associated with varying lithology within a single geological formation.'

The terms 'acidic' and 'basic' are used by botanists and geologists to describe very different types of rocks. Geologically, they only refer to igneous rocks; 'basic rocks' were designated as such in comparison to 'acidic rocks' which were originally defined as rocks containing over 66% silica. 'Basic rocks' then became rocks containing less than 66% silica and 'Ultrabasic rocks' those with less than 45%. The terms have now been modified with the quartz and feldspar content being important rather than that of silica, but the general pattern remains. Geologically 'basic rocks' can be very nutrient-poor and usually support an extremely dull lichen flora, i.e. gabbro. Botanically, 'basic' rocks are any type of rock which contains free bases in the chemical sense and are invariably nutrient-rich and support a diverse flora. Conversely, 'acid' rocks do not contain free bases and generally support a less diverse flora. In this work, 'basic' and 'acidic' are always used in the botanical sense unless otherwise stated.

1•4•3•2 Types of Rock

Much of Scotland is composed of metamorphosed rock and its composition, particularly its base content, depends upon the nature of the rock before metamorphosis occurred. Consequently there is frequently more variation within geologically similar rocks than there is between widely differing ones. The three major types of rock; metamorphic, sedimentary and igneous, will be dealt with in turn.

Metamorphic Rocks

These are by far the most frequent type of rock in the Scottish Highlands. They can be divided into three chronological series which are also arranged geographically from north-west to south-east (Fig. 1•10). They are dealt with in order.

Lewisian - This is mostly restricted to the far north-west of the mainland (west of the Moine Thrust) and the Hebrides with occasional inliers further east. It forms a very ancient landscape which has been heavily eroded and few high hills remain, although the Letterewe Forest group north of Loch Maree (e.g. a 'Mhaighdean) are a notable exception The rock is predominately gniess and mostly very acidic but occasional basic areas are to be found, although these are often of very small extent and hard to locate.

Along the line of the Moine Thrust, later Cambrian rocks have been metamorphosed to form quartzite and these often result in high mountains, e.g. Beinn Eighe, Liathach, Fionavan, Arkle. However, quartzite is a nutrient-defficient rock and supports a very impoverished flora.

Moine - This series forms the underlaying rock of much of the Highlands. It extends from the Moine Thrust to the Great Glen Fault and beyond this eastward to the Cairngorms (which are a granite intrusion) and southwards roughly to a line joining Oban and Braemar. These are also predominately acidic rocks, chiefly of quartzite, feldspars and granulite but also with occasional schists.

Dalradian - These cover the area to the south and east of the Moine series and north of the Highland Boundary Fault. They are the most botanically important of the three series. They include much basic schist - most notably in the Breadalbane Mountains of Central Perthshire and further east in the Glens of Angus, as well as seams of metamorphosed limestone (e.g. Ballachullish, Blair Atholl) which occasionally outcrops at high altitude, e.g. Coire Cheap in the Ben Alder range.

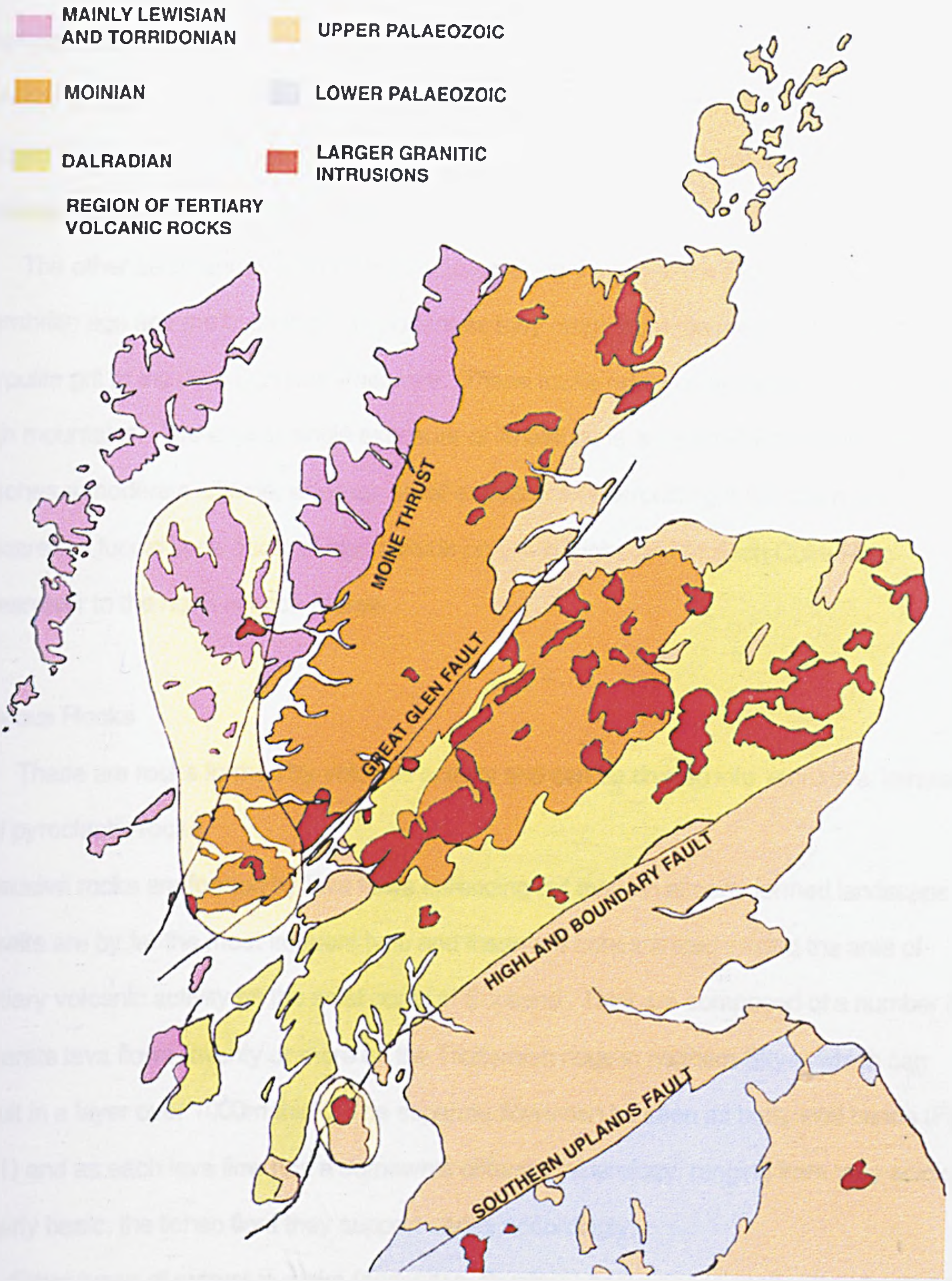

Figure 1•10. Map of metamorphic rock series and major granitic intrusions in the Scottish Highlands (from Craig 1990).

Sedimentary Rocks

These are mostly restricted to the vicinity of the Moine Thrust and the adjacent area of Lewisian rocks. By far the most extensive is the Torridonian Sandstone which forms a number of high mountains, e.g. An Teallach, Ben Mor Coigach and the isolated hills of Assynt (Suilvan, Canisp, Cul Mor, etc.). This rock is also mostly acidic although, as with the Lewisian, small, isolated, base-rich areas do occur.

The other sedimentary rocks which outcrop along the line of the Moine Thrust are of Cambrian age and are botanically important as they range from the mildly calcareous serpulite grit to the pure Durness limestone. These rocks rarely cover large areas or form high mountains. The largest single exposure of limestone is at Inchnadamph but it only reaches a moderate altitude, whereas small exposures of serpulite grit and the more calcareous fucoid beds occur at high altitude on Beinn Eighe and Mullach Coire Mhic Fhearchair to the north of Loch Maree.

Igneous Rocks

These are rocks formed by volcanic activity and can be divided into extrusive, intrusive and pyroclastic rocks.

Extrusive rocks are formed by lava flows spreading out over an already formed landscape. Basalts are by far the most frequent type and these are concentrated around the area of Tertiary volcanic activity on the west coast of Scotland. They are composed of a number of separate lava flows (twenty or more on the Trotternish ridge in northern Skye) which can result in a layer over 1000m thick. The separate flows can be seen as horizontal bands (Fig. 1•11) and as each lava flow has a somewhat different minerology, ranging from very acidic to fairly basic, the lichen flora they support varies accordingly.

Other types of extrusive rocks (andesites, rhyolites) occur occasionally elsewhere, e.g. the summit of Ben Nevis and in Glen Coe (Fig. 1•12), and can also be botanically important.

Intrusive rocks are formed when a volcanic lava solidifies before it reaches the surface but is later exposed by weathering of the overlying rock. They are more widely distributed than extrusive rocks and are to be found scattered over much of the Scottish Highlands.

Figure 1•11. Cuithearaing (Quiraing) on the Trotternish ridge, Northern Skye; showing successive lava flows.

The most frequent type is granite and as this is a relatively young, hard rock, it often forms very high ground (e.g. the Cairngorms). The other main type of intrusive rock is gabbro which forms the Cullins of the Isle of Skye. Both granite and gabbro are very nutrient poor rocks and support a correspondingly impoverished flora.

Pyroclastic Rocks are formed of material ejected from the vent of a volcano. They occur associated with other igneous rocks and can be botanically important.

1•4•3•3 Geological Factors which Influence Lichen Distribution

Basic Rocks - The presence of basic rocks is the single most important geological factor influencing lichen distribution. The location of limestone outcrops in the Scottish Highlands is shown in Fig. 1•13, which also shows where these rocks outcrop at high altitude.

Weathering - How a rock weathers (and, consequently, the range of habitats available for lichen colonization) depends very much upon its structure and hence its geology. This is admirably demonstrated on the Isle of Skye where the rounded contours of the granite Red

Hills contrast with the jagged sky-line of the gabbro Cullins (see Craig 1990, Fig. 13•12) and the dramatic land-slips and lava flows of the Tertiary basalts of the Trotternish ridge. (Fig. 1•11).

Figure 1•12. Aonach Dubh, Glen Coe; showing the basic, richly vegetated andesite strata below overlain by almost bare acidic rhyolite strata (junction shown by arrows).

Schists are characterized by their foliated structure and weather readily to form a detritus and numerous micro-habitats which more irregularly structured rocks do not produce. This is the main reason why even acid schist is a better lichen substratum than most other rocks.

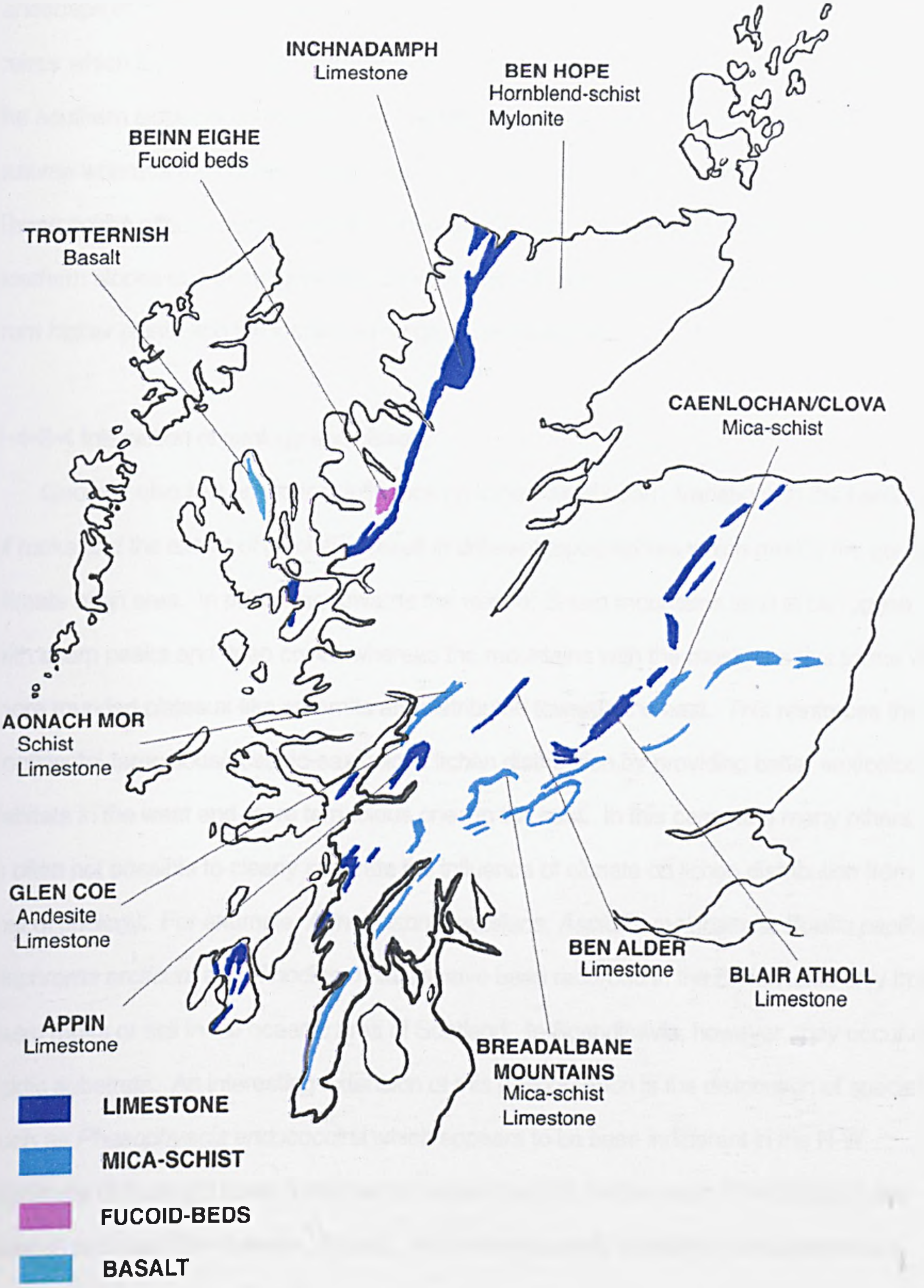

Figure 1·13. Map showing the distribution of strongly basic rock in the Scottish Highlands.

Glaciation This is a very special kind of weathering and has had a dramatic effect on the landscape of the Scottish Highlands. It is the cause of the deep north or north-east facing coires which feature strongly in the anatomy of many mountains. It is often the case that the southern slopes of a mountain are smooth and grassy with only the occasional rock outcrop whereas the northern side is cut into by deep, rocky coires (Figs 1•15 and 1•16). These coires often provide excellent lichen habitats and are invariably richer than the southern slopes due to the generally damper (but not wet) conditions, lack of competition from higher plants and the increased range of microhabitats.

1•4•3•4 Interaction of geology and climate

Geology also has an indirect influence on lichen distribution. Variations in the hardness of rocks and the extent of glaciation result in different topographies which modify the general climate of an area. In particular, towards the west of Britain mountains tend to be rugged with sharp peaks and deep coires whereas the mountains with the most massive forms with more rounded plateaux-like summits are distributed towards the east. This reinforces the continental-terricolous/oceanic-saxicolous lichen distribution by providing better saxicolous habitats in the west and more terricolous ones in the east. In this case, and many others, it is often not possible to clearly separate the influence of climate on lichen distribution from that of geology. For example, *Arthrorhaphis vacillans, Aspicilia melanaspis, Buellia papillata, Nephroma arcticum* and *Rinodina mniarea* have been recorded in the British Isles only from basic rocks or soil in the oceanic area of Scotland. In Scandinavia, however, they occur on acidic substrata. An interesting extension of this phenomenon is the distribution of species such as *Phaeophyscia endococcina* which appears to be base indifferent in the N-W Highlands of Scotland but is restricted to base-rich rocks further south (The English Lake District) and east (Ben Lawers, Angus). In its more easterly localities it is subjected to a much more continental climate.

Lichen distribution is a result of a number of interacting climatic and geological factors which are usually impossible to separate. It is not yet possible to make more than very general correlations between lichen distribution and the climate but some progress has been

Figure 1•15. Ladhar Bheinn (Knoydart) from the south; showing smooth rounded vegetated slopes with little exposed rock.

Figure 1•16. Ladhar Bheinn (Knoydart) from the north; showing a deep coire with bare rock and loose boulders which are an important lichen habitat.

made in relating lichens to rock-type, particularly with regard to its pH.

1.4•3•5 Classification

Brown *et al.* (1993b) devised a classification of the geology of the Scottish Uplands which they used to assess the relationship between the geology of a site and its plant community diversity. They outline the difficulties involved, i.e. that much of the biologically relevant data (rock pH, composition, metamorphism and weathering properties) are not available for the Scottish Highlands and were, consequently, constrained to work with mapped variables, i.e. chronological sequence and general lithology. Not surprisingly given these constraints they detected very little effect of geology on the diversity of plant communities, with the notable exception of the Breadalbane Mountains in Perthshire.

Their classification is given in Table 1•4. They divide the main chronological series into basic, intermediate and acid rocks but do not specify whether these terms are used in the geological or botanical sense. The use of these terms for metamorphic and sedimentary rocks suggests a botanical usage while the use of 'intermediate', the lack of a 'basic' sub-division of the SODJ series and a reliance on 'mapped variables' suggests a geological one.

Table 1•4. Rock types identified by Brown *et al.* 1993b as potentially having an effect on the distribution of plant communities in the Scottish Highlands.

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1) Torridonian
  a) basic
  b) intermediate
  c) acidic

2) Moine
  a) acidic

3) Dalradian
  a) basic
  b) intermediate
  c) acidic

4) Silurian, Ordovician, Devonian & Jurassic (SODJ)
  a) intermediate
  b) acidic

5) Granites (inc. Gabbro and Syenite)
6) Extrusive basalts and lavas
7) Intrusive basic dykes
8) Limestone

This classification obviously has severe limitations when assessing the influence of geology on plant distribution. Apart from the problems mentioned above it makes no distinction between acid or basic basalts and lavas. Of more value would be a classification based upon lithological variation (i.e. the composition and texture of rock).

Composition - By far the most botanically important aspect of the composition of a rock is its pH and this can be readily ascertained in the field by using indicator species. Most rock can be considered to be acid (siliceous) unless it supports species indicating more basic conditions. Intermediate (sub-basic) rocks are indicated by some of the less demanding species of the *Rhizocarpon petraeum* nodum (James *et al.* 1977), e.g. *Caloplaca flavovirescens, Catillaria chalybeia, Pertusaria flavicans, Polyblastia theleodes, Rhizocarpon petraeum, Porpidia speirea,* etc. while truly basic conditions are indicated by *Collema* spp, *Gyalecta jenensis, Leptogium* spp., *Placynthium nigrum, Solorina saccata,Toninia aromatica,* and an abundance of pyrenocarpous species.

The only other chemical characteristic of major botanical consequence is metal enrichment. The only metal ion that is at all frequent is iron, readily indicated by the presence of *Acarospora sinopica.* Heavy-metals are also encountered occasionally but these also have a unique, easily identifiable lichen flora associated with them.

Texture - This can be assessed by recording a number of characters of the rock being studied e.g. hardness, schistosity, fine/coarse-grained. Unfortunately, there are no means of readily assessing these variables in the field.

In this work the composition and texture of rocks are only assessed subjectively. Although this is far from ideal it has the advantage over using mapped variables that the variables are at least relevant to plant distribution; a subjective assessment of 'acid or basic' or 'fine or coarse grained' rock is more important than knowing if the rock is part of the Moine or Dalraidian series.

Other montane areas of the British Isles have a similar mix of acid and basic rocks as the Scottish Highlands with the former dominating in all cases. Only in the Northern Pennines are there extensive limestone outcrops at a moderately high altitude (to 710m) but these have not been properly surveyed and are not considered in this work. There are also significant basic outcrops in North Wales and the West of Ireland but only small amounts in the Lake District.

CHAPTER 2

NEW TAXA, TAXONOMY and IDENTIFICATION

2•1 **Introduction**
2•1•1 Additions to the British Lichen Flora
2•1•2 Unidentified Collections

2•2 **Taxonomy**
2•2•1 Introduction
2•2•1•1 Infra-specific Taxa
2•2•1•2 Probable Systematic Adjustments
2•2•2 Descriptions of New Taxa

2•3 **Identification**
2•3•1 Keys to Sterile, Crustose Saxicolous and Terricolous Species
2•3•1•1 Introduction
2•3•1•2 The Keys
2•3•2 Keys to Genera
2•3•2•1 *Lecidea*
2•3•2•2 *Porpidia*
2•3•2•3 *Rhizocarpon* subgenus *Phaeothallus*
2•3•2•4 *Rimularia*

2•1 INTRODUCTION

Sound taxonomy is an essential pre-requisite of any biological investigation; research based on incorrect or incomplete taxonomy must be considered suspect. The large number of taxonomic problems concerning the British montane lichen flora contributes to its reputation of being 'difficult' and, in the hope that a better understanding of the taxa involved will promote more and better research, a considerable amount of attention has been given to this subject.

All the montane species added to the British lichen flora since the publication of *The Lichen Flora of Great Britain and Ireland* (Purvis *et al.* 1992) are briefly described. Short descriptions are also given of all the problematic collections made during the course of this study. These are followed by full descriptions of those taxa which are well enough understood to be formally described.

Although *The Lichen Flora of Great Britain and Ireland* (Purvis *et al.* 1992) has done much to assist in the identification of British lichens it did not include a key to sterile, saxicolous and terricolous species and, as these are particularly frequent in the upland/montane region, the production of a key to the upland/montane sterile saxicolous and terricolous lichens was considered to be an appropriate aspect of this research.

Keys are also provided to four genera (*Lecidea, Porpidia, Rhizocarpon* subgenus *Phaeothallus* and *Rimularia*) which have either been significantly revised since 1992 or to which several taxa have been added during this study.

2•1•1 Additions to the British Lichen Flora

During the course of this research a considerable number of species have been recorded for the first time from the British Isles. The following 24 species, which do not appear in *The Lichen Flora of Great Britain and Ireland* (Purvis *et al.* 1992), have all been recorded from the mountains of the British Isles by the author, although earlier, mis- or un-identified specimens have sometimes been located. In addition four other species were rediscovered in the British Isles

***Arthrorhaphis vacillans* Th. Fr. & Almq.** - One collection from the Inchnadamph NNR. Over bryophytes on limestone (although the vegetation is distinctly calcifuge). This species is distinguished from other members of the genus by its 3-septate ascospores (Fig. 2•1).

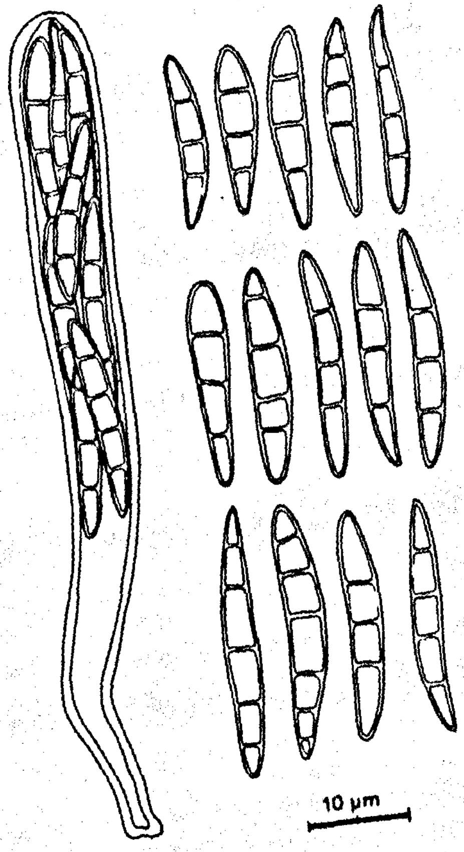

Figure 2•1. *Arthrorhaphis vacillans* - drawing of spores and ascus. (from Clauzade & Roux 1985).

***Biatora subduplex* (Nyl.) Printzen** - Collected from two sites on the Ben Lawers NNR. It occurs over bryophytes in shaded situations. Distinguished from *B. vernalis* by being completely colourless internally.

***Buellia papillata* (Sommerf.) Tuck.** - Collected from base-rich, montane heath on the Beinn Eighe NNR. Overgrowing bryophytes (and possibly *Pannaria pezizoides*). Differs from *B. insignis* which occurs in a similar habitat, by its smaller ascospores (18-24 x 8-10µm) and absence of oil-droplets in the hymenium.

***Fuscidea oculata* Wirth** - Collected from Glen Clunie (S. Aberdeen). This is the sorediate morph of *Fuscidea intercincta* and probably not worthy of taxonomic recognition.

***Lecanora marginata* (Schaerer) Hertel & Rambold** - Previous British records of this species are referable to *L. atromarginata* (H. Magn.) Hertel & Rambold which differs in having innate apothecia and containing stictic acid instead of atranorin. All British specimens of *L. marginata*, from the Breadalbane mountains and Carn Eige, lack usnic acid (subsp. *elata*).

'*Lecidea*' *luteoatra* Nyl. - Locally frequent on hard, fine-grained acid rocks (particularly quartzite) throughout the Scottish Highlands. It has a yellow thallus (containing usnic acid) with black, innate apothecia. The first record appears to be by B.J. Coppins from Ben Avon.

***L. promiscens* Nyl.** - A member of the *L. auriculata* group but with a less massively developed exciple with wider hyphae. It has been recorded from exposed sandstone boulders at high altitude in the NW Highlands of Scotland and on the sides of granite boulders at intermediate altitude in the Cairngorms where it appears to be quite frequent. Probably overlooked elsewhere.

***L. promiscua* Nyl.** - A member of the *L. auriculata* group but with a well-developed thallus which is UV+ whitish due to the presence of 2'-O-methylperlatolic acid. Only recorded in the

British Isles from the Northern Cairngorms but probably overlooked elsewhere.

***L. syncarpa* Zahlbr.** - Similar to *L. paupercula* but with norstictic acid in place of stictic acid and smaller ascospores. British collections also appear to have a thicker thallus. Recorded on granite boulders from the Northern Cairngorms and Aonach Mór (Lochaber) but probably overlooked for *L. paupercula*, although this species is itself not common.

***Lecidea swartzioidea* Nyl.** - Frequent throughout the montane/upland areas of the British Isles. Previously confused with *L. lapicida* var. *pantherina* (syn. *L. lactea*) from which it differs in having a dark brown, not pale brown to colourless, hypothecium. A number of collections with a densely pruinose apothecial disc *(L. lithophiloides* (Nyl.) are referred here.

***Lecidella patavina* (A. Massal.) Knoph & Leuckert** - Known from a single gathering on the Ben Lawers NNR. It is similar to *L. stigmatea* from which it differs primarily in that the hymenium is rich in oil droplets.

***Lopadium coralloideum* (Nyl.) Lynge** - Occasional over bryophytes in damp crevices on the Ben Lawers NNR and the nearby Meall na Samhna. It consists of numerous, olive -brown, coralloid squamules.

***Micarea marginata* Coppins** - Although not restricted to montane areas this species is particularly frequent around areas of prolonged snow-lie where it is always abundantly fertile. In other habitats apothecia are rare. It is also fairly frequent elsewhere in montane areas but has only been seen with pycnidia.

Miriquidica liljenstroemii* (Du Rietz) Rambold & Ove-Larsson *in ed. - Occasional on the tops of acidic boulders in the Cairngorms and rarely further west (Ben Lawers, Ben Cruachan). It is similar to *M. nigroleprosa* but lacks psoromic acid (Pd-) and has a darker grey, almost black, thallus.

***Phylliscum demangeonii* (Moug. & Mont.) Nyl.** - On quartzite boulders below waterfall (probably flushed by base-rich water (Fig. 2•2). The small brown-black, peltate thalli and 12/16 spored asci are diagnostic.

Figure 2•2. *Phylliscum demangeonii*, Ben More Assynt Forest. The only British collection was made from the flat quartzite boulder on the far right of the picture.

***Porpidia grisea* Gowan** - the sorediate morph of *P. tuberculosa*. Probably worthy of recognition onlyat infraspecific level. This taxon is discussed more fully in section 2•3•2•2 (p. 170).

***Porpidia ochrolemma* (Vainio) Brodo & R. Sant.** - Known from two collections from the Snowdon range in North Wales. This species has a smooth orange thallus, blue-grey punctiform soralia and contains stictic acid. *P. melinodes* is similar but has a more areolate thallus and contains confluentic acid.

***Porpidia zeoroides* (Anzi) Knoph & Hertel** - Recorded from the Ben Lawers NNR and one locality in Argyll (Ben Sgulaird). It differs from *P. superba* in the apothecia having a black, not brown disc and the outer edge of the exciple being white pruinose (Fig. 2•3).

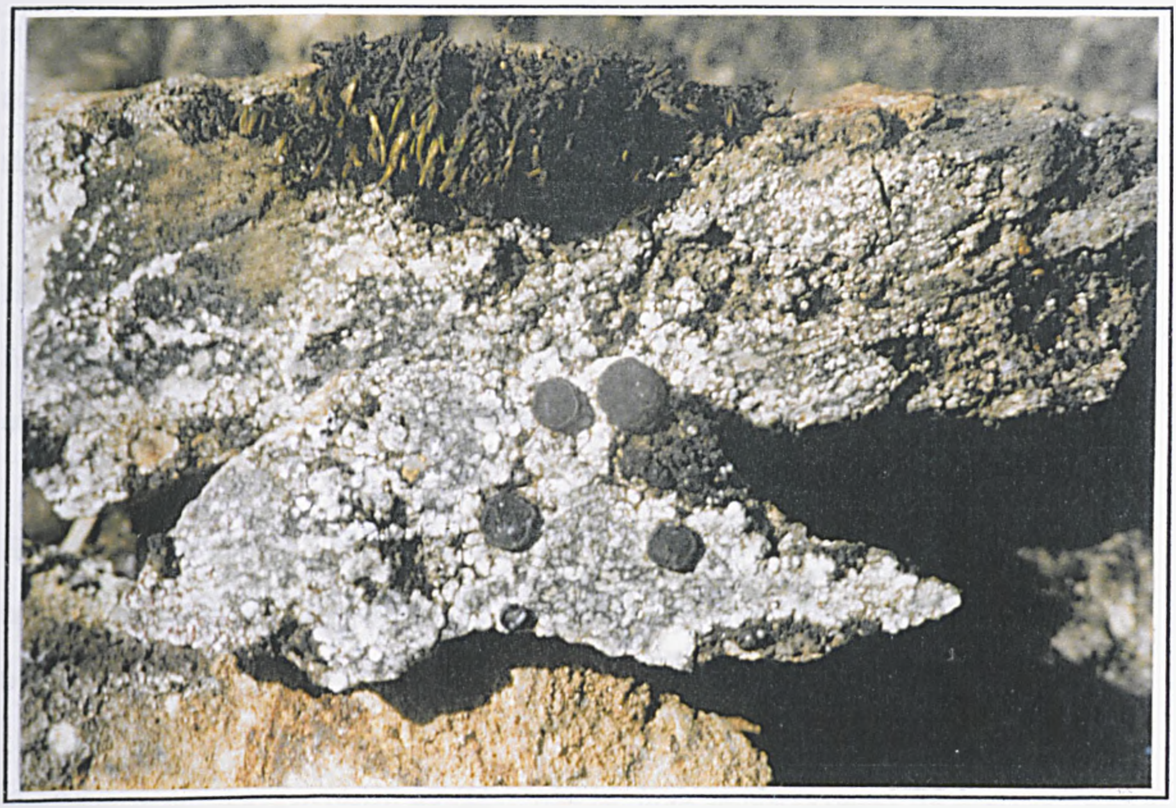

Figure 2•3. *Porpidia zeoroides*. (Magnification: x4)

Pseuephebe minuscula **(Nyl.) Brodo & Hawksw.** - On top of granite boulders in the Northern Cairngorms. Similar to *P. pubescens* but with flattened branches, especially near the point of attachment where it appears almost foliose, resembling a *Parmelia (Melanelia)* sp.

Rhizocarpon anaperum **(Vainio) Vainio** - The first British collection of this member of the *R. obscuratum* group was made by W. Watson from 'near the summit of Snowdon' in 1929 although it was mis-identified as *R. grande*. It has subsequently been correctly recorded from a number of Scottish mountains (usually on pebbles in damp coires), Carnedd Llewellyn in North Wales (where it is abundant) and from spoil on four disused metal-mines in Mid Wales. It is characterized by its dark brown to orange thallus, small apothecia and broadly ellipsoid, muriform ascospores.

Rhizocarpon cinereonigrum **Vainio** - Recorded from two areas of prolonged snow-lie in the Scottish Highlands (Ben Ghlas and Aonach Mòr). It is very similar to *R. badioatrum* from which it differs in the presence of stictic acid in its thallus (*R. badioatrum* lacks lichen substances) and its ecology of being confined to high altitudes (*R. badioatrum* is a species of occasionally inundated rocks on the margins of sub-montane/low-montane lochans and streams).

Rhizocarpon submodestum (Vainio) Vainio - Recorded from Glas Maol (damp coire) and Aonach Mòr (prolonged snow-lie). Distinguished by its small grey thallus (<1cm diam.) containing stictic acid and persistently 3-septate ascospores.

Rimularia sphacelata (Th. Fr.) Hertel & Rambold - Over moribund bryophytes on granite boulder on the north ridge of Aonach Mòr. Distinguished by its white thallus containing norstictic acid.

Thelidium aeneovinosum (Anzi) Arnold - Collected from semi-inundated, mica-schist rocks at several sites in the Breadalbane Mountains. It is similar to *T. pyrenophorum* but has larger ascospores.

Rediscovered

In addition to those additions to the British lichen flora listed above a number of taxa were recorded for the first time in the British Isles this century.

Micarea submoestula - Known from several sites on the tertiary basalt of Western Scotland, e.g. Trottemish (Skye), Ben Hiant (Ardnamurchan), Ardmeanach (Mull). Previously only known from a 19th century record from the West of Ireland.

Polyblastia gothica - Known from several Scottish mountains where it grows over bryophytes on summit heaths and around areas of prolonged snow-lie. Not recorded in Britain since 1864.

P. helvetica - Frequent in similar habitats to *P. gothica*. This taxon has been recorded this century but was considered to be very rare.

Toninia rosulata - Collected from a single calcareous mica-schist crag above Lochan nan Cat on the Ben Lawers NNR. Previously known in Britain from only two 19th century records, also from the Ben Lawers NNR.

2•1•2 Unidentified Collections

During the investigation of the British montane lichen flora approximately 50 apparently undescribed taxa have been discovered and the taxonomic position of some previously unplaced entities elucidated. A number of others appear to resemble taxa not previously recorded from the British Isles but have yet to be confirmed as such.

Most names are working, herbarium names and have yet to be validly published. The exceptions are *Catillaria gilbertii* Fryday & Coppins, *Halecania bryophila* Fryday & Coppins, *H. micacea* Fryday & Coppins and *Stereocaulon plicatile* (Leighton) Fryday & Coppins. It is possible that some of the entities described below are extreme variants of known species.

***Adelolecia pilati* 'subsp. *pachythallina*' ad int.** - full description in section 2•2•2.

'*Amelia andreaeaicola*' ad int. - full description in section 2•2•2.

'*A. grisea*' ad int. - full description in section 2•2•2.

Aspicilia* aff. *grisea - Collected from Coire nam Beitheach in Glen Coe. This entity differs from *A. grisea* in its much paler, white thallus and in norstictic acid being confined to the soredia. One collection only.

Biatorella sp. - Known from a single collection from limestone near Shiehallion, Mid Perthshire, this species has numerous white apothecia on an almost non-existent thallus growing over bryophytes. One collection only.

Bryanora ?septentrionalis - a specimen from the summit ridge of Aonach Mòr (Lochaber) agrees with this species (which is close to *B. curvescens*) in lacking norstictic acid in the exciple. However, it agrees with *B. curvescens* in all other respects and is most probably a norstictic acid deficient strain of that species. One collection only.

Caloplaca ?insignis - Collected from Glen Lochay (Killin). This appears to be a parasitic species on *Aspicilia caesiocinerea* but the material is poor and a definite determination impossible. One collection only.

C. cf. vitellinula - Collected from vertical andesite in Glen Coe where it is quite frequent. It has a thin yellow to orange cracked-areolate thallus which becomes dispersed towards the margin and concolorous apothecia. One collection only.

Dr U. Søchting (Copenhagen) says of this collection "..similar to what has been called *C. vitellinula* auct. ..... The complex is by now badly understood, so a more precise identification is probably not possible at present."

***Catillaria gilbertii* Fryday & Coppins sp. nov.** - full description in section 2•2•2.

***Chromatochlamys 'confusum'* ad int.** - full description in section 2•2•2.

***C. 'geislerioides'* ad int.** - full description in section 2•2•2.

***Cliostomum 'subtenera'* ad int.** - full description in section 2•2•2. This species is closely related to *Lecanora tenera* which has recently been moved to *Cliostomum* (Ekman *in ed.*)

Dactylospora 'suburceolata" ad int. - Lichenicolous fungus. Known from two collections from the Ben Lawers NNR and one from the nearby Meall na Samhna, this species is lichenicolous on an unidentified, grey crustose lichen (possibly *'Lecidea' hypnorum*). It is similar to *D. urceolata* but differs in the persistently 3-septate ascospores and other minor apothecial characters.

Fuscidea 'poeltii' ad int. - full description in section 2•2•2.

F. cf. praeruptorum - Occasional to abundant in hyper- oceanic areas of Scotland (Outer Hebrides, Isle of Mull, Ardnamurchan) this entity is chemically identical to *F. praeruptorum* but differs in that the thallus consists of dispersed areoles on a black prothallus and that the soralia are discrete and punctiform. It is most probably a growth form of *F. praeruptorum*.

Halecania bryophila Fryday & Coppins sp. nov. - full description in section 2•2•2.

Halecania micacea Fryday & Coppins sp. nov. - full description in section 2•2•2.

Hymenelia ?pallida - Collected from the top of an acid boulder in Ardgour. Its distinguishing character is its colourless thallus and apothecia. One collection only.

Lecanora ?koreaensis - Collected from shaded rocks in the Outer Hebrides and Mar Forest, Braemar. This is a yellow, leprose species which contains usnic acid. It is locally abundant in this habitat in upland regions of the British Isles.

Lecidea aff. paupercula - Known from several sites in the Scottish Highlands (Isle of Mull, Rannoch, Strontian, East Perthshire, Angus). It has a small (usually <2cm diam.), pale grey-brown, Atrobrunnea-type thallus with an I+ blue medulla but all other spot-tests negative. It most closely resembles *L. paupercula* but that species has a more wide-spreading, red-brown to dark grey-brown thallus which usually reacts K+ yellow, Pd+ orange (stictic acid). A specimen is with Dr H. Hertel (Munich).

Lecidea* aff. *plana - Collected from the top of a boulder in pasture in Glen Lochay (Mid-Perthshire) and from the summit of Ben Lomond (Stirlingshire). It differs from *L. plana* in having a thick, grey thallus and possibly also containing confluentic acid in addition to planaic acid.

Lecidea* aff. *haerjedalica - Collected from granite on West Lewis (Outer Hebrides) and siliceous rock on Fraoch-bheinn (Westerness). It has a reduced *atrobrunnea*-type thallus with all spot tests reactions negative (including I), no substances being detected by tlc. It is similar to *L. haerjedalica* but differs in having a dark brown hypothecium, lacking an I+ blue medulla and also possibly having slightly larger ascospores (10-12x5-7µm).

Lecidella* aff. *anomaloides - Collected from Creag Loisgte near the summit of Ben Lawers. It differs from *L. anomaloides* in having a pale exciple. One collection only.

Lecidella* aff. *asema - Known from a number of sites in the Breadalbane Hills, as well as Glen Coe, Kintail, and Beinn Dearg (Wester Ross), this entity differs from *L. asema* in its less verrucose, pinkish thallus and larger apothecia. A specimen is with J. Knoph (Berlin).

***Lemmopsis* sp.** - collected from the Trotternish ridge on the Isle of Skye and the Snowdon range in North Wales. It is minutely fruticose and has been placed in *Lemmopsis* by Prof. P.M. Jørgensen (Bergen).

***Lepraria* sp. 'A'** - Collected from Clisham, North Harris. Contains psoromic acid

***Lepraria* sp .'B'** - Collected from Glen Bhaltos, West Lewis. Contains ?rangiformic/ roccellic acid.

Melaspilea sp. - collected from damp pebbles at >900m from two sites in Scotland; Glas Maol and Bidean nan Bian. It has colourless, 1-septate ascospores 15x7µm constricted at the septum and a green photobiont (i.e. not *Trentepohlia*).

Miriquidica aff. intrudens - Collected from Creag na h' Achlarich on Beinn Heasgarnich (Fryday 2236) This entity resembles *M. intrudens* although it does not appear to be parasitic. Dr G. Rambold (München) remarks of this specimen '.. by habitus very similar to *M intrudens* .... the lichenicolous growth as well as the thallospores *etc.* are not to be stated undoubtedly.'

M. cf. instrata - Collected from Coire nam Beitheach in Glen Coe (Fryday 3300). Dr Rambold remarks '... The specimen fits mostly with the combination of characters in *M. instrata*.'

?Moriola sp. - collected from montane heaths on Ben Lawers and Beinn Heasgarnich this entity has a brown thallus consisting of brown 'sphaerocysts' (green algae inside a globose, fungal sheath) and occasional small, lecanorine apothecia with 1-septate ascospores 15-18 x 5.5-6.0 µm.

Ochrolechia tartarea 'f. sorediata' ad int. - full description in section 2•2•2.

Placynthium aff. asperellum - Collected from damp schist in the Breadalbane Mountains and the Snowdon range in North Wales. It has long, narrow, terate brown lobes forming a ±continuous crust.

P. aff. nigrum - Fairly frequent throughout the Scottish Highlands on basic rocks. It is always sterile and differs from *P. nigrum* in that the thallus is covered by a mass of coralloid isidia.

Porina ?nigratula - Collected from two localities in the Breadalbane Mountains. It resembles *P. mammillosa* but has a coralloid thallus recalling *Zamanhofia*. A specimen is with A. Orange (Cardiff).

Porpidia '*confluenta*' ad int. - full description in section 2•2•2.

P. '*striata*' ad int. - full description in section 2•2•2.

P. aff. *flavicunda* - Known from a number of sites throughout the Scottish Highlands, this entity resembles *P. flavicunda* macroscopically but differs in the thallus always lacking lichen substances (confluentic acid in *P. flavicunda* s.str.). The apothecia have a persistent smooth, wide margin with a slightly pruinose disc and the exciple and hypothecium always contain a K+red pigment. A fuller discussion on the problems surrounding the orange species of *Porpidia* is given in the notes on the Key to *Porpidia* (Section 2•3•2•2)

P. '*smaragdula*' - Known from one collection from disused mine workings at Strontian, this species resembles *P. melinodes* in having an orange thallus with blue-grey soredia. It differs in its distinctive bright blue epithecium - a character otherwise only known in the genus in the very different *P. hydrophila*. This collection possibly belongs in the closely related *Farnoldia*.

P. aff. *contraponenda* - Chemically identical to *P. contraponenda* but with soredia.

P. aff. *glaucophaea* - This species is not rare in the Scotish Highlands. It is chemically similar to the lowland *P. soredizodes* but has a much thicker, more warted thallus.

P. *superba* 'var. *sorediata*' ad int. - full description in section 2•2•2.

Rhizocarpon '*caesium*' ad int. - full description in section 2•2•2.

R. '*colludens*' (Nyl.) ad int. - full description in section 2•2•2.

R. *colludens* subsp. '*rufoatrum*' ad int. - full description in section 2•2•2.

***R. 'sublavatum'* ad int.** - full description in section 2•2•2.

***R.* sp. 'A'** (Gilbert *et al.* 1988) - Also collected from a further site on the Ben Lawers N.N.R. Further work needed.

***Ropalospora lugubris* 'subsp. *sorediata*' ad int.** - full description in section 2•2•2.

***Stereocaulon plicatile* (Leighton) Fryday & Coppins comb. nov.** - Full description in section 2•2•2.

Sterile Crust 'A' - Collected from Glen Coe, this entity somewhat resembles *Fuscidea gothoburgensis* but contains stictic acid. It has a brown thallus with creamy, punctiform, soredia. One collection only.

2·2 TAXONOMY

2·2·1 Introduction

Many of the unidentified collections made during the course of this study are well enough understood to be formally described, either because they are very distinctive (e.g.'*Amelia andraeaeicola*', *Halecania 'bryophila'*, *Lecanora 'subtenera'*, etc.) or because they are relatively frequent (e.g. *Chromatochlamys 'confusum'*, *Porpidia 'striata'*, *Rhizocarpon 'sublavatum'*, etc.) . In preparation for this, descriptions of these taxa are provided below.

Although some of these taxa were discovered before this particular research programme was begun they are included here as knowledge of their distribution and ecology has increased during the course of this study. Most of the microscopic work and all the work on their systematic position with relation to other taxa has also taken place during the period of this study.

2·2·1·1 Infraspecific taxa

The tendency to reproduce by the production of vegetative propagules rather than sexually is much more fequent in lichens than it is in vascular plants. In vascular plants these often occur in montane habitats (e.g. *Deschampsia cespitosa* subsp. *alpina*, *Festuca vivipara*, *Huperzia selago*, *Poa alpina*, *Persicaria viviparum*, *Saxifraga cernua*) as an adaptation to stress and the short growing season (Raven & Walters 1956). Due to the nature of lichens as dual organisms the role of vegetative reproduction has a different function. Rather than being an adaptation to stress it is a colonizing mechanism as both symbionts are involved whereas in sexual reproduction only the mycobiont is propagated. Consequently, in montane habitats where lichens are well adapted to their particular ecological niche, fertile reproduction is favoured and the production of vegetative propagules occurs primarily in species which also occur in an atypical habitat (e.g. damp rocks) or as an extension of altitudinal range. Of the 282 taxa identified as montane specialists (section 3·1·2), 27 produce vegetative propagules. Of these 17 are low-montane (10·24%), 10 mid-montane (9·6%) and none are high-montane, suggesting that vegetative reproduction becomes less favoured with increasing altitude. Although 6 of the 18 new taxa described in section 2·2·2 reproduce vegetatively this is more a consequence that they have been overlooked in the past than an indication of the importance of vegetative reproduction in montane lichens. Of these 6 taxa, two (i.e. *Fuscidea poeltii* and *Porpidia confluenta*) appear to be confined to montane habitats, and *F. poeltii* reproduces sexually in addition to vegetatively. Of the others, *Porpidia superba* var. *sorediata* occurs in much damper habitats than the typical form, whereas the other 3 appear to be reproducing vegetatively as an extension of their range. However, the phenomenon described for vascular plants may also be of limited occurrence as the frequent woodland species *Micarea cinerea* almost invariably occurs in montane heaths as its anamorph (see section2•2•1•2).

A great deal of thought has been given to the level at which to recognise infraspecific taxa, in particular those entities which are clearly morphs of already described taxa but reproduce vegetatively by the production of soredia, isidia or pycnidia rather than sexually through the production of ascomata. Traditionally, following Du Rietz (1924), these were considered to be distinct species and this has also been the level chosen more recently by Tønsberg (1992) when he described the sorediate morph of *Micarea peliocarpa* as *M. coppinsii*. In general, however, the recent trend is to afford the production of vegetative propagules less significance and they have usually been treated as forms (Tehler 1983, Gilbert & Coppins 1992) or sometimes not afforded any taxonomic recognition at all (Sipman 1983, Niebel-Lohmann & Feuerer 1992). This latter solution is the most appropriate where vegetative and sexual propagules are produced on the same thallus, as occurs, for example, in some species of *Fuscidea* (e.g. *F. cyathoides, F. intercincta, F. kochiana, F. lygaea*) but where the two means of reproduction occur on separate plants this indicates a significant genetic difference which is worthy of taxonomic recognition. In this case the vegetatively reproducing morph must be recognised taxonomically as otherwise the information regarding its distribution will be lost.

Poelt (1994) reviewed this problem concluding that where asexual reproduction is the only, or major, form of reproduction then the entity should be treated as a distinct taxon. However, the examples he gives are of species pairs where the two morphs are separated geographically, often on different continents, whereas those considered here usually occur together or are, at most, separated only by altitude or substratum preference. Where there are no other significant differences (e.g. in morphology or chemistry) I consider that to treat them at species rank is to give them too great a distinction. This would also disguise the close relationship between the two taxa.

Some infraspecific rank is, therefore, appropriate but the decision as to which is not obvious. Although 'form' is the rank most often used (*Dirina massiliensis* f. *sorediata, Lecidea pycnocarpa* f. *sorediata, Thelidium papulare* f. *sorediatum, Verrucaria macrostoma* f. *furfuracea*), 'subspecies' (e.g. *Lecanora campestris* subsp. *dolomitica*) and 'variety' (e.g. *Fuscidea cyalthoides* var. *sorediata, Schaereria fuscocinerea* var. *sorediata, Stereocaulon vesuvianum* var. *nodulosum*) have also both been employed. In all these cases there are little, if any, other changes in thallus morphology or chemistry.

Because differences in method of reproduction imply a greater genetic difference than, for example, morphological or chemical differences I consider the rank of 'subspecies' to be the most appropriate for those vegetatively reproducing morphs where ascomata are unknown or extremely rare. This is also the rank given to vascular plants which reproduce vegetatively (e.g. *Deschampsia cespitosa* subsp.*alpina*). The other two infraspecific ranks may be more appropriate where the main differences are morphological or chemical, including those vegetatively reproducing morphs which occasionally, or even regularly produce apothecia.

The guidelines I have used for deciding which rank to assign an entity are given in Table 2•1.

Table 2•1. Guidelines used for deciding to which taxonomic rank to assign vegetatively reproducing morphs of fertile species.

Species	Ascomata unknown or extremely rare. Additional significant differences (i.e. in morphology, ecology, distribution or chemistry).
Sub-species	Ascomata unknown or extremely rare. No other significant differences apart from ecology.
Variety	Ascomata occasionally present. Additional significant differences.
Form	Ascomata occasionally present. No other significant differences.
	Ascomata usually present. Additional significant differences.
No Rank	Ascomata usually present. No other significant differences.

Unfortunately it is rarely possible to determine from published sources whether the production of soredia etc. is accompanied by a corresponding decrease in the production of ascomata (e.g. Purvis *et al.* 1992). Original descriptions are sometimes of use but these also often just report the presence of vegetative propagules, especially older descriptions. They are also often based on an unrepresentative range of specimens. It is also dangerous to rely on an examination of herbarium specimens for the same reason;these rarely give a true representation of the relative abundance of ascomata in a population as it is usually the best developed specimens (i.e. those with apothecia) which are collected. However, if all, or the majority, of herbarium specimens of a taxon are sterile then it is probably safe to assume that the taxon rarely produces ascomata. It is only by an examination of a representative range of specimens that the correct rank of an entity can be ascertained and for this there is no substitute for field work.

The situation concerning pycnidiate morphs (anamorphs) of fertile species is somewhat more complicated as although plants are to be found reproducing solely by pycnidia, these are also frequently to be found on fertile plants. The case of *Micarea cinerea* and its anamorph is a good example. The anamorph is a frequent lichen of acidic montane heaths and the lack of apothecia led to its being described as a separate species in a new genus (*Hastifera tenuispora* Hawks. & Poelt 1986). However, although the anamorph rarely produces apothecia the fertile plant often produces pycnidia and so to accept it at the rank of subspecies probably overstates its distinctiveness. In this case the presence of ecological differences (*M. cinerea* usually occurs over bryophytes in damp woodlands) and the occasional occurrence of apothecia is sufficient to warrant recognition at the rank of 'variety' (i.e. *Micarea cinerea* var. *tenuispora*). Similarly, the anamorph of *Micarea marginata* is known from a wide range of saxicolous habitats (lowland walls to pebbles in montane heaths) but it is only regularly found with apothecia in the vicinity of areas of prolonged snow-lie where the anamorph is unknown. To recognise the anamorph at infra-specific level, possibly 'variety', makes ecological sense although *Trapelia obtegens* shows a similar distribution but the snow-bed plants are apparently indistinguishable from the lowland ones. This is discussed more fully in Chapter 4. The case of the common upland/montane species *Fuscidea cyathoides* represents a different situation. Mosaics of this species frequently include some plants with numerous pycnidia but no apothecia among the normally fertile population. This is similar to the case of sorediate morphs among fertile populations of other species and such plants are probably not worthy of taxonomic recognition.

When the differences are confined to morphology, ecology or chemistry the choice as to which infraspecific taxon is most appropriate can only be based on the number and degree of the differences. In both cases described below, *Adelolecia pilati* subsp. *'pachythallina'* and *Rhizocarpon colludens* subsp. *'rufoatra'*, differences in all three characters are involved and so the highest infraspecific rank is used. If the differences had been fewer or less pronounced then 'variety' or 'form' would have been more appropriate. It would have required differences in apothecial anatomy for the taxon to be recognised as a distinct species.

The application of the guidelines outlined above to already described montane taxa will result in a number of changes of taxonomic rank. Among these are that the sorediate forms of *Lecidia pycnocarpa* (*L. pycnocarpa* f. *sorediata* Coppins & Fryday) and *Thelidium papulare* (*T. papulare* f. *sorediatum* Coppins) will be raised to subspecies level whereas *Lecanora soralifera* would become *L. intricata* subsp. *soralifera.*

2•2•1•2 Probable systematic adjustments

In addition to the new taxa described below a number of other systematic adjustments concerning taxa frequent in montane areas are also required. These include:-

1) **The Micarea assimilata group** - This group of species (*M. assimilata, M. incrassata, M. paratropa, M. submoestula*) differ from the type specimen of *Micarea* (*M. prasina*) in a number of respects:-

- they have relatively large ascospores and relatively stout paraphyses, 1•5-1•7(-2•0)µm thick (0•5-1•0µm in *M. prasina*) which are simple but branched above (branched and anastomosing in *M. prasina*).
- they have a well-developed thallus composed of thick, corticate, convex areoles which lack lichen substances.
- they usually have cephalodia containing *Stigonema* or are associated with loose

colonies of the cyanobacterium.

- they mostly have an 'arctic-alpine' distribution, in the British Isles being confined to the tops of the highest mountains in the Scottish Highlands. The exception is *M. submoestula* which has an oceanic distrbution. In the British Isles this species has been recorded recently only from the tertiary basalt of the west coast of Scotland.

They do, however, all have a micareioid photobiont.

Two other species of *Micarea* (*M. crassipes* and *M. melaenida*) have also been provisionally referred to this group (Coppins 1983). Although both lack the characteristic cephalodia of the group they share a number of other characters which reduce the distinction of the *M. assimilata* group from the rest of the genus. *M. crassipes* has an 'arctic-alpine' distribution and a bryophilous habitat but differs in having apothecia with a well developed exciple and a more granular thallus. The non-British *M. melaenida* has a southern, low-altitude distribution, occurs on sandy soils, has a less well-developed thallus and smaller apothecia. If *M. crassipes* is accepted as a member of this group then the name *Helocarpon* Th. Fr. is available.

2) ***The Stereocaulon leucophaeopsis* group** - This group of species (*S. leucophaeopsis, S. tomense* and, the recent new combination *S. plicatile* (Fryday & Coppins 1996b)), form a well-defined group within *Stereocaulon*. They all lack pseudopodetia, their apothecia developing from between the thalline areoles, and they all have a dark hypothecium. They also lack well-defined cephalodia, although loosely associated colonies of cyanobacteria are often present. Other species of *Stereocaulon* all have apothecia borne on pseudopodetia and have a hyaline hypothecium. They also regularly bear well-defined cephalodia. However, they share the same ascus-structure (*Porpidia*-type) as the rest of the genus and have a similar chemistry (atranorin plus stictic or lobaric acids). They also have similar ascospores, although the submuriform ascospores of *S. plicatile* are somewhat anomalous.

It is probable that these three species should be recognised at sectional, sub-generic or even generic level.

2·2·2 Descriptions of New Taxa

Sufficient material is to hand of the following entities for them to be confidently described as taxa new to science. Two new combinations are also made.

New Genus (1)

Amelia

New Species (13)

Amelia andreaeaicola
A. grisea
Catillaria gilbertii Fryday & Coppins
Chromatochlamys confusum
C. geislerioides
Cliostomum subtenera
Fuscidea poeltii
Halecania bryophila Fryday & Coppins
H. micacea Fryday & Coppins
Porpidia confluenta
P. striata
Rhizocarpon caesium
R. sublavatum

Infraspecific taxa (5)

Adelolecia pilati subsp. *pachythallina*
Ochrolechia tartarea f. *sorediata*
Porpidia superba var. sorediata
Rhizocarpon colludens subsp. *rufoatrum*
Ropalospora lugubris subsp. *sorediata*

New Combinations (2)

Rhizocarpon colludens
Stereocaulon plicatile (Leighton) Fryday & Coppins

Adclolccia pilati 'subsp. *pachythallina*' ad int.

Typus: Caledonia, Argyll Main (V.C. 98), Glen Coe, Coire nam Beitheach, 27/1454, 1075m, vertical, S-facing acid rock (?rhyolite) in NE-facing coire, 14 August 1992, *A.M. Fryday* 3405 (E-holotypus)

Thallus cracked-areolate; areoles flat to slightly convex with a shiny surface; 0•1-0•25mm thick, white. *Photobiont* chlorococcoid, cells 9-15µm diam.

Apothecia black, lecidine, 0•4-0•8mm diam., with a persistent, slightly raised proper exciple, flat, becoming slightly convex when over mature. *Hymenium* blue-tinged, I+ blue, N+ red, 35-45µm tall; epihymenium dark blue, N+ red. *Paraphyses* simple to sparingly branched not swollen at apices. *Asci* clavate, 30 x 15µm, *Biatora*-type. *Ascospores* hyaline, simple,7-8 x 3-4µm. *Hypothecium* pale to mid brown. *Excipulum* composed of radiating hyphae 4-5µm wide, pale to mid brown with dark brown cortical cells, K+ magenta solution (7-chloroemodin).

Conidiomata not seen.

Chemistry: C-, K+ yellow, Pd-, UV-; atranorin, zeorin in thallus and 7-chloroemodin in exciple by TLC.

Adelolecia pilati subsp. *pachythallina* differs from subsp. *pilati* in its thicker thallus, smaller apothecia with less pronounced proper exciple and the presence of zeorin in the thallus. British specimens of the two varieties also show an ecological difference; subsp. *pachythallina* being known only from truly montane situations whereas subsp. *pilati* is primarily an upland species often growing on walls. The only other record of subsp. *pachythallina* is from Iceland (G. Rambold pers. com.) which suggests that this subspecies may be an arctic taxon and subsp. *pilati* an alpine one.

A number of other, non-British, collections of *A. pilati* which, although they apparently lack zeorin, have the morphological characters of subsp. *pachythallina* (G. Rambold pers. com.) are also probably referable here. The existence of these apparently intermediate specimens suggests that the two entities are conspecific although further study may show subsp. *pachythallina* to be worthy of recognition at species level.

Additional specimen examined: **Scotland: V.C. 88,** Mid-Perthshire, Ben Lawers NNR, West side of Ben Ghlas, 27/6240, 1050m, exposed side of acidic schist boulder, 26 March 1991, *Fryday* 2128.

Additional note: Dr G. Rambold (Munich) has additional records of this taxon. There are also a number of synonyms of *A. pilati* which may provide a validly published name (Santesson 1993) which it will be necessary to check before a formal description can be made.

'Amelia' ad int., gen. nov.

Typus: *'Amelia andreaeaicola'* ad int.

Thallus of small verrucose to sub-squamulose areoles. Forming small patches. *Photobiont* chlorococcoid, (6-)8-12(-15)µm diam.

Apothecia abundant, often covering much of the thallus. Small 0•1-0•25 mm diam., disc pale to dark brown (translucent when moist) usually with a paler proper exciple; flat to slightly convex, becoming strongly convex and distorted when over-mature. Initially immersed in thalline verrucae but becoming 1/2-3/4 emergent. Thalline exciple present in young apothecia but soon becoming excluded. *Hymenium* 100-120µm tall, I+ pale bluish or greenish. *Paraphyses* branched above but not anastomosing, septate; *c* 1•5-1•7µm wide slightly swollen at apex (to 2•5µm) with brown cap. Epihymenium with brown granules decolourizing in K. *Asci* numerous, 8-spored, ?*Catillaria*-type, 45-50 x 17-22µm, contents I+ red-brown. *Ascospores* simple, narrowly ellipsoid-fusiform to oblong-ellipsoid, 10-24 x 5-7µm. *Hypothecium* colourless, strongly conglutinated. *Excipulum* hyaline, but dull green (K+ brown) pigment at its outer edge, I+ deep blue or mauve.

Conidiomata not seen

Chemistry: C-, KC-, K-, PD-. UV-, not tested by TLC.

'*Amelia andreaeaicola*' ad int.

Typus: Caledonia, South Aberdeenshire (V.C. 92), Glas Maol, 37/161771, 900m, over *Andreaea* sp. on small stones and boulders in north-facing coire affected by late snow-lie, 12 September 1991, *A.M. Fryday* 2938 (E-holotypus)

Thallus of small verrucose to sub-squamulose areoles, chestnut to dark brown (paler in shade) occasionally greyish. Forming small patches (to c. 1cm diam.) over *Andreaea* spp. *Photobiont* chlorococcoid, cells (6-)8-12(-15)µm diam.

Apothecia abundant, often covering much of the thallus, small. 0•1-0•25 mm diam.; disc dark to chestnut brown (translucent when moist) usually with a paler proper exciple, flat to slightly convex becoming strongly convex and distorted when over-mature. Initially immersed in thalline verrucae but becoming 1/2-3/4 emergent. Thalline exciple present in young apothecia but soon becoming excluded. *Hymenium* 100-120µm tall, I+ pale bluish or greenish. *Paraphyses* branched above but not anastomosing, septate; *c* 1•5-1•7µm wide slightly swollen at apex (to 2•5µm) with brown cap. Epihymenium with brown granules decolourizing in K. *Asci* numerous, 8-spored, ?*Catillaria*-type, 45-50 x 17-22µm, contents I+ red-brown. *Ascospores* narrowly ellipsoid-fusiform, 18-24 x 5-7µm, often wider at one end. *Hypothecium* colourless, strongly conglutiated. *Excipulum* hyaline, but dull green (K+ brown) pigment at its outer edge, I+ deep blue or mauve.

Conidiomata not seen.

Chemistry: C-, KC-, K-, PD-. UV-, not tested by TLC.

This species was first recorded by Gilbert & Fox (1985), although they initially identified it as *Caloplaca nivalis*. *Amelia andreaeaicola* resembles that species in the shape of its ascospores and habitat but differs from it in all other respects; most obviously in the colour and size of its apothecia. It is a frequent species around areas of late snow-lie in the Scottish Highlands (Fig.2•4) where it overgrows *Andreaea* spp. on the flat upper surfaces of siliceous rocks. It belongs to a very specialized community restricted to that habitat (see section 5•4•3•2), associated species including *Euopsis pulvinata, Lecanora leptacina, Frutidella* *caesioatra* (syn. *Lecidea caesioatra*), *Lecidella bullata*, *Lepraria neglecta*, *Micarea paratropa* (syn. *M. subviolascens*), *Miriquidica griseoatra*, *Polyblastia gothica*, *Rhizocarpon anaperum*, *Stereocaulon plicatile* (see below and Fryday & Coppins 1996b) *S. tornense* and *'Toninia' squalescens*.

Additional specimens examined: **Scotland: V.C. 88,** Mid-Perthshire: Ben Lawers, Gully on south ridge, 27/637410, 1150m, over *Andreaea* sp. on exposed rock face, 11 July 1989 *Fryday* (hb Fryday). **V.C. 94,** Banffshire: Cairn Lochan, Feith Buidhe, 28/9801, c. 1125m, over *Andreaea* sp. on granite boulder beside area of prolonged snow-lie, 7 September 1989, *Fryday* (hb Fryday). **V.C. 96,** East Inverness-shire: Ben Alder Range, Aonach Beag, above Coire Cheap, 27/4575, 1025m, over *Andreaea* sp. on rock affected by prolonged snow-lie, 8 August 1994, *Fryday* [5550] *& S. Chambers*; Cairn Gorm, Ciste Mhearad, 38/0104, 1100m, over *Andreaea* sp. on granite boulder beside area of prolonged snow-lie, 1 September 1994, *Fryday* 5606. **V.C. 97,** West Inverness-shire: Seang Aonach Mòr, Aonach Mòr, 27/1972, 1150m, over *Andreaea* sp. on granite boulder above area of prolonged snow-lie, 26 June 1990, *Fryday* [1218], *Gilbert & Coppins*; Coire an Lochain, Aonach Mòr, 27/1973, 1000 m, over *Andreaea* sp. on acid rock boulder below area of prolonged snow lie, 21 August 1990, *Fryday* [1327] *& Gilbert*; Creag Meagaidh, N-W of summit, 27/407871, 1000 m, over *Andreaea* sp. on acid rock above area of prolonged snow lie, 14 September 1994, *Fryday* [5624] *& Gilbert*.

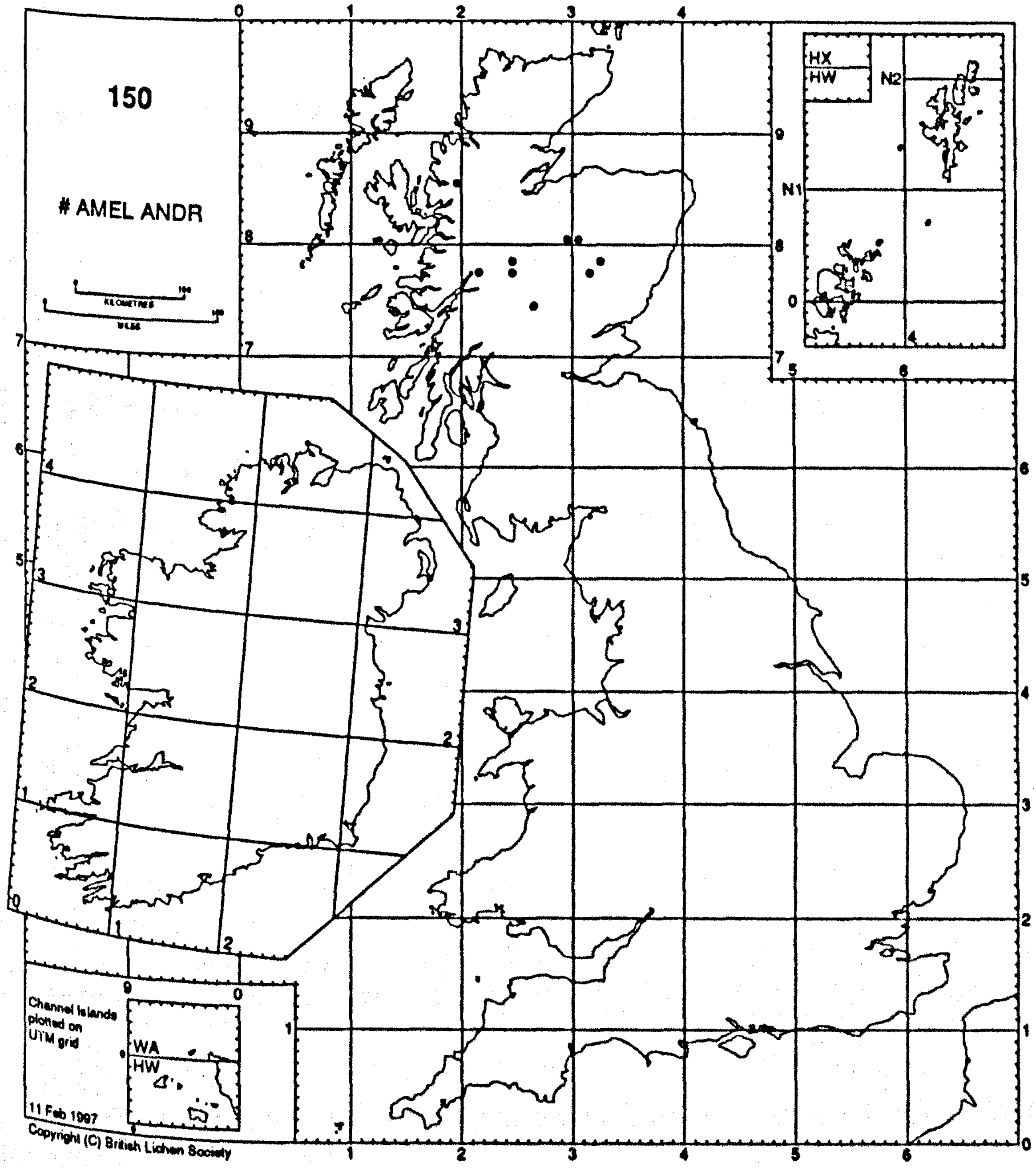

Figure 2-4. Distribution of *'Amelia andreaeaicola'* ad int.

'Amelia grisea' ad int.

Typus: Caledonia, Mid Perthshire (V.C. 88), Ben Lawers, north side of east summit ridge, 27/637413, 1190m, on bryophyte turf in summit heath, 13 July 1995, *A.M. Fryday* 6130 (E-holotypus)

Thallus pale grey, thin to verrucose, in small patches (to 1 cm) in montane heaths. *Photobiont* chlorococcoid, (6-)8-12(-15)µm diam.

Apothecia similar to *A. andreaeaicola* in all respects except paler apothecia discs and ascospores which are oblong-ellipsoid, 10-14 x 5-7µm.

Conidiomata not seen.

Chemistry: C-, KC-, K-, PD-. UV-, not tested by TLC.

Amelia grisea is similar to *A. andraeaeicola* but differs in its terricolous habitat, grey thallus and shorter ascospores. All except one record of the species are from exposed montane heaths. The anomalous record is from Ciste Mhearad, Cairn Gorm (*Fryday* 6311) where *A. grisea* was collected, growing adjacent to *A. andreaeaicola*, on the top of a granite boulder protruding from an area of late snow lie. Habitat details for one specimen (Fryday 5556) indicates that it occurs in N.V.C. community U8 *Carex bigelowii-Polytrichum alpinum* sedge heath (Rodwell 1992). The data from a 2x2 m relevé taken at this site are shown in TABLE 2•2

The vegetation formed a mosaic of areas dominated by either *Salix herbacea/Carex bigelowii* or *Anthelia* sp./*Polytrichum sexangulare* with *Cladonia bellidiflora* and *Stereocaulon saxatile* strongly associated with the former and crustose lichens (including *A. grisea*) with the latter.

A brief description of *A. grisea* was given by Gilbert *et al.* 1988:239 as *Lecidea* sp. 'A'.

Additional specimens examined: **Scotland: V.C. 88,** Mid-Perthshire: Ben Lawers, S-E ridge, 27/6441, 1050m, over *Anthelia* sp. in montane heath on exposed ridge, 17 August 1994, *Fryday* 5556; Beinn Heasgarnich, summit heath, 27/413383, 1075m, on the ground, 10 July

1995, *Fryday* 6112; *ibid.* eastern flank, 27/415383, on ground in *Carex bigelowii/ Polytrichum alpinum* heath near area of prolonged snow-lie, 10 July 1995, *Fryday* 6113 & 6115. **V.C. 96,** Easterness, Cairn Gorm, Ciste Mhearad, 38/011045, 1100m, over *Andreaea* sp. on top of granite boulder in late snow field, 12 September 1995, *Fryday* 6311.

Table 2•2. Data from a 2x2m relevé taken from the SE ridge of Ben Lawers, Mid-Perthshire (GR 27/6441, Alt. 1050m. Cover values are on the Domin scale.

Cover	80%	Height of Vegetation	1-3 cm
Bryophyte Cover	20%	Slope	3%
Lichen Cover	3%	Aspect	80°
Salix herbacea		7	
Carex bigelowii		7	
Festuca ovina		4	
Galium saxatile		2	
Nardus stricta		1	
Anthelia sp.		5	
Polytrichum alpinum		2	
P. sexangulare		3	
Amelia grisea		1	
Cladonia bellidiflora		3	
Lecidea limosa		3	
Stereocaulon saxatile		2	
Frutidella caesioatra		2	
Micarea turfosa		2	
M. cinerea (anamorph)		1	
M. peliocarpa		1	
Ochrolechia androgyna		1	
Catillaria contristans		1	
Omphalina sp. (sterile)		1	

Catillaria gilbertii Fryday & Coppins sp. nov.

Typus: Caledonia, V.C. 88, Mid-Perthshire, Ben Lawers NNR, Head of Coire Odhar, east side of Meall Corranaich, 27/617407, 890 m, slightly sloping, mica-schist rock face, 19 May 1992, *A.M.Fryday* 3100 (E- holotypus).

Thallus effuse, cracked-areolate; areoles flat to slightly convex with an irregular surface; dark chocolate brown to dark grey. Cortex ±indeterminate, some hyphae swollen and either brown (N-) or blue (N+ red). *Photobiont* chlorococcoid, cells 8-12µm diam.

Apothecia black, lecidine, 0•3-0•7mm, with a persistent, slightly raised proper margin; flat to slightly convex, occasionally with a central umbo. *Hymenium c.* 60µm high, epihymenium dark-brown, K-, N-. *Paraphyses* simple, branched towards apex, 0•8-1•0(-1•5)µm; distinctly capitate with dark brown hood, 2•5-4•0µm wide. *Asci* broadly cylindrical to clavate, *Catillaria*-type *c.* 45 x 15-20µm, (12-)16 spored. *Ascospores* 1-septate, oblong-ellipsoid, 10-12 x 2•5-3•0µm. *Hypothecium* colourless, composed of strongly conglutinate hyphae. *Excipulum* composed of colourless, radiating hyphae, becoming swollen (to 5µm) and dark brown at outer surface; reflexed below the hypothecium.

Conidiomata pycnidia, immersed in the thallus, *c.* 60-80µm diam.; wall hyaline but brown (K-, N-) around the ostiole. *Conidiophores* multiseptate, with conidia borne both laterally and terminally; *conidia* ellipsoid to ovoid-ellipsoid, 2•5-3•0 x 0•8-1•4µm.

Chemistry: C-, KC-, K-, PD-, UV-. Not tested by TLC.

This new species has been recorded only from calcareous mica-schist on the Ben Lawers NNR and in Glen Clova, Angus (not Glen Esk as reported in Fryday & Coppins 1996a) where it grows in an assemblage of rare montane calcicole lichens. Among the species associated with the collections from the Ben Lawers NNR are *Acarospora badiofusca, A. rhizobola, Agonimia tristicula, Caloplaca holocarpa, Catapyrenium cinereum, Koerberiella wimmeriana, Lecanora albescens, L. atromarginata, Miriquidica complanata, Placynthium* cf. *nigrum, Polyblastia rugulosa, Porpidia* cf. *zeoroides* and *Staurothele rugulosa.*

Catillaria gilbertii may be overlooked in the field for two, closely related, species which occur in the same habitat, the common *C. chalybeia* - from which it differs in its browner, more widespreading thallus and by its somewhat larger apothecia, and the very rare *Halecania rhypodiza* - which can usually be distinguished by the presence of a thalline margin to the young apothecia.

A small collection, with only two apothecia, from the Snowdon range in North Wales (Fryday 6334) also has 16-spored asci and similar sized apothecia but differs in having a pale, inconspicuous thallus, without blue-green pigment, and red-brown apothecia. This may be an aberrant form of *C. gilbertii.*

Additional specimens examined: **Scotland: V.C. 88,** Mid-Perthshire: Ben Lawers, SW-cliffs, 27/6341, 1100m, on exposed mica-schist, 16 June 1989, *Fryday* (E); *ibid.* Creag Loisgte, 27/632411, 1025m, on S-E facing, mica-schist crag, 17 August 1994, *Fryday* 5563; *ibid.* Glen Roro, 27/6141, 900m, on top of low, mica-schist rock, 1991, *Fryday 2119* (E). **V.C. 90,** Angus, Glen Clova, Coire Fee, 37/27, 25 August 1989, *R.C. Munro* (E).

Chromatochlamys 'confusum' ad int.

Typus: Cambria: V.C. 49, Caernarfon-shire, Pass of Llanberis, Cwm Uchaf, 23/6255, 825m, over bryophytes on calcareous rock in damp, north-facing coire, 23 September 1993, *A.M. Fryday* 4676 (E-holotypus).

Thallus grey, continuous, thin (*c.* 50µm thick); over bryophytes (usually *Hypnum hamulosum*). *Photobiont* chlorococcoid, cells 10-15µm diam.

Perithecia numerous, dark brown to black, globose in section 0•3-0•5 mm diam., half to three-quarters immersed. *Involucrellum* absent. *Paraphysoids* persistent, 2•0-2•5µm wide, sparingly branched. *Asci* cylindrical (to sub-clavate), 140-160 x 25-28µm, outer wall *c.*2µm thick; apex with a distinct ocular chamber, I-; contents of ascus I+ red-brown; 6-8 spored. *Ascospores* 32•5-46•6-58 x 11-13µm, elongate ellipsoid, hyaline, sub-muriform to muriform. *Excipulum* 70-80µm thick, dark brown above, colourless below.

Conidiomata not seen.

Chemistry: C-, KC-, K-, PD-, UV-. Not tested by TLC.

Anatomically *Chromatochlamys confusum* closely resembles *C. larbalestieri* but it differs from that very rare species morphologically and in having a totally different ecology, *C. larbalestieri* occurring on semi-inundated siliceous rocks. The two species do, however, have a very similar distribution both being recorded only from oceanic regions of the British Isles (Fig. 2•5), although *C. confusum* appears to be most frequent in North Wales from where *C. larbalestieri* has yet to be recorded. The new species is also likely to be confused with *C. muscorum* v. *octospora*, which occasionally occurs in the same habitat, but that taxon has a very thin, inapparent, varnish-like thallus, and smaller, paler brown, pyriform perithecia. The main differences between the three species are summarized in Table 2•3.

In all its known locations *C. confusum* occurs in assemblages rich in rare, calcicole lichens (e.g. *Strigula stigmatella* v. *alpestris, Thelopsis melathelia* and *Vestergrenopsis elaeina*).

Additional specimens examined: **Wales; V.C. 49,** Caernarfon-shire: Cwm Idwal, N-E of Twll Du, 23/640588, 500m, over bryophytes on side of large, calcareous boulder, 4 June 1994, *Fryday* 5318; Pass of Llanberis, Cwm Uchaf, beside Llyn Glas, 23/6155, 650m, over bryophytes on basic rock outcrop, 9 October 1994, *Fryday* [5698] *& Chambers*; Pass of Llanberis, Cwm Glas, 23/6155, 750m, over bryophytes on stratified basic rocks on back wall of cwm, 9 October 1994, *Fryday* [5711 & 5717] *& Chambers*; Pass of Llanberis, Cwm Glas-bach, 23/6056, 600m, over bryophytes on calcareous rocks face, 10 October 1994 *Fryday* 5727, 5733 & 5740; Pass of Llanberis, Cwm Uchaf, damp, north-facing crag, 23/6255, 825m, over bryophytes on calcareous rock, 18 October 1995, *Fryday* 6343. **Scotland; V.C.98,** Argyll Main, Glen Coe, base of Aonach Dubh, 27/1556, 200m, over bryophytes on andesite crag, 22 June 1992, *Fryday* 3233. **V.C. 104, North-Ebudes,** Isle of Skye, Trottenish, Quiraing 18/4569, 250m, over bryophytes on shaded basalt crags, 20 June 1990, *Fryday* 1263.

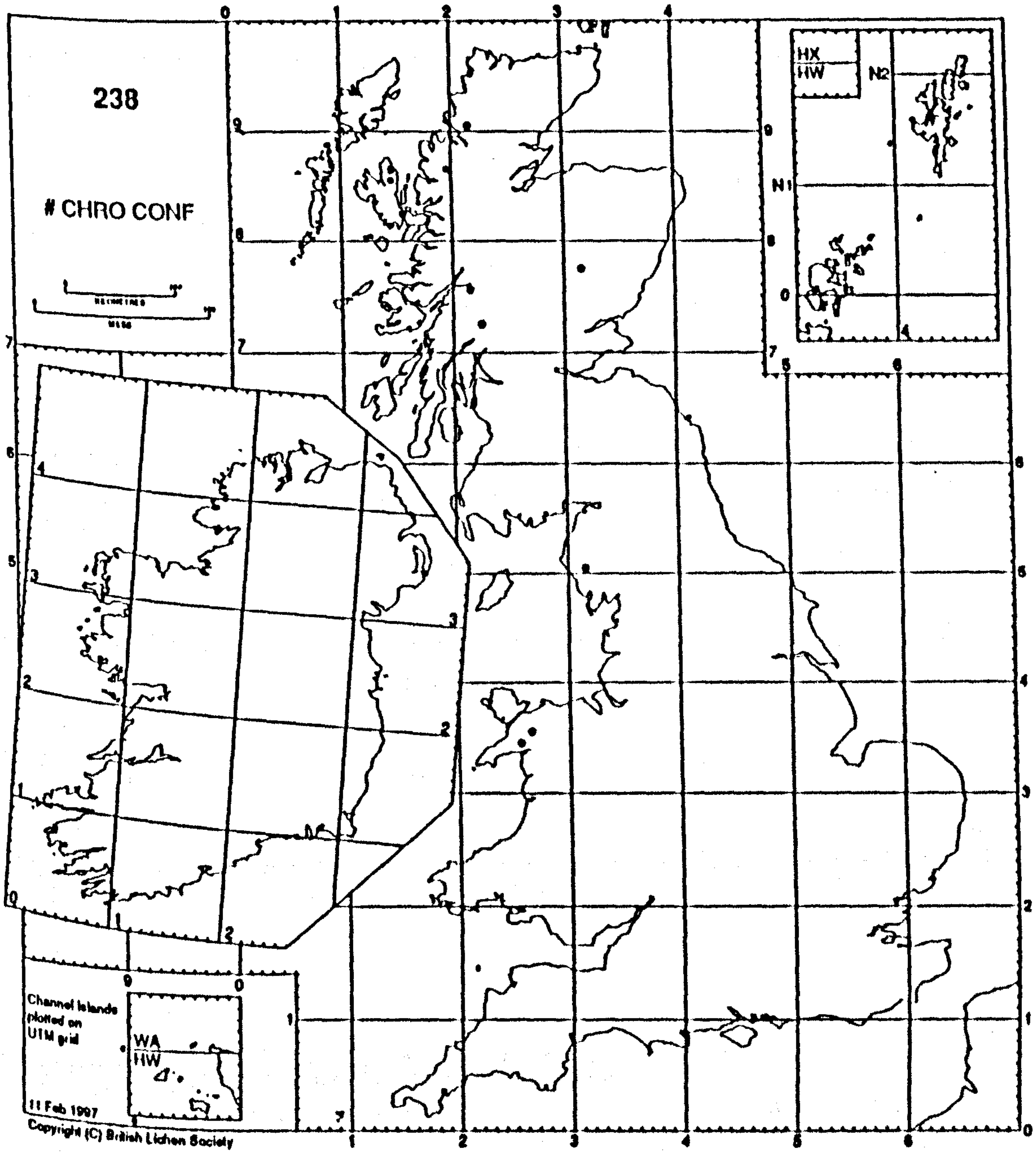

Figure 2·5. Distribution of *Chromatochlamys 'confusum'* ad int.

Table 2•3. Main differences between *Chromatochlamys 'confusum'*, *C. larbalestieri* and *C. muscorum* v. *octospora*.

	C. confusum	***C. larbalestieri***	***C. muscorum* v. *octospora***
Ecology	over bryophytes on calcareous, montane rocks	semi-inundated, siliceous rocks in streams; possibly parasitic on aquatic *Verrucaria* spp.	over bryophytes, usually corticolous, occasionally on calcareous montane rocks
Thallus	grey, continuous	brown, cracked-areolate	white,very thin, membranous
Perithecia	black. 1/2-3/4 immersed 0•3-0•5mm diam., globose	black 3/4 immersed 0•15-0•2mm diam., flattened vertically	brown 3/4-±completely immersed 0•3-0•6 mm diam., rounded to broadly pyriform.
Exciple	upper 1/2-3/4 dark brown	rarely more than upper 1/3 pigmented; pale brown	pale brown above, colourless below.
Spores*	32•5-46•6-57•75 x 11-13µm	44•1-56•8-68•6 x 13-15µm	40-60 x 15-20µm.

*- 10 measured for each of *C. 'confusum'* and *C. larbalestieri*, measurements for *C. muscorum* v. *octospora* from Mayrhofer & Poelt 1985.

Chromatochlamys 'geislerioides' ad int.

Typus: Caledonia; V.C. 88, Mid-Perthshire, Ben Lawers, ridge north of summit, 27/635.415-8, 1050-1180m, over low-growing bryophytes on exposed turf, 16 July 1985, Coppins (11061), *Gilbert & Fox* (E-holotypus)

Thallus very thin and varnish-like, white to pale grey, terricolous on arenaceous soils. *Photobiont* chlorococcoid, cells 8-11µm diam.

Perithecia scattered, three-quarters to totally immersed with only the ostiole apparent, colourless but dark pigmented in upper, exposed section, *c.* 0•1mm diam. *Paraphysoids* persistent, slender 0•7-1•0µm wide, branched and anastomosing. Conglutinate periphysoides present inside ostiole. *Involucrellum* absent. *Asci* cylindrical (to sub-clavate), 60-78 x 14-18µm, outer wall c.1•5µm thick; apex with a distinct ocular chamber, I-; contents of ascus I+

red-brown; 8-spored. *Ascospores* 20-25(-36) x 6-7(-9)µm., 5-7 septate, hyaline, clavate-fusiform. *Excipulum* bright aeruginose-green (K-, N+ violet) in upper part, 16-20µm thick, hyaline below and inapparent.

Conidiomata often present, bacilliform, 4-5 x 1µm.

Chemistry: C-, KC-, K-, PD-, UV-. Not tested by TLC.

This species is placed in *Chromatochlamys* on account of its ascus structure and persistent paraphysoids although it differs from most of the described species of the genus in the smaller, septate (not muriform) spores and the less massively developed excipulum. It is apparently close to, the non-British, *C. vezdae* but that species has septate to sub-muriform spores, a differently pigmented excipulum and grows on lignum (Mayrhofer & Poelt 1985). *C. geislerioides* appears to be congeneric with *C. vezdae* but the systematic position of both species is unclear. Dr H. Mayrhofer has suggested an affinity with *Strigula* or *Geisleria* (pers. comm.) but both differ from *C. geislerioides* in a number of respects. It is possible that a new genus will be required to accommodate these two species. *C. geislerioides* was first mentioned by Gilbert *et al.* (1988) as ?*Geisleria* sp. (p. 238).

Additional specimens examined: **Scotland, V.C. 88,** Mid-Perthshire: Beinn Heasgarnich, N-E ridge, 27/421381, 935m on ground in *Festuca/Agrostis/Alchemilla alpina* heath, 10 July 1995, *Fryday* 6106 & 6108; ibid. E-flank, 27/415383, 1025m on ground in *Carex bigelowii/Polytrichum alpinum* heath near area of prolonged snow-lie, 10 July 1995, *Fryday* 6117 & 6120; Ben Lawers, E ridge, 27/642414, 1050m. on the ground in *Carex bigelowii/Polytrichum alpinum* heath, 13 July 1995, *Fryday* 6128. **V.C. 92,** South Aberdeenshire, Glas Maol, upper rim of northern coire, 37/1677, 1000m on the ground in *Carex bigelowii/Polytrichum alpinum* heath on solifluction terracettes, *Fryday* 6053; **V.C. 94,** Banffshire, Cairngorm plateaux between Cairn Gorm and Cairn Lochan, 28/9902, 1100m, on ground in *Juncus trifidus/Carex bigelowii* heath, 16 June 1994, *Fryday* (5376) & *Gilbert.* **V.C. 96(-97),** East(-West) Inverness-shire, Creag Meagaidh, west ridge, 27/4287, 1100m, On ground in summit heath, 27 July 1995, *Fryday* 6173.

Cliostomum 'subtenera' ad int.

Typus: Caledonia: Stirlingshire (V.C. 86), Ben Lomond, Coire a' Bhathaich, 27/369027, 925m, in sheltered underhang on schistose rock, 25 September 1994, *A.M. Fryday* 5663 (E-holotypus).

Thallus effuse, thin and discontinuous, occasionally thicker (to 0•4mm), white, non-corticate. Soralia pale green, covering most of the thallus, 0•1-0•3mm diam. soon confluent and appearing effuse; soredia farinose c. 0•02mm diam. *Photobiont* chlorococcoid, cells 8-12 µm diam.

Apothecia scattered, sessile, 0•4-0•8mm diam., becoming tuberculate and then to 1•2mm diam., disk pinkish brown to pale brown with paler margin, slightly convex soon becoming tuberculate with excluded margin. *Hymenium* hyaline, I+ blue, 40-45µm tall, epihymenium brown, granular, K+ colourless. *Paraphyses* 1•5-2•0µm wide moderately branched and anastomosing, apices to 3µm wide, pigmented cap absent. *Asci c.* 30 x 12µm, clavate, *Bacidia*-type. *Ascospores* hyaline, 0-1 septate, narrowly ellipsoid to fusiform, often slightly curved, (10-)12-15(-20) x 3-4µm. *Hypothecium* hyaline, composed of randomly orientated hyphae. *Excipulum* composed of conglutinate radiating hyphae 5µm wide, internally colourless to yellow-brown with grey-brown granular intrusions not dissolving in K, outer cells with brown pigment, K+ colourless.

Conidiomata pycnidia, numerous; flesh-coloured to pale brown, immersed in thicker areas of the thallus. *Conidia* bacilliform 8-9 x 0•8-1•0µm.

Chemistry: thallus and soredia C-, K+ yellow, Pd+ orange, UV+ dull yellow; atranorin, stictic acid and zeorin by TLC.

Cliostomum subtenera is similar to *C. tenera* but differs from it in a number of details which, when taken together, indicate that a separate species is involved. The most obvious differences are that the new species is sorediate and has a wider ecological amplitude - it occurs in underhangs in montane situations as well as in coastal habitats. However, it also has larger apothecia and spores as well as a different chemistry.

Cliostomum subtenera is known only from Coire a' Bhathaich near the summit of Ben Lomond and Llam Carw on Anglesey; at both localities it is frequent in shaded underhangs on schistose rock. The wider ecological amplitude of *C. subtenera* is consistent with the hypothesis of species which reproduce vegetatively being colonising species.

It has long been realized that *Lecanora tenera* was not congeneric with the type species of *Lecanora* (*L. subfusca*). It has been placed in *Lecania* (Clauzade & Roux 1985) on account of its ascus structure and 0-1 septate spores but its chemistry and conidia are not consistent with that genus. *L. tenera* has recently been transferred to *Cliostomum* (Ekman, *in ed.*), athough it appears to differ in many respects from the common corticolous species *Cliostomum griffithii* which has short bacilliform conidia.

Additional specimens examined: **Wales: V.C. 52**, Anglesey, NE of Amlwch, cove E of Llam Carw, 23/460936, on vertical siliceous ('green' schist) coastal rocks above HWM, 11 June 1995, *S.P. Chambers* (E). **Scotland: V.C. 86**, Stirlingshire, Ben Lomond, Coire a' Bhathaich, 27/368027, 925m, in sheltered underhang on schistose rock, 22 August 1994, *Fryday* 5590.

Fuscidea 'poeltii' ad int.

Typus: Caledonia; V.C. 105, West Ross, Beinn Eighe NNR, ridge between Spidean Coire nan Clach and Coinneach Mhòr, 18/9659, *c.*950m, cambrian quartzite crags, 22 July 1991, *A.M.Fryday* 2724.

Thallus usually widespreading, cracked-areolate, pale-grey to (rarely) brown, areoles flat, 0•15-0•4 mm diam. *Soralia* mostly punctiform arising from the centre of each areole, 0•1-0•2mm diam., less often following cracks in the thallus and becoming stellate; soredia blue-grey (K-, N-), 20-25µm diam. *Photobiont* cells thick-walled, 7-16(-19) x 8-12(-13)µm, often dividing to give 2-4 daughter cells.

Apothecia black lecideine, sessile 0•5-1•0mm diam., proper exciple persistent, becoming flexuose, occasionally umbonate. *Hymenium* 70-90 µm tall, upper third with brown pigment. *Paraphyses* simple, 2•5µm wide, swelling to 5µm at apex with dark brown hood. *Asci* *c.*45 x 20µm, *Teloschistes*-type. *Ascospores* hyaline, simple, broadly ellipsoid, 7-9 x 5-6µm. *Hypothecium* colourless. *Excipulum* of branched, anastomosing hyphae, colourless with dark brown outer cells, reflexed below apothecium.

Conidiomata not seen.

Chemistry: thallus C-, K-, PD-, UV-; soredia and medulla C-, K-, PD-, UV+white; divaricatic acid detected by TLC.

Fuscidea poeltii is locally common on exposed, hard acidic rocks in the NW Scottish Highlands. It is particularly common on quartzite and at the type locality covers large areas and is the most frequent species. Associated species are few but include *F. gothoburgensis*, *F. intercincta* and *Ionaspis odora*.

Fuscidea poeltii is unusual amongst lichenized fungi in regularly producing both sexual and asexual propagules. It is the only sorediate member of the genus occurring in the British Isles which is also usually fertile. It most closely resembles sorediate morphs of *F. intercincta* (?*F. oculata*) but that species has apothecia with a white margin and convex soralia. However, as the soredia of *F. poeltii* are very small and inconspicuous they are easily overlooked in the field and this species may then be mistaken for other, non-sorediate, members of the genus (e.g. *F. lygaea*). Other sorediate saxicolous species of *Fuscidea* containing divaricatic acid are *F. gothoburgensis* and *F. recensa* both of which are very rarely fertile. *F. recensa* is a very different species with a thicker thallus, more wide-spreading, often convex soredia and curved ascospores whereas *F. gothoburgensis* differs mainly in thallus morphology and ecology - it having a much more dispersed thallus and usually occurs in shaded underhangs. It is possible that *F. poeltii* is conspecific with *F. gothoburgensis* and a detailed examination of the apothecia of both species is required to clarify this matter.

F. poeltii was included in Clauzade & Roux (1985) as *F. alpina* V. Wirth & Poelt but it has not been formally described under that name.

Additional specimens examined: **Scotland; V.C. 88,** Mid-Perthshire, Coire-cheathaich, Creag Mhór, 27/4034, 550m, on quartzite intrusion on side of large schistose boulder, 28 May 1993, *Fryday* 2358 (E). **V.C. 98,** Argyll Main, Ben Starav, 27/1342, 850m, shaded side of granite boulder, 22 May 1991, *Fryday* [2341] *& Goddard*; Glen Coe, Aonach Eagach, S side of E ridge of Sgurr nam Fiannaidh, 27/1458, 900m, top of exposed granite rock, 14 July 1992, *Fryday* 3327. **V.C. 105,** West Ross, Beinn Eighe NNR, ridge between Spidean Coire nan Clach and Coinneach Mhòr, 18/9659, c.950m, cambrian quartzite crags, 22 July 1991, *Fryday* 2725.

Halecania bryophila Fryday & Coppins sp. nov.

Typus: Caledonia: Mid-Perthshire (V.C. 88), Ben Lawers NNR, Meall Garbh, 27/574385, 900m, on bryophytes on damp, mica-schist crag, June 1989, *A.M. Fryday.* (E-holotypus).

Thallus effuse, ±continuous not forming discrete areoles or granules, brownish-grey. Upper cortex poorly developed, surface hyphae brown (N-). *Photobiont* chlorococcoid, cells 8-15 µm diam.

Apothecia numerous, 0•2-0•5(-0•6)mm diam., disc mid- to dark-brown with raised, concolourous to slightly paler proper exciple, thalline exciple biatorine in young apothecia, soon excluded but algal cells usually visible in section. *Hymenium* hyaline, I+ blue, 40-55µm tall, epihymenium brown, N-, paler in K. *Paraphyses* simple, occasionally branched above, slender 1-1•7µm, distinctly capitate to 4µm with brown cap. *Asci* cylindrical, 45-50 x 12µm, *Catillaria*-type. *Ascospores* hyaline, 1 septate with perispore in K, 14-17 x 4.5-5•5µm (in K, excluding perispore). *Hypothecium* hyaline. *Excipulum* composed of conglutinate, hyaline hyphae 2•5-3•5µm wide, outer section (7-10µm wide) brown, cells with brown pigment caps 3•0-4•0µm wide.

Conidiomata not seen.

Chemistry: C-, KC-, K-, PD-, UV-. Not tested by TLC.

Halecania bryophila most closely resembles the very rare *H. rhypodiza*, which is known from Ben Lawers, not least in the almost imperceptible thalline margin. However, that species grows on calcareous rocks, has a darker thallus and smaller spores. The only other species of *Halecania* which grows over bryophytes is *H. lecanorinum*, known from the alps, which also has smaller spores, different thallus characters and is restricted to pure limestone.

H. bryophila has been recorded from only two sites on the Ben Lawers NNR in the Breadalbane Mountains where it overgrows bryophytes in an assemblage of rare montane calcicole lichens. Species of lichen associated with the two collections include *Acarospora rhizobola, Catapyrenium lachneum, Cladonia pocillum, Collema auriforme, Lecanora albescens, L. atromarginata, 'Lecidea' hypnorum, Leptogium imbricatum, Porpidia superba, Psora rubiformis* and *Tephromela atra.* The perithecia of *Decampia hookeri* are also present on the thallus.

Additional specimen examined: **Scotland: V.C. 88,** Mid-Perthshire, Ben Lawers, Craeg Loisgte 27/632411, 1025m, Over bryophytes (*Grimmia ?montana*) on SE-facing mica-schist crag, 17 August1994, *Fryday* 5564

Halecania micacea Fryday & Coppins sp. nov.

Typus: Caledonia: V.C. 88, Mid-Perthshire, Ben Lawers NNR, Meall Garbh, crags at head of Coire Riadhailt, 27/5738, 800m, mica-schist buttress at base of east-facing crag, 25 July 1989, *A.M. Fryday* (E-holotypus, UPS-isotypus).

Thallus effuse of convex pinkish-brown areoles. Areoles *c.* 0•2-0•4mm diam., matt, often dispersed. *Photobiont* chlorococcoid, cells 9-12 µm diam.

Apothecia scattered, 0•2-0•5mm diam., disc mid-brown with paler, waxy proper exciple, thalline exciple concolorous with the thallus but soon excluded. *Hymenium* hyaline, I+ blue, 45-60µm tall, epithecium brown, N-, paler in K. *Paraphyses* moderately branched and anastomosing above, 0•8-1•5µm, distinctly capitate with brown, distinctly capitate apices

(2•7-3•5µm). *Asci* cylindrical 35-40 x 10-12µm, *Catillaria*-type. *Ascospores* hyaline, 1 septate with distinct perispore in K, 9•5-12•0 x 4•5-5•5µm (in K, excluding perispore). *Hypothecium* hyaline. *Excipulum* outer cells with pale brown pigment.

Conidiomata not seen.

Chemistry: thallus C-, K-, KC-, PD+ red, I-, UV-; argopsin detected by TLC.

The new species most closely resembles *Halecania ralfsii* but differs in its habitat, more warted thallus, paler apothecia (especially the proper exciple) and the slightly smaller ascospores. It is so far known from only two sites in the Breadalbane Mountains where it occurs in north-facing coires at the base of calcareous mica-schist crags. Species occurring in the same area as the type collection include *Biatora vernalis, Collema glebulentum, Koerberiella wimmeriana, Lecanora frustulosa, Placynthium asperellum, P. flabellosum, P. nigrum* and *P. pannariellum.*

Additional specimen examined: **Scotland: V.C. 88,** Mid-Perthshire, Meall na Samhna, 27/4933, 700 m, damp, north-facing, mica-schist crag, 26 May 1991, *Fryday* 2354.

Ochrolechia *tartarea* 'f. *sorediata*' ad int.

Typus: Caledonia: V.C. 88, Mid-Perthshire, Ben Lawers NNR, Coire Odhar, Burn of Edramucky, 27/612390, 600m, side of acidic mica-schist boulder, 21 May 1992, *A. M. Fryday* 3105 (E-holotypus)

Thallus usually thick and tartarous, composed of shiny grey convex areoles *c.* 0•5-1•0mm diam. pinkish papillae (0•2-0•25mm diam.) usually present. *Soralia* arising from papillae becoming confluent, granular pinkish-cream, soredia 0•05-0•15mm diam. (Fig. 2•6). *Photobiont.* chlorococcoid, cells 8-12µm diam., dividing internally to give 2-5 daughter cells.

Apothecia infrequent, rarely well developed. Identical to those of *O. tartarea* f. *tartarea.*

Conidiomata not seen.

Chemistry: C+ red, K+ pale yellow, KC+ red, Pd- . gyrophoric acid,

Figure 2-6. *Ochrloechia tartarea* 'f. *sorediata'* ad int. (Magnification: x4)

The production of soredia is common within *Ochrolechia*, often as the primary means of reproduction. Of the ten British species, only *O. szatalensis* and *O. xanthostoma* are not known to produce them. Some thought was given to whether the present entity deserved taxonomoic recognition as it is far less common than f. *tartarea* and may only represent an aberrant form. However, it does tend to occupy a somewhat different ecological niche (more shaded) and the ontogeny of the soredia, developing from the thalline papillae which in f. *tartarea* give rise to apothecia, indicates that the production of soredia is an alternative reproductive strategy suggesting a significant genetic difference.

Ochrolechia tartarea f. *sorediata* is most likely to be confused with *O. androgyna* but the presence of thalline papillae and the shaded habitat are usually sufficient for correct identification. This entity is apparently the same as that recognised as *O. androgyna* sp. 'B' by Tønsberg (1992); if this is so then there are a number of other records from trees in Scotland and Norway that will have to be included.

Additional specimens examined: **Scotland, V.C. 88,** Mid-Perthshire: Ben Lawers NNR, West side of Ben Ghlas, 27/6240, 1050m, shaded side of acidic mica-schist boulder, 26 March 1991, *Fryday* 2126 (fertile); Meall na Samhna, 27/4733, 750m, damp mica-schist crags, 31 May 1991, *Fryday* 2389.

Porpidia 'confluenta' ad int.

Typus: Caledonia: V.C. 88, Mid-Perthshire, Ben Lawers NNR, Burn of Edramucky, 27/614394, 675m, on acidic mica-schist boulder by stream, 21 May 1992, *A.M. Fryday* 3108 (E- holotypus)

Thallus effuse, of dispersed, white, convex areoles 0•4-0•7mm diam. Soralia tuberculate, arising from the areoles, blue-grey, 0•2-0•4mm diam., becoming confluent. *Photobiont* chlorococcoid, cells (3•5)4-5 x 5-6(-7)µm diam.

Apothecia black, lecidine, epruinose, 0•5-1•2mm diam., often 2-5 apothecia confluent (then -2•0mm diam.), proper margin thin and persistent not or only slightly raised, smooth, flexuose in confluent apothecia. *Hymenium* hyaline, I+ blue, 110-120µm tall, epihymenium olivaceous. *Paraphyses* numerous, septate, branched and anastomosing. *Asci* cylindrical, 70-75 x 15-22µm, *Porpidia*-type. *Ascospores* hyaline, halonate, non-septate, ellipsoid 17-21 x 6-7µm. *Hypothecium* dark brown, upper section (subhymenium) pale brown to hyaline *c.* 25 µm tall. *Excipulum* of thin radiating hyphae 2•5-4•0µm wide, pale brown with dark blue-back expanded cells at the surface.

Conidiomata not seen.

Chemistry: thallus C-, K- (but + numerous small 'oil droplets' when viewed in section), KC-, PD-, UV-; confluentic acid and accessories by TLC. Medulla I-.

The affinities of *Porpidia confluenta* within *Porpidia* are unclear. It has the narrow excipular hyphae of the *P. albocaerulescens* group but lacks the paler inner exciple typical of that group. It most closely resembles *P. tuberculosa* although it has very different apothecia (epruinose, narrow excipular hyphae) and as *P. tuberculosa* rarely occurs without apothecia in montane areas confusion is unlikely. When sterile it can be distinguished from *P. tuberculosa* by its thicker thallus and I- medulla. It also has a characteristic ecology, usually occurring on the upper surfaces of low, flat rocks at high altitude where it is not rare (Fig. 2•7). Associated species include *Aspicilia caesiocinerea* aggr., *Lecanora polytropa, Porpidia crustulata, Rhizocarpon colludens* (see below) and *R. geographicum* aggr.

Additional specimens examined: **Scotland: V.C. 88,** Mid-Perthshire: Ben Lawers, west side of Creag an Fhithich, 27/6342, 900m, top of low, flat mica-schist rock, 18 July 1989, *Fryday* (hb. Fryday); Ben Lawers NNR, south ridge of Meall Corranaich, 27/6140, 950m, low mica-schist rock, 1 August 1989, *Fryday* (hb. Fryday, fertile); Meall na Samhna, Lochan Coire Dhudhchlair, 27/4932, 735m, vertical acid mica-schist rock beside lochan, 2 June 1990, *Fryday* 1165 (fertile); Ben Lawers NNR, Glen Roro, 27/6141, 850m, top of low mica-schist rock, 26 March 1991, *Fryday* 2123. **V.C. 97,** West Inverness-shire: Sunart, Beinn Resipol, 17/7565, 650m, vertical shaded schistose rock face, 19 June 1992, *Fryday* 3192; Creag Meagaidh, N-W of summit, 27/417880, 950m, on low schistose boulder, 13 September 1994, *Fryday* 6515 (fertile). **V.C. 98,** Argyll Main: Stob Ghabhar, S-E of summit, 27/2345, c. 1050m, top of low schistose boulder, 31 January 1992, *Fryday* 3045; Glen Coe, Lower Coire nam Beitheach, 27/1455, 650m, top of low boulder, 14 August 1992, *Fryday* 3419. **V.C. 103,** Mid Ebudes, Isle of Mull, Ardmeanach, Burg, 17/4226, 100m, basalt crag, 30 May 1993, *Fryday* 4431. **V.C. 110,** Outer Hebrides, North Harris, Glen Ulladale, Cragan Leathan, 19/0713, c. 200m, Lewisian Gniess outcrop, 29 June 1991, *Fryday* 2614 (fertile).

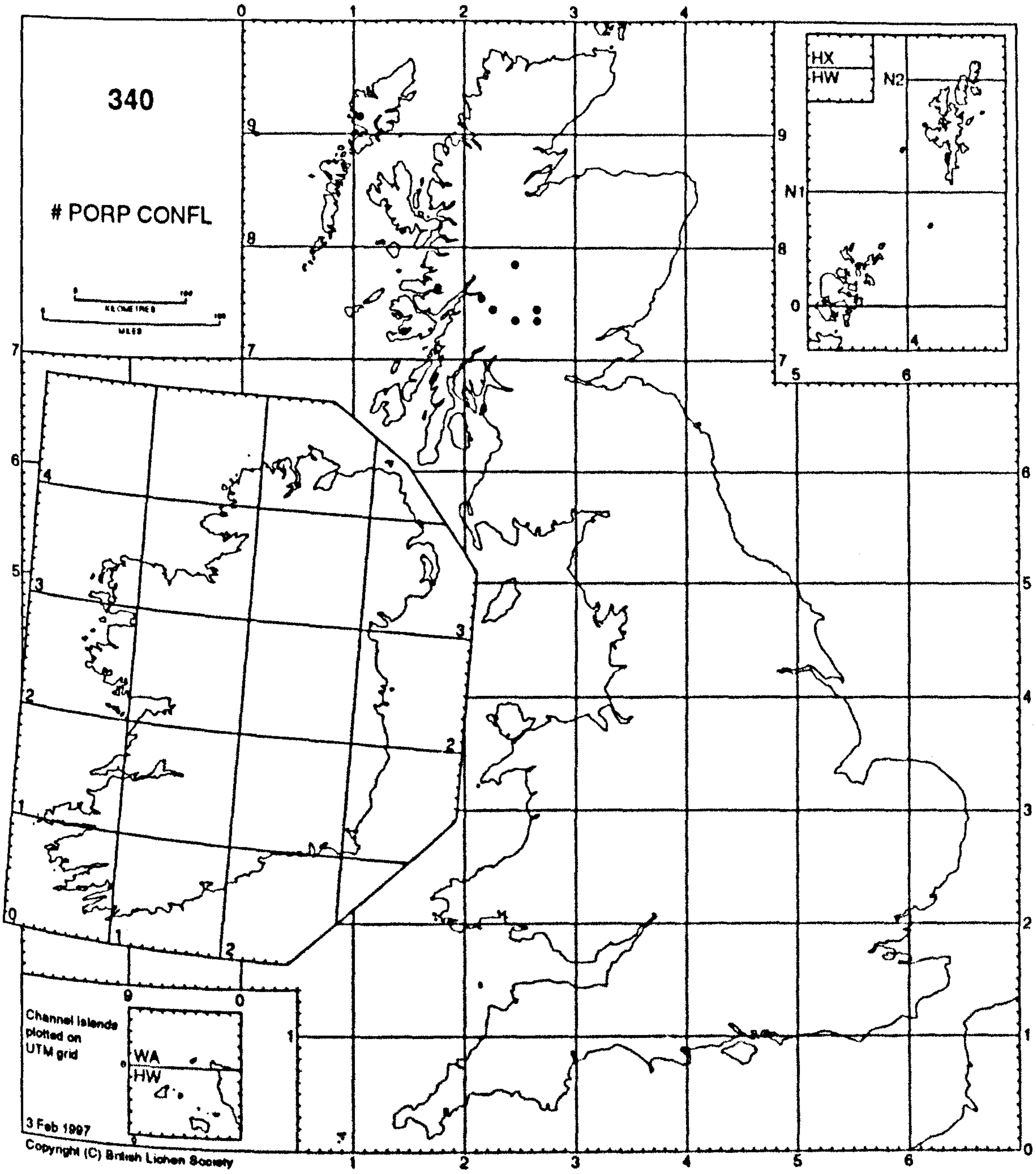

Figure 2-7. Known distribution of *Porpidia 'confluenta'* ad int.

Porpidia 'striata' ad int.

Typus: Caledonia: V.C. 88, Mid-Perthshire, Meall nan Subh, 27/4539, 770m, on acid stone in wind-swept heath, 24 March 1991, *A.M. Fryday* 2101 (E - holotypus, M - isotypus)

Thallus endolithic to scarcely apparent; if visible then composed of thin, flat, pale grey areoles. Occasionally better developed with whitish areoles when in less exposed situations. *Photobiont* chlorococcoid, cells (3•5)4-5 x 5-6(-7)µm diam.

Apothecia black, lecidine, epruinose, (0•3-)0•5-1•0(-1•2)mm diam.; pore-like when young, expanding when mature, proper margin persistent, thick and raised, radially striate. *Hymenium* hyaline, I+ blue, 70-80µm tall, epihymenium brown-oliveaceous (brighter in K). *Paraphyses* numerous, very thin with swollen pigmented cap (2•5-3•0µm wide), branched and anastomosing. *Asci* cylindrical 60-70 x 20-25µm, *Porpidia*-type. *Ascospores* hyaline, halonate, non-septate, ellipsoid 16-18 x 8-9µm. *Hypothecium* dark brown, upper section (subhymenium) hyaline 20-25µm tall . *Excipulum* of radiating hyphae 3•0-4•0 µm wide, outer 10-15µm carbonaceous, cracked; inner cells pale brown.

Conidiomata frequent when thallus apparent; pycnidia, 0•05-0•2µm diam. black with raised, white pseudothalline margin when young, becoming sessile with a gnarled surface when old. *Conidia* bacilliform 6-8 x 0•5µm.

Chemistry: no substances detected by TLC.

Porpidia striata is a frequent species of siliceous rocks and pebbles in the Scottish Highlands and North Wales (Fig. 2•8). It is most frequent on pebbles embedded in exposed, wind-swept heaths where it is often the dominant species. It most closely resembles *P. crustulata* but is distinguished from that species by its unique exciple structure. The radially striate exciple makes it an easily recognisable species in the field. Associated species are few, the lichen usually growing on its own on otherwise uncolonised surfaces, but include *Protothelenella corrosa*, *Porpidia macrocarpa* aggr. and *P. tuberculosa*.

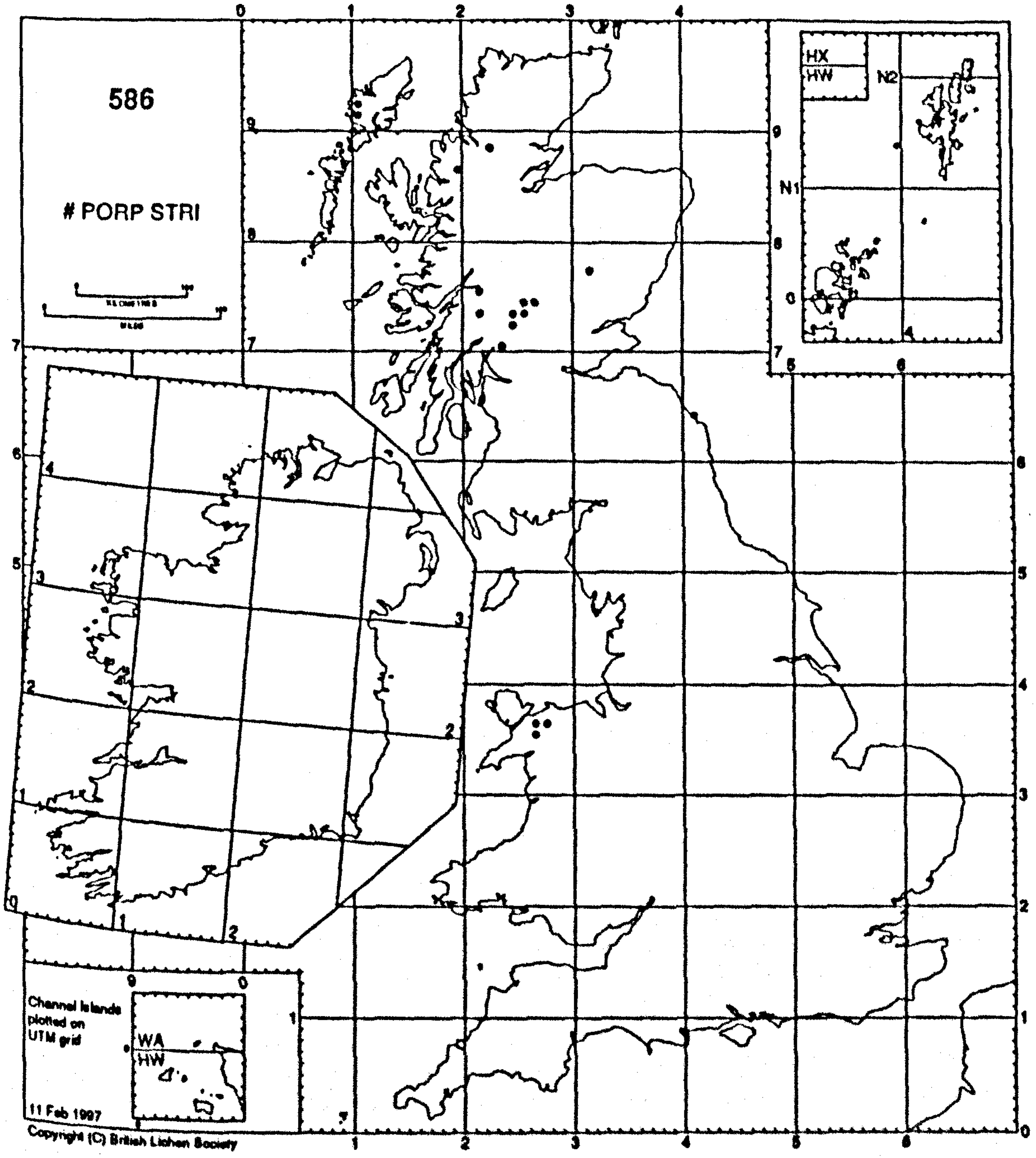

Figure 2-8. Known distribution of *Porpidia 'striata'* ad int.

A brief inspection of the specimens of *Porpidia* housed in BM and E showed that many collections previously placed in *P. albocaerulescens, P. cinereoatra, P. crustulata* and *P. macrocarpa* belong in the new species. It is possible that a validly published name for this species is available in the extensive synonymy of these species.

Selected additional specimens examined: **Wales: V.C. 49,** Caernarfon-shire, Carnedd Dafydd, Foel Meirch, 23 /6563, 800m, siliceous pebbles in montane heath, 3 June 1994, *Fryday*, 5341; Glyder Fach, Bwlch y Ddwy-Glyder, 23 /6558, 900m, on siliceous pebbles in damp heath just below rim of cwm, 8 October 1994, *Fryday*, 5671; Carnedd Llewelyn, Gledrffordd, 23 /7065, 750m, siliceous pebble in montane heath, 11 October 1996, *Fryday*, 7129 & 7130. **Scotland: V.C. 86,** Stirling-shire, Ben Lomond, S-E of summit, 27/368027, 950m, quartzite pebble in exposed schistose boulder, 25 September 1994, *Fryday* 5662. **V.C. 88,** Mid Perthshire: Ben Lawers, N. ridge 27/6341, 1100m, schistose rock, 15 June 1989, *Fryday* (Hb. Fryday); Meall nan Tarmachan, top of S. ridge, 27/5838, 900m, low lying rocks on ground in bealach, 22 November 1990, *Fryday* 1456 (thick thallus); Killin, Allt na Ceardaich, 27/5734, 225m, acidic boulder, 25 January 1991, *Fryday* 2028; Ben Lawers NNR, Creag an Lochain, 27/5941 650m, Exposed acid crags, 22 March 1991, *Fryday* 2086; Beinn Heasgarnich, West of Creag nam Bodach, 27/4438, 650m, small stone in wind-swept heath, 13 April 1991, *Fryday* 2150; Cruach Ardrain, bealach between Stob Glas and summit, 27/4020, 800m, pebble in heath, 27 January 1992, *Fryday* 3039; Ben Lawers NNR, Head of Coire Odhar, 27/6240, 875m, mica-schist pebble in wind-swept bealach, 14 June 1995, *Fryday* 6024. **V.C. 98,** Argyll Main: Dalmaly, Beinn Eunaich, 27/1332, 850m, pebble on exposed montane heath, 1 May 1991, *Fryday* 2246; Glen Coe, Bidean nam Bian, 27/1454, 1080m, bealach south of Stob Coire nam Beith, pebble in wind-swept heath, 14 August 1992, *Fryday* 3410. **V.C. 110,** Outer Hebrides: West Lewis, Teinnasval, 19/0324, 350m, siliceous boulder, 22 June 1991, *Fryday* 2501 & 2503; North Harris, Glen Ulladale, Cragan Leathan, 19/0713, c. 200m, Lewisian Gniess outcrop, 29 June 1991, *Fryday* 2615.

Porpidia superba '*var. sorediata*' ad int.

Typus: Caledonia: V.C. 98, Argyll Main, Glen Coe, Coire nam Beitheach, 27/1454, 1000m, damp rock in N-facing coire, 14 August 1992, *A.M. Fryday* 3415 (E - holotypus)

Thallus effuse, cracked-continuous to areolate, thin to moderately thick (0•4 mm); creamy-white. Soralia concolorous to somewhat darker, arising from cracks in the thallus, irregular. *Photobiont* chlorococcoid, cells (3•5)4-5 x 5-6(-7)µm diam.

Apothecia usually present, brown, lecidine, usually constricted at the base; epruinose or slightly white pruinose, 0•8-2•0mm diam. proper margin persistent, thick and tumid, darker than the disc . Anatomy; identical to *P. superba* f. *superba*.

Conidiomata frequent, pycnidia, 0•05-0•2µm diam. brown with raised, white pseudothalline margin when young, becoming sessile when old. *Conidia* bacilliform 6-8 x 0•5 µm.

Chemistry: thallus C-, K+ yellow, Pd+ orange; stictic acid and accesories by TLC.

Porpidia superba var. *sorediata* differs from the typical form primarily in the production of soredia, although there are also morphological and ecological differences. Although the typical form usually occurs on shaded basic rocks, var. *sorediata* usually occurs on vertical, flushed basic rocks (mica-schist, andesite, etc.). It appears to be somewhat less frequent than the typical form , being recorded from North Wales and the Central Highlands of Scotland (Fig. 2•9) and also from Sweden (L.-E. Muhr *pers. comm.*). The flushed habitat appears to result in the production of a thinner, smoother thallus than the typical form as the thallus is thickest where it is protected from the affects of flushing. However, other members of the genus also have a thinner thallus when soredia are produced (i.e. *P. tuberculosa/P. grisea* and *P. melinodes/P. flavicunda*).

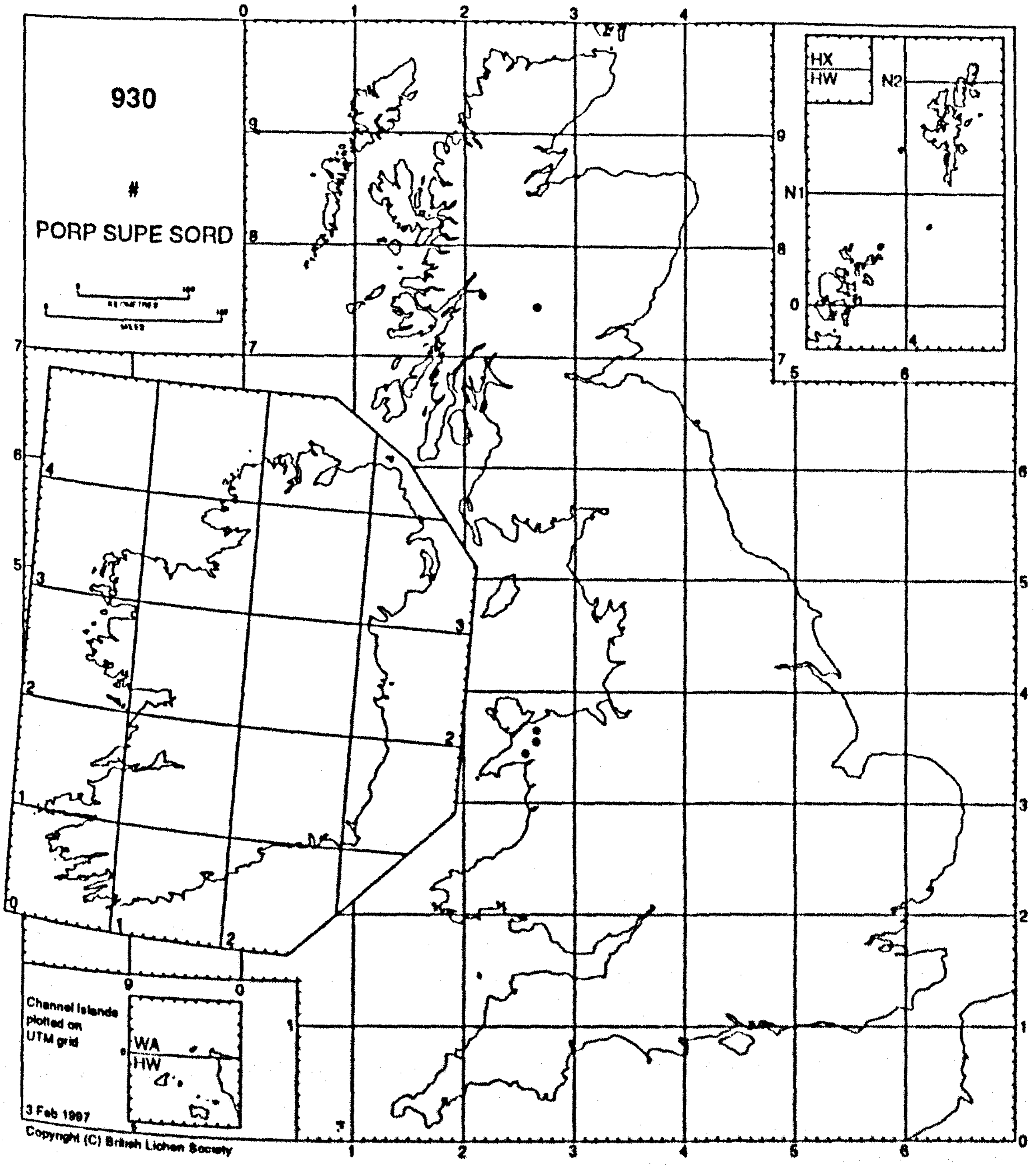

Figure 2-9. Known Britiish distribution of *Porpidia superba* 'var, *sorediata*' ad int.

Usually fertile , non-sorediate, species of lichens occasionally produce isolated sorediate plants among a normal (i.e. fertile) population. However, the sorediate morph of *P. superba* occupies a different ecological niche from the typical form and, consequently, the two forms rarely occur together. It is, therefore, necessary to afford the sorediate morph some taxonomic recognition and, as apothecia are usually produced in addition to soredia (although rarely abundant) and there are ecological and morphological differences but no obvious anatomical ones, the rank of 'variety' would appear to be the most appropriate.

Additional specimens examined: **Wales: V.C. 49,** Caernarfon-shire: Cwm Idwal, South of Twll Du, 23/6558, 600m, vertical, flushed basic crags, 4 June 1994, *Fryday* 5327; Ysgolion Duon, Grib Leon, 23/6663, 600m, vertical, flushed basic crags, 5 June 1994, *Fryday* 5336; Beddgelert, Moel yr Ogof, 23/5547, 250m, side of large boulder below basic crags, 6 June 1994, *Fryday* 5344. **Scotland: V.C. 88,** Mid-Perethshire, Ben Lawers NNR, Lochan nan Cat, 27/6442, 750m, mica-schist boulder near stream, 6 July 1989, *Fryday* (hb Fryday). **Sweden:** no details, *L.-E. Muhr* 11135.

Rhizocarpon 'caesium' ad int.

Typus: Caledonia; V.C. 104, North Ebudes, Isle of Skye, Quiraing (Cuithearaing), 18/4569, 250m, slightly basic basalt crags, 8 June 1991, *A.M. Fryday* 1448 (E- holotypus).

Thallus rimose to cracked areolate, blue-grey occasionally slightly oxydated; areoles 0•2-0•5mm diam., flat. *Photobiont* chlorococcoid, cells (10-)12-15(-18)µm diam.

Apothecia black, lecidine flat and innate to slightly convex, 0•8-1•3(-2•0)mm diam.; proper exciple (if apparent) thick but barely raised. *Hymenium* hyaline, I+ blue, 120-140µm tall; epihymenium bright aeruginose. *Paraphysoids c.* 2•5µm thick scarcely swelling at apex (to 3•0µm) with sharply delimited bright blue pigmented cap (K+ brighter, N+ red); sparingly branched and anastomosing. *Asci c.* 70 x 30µm, *Rhizocarpon*-type. *Ascospores* hyaline, halonate, 1-septate, 8/ascus, 15-18 x 7-8•5µm. *Hypothecium* dark brown. *Excipulum* of radiating hyphae, pale brown with dark brown outer cells.

Conidiomata not seen.

Chemistry: C-, K-, KC-, Pd-. No substances detected by TLC.

Rhizocarpon caesium is a fairly distinctive species which is usually easily identifiable in the field by its blue-grey thallus, large, innate apothecia and habitat of somewhat basic rocks (basalt, andesite, schists etc.). Microscopically it is similar to *R. hochstetteri* with which it shares the small, colourless, 1-septate ascospores and paraphysoids with a sharply delimited, blue pigmented cap although it differs in having a more vividly aeruginose epihymenium (Fig. 2•10). It is also very different macroscopically, having a more wide-spreading, rimose, blue-grey thallus and larger, flatter apothecia than *R. hochstetteri.* Previous records from Scotland have also been mistakenly named *R. expallescens* (i.e. Gilbert & Fox 1986) but that species occurs only on limestone and has a K+ purple excipulum.

Rhizocarpon caesium is not a rare species in the oceanic regions of Scotland where it is most frequent on the basic, tertiary basalt of the Inner Hebrides (Fig. 2•11). The Welsh collections are all from base-rich, igneous rocks. The records from further east (Mid- and East-Perthshire and Angus) are from mica-schist rocks in or near streams; although no habitat details are available for the East-Perthshire record it was associated with *Hymenelia lacustris,* clearly placing it in this habitat. Among the associated species are *Belonia nidarosiensis, Placynthium tantaleum, Porpidia superba* and *Thelidium papulare.*

Additional specimens examined: **Wales; V.C. 49,** Caernarfon-shire: Cwm Idwal, S. of Twll Du, 23/6358, 550m, vertical flushed basic crags, 4 June 1994, *Fryday* 5325; *ibid.*, N. of Twll Du, 23/6358, 600m, vertical flushed basic crags, 4 June 1994, *Fryday* 5328; Pass of Llanberis, Cwm Glas, 23/6155, 750m, basic rock above lake, 9 October 1994, *Fryday* [5708] *& Chambers.* **Scotland; V.C. 88,** Mid-Perthshire, Ben Lawers, Creag an Fhiathaech, 27/64,24, 850m, mica-schist rock-face, 6 July 1989, *Fryday* (hb. Fryday); Beinn Heasgarnich, Allt Lairig nan Lunn, 27/4338, 625m, acid rocks beside stream, 26 April 1991, *Fryday* 2223. **V.C. 89,**

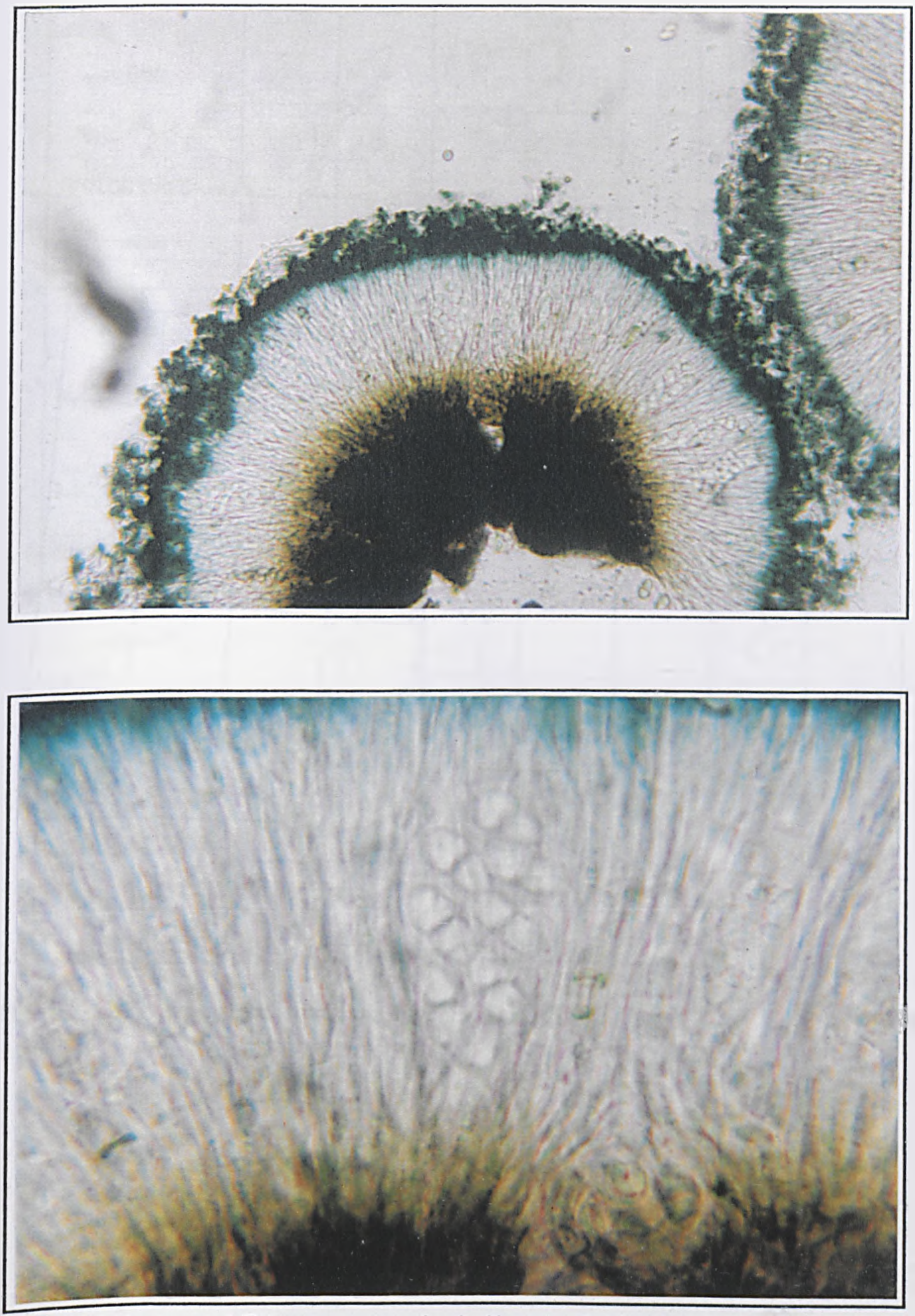

Figure 2-10. Anatomy of *Rhizocarpon 'caesium'* ad int. showing strongly aeruginose epihymenium. (Magnification: a) x175, b) x700)

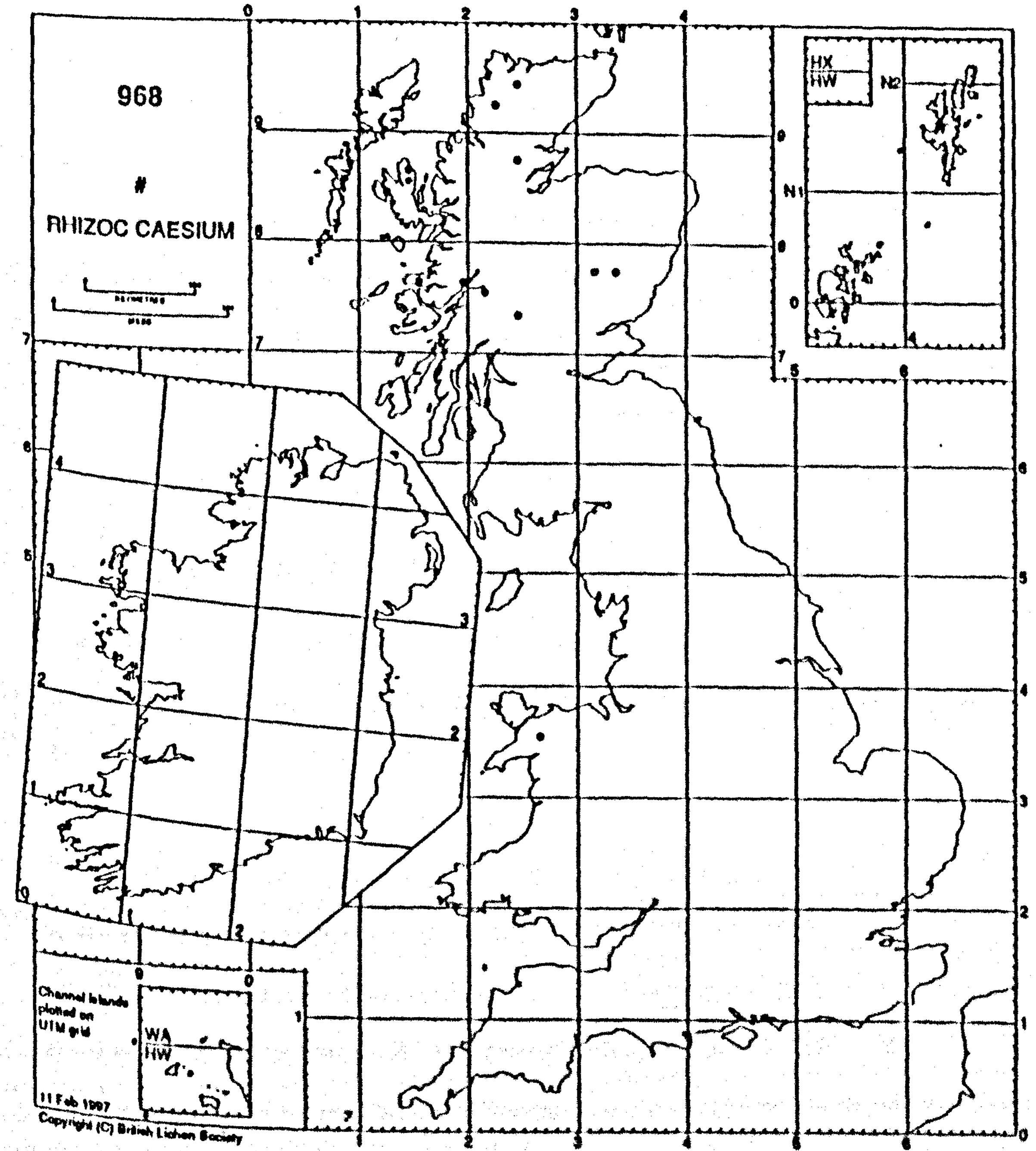

Figure 2•11. Known distribution of *Rhizocarpon 'caesium'* ad int.

East-Perthshire, Glen Shee, 1930, *W. Watson* (BM). **V.C. 90,** Angus, Glen Clova, 37/305736, c. 300m, in and beside small burn, 1991, *R. Munro* (hb Fryday). **V.C. 98,** Argyll Main, Glen Coe, Base of Aonach Dubh, 27/1556, 200m, andesite crag, 22 June 1992, *Fryday* 3241. **V.C. 104,** North Ebudes: Isle of Skye, The Storr, 18/4953, 500m, exposed basalt crag, 22 July 1990, *Fryday* 1282; *ibid.*, E. crags of Sgurr Mor, 18/4470, 300m, basalt crags, 7 September 1991, *Fryday* 2920. **V.C. 108,** West Sutherland, Ben Hope, 29/4749, 550m, on epidiorite outcrop, July 1984, *O. Gilbert* (BM).

Rhizocarpon colludens 'subsp. *rufoatrum*' ad int.

Typus: Caledonia; V.C. 97, Westerness, Ben Nevis, summit plateau, 27/1671, 1340m, exposed acidic rocks on summit, 25 August 1991, *A.M. Fryday* [1358], *O.L.Gilbert & V.J. Giavarini* (E - holotypus, M - isotypus).

Thallus effuse, areolate, red-brown, to *c.* 0•35mm thick; areoles 0•5-1•0mm diam., flat to slightly convex. *Photobiont* chlorococcoid, cells (10-)12-15(-18)µm diam.

Apothecia black, lecidine flat to slightly convex, 0•5-1•0(-1•2)mm diam.; proper exciple thin to moderately thick, barely raised. *Hymenium* hyaline, I+ blue 110-120µm tall; epihymenium blue-black, brighter blue in K. *Paraphysoids c.* 2•5µm thick scarcely swelling at apex (to 3•0µm) with blue-black pigmented cap (K+ brighter, N+ red); sparingly branched and anastomosing. *Asci c.* 85-95 x 30-35µm, *Rhizocarpon*-type. *Ascospores* hyaline, becoming brown when over-mature, halonate, 1-septate, 8/ascus, 21•5-25•0(-28•0) x 11•0-12•0µm. *Hypothecium* dark brown. *Excipulum* of radiating hyphae, dark brown throughout.

Conidiomata not seen.

Chemistry: thallus C-, K+ yellow, Pd+ orange; stictic acid and accessories by TLC.

Rhizocarpon colludens subsp. *rufoatrum* is separated from subsp. *colludens* by its red-brown (rather than grey-brown) thallus, its ecology of being restricted to very high altitudes (at least in the U.K.) and the presence of stictic acid in the thallus. One specimen with the morphology and ecology of subsp. *rufoatrum* did not contain stictic acid but the production of this substance in other species of *Rhizocarpon* is also irregular. Although I could detect no significant differences in the anatomy of the two taxa a more detailed investigation may yield information which would justify treating them as distinct species. Associated species include *Frutidella caesioatra, Ionaspis odora, Miriquidica griseoatra, Porpidia tuberculosa, Rhizocarpon geographicum* aggr., *R. polycarpum* and *Stereocaulon tornense.*

Additional specimens examined: **Scotland: V.C. 88,** Mid-Perthshire: Ben Lawers, top, July 1864, *I. Carroll* (BM); *ibid.*, gully, 1869, *J. Stirton* (BM) [on granite!]; Beinn Cheathaich, 27/4432, 925m, acidic boulder on summit, 5 May 1991, *Fryday* 2278. **V.C. 96,** Easterness, Cairngorm, Ciste Mhearad, 38/0104,1075m, granite boulder by late snow bed, 20 August 1995, *Fryday* 6259. **V.C. 97,** Westerness: Aonach Mor, 27/1972, 1150m, acidic rock above late snow patch, 26 June 1990, *Fryday* 1225; *ibid.*, Coire an Lochain, 27/1973, 1050m, acidic rocks below late snow patch, 21 August 1990, *Fryday* 1311 & 1314. **V.C. 98,** Argyll Main, Dalmally, Beinn a' Chochuill, 27/1132, 850m, exposed granite boulder, 1 May 1991, *Fryday* 2251. **V.C. 104,** North Ebudes, Isle of Skye, Trotternish, The Storr, 18/4954, 700m, exposed acid boulder, 22 July 1990, *Fryday* 1283. **V.C. 105,** West Ross-shire, Beinn Dearg, 28/2581, 1000m, rocks above late snow bed, 10 August 1995, *Fryday* 6228 & 6242.

Rhizocarpon 'sublavatum' ad int.

Typus: Caledonia; V.C. 97, Westerness, Ben Nevis, Coire Leis, 27/171712, 1050m, on loose stones below crag, 5 September 1996, *A.M. Fryday* 7101 (E-holotypus, BM, UPS, M, WIS -isotypus)

Thallus effuse, usually in small patches 1-2cm diam. but sometimes coalescing to cover larger areas, cracked-areolate, thin, mid to dark grey occasionally brown-grey; areoles 0•2-0•3(-0•4)mm diam., flat to slightly convex, hypothallus clearly visible. *Photobiont* chlorococcoid, cells (10-)12-15(-18)µm diam.

Apothecia black, lecidine innate when young, becoming sessile when mature, 0•3-0•5(0•8)mm diam.; proper exciple persistent, thick and raised. *Hymenium* hyaline, I+ blue, 120-140µm tall; epihymenium olivaceous (K+ blue, N+ red). *Paraphysoids c.* 2•0 µm thick scarcely swelling at apex (to 3•0µm), with pigmented cap; sparingly branched and anastomosing. *Asci*, *c.* 80-100 x (27-)32-40(-45)µm, *Rhizocarpon*-type. *Ascospores* hyaline, halonate, eu-muriform, 15-20(-25) cells in optical section, 8/ascus, (22•0-)27•0-32•0(-40•0) x (11•0-)14•0-16•0(-17•5)µm, length/breadth ratio (1•6-)1•8(-2•4). *Hypothecium* mid- to dark brown. *Excipulum* of radiating hyphae, pale brown with darker outer cells (K+ blue-black).

Conidiomata not seen.

Chemistry: C-, K-, KC-, Pd-. No substances detected by TLC.

Rhizocarpon sublavatum is, in many respects, intermediate between *R. reductum* (syn. *R. obscuratum* auct.) and *R. lavatum* and has probably contributed to the confusion surrounding the former species. Like *R. lavatum*, with which it often grows, it has eu-muriform ascospores but they are both smaller (33•0-50•0µm long in *R. lavatum*) and have a lower length/breadth ratio (2•0-3•1 in *R. lavatum*). It also has smaller, more sessile apothecia (Fig. 2•12). The thallus of *R. lavatum* is also more often rimose than areolate and browner than in *R. sublavatum*. It is also often the host to parasitic fungi (*Endococcus* spp.) but these have not been observed on *R. sublavatum*, even when the two species grow together. *R. reductum* has smaller, sub-muriform spores, a thallus containing stictic acid (K+ yellow, Pd+ orange) and is rarely encountered at the altitudes at which *R. sublavatum* occurs. The species closest to *R. sublavatum* in both macroscopic and microscopic characters is *R. anaperum*.; both have spores of a similar size and shape (Figs 2•16 & 2•17, pp.180-183) but *R. anaperum* has a taller thecium with narrower, more branched paraphysoids as well as a different apothecial pigmentation - only brown pigments present. Macroscopically *R. anaperum* has a browner, more granular-areolate thallus. The two species often grow together when they remain morphologically distinct.

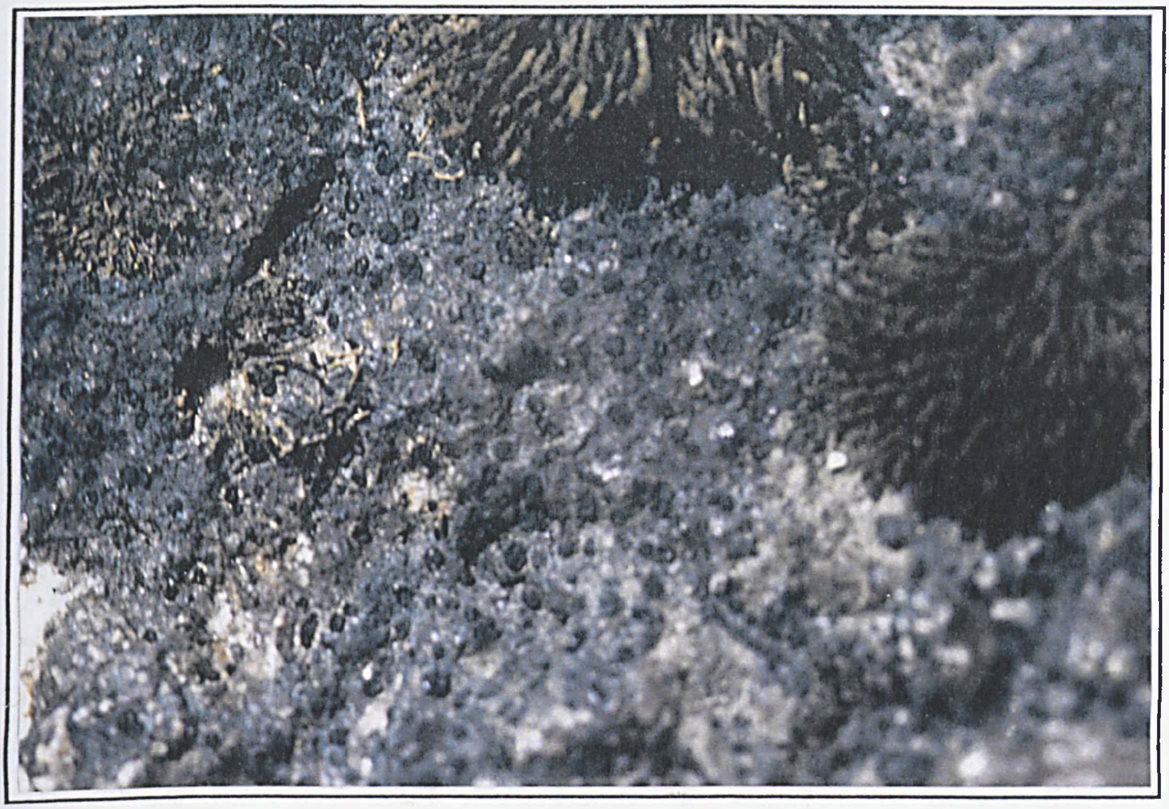

Figure 2.12 *Rhizocarpon 'sublavatum'* ad int. showing small, sessile apothecia. (Magnification: x4)

Rhizocarpon sublavatum is typically a species of damp, siliceous, montane rocks widely distributed across the Scottish Highlands (Fig 2•13). It often forms mosaics with species such as *Ionaspis odora, Porpidia contraponenda, P. tuberculosa, Rhizocarpon anaperum, R. lavatum* and *Stereocaulon tornense* although in its type locallity, where it is abundant, it is almost the only lichen growing on loose stones at the base of a high cliff, suggesting that it is a colonising species, perhaps replacing *R. reductum* in this role at high altitudes.

Additional specimens examined: **Scotland; V.C. 88,** Mid-Perthshire: Ben Lawers NNR, Lochan nan Cat, 27/6442, 750m, rocks near stream, 6 July 1989, *Fryday* (hb Fryday); Meall na Cnap-laraich, 27/5039, 775m, siliceous rocks, July 1989, *Fryday* (hb Fryday); Beinn Heasgarnich, Allt Tarsuinn, 27/4338, 700m, top of acid rock beside stream, 26 April 1991, *Fryday* 2227; Meall Corranaich, 27/6140, 1000m, quartzite pebble, 4 May 1991, *Fryday* 2158a. **V.C. 96,** Easterness: Cairngorm, Ciste Mhearad, 38/0104,1075m, granite boulder by late snow bed, 20 August 1995, *Fryday* (6259) *& S. Chambers*; *ibid.*,12 September 1995,

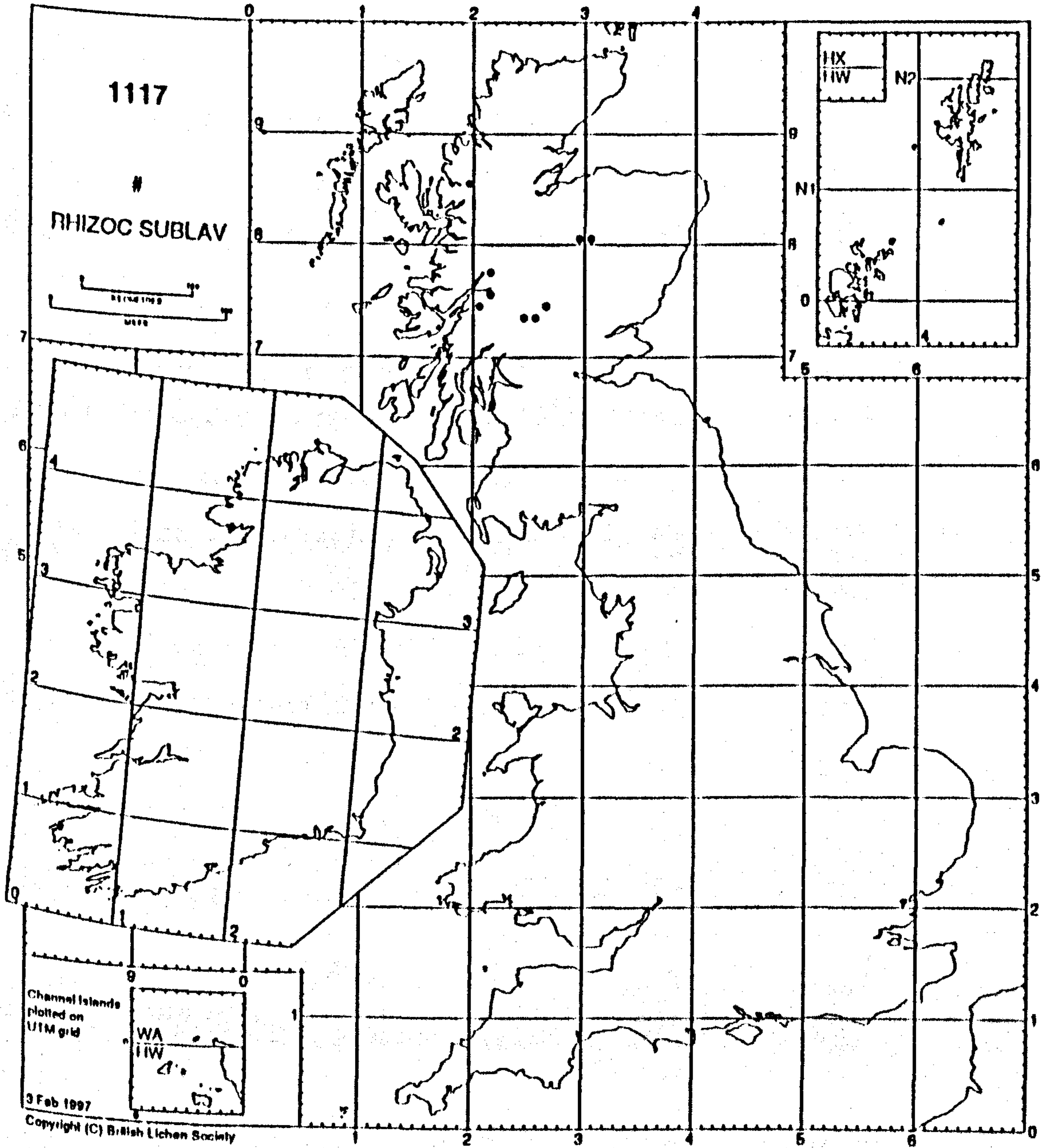

Figure 2•13. Known distribution of *Rhizocarpon 'sublavatum'* ad int.

Fryday 6308; Coire an Lochain,28/9802, 1000m, granite rocks in N-facing coire, 21 August 1995, *Fryday* (6282) *& S. Chambers.* **V.C. 97,** Westerness: Aonach Mor, Coire an Lochain, 27/1973, 900m, acid rocks beside water slide, 21 August 1990, *Fryday* (1308) *& O. Gilbert*; Ben Nevis, summit plateau, 27/1671, 1340m, shaded rocks on N. crags, 25 August 1990, *Fryday* (1365), *O. Gilbert & V. Giavarini.* **V.C. 98,** Argyll Main: Glen Coe, Bidean nam Bian, just west of summit, 27/140542, 1075m, on pebbles in wind-swept bealach, 14 August 1992, *Fryday* 3411; Ben Sguilard, W. ridge, 27/021448, 400m, amoung bryophytes on damp, schistose rock outcrop, 9 July 1995, *Fryday* (6084) *& R. Leishman*; Glen Coe, between Stob Coire nam Beith and Bidean nam Bian, 17/139544, 1080m, on top of igneous rock outcrop (?andesite) on damp, N-E-facing slope, 29 July 1995, *Fryday* 6187&8. **V.C. 105,** West Ross-shire, Liathach, Coireag Cham, 18/914577, 800m, sandstone boulder in area moderately affected by late snow lie, 7 August 1995, *Fryday* 6198.

Ropalospora lugubris **'subsp. *sorediata*' ad int.**

Typus: Caledonia, V.C. 98, Argyll Main, Glen Coe, Coire nam Beitheach 27/142.545, 875m alt., on east-facing rhyolite crag in dry underhang, 15 July 1992, *A.M. Fryday* 3347 c. fr. (E-holotypus).

Thallus crustose, dark grey (often purple tinged) or pale to dark brown, cracked areolate, areoles plane to verrucose. Soralia *c.*0•1-0•5 mm diam., initially discrete but usually becoming confluent; soredia concolorous with the thallus, coralloid-granular; usually becoming pale yellow-brown, farinose. *Photobiont* cells thick-walled, 7-16(-19) x 8-12(-13)µm, often dividing to give 2-4 daughter cells.

Apothecia very rare, identical to *R. lugubris* f. *lugubris*.

Conidiomata not seen.

Chemistry: C-, K-, KC-, Pd-. Unidentified substance at A:4, G:4 colourless, UV+ white; brownish-pink, UV+ cream after developing, accompanied by two accessories with the same characteristics at about A:3, G:3-4.

The production of soredia occurs in most species of the genus *Fuscidea* (to which *Ropalospora* is very closly related) often as the primary means of reproduction. Species which usually reproduce by apothecia also occasionally produce soredia but these are rare (but cf. *Fuscidea poeltii* above), only occur within normal fertile populations and the sorediate plants are always fertile; *F. cyathoides* var. *sorediata* is a described example but I have also seen sorediate specimens of *F. intercincta* (?*F. oculata*), *F. kochiana* and *F. lygaea*. *Ropalospora lugubris* subsp. *sorediata*, however, is very rarely fertile and is also more frequent and widespread than the non-sorediate plant. For this reason it is considered appropriate to afford it some taxonomic recognition and the rank of subspecies seems most suitable.

Ropalospora lugubris subsp. *sorediata* was described as *Fuscidea* sp. A by Gilbert *et al.* (1988,238) and has subsequently been found to be widespread on acidic rocks throughout the western Scottish Highlands (Fig. 2•14). Similarities of thallus morphology and ecology suggested that it may be the sorediate counterpart of *R. lugubris* and the discovery of a population with mature apothecia confirmed this opinion.

Ropalospora lugubris subsp. *sorediata* is more widespread than subsp. *lugubris* over much of the western Highlands and is by far the more common morph. However, in the Torridonian sandstone areas of North-West Scotland where *R. lugubris* subsp. *lugubris* is fairly frequent, subsp. *sorediata* is rare.

The variation in thallus colour and morphology of *R. lugubris* subsp. *sorediata* is similar to that found in subsp. *lugubris* and appears to be due to environmental conditions; specimens with a thinner thallus occurring on fine-grained rocks (e.g. rhyolite, basalt etc.) and those with a thicker thallus on more friable rocks (e.g. schists). Superficially, *R. lugubris* subsp. *sorediata* appears to have two different types of soredia as they are initially granular-coralloid and concolourous with the thallus often coalescing to cover areas up to 5 mm diam. but these later 'burst' (or abrade) giving rise to smaller cream coloured farinose soredia. There is occasionally very little evidence of the original form but careful examination will usually reveal some darker, granular soredia around the edges of, at least some, soralia. Associated

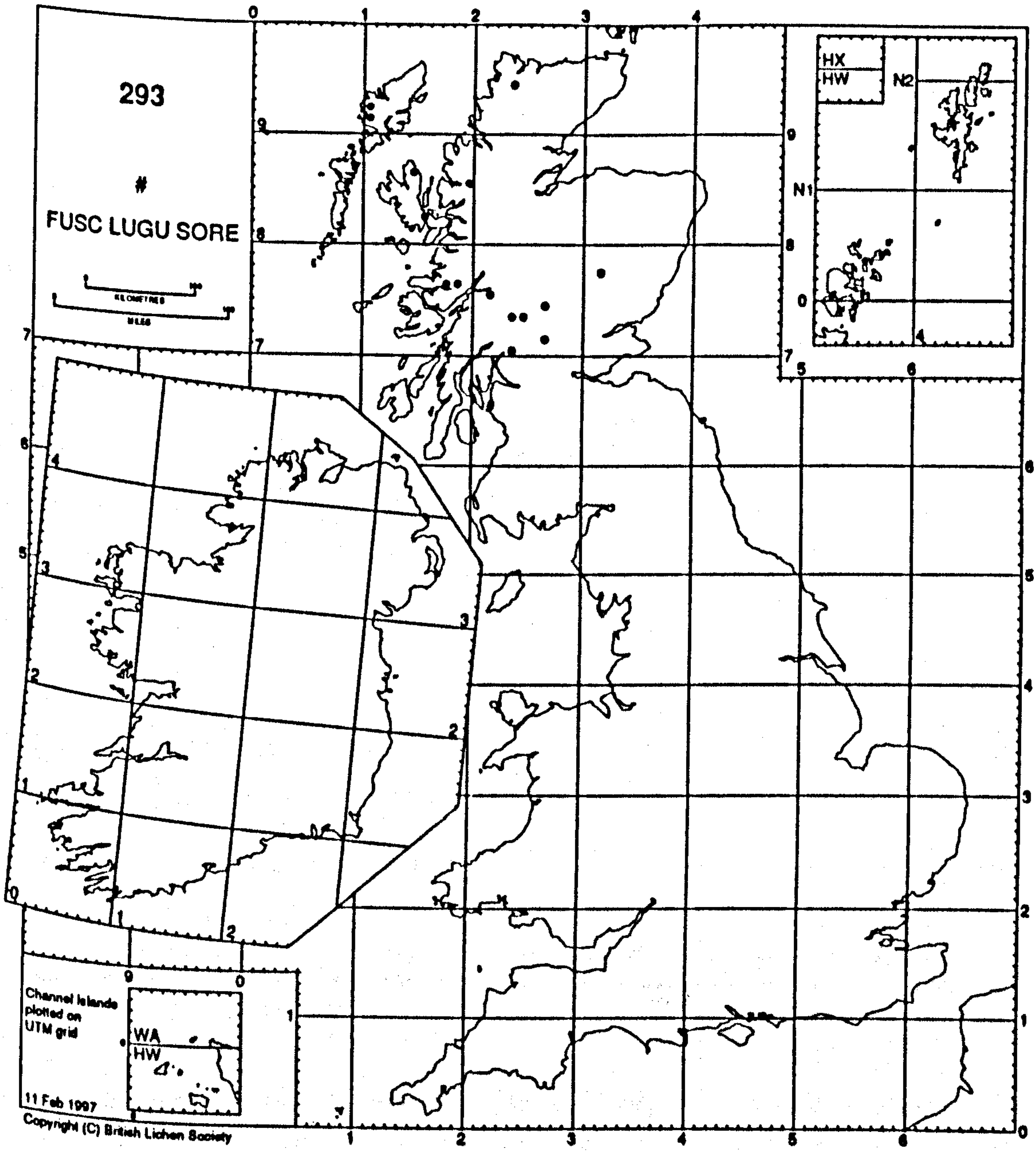

Figure 2.14. Known distribution of *Ropalospors lugubris* 'subsp. *sorediata*' ad int.

species include *Coccotrema citrinescens, Fuscidea gothoburgensis, F. intercincta, Lepraria lobificans, Pertusaria corallina, Porpidia* spp., and *Rhizocarpon geographicum* aggr.

The relationship of this species to the Scandinavian *R. atroumbrina* - which is not known fertile - is in need of investigation. *R. atroumbrina* apparently differs from *R. lugubris* subsp.. *sorediata* in its more coralloid soredia which have a different ontogeny (S. Ekman, pers. comm.).

Additional specimens examined: **Scotland: V.C. 88,** Mid-Perthshire: Ben Ghlas, Crags at head of Coire Odhair, 27/6240, 900 m, on west-facing mica-schist crags, 3 August 1989, *Fryday* (hb Fryday); Beinn Heasgarnich, Creag na h-Acharich, 27/4238, 750 m, exposed acidic crag, 26 April 1991, *Fryday* 2237-9 [with immature apothecia]; Creag Mhór, N-E Crags, 27/3936, 800 m, mica-schist underhang, 17 May 1991, *Fryday* 2332; Beinn Heasgarnich, North Ridge, 27/4238 950 m. mica-schist boulder, 18 August 1991, *Fryday* 2834; Ben Vorlich, 27/6219, c. 600 m, on underside of schistose boulder, 13 February 1992, *Fryday* 3052. **V.C. 97,** West Inverness-shire: Sunart, Strontian River, 17/8666, 250 m, acid rock in ravine below disused metal mine, 18 June 1992, *Fryday* 3174; Sunart, Beinn Resipol, 17/7565, 450 m, vertical, shaded acidic rock, 19 June 1992, *Fryday* 3193. **V.C. 98,** Argyll Main, Glen Coe, Achnambeithach, 27/1356, 200 m, underside of ?rhyolite boulder, 15 July 1992, *Fryday* 3348. **V.C. 104,** North Ebudes: Isle of Skye, An Carnach, 18/5520, 200 m, east-facing basalt crag, 4 June 1991, *Fryday* 2390-1; *ibid.*, Quiraing (Cuithearaing), 18/4569, 250 m, exposed basalt crags, 8 June 1991, *Fryday* 2452. **V.C. 108,** West Sutherland, Creagan Meall Hourn, N-E facing crags above An Dubh Loch, 29/3445, c.475 m, shaded underhang. 22 September 1991, *Fryday* 2952 **V.C. 110,** Outer Hebrides: West Lewis, Glen Raonasgill, Teinnasval, 19/0326, shaded acidic (?granite) boulder, 22 June 1991, *Fryday* 2507; North Harris, Glen Ulladale, Creagan Leathan, 19/0712, exposed east-facing crag, 29 June 1991, *Fryday* 2612.

NEW COMBINATIONS

Rhizocarpon colludens (Nyl.) ad int.

Lecidea colludens Nyl. *Flora* **53**:38 (1870).

Syntypus; Nyl. 10047, 10060 (*Lecidea atroalba* v. *chlorospora*), Vainio - sec. spec. orig. *Acta Societatis Fauna Flora Fennica* **53(1)**:332 (*Lichenographia Fennica* **II**).

Thallus thick, cracked- areolate, areoles flat to slightly convex 0•2-0•8mm diam.; grey-brown to red-brown. *Photobiont*. chlorococcoid.

Apothecia frequent, black, lecidine, immersed in the thallus and immarginate (exciple if present thick and scarcely raised) or sessile with persistent exciple. *Hymenium* 100-120µm tall, hyaline, I+ blue. Epihymenium blue-black (K+ blue, N+ red). *Paraphysoids* branched and anastomosing, 2•5-3•0µm wide (swelling at apex to 3•5µm), with sharply delimited blue-black pigmented cap. *Asci* *c*.100 x 30 µm, *Rhizocarpon*-type. *Ascospores* hyaline becoming brown when over-mature, halonate, 8/ascus, 1-septate, 24-30 x 12-15µm. *Hypothecium* dark brown. *Excipulum* of radiating, dark brown hyphae.

Conidiomata not seen.

Chemistry: C-, K- or K+ yellow, KC-, Pd- or Pd+ orange . No substances or stictic acid detected by TLC

Rhizocarpon colludens has usually been included within *R. hochstetteri* and although it has the colourless, 1-septate ascospores and paraphysoids with sharply delimited, pigmented caps of that species it is clearly distinct. The most obvious difference is the much larger ascospores of *R. colludens* but the two species also differ in a wide range of characters which are summarized in Table 2•4.

The description of *R. hochstetteri* given by Purvis *et al.* (1992) is a combination of elements of *R. colludens* and a further undescribed species, *R. oceanicum* ad int. (see Section 2•3•2•3 and Fryday 1996). This latter species, which is frequent on siliceous boulders in oceanic woodlands, is similar to *R. hochstetteri* with respect to ascospore size and as the ascospore dimensions given by Purvis *et al.* refer to *R. colludens* this explains the discrepancy with continental specimens which they mention.

Table 2-4. Comparison of the main features separating *Rhizocarpon colludens* from *R. hochstetteri*.

	R. colludens	***R. hochstetteri***
Habitat	Exposed upland and montane rocks	Usually shaded upland rocks, particularly frequent on spoil from disused metal-mines.
Thallus	Grey-brown (subsp. *colludens*) to red-brown (subsp. *rufoatrum*).	White to grey to grey-brown.
	Thick, areoles convex.	Thin, areoles flat.
	Widespreading.	Seldom > 2 cm diam.
Chemistry	No substances (subsp. *colludens*), or stictic acid (subsp. *rufoatrum*).	No substances, stictic acid or norstictic acid.
Apothecia	Flat and ±immarginate or convex with thick exciple.	Remaining flat with persistent, thinner exciple.
Epihymenium	blue-black .	blue-black to olive-brown.
Thecium	c. 150µm high.	80-90µm high.
Ascospores	26-30µm long.	14-16µm long.

Of the 28 specimens of *R. colludens* examined 9 contained stictic acid. These were all from high altitude (over 900m) and had a thick red-brown thallus with innate, immarginate apothecia and hymenium and spore dimensions towards the upper end of the range. Conversely, most specimens lacking stictic acid tended to have a grey-brown thallus with sessile apothecia and smaller apothecial dimensions. It is considered that these differences are sufficient to warrent recognising the two entities as distinct taxa and as the differences are mainly ecological and morphological rather than anatomical, the rank of subspecies seems most appropriate. As the type-specimen of *R. colludens* has all the characters of the stictic acid deficient strain the stictic acid containing strain is described above as ***R. colludens*** subsp. *rufoatrum* ad int.

Species associated with subsp. *colludens* include *Lepraria caesioalba, Miriquidica complanata, Porpidia tuberculosa* and *Rhizocarpon lavatum.*

Selected additional specimens examined: **Wales: V.C. 49,** Caernarfonshire, Gwastadnant, Cwm Glas-bach, 23/6156, 325m, on top of low flat boulder, 10 October 1994, *Fryday* 5747. **Scotland: V.C. 88,** Mid-Perthshire: Glen Dochart, Ledcharrie, 27/50228, 175m, acid boulder, October 1989, *Fryday* (hb. Fryday); Ben Lawers range, Glen Roro, 27/6141, 900m, top of low mica-schist rock, 26 March 1991, *Fryday* 2120; Beinn Heasgarnich, Creag na h-Achlarich, 27/4238, 750m, top of flat acidic rock, 13 April 1991, *Fryday* 2159. **V.C. 97,** West Inverness-shire: Aonach Mor, north of bealach,27/1972, 1100m, schistose crags near cornice snow bed, 23 August 1990, *Fryday* [1336], *Gilbert & Giavarini*; Ben Nevis, summit plateau, 27/1671, 1340m, top of crags affected by cornice snow bed, 25 August 1990, *Fryday* [1355], *Gilbert & Giavarini.*

Stereocaulon plicatile (Leighton) Fryday & Coppins

Lecidea plicatilis Leighton, *Ann. Mag. nat. Hist., ser. 4,* 4:201 (1869) - *Rhizocarpon plicatile* (Leight.) A. L. Sm., *Monogr. Brit. Lich.* 2:197 (1911). Type: Wales, [**V.C. 48,** Merioneth] Cader Idris, Llyn-y-Cae, on schistose rocks, 1869, *W. A. Leighton* (BM - holotypus).

Thallus crustose, thin (to 0•2 mm thick), rimose to areolate, sorediate. *Areoles*, when discrete, c. 0•2-0•6mm wide, confluent to scattered, plane to slightly convex, whitish to grey, matt to slightly glossy, only rarely a few with hyaline centres. *Cortex* 28-70µm thick, hyaline, densely encrusted with minute crystals (mostly K+ dissolving yellow, hyphae c. 2•5-3µm (in K); epinecral layer often present, to 12µm thick. *Soralia* 0•2-0•3(-0•4)mm diam., arising from cracks in the areoles, discrete to becoming confluent, pale green to bluish green or brown. *Soredia c.* 25-50µm diam., greenish white, but surface soredia often brown tinged; surface hyphae brown-walled (pigment K-, N-). *Photobiont* ?trebouxioid, cells 6-11µm diam. or ellipsoid and 7-14 x 4-8µm. Cephalodia absent.

Apothecia (0•2-)0•6-1•2(-1•6)mm diam., sessile, blackish with a brown tinge (especially when moistened); disc flat to slightly convex, epruinose; margin usually distinct but becoming reflexed or folded in old apothecia, *c.* 0•1mm thick, smooth. *Hymenium* (80-)90-100(-110)µm tall, hyaline, but I+ blue around the asci; epihymenium 15-18µm tall, reddish brown, K-, N-. *Paraphyses* mostly simple, only a few occasionally branched or anastomosed, 1•3-1•5µm thick in mid-hymenium; apices swollen to 3-4µm, with distinct, dark brown apical caps. *Asci* clavate-cylindrical, (65-)70-95 x15-25µm, (4-)8-spored, apical dome I+ blue with dark blue, axial tube (*Porpidia*-type). *Ascospores* 20-32 x 10-15µm, variously ovoid, ellipsoid or fusiform, hyaline, submuriform to muriform with 3-7 transverse septa and 1-6 transverse cells with 1 (very rarely 2) longitudinal septum, without a distinct perispore. *Subhymenium* often difficult to distinguish from hypothecium, but usually paler and 15-30µm tall. *Hypothecium* 40-70 µm tall reddish brown, K+ orange-red tinge. *Excipulum* distinct, running beneath the hymenium almost to the centre of the apothecium, dark reddish brown within, somewhat paler towards the edge, formed of dense, radiating, strongly conglutinated hyphae, 2•5-3•5µm thick, with a rather thick wall and a narrow lumen; apical cells at edge of excipulum swollen to 4µm, often with distinct apical caps (as in paraphyses).

Conidiomata pycnidia, immersed in the areoles, *c.* 60-70µm diam., dark reddish brown, globose. *Conidiogenous cells* sessile or on once-branched conidiophores, forming mainly acrogenous (rarely also pleurogenous) conidia. *Conidia* (spermatia) 14-18(-22) x 0•5-0•7µm, hyaline, filiform, curved.

Chemistry: Cortex K+ yellow, Pd- or Pd(f)+ yellow; soralia K+ yellow, Pd+ orange; medulla K+, or K(f)+ yellow, Pd-; all parts C-, KC-, UV-. Atranorin and stictic acid by TLC.

The holotype of *Lecidea plicatilis* in BM, collected from Cader Idris, North Wales in 1869, is small and in poor condition. It consists of four flakes of rock (totalling *c.* 1 cm^2) with only two, immature, apothecia. However, detailed anatomical notes were made by P.W. James in 1960 and the specimen has been subjected to TLC and found to contain stictic acid and atranorin. Close examination of the thallus fragments revealed the presence of soredia developing along cracks in the thallus.

Lecidea plicatilis was transferred to *Rhizocarpon* by A.L. Smith on account of its muriform spores. There is an undated annotation on the herbarium sheet from Feuerer referring it to *R. obscuratum* as well as an annotation in pencil (?Lamb) querying its placement in *Rhizocarpon.* Its true identity was discovered during research into *Rhizocarpon* subgenus *Phaeothallus* for this study when it was realized that it was a specimen of a crustose *Stereocaulon* (similar to *S. tornense* but with muriform, not 3-septate ascospores) known from a number of sites in the Scottish Highlands and previously believed to be undescribed.

Due to the poor condition of the type specimen and the confusion surrounding this entity (*R. plicatile* supposedly contains norstictic acid) a description of the species is given here. The ecology and systematic position of this species is discussed more fully in Fryday & Coppins (1996b).

Selected additional specimens examined: **Wales: V.C. 49,** Caernarfon-shire, Snowdon range, Crib-goch, 23/6255. *c.* 850 m, pebbles in *Festuca* heath, 1993, *Fryday* 4671 (hb Fryday). **Scotland: V.C. 88,** Mid-Perthshire: Ben Lawers range: crags to N of Ben Ghlas, 27/625405, *c.* 1000 m, on vertical acid rocks, 25 August 1989, *Fryday* (E, M); Ben Lawers range, Ben Ghlas, 27/624405, *c.* 1020 m, on acid rocks subject to late snow-lie, 23 October 1989, *Fryday* (E); Ben Ghlas, 27/62.40, *c.* 1050 m, on acid rock, subjected to late snow-lie, October 1989, *Fryday* (E, hb Fryday); Beinn Heasgarnich, Coire Heasgarnich, 27/414384, 1050 m, October 1989, *Fryday* (E, hb Fryday). **V.C. 92,** South Aberdeen, Glas Maol, 37/1677, *c.* 900 m, on pebbles and boulders in north-facing corrie, 1991, *Fryday* 2933 (hb Fryday). **V.C. 97,** Westerness: Fort William, Aonach Mòr, 27/1972, 1150 m, 1990, *Fryday* 1214 (E); Creag Meagaidh, 27/4087, 1000 m, on low silceous boulders in grass heath above area of late snow-lie, September 1994, *Fryday* [5608 & 5610] *& Gilbert* (hb Fryday); *ibid.*, 1995, Fryday 6163 (hb Fryday). **V.C. 98,** Argyll Main, Glen Coe, Coire nam Beitheach, 27/1454, c. 1100 m, vertical rocks in NE-facing coire influenced by late snow-lie, 1992, Fryday 3397 (hb Fryday).

2•3 IDENTIFICATION

2•3•1 Keys to sterile crustose saxicolous and terricolous lichens occurring in the montane areas of the British Isles.

2•3•1•1 Introduction

Saxicolous lichens are generally perceived to be 'difficult' and, consequently, have received far less attention than corticolous ones. However, this is largely a self-perpetuating problem as the main reason they remain 'difficult' is because they are little studied. Their 'difficulty' is primarily a consequence of two factors:-

a) many grow in areas little visited by lichenologists (i.e. uplands and mountains) and are, therefore, less often encountered.

b) the nature of their substrata means that they are often both time-consuming to collect and it is more difficult to obtain a good specimen for detailed examination.

This unsatisfactory situation is even more pronounced when it comes to sterile saxicolous species. Sterile corticolous lichens which are fewer in number, easier to collect and more frequently encountered have been the subject of comprehensive studies in Scandinavia (Tønsberg 1992) Central Europe (Schreiner & Hafellner 1992) and Great Britiain and Ireland (Purvis *et al.* 1992). In contrast there are no recent studies devoted to sterile saxicolous species in these areas and no recent key which attempts to treat all the known species in a region.

Every attempt has been made to make the following keys to sterile saxicolous crustose lichens as complete as possible. Species which are usually corticolous and only occasionally occur on rock are included as are a number of undescribed taxa, most of which will be formaly described in taxononic papers currently in preparation. Where a species is known to occur as more than one chemotype, all but the very rarest are included. However, it is not possible to allow for every eventuality and the possibility of unusual ecologies and chemistries should always be borne in mind. It should also be stressed that the keys are intended for use with well developed specimens which usually occur without fruiting bodies; many specimens of usually fertile species with a poorly developed thallus or lacking ascomata will remain indeterminate. It should also be borne in mind that these keys are not intended as a self-sufficient means of identification. When a specimen has been 'keyed-out' it should be checked against a more detailed description, preferably in Purvis *et al.* (1992).

For the most part, only thallus morphology and chemical spot tests are used as characters in the keys, although occasionally the colour reaction under UV light is required. Ecological and distributional information is sometimes included when this helps to increase the certainty of a determination but this should always be treated with, at least, the same caution as other characters.

The majority of the species of the genera *Lepraria* and *Leproloma* have been omitted from them keys as:

a) their identification is often extremely difficult without resorting to TLC

b) a key to these two genera has recently been published (Orange 1995); this should be consulted, along with the present 'Key 1', for all leprose species.

However, *Leproloma membranaceum* and the species of the *Lepraria caesioalba* group (including the granular form of *Lepraria cacuminum*) are included as the lobed thallus of the former and the well-developed, granular thallus of the latter could result in their being mistaken for other genera.

Chemical 'spot-test' reactions are often best carried out microscopically by mounting a section of the specimen to be tested on a slide and flooding the preparation with the appropriate chemical. This applies particularly to reactions with C, especially on those species with a dark thallus (*Rimularia furvella, Placynthiella icmalea* etc.). The reaction given with Pd is that for the freshly dissolved reagent in methylated spirits. The reaction of atranorin with Pd may cause some confusion. This is represented in the keys as Pd- or faint yellow but the colour often develops over a period of about 30 seconds to produce quite a distinct colour. A true Pd+ yellow reaction develops within 5- 10 seconds of application of the reagent. In cases of doubt the reagent should be tested on a specimen of a common species known to contain atranorin (e.g. *Evernia prunastri, Lecanora chlarotera, Physcia* spp., *Platismatia glauca, Tephromela atra*).

When using the keys it is recommended that specimens should, if possible, be examined using a x10 binocular microscope fitted with powerful top lighting.

The presence of confluentic acid (used as a character in Key 4) can be detected, without resorting to thin-layer chromatography, as described by Fryday (1991a).

2·3·1·2 The Keys

Synopsis

1 Thallus with at least some corticate areas 2
Thallus completely non-corticate or leprose .... **Key 1**

2(1) Thallus and soredia C-, KC- 3
Thallus and/or soredia C+ or KC+ red, orange or yellow .... **Key 2**

3(2) Thallus sorediate, or with blastidia 4
Thallus without soredia etc 5

4(3) Thallus or soredia either K+ or Pd+ .... **Key 3**
Thallus with all spot test reactions negative .... **Key 4**

5(3) Thallus either K+ or Pd+ .... **Key 5**
Thallus with all spot test reactions negative .... **Key 6**

KEY 1

Sterile saxicolous and terricolous lichens with a non-corticate or leprose thallus

1 Thallus C+ red (or at least KC+ reddish-orange) or C+ persistent orange 2

Thallus C- 7

2(1) C+ persistent orange. Thallus yellow-green to green (occasionally straw-coloured) when fresh. Thallus of farinose soredia, 20-30(-50)µm diam 3

Thallus C+ red 4

3(2) Thallus composed of yellowish-green soredia. Usnic acid present .... ***Lecanora expallens***

Thallus green-grey to straw coloured (usnic acid absent); surface soredia often brown, grey or flecked blue-grey .... ***Lecidella scabra***

4(2) Thallus of ±smooth, grey granules, forming irregular rosettes; granules >0.1m diam. Pd+ yellow (alectorialic acid). Usually in exposed situations .... ***Lepraria neglecta***

Thallus non-corticate, brown 5

5(4) Thallus greenish-brown of soft, sorediose granules. On damp siliceous rocks and stones .... ***Trapelia obtegens***

Thallus dark brown to black, the surface minutely isidioid or granular 6

6(5) Isidia simple, Photobiont cells 6-12µm diam. On exposed siliceous rocks .... ***Rimularia furvella***

Isidia ±branched. Photobiont cells 5-9µm diam. On damp, shaded rocks .... ***Placynthiella icmalea***

7(1) Photobiont *Trentepohlia* 8

Photobiont chlorococcoid 9

8(7) Thallus widespreading, thin, pinkish; UV-. On calcareous rocks (N+) .... ***Belonia nidarosiensis***

Thallus greyish-white, tinged pink forming thick cushions; UV+ ice-blue (lepraric acid). On acidic rocks (N-) .... ***Lecanactis latebrarum***

9(7) Thallus yellow, yellow-green or green 10

Thallus grey, brown or black 20

10(9) Thallus K+ purple 11

Thallus K+ yellow or K- 12

11(10) On acidic rocks. Blue-grey patches (K-, UV+ white) usually present .. ***Lepraria incana***

On ±calcareous rocks. Thallus completely yellow or greenish- yellow .... ***Caloplaca citrina***

12(10) Thallus K+ yellow (atranorin) 13

Thallus K- (atranorin absent) 14

13(12) White, arachnoid prothallus usually present. Centre of thallus completely leprose; soredia uniformly yellow (usnic acid) .... ***Haematomma ochroleuca* v. *ochrolecua***

Prothallus absent. Thallus non-corticate with ±discrete, blue- grey flecked soredia. Usually coastal .... ***Lecania baeomma***

14(12) Thallus of goniocysts, 0•1-0•4 mm diam. without pigments. Photobiont micareoid. Usually on bryophytes but occasionally directly on siliceous rocks ... ***Micarea prasina***

Thallus leprose (non corticate). Coloured by yellow, green or bright yellow-green pigments. Photobiont not micareoid 15

15(14) Bright green or yellow-green, (pulvinic acid derivatives); usnic acid absent 16

Thallus yellow to yellow green (usnic acid). Over bryophytes on silicous rocks, usually in crevices .... ***Lecanora* sp.**

16(15) Thallus rarely more than 1-2 cm diam. composed of small areoles which break down into granular soredia. Rhizocarpic acid present .... ***Arthrorhaphis citrinella***

Thallus more wide-spreading. completely leprose 17

17(16) In shaded underhangs. Thallus yellow-green 18

On± vertical rock-faces. Thallus bright, citrine yellow 19

18(17) Photobiont usually Trebouxioid. Rhizocarpic acid present. Thallus granules <0•l mm .... ***Psilolechia lucida***

Photobiont usually *Stichococcus*. Pulvinic and vulpinic acids present .... ***Chaenotheca furfuracea***

19(17) Thallus granules >0•1 mm. Calycin and vupinic acid present ...... ***Chrysothrix chlorina***

Thallus granules 0•01-0•1 mm. Calycin or pinastric acid present .... ***Chrysothrix candelaris***

20(9) Thallus brown, covered with minute, fragile blastidia. Usually on copper-rich rocks .... ***Rhizocarpon furfurosum***

Thallus cream to grey 21

21(20) Thallus of ±smooth, grey granules forming rosettes in exposed situations 22

Thallus otherwise. Usually in shaded situations 25

22(21) ThallusPd+ deep yellow or red 23

Thallus Pd- or faint yellow (atranorin) 24

23(22) Thallus Pd+ red (fumarprotocetraric acid) .... ***Lepraria caesioalba***

Thallus Pd+ yellow (psoromic acid) .... ***Lepraria* cf. *caesioalba***

24(22) Porphyrilic acid by TLC .... ***Lepraria cacuminum***

Porphyrilic acid absent. .... ***Lepraria borealis***

The granular form of *Lepraria cacuminum,* which appears to be much rarer than the leprose form, can be reliably separated from *Lepraria borealis* only by TLC.

25(21) Thallus with distinct lobes,forming irregular rosettes. Pd+ orange (pannaric acid). Methyl pannaric and stictic acids absent .... ***Leproloma membranaceum***

Thallus not lobed; prothallus or a marginal corticate area often present 26

26(25) Thallus grey, blue-grey or ±black, usually with a prothallus; Pd- or pale yellow (atranorin) 27

Thallus creamy-white to pale grey, without a prothallus; Pd+ yellow or orange (very rarely Pd-) 28

27(26) Thallus whitish or pale grey, farinose, white, arachnoid prothallus usually present. On shaded rocks .... ***Haematomma ochroleucum* v. *porphyrium***

Thallus completely dissolved into blue-grey, granular soredia 50- 80µm diam.). Blue-black prothallus often present. On exposed rock .... ***Tephromela grumosa***

27(26) Thallus often with a marginal corticate area; Pd± orange-red, K+ yellow, UV- (atranorin, zeorin and usually fumarprotocetraric acid). Most often over bryophytes, rarely directly on rock .... ***Catillaria pulverea***

Thallus without a marginal corticate area; Pd+ yellow, K+ orange, UV+ glaucous (thamnolic and perlatolic acids). Terricolous .... ***Icmadophila ericetorum***

KEY 2

Sterile saxicolous and terricolous, crustose lichens with C positive spot-test reaction

1 Thallus and/or soredia C+ persistent orange (xanthones) 2

Thallus and/or soredia C+ yellow or fleeting red 6

2(1) Thallus with thin isidia .... ***Pertusaria flavocorallina***

Thallus with soredia 3

3(2) Thallus Pd+ orange. On ±basic rocks .... ***Pertusaria amarescens***

Thallus Pd- 4

4(3) Thallus yellow-green, smooth to coarsely warted. Soredia granular20-40µm diam .... ***Pertusaria flavicans***

Soredia farinose (<20µm diam) 5

5(4) Thallus grey-green (usnic acid absent), thin to coarsely granular. Soredia blue-green .... ***Lecidella scabra***

Thallus yellowish-green (usnic acid), effuse, granular, rarely cracked areolate. Soralia concolourous .... ***Lecanora expallens***

6(1) Photobiont *Trentepohlia* 7

Photobiont chlorococcoid 9

7(6) Thallus C-; with numerous stalked white pruinose pycnidia, the tips of which react C+ red. Over bryophytes .... ***Lecanactis abietina***

Thallus C+ red; without stalked pycnidia. Directly on rock 8

8(7) Thallus thin, brownish .... ***Opegrapha gyrocarpa***

Thallus usually thick, white-grey (occasionally thin and dispersed when on siliceous rocks); soredia 30-50µm diam. Medulla UV+ glaucous or (rarely) yellow. Contains lecanoric acid and erythrin .... ***Dirina massiliensis* f. *sorediata***

9(6) Thallus distinctly lobed, placodioid or squamulose 10

Thallus without lobes 14

10(9) Thallus composed of greenish-grey, olive-brown to dark brown ±discrete, ascending squamules (to 1•2mm diam), the margins slightly upturned with white, farinose soredia .... ***Hypocenomyce scalaris***

Thallus crustose with marginal lobes. If squamules discrete then never ascending 11

11(10) Squamulose, marginal lobes >0•2mm wide 12

Placodioid, marginal lobes <0•15mm wide 13

12(11) Squamules distinct >0•5mm wide. Often with coarse isidiate soredia. Terricolous, usually among rocks .... ***Trapeliopsis wallrothii***

Squamules indistinct <0•4mm wide. Never sorediate or isidiate. Usually saxicolous, rarely terricolous .... ***Trapelia involuta***

13(11) Thallus shiny, often with small depressions. Soralia at the level of the thallus, usually blackish, sometimes capitate and greenish. Cephalodia usually not distinctly lobate. 5-O-methylhiascic acid present .... ***Placopsis lambii***

Thallus matt, or shiny only at lobe tips, without depressions. Soralia often eroded, rarely black. Cephalodia usually distinctly lobate. 5-O-methylhiascic acid absent .... ***Placopsis gelida***

14(9) Thallus developing thin, spine-like extensions. Usually terricolous in montane heaths

.... *Ochrolechia frigida*

Thallus otherwise 15

15(14) Thallus without soralia. Isidia, papillae, pycnidia or apothecia initials present 16

Thallus with soralia or sorediose patches 24

16(15) Thallus ±completely isidiate, isidia obscuring the thallus 17

Thallus with scattered papillae, pycnidia or apothecia initials 19

17(16) Thallus and isidia white or pale grey, isidia >0•3mm wide; Pd+ red

.... *Pertusaria oculata*

Thallus and isidia brown (occasionally greenish); isidia <0•05mm wide; Pd- 18

18(17) Isidia simple. Photobiont cells 6-12µm diam. On exposed siliceous rocks

.... *Rimularia furvella*

Isidia ±branched. Photobiont cells 5-9µm diam. On damp, shaded rocks

.... *Placynthiella icmalea*

19(16) Thallus with papillae. Saxicolous 20

Thallus with pycnidia or apothecia initials 21

20(19) Thallus thin, grey to pinkish-brown. Papillae 0•05x0•1mm .... *Rimularia intercedens*

Thallus thick and tarterous (to 3mm), pale to dark grey. Papillae larger

.... *Ochrolechia tartarea*

21(20) Thallus C-, composed of convex greenish-grey to orange areoles, C+ red apothecia initials or pycnidia present .... *Trapelia mooreana*

Thallus C+ red, papillae present 22

22(21) Saxicolous. Thallus well-developed, cracked-areolate; ±shiny,whitish-grey to grey-brown. Photobiont not micareoid. Conidia 7-10µm long .... ***Lecidea fuscoatra***
Usually terricolous, rarely saxicolous. Thallus of ±globose areoles, green-grey to yellowish. Photobiont micareoid. Conidia longer 23

23(22) Conidia flexuose, 50-110µm long .... ***Micarea cinerea***
Conidia curved or sigmoid,20-40µm long .... ***Micarea peliocarpa***

24(15) Thallus C+ yellow, KC+ yellow; thin, white-grey, smooth. Soralia often excavate and in lines, becoming crowded and confluent .... ***Ochrolechia microstictoides***
Thallus C+ red, KC+ red 25

25(24) Thallus or soredia Pd+ yellow, orange or red 26
Thallus and soredia Pd- or faint yellow 32

26(25) Thallus of greyish granules 27
Thallus not of greyish granules 29

27(26) Thallus or sorediose patches Pd+ red (argopsin and gyrophoric acid)
.... ***Micarea leprosula***
Thallus and soredia Pd+ yellow (alectorialic acid) 28

28(30) Granules usually forming irregular rosettes, not eroding to form sorediate patches
.... ***Lepraria neglecta***
Granules usually forming an effuse crust; granules fragile and often eroding to form sorediose patches .... ***Micarea submilliaria***

29(26) Growing directly on rock, soredia greenish to brown 30
Growing on bryophytes or soil; soredia grey-white to creamish 31

30(29) Soredia greenish, K- or faintly K+ yellow (alectorialic acid). Photobiont *Chlorella*-like .... ***Fuscidea praeruptorum***

Soredia brown, K+ red (norstictic acid), forming acicular crystals (microscope). Photobiont Trebouxioid .... **Rimularia furvella**

31(29) Soralia ±discrete, formed by the apices of papillate granules bursting open. Alectorialic and barbatolic acids present .... ***Pertusaria geminipara***

Soredia widepreading, formed by eroding thallus. Gyrophoric acid and unidentified substance present .... ***Ochrolechia inaequatula***

32(25) Thallus of effuse granules 33

Thallus with ±discrete soralia 34

33(32) Thallus dark brown to black, the surface minutely isidioid or granular. On exposed siliceous rock .... ***Rimularia furvella***

Thallus greenish-brown of soft, sorediose granules. On damp siliceous rocks and stones .... ***Trapelia obtegens***

34(32) Saxicolous 35

Terricolous or bryophilous 42

35(34) Thallus thin or poorly developed, K- (atranorin absent) 36

Thallus thick and clearly visible 37

36(35) Soralia green, punctiform; photobiont micareoid .... ***Micarea coppinsii***

Soralia pale buff to ochraceous brown, not punctiform; photobiont not micareoid .... ***Trapelia obtegens***

37(35) Thallus pale grey-green to dark chocolate brown, soredia pale ochre yellow to pale
yellow green. UV+ bluish-white .... ***Ropalospora hibernica***
Thallus and soredia otherwise 38

38(37) Thallus of irregular grey-green convex areoles; soralia grey-green to blue-green
.... ***Trapeliopsis flexuosa***
Thallus and soredia without green or blue-green colour 39

39(38) Thallus tinged pink; margin composed of discrete, ±effigurate areoles. Photobiont
Chlorella-like .... ***Trapelia placodioides***
Thallus white or grey; margin entire. Photobiont Trebouxioid 40

40(39) Thallus and soredia white, C+ carmine red (lecanoric acid), gyrophoric acid absent
.... ***Pertusaria lactea***
Thallus grey, soredia cream to grey-green; C+ orange-red, (gyrophoric acid)
(*Ochrolechia androgyna* s. lat.) 41

41(40) Thallus usually very thick (up to 3mm), grey-white; often with numerous pinkish
papillae .... ***Ochrolechia tartarea 'f. sorediata'*** ad int.
(*Ochrolechia androgyna* 'B', sensu Tønsberg)
Thallus thinner, creamy-white; without papillae .... ***Ochrolechia androgyna***
(*O. androgyna* 'A', sensu Tønsberg)

42(34) Thallus and soredia without green or yellowish colouration; thallus white-grey, soralia
cream coloured .... ***Ochrolechia androgyna 'A'***
Thallus and/or soralia with green or yellowish colouration 43

43(42) Thallus with irregular orange-red patches, K+ purple ... ***Trapeliopsis pseudogranulosa***
Thallus without orange-red patches 44

44(43) Soralia grey-green to dark green, often tinged blue-green .... *Trapeliopsis flexuosa*

Soralia whitish to brownish yellow, sometimes tinged blue-green

.... *Trapeliopsis granulosa*

Poorly developed or shaded specimens of these two species are often impossible to separate. They are described in detail by Coppins & James, 1984.

.KEY 3

Sterile saxicolous and terricolous lichens with soralia or blastidia and C negative but K or Pd positive spot-test reactions.

1 Thallus orange or yellow, K+ purple (anthraquinone pigments) 2

Thallus not orange or yellow, K+ red or yellow, or K- (anthraquinone pigments absent). If greenish-yellow then not K+ purple 4

2(1) Thallus with marginal lobes. Soralia bright yellow, lighter than thallus

....*Caloplaca cirrochroa*

Thallus crustose, without marginal lobes 3

3(2) Thallus with discrete soralia. On ±vertical, acidic or slightly basic montane rock-faces

.... *Caloplaca obliterans*

Thallus with effuse soralia. Widespread; usually on basic rocks and walls

.... *Caloplaca citrina*

4(2) Thallus and/or soredia K+ red (norstictic acid); acicular crystals formed (microscope)

.... 5

Thallus and soredia K+ yellow or orange or K- (acicular crystals not formed) 8

5(4) Thallus with crowded, ±globose isidia like papillae which leave eroded, granular-sorediate patches .... ***Pertusaria lactescens***

Thallus without isidia or papillae; soredia present 6

6(5) Thallus grey; soralia discrete, soredia concolorous and granular-isidiate (?*A. simoensis*) or yellow-green and farinose (*A. grisea*) .... ***Aspicilia grisea aggr.***

Thallus white or cream, soralia becoming confluent 7

7(6) Thallus thick, rimose-cracked-areolate. Soralia ±convex, arising from wide, low warts; at first discrete becoming confluent. Soredia coarsely-granular, creamish-grey. Saxicolous .... ***Pertusaria excludens***

Thallus thin, continuous or sparingly cracked. Soralia very irregular, shallow, ulcerous to effuse. Soredia fine-powdery to coarsely-granular, often greenish. Often over bryophytes .... ***Phlyctis argena***

8(4) Soralia KC+ violet 9

Soralia KC- 11

9(8) Soralia not formed on thalline warts .... ***Pertusaria amara***

Soralia formed by the breaking down of thalline warts 10

10(9) Thallus forming compact cushions of sorediate, warted papillae .... ***Pertusaria amara* f. *pulvinata***

Papillae more scattered, only occasionally breaking down to form granular soredia .... ***Pertusaria melanochlora***

11(8) Thallus distinctly lobed or squamulose. Pd+ orange (stictic acid) 12

Thallus without lobes, sometims of dispersed areoles 13

12(11) Thallus composed of congested squamules. Pd+ orange (stictic, ±norstictic acids) .... ***Baeomyces rufus***

Thallus of ±dispersed, narrow lobes. Pd+ red (argopsin) ..... ***Solenopsora vulturiensis***

13(11) Thallus or soredia, Pd+ red, orange or distict yellow 14

Thallus and soredia Pd- or faintly yellow 29

14(13) Thallus with discrete soralia, at least in part; sometimes coalescing when older 15

Thallus with effuse soredia, corticate area confined to the thallus margin 27

15(14) Thallus orange, brown or green 16

Thallus white or grey; sometimes becoming yellow or orange due to oxydization if on iron-rich rocks 20

16(15) Thallus green, soredia bright yellow-green (pulvinic acid derivatives; stictic acid absent) 17

Thallus orange or brown. soredia blue-black or brown (stictic acid; pulvinic acid derivatives absent) 18

17(16) Soralia arising from the margins of the areoles .... ***Lecanora subaurea***

Soralia arising fron the centre of the areoles .... ***Lecanora epanora***

18(16) Thallus of discrete brown areoles on a powdery black hypothallus that produces thallospores. Soredia brown, abrading creamish .... ***Protoparmelia nephaea***

Thallus yellow-orange, oxydated; continuous. Soredia blue-black 19

19(18) Thallus ochre to yellow-orange; areoles often dispersed, uneven to stongly convex. On metal-rich rocks, often with *Acarospora sinopica* .... ***Miriquidica atrofulva***

Thallus yellow-orange, cracked-areolate; areoles ±flat, usually on damp siliceous rocks .... ***Porpidia ochrolemma***

20(15) Thallus Pd+ red (fumarprotocetraric acid) .... ***Pertusaria aspergilla***

Thallus Pd+ orange or yellow (fumarprotocetraric acid absent) 21

21(20) Pd+ yellow (psoromic acid). Soralia ±tuberculate; soredia blue-black .... ***Miriquidica nigroleprosa***

Pd+ orange (stictic acid) 22

22(21) Thallus of flat to convex areoles, often cracked with green soralia arising from the cracks. Soredia becoming blue-grey or brownish when old. Atranorin present 23

Soredia not arising from cracks in the areoles; white, grey or blue-grey, never green. Atranorin absent 24

23(22) Areoles usually forming a ±continuous crust .... ***Stereocaulon tomense***

Areoles usually ±dispersed .... ***Stereocaulon plicatile***

In the absence of apothecia it is not possible to separate these two species with any degree of certainty.

24(22) Thallus thin, or sub-continuous to scurfy and indistinct .... ***Porpidia soredizodes***

Thallus well developed 25

25(24) Thallus of white convex areoles; soredia blue-grey. Cephalodia absent. On exposed rocks .... ***Porpidia aff. glaucophaea***

Thallus cracked areolate to verrucose, soredia cream or grey 26

26(25) Thallus creamy-white. Soredia ±concolourous. Cephalodia often present. On shaded, damp rocks .... ***Coccotrema citrinescens***

Thallus grey. Soredia concolorous and granular-isidiate (?*A. simoensis*) or yellow-green and farinose (*A. grisea*). Cephalodia absent. Usually on exposed rocks

.... ***Aspicilia grisea* aggr.**

27(14) Thallus brown. Densely covered with minute, fragile blastidia

.... ***Rhizocarpon furfurosum***

Thallus white, grey or green. Without blastidia 28

28(27) Thallus thin, smooth; grey-white to glaucous. Cortex usually visible only at margin.

Zeorin by TLC .... ***Catillaria pulverea***

Thallus thick, warted, dark grey-green. Zeorin absent .... ***Lecanora conizaeoides***

29(13) Thallus with discrete soralia, at least in part; sometimes coalescing when older 30

Thallus with effuse soredia, corticate area confined to the thallus margin 37

30(29) Thallus usually of ±dispersed areoles, each areole having a dark centre (similar to the phyllocladia of *Stereocaulon vesuvianum*). Bluish-green soredia arising from the edge of each areole and remaining ±discrete .... ***Stereocaulon leucophaeopsis***

Areoles without darkened centre 31

31(30) Soredia whitish-blue to blue-black 32

Soredia whitish-green to yellow 34

32(31) Soredia whitish-blue, hemispherical, remaining discrete .. ***Tephromela pertusarioides***

Soredia grey-blue to blue-black, not hemispherical 33

33(32) Soralia usually remaining discrete; soredia 20-35µm diam.

.... ***Lecidea pycnocarpa* f. *sorediata***

Soralia soon becoming confluent, soredia granular, 50-80µm diam.

.... ***Tephromela grumosa***

34(31) Soredia bright yellow to yellow-green (usnic acid) 35

Soredia creamy white to whitish-green (usnic acid absent) 36

35(34) Soredia yellow to yellow-green, developing from the edges of the areoles, later becoming confluent .... ***Lecanora orosthea***

Soredia bright yellow, not developing from the edges of the areoles, not becoming confluent; strongly convex .... ***Mycoblastus alpinus***

36(34) Red pigment present in medulla. Thallus thick, smooth. Soralia creamy-yellow .... ***Mycoblasus sanguinarius* f. *leprosus***

Red pigment not present in medulla. Thallus continuous, granular, composed of dispersed to aggregated warted areoles. Prothallus when present, white or bluish .... ***Lecanora caesiosora***

37(29) Thallus white to grey; soredia blue-grey, darker than thallus 38

Thallus and soredia concolorous 39

38(37) Thallus white to yellow-white, indeterminate; ±completely dissolved into blue-grey speckled, farinose soredia (20-25µm diam). Contains atranorin, chloratranorin and gangaleoidin. On shaded rocks, predominantly coastal .... ***Lecania baeomma***

Thallus pale-grey, corticate, sometimes with blue-black prothallus. Soredia blue-grey, granular, 50-80µm diam. Contains atranorin and unidentified substance. On exposed rocks .... ***Tephromela grumosa***

39(37) Thallus pale grey, farinose with conspicuous white prothallus. On ±dry, vertical, ±shaded rock faces .... ***Haematomma ochroleucum* f. *porphyrium***

Thallus and soredia whitish to yellow 40

40(39) Thallus thin, pale yellow (usnic acid); delimited by a white prothallus

.... ***Haematomma ochroleucum* f. *ochroleucum***

Thallus greenish-white to glaucous (usnic acid absent); corticate region usually visible at the margin but hypothallus absent .... ***Catillaria pulverea***

KEY 4

Sterile saxicolous and terricolous, crustose lichens with soralia or blastidia with all spot-test reactions negative

1 Photobiont *Trentepohlia*. Thallus dark chocolate brow tinged lilac, soredia dark brown to lilac. Often forming mosaics with *Opegrapha gyrocarpa*. Confluentic acid present .... ***Enterographa zonata***

Photobiont chlorococcoid 2

2(1) Thallus with blastidia. Thallus thin, effuse, scurfy, ±cracked areolate .. ***Lecania erysibe***

Thallus with true soredia 3

3(2) Terricolous, or over bryophytes 4

Saxicolous, directly on rocks 7

4(3) Areoles granular, convex or ±spherical 5

Areoles flat or thallus varnish-like 6

5(4) Thallus dull grey-green, granules (goniocysts) 0•1-0•4 mm diam. Photobiont micareoid .... ***Micarea prasina***

Areoles bright yellow-green. Photobiont not micareoid .... ***Arthrorhaphis citrinella***

6(4) Thallus of small grey squamules with ascending, grey-green sorediate apices .... ***Trapeliopsis glaucolepidea***

Thallus thin, membrane-like; covered with ±discrete, yellow-green soralia

.... ***Trapeliopsis gelatinosa***

7(3) Thallus yellow, pale grey or green 8

Thallus orange, brown or dark grey to black 20

8(7) Soralia yellow (usnic acid) 9

Soralia green, white, grey or bluish (usnic acid absent) 11

9(8) Soralia arising from the edge of each areole .... ***Lecanora handelii***

Soralia arising from the centre of each areole 10

10(9) Thallus thick, areoles rounded and warted with entire margins .... ***Lecanora epanora***

Thallus thinner, areoles flattened; subsquamulose, margins often crenulate

.... ***Lecanora soralifera***

11(8) On basic rocks (N+). Thallus green. Areoles ±dispersed. soredia greyish green

.... ***Polyblastia efflorescens***

On siliceous rocks (N-). Thallus grey 12

12(11) Medulla 1+ blue. Soralia punctiform, tuberculate, blue-grey. Confluentic acid present

.... ***Porpidia tuberculosa***

Medulla I- 13

13(12) Medulla UV+ white (divaricatic or perlatolic acids) 14

Medulla UV- (divaricatic and perlatolic acids absent) 16

14(13) Soredia blue-grey. Photobiont Trebouxioid. Perlatolic acid by TLC

.... ***Mycoblastus caesius***

Soredia white to brown. Photobiont *Chlorella*-like. Divaricatic acid by TLC 15

15(14) Thallus of thin, pale-grey, ±dispersed areoles on a black hypothallus. Soredia ±concolorous .... ***Fuscidea gothoburgensis***

Thallus continuous, pale grey to brownish-grey. Soredia soon becoming confluent; cream, often becoming brownish .... ***Fuscidea recensa***

16(13) Thallus of grey, subsquamulose or convex areoles. Soredia concolorous, arising from the edge of each areole but often becoming confluent .... ***Lecanora handelii***

Thallus otherwise, soredia not arising from the edge of each areole 17

17(16) Thallus waxy, often with zoned margin. Soralia large, 1-4 mm diam., often becoming confluent; or soredia effuse 18

Thallus thick without zoned margin or delimiting prothallus. Soralia <1mm diam., remaining discrete

.... 19

18(17) Soralia typically concave and marginate; soredia granular

.... ***Pertusaria albescens* v. *albescens***

Soralia less well-defined; soredia becoming granular-coralloid

.... ***Pertusaria albescens* v. *corallina***

19(17) Thallus glaucous, continuous to cracked-areolate. Soredia usually irregular in shape, sometimes arising along cracks in the thallus. On flushed, or damp, siliceous or slightly basic rocks. Confluentic acid absent .... ***Porpidia glaucophaea***

Thallus pale-grey, composed of convex areoles. Soredia irregularly rounded, blue-grey. On exposed siliceous rocks. Confluentic acid present

.... ***Porpidia 'confluenta' ad int.***

20(7) Thallus dark grey to black with ±concolorous soralia. Miriquidic acid present by TLC

.... ***Miriquidica liljenstroemii***

21(20) Thallus orange with discrete, blue-grey soralia .... ***Porpidia melinodes***

Thallus brown with concolorous soredia 22

22(21) Soredia ±farinose, arising from cracks in the thallus. On basic rocks

.... ***Thelidium papulare* f. *sorediatum***

Soredia initially punctiform, soon becoming confluent. Not arising from cracks in the thallus. On siliceous rocks .... ***Ropalospora lugubris* f. *sorediata***

KEY 5

Sterile saxicolous and terricolous crustose lichens without soralia, but isidia or pycnidia often present, and with C- but either K+ or Pd+ spot-test reactions

1 Thallus yellow to yellow-green 2

Thallus grey, green, brown or black 4

2(1) Thallus K+ purple (anthraquinone pigments). Thallus warty-scaly, marginal lobes poorly differentiated. On calcareous soils .... ***Fulgensia bracteata***

Thallus K- (anthraquinone pigments absent) 3

3(2) Thallus with well-developed marginal lobes, 1-3mm wide; bright yellow-green. Over bryophytes at high altitude .... ***Catolechia wahlenbergii***

Thallus crustose, areolate to subsquamulose; yellow-green. On thallus of *Baeomyces rufus* on acidic soils .... ***Epilichen scabrosus***

4(1) Thallus K+ red (norstictic acid); acicular crystals formed [microscope) 5

Thallus K+ yellow or K- (norstictic acid absent) 9

5(4) Thallus papillate or isidiate; leaving non-sorediate pits when shed 6
Thallus not isidiate, grey. *Aspicilia cinerea* aggr. 7

6(5) Thallus of ±contiguous, effigurate squamules with papillae with pale brown apices. Papillae not constricted at base. On damp rocks and soil ..... ***Baeomyces* cf. *carneus***
Thallus rimose-cracked or areolate with isidia 0•5-1•0 mm diam, constricted at the base, rounded or top shaped. On dry well-lit siliceous rocks. Often maritime .... ***Pertusaria pseudocorallina***

7(5) Conidia 7-12 µm long .... ***Aspicilia intermutans***
Conidia >10 µm long 8

8(7) Conidia 11-16 µm long .... ***Aspicilia cinerea***
Conidia 15-28 µm long .... ***Aspicilia epiglypta***

9(4) Photobiont *Trentepohlia;* usually on vertical rock faces: Pd+ yellow, UV- .... ***Lecanactis dilleniana***
Photobiont chlorococcoid 10

10(9) Thallus consisting entirely of grey granules 11
Thallus otherwise 14

11(10) Thallus Pd- or faint yellow (±atranorin) 12
Thallus Pd+ yellow or red. Psoromic or fumarprotocetraric acids 13

12(11) Porphyrilic acid by TLC .... ***Lepraria cacuminum***
Porphyrilic acid absent .... ***Lepraria borealis***

The granular form of *Lepraria cacuminum*, which appears to be much rarer than the leprose form, can only be separated from *Lepraria borealis* by TLC.

13(11) Thallus Pd+ red (fumarprotocetraric acid) .... ***Lepraria caesioalba***

Thallus K-, Pd+ yellow (psoromic acid) .... ***Lepraria cf. caesioalba***

14(10) Thallus with prostrate or erect pseudopodetia 15

Thallus without pseudopodetia 16

15(14) Terricolous. Thallus K+ yellow (atranorin). Pseudopodetia erect and swollen; scattered or crowded, cylindrical or conical, simple or branched .... ***Pycnothelia papillaria***

Saxicolous. Thallus K+ orange (stictic acid). Pseudopodetia prostrate, dorsiventral; upper surface with phyllocladia with darker centres .... ***Stereocaulon vesuvianum* v. *symphycheiloides***

16(14) Thallus with isidia or papillae 17

Thallus without isidia and papillae 20

17(16) Terricolous or over bryophytes on rocks. Densely isidiate, almost totally obscuring the thallus. Thallus Pd+ red (fumarprotocetraric acid) 18

Saxicolous. Isidia more scattered or absent from margin, thallus clearly visible. Thallus Pd+ yellow or orange (thamnolic or protocetraric acids) 17

18(17) Isidia 0•4-1•0 mm thick, uniformly white .... ***Pertusaria dactylina***

Isidia 0•3-0•5 mm thick, white, tips ±browned K+ purple at the apices [microscope) .... ***Pertusaria oculata***

19(17) Thallus Pd+ orange (protocetraric acid); with abundant, coarse, crowded papillae; KC+ violet .... ***Pertusaria melanochlora***

Thallus Pd+ yellow-orange (thamnolic acid); isidia finer. KC- .... ***Pertusaria corallina***

20(16) Thallus placodioid 21

Thallus crustose or squamulose 22

21(20) Tericolous. On acid soils. Thallus green-grey, marginal lobes to 5mm wide .... ***Baeomyces placophyllus***

Saxicolous. On nutrient-enriched or slightly calcareous rock. Thallus greenish-yellow to yellow-brown, marginal lobes <1mm wide .... ***Lecanora muralis***

22(20) Thallus squamulose or granular 23

Thallus crustose, areolate or smooth 24

23(22) Thallus grey, often greenish when wet; cephalodia present between the squamules. K+ yellow, Pd- (atranorin) .... ***Pilophorus strumaticus***

Thallus green-grey to brownish. Crustose/squamulose. On soil or damp rocks. K+ yellow, Pd+ orange (stictic acid) .... ***Baeomyces rufus***

24(22) Thallus Pd+ red (fumarprotocetraric acid). Brownish pycnidia usually present .... ***Fuscidea cyathoides***

Thallus Pd+ orange (fumarprotocetraric acid absent) 25

25(24) Thallus grey-white, continuous, usually with pinkish, rounded schizidia. K+ orange, Pd+ orange (bacomycesic acid, ±squamatic acid, atranorin). Terricolous .... ***Dibaeis baeomyces***

Thallus brown, areolate; on a black, powdery prothallus. K+ yellow, Pd+ orange (stictic acid). Saxicolous .... ***Protparmelia nephae***

Sterile specimens of some, usually fertile, *Rhizocarpon* spp. will key out here. *P. nephaea* can be separated from such specimens by the presence of thallospores on the prothallus.

KEY 6

Sterile saxicolous and terricolous lichens without soralia, but isidia or pycnidia often present, all spot-test reactions negative

1 Thallus yellow or yellow-green (pulvinic acid derivatives) 2

Thallus grey, green, brown or black 4

2(1) Thallus of convex, bullate squamules up to 1mm diam. On ±basic substrata (usually terricolous) .... ***Arthrorhaphis alpina***

Thallus of smaller granules. On siliceous rocks 3

3(2) Thallus bright golden-yellow; of coarse rounded granules ....***Candelariella coralliza***

Thallus dull yellow-orange; of flattened subsquamulose granules ....***Candelariella vitellina***

4(1) Photobiont Cyanobacteria 5

Photobiont Chlorophyceae 12

5(4) Thallus with marginal lobes 6

Thallus without marginal lobes 10

6(5) Marginal lobes very narrow (0•05-0•2mm) 7

Marginal lobes wider (0•3-1•0mm) 8

7(6) Thallus forming distinctive radiating rings and arcs; inner part ±bare or with scattered areoles .... ***Placynthium subradiatum***

Thallus black, shiny; marginal lobes short and fan-shaped; inner part densely granular isidiate .... ***Placynthium asperellum***

8(6) On semi-inundated acid rocks. Thallus grey to brown, matt; marginal lobes relatively wide (*Phaeophyscia*-like), inner part with lobules or folioles . ***Placynthium flabellosum***

On ±basic rocks 9

9(8) Prothallus absent. Thallus pale-brown to olive-brown; upper surface striate, nodulose towards the centre, lower surface white. Lobes elongate, 0•2-0•4mm wide, widening to 0•8mm at the apices. On ±vertical, flushed rocks, but avoiding seepage tracks .... ***Vestergrenopsis elaeina***

Distinct blue-black prothallus present. Thallus dull olive-brown to black; upper surface not striate, with numerous coralloid to flattened isidia, lower surface dark. Lobes radiating 0•7-1•0mm wide. On semi-inundated rocks or in seepage tracks .... ***Placynthium pannariellum***

10(5) Thallus surface covered by flat, granular squamules 11

Thallus areolate 12

11(10) Conspicuous, blue-black prothalius usually present. Thallus rarely grey pruinose .... ***Placynthium nigrum***

Prothallus absent. Thallus densely grey pruinose .... ***Placynthium garovaglii***

12(10) Photobiont *Calothrix* .... ***Porocyphus* spp.**

Photobiont not *Calothrix* 13

13(12) Photobiont *Chroococcidiopsis* or *Gloeocapsa*, cells with a reddish-brown K+ purple gelatinous sheath .... ***Cryptothele/Pyrenopsis* spp.**

Photobiont chroococcoid, cells without reddish-brown K+ purple gelatinous sheath .... ***Psorotichia/Pterygiopsis* spp.**

In the absence of apothecia the species of *Porocyphus*, *Cryptothele*, *Pyrenopsis*, *Psorotichia* and *Pterygiopsis* are very difficult to determine beyond generic level. However, *Pyrenopsis subareolata* appears to be the most frequent species.

14(4) Photobiont *Trentepohlia*. Pycnidia present 15
Photobiont chlorococcoid 16

15(14) Pycnidia with white pruinose tips which react C+ red. Conidia 12- 17x2-3µm. Usually over bryophytes in underhangs .... ***Lecanactis abietina***
Pycnidia without white pruinose tips. Conidia 4•2-7•0x0•5-1•4µm. On damp, shaded calcareous rocks and stones .... ***Opegrapha calcarea***
(*O. saxatilis* auct brit.)

16(14) Thallus consisting entirely of minute squamules (0•1-1•0x0•1-0•3mm), coralloid isidia or goniocysts; yellow-green, green-grey or green-brown. Usually associated with bryophytes in calcareous habitats 17
Thallus granular, crustose or squamulose; if squamulose then squamules larger ... 19

17(16) Thallus consisting of numerous, small, ±discrete, grey-green squamules .... ***Agonimia tristicula***
Thallus composed entirely of minute, yellow-green goniocysts or green- brown, coralloid isidia 18

18(17) Thallus composed entirely of green-brown coralloid isidia. Rare montane species .... ***Lopadium coralloideum***
Thallus composed of yellow-green to dark-green goniocysts. Widespread species of disturbed soils; usually associated with metal contamination .... ***Vezdaea leprosa***

19(16) Thallus squamulose. Terricolous 20
Thallus granular, crustose or placodioid 21

20(19) Thallus of pale brown squamules (bright green when wet), attached by long rhizines. In crevices in calcareous rocks .... ***Acarospora rhizobola***

Thallus chestnut-brown to dark-brown, coarsely areolate to subsquamulose; often forming large ±orbicular patches (to 7cm diam.). In acidic montane heaths (occasionally over bryophytes on siliceous boulders .... ***Lecidoma demissum***

21(19) Thallus placodioid, greenish-yellow to yellow-brown. On nutrient-enriched siliceous or slightly calcareous boulders .... ***Lecanora muralis***

Thallus not placodioid 22

22(21) Thallus consisting entirely of grey granules, <0•2mm diam. In exposed acidic situations 23

Thallus otherwise 24

23(22) Porphyrilic acid by TLC .... ***Lepraria cacuminum***

Porphyrilic acid absent .... ***Lepraria borealis***

The granular form of *Lepraria cacuminum*, which appears to be much rarer than the leprose form, can only be separated from *Lepraria borealis* by TLC.

24(22) Thallus with isidia or hyphophores. In calcareous habitats 25

Thallus without isidia or hyphophores 26

25(24) Thallus very thin, varnish-like, over bryophytes. Brown, top-shaped hyphophores present .... ***Gyalideopsis scotica***

Thallus pinkish-grey, usually on damp rocks. With scattered isidia
.... ***Koerberiella wimmeriana***

26(24) Thallus chestnut-brown to dark-brown, coarsly areolate to subsquamulose; often forming large ±orbicular patches (to 7cm diam.). In acidic montane heaths

(occasionally over bryophytes on siliceous boulders). Pycnidia unknown
.... ***Lecidoma demissum***

Thallus usually less well-developed, if well-developed then on rocks. Pycnidia present
.... 27

27(26) Pycnidia whitish 28
Pycnidia pink-brown to black 29

28(27) Conidia 4•5-7x1-1•5µm, straight. Thallus UV+ pink .... ***Bacidia carneoglauca***
Conidia 26-47x1 1-1•5µm, curved. Thallus UV- .... ***Bacidia arnoldiana* group**

In the absence of apothecia the members of the *B. arnoldiana* group are impossible to tell apart. However, *B. arnoldianum* appears to be the most frequent species.

29(27) Conidia helicoid, 7-10x5-6µm .... ***Micarea subnigrata***
Conidia not helicoid 30

30(29) Conidia >20µm long, curved 31
Conidia <20µm long, straight 33

31(30) Pycnidia C- in section. Conidia curved, 24-32µm long .... ***Micarea marginata***
Pycnidia C+ red in section 32

32(31) Conidia curved or sigmoid, 20-40µm long .... ***Micarea peliocarpa***
Conidia flexuose, 50-110µm long .... ***Micarea cinerea***

33(30) Pycnidia C+ red. Conidia 5-6x0•7µm; thallus of ±convex fawn to ochraceous granules
.... ***Trapelia mooreana***
Pycnidia C- 34

34(33) Pycnidia stalked. Conidia 7-15µm long. Usually over bryophytes . ***Micarea botryoides***

Pycnidia not stalked. Conidia 3-5µm long. Directly on rocks 35

35(34) Conidia 9-15x0•8µm. Pycnidia with a ±raised thalline margin. Thallus grey, medulla I+ blue. On heavy-metal rich rocks .... ***Lecidea inops***

Conidia 7-12x1-1•3µm. Pycnidia without a raised thalline margin. Thallus thin, dark green-black, medulla I-. On inundated rocks in montane streams ..***Gyalidea diaphana***

2•3•2 Keys to Genera

2•3•2•1 *Lecidea* Ach.

A key to the genus *Lecidea* is included here for three reasons:-

a) It has long been recognised that the genus *Lecidea* is heterogeneous as it was formally used for all crustose lichens with lecidine apothecia (*ie.* lacking a thalline exciple) and simple ascospores. Purvis *et al.* (1992) recognised this fact, stating that only 17 of the 52 species they included in the genus belonged to *Lecidea* s. str. and that, in fact, several of them had already been removed, e.g. *L. atrofulva* to *Miriquidica*, *L. carrolliii* to *Japewia*, *L. erratica* to *Micarea*, etc. This process has continued with other taxa being removed (e.g. *L. caesioatra* to *Frutidella*, *L. inquinans* and *L. polycarpella* to *Micarea*).

b) *Lecidea* s. str. has recently been the subject of a comprehensive study by Professor Dr H. Hertel (Munich) who has produced a key to the European species (Hertel 1995). This has permitted the identification of a number of collections from the British Isles which it was previously impossible to name. A number of other collections, however, still remain un-named (*cf.* section 2•1•2). There is also little doubt that further taxa have yet to be discovered in the British Isles (e.g. *L. tessellata*).

c) Due to errors and unclear species concepts, in the key to saxicolous members of the genus, Purvis *et al.* fail to correctly identify a number of species. In particular, many with narrow ascospores do not 'key-out' correctly.

The Key included here is based upon that of Dr Hertel but, in addition, includes those saxicolous species of *Lecidea* s. lat. included in the genus by Purvis *et al.* as well as three entities recorded from the Scottish Highlands which appear to be undescribed (see section 2•1•2). Notes on the montane species recorded as new to the British Isles are given in section 2•1•1.

In the key the term 'Atrobrunnea-type thallus' is used on several occasions. This is the thallus type present, for example, in the well-known *L. fuscoatra* which has a cortex consisting of a hyaline epinecral layer (4-50µm thick) overlaying a pigmented layer (5-10µm thick) giving the thallus a shiny appearance.

Key to the Species

I Exciple C+ red in section (microscope) 2
Exciple C- 8

2(1) Medulla and exciple I-. Gyrophoric acid in apothecia and thallus (anziaic and 2'-O-methylanziaic acids absent) 3
Medulla and/or exciple I+ violet. Anziaic and/or 2'-0-methylanziaic acids present (gyrophoric acid absent) 6

3(2) On calcareous stone .... *L. subspeirea*
On siliceous stone 4

4(3) Thallus absent or poorly developed, 0•1-0•2mm thick. Apothecia 0•25-0•7(-1•0)mm diam. Exciple grey .... *L. confluentula*
Thallus thick and areolate, >0•2mm thick. Apothecia larger, 0•6-1•6(-2•5)mm diam. 5

5(4) Ascospores 7•0-12•0 x 3•5-5•0µm. Apothecia 0•6-0•8(-1•5)mm diam. Thallus mostly thin .... *L. siderolithica*
Ascospores 11•0-14•1 x 4•4-6•1µm. Apothecia 0•6-1•3(-2•5)mm diam. Thallus thicker .... *L. fuscoatra*

6(2) Ascospores subglobose, length/breadth ratio 1•0-1•8; 4•8-7•5 x 3•6-4•6µm .... *L. auriculata subsp. brachyspora*
Ascospores ellipsoid, length/breadth ratio 2•0-3•6 7

7(6) Thallus 0•2-1•0mm thick, medulla with perlatolic acid (UV+ white). Ascospores 7•7-10•8 x 3•1-3•8µm .... *L. inops*

Thallus mostly absent, medulla without perlatolic acid (UV-). Ascospores 7•2-10•3 x 2•3-3•4µm .... *L. diducens*

8 (1) Medulla I+ violet 9
Medulla I- 43

9(8) Ascospores 2•4-4•0µm wide. Hymenium 30-50µm high 10
Ascospores >4•0 µm wide 15

10(9) Thallus of Atrobrunnea-type. Thallus K+ red (norstictic acid), acicular crystals formed (microscope) .... *L. syncarpa*
Thallus not Atrobrunnea-type 11

11(10) Thallus with perlatolic acid (UV+ white). On copper-rich rocks .... *L. inops*
Thallus not containing perlatolic acid (UV+ white or UV-). Not on copper-rich rocks 12

12(11) Apothecia 0•3-0•5(-1•0)mm diam. Epihymenium olive-green to brown-black .... *L. promixta*
Apothecia 0•6-1•8(-4•0)mm diam. Epihymenium mostly green to blue-green 13

13(12) Exciple massively developed; hyphae in central region 2•0-3•0µm wide forming a network. Thallus absent or poorly developed; with confluentic acid (UV-). Ascospores 6•6-11•0 x 2•4-3•5µm .... *L. auriculata* subsp. *auriculata*
Exciple smaller; hyphae in central region 3•0-4•5µm wide, not forming a network. Thallus well-developed or not. Confluentic or 2'-O-methylperlatolic acids present. Ascospores 7•5-11•8 x 2•8-4•7µm 14

14(13) Thallus absent or poorly developed; with confluentic acid (UV± dull grey).

Ascospores 8•2-11•8 x 2•8-4•4µm .... *L. promiscens*

Thallus thick, white; with 2'-O-methylperlatolic acid (UV+ white). Ascospores 7•5-11•7 x 3•2-4•7 µm .... *L. promiscua*

15(9) Ascospores 4•1-5•0µm wide 16

Ascospores >5•0µm wide 32

16(15) Thallus of Atrobrunnea-type 17

Thallus not of Atrobrunnea-type 19

17(16) Thallus K+ red, Pd+ yellow (norstictic acid), acicular crystals formed (microscope). Ascospores 6•6-11•6 x 3•5-6•0µm; length/breadth ratio 1•8-2•7 .... *L. syncarpa*

Thallus K+ yellow, Pd+ orange (stictic acid) or K-, Pd- (no substances). Ascospores 8•6-15•5 x 4•8-8•0µm; length/breadth ratio 1•5-2•5 18

18(17) Hypothecium mid- to dark-brown. Ascospores 9•5-15•5 1 5•3-8•0µm .... *L. paupercula*

Hypothecium colourless to pale-brown. Ascospores 8•6-11•3 x 4•8-5•7µm .... *L. haerjedalica*

19(16) Thallus absent or poorly developed 20

Thallus well-developed 26

20(19) Exciple K+ red (norstictic acid), acicular crystals formed (microscope) .... *L. ecrustacea*

Exciple K+ yellow or K- 21

21(20) Hypothecium colourless or pale brown 22

Hypothecium mid- to dark-brown 23

22(21) Exciple with 25-45µm thick cortical zone; inner zone pale red- brown, K+purple
.... **_L. haerjedalica_**

Exciple with 8-20µm thick cortical zone; inner zone colourless to pale brown, K-
.... **_L. lapicida_ var. _lapicida_**

23(21) Ascospores subglobose, length/breadth ratio 1•0-1•8; 4•8-7•5 x 3•6-4•6
.... **_L. auriculata_ subsp. _brachyspora_**

Ascospores ellipsoid, 8.2-16.0µm long 24

24(23) Ascospores 4•7-7•0µm wide. stictic acid or (rarely) no substances present
.... **_L. lapicida_ var. _lapicida_**

Ascospores 2•8-4•5µm wide. Confluentic acid or no substances present 25

25(24) Exciple with pale to mid-brown inner section. Ascospores 10•8-16•0 x 3•8-4•5µm.
Lichen substances absent .... **_L. promixta_**

Exciple with unpigmented inner section. Ascospores 8•2-11•8 x2•8-4•4µm.
Confluentic acid present .... **_L. promiscens_**

26(19) Thallus K+ red (norstictic acid), acicular crystals formed (microscope) 27

Thallus K+ yellow or K- 28

27(26) Hypothecium colourless to pale brown .... **_L. lapicida_ var. _pantherina_**

Hypothecium dark- to black-brown .... **_L. swartzioidea_**

28(26) Hypothecium colourless or pale yellow-brown .... **_L. lapicida_ var. _lapicida_**

Hypothecium mid- to dark-brown 29

29(28) Ascospores subglobose, length/breadth ratio 1•0-1•8; 4•8-7•5 x3•0-4•6µm
.... **_L. auriculata_ subsp. _brachyspora_**

Ascospores ellipsoid, 7•5-16•0µm long 30

30(29) Stictic acid or (rarely) no substances present .... ***L. lapicida* var. *lapicida***

Confluentic or 2'-O-methylperlatolic acids present. Stictic acid also occasionally present 31

31(30) Ascospores 9•7-14•0 x 4•2-5•9µm. Thallus mid- to dark-grey. Confluentic (and occasionally also stictic) acid present .... ***L. confluens***

Ascospores 7•5-11•7 x 3•2-4•7µm. Thallus whitish. 2'-O-methylperlatolic acid present .... ***L. promiscua***

32(15) Thallus and/or exciple K+ red (norstictic acid), acicular crystals formed (microscope) 33

Thallus and exciple K+ yellow or K- 36

33(32) Thallus absent or poorly developed .... ***L. ecrustacea***

Thallus well-developed 34

34(33) Thallus of Atrobrunnea-type .... ***L. syncarpa***

Thallus not Atrobrunnea-type 35

35(34) Hypothecium colourless to pale brown .... ***L. lapicida* var. *pantherina***

Hypothecium dark- to black-brown .... ***L. swartzioidea***

36(32) Thallus absent or poorly developed 37

Thallus well-developed 38

37(36) Exciple with 25-45µm thick cortical zone; inner zone pale red-brown, K+purple .... ***L. haerjedalica***

Exciple with 8-20µm thick cortical zone; inner zone colourless to pale brown, K-

.... ***L lapicida* var. *lapicida***

38(36) Thallus of Atrobrunnea-type 39

Thallus not Atrobrunnea-type 41

39(38) Hypothecium colourless to pale-brown. Ascospores 8•6-11•3 x 4•8-5•7 1µm

....***L haerjedalica***

Hypothecium mid- to dark-brown 40

40'39) Thallus widespreading, red-brown. Ascospores 9•5-15•5 x 5•3-8•0µm

.... ***L paupercula***

Thallus rarely >2cm diam, pale grey-brown .... ***L aff. paupercula***

41(38) Thallus bullate-areolate; rust-brown. Sub-hymenium blue-green .... ***L silacea***

Thallus ±plane; whitish or grey, not or only partly rust-brown. Sub-hymenium colourless 42

42(41) Sictic acid or (rarely) no substances present. Thallus white to pale grey

.... ***L lapicida* var. *lapicida***

Confluentic acid present. Stictic acid also occasionally present. Thallus mid- to dark-grey .... ***L confluens***

43(8) On siliceous rocks, boulders, walls or pebbles. N- 44

On chalk pebbles, limestone or other highly calcareous rocks 69

44(43) Thallus with blue-grey soralia 45

Thallus without soralia 46

45(44) Thallus grey, Pd+ faint yellow, K+ yellow (atranorin) .... ***'L' pycnocarpa*** f. ***sorediata***

Thallus rust-orange; Pd+ orange, K+ yellow (stictic acid) .... ***Miriquidica atrofulva***

46(44) Hypothecium colourless to pale yellow-brown 47

Hypothecium mid- to dark-brown 53

47(46) Apothecia mostly <0•2μm diam .... ***Micarea polycarpella***

Apothecia mostly >0•2 diam 48

48(47) Thallus absent or poorly developed 49

Thallus well-developed 50

49(48) Ascospores 4•8-5•7μm wide. Lichen substances absent ....***L. haerjedalica***

Ascospores 3•6-46μm wide. Planaic acid present .... ***L. plana***

50(48) Thallus yellow (usnic acid). Apothecia ±innate .... ***'L' luteoatra***

Thallus grey, brown or white (usnic acid absent) 51

51(50) Thallus Atrobrunnea-type .... ***L. haerjedalica***

Thallus not Atrobrunnea-type 52

52(51) Thallus white to pale grey. Apothecia ± angular, disc brownish when wet. Epihymenium brown. Planaic acid present (cnfluentic acid absent) .... ***L. lithophila***

Thallus dark grey. Apothecia round, disc black when wet. Epihymenium green. Confluentic acid present (planaic acid absent) .... ***L. aff. plana***

53(46) Thallus absent or poorly developed 54

Thallus well-developed 61

54(53) Thallus poorly developed but clearly Atrobrunnea-type .... ***L* aff. *haerjedalica***

Thallus not Atrobrunnea-type 55

55(54) Hypothecium deep red, K+ crimson-purple. Asci *Catillaria*-type. Ascospores (7•0-)9•0-12•0 x 3•0-3•5µm .... ***'L' commaculans***

Hypothecium brown, K-. Asci not *Catillaria*-type 56

56(55) Ascospores mostly >11.0µm long 57

Ascospores mostly <11.0µm long 59

57(56) Hymenium with blue-violet granules (K+ green). Asci *Porpidia*-type. On semi-inundated rocks .... ***'L' ahlesii***

Thecium without blue-violet granules. Asci *Lecidea*-type 58

58(57) Inner area of exciple brownish, not sharply differentiated, without crystals. Hymenium colourless .... ***L promixta***

Inner area of exciple grey to dirty-grey, sharply differentiated from the hypothecium, with crystals. Hymenium usually red-violet (stronger in K) .... ***L sarcogynoides***

59(56) Apothecia 0•2-0•4(-0•7)µm diam. Thallus usually with numerous pycnidia. Asci *Micarea*-type .... ***Micarea erratica***

Apothecia (0•3-)0•5-1•8µm diam. Thallus without numerous pycnidia. Asci *Lecidea*-type 60

60(59) Hymeniun usually red-violet (stronger in K), rarely colourless. Ascospores 9.0-12.0 x 2.7-4.0µm. Excipular hyphae, in central region, 3.0-4.5µm diam. .... ***L sarcogynoides***

Hymenium colourless or weakly greenish. Ascospores 6.6-11.0 x 2.4-3.5µm. Excipular hyphae, in central region, 2.0-3.0µm diam. ***L auriculata* subsp. *auriculata***

61(53) Thallus K+ red (norstictic acid), acicular crystals formed (microscope) .... ***Rimularia mullensis***
Thallus K+ yellow or K- 62

62(61) Thallus red-brown to dark brown, of convex to subglobose, ±squamulose, wart-like areoles. Asci *Catillaria*-type .... ***'L.' fuliginosa***
Thallus whitish-grey to dark grey (to brown-grey), cracked-areolate to granular-warted, never squamulose. Asci not *Catillaria*-type 63

63(62) Hymenium >80µm high. Apothecia immersed 64
Hymenium <80µm high 65

64(63) Thallus whitish; Pd+ yellow, K+ yellow (atranorin and psoromic acid). Apothecia brown. Asci *Biatora*-type. Ascospores 12-18 (-23) x 5-6 (-7)µmm. On damp ±shaded rocks .... ***'L.' phaeops***
Thallus grey; Pd+ orange, K+ yellow (stictic acid). Apothecia black. Asci *Rimularia*-type. Ascospores (8-)9-11 x 4-7(-8)µm. On exposed rocks ...... ***Rimularia gyrizans***

65(63) Apothecia in botryose clusters. Asci not *Lecidea*-type. Thallus K+ yellow (atranorin) .... ***'L.' pycnocarpa***
Apothecia arising singly. Asci *Lecidea*-type. Thallus K- 66

66(65) Thallus with 2'-O-methylperlatolic acid (UV+ whitish). Ascospores 7·5-11·7 x 3·2-4·7µm .... ***L. promiscua***
Thallus without 2'-O-methylperlatolic acid (UV-) 67

67(66) Ascospores <4.0µm wide .... ***L. auriculata* subsp. *auriculata***
Ascospores >4·0µm wide 68

68(67) Thallus of convex, bullate areoles. Apothecia 0·2-0·4mm diam ..... ***L. endomelaena***

Thallus of flat to slightly convex areoles. Apothecia 0•6-0•8mm diam .... *L. siderolithica*

69(43) Thallus superficial. Epihymenium dull greenish; hypothecium red-brown to black. Ascospores 11-14 x 7-9µm .... *'L.' advertens*

Thallus ±immersed. Epihymenium red-brown; hypothecium orange-brown. Ascospores (14-)16-19 x (5-)6-8µm .... *L.' lichenicola*

Note on the *L. lapicida* group.

This group of species contain either norstictic acid, stictic acid or no lichen substances. Dr Hertel considers the norstictic acid containing strain with a well-developed thallus (previously known as *L. lactea*) to be a variety of *L. lapicida* (var. *pantherina*) and the morph without a well-developed thallus to be a distinct species (*L. ecrustacea*). Norstictic acid containing specimens with a dark hypothecium are also recognised as a distinct species (*L. swartzioidea*) but those specimens with a dark hypothecium but with a thallus containing stictic acid or no lichen substances are retained in *L. lapicida*. The taxonomy of the group would appear to be in need of further investigation.

Key to the L. lapicida group.

1 Thallus poorly developed or endolithic .... *L. ecrustacea*

Thallus well-developed 2

2(1) Thallus containing stictic acid or no lichen substances .... *L. lapicida* var. *lapicida*

Thallus containing norstictic acid 3

3(2) Hypothecium mid- to dark-brown .... *L. swartzioidea*

Hypothecium hyaline to pale brown .... *L. lapicida* var. *pantherina*

Synonyms

Purvis *et al.*	**Hertel (1995)**
L. brachyspora	*L. auriculata* subsp. *brachyspora* Th. Fr.
L. lactea	*L. lapicida* var. *pantherina* Ach.
L. matildae	*L. confluentula* Müll. Arg.
L. nigrogrisea	*L. siderolithica* Müll. Arg.
L. pernigra	*L. promixta* Nyl.

	Others (author citations do not refer to publications)
L. atrofulva	*Miriquidica atrofulva* (Sommerf.) Rambold & Schwab (1990)
L. erratica	*Micarea erratica* (Körber) Hertel, Rambolld & Pietschm. (1989)
L. gyrizans	*Rimularia gyrizans* (Nyl.) Hertel & Rambold (1990)
L. mullensis	*Rimularia mullensis* (Stirton) Coppins (1993)
L. polycarpella	*Micarea polycarpella* (Erichsen) Coppins & Palice (1995)

Ressurected from Synonymy

L. ecrustacea (Anzi) Arnold

L. swartzioidea Nyl.

New to Britain

L. haerjedalica H. Magn.

L. promiscens Nyl.

L. promiscua Nyl.

L. syncarpa Zahlbr.

'*L.*' *luteoatra* Nyl.

New to Science

L. subspeirea Coppins, P. James & Hertel

2·3·2·2 *Porpidia* Körber

Introduction

In the British mountains, specimens of the genus *Porpidia* are probably commoner than those of any other genus. Because of their importance in the biodiversity of montane ecosystems they are the most studied of the recent segregates of *Lecidea* (e.g. Hertel 1975, Hertel & Knoph 1984, Knoph 1984, Schwab 1986, Gowan 1989, Gowan & Ahti 1993). In spite of this, although it is usually easy to identify a lichen as a *Porpidia*, it is often very difficult, or impossible, to assign it to a particular species. Species concepts are still unclear within the genus with many of the characters used in separating taxa (e.g. chemistry, width of excipular hyphae) being revealed only after detailed microscopic/biochemical investigation.

The key and notes provided here are not intended as a definitive statement on the genus, more a summary of my current understanding of the various taxa and an outline of some of the problems which need to be addressed before the genus (in the British Isles at least) can be considered reasonably well understood.

The most recent checklist of British lichens (Purvis *et al.* 1993) lists 14 species in the genus but the present study has added two more (i.e. *P. ochrolemma* and *P. zeoroides*) to the British flora and a further three undescribed taxa (*P. 'confluenta', P. 'striata'* and *P. superba 'var. sorediata'*). A number of other anomalous collections and the systematic position of *P. grisea*, the sorediate counterpart of *P. tuberculosa*, are also discussed.

Key to the Species

1 Thallus with soredia 2
Thallus without soredia 13

2(1) Medulla I+ blue .... ***P. tuberculosa***
Medulla I- 3

3(2) Thallus K+ yellow, Pd+ orange (stictic acid) 4
Thallus K-, Pd- (stictic acid absent) 8

4(3) On basic rocks, usually in damp situations. Thallus thin, continuous-cracked. Apothecia, with brown disc, usually present .... ***P. superba* 'var. *sorediata*' ad int.**
On siliceous rocks 5

5(4) Thallus orange 6
Thallus grey 7

6(5) Thallus thin, cracked-rimose, pale creamy orange. On damp rocks, usually beside streams. Confluentic acid absent .... ***P ochrolemma***
Thallus thicker, areolate, darker orange. Habitats more varied. Confluentic acid usually present .... ***P. melinodes***

7(5) Thallus thin. Lowland species .... ***P. soredizoides***
Thallus thick, ±warted. Upland/montane species .... ***P.* aff. *glaucophaea***

8(3) Confluentic acid present (K+ numerous 'oil droplets' in section) 9
Confluentic acid absent 10

9(8) Thallus orange, areolate .... ***P. melinodes***

Thallus white-grey, warted. On exposed montane rocks .... ***P. confluenta* ad int.**

10(8) Thallus grey 11

Thallus orange, thin and smooth; soralia round 12

11(10) Thallus thin to moderately thick, grey to blue-grey; soralia tuberculate and punctiform to convex and irregular, never in lines. Methyl 2'-O- methylmicrophyllinate present .... ***P.* cf. *contraponenda***

Thallus glaucous, thick and warted with irregular soredia or thinner and soralia in lines. 2'-O-methylsuperphyllinic acid present .... ***P. glaucophaea***

12(10) Epihymenium vivid aeruginose, Exciple uniformly dark, composed of cellular hyphae. No substances by TLC (probably referable to *Famoldia* - one collection only) .... ***P.* sp. 'A'**

Epihymenium olive-brown; exciple ±colourless internally, composed of narrow hyphae. 2' -O-methylperlatolic acid present .... ***P. melinodes***

13(1) Epihymenium vivid aeruginose. Usually on ±semi-inundated, siiceous rocks .... ***P. hydrophila***

Epihymenium brown or olivaceous 14

14(13) On ±basic rocks 15

On siliceous rocks 17

15(14) Medulla 1+ blue. Apothecia ±innate, usually pruinose. Confluentic acid present (K+ numrous oil 'droplets' in section) .... ***P. speirea***

Medulla I-. Thallus K+ yellow (stictic acid) 16

16(15) Apothecia ±constricted below, disc brown, outer edge of exciple not pruinose; thallus usually bullate .... ***P. superba***

Apothecia not constricted below, disc black, outer edge of exciple white pruinose; thallus smooth .... ***P. zeoroides***

17(14) Confluentic acid present (K+ numerous 'oil droplets' in section) 18

Confluentic acid absent (K+ red or yellow or K-) 21

18(17) Medulla I+ blue .... ***P. tuburculosa* f. *grisea* ad int.**

Medulla I- 19

19(18) Thallus ±uniformly orange. Excipular hyphae <4µm wide .... ***P. flavicunda***

Thallus grey. If oxydated then excipular hyphae >4µm wide 20

20(19) Thallus smooth, ±thick and continuous .... ***P. cinereoatra***

Thallus warted, ± dispersed on a black prothallus .... ***P. musiva***

21(17) Thallus K+ red (norstictic acid), acicular crystals formed (microscope). Usually maritime, but also in montane areas .... ***P. platycarpoides***

Thallus K+ yellow or K-, norstictic acid absent 22

22(21) Proper exciple persistent, radially striate. Internally, exciple with carbonaceous cortex and ±colourless medulla .... ***P. 'striata'* ad int.**

Proper exciple ±smooth (at most flexuose). Internally without carbonaceous cortex 23

23(22) Excipular hyphae 2-3µm wide. Thallus orange .... ***P. flavicunda***

Excipular hyphae >4µ wide. Thallus grey, sometimes partly oxydated 34

24(23) Ascospores 12-16(-18)µm long, hymenium 70-90µm high .... ***P. crustulata***

Ascospores 16-18(-21)µm long, hymenium 90-110µm high 25

25(24) Apothecia densely pruinose, excipular hyphae 5-6µm wide. Thallus K+ yellow (stictic acid) .... ***P. platycarpoides***

Apothecia not or only slightly pruinose, excipular hyphae narrower. Thallus K+ yellow or K- (stictic acid or no substances present) 26

26(25) Thallus usually thin or non-apparent; K+ yellow, Pd+ orange (stictic acid) or K-, Pd- (no substances) .... ***P. macrocarpa***

Thallus usually moderately thick. Thallus K-. Methyl 2'-O-methylmicrophyllinate present 27

26(25) Apothecia sessile .... ***P. contraponenda***

Apothecia ±immersed, white ring present between exciple and disc when young .... ***P. aff. contraponenda***

Notes on the species

P. cinereoatra - Gowan (1989), Gowan & Ahti (1993) separated *L. lowiana* from this species primarily because of its thinner thallus and arctic distribution. As I have found a continuum of thallus thickness from ±endolithic to thick and warted (*P. musiva*) I have retained all collections in *P. cinereoatra*.

P. 'confluenta' ad int. - cf. section 2•2•2 for a full description of this species.

P. contraponenda - This species is characterized by the presence of Methyl 2'-O-methylmicrophyllinate in the thallus. The species is morphologically heterogenous, one entity has sessile apothecia (*P. contraponenda* s. str.) the other has ±innate apothecia with the inner edge of the exciple being white pruinose (*P. aff. contraponenda*). I have also seen several, morphologically variable, sorediate collections with this chemistry (*P.* cf. *contraponenda*). Gowan (1989) separated *P. diversa* from this species on the basis of its aeruginose epihymenium, usually smaller apothecia, and a different distribution. I have found the colour of the epihymenium to vary from olive-green to aeruginose in a single plant and so cannot accept this distinction.

P. crustulata - A common species in upland and montane habitats. It is an early colonizer of bare rock surfaces and is frequent around areas of prolonged snow-lie. It is distinguished from *P. macrocarpa* in the field by its smaller apothecia and microscopically by its smaller ascospores, lower thecium and thicker excipular hyphae.

Gowan (1989) described a new species, *P. tomsonii*, to accommodate specimens with characters intermediate between these two species.

P. flavicunda - Although all British specimens of *P. flavicunda* examined contained no lichen substances studies, in other areas have shown that the chemotype containing confluentic acid is usually by far the most frequent. Gowan (1989) mentions four chemical races of this species in North America with the confluentic acid race constituting 93% of the total whereas that lacking lichen substances is very rare (3%). Knoph (1984) states that only the confluentic acid race is known from Europe.

Gowan & Ahti (1993) have shown that the name *P. flavocaerulescens* refers to the non-sorediate species and that the name *P. melinodes* is available for the sorediate entity. However, Santesson (1993) considers that due to the confusion this would cause, *P. flavicunda* should be retained for the non-sorediate morph. I have followed Santesson.

P. glaucophaea - Sorediate specimens of *Porpidia* which contain 2'-O-methylsuperphyllinic acid in their thallus are referred here. *P. glaucophaea* is usually described as occurring on siliceous rocks and having soralia developing in lines along cracks in the thallus. Montane specimens, however, occur on weakly basic rock and have a thick thallus with ±rounded or irregular soralia not developing from cracks in the thallus. Apothecia are rare but appear to agree well with those described for *P. glaucophaea.* The relationship of these specimens to *P. glaucophaea* s. str. warrants further investigation.

P. aff. glaucophaea - This entity is morphologically similar to *P. glaucophaea* but differs in having stictic acid in its thallus. In this respect it is similar to the lowland *P. soredizodes* from which it differs primarily in having a thicker, well-developed thallus.

P. hydrophila - An occasional species of semi-inundated rocks and other damp habitats in upland/montane areas. It is readily distinguished from all other described species of *Porpidia* by its bright aeruginose pigmented epihymenium.

P. melinodes - Gowan & Ahti (1993) showed this to be the correct name for the species previously known as *P. flavocaerulescens.*

Gowan & Ahti discuss this species and the closely related *P. flavicunda* (as *P. flavocaerulescens*) in some detail. They conclude that two separate species are involved based mainly on the thinner thallus of *P. melinodes* and the different secondary chemotypes which occur; the primary chemotype of both taxa containing confluentic acid. However, other species pairs within *Porpidia* also have a thinner thallus when sorediate (e.g. *P. superba, P. tuberculosa*) and so this difference should probably be treated with caution. Of more interest is that all British specimens of *P. flavicunda* lack lichen substances and so differ in primary chemotype not only from other populations of *P. flavicunda* but also from British collections of *P. melinodes*. The complex warrants further investigation.

P. musiva - This is a member of the *P. cinereoatra* group characterized by its thick, white thallus, epruinose apothecia and slightly larger ascospores.

***P. ochrolemma* (Vainio) Brodo & R. Sant.** - Recently recorded from North Wales (Fryday 1996b). It has a smooth ±continuous yellow-orange thallus, reminiscent of *Hymenelia lacustris* but with numerous grey-white soredia. As it also occurs on siliceous rocks in streams it was placed in *Hymenelia* by Gowan & Ahti (1993).

It differs from *P. melinodes* in its smoother, more creamy-yellow thallus and in containing only stictic acid (*P. melinodes* also occasionally contains stictic acid but confluentic acid is always present as well). The two species differ morphologically, the thallus of *P. melinodes* is areolate whereas that of *P. ochrolemma* is rimose. Both species are illustrated in colour by Gowan & Ahti (1993).

P. platycarpoides - This species is usually easily identified by its densely pruinose apothecia and the presence of norstictic acid in its thallus and exciple (K+ red, acicular crystals formed - visible in section). However norstictic acid is occasionally replaced by stictic acid (K+ yellow solution in section) but *P. platycarpoides* can then be distinguished by its wide excipular hyphae (4-8µm wide).

P. platycarpoides is not uncommon in montane areas although it is primarily a species of maritime rocks.

P. soredizodes - A lowland species which is extremely rare in montane areas.

P. speirea - This is a characteristic species within the genus being the only one restricted to basic rocks and having an I+ blue medulla. It is most likely to be mistaken for the morphologically similar *Rhizocarpon umbilicatum.*

The Central European *P. trullisata* also occurs on basic rocks and has an I+ blue medulla but contains stictic acid (K+ yellow, Pd+ orange) rather than the confluentic acid found in *P. spierea.*

***P. 'striata'* ad int.** - cf. section 2•2•2 for a full description of this species.

P. superba - A distinctive species of basic rocks. The well-developed bullate thallus and apothecia with a brown disc and constricted base are characteristic. However morphs also occur (particularly in damp situations) where the thallus is less well-developed and the apothecia disc darker. These are sometimes difficult to separate from *P. zeoroides* which is then most readily separated by the densely pruinose outer rim of the exciple. Gowan (1989) described a new species, *P. calcarea,* with characters intermediate between *P. superba* and *P. zeoroides*, on the basis of three collections from the shores of Lake Superior. More work is needed on these and other intermediate specimens.

The sorediate morph ('f. *sorediata* ad int.) occurs on damp, usually vertical and periodically flushed, slightly basic rocks. It is described in full in section 2•2•2.

P. tuberculosa - Gowan (1989) described non-sorediate, fertile material of *P. tuberculosa* as a distinct species, *P. grisea*. However, the presence of a complete range of intermediates, from abundantly fertile with scattered soredia through specimens with equal numbers of both to abundantly sorediate material with scattered apothecia suggests that only one species is involved. Soredia production appears to be associated with areas of thinner thallus and there is a tendency for lowland/upland plants to have a thin thallus and produce soredia whereas most montane plants have a thick thallus and apothecia. Where both soredia and apothecia are produced on the same plant the soredia are strongly associated with areas of thinner thallus and the apothecia with areas of thicker thallus.

Interestingly, specimens from the vicinity of areas of prolonged snow-lie have the thin thallus and abundant soredia of the lowland morph suggesting that this is a stress-tolerant form whereas the morph with a thick thallus is a better competitor. The rank of 'form' appears to be the most appropriate level at which to recognise fertile specimens with a thick thallus.

A similar situation occurs in *P. superba* (and possibly *P. flavicunda*) where the sorediate morph also has a thinner thallus. The sorediate morph of *P. superba* also occurs in a more stressed habitat than the fertile one.

P. zeoroides - Recently recorded from calcareous rocks on Ben Lawers (Mid-Perthshire) and Ben Sgulaird (Argyll). This species differs from *P. superba* in having black apothecia, which are not constricted at the base, and a white pruinose outer rim to the exciple. It is probably more widespread in the Breadalbane Mountains (and elsewhere) but has been overlooked for *P. superba*.

P. sp. 'A' - Recorded from a wall at a disused mine at Strontian (Argyll), this entity has an orange thallus, which lacks lichen substances by TLC, blue-grey soredia and apothecia with a bright aeruginose epihymenium and a dark, carbonaceous exciple. The latter character suggests a placement in *Farnoldia* but the only European species of that genus with an orange thallus is the rare *F. dissipabilis* (Nyl.) Hertel which, however, lacks soredia, has a green-brown epihymenium and occurs on calcareous rocks. In *Porpidia* it is closest to *P. melinodes* from which it differs in the aeruginose epihymenium, the carbonaceous exciple and the lack of lichen substances.

2·3·2·3 *Rhizocarpon* Lam. ex D.C. subgenus *Phaeothallus* Thomson

Introduction

The non-yellow species of *Rhizocarpon* (subgenus *Phaeothallus*) constitute an important component of the montane lichen vegetation and many of my collections failed to fit in with current taxonomic concepts; in particular the revision by Feuerer (1991), which used a rather broad species concept, failed to do justice to the variation I was encountering. The account of *Rhizocarpon* in Purvis *et al.* (1992) mentions a number of species where there are apparent problems e.g. *R. hochstetteri* and *R. obscuratum* and it soon became clear that most upland/montane specimens called *R. obscuratum* were in fact *R. lavatum* and that there were also at least two very distinct entities included within *R. hochstetteri*. Consequently, special attention has been paid to these groups, extensive collections have been made and subjected to a detailed microscopic analysis. This was followed up with herbarium work in the Natural History Museum and the Royal Botanic Garden, Edinburgh; I have also seen a small number of collections from Scandinavia (principally in the *R. copelandii* group).

Conversely, other species of the subgenus have not been studied; in particular those montane species which occur on basic rocks (e.g. *R. caeruleoalbum, R. chioneum, R. expallescens*) primarily because they are very rare. Other species not studied include *R. geminatum* and *R. polycarpum*, both of which would probably benefit from close scrutiny.

The keys presented here must be considered provisional for three main reasons:-

a) The genus is relatively poorly represented in the British Isles compared with, for instance, Scandinavia. Many species are rare and it will be necessary to examine foreign material to gain a clear concept of these.

b) More work is needed on a number of problem areas (e.g the *R. copelandii* group).

c) Although the main taxonomic entities are established, the correct names for them are not. In particular, there are numerous previously published names included in the synonymy of *R. hochstetteri* and it will be necessary to examine the type material of many of these.

In cases of doubt, I have tended to retain species as separate entities rather than lump them together as it is easier to combine separately recorded species than it is to separate ones recorded together. Consequently, *R. cinereonigrum* and *R. jemtlandicum* are retained as distinct from *R. badiotrum* and *R. cyclodes* respectively, although I strongly suspect that they are better treated at infra-specific level.

Not included in the key are the lichenicolous *R. advenulum* (on *Pertusaria* spp.) and *R. ochrolechiae* (on *Ochrolechia parella*).

Key to the species

1 Ascospores 1-septate (occasionally 3-septate or submuriform) 2
Ascospores 3-septate to eumuriform 21

2(1) Ascospores remaining colourless (over-mature spores sometimes becoming brown, but then usually distorted) 3
Ascospores soon becoming dark blue-black (occasionally brown) 15

3(2) Medulla I+ blue; ascospores occasionally becoming 3-septate or submuriform 4
Medulla I-; ascospores usually remaining 1-septate 5

4(3) Thallus usually C+ red (gyrophoric acid). Epihymenium K-, maritime species .... ***R. richardii***
Thallus usually C-. Epithecium K+ purple, upland/montane species . ***R. polycarpum***

5(3) On basic rock 6
On siliceous rock 9

6(5) On slightly calcareous rocks (epidiorite, basalt, andesite) in oceanic areas. Rarely on semi-inundated siliceous rocks further east (Scotland). Thallus grey, K-, Pd-. Apothecia flat to slightly convex, to 1.5mm diam., ±immarginate. Spores 16-18 (-19) x 7-8µm. Epihymenium aeruginose, especially in K .... ***R 'caesium' ad int.***
Usually on more strongly basic rock, especially limestone. Thallus white; apothecia

smaller. Epithecium olivaceous to brown 7

7(6) Epihymenium K+ purple .... ***R. chioneum***

Epihymenium K- 8

8(7) Exciple K-. Apothecial disc usually pruinose. Thallus K+ yellow, Pd+ orange (stictic acid) .... ***R. caeruleoalbum***

Exciple K+ purple. Apothecial disc not pruinose. Thallus K-, Pd- .. ***R. expallescens***

9(5) Thallus K+ red, Pd+ yellow (norstictic acid) 10

Thallus K+ yellow, Pd+ orange (stictic acid) or K-, Pd- (no substances) 11

10(9) Thallus white or pale grey, warted-areolate, usually <1cm diam. Epihymenium bright blue-black; paraphysoids with only slightly swollen pigmented caps; remaining ±conglutinate in K. On disused metal-mine spoil, montane rocks and coastal shingle .... ***R. aff. cinereovirens***

Thallus pale grey to brown, areolate, usually >1cm diam. Epihymenium usually blue-black (occasionally olivaceous-brown); paraphysoids with ±distinct, abruptly swollen pigmented caps, ±separating in K .... ***R. hochstetteri***

11(9) Apothecia flat to slightly convex, to 1•5mm diam., ±immarginate. Epihymenium aeruginose, especially in K. Thallus grey, K-, Pd-. Ascospores 16-18(-19) x 7-8µm. Usually on slightly basic or semi-inundated acidic rocks
.... ***R. 'caesium'*** **ad int.**

Apothecia smaller. Epihymenium blue-black or brown 12

12(11) Ascospores >24 µm long, usually becoming brown when old. Paraphysoids with only slightly swollen pigmented cap; remaining conglutinate in K 13

Ascospores usually <22 µm long, rarely becoming brown when old. Paraphysoids with ±distinct, abruptly swollen pigmented caps; separating in K 14

13(12) Thallus grey-brown; Usually K-, Pd- (stictic acid absent). On exposed upland/montane siliceous boulders .... ***R. colludens* (Nyl.) ad int.**

Thallus red-brown; Usually K+ yellow, Pd+ orange (stictic acid). Restricted to high altitude (>900m) .... ***R. colludens* v. *rufoatrum* ad int.**

14(14) Thallus thin, olivaceous-brown, continuous; K-, Pd-. Apothecia with thin, persistent exciple. Ascospores 19-21 x 9-11µm. Epihymenium brown. Frequent oceanic species, becoming scarce in Scotland although extending as far north as Knoydart. Usually on boulders in woodlands but becoming upland/montane in SW England (Dartmoor) and SW Ireland (Brandon Mountain) .... ***R. oceanicum* ad int.**

Thallus white, grey or brown, areolate; K+ yellow, Pd+ orange (stictic acid) or K-, Pd- (no substances). Apothecia with thicker exciple or occasionally immarginate. Ascospores 14-16(-18) x 7-8µm. Epihymenium usually blue-black. Upland or montane species .... ***R. hochsteteri***

15(2) Medulla I+ blue 16

Medulla I- 17

16(15) Thallus C-, K-, Pd-. Ascospores 12-16 x 6-8µm; exciple K+ purple .. ***R. simillimum***

Thallus C+ red, K+ yellow, Pd+ orange (gyrophoric and stictic acids). Ascospores 22-27 x 11-14µm .... ***R. 'subgrande'* ad int.**

17(16) Epihymenium K+ purple 18

Epihymenium K- 19

18(17) Thallus K-, Pd- (no substances). Sub-montane; usually on semi-inundated boulders in streams or the margins of lakes .... ***R. badioatrum***

Thallus K+ yellow, Pd+ orange (stictic acid). Apparently restricted to high altitude, usually associated with areas of prolonged snow-lie .... ***R. cinereonigrum***

19(17) Thallus of plane to convex white areoles; K+ red, Pd+ yellow (norstictic acid). Exciple K+ purple. Usually on shaded rocks or sides of boulders at intermediate altitudes but also on tops of low boulders at high altitude on Ben Avon (Fig. 2•15a) .... ***R. copelandii***

Thallus grey to brown; K+ yellow, Pd+ orange (stictic acid). Exciple K-. Usually on exposed mountain tops 20

20(19) Thallus usually grey, areoles up to 1mm diameter. Epihymenial pigment diffuse. Apothecia innate, flat to slightly convex, exciple indistinct. Usually on tops of exposed montane boulders (Fig. 2•15b) .... ***R. ?cyclodes* Hellb. ex. Th. Fr.**

Thallus usually brown, areoles up to 1.5mm diam. Epihymenial pigment less diffuse. Apothecia sessile remaining flat with a persistent, thick, raised exciple. Usually associated with areas of prolonged snow-lie (Fig. 2•15c) .... ***R. jemtlandicum.***

21(1) Ascospores predominantly 3-septate (if medulla I+ blue see 2a) 22

Ascospores usually with some longitudinal septa 23

22(21) Thallus orange to rust-red. Apothecia umbonate to gyrose. Most often on metal-rich rocks .... ***R. oederi***

Thallus grey. Apothecia smooth. On montane rocks .... ***R. submodestum***

23(21) Ascospores dark brown 24

Ascospores colourless 26

24(23) Ascus 2-spored. Medulla I- .... ***R. geminatum***

Ascus 8-spored. Medulla I+ blue 25

25(24) Thallus brown, C+ red (gyrophoric acid). Epihymenium K- .... ***R. grande***

Thallus white, C-. Epihymeniun K+ purple or K- .... ***R. geographicum***

26(23) On calcareous rocks 27

On siliceous rocks 28

27(26) Ascospores sub-muriform (3-4 transverse, 1(-2) longitudinal septa), 15-30 x 9-16µm. Thallus K+ yellow, Pd+ orange (stictic acid), white. Exciple thickly white pruinose, disc usually pruinose. On pure limestone or other strongly basic rocks .... ***R. umbilicatum***

Ascospores strongly muriform (3-9 transverse, 1-2 longitudinal septa), 30-40(-50) x 14-19(-24)µm. Thallus K+ yellow, Pd+ orange or K-, Pd- (±stictic acid), grey to white. Exciple often white pruinose on inner edge, disc not pruinose. Also frequent on weakly calcareous rocks as well as limestone .... ***R. petraeum***

28(26) Thallus continuously, finely isidiate-sorediate (blastidia). On metal-rich rocks. Apothecia rare .... ***R. furfurosum***

Thallus otherwise. Apothecia usually present 29

29(28) Asci 2-spored .... ***R. subgeminatum***

Asci 8-spored 30

30(29) Medulla I+ blue. Epihymenium usually K+ purple; exciple K+ purple . ***R. distinctum***

Medulla I- 31

31(30) Epihymenium K+ purple. Apothecia innate. On semi-inundated rocks .... ***R. amphibium***

Epihymenium K- 32

32(31) Ascospores submuriform, usually <25µm long 33

Ascospores eumuriform, usually >25µm long 34

33(32) Ascospores (16-)18-22 x (10-)11-13µm. Length/breadth ratio 1.5-2.0. Thallus indistinct, K-, Pd- (stictic acid absent). Rare upland/montane species (Figs 2•16c & 2•17a) .... ***R. postumum***

Ascospores 19-28 x 10-12. Length/breadth ratio 1.75-2.75. Thallus well-developed, K+ yellow, Pd+ orange or K+ red, Pd+ yellow (stictic or norstictic acids), common species of rocks and pebbles (Figs 2.16b & 2.17b) .... ***R. reductum***

34(32) Ascospores 33-50 x 12-17µm. Length/breadth ratio 2.0-3.0 35

Ascospores usually <30µm long. Length/breadth ratio 1.5-2.0 36

35(34) Upland/montane species of damp rocks. Thallus dark-grey to various shades of brown, most often pale creamy brown; cracked-continuous, usually widespreading. Apothecia large (to 1•5mm) with thick tumid margin, not pruinose, not arranged concentrically. Ascospores usually 35-45µm long (Figs 2.16a & 2•17e) .... ***R. lavatum***

Lowland/upland species of exposed rocks. Thallus white to pale-grey; areolate, usually in discrete, ±orbicular patches. Apothecia smaller often with a pruinose exciple, often arranged concentrically. Ascospores usually 30-35µm long (Fig. 2•17f) .... ***R. petraeum***

36(34) Thallus brown, granular-areolate. Ascospores 22-33 x 11-19µm. Only brown pigments present internally; epihymenium K+ grey, at least in places (Figs 2.16d & 2.17d) .... ***R. anaperum***

Thallus grey, cracked-areolate. Ascospores 17-36 x 11-15µm. Brown and blue pigments present internally; epihymenium K+ aeruginose (at least in places), exciple edge K+ aeruginose (Figs 2•16e & 2•17c) .... ***R. sublavatum ad int.***

Figure 2•15. *Rhizocarpon copelandii* sensu lato. a) *R. copelandii* sensu stricto. (Magnification: x4)

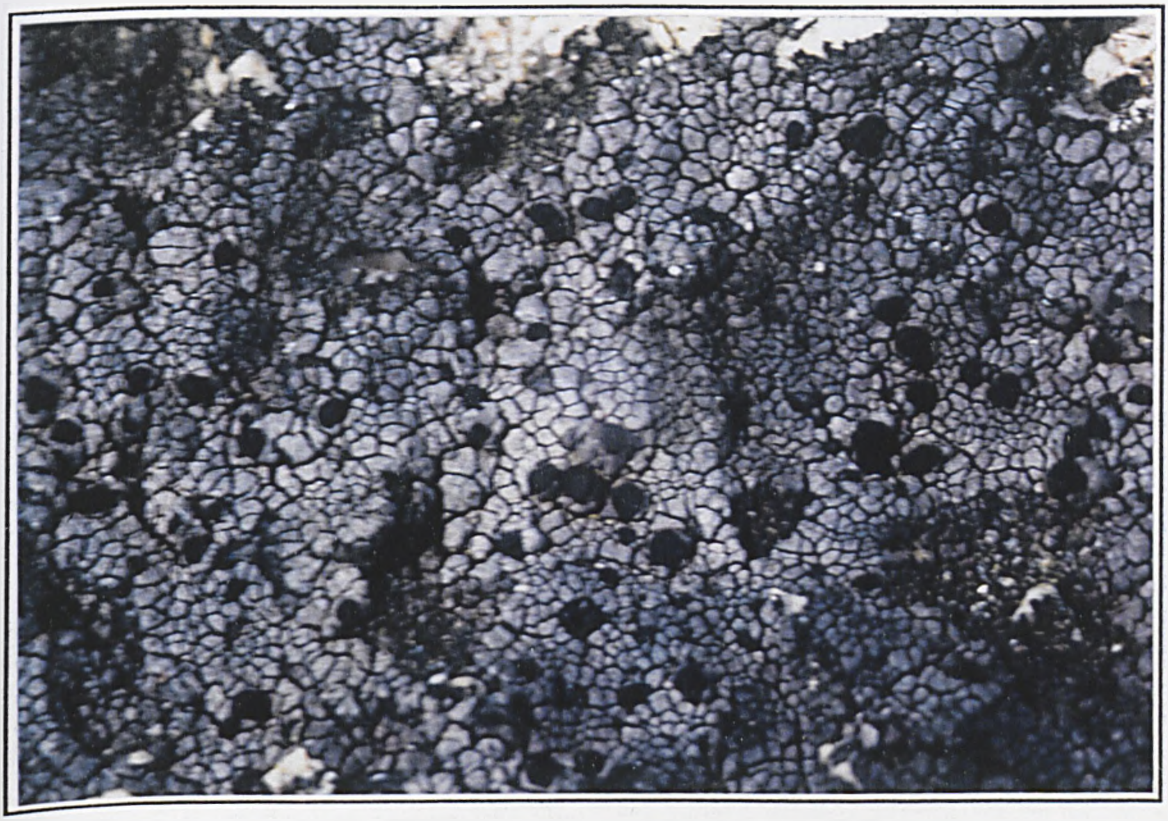

Figure 2•15. *Rhizocarpon copelandii* sensu lato. b) *R. ?cyclodes*. (Magnification: x4)

Figure 2•15. *Rhizocarpon copelandii* sensu lato. c) *R. jemtlandicum*. (Magnification: x4)

Figure 2.16. Ascospores of the *'Rhizocarpon 'obscuratum'* group. a) *R. lavatum*. (Magnification: x700)

Figure 2.16. Ascospores of the *'Rhizocarpon 'obscuratum'* group. b) *R. reductum*. (Magnification: x700)

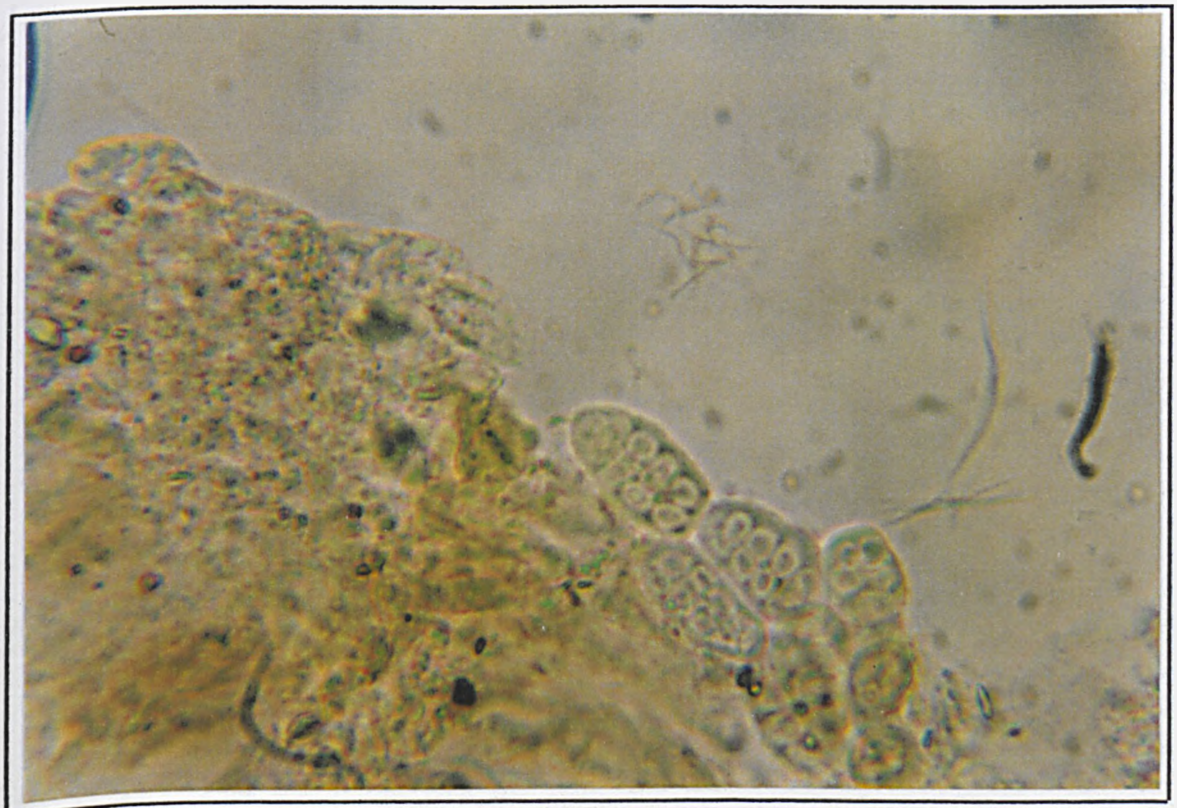

Figure 2.16. Ascospores of the *'Rhizocarpon 'obscuratum'* group. c) *R. postumum*. (Magnification: x700)

Figure 2.16. Ascospores of the *'Rhizocarpon 'obscuratum'* group. d) *R. anaperum.* (Magnification: x700)

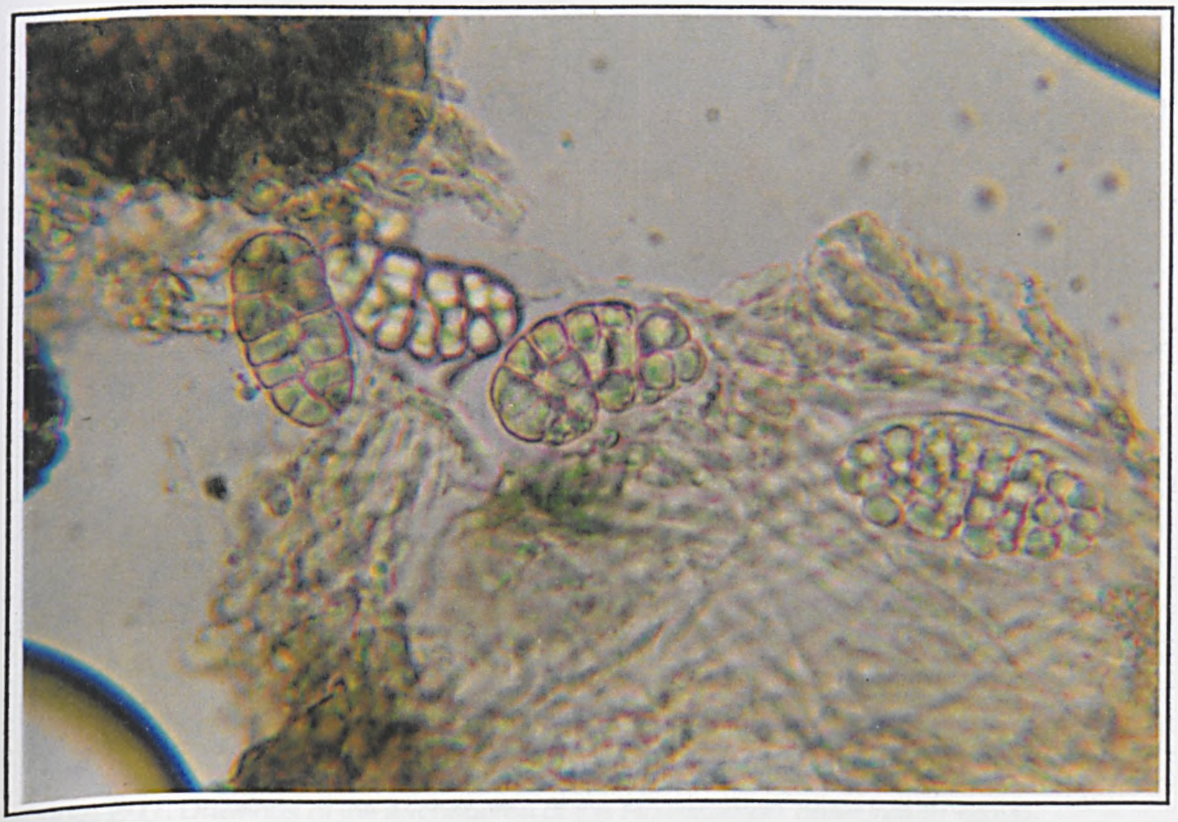

Figure 2.16. Ascospores of the *'Rhizocarpon 'obscuratum'* group. e) *R. 'sublavatum'* ad int. (Magnification: x700)

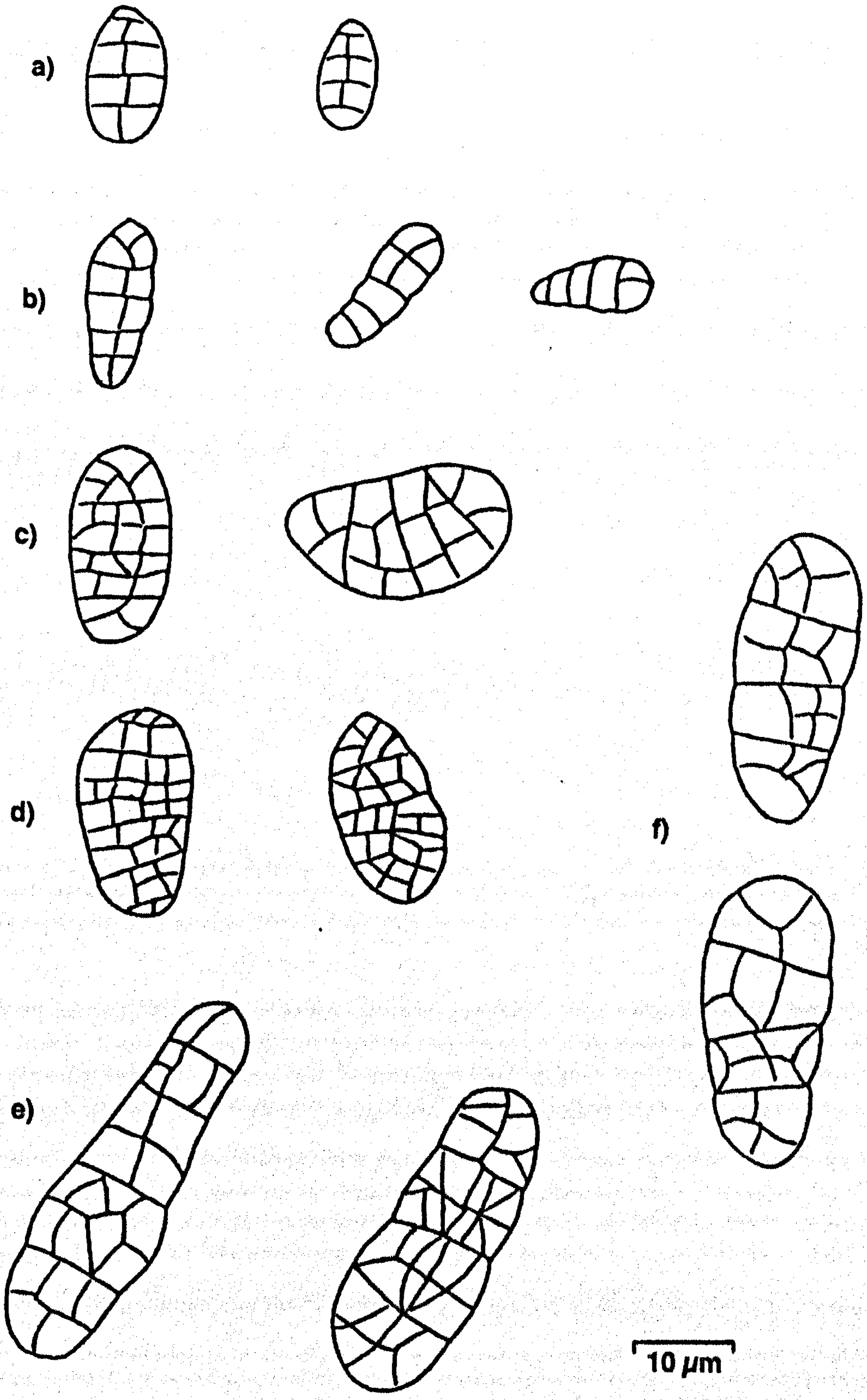

Figure 2•17. Drawings of the ascospores of the *Rhizocarpon 'obscuratum'* group.
a) *R. postumum* b) *R. reductum* c) *R. 'sublavatum'* ad int. d) *R. anaperum* e) *R. lavatum* f) *R. petraeum*.

Table 2-4. Summary of important distinguishing characters.

a - spore septation	d - epihymenium K+ p	g - norstictic acid
b - spore colour	e - exciple K+ p	h - stictic acid
c - medulla I+ b	f - gyrophoric acid	i - calcareous rock

Species	a*	b+	c	d	e	f	g	h	i
R. badioatrum	1	d	-	+	+	-	-	-	-
R. cinereonigrum	1	d	-	+	+	-	-	+	-
R. copelandii	1	d	-	-	+	-	+	-	-
R. ?cyclodes	1	d	-	-	-	-	-	+	-
R. jemtlandicum	1	d	-	-	-	-	-	+	-
R. simillimum	1	d	+	-	+	-	±	±	-
R. 'subgrande'	1	d	+	+	+	+	-	+	-
R. caeruleoalbum	1	c	-	-	-	-	-	±	+
R. 'caesium'	1	c	-	-	-	-	-	-	±
R. chioneum	1	c	-	+	+	-	-	+	+
R. cf. *cinereovirens*	1	c	-	-	-	-	+	-	-
R. colludens	1	c	-	-	-	-	-	-	-
'v. rufoatrum'	1	c	-	-	-	-	-	+	-
R. expallescens	1	c	-	-	+	-	-	-	+
R. hochstetteri	1	c	-	-	-	-	±	±	-
R. 'oceanicum'	1	c	-	-	-	-	-	-	-
R. polycarpum	1	c	+	+	+	±	-	±	-
R. richardii	1	c	+	-	-	±	-	±	-
R. oederi	3	c	-	-	-	-	-	+	-
R. submodestum	3	c	-	-	-	-	-	+	-
R. amphibium	sm	c	-	+	+	-	-	-	-
R. distinctum	sm	c	+	±	+	±	-	±	-
R. postumum	sm	c	-	-	-	-	-	-	-
R. reductum	sm	c	-	-	-	-	±	+	-
R. umbilicatum	sm	c	-	-	-	-	-	+	+
R. geminatum	em	d	-	+	+	-	-	±	-
R. grande	em	d	+	-	-	+	±	±	-

R. anaperum	em	c	-	-	-	-	-	-	-
R. petraeum	em	c	-	-	-	-	-	±	±
R. furfurosum	em	c	-	-	-	-	-	+	-
R. lavatum	em	c	-	-	-	-	-	-	-
R. subgeminatum	em	c	-	-	+	-	-		-
R. 'sublavatum'	em	c	-	-	-	-	-	-	-

*sm = submuriform, em = eumuriform

+d = dark, c = colourless

NOTES

***R. amphibium* (Fr.) Th. Fr.** New to the British Isles. The specimen from Caenlochan provisionally placed here by Purvis *et al.* (1992:539) belongs in *R. lavatum*. However *R. amphibium* has subsequently been recorded from NE Scotland (Glen Quoich) and N. England (Upper Teesdale and the Lake District). It is an upland rather than a montane species.

***R. anaperum* (Vainio) Vainio** New to the British Isles. Recorded from a number of damp north-facing coires and occasionally near areas of late snow-lie in Scotland as well as from the summit of Carnedd Llewelyn in North Wales, where it is abundant. The first British record was made by Watson from Snowdon in 1926 but the specimen (in BM) was mis-identified as *R. grande*. It is also known from four disused metal-mines in mid-Wales.

Feuerer (1991) referred this species to *R. obscuratum*, but even allowing for the previous concept of that species, it is clearly morphologically and anatomically distinct.

R. badioatrum As suggested in Purvis *et al.* (1992) records of *R. badioatrum* from the Cairngorms (in particular from the late-lying snow bed in Ciste Mhearad (Gilbert and Fox 1985) belong in *R. jemtlandicum*. This accounts for the reports of stictic acid in British specimens of *R. badioatrum* (also mentioned by Purvis *et al.*) although it is possible that some records are of *R. cinereonigrum*.

R. badioatrum is most frequently a species of siliceous rocks in or on the edge of upland/montane lakes and streams. Two distinct entities are recognised within *R. badioatrum*

(Timdal & Holten-Hartwig 1988) but only one has been recorded from the British Isles.

R. caeruleoalbum A montane lichen of strongly calcareous rocks. British specimens are rare and the species was not studied.

R. 'caesium' ad int. New to science. The record of *R. expallescens* from Ben Hope (Gilbert and Fox 1986; Purvis *et al.* 1992) refers to this species. It most frequently occurs on slightly basic rocks in hyper-oceanic areas (Trotternish, Isle of Skye to North Wales) where it can be locally common. There are, however, a few records from semi-inundated siliceous rocks further east in Scotland.

R. chioneum A montane species of strongly calcareous rocks. British specimens are rare so the species was not studied.

R. cinereonigrum Vainio New to the British Isles. Separated from *R. badioatrum* primarily by the presence of stictic acid and its ecology, *R. cinereonigrum* occurs only at very high altitudes, most often in the vicinity of areas of prolonged snow-lie. It probably only deserves recognition as a variety of *R. badioatrum.*

R. aff. cinereovirens The type of *R. cinereovirens* (in BM) is a norstictic acid containing strain of *R. hochstetteri.* The description in the key refers to specimens from disused metal-mine spoil in Wales and Scotland which differ from *R. hochstetteri* in morphology and anatomy and for which it will probably be necessary to find a new name. This entity has also been recorded from summit rocks in the Ben Nevis range and coastal shingle in N.E. Scotland

R. colludens (Nyl.) ad int. New combination, resurrected from synonymy. This is a common upland/montane species of siliceous rocks usually called *R. hochstetteri* by British and Scandinavian lichenologists. However, it differs from that species by its much larger spores, taller thecium and less distinctly capitate paraphysoids that remain conglutinate in K.

It has a grey-brown thallus and lacks stictic acid. The **v. *rufoatrum* ad int.** (new to science) differs in the presence of stictic acid as well as the thicker red-brown thallus and its habitat of high altitudes only.

R. concentricum See *R. petraeum* and *R. reductum*.

R. copelandii The holotype of this species (in L) has a thallus composed of dispersed, grey, convex areoles and a K+ purple exciple. British specimens differ in having a thallus composed of white, flat to bullate areoles but as intermediates occur and they appear anatomically identical to the type-specimen they are included in *R. copelandii*.

Timdal & Holten-Hartwig (1988) have a much broader concept of this species, including collections closer to *R. jemtlandicum* and/or containing stictic acid. These are here provisionally referred to *R. cyclodes* (Fig. 2•15).

R. ?cyclodes Resurrected from synonymy (see *R. copelandii*). This appears to be the earliest available name for those specimens included in *R. copelandii* by Timdal & Holten-Hartwig (1988) but which have a continuous, areolate thallus and lack a K+ purple exciple. However, its separation from *R. jemtlandicum* is in need of further investigation.

This entity is not rare at high altitudes in the Scottish Highlands although it has in the past been confused with *R. jemtlandicum*. British specimens are all morphologically similar and contain stictic acid. However, even after the removal of *R. copelandii* s. str., Scandinavian specimens (in UPS) are morphologically more varied and some also contain norstictic acid in place of stictic acid. The complex warrants further study.

R. distinctum This is an upland species rather than a montane one so was not studied. *R. distinctum* has a red-brown, K+ purple epihymenium. However, I have a collection (from East Lothian) which has a blue-black, K+ brighter blue epihymenium, although the exciple is red-brown, K+ purple. All other characters coincide with those of *R. distinctum* so I have no hesitation in including it in this species.

R. expallescens This is an extremely rare species recorded in the British Isles only from Coire Cheap (Ben Alder) and Caenlochan. The record from Ben Hope (Gilbert & Fox 1986; Purvis *et al.* 1992) is referable to *R. caesium*. All other records, including those from disused Welsh metal-mines, belong in *R. hochstetteri* s. str.

R. furfurosum This is an upland rather than a montane species, restricted to heavy metal containing rocks, so was not studied.

R. geminatum This is an upland/montane rather than a true montane species and, as collections are not common, it was not studied.

***R. grande* (Flotow) Arnold** New to the British Isles. Recently recorded from North-East Wales (Clwyd). I have not seen this collection so cannot comment on it.

R. hochstetteri The description in Purvis *et al.* (1992) reflects the confusion surrounding this species in the British Isles, it being a composite description of *R. colludens* and *R. 'oceanicum'*. The description of this species in Timdal & Holten-Hartwig (1988) refers to *R. colludens*. I have been unable to locate the type specimen of *R. hochstetteri* but from the original description (Körber, 1861) and its location, along with the descriptions and opinions of subsequent German/Austrian authors (Poelt and Vezda 1981, Wirth 1987, 1995, Feuerer 1987) I am confident that my concept of the species coincides with that of Körber.

There is a tendency for specimens with a brown thallus to have flat areoles, lack stictic acid and have an olive-brown epihymenium whereas those with a grey thallus are more often warted, contain stictic acid and have a blue-black epihymenium. However, I have seen specimens with all possible combinations of characters so I am including them all within the same taxon. It may be that further study will alter this opinion.

Specimens from disused mine spoil in mid-Wales, with a pale grey thallus, appear to have a shallower thecium and be more intensely pigmented internally. These may represent a distinct taxon.

R. jemtlandicum In the British Isles this species is confined to rocks in the vicinity of areas of prolonged snow-lie. Most previous records from the British Isles refer to the closely related *R. ?cyclodes*. *Rhizocarpon jemtlandicum* is morphologically and ecologically distinct from *R. ?cyclodes* although anatomically it differs in only minor respects. They are here retained as separate species pending a more detailed investigation of this complex.

R. lavatum This species is very variable morphologically but is anatomically well defined by its large muriform spores and thick, tumid exciple. It is not restricted to lake and stream sides as stated by Purvis *et al.* but is far more widely distributed, being frequent on damp rocks throughout the Scottish Highlands and elsewhere. The ochraceous tinge to the thallus also mentioned by Purvis *et al.* is only rarely encountered. The earliest available name for this species is *R. obscuratum* (see note under that species). However as this would cause considerable confusion it will be necessary to preserve the name *R. lavatum* by a formal rejection of *R. obscuratum* (see below).

R. oederi This is an upland species, largely confined to heavy metal containing rocks, rather than a montane one so it was not studied.

R. obscuratum The type material of *Lecidea petraea* var. *obscurata* Ach., upon which this name is based, is a small form of the species currently known as *R. lavatum*. As the name *R. obscuratum* has been used for *R. reductum* (see below) as well as small forms of *R. lavatum*, it seems wisest to reject the name altogether.

R. 'oceanicum' ad int. New to science. This species is closely related to *R. hochstetteri* and many British records of that species belong here. It differs from *R. hochstetteri* mainly in its smooth olive-brown thallus and habitat of siliceous rocks in oceanic woodlands.

R. petraeum This is an widespread species most frequent on weakly basic rocks, although it also occurs on siliceous rocks in the lowlands and more strongly basic substrata in montane situations.

The presence of stictic acid in *R. petraeum* is variable and, when present, is located in the cortex rather than the medulla. There is a possible correlation with the thickness of the thallus; specimens with a thin thallus, from montane areas, apparently lacking lichen substances (by TLC) and this warrants further investigation

Feuerer (1991) showed *R. petraeum* to be the correct name for the species previously known as *R. concentricum.*

R. plicatile *Lecidea plicatilis* was transferred to *Rhizocarpon* by A. L. Smith on account of its muriform spores. The syntype (in BM) collected by Leighton from Cader Idris (N. Wales) is small and in poor condition with only two immature apothecia. However, detailed anatomical notes were made by P. W. James in 1960 and the specimen was subjected to TLC in 1983 and found to contain stictic acid and atranorin. It is also obscurely sorediate. There is an annotation in pencil on the herbarium sheet (?Lamb) querying its placement in *Rhizocarpon* and an undated determination of *R. obscuratum* by Feuerer; who does not treat *R. plicatile* in his most recent work (Feuerer 1991).

The specimen is referable to a crustose *Stereocaulon* species very close to *S. tornense* (but with muriform rather than 3- septate spores) known from a number of localities in Scotland and one in North Wales. It was previously believed to be undescribed (Fryday & Coppins 1996b).

R. rubescens, usually considered a synonym of *R. plicatile*, is a distinct species and not a norstictic acid containing strain of *R. reductum* as suggested by Fryday (1996a). It has larger eumuriform ascospores than *R. reductum*, 27-35x11-14µm, and apothecia with a prominent thin proper exciple. It has not been correctly reported from the British Isles.

Most other British collections named *R. plicatile* are referable to *R. reductum.*

R. polycarpum Most records of this species are from upland habitats, so it was not studied.

The chemistry of *R. polycarpum* and, the closely related, *R. richardii* is reported as *R. richardii* - stictic acid, gyrophoric acid or both; *R. polycarpum* - stictic acid or none (Timdal &

Holten-Hartwig 1988). However, Mackenzie-Lamb (1940) cites a collection from Somerset with a C+ red thallus and K+ purple epihymenium (i.e. *R. polycarpum* with gyrophoric acid) and I have also collected similar specimens from Glen Coe. These apparant intermediates reduce the distinction between the two species considerably but they are here retained as distinct (separated by the K+ purple exciple of *R. polycarpon*) pending a more critical investigation of this group.

Two further collections from maritime rocks (Islay and Harris) have dark ascospores, a K+ purple epihymenium and contain stictic and gyrophoric acid (i.e. *R. richardii* with a K+ purple epihymenium). Although Laundon (1986) has shown that spore colour is very variable in *R. richardii* these are here provisionally referred to a distinct species, *R. 'subgrande'* ad int. (see below).

R. postumum The single British gathering of this species mentioned in Purvis *et al.* (1992) is referable elsewhere; possibly to an apparently undescribed species known from two other collections, also from Ben Lawers (cf. Gilbert *et al.* 1988 - as *Rhizocarpon* sp. 'A'). However there are two specimens of *R. postumum* in BM, from Ben Lawers (Holl 1886) and Caithness (Willey 1905) and I have also collected this species more recently in West Sutherland. The type collection (in H-NYL) is also from Scotland but unlocalised.

***R. reductum* Fr.** Resurrected from synonymy. This entity has usually been called *R. obscuratum*. (see note under that name). It is a colonizing species of siliceous rocks in upland areas, being absent from high altitudes in the Scottish Highlands (where it appears to be replaced by *R. 'sublavatum'*, see below). It does, however, reach high altitudes in North Wales, including the area of longest snow-lie on Carnedd Llewelyn, where *R. 'sublavatum'* is unknown.

The only recent work to recognise *R. reductum* as a distinct species is Foucard (1990) although he separates it from *R. obscuratum* on morphological characters.

R. richardii This is a species of maritime rocks, so was not studied. See note under *R.*

polycarpum.

R. simillimum - Very rare upland species. Not studied.

R. subgeminatum An upland species, so not studied. This species appears to be fairly frequent at low to intermediate altitudes in the Scottish Highlands where it usually occurs on the sloping upper sides of siliceous boulders. British specimens are reported as containing no lichen substances (Purvis *et al.* 1992). However, Timdal & Holten-Hartwig (1988) report four chemotypes among Scandinavian specimens, which are also morphologically and anatomically rather varied. The complex clearly warrants further study, particularly with reference to the K+ purple exciple which does not appear to have been mentioned in previous studies.

***R. 'subgrande'* ad int.** New to science. A species of maritime rocks so not studied. In habitat it is very similar to *R. richardii* from which it differs primarily in its dark ascospores and K+ purple epihymenium and exciple. It is also close to *R. grande* but differs in having 1-septate ascospores. It is known from only two collections, from maritime rocks on Islay and Harris (both in the Hebrides), but has probably been overlooked for *R. richardii.* On Harris it occurred on a vertical rock face several hundred metres from the shore.

***R. 'sublavatum'* ad int.** New to science. Often occurs with *R. lavatum* on damp, montane rocks. In this situation *R. lavatum* is often the host to lichenicolous fungi but *R. sublavatum* always remains uninfected. It most closely resembles *R. anaperum* and its separation from that species relies upon a number of small details. However both species often occur together when they remain morphologically distinct and easily separated.

In Coire Leis (Ben Nevis) *R. sublavatum* is the dominant species on loose rocks below a high cliff face. There are very few associated species and it appears probable that this is a colonizing species, replacing *R. reductum* in this role at high altitudes.

***R. submodestum* (Vainio) Vainio** New to the British Isles. Very rare so not studied. The species with 3-septate spores are poorly understood. Both British collections (Glas Moal and Aonach Mor) contain stictic acid. Feuerer (1991) included this species in *R. obscuratum.*

R. umbilicatum Primarily an upland species of strongly calcareous rocks so not studied.

2•3•2•4 - *Rimularia* Nyl.

Introduction

In the recently published *The Lichen Flora of Great Britain and Ireland* (Purvis *et al.* 1992) the only species included in *Rimularia* were *R. fuscosora* Muhr & Tønsberg and *R. limborina* Nyl. However, the subsequent *Checklist of the Lichens of Great Britain and Ireland* (Purvis *et al.* 1993) includes nine species; mainly as the result of recent taxonomic work (e.g. Hertel & Rambold 1990).

Two species in Purvis *et al.* (1992) - *Lecidea gyrizans* and *Mosigia illita* - were mentioned as having been recently transferred to *Rimularia* (the latter as *R. badioatra*) while two others, *Lecidea furvella* and *L. insularis*, had already been moved to the genus by Rambold & Hertel; although this placement was not universally accepted in the restricted sense of the genus then current. In Purvis *et al.* (1993) two further species were transferred; *Lecidea mullensis* - considered by Hertel & Rambold to be a chemical race of *R. gyrizans* - and *Mosigia intercedens* - which they considered to be the anamorph of *R. badioatra*.

Recent field work in Scotland has added a further species, *R. sphacelata*, to the British list, while a number of others have been found to be more frequent than previously reported.

The diagnostic feature of *Rimularia* is its distinctive ascus tip structure although it is most easily recognised microscopically by its richly branched, monilioid paraphyses. The apothecia of many members of the genus are umbonate or gyrose (e.g. *R. badioatra, R. mullensis, R sphacelata*) and this can be a useful character for field identification. The only other species in the family *Rimulariaceae* to occur in Britain is *Lithographa tesserata*, which can be distinguished by its sessile, lirelle-like apothecia. The genus is characteristically one of upland/montane siliceous rocks although the recently described *R. fuscosora* is epiphytic.

Key to the Species

1 On bark; discrete, punctiform soredia present .... ***R. fuscosora***

On rocks, bryophytes or other lichens; discrete soredia absent 2

2(1) Thallus C+ red (gyrophoric acid) 3

Thallus C- (gyrophoric acid absent) 5

3(2) Thallus dark brown-black, granular/scurfy, effuse with a leprose appearance. Usually lichenicolous .... ***R. furvella***

Thallus pink-brown, smooth. Directly on rock 4

4(3) Thallus with numerous papillae. Usually sterile .... ***R. intercedens***

Thallus without papillae. Usually fertile; apothecia innate, contorted/umbonate .... ***R. badioatra***

5(2) Thallus K+ red (norstictic acid) 6

Thallus K+yellow or K- (norstictic acid absent) 7

6(5) Overgrowing bryophytes on montane rocks. Thallus white, cracked-areolate. Apothecia round (except when distorted by compression) with thick, persistent proper exciple. Only known in the British Isles from one collection at >1000m (Aonach Mor, West Inverness) .... ***R. sphacelata***

On upland and montane, siliceous rocks and boulders. Thallus dark grey. Apothecia usually contorted, slit-like .... ***R. mullensis***

7(6) Lichenicolous lichen on *Lecanora rupicola*; usually maritime .... ***R. insularis***

Directly on rocks; upland 8

8(7) Thallus K+ yellow (stictic acid); apothecia 0.2-0.5 mm, innate; proper exciple thin;

spores 9-11 x 4.7-7 µm .... *R. gyrizans*

Thallus K- (stictic acid absent); apothecia 0.5-0.8 mm, sessile; proper exciple thick and cracked, spores 18-30 x 10-18µm .... *R. limborina*

Notes on the montane species.

R. badioatra - This species was previously placed in *Mosigia* (as *M. illita*) along with the closely related *R. intercedens*. They are characterized by their pinkish-brown, C+ red thallus and habitat of fine-grained, usually igneous, siliceous rock. Both are frequently found in mosaics but when growing alone *R. badioatra* usually forms small, discrete thalli whereas *R. intercedens* is typically more widespreading.

R. furvella - Locally frequent but easily overlooked for a dark stain on siliceous rocks and other lichens. Chemically variable.

R. gyrizans - Probably not rare on sunny, siliceous rocks throughout the Scottish Highlands (as well as North Wales) but easily overlooked. See *R. mullensis* below.

R. intercedens - See note under *R. badioatra* above. *R. intercedens* is known fertile in the British Isles from only two sites near Loch Hourn in N-W Scotland.

R. limborina - Uncommon species of upland/ontane siliceous rocks. Easily distinguished in the field by its distinctive gyrose-umbonate apothecia with a thick, cracked exciple.

R. mullensis - *R. mullensis* is closely related to *R. gyrizans* with which it often grows. It differs primarily in the presence of norstictic acid (K+ red, Pd+ yellow) in place of stictic acid (K+ yellow, Pd+ orange) although it can usually be separated in the field by its more slit-like apothecia and darker grey thallus formed of more convex areoles (Fig. 2•18).

R. mullensis is widely distributed throughout the highlands of Scotland (mostly above c. 500 m.) sometimes becoming frequent at high altitudes. There is one record from

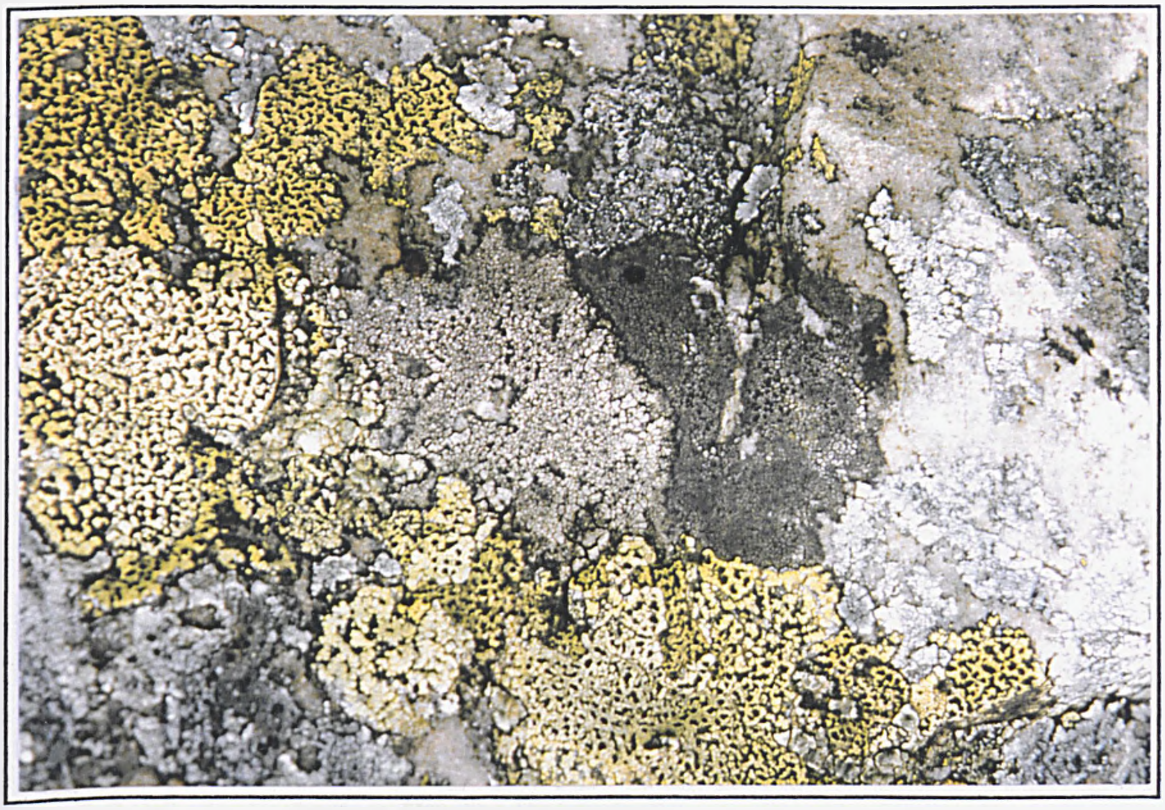

Figure 2·18. *Rimularia gyrizans* (left) and *R. mullensis* (right) growing together on exposed, sunny quartzite, at 800m on the southern side of Sgurr nam Fiannaidh, Aonach Eagach, Glen Coe, Argyll. (Magnification: x1.

Dartmoor and the species probably also occurs in the mountains of Northern England and Wales.

Both species occasionally have small patches of *Orphniospora moriopsis* growing on their thallus, apparently parasitically.

R. sphacelata - The only member of the genus present in the British Isles to grow over bryophytes in montane situations. It can be separated from other fertile bryicolous species with small simple spores by the presence of norstictic acid in the thallus (K+ red - acicular crystals in microscopic section).

CHAPTER 3

THE RESOURCE - ECOLOGY and DISTRIBUTION

3•1 The Resource
- 3•1•1 General Observations
- 3•1•2 List of montane species

3•2 Ecology and Distribution
- 3•2•1 Introduction
- 3•2•2 Ecology
- 3•2•3 Distribution
  - 3•2•3•1 Introduction
  - 3•2•3•2 Factors Affecting Distribution
- 3•2•4 Comparison of British Oceanic Montane Areas

3•1 THE RESOURCE

3•1•1 Introduction

The montane zone is, for reasons given in section 1•4•2•4, better defined on bio-geographical terms rather than on purely physical ones (i.e. by the plant communities present in an area rather than simply by its altitude). The criterion most often used in other parts of the world is the natural tree-line but in the British Isles the upland/sub-montane zone is so heavily modified by anthropogenic effects (primarily over-grazing) that this is difficult to determine. For practical reasons, therefore, the montane zone in the British Isles is considered to begin where prostrate *Calluna vulgaris* begins to dominate the vegetation. However, although this is a well-defined ecological distinction in the more continental, eastern Highlands it is far less widespread in more oceanic areas and, consequently, of less application in defining the start of the montane zone. It is probable that lichens identified as having a montane rather than an upland distribution in eastern areas can be used to characterize the montane zone in the west. Saxicolous species will probably be most appropriate for this as they are less affected by climatic conditions due to the more uniform nature of the substratum. Soil conditions in the east are far drier and better drained than in the west and, consequently, support a different lichen vegetation.

Previous studies (e.g. Gilbert & Fox 1985, 1986, Gilbert *et al* 1988, 1992, Gilbert & Giavarini 1993) have treated the montane zone as a single unit, although different habitats have usually been identified that support distinctive assemblages of lichens. This is refined here by dividing the montane flora into a number of zones. In continental Europe the montane zone is divided into sub-alpine *Betula* scrub and medium shrubs to low-alpine dwarf shrubs, middle-alpine grassland, moss and lichen heaths to high-alpine stone desert and finally to permanent snow and ice (Thompson & Brown 1992). This classification is adapted here for use in the British Isles (which generally lacks this clear-cut zonation due to the past effects of deforestation and more recent over-grazing). The definition of 'low-montane' is equivalent to 'low-alpine (i.e. dwarf shrubs) with anything above this being mid-montane, except for areas in the vicinity of prolonged snow-lie which are classified as high-montane, i.e.:-

a) **Upland/Low-montane** - Plants having the centre of their distribution in the upland zone (i.e. above the level of arable farming) but which also frequently occur in the montane zone (i.e. above the tree- line). Many of these species probably belong to the sub-montane zone but this is largely absent in the British isles (*cf.* section 1•4•2•4).

b) **Low-montane** - plants having the centre of their distribution above the tree-line but below the upper limit of ericaceous shrubs i.e. NVC Communities H19 *Vaccinium myrtillus/ Cladonia arbuscula* and H20 *V. myrtillus/ Racomitrium lanuginosum* (Rodwell, 1992)

c) **Mid-montane** - plants having the centre of their distribution above the level of ericaceous shrubs but below the permanent snow-line.

d) **High-montane** - plants having the centre of their distribution in areas affected by prolonged snow-lie.

These zones are considerably less definite in practice than they appear in theory and there is a substantial amount of overlap between one zone and another. Consequently, it is often impossible to place a species clearly in a particular zone.

The 'high-montane' zone is usually described as the area above mid-montane grassland, and moss and lichen heath which consists of stone desert and permanent ice and snow (Thompson & Brown 1992). This definition encompasses two very distinct habitats united by their lack of vascular plants; stone deserts tending to be associated with exposed summits and plateaux with permanent snow fields occurring in more sheltered situations. The vegetation in the vicinity of areas of prolonged snow-lie in the Scottish Highlands is very different from that of the surrounding mid-montane communities and this is sufficient justification for it to be treated separately. Whether it is true 'high-montane' vegetation is of lesser importance as this is the most appropriate name for it. The stone deserts of some of the highest summits in the Scottish Highlands, however, are probably best excluded from the 'high-montane' zone as the lichen communities they support are often very similar to those of exposed rock outcrops and boulder fields at lower altitudes. It is probable, in fact, that saxicolous species need to be considered separately from a system which was devised to classify terricolous, vascular plant vegetation. This would also solve the problem of the lichen assemblages in the vicinity of areas of prolonged snow-lie as the most characteristic of these are also saxicolous (*cf.* section 5•4•3•2).

In many instances in this chapter it has been necessary to make subjective, informed decisions as to which montane zone or distribution pattern is most appropriate for a particular species. This is necessary as lack of data regarding lichen distribution means that documented evidence is often mis-leading being based on unequal recording of different areas. However, in the majority of cases it is possible to discern general patterns.

3•1•2 List of Montane Species

The total resource of montane lichens (i.e. lichens which can be considered to have the centre of their British distribution in the montane zone) consists of some 287 taxa. These are listed in Table 3•1 in which they are arranged by the lowest montane zone in which they occur; 172 are centred on the low-montane, 103 on the mid-montane and 12 on the high-montane. There are also 105 taxa that regularly occur in both the upland and low-montane zones but which are rarely encountered at higher altitudes; these are listed separately in Table 3•2. This table does not include many common upland taxa which also occur, with less frequency, in the low-montane zone (e.g. *Fuscidea cyathoides, Porpidia crustulata, P. macrocarpa, P. tuberculosa, Protoparmelia badia*, etc.). This list is incomplete as the distinction between strictly upland species and those which also extend their range into the low-montane zone is not clear-cut and open to much discussion.

Species in parenthesis occur, with some regularity, in a non-montane/upland habitat (usually woodland or coastal) and in some cases this is their primary habitat. They are included in this Table 3•2 for one of two reasons:-

a) they are particularly frequent in montane areas, e.g. *Baeomyces rufus, Ochrolechia tartarea, Trapeliopsis gelatinosa*

b) they indicate a particular habitat, usually a calcareous substratum, (e.g. *Agonimia tristicula, Bacidia sabulatorum, Trapeliopsis wallrothii*).

In some cases e.g. *Pannaria pezizoides,* both reasons apply.

The number of species occurring in these zones decreases from low- to high-montane as the total area which the zones occupy decreases and the number of available habitats falls correspondingly.

Table 3•1. Montane Lichens Occurring in the British Isles.

KEY

Montane Zone

Low - Low-montane
Mid - Mid-montane
High - High-montane (Snow-bed)

Substratum Type

Sax - Saxicolous
Terr - Terricolous
Bry - Bryophilous
Lich - Lichenicolous
Fluv - Fluvial (In streams or lakes)

Substratum Base Status

Acid - Acidic
Int - Intemediate
Calc - Calcareous

Rarity

Red Data Category

Ext - Extinct
End - Endangered
Vuln - Vulnerable
DD - Data Deficient

Other Categories

Rare - rare species
VRare - very rare species
New-S - New to Science
New-B - New to the British Isles

Taxon	**Zone**	**Substratum**	**Base Status**	**Rarity**
Low-Montane (172 taxa)				
Acarospora badiofusca	Low	Sax	Calc	Rare
A. rhizobola	Low/Mid	Sax	Calc	Vuln
Alectoria nigricans	Low(Mid)	Terr	Acid	
A. ochroleuca	Low	Terr	Acid	Vuln
A. sarmentosa subsp. *vexillifera*	Low	Terr	Acid	Rare
Amygdalaria consentiens	Low/Mid	Sax	Acid	Rare
Arthonia myriocarpalla	Low	Sax	Calc	DD
Arthrorhaphis alpina	Low/Mid	Sax/Terr	Acid	Rare
A. muddii (syn. *A. fuscireagens*)	Low/Mid	Lich(Terr)	Acid	Rare
A. vacillans	Low	Terr	Int.	New-B
Aspicilia melanaspis	Low	Fluv(Sax)	Int.	Vuln
A. recedens	Low	Fluv(Sax)	Acid	DD
Bacidia herbarum	Low	Bry(Sax)	Calc	Vuln
Baeomyces placophyllus	Low	Terr	Acid	
Belonia calcicola	Low	Sax	Calc	DD
B. russula	Low(Mid)	Sax	Calc	Rare
Brigantiaea fuscolutea	Low	Bry	Calc	Rare
Bryoria chalybeiformis	Low	Sax/Bry	Acid	
Caloplaca approximata	Low/Mid	Sax	Calc	Rare
(*C. concilians*)	Low	Sax	Calc	DD

C. obliterans	Low	Sax	Int	
(*Catapyrenium cinereum*)	Low/Mid	Terr	Calc	Rare
C. daedaleum	Low	Terr	Calc	Rare
C. lachneum	Low	Terr	Calc	
Catillaria modesta	Low	Sax	Calc	Vuln
C. picila	Low	Sax	Calc	Ext
C. gilbertii	Low	Sax	Calc	New-S
Cecidonia umbonella	Low/Mid	Lich(Sax)	Acid	
Cetraria nivalis	Low	Terr	Acid	
Cladonia macrophylla	Low	Sax/Terr	Acid	
C. pleurota	Low/Mid	Terr	Acid	DD
(*C. symphicarpa*)	Low	Sax	Calc	
(*C. zopfii*)	Low	Terr	Acid	
Clauzadeana macula	Low	Sax	Acid	
Coccotrema citrinescens	Low	Sax	Acid	
Collema callopismum	Low	Sax	Calc	DD
C. ceraniscum	Low/Mid	Bry	Calc	V
C. parvum	Low	Sax	Calc	Vuln
Cornicularia normoerica	Low/Mid	Sax	Acid	
Dermatocarpon arnoldianum	Low	Fluv(Sax)	Acid/Int	DD
D. deminuens	Low	Fluv'Sax)	Acid/Int	New-B
D. intestiniforme	Low	Fluv(Sax)	Calc	
D. leptophyllodes	Low	Fluv(Sax)	Calc	DD
D. meiophyllizum	Low	Fluv(Sax)	Calc	
D. rivulorum	Low	Fluv(Sax)	Acid/Int	DD
Epigloea medioincrassata	Low	Bry	Acid	
Euopsis granatina	Low/Mid	Sax	Acid/Int	Rare
Fuscidea intercincta	Low	Sax	Acid	
F. kochiana	Low	Sax	Acid	
F. 'poeltii ad int.'	Low/Mid	Sax	Acid	New-S
Gyalecta foveolaris	Low	Bry	Calc	Rare
G. geoica	Low	Bry	Calc	Rare
Gyalidea fritzei	Low	Sax	Calc	Rare
Gyalideopsis scotica	Low/Mid	Bry(Terr)	Calc	Rare
Halecania rhypodiza	Low	Sax	Calc	Vuln
H. micacea	Low	Sax	Calc	New-S
Ionaspis cyanocarpa	Low	(Fluv)Sax	Acid	Rare
I. heteromorpha	Low	Sax	Calc	Vuln
I. melanocarpa	Low	Sax	Calc	Vuln

I. odora	Low/Mid/High	Sax	Acid	
I. suaveolens	Low/Mid/High	Sax	Acid	
Japewia tornoënsis	Low	Bry	Calc	Vuln
Koerberiella wimmeriana	Low	Sax	Calc	Rare
Lecanactis abscondita	Low	Sax	Calc	Rare
Lecanora achariana	Low	Fluv(Sax)	Int	End
L. atromarginata	Low/Mid	Sax	Calc	Vuln
L. atrosulphurea	Low/Mid	Sax	Acid	Rare
L. chlorophaeodes	Low/Mid	Sax	Acid	Rare
L. epibryon	Low/Mid	Bry	Calc	Vuln
L. paupercula	Low/Mid	Sax	Acid	
L. promiscens	Low/Mid	Sax	Acid	New-B
L. promiscua	Low/Mid	Sax	Acid	New-B
L. pycnocarpa	Low/Mid	Sax	Acid	
L. aff. *paupercula*	Low	Sax	Acid	New-S
Lecidella aff. *asema*	Low	Sax	Acid	New-S
Lempholemma intricatum	Low	Sax	Calc	Rare
L. radiatum	Low	Sax	Calc	Rare
aff. *L. isidioides*	Low	Sax	Calc	New-S
Lepraria cacuminum	Low/Mid	Bry(Sax)	Acid	
Lithographa tesserata	Low	Sax	Acid	
Lopadium coralloideum	Low/Mid	Bry	Calc	Rare
Megaspora verrucosa	Low/Mid	Bry/Terr	Calc	Rare
Melanelia commixta	Low/Mid	Sax	Acid	
M. hepatizon	Low/Mid	Sax	Acid	
Miriquidica complanata	Low	Sax	Acid	
(*Mniacea nivea*)	Low	Bry	Calc	DD
Ochrolechia frigida	Low(Mid)	Terr	Acid	
O. xanthostoma	Low	*Calluna*	Acid	
Omphalina luteovitellina	Low	Terr	Acid	
Orphniospora moriopsis	Low	Sax	Acid	
Pannaria hookeri	Low	Sax	Calc	Rare
(*P. pezizoides*)	Low/Mid	Bry(Terr)	Int/Calc	Rare
P. praetermissa	Low/Mid	Bry	Calc	VRare
Parmelia incurva	Low	Sax	Acid	
Peltigera elisabethae	Low/Mid	Bry	Calc	Rare
P. venosa	Low	Bry	Calc	Vuln
Pertusaria amarescens	Low	Sax	Calc	Rare
P. flavicans	Low	Sax	Int	

P. flavocorallina	Low	Sax	Calc	DD
P. geminipara	Low/Mid	Bry	Acid	DD
Phaeophyscia endococcina	Low	Fluv(Sax)	Acid	Vuln
P. sciastra	Low	Fluv(Sax)	Calc	Rare
Pilophorus strumaticus	Low	Sax	Acid	
Placynthium asperellum	Low	Sax	Calc	Rare
P. flabellosum	Low	Fluv(Sax)	Acid	
P. pannariellum	Low	Sax	Calc	Rare
P. pluriseptatum	Low	Sax	Calc	DD
Platismatia norvegica	Low	Sax/Terr	Acid	
Polyblastia cupularis	Low	Sax	Calc	
P. effllorescens	Low	Sax	Calc	
P. inumbrata	Low	Sax	Calc	
P. melaspora	Low	Sax	Calc	
P. theleodes	Low	Sax	Calc	
P. verrucosa	Low	Sax	Calc	DD
P. wheldonii	Low(Mid)	Bry/Sax/Terr	Int/Calc	
Polysporina cyclocarpa	Low	Sax	Calc	DD
Porina mamillosa	Low	Bry	Calc	Rare
Porocyphus rhemicus	Low	Sax	Calc	DD
Porpidia ochrolemma	Low	Sax(?Fluv)	Acid	New-B
P. superba	Low	Sax	Calc	
'*f. sorediata*' ad int.	Low	Sax	Calc	New-S
P. zeoroides	Low	Sax	Calc	New-B
Protoblastenia siebenhaariana	Low	Sax	Calc	Rare
Pseudephebe minuscula	Low/Mid	Sax	Acid	New-B
Psora decipiens	Low	Terr	Calc	
P. globifera	Low	Sax	Calc	End
P. rubifomls	Low	Sax	Calc	Vun
Pyrenocollema bryospilum	Low	Bry(Terr)	Int	
P. caesium	Low	Sax	Calc	Rare
Pyrenopsis furfuracea	Low	Sax	Calc	DD
P. grumulifera	Low	Sax	Calc	Rare
P. impolita	Low	Sax	Acid	
P. phylliscella	Low	Sax	Acid	Rare
P. subareolata	Low	Sax	Acid	
Rhizocarpon badioatrum	Low	Sax(Fluv)	Acid	
R. caeruleoalbum	Low	Sax	Calc	DD
R. chioneum	Low	Sax	Calc	DD

(*R.* aff. *cinereovirens*)	Low/Mid	Sax	Acid	
R. copelandii	Low(Mid)	Sax	Acid	
R. inarense	Low	Sax	Acid	DD
R. intermediellum	Low	Sax	Acid	DD
R. lavatum	Low/Mid/High	Sax	Acid	
R. polycarpum	Low/Mid	Sax	Acid	
R. postumum	Low	Sax	Acid	DD
R. superficiale	Low	Sax	Acid	
Rimularia limborina	Low	Sax	Acid	
(*Rinodina confragosa*)	Low	Sax	Acid	
R. parasitica	Low	Lich(Sax)	Acid(Int)	DD
Ropalospora lugubris	Low	Sax	Acid	
'subsp. *sorediata*' ad int.	Low/Mid	Sax	Acid	New-S
Sagiolechia rhexoblephara	Low/Mid	Bry	Calc	Rare
S. protuberans	Low	Sax	Calc	Rare
Solorina bispora	Low/Mid	Terr	Calc	Rare
Spilonema paradoxum	Low	Sax	Calc	Rare
S. revertens	Low	Sax	Calc	Rare
Staurothele succedens	Low	Sax	Calc	
Stereocaulon condensatum	Low(Mid)	Terr	Acid	
(*S. leucophaeopsis*)	Low/Mid	Sax	Acid	
Strigula stigmatella v. *alpestris*	Low	Bry	Calc	Rare
Thelidium aeneovinosum	Low	Fluv(Sax)	Acid(Int)	Rare
T. fumidum	Low	Sax	Calc	Rare
T. papulare f. *sorediatum*	Low	Sax	Calc	Rare
Thermutis velutina	Low	Fluv(Sax)	Acid(Int)	Rare
Toninia rosulata	Low	Sax	Calc	End
T. squalida	Low	Sax/Bry	Calc	Rare
Trapelia mooreana	Low/Mid	Sax	Acid	
Trimmatothele cf. *perquisita*	Low/Mid	Sax	Calc	DD
Umbilicaria hyperborea	Low/Mid	Sax	Acid	Rare
U. proboscidea	Low/Mid	Sax	Acid	
U. torrefacta	Low/Mid	Sax	Acid	
Verrucaria margacea	Low/High	Fluv(Sax)	Acid	
Vestergrenopsis elaeina	Low/Mid	Sax	Calc/Int	Vuln

Taxon	Zone	Substratum	Base Status	Rarity
Mid-Montane Taxa (103)				
Adelolecia pilati ' subsp. *pachythallina*' ad int.	Mid	Sax	Acid	New-S
Allantoparmelia alpicola	Mid	Sax	Acid	
'*Amelia grisea*' ad int.	Mid/High	Bry(Terr)	Acid	New-S
(*Arctomia delicatula*)	Mid	Terr	Calc	DD
Biatora carneoalbida	Mid	Bry	Calc	VRare
B. cuprea	Mid	Bry	Calc	Ext
B. tetramera	Mid	Bry	Calc	DD
(*B. vernalis*)	Mid	Bry(Terr)	(Int)Calc	Rare
Biatorella hemisphaerica	Mid	Bry	Calc	Vuln
Bryonora curvescens	Mid	Bry	Acid(Int)	Vuln
Bryoria nitidula	Mid	Terr	Acid	Ext
Buellia insignis	Mid	Bry(Terr)	Calc	Vuln
B. papillata	Mid	Bry(Terr)	Calc	New-B
Caloplaca cinnomomea	Mid	Bry	Calc	End
C. nivalis	Mid	Bry(Sax)	Int	End
Catapyrenium waltheri	Mid	Terr	Calc	DD
Catillaria contristans	Mid/High	Terr	Acid	
Catolechia wahlenbergii	Mid	Bry(Sax)	Acid	Vuln
Cecidonia xenophana	Mid/High	Lich(Sax)	Acid	
Cetraria ericetorum	Mid	Terr	Acid	
Cetrariella delisei	Mid	Terr	Acid	Rare
Chromatochlamys '*geislerioides*' ad int.	Mid	Terr	Acid	New-S
Cladonia bellidiflora	Mid/High	Terr	Acid	
C. coccifera s.str.	Mid	Terr	Acid	Rare
C. maxima	Mid/High	Terr	Acid	Vuln
Euopsis pulvinata	Mid/High	Sax/Bry	Acid	
Frutidella caesioatra	Mid/High	Terr/Sax(Bry)	Acid	
Fulgensia bracteata	Mid	Terr	Calc	Vuln
Gyalidea diaphana	Mid/High	Fluv(Sax)	Acid	DD
Halecania alpivega	(Low)Mid	Sax	Calc	Vuln
H. bryophila	Mid	Bry(Sax)	Calc	New-S
Hypogymnia intestiniforme	Mid	Sax	Acid	End
Lecanora frustulosa	Mid	Sax	Calc	Vuln

L. marginata subsp. *elata*	Mid	Sax	Acid/Int	New-B
Lecidea berengeriana	Mid	Bry(Terr)	(Acid)Calc	Rare
L. hypnorum	Mid/High	Bry(Terr)	(Acid)Calc	Rare
L. limosa	Mid/High	Terr	Acid	
L. luteoatra	Mid	Sax	Acid	New-B
L. syncarpa	Mid	Sax	Acid	New-B
Lecidella patavina	Mid	Sax	Int	New-B
L. wulfenii	Mid	Bry(Sax)	Calc	Vuln
Lecidoma demissum	Mid	Terr	Acid	
Lepraria neglecta	Mid/High	Bry	Acid	
Lopadium pezizoideum	Mid	Bry	Calc	Rare
Melaspilea sp.	Mid	Sax	Acid	New-S
Micarea assimilata	Mid	Bry(Terr)	Acid(Int)	VRare
M. cinerea (anamorph)	Mid/High	Terr	Acid	
M. crassipes	Mid	Bry	Acid(Int)	Vuln
(*M. marginata* (anamorph))	Mid	Sax	Acid	Rare
M. incrassata	Mid	Bry(Terr)	Acid(Int)	Rare
M. submilliaria	Mid	Bry	Acid	
M. turfosa	Mid/High	Terr	Acid	
M. viridiatra	Mid/High	Terr	Acid	
Miriquidica liljenstroemii	Mid	Sax	Acid	New-B
M. lulensis	Mid	Sax	Acid	Rare
M. nigroleprosa	Mid	Sax	Acid	
Nephroma arcticum	Mid	Terr	Acid(Int)	End
Parmelia stygia	Mid	Sax	Acid	
Peltigera scabrosa	Mid	Terr	Acid	Vuln
Pertusaria bryontha	Mid	Bry	Calc	End
P. dactylina	Mid	Sax/Terr	Acid	
P. glomerata	Mid	Bry	Calc	Vuln
P. oculata	Mid	Sax/Terr	Acid	
Placidiopsis pseudocinerea	Mid	Terr	Calc	DD
Polyblastia gothica	Mid/High	Bry(Terr)	Acid	DD
P. helvetica	Mid	Bry(Terr)	Acid	DD
P. sendtneri	Mid	Bry	Calc	Vuln
P. terrestris	Mid	Sax/Bry	Int/Calc	Rare
Porpidia 'confluenta' ad int.	Mid	Sax	Acid	New-S
P. contraponenda	(Low)Mid/High		Sax	Acid
P. 'striata' ad int.	Mid	Sax	Acid	New-S
Protothelenella corrosa	Mid/High	Sax	Acid	

P. sphinctrinoidella	Mid/High	Bry(Terr)	Acid	
P. sphinctrinoides	Mid/High	Bry(Terr)	Acid	
Psuedephebe pubescens	Mid	Sax	Acid	
Rhizocarpon alpicola	Mid	Sax	Acid	
(*R. anaperum*)	Mid	Sax	Acid	New-B
R. '*colludens* subsp. *rufoatrum*' ad int.	Mid/High	Sax	Acid	New-S
R. ?cyclodes	Mid	Sax	Acid	
R. eupetraeoides	Mid	Sax	Acid	
R. expallescens	Mid	Sax	Calc	VRare
R. '*sublavatum*' ad int.	Mid/High	Sax	Acid	New-S
R. submodestum	Mid(High)	Sax	Acid	New-B
Rimularia sphacelata	Mid	Bry	Acid	DD
Rinodina mniaraea v. *cinnamomea*	Mid	Terr	Calc	End
Schadonia fecunda	Mid	Bry(Terr)	Calc	Vuln
Solorina crocea	Mid	Terr	Acid	
Sporastatia polyspora	Mid	Sax	Acid	Rare
S. testudinea	Mid	Sax	Acid	VRare
Staurothele arctica	Mid	Sax	Acid	DD
S. areolata	Mid(High)	Fluv(Sax)	Acid	Vuln
Stereocaulon alpinum	Mid	Terr	Acid	Rare
S. plicatile	Mid(High)	Sax	Acid	Rare
S. saxatile	Mid(High)	Sax	Acid	
S. spathuliferum	Mid	Sax	Acid	Rare
S. tornense	Mid(High)	Sax	Acid	
Tephromela armeniaca	Mid	Sax	Acid	Rare
Thamnolia vermicularis	Mid	Terr	Acid	
(*Thelidium minutulum*)	Mid	Terr	Acid	
Thelopsis melathelia	Mid	Bry(Sax)	Calc	Rare
Toninia coelestina	Mid	Sax	Calc	Vuln
T. cumulata	Mid	Sax	Calc	Vuln
T. fusispora	Mid	Sax	Calc	Rare

Taxon	Zone	Substratum	Base Status	Rarity
High-Montane taxa (12)				
'Amelia andraeaeicola' ad int.	High	Bry(Sax)	Acid	New-S
Bellemerea alpina	High	Sax	Acid	End
Cladonia phyllophora	High	Bry(Terr)	Acid	Rare
C. stricta	High	Terr	Acid	Vuln
Lecanora leptacina	High	Bry(Sax)	Acid	Rare
Lecidella bullata	High	Sax	Acid	Rare
Micarea marginata	High	Sax	Acid	Rare
M. paratropa	(Mid)High	Sax	Acid	
Miriquidica griseoatra	High	Sax	Acid	Rare
Rhizocarpon cinereonigrum	High	Sax	Acid	New-B
R. jemtlandicum	High	Sax	Acid	Rare
Toninia squalescens	(Mid)High	Bry(Sax)	Acid	
TOTAL MONTANE TAXA 287				

Table 3-2. Upland/Low-montane lichens Occurring in the British Isles.

Absconditella sphagnorum
Agonimia tristicula
Amygdelaria pelobotryon
Bacidia sabulatorum
Baeomyces rufus
Belonia incamata
Bryophagus gloeocapsa
Bryoria bicolor
B. fuscescens
B. nadvimikiana
Buellia leptocline
B. uberior
Caloplaca flavovirescens
C. cf. *vitellinula*
Carbonea vorticosa
Catillaria scotinodes
Cetraria aculeata
Chromatochlamys 'confusum' ad int.
Cladonia arbuscula
C. ciliaris
  var. *tenuis*
C. coccifera aggr.
C. cyathomorpha
C. deformis
C. fragilissima
C. luteoalba
C. metacorallifera
C. rangiferina
C. strepsilis
C. sulphurina
C. uncialis
Claurouxia chalybeioides
Collema dichotomum
C. flaccidum
C. glebulentum
Dibaeis baeomyces
Ephebe hispidula
E. lanata
Fuscidea austera
F. mollis
F. praeruptorum
F. recensa
Gyalidea hyalinescens
Lecanora cenisia
Lecidea auriculata
L. commaculans
L. confluens
L. diducens
L. inops
L. lapicida
L. pycnocarpa f. *sorediata*
L. siderolithica
L. phaeops
?Lemmopsis sp.
Lempholemma botryosum
L. cladodes
Lepraria caesioalba
Massalongia camosa
Micarea peliocarpa
Mniacea jungermanniae
Ochrolechia inaequatula
O. tartarea
  'f. sorediata' ad int.
Peltigera leucophlebia
Pertusaria lactescens
Placopsis gelida s. lat.
Placynthium tantaleum
Polyblastia gelatinosa
Porina guentheri
  var. *lucens*
P. intergungens
Porocyphus coccodes
P. kenmorensis
Porpidia flavicunda

P. glaucophaea
P. melinodes
P. speirea
Protoparmelia picea
Pterygiopsis coracodiza
Pyrenocollema strontianense
Rhizocarpon 'caesium' ad int.
R. 'colludens' ad int.
R. geographicum
R. petraeum
R. simillimum
R. umbilicatum
Rimularia badioatrum
R. gyrizans
R. intercedens
R. mullensis
Rinodina fimbriata
R. interpolita
Stereocaulon vesuvianum
Tephromela aglaea
T. pertusarioides
Thelidium papulare
T. pluvium
T. pyrenophorum
Toninia lobulata
T. thiopsora
Trapelia obtegens
Trapeliopsis gelatinosa
T. wallrothii
Umbilicaria crustulosa
U. cylindrica
U. deusta

TOTAL UPLAND/LOW-MONTANE TAXA: 105

3•2 ECOLOGY AND DISTRIBUTION

3•2•1 Introduction

When considering the distribution and ecology of montane lichens it is important to bear in mind the statement of Barry (1992) quoted in section 1•4•2, 'Local contrasts of slope angle and orientation give rise to such large variations in local climatic conditions that it seems doubtful whether the concept of a 'regional mountain climate' has much validity or value. It is more meaningful to describe the typical range of climatic elements produced in particular topographic situations according to the type of air-flows that occur, bearing in mind the major controls of altitude, latitude and continental location.'

In this study 'distribution' is taken to be the effects of Barry's 'three controls' whereas 'ecology' is the effects of the 'particular topographic situations'. This is an artificial distinction as distribution patterns are created by species favouring the different ecological conditions created by altitude, latitude and continental location. The other major factor which affects distribution, geology and in particular the base status of the substratum, confirms this as it is clearly an ecological control but has a significant effect on lichen distribution.

3•2•2 Ecology

It is impossible to over-emphasize the importance of micro-environment in lichen ecology. Lichens do not have the nutrient-absorbing root system of vascular plants and, consequently, have a more intimate relationship with their immediate environment The very precise environmental requirements of many lichens means that minor changes in the habitat, i.e. a slight depression in a rock surface or a seepage track, results in a completely different lichen community. This makes them excellent indicators of micro-environments.

The ecological factors affecting the small-scale habitat preferences of lichens are numerous, poorly understood and little studied. They are the province of the physiological ecologist (Kershaw 1985) so are largely outside the scope of this study although some are dealt with to a limited extent here and in Chapter 4.

Measuring the environment of these micro-communities is extremely difficult, consequently, the relationship between changes in environmental conditions and lichen communities is not fully understood. Standard meteorological measurments are made 1-2 metres above the ground where conditions are often vastly different from the actual operating environment of the lichen. The thermal properties of the boundary layer result in thallus temperatures of lichens that grow entirely within this zone being considerably higher than standard meteorological measurements would suggest. These higher thallus temperatures are little affected by latitude or elevation, and arctic or alpine crustose or adpressed foliose lichens in the boundary layer will commonly experience thallus temperatures which are more typical of lowland temperate or tropical air temperatures. Secondary modifications of thallus temperature can further be induced by dark cortical pigmentation, effectively lowering the thallus albedo, and elevating thallus temperature. This appears to be an effective means of maximizing carbon assimilation during snow-melt conditions in arctic and alpine species (Kershaw, 1983). A dissected thallus will also aid water uptake, as this is directly related to the area/weight ratio of the lichen thallus, and the sooner the lichen will be able to commence metabolising.

The net optimal temperature for photosynthetic rate of arctic lichens is not necessarily lower than that of tropical ones. It also depends on the micro-climate of the lichen (boundary-layer effect etc.) and the temperature at the time when the lichen will be metabolically active, i.e. when moist. Most lichens can survive extended periods of both high and low temperatures when in the dry state, although this may vary between species and usually depends upon the normal operating conditions of the lichen. However, resistance when wet is far lower and there is also more variability within individual species depending on the time of year. The ability of lichens to lose water rapidly is therefore important for survival in montane environments where the operating temperature of the lichen is liable to rapid change. The ability to take up water rapidly is also important as it enables lichens to take quick advantage of favourable conditions which may be short-lived in the unstable environment that exists in these areas. This ability of lichens is one reason why they form a large percentage of the vegetation in montane environments.

The evolution of an effective lichen thallus appears to be a compromise between the provision of an efficient moisture-holding structure for the normally aquatic algal component, and one which does not at the same time limit free gas exchange (Kershaw, 1985). In general, species with a low optimal thallus saturation level for maximum net photosynthesis tend to inhabit xeric environments while those which show little decrease in photosynthetic rate with increased thallus hydration inhabit more mesic ones. However, this can be modified by thallus structure and morphology (tomentum, finely divided thallus, gelatinous thallus, cyphellae/cortical cracks etc.) so that species with widely differing ecological requirements have a similar photosynthetic response curve with increasing thallus hydration. Lichens differ widely in response to extremes of thallus hydration. *Rhizocarpon geographicum* is killed by 2-3 days immersion in water but can survive total desiccation for prolonged periods whereas *Verrucaria elaeomeleana* (?*funkii*) can survive prolonged periods of total immersion but is soon killed by desiccation.

Nitrogen-fixation by cyanobacteria depends upon a number of environmental factors causing large seasonal and diurnal fluctuations. The most critical of these is illumination but this is required only at a relatively low level and provided this is satisfied then thallus hydration has the most effect on the rate of nitrogenase activity. Significantly, cephalodia are invariably dark coloured as are many lichens with cyanobacteria as photobiont (e.g. *Collema, Leptogium, Placynthium*). Temperature has little direct effect but, as it affects evaporation, it has an effect on thallus hydration and thus on the rate of nitrogen fixation. Bright sunshine is not required but cover by snow will stop nitrogenase activity. Consequently, lichens containing cyanobacteria, either as their main photobiont or in cephalodia, will inhabit damp but well illuminated habitats. Of the 29 species identified by Gilbert *et al.* (1992) as Character or Selective snow bed species none have cyanobacteria as their main photobiont and only two, *Solorina crocea* and *Stereocaulon spathuliferum*, contain cephalodia (although two other, *Micarea paratropa* (as *M. subviolascens*) and *Stereocaulon tornense* are usually associated with colonies of cyanobacteria).

An example of the effects of small scale environmental changes, and of 'particular topographic situations', on lichen distribution is shown by the stratification of lichens on the near-vertical, south-west facing (windward) sides of low granite boulders on the summit of south-west facing (windward) sides of low granite boulders on the summit of Cairngorm (Fig. 3•1).

Figure 3•1. S-W face of boulder near summit of Cairngorm showing lichen zonation; bare rock lowest zone, dark *Umbilicaria torrefacta* zone, yellow-green *Rhizocarpon* zone and upper zone dominated by pale-grey *Umbilicaria cylindrica*, *Lecidea* and *Porpidia* species.

The part of these boulders closest to the ground is completely devoid of lichen growth, above this is an area dominated by the dark-grey/black thalli of the foliose lichen *Umbilicaria torrefacta* followed by a broad yellow/green band of *Rhizocarpon* subgenus *Rhizocarpon* species,while the sub-apical slope and brow of the boulders are dominated by the pale-grey thalli of *Umbilicaria cylindrica* and species of *Lecidea* and *Porpidia*. These boulders are rarely more than 0.5m high and those that exceed this height do not support this distinctive stratification.

The environment in which these boulders occur is particularly harsh, with frequent very strong winds (Dybeck & Green 1955; McClatchey 1996) so although the area is over 1200m altitude it is largely swept clear of snow for much of the winter and exposed to the severe abrading effects of air-borne granite gravel which covers much of the surrounding plateau. Wind speeds near the ground are much lower than those recorded even at 1m (Warren Wilson 1959; Gieger 1966) and the large number of low boulders in this area will further disrupt the air-flow. It is, therefore, likely that a small wedge of snow will accumulate for some considerable time against the lower parts of these boulders and this, together with the strong abrading effect of gravel caught in the pockets between the boulders, will result in the absence of lichens from the lowest zone. Warren Wilson (1959) showed that the highest wind speeds occur on the brow of an obstruction; consequently, this will be the first area swept clear of snow. However, it was reported by Larson & Kershaw (1975) that in a lichen-heath characterized by a system of shallow ridges and trenches the pale thalli of *Cetraria nivalis* and *Cladonia alpestris* tended to occupy the trenches, where the snow would lie longest, while the dark coloured thalli of *Bryocaulon divergens* and *Bryoria nitidula* favoured the ridges, which would sooner be swept clear of snow (although the pale coloured *Alectoria ochroleuca* also favoured ridge tops). They hypothesised that *Bryoria nitidula* was restricted to ridge tops as, in order to achieve a net yearly carbon balance, it needed to photosynthesise during the cool temperatures of spring in order to offset the net respiratory losses in the higher temperatures later in the year. They also noted that the dark pigments produced by the thalli of *Bryoria nitidula* absorb heat from the incident insolation and form 'melt-holes' in the snow allowing the lichens to photosynthesise earlier than would a pale species in a similar position. Pale coloured lichens are not as seriously affected by high summer temperatures and are able to tolerate the shorter growing season caused by prolonged snow-cover in the hollows.

It would appear that the situation on Cairn Gorm is the reverse of this with the darkest lichens at the bottom of the zonation. However, dark thallus pigmentation is of value in melting a thin layer of snow and, given the regularity of high wind speeds on the summit of Cairn Gorm, this is probably all that will be present. It is possible, therefore, that restriction of light penetration due to prolonged snow cover, with a consequent shortening of the growing season, is responsible for this lichen zonation. However, it is interesting to note that the colour zonation - dark, green, grey - is similar to the better known - black, orange, grey - found on south-facing sea shores (Ferry & Sheard 1969; Fletcher 1973a & b), although completely unrelated species are involved. No satisfactory explanation has been advanced for the zonation on rocky shores but it is possible that the dark colouration of the lichens at the lowest level of both stratifications is an adaption to damp conditions, either from periodic immersion in water or prolonged exposure to snow.

The presence of the *Rhizocarpon* species in an intermediate position is probably a response to the elevated levels of ultra-violet radiation which occur at high altitiudes. The yellow-green colouration of these lichens is due to the presence of rhizocarpic acid in the thallus, a chemical which is usually considered to give the plant some protection against ultra-violet (UV) radiation (Galloway 1993; Rikkinen 1995). Protection from UV is required more by lichens growing on the south-west sides of boulders than those growing on the tops as the former will still be damp and photosynthetically active during the hottest part of the day when insolation levels are highest. Lichens occurring on the tops of the boulders will be able to survive without such protection as they will be dehydrated and dormant at this time.

Other examples of the micro-ecology of lichens are given in the Appendix where the precise ecological niches occupied by two very rare montane lichens are described in detail.

3•2•3 Distribution

3•2•3•1 Introduction

Distribution patterns of montane lichens are usually illustrated by 'dot maps'. These show the areas (usually 10 km squares) from which a particular taxon has been recorded but not its relative abundance or its habitat which can result in a distorted picture. This problem is greatest with rare or very common species, as with taxa having an intermediate frequency the spread of records alone is usually sufficient to represent the true distribution. Where a taxon has been recorded from only a few squares or, alternatively, from almost every one then its relative abundance within those squares and the ecological niche it inhabits becomes important in determining its distributional tendency. This is illustrated by the maps of *Miriquidica nigroleprosa* and *Orphniospora moriopsis* (Fig. 3•2) both of which show scattered distributions throughout the Scottish Highlands with no oceanic or continental bias. In fact, both species are frequent in the Cairngorm mountains but extremely rare elsewhere and, consequently, have a distinctly continental distribution. Similarly the map for *Rhizocarpon caesium* ad int. (Fig. 2•11) shows an oceanic distribution with three outliers further east. What it does not show is that the oceanic records are from dry, slightly basic rocks whereas those from further east are from semi-inundated, siliceous rocks.

In spite of these disadvantages 'dot maps' are still the best, readily available, indication of species distribution and are used to illustrate various distribution patterns in the following discussion although, for the reasons given above, rare or very common species are generally avoided.

3•2•3•2 Factors Affecting Distribution

Barry's 'three controls' were also identified by Brown *et al.* (1993) as explaining most of the variation in plant community distribution throughout the Scottish Uplands. Using canonical correspondence analysis (CCA) they found that oceanicity was the most important of the three, followed by altitude and then latitude. Although, in reality, it is difficult to separate the effects of the three factors as they are all interconnected, and the resulting distribution pattern is often a cumulative result of effects from various sources, this is the order in which they will be discussed here.

Oceanicity - It is unrealistic to expect lichens to show clear cut-distribution patterns in an area as small as the British Isles. The range of habitats is such that, for instance, the flat summit plateau of Aonach Mor in the western Highlands supports a comparatively 'continental' vegetation whereas the coire on the northern side of Glas Maol, on the East-Perthshire/South Aberdeenshire border, has a distinctly 'oceanic' one. This is confirmed by the presence of

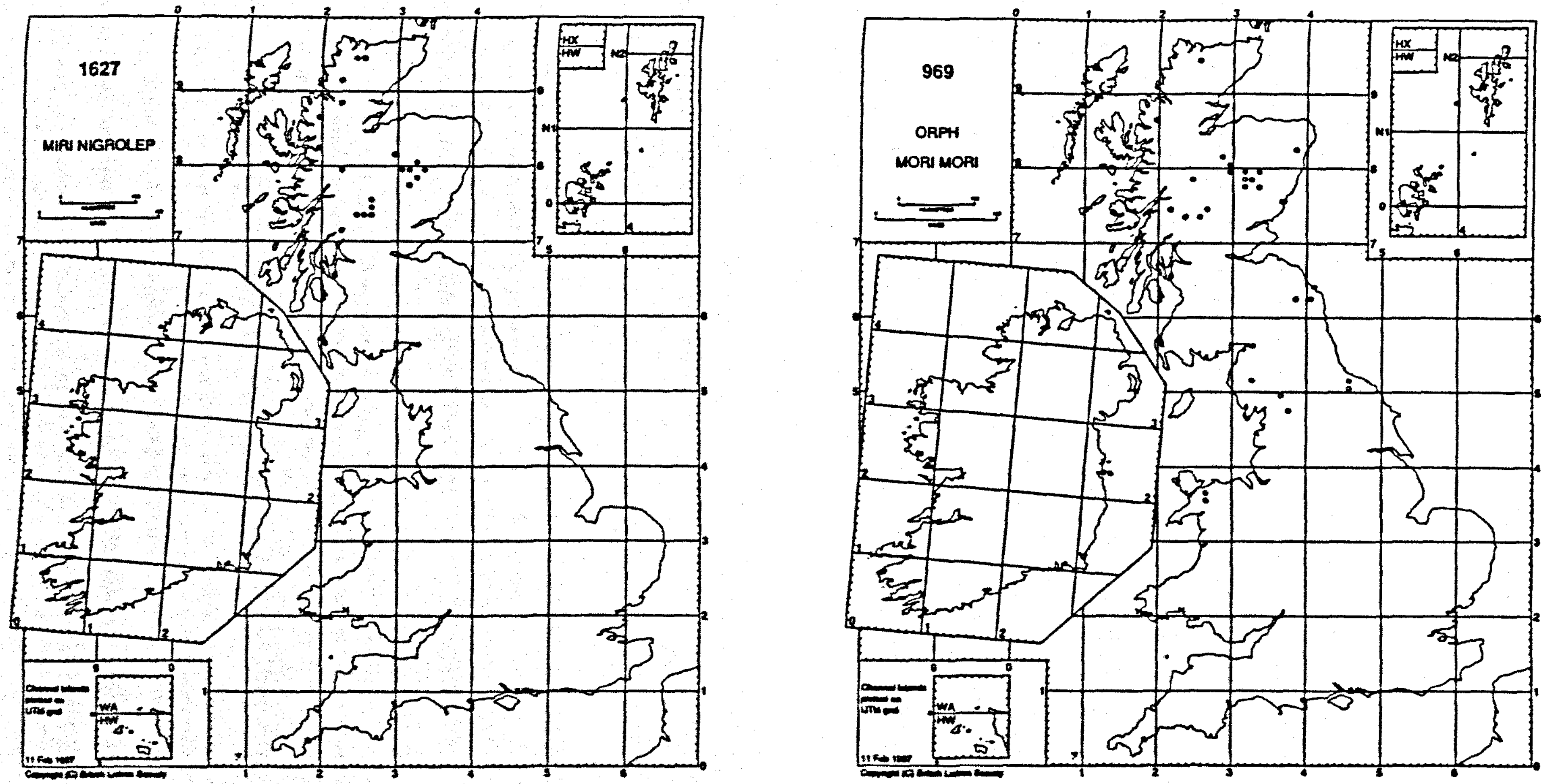

Figure 3-2. Distribution maps of lichens showing apparent lack of east-west bias; a) *Miriquidica nigroleprosa*, b) *Orphniospora moriopsis*

Cladonia maxima on the former (Fig. 3•3) and *Stereocaulon plicatile* and *Rhizocarpon anaperum* in the latter (Fig. 3•4). However, many species do exhibit distinctly continental or oceanic distributions (see Table 3•4) with those confined to the eastern mountains largely being terricolous and those confined to the western mountains saxicolous. Some of these show a strongly continental (e.g. *Alectoria ochroleuca, Cetrariella delisei,* (Fig. 3•5), *Cladonia stricta*) or oceanic distribution (e.g. *Chromatochlamys 'confusum'* ad int. (Fig. 2•5), *Coccotrema citrinescens* and *Toninia thiopsora* (Fig. 3•6)) whereas in others the eastern (e.g. *Alectoria sarmentosa* subsp. *vexillifera* (Fig. 3•7)) or western (*Placopsis gelida, Trapelia mooreana* (Fig. 3•8)) tendency is less pronounced.

The most obvious overall effect of an oceanic climate is that the montane zone extends to a much lower altitude. This is well illustrated by Ratcliffe & Thompson (1988) who give the altitudinal ranges for sub-montane *Calluna vulgaris* heaths at three sites across the Scottish Highlands (Table 3•3).

Table 3•3. Altitudinal Ranges of sub-montane Calluna vulgaris heath across the Scottish Highlands (from Ratcliffe & Thompson 1988).

Site	**Altitude (m.)**
The Cullin	200-730
Creag Meagaidh	600-900
Lochnagar	740-1100

The implications of this are that the relatively low altitude of the British mountains is less of a restriction to the development of an extensive montane vegetation in the west than in the east. The Cullin reach an altitude of 1009m and Creag Meagaidh, which has a relatively oceanic vegetation, 1130m which implies that there is 279 and 230m respectively of montane habitat above the highest sub-montane vegetation. Although Lochnagar is higher at 1154m the amount of land above the highest sub-montane vegetation is far less at 54m.

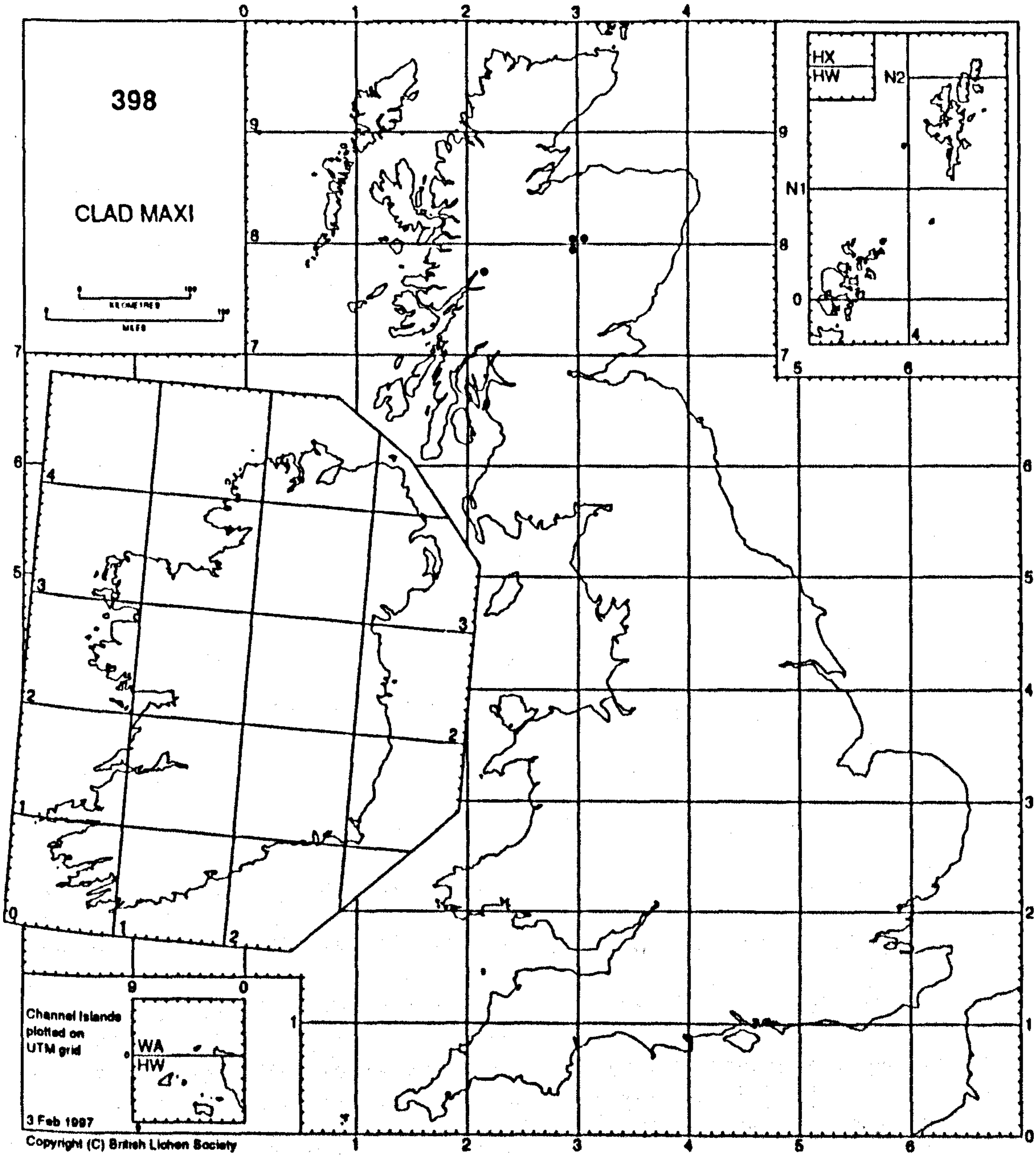

Figure 3·3. Distribution of *Cladonia maxima*, showing a continental distribution with an oceanic outlier on Aonach Mor (Lochaber).

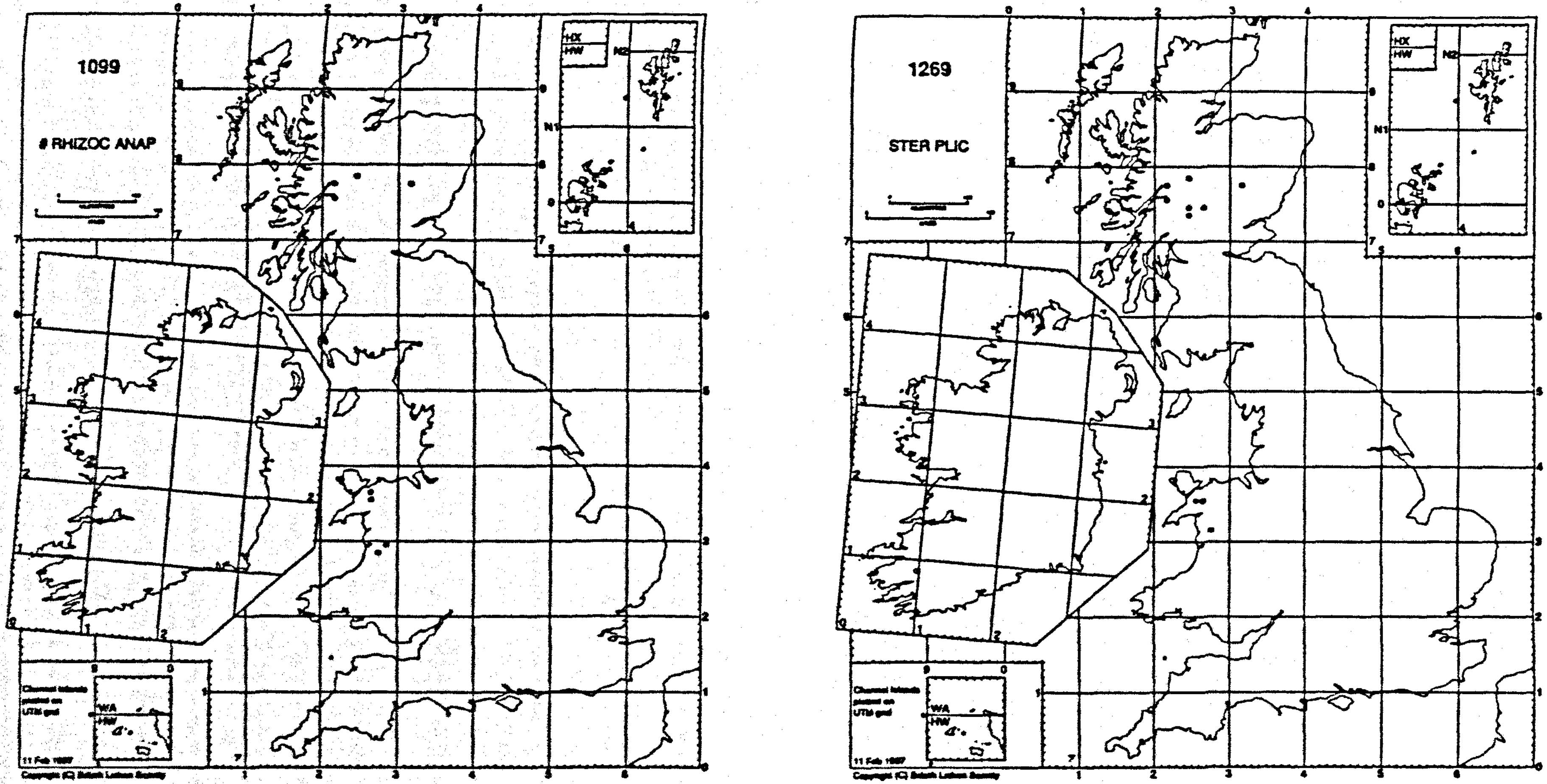

Figure 3-4. Distribution maps of lichens which show an oceanic distribution but with continental outliers on Glas Moal; a) *Rhizocarpon anaperum*, b) *Stereocaulon plicatile.*

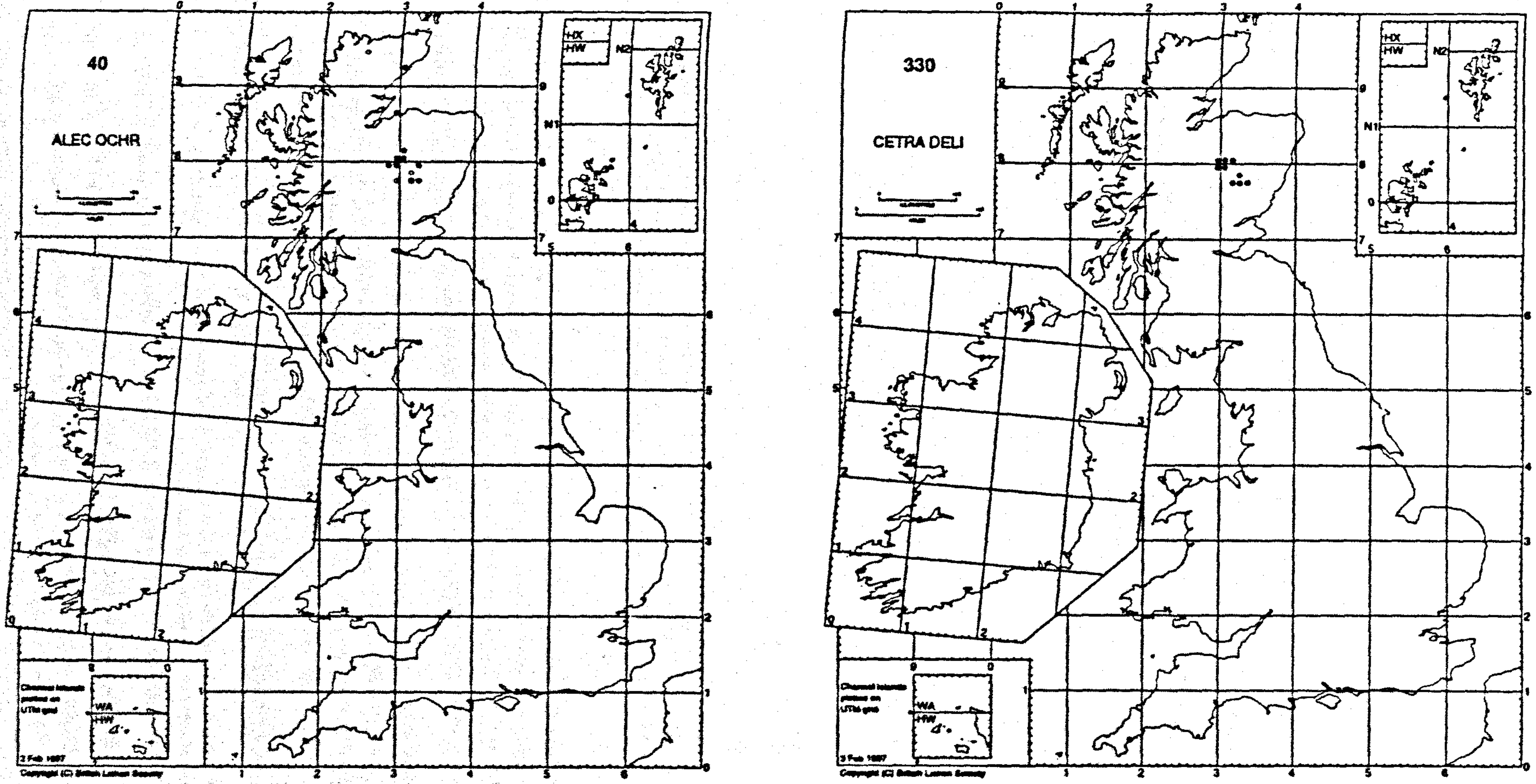

Figure 3-5. Distribution maps of lichens with a strong continental distribution; a) *Alectoria ochroleuca*, b) *Cetrariella delisei*.

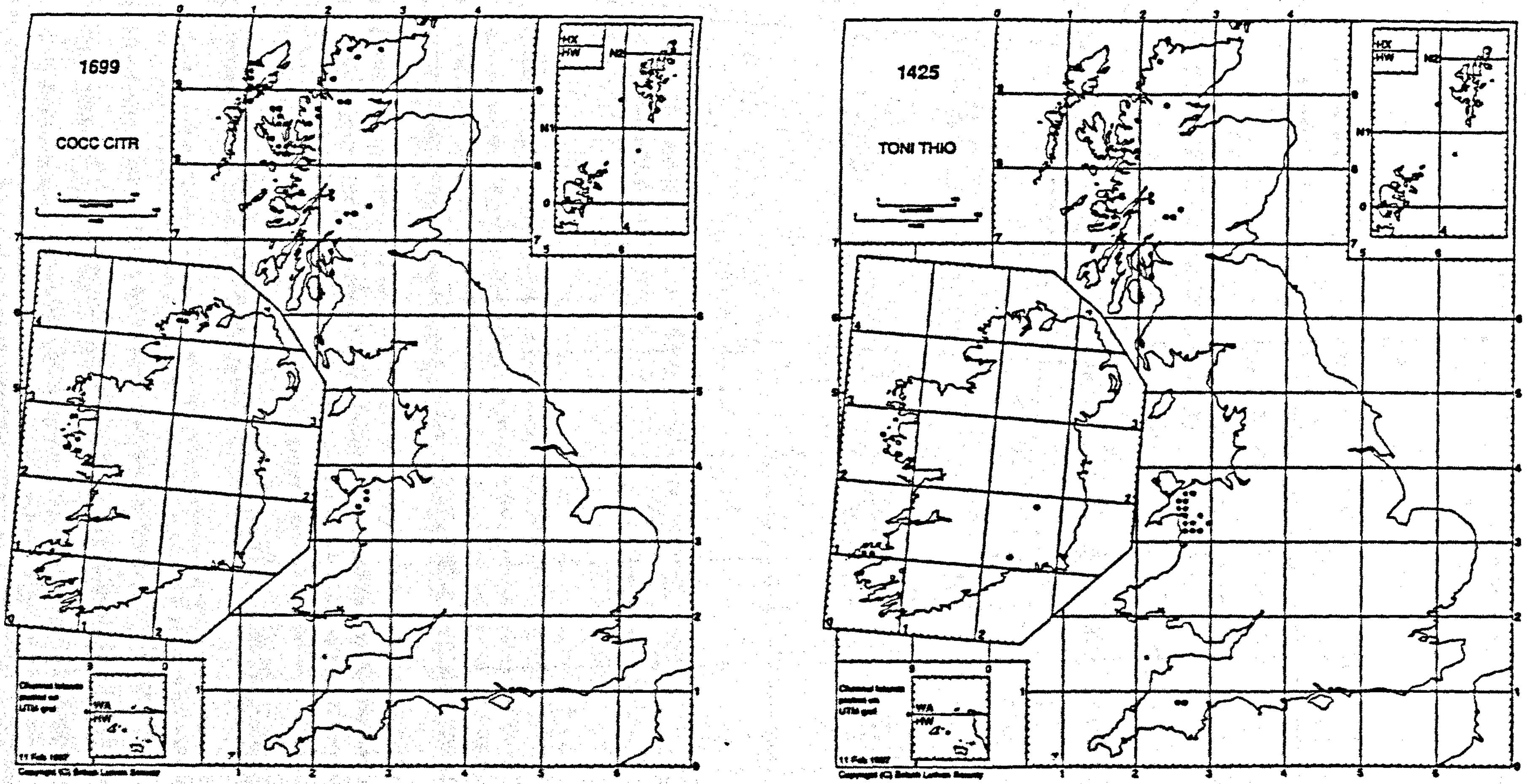

Figure 3-6. Distribution maps of lichens with a strong oceanic distribution; a) *Coccotrema citrinescens*, b) *Toninia thiopsora*.

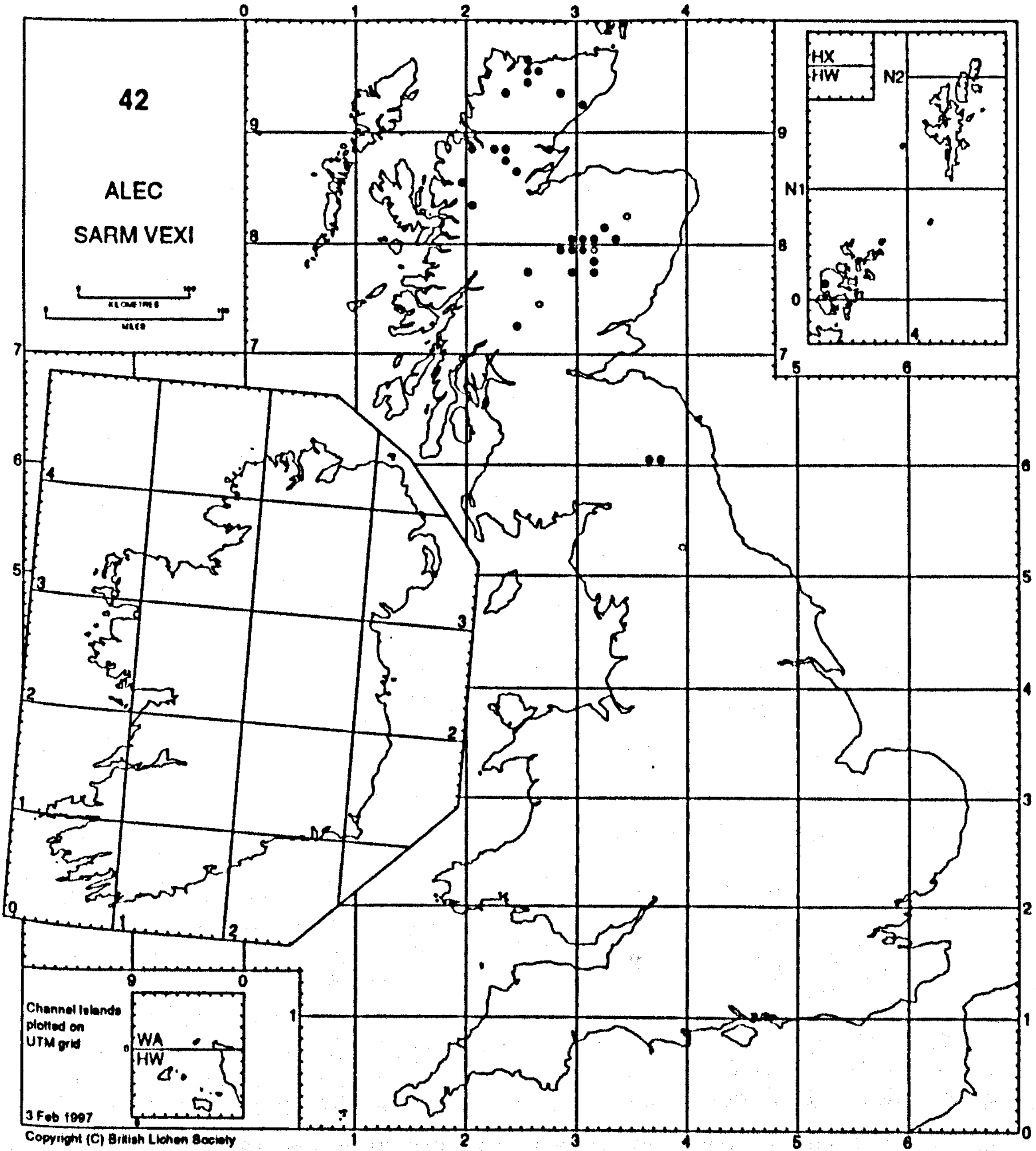

Figure 3-~~8~~7. Distribution of *Alectoria sarmentosa* subsp. *vexillifera*, a lichen with ~~a~~ weak continental distribution.

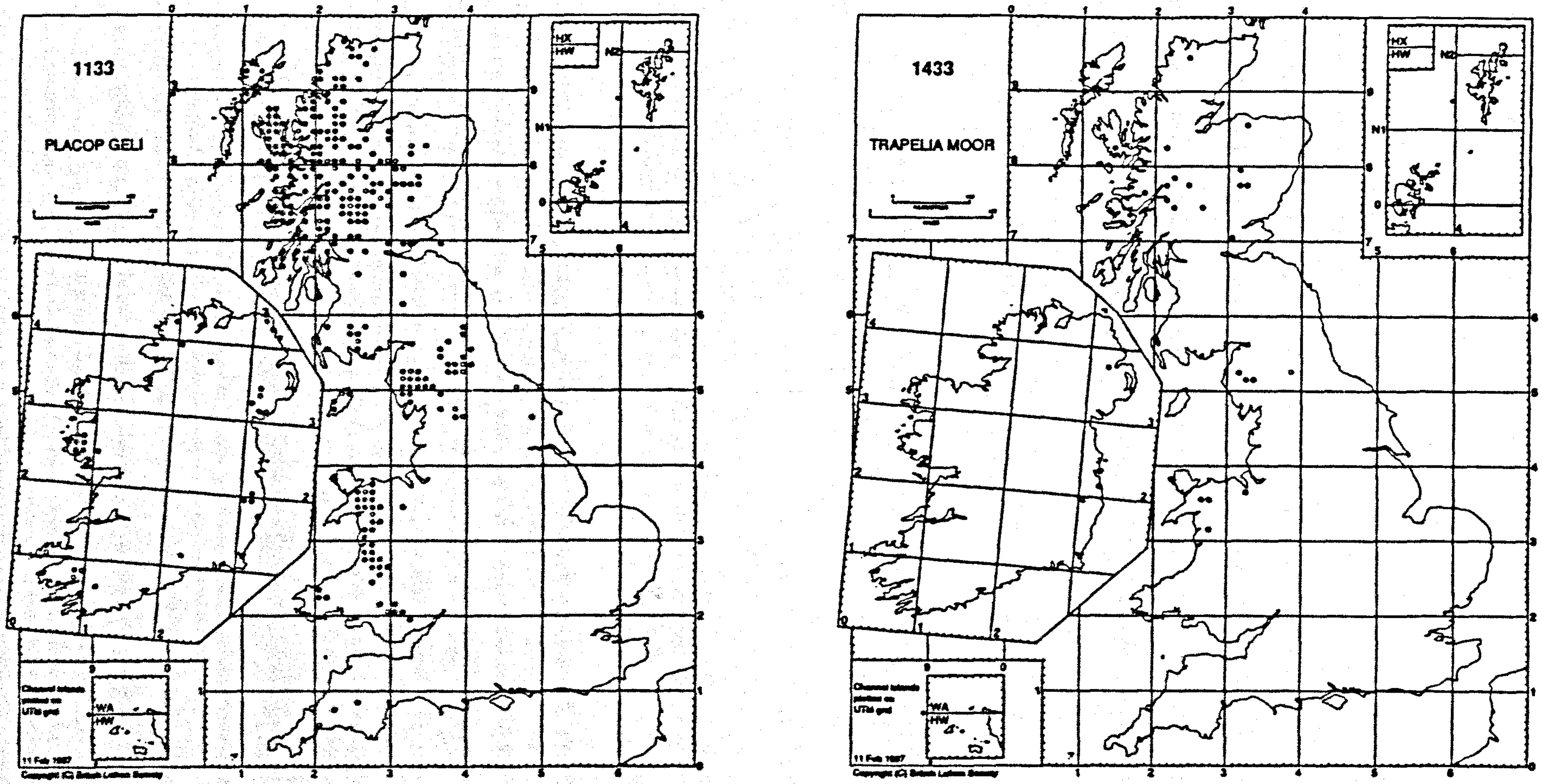

Figure 3-8. Distribution maps of lichens with a weak Oceanic distribution; a) *Placopsis gelida* s. lat., b) *Trapelia mooreana*.

These can only be rough calculations as topography plays an important role in determining the altitudinal limits of vegetation and true montane vegetation does extend well below 1100m on Lochnagar. Topography also means that the rounded summit of Lochnagar probably supports more land above 1100m than the pointed peaks of The Cullin do above 730m. However, the figures indicate that the summit of Lochnagar is only marginally montane whereas those of The Cullin and Creag Meagaidh are well within that zone and, consequently, would be expected to support a better developed, more diverse montane flora.

The effects on the climate of the British Isles of its extreme oceanic position were discussed in section 1•4•2•1. Briefly they are:-

a) high atmospheric humidity and precipitation (mostly falling as rain).

b) high winds.

c) low seasonal variation in cloudiness and temperature.

d) high altitudinal temperature lapse-rate.

Ecologically the most important of these is high atmospheric humidity and precipitation. High precipitation results in an almost permanently water-logged soil in the western mountains which is, consequently, extremely unsuitable for lichen growth. There is, in general, a shift from terricolous to saxicolous as the preferred substratum in oceanic areas, expressed in both percentage cover and species diversity. Certain species which are strictly terricolous in the east become saxicolous or grow over bryophytes on rocks further west (e.g. *Cladonia* spp., *Pertusaria oculata*) as these provide better drained conditions Some corticolous species with a continental distribution (e.g. *Chaenotheca furfuracea, Lecanactis abietina, Mycoblastus caesius, Thelotrema lepadinum*) also become saxicolous in upland/low-montane oceanic areas (Fryday 1993, Fryday & Coppins 1994, Gilbert & Fryday 1996). Although the reasons for this are less clear they are probably also related to a better drained substratum.

Another important consequence of an oceanic climate which affects lichen distribution is the formation and ablation of snow-beds. Information on the actual amount of snow-fall in particular areas is hard to come by; most studies deal with precipitation in general or are concerned more with length of snow-lie. It is difficult to discover, therefore, whether more snow falls in oceanic or continental areas as although precipitation is higher in the former the milder climate will result in more of this falling as rain. What is certain is that the topography of the oceanic mountains is not conducive to the formation of deep snow-fields. Snow-beds are usually formed in north-east facing hollows and on slopes where snow accumulates after being blown from extensive, exposed summit plateaux. As the oceanic mountains are mostly devoid of rounded summit plateaux deep snow-beds are rarely formed. Probably the best example of an oceanic snow-bed is that on Beinn Dearg (West Ross), a mountain which, untypically, has an extensive summit plateau. The other factor acting against long lying snow-beds in oceanic areas is the high atmospheric humidity in these areas which causes snow to melt far more quickly than in continental areas (Geiger 1966). This subject is dealt with more fully in Chapter 5.

The consequence of this for lichen distribution is that although the distinctive assemblage of saxicolous lichens faithful to areas of prolonged snow-lie in the British Isles (e.g. *'Amelia andeaeaicola'* ad int., *Lecanora leptacina, Lecidella bullata, Micarea paratropa, Miriquidica griseoatra, Rhizocarpon jemtlandicum, Toninia squalescens*) appears to tend towards a continental distribution, this is a result of the distribution of areas of prolonged snow-lie and the distribution of the assemblage, if not the individual species, is distinctly oceanic. However, *Micarea paratropa*, which is locally frequent in the western Highlands but has not been recorded from the Cairngorms and is only otherwise known from two records from Norway, does appear to have a distinctly oceanic distribution. This also applies, to a lesser extent, to *Stereocaulon tornense* and *Toninia squalescens*, both of which are rare in the Cairngorms but are more widely distributed in western Scotland and Scandinavia. *'Amelia andreaeaicola'* also appears to have an oceanic distribution as, in spite of a bias towards eastern sites in the British Isles, it is apparently unknown in Scandinavia and has only otherwise been recorded from British Columbia, which also has a highly oceanic climate.

The distribution of other members of the assemblage in Scandinavia suggests that whereas the individual species may have a continental distribution the assemblage as a whole has a distinctly oceanic one. Santesson (1993) gives a northern distribution with no east or west bias for all the described species (except *M. paratropa*) and makes no mention of snow-fields in their habitat preferences, and Creveld (1981), although mentioning many of the individual species, makes no mention of the assemblage.

It is commonly believed that bryophytes are more frequent and important in the wetter west of the country and lichens more frequent and important in the drier east. This may be true when viewed from the perspective of a vascular-plant ecologist as lichens are more frequent and important as a structural element of the terricolous vegetation in eastern areas. However, it is important to remember that although we generally refer to 'oceanic' and 'continental' areas of the British Isles, even those areas with the most continental climate are still 'oceanic' when viewed on a European scale (cf. Fig. 1•3). It is the lichen-rich *Calluna vulgaris* heaths that are of particular interest as these are 'virtually unique to the British Isles' (Thompson & Brown 1992) and are viewed as a distinctly oceanic vegetation type. The terricolous lichen vegetation associated with *Calluna vulgaris* heath is best considered as a fragmented, species-poor outlier of that present in Scandinavia and, consequently, is of only national interest. Conversely, the saxicolous lichen vegetation of the hyper-oceanic mountains of the western Highlands is far more important both intrinsically, with a number of rare and apparently endemic taxa (Table 3•4), and as a major contributor to the botanical bio-diversity of the montane ecosystem.

Table 3•4 lists montane species considered to have either a pronounced Continental or Oceanic distribution in the British Isles. The continental list has 13 taxa, including the extinct, and doubtfully British, *Bryoria nitidula*, whereas the Oceanic list has 33, includes a number of species which are either endemic to the British Isles (e.g. *Gyalideopsis scotica, Stereocaulon plicatile*) or extremely rare elsewhere (e.g. *Coccotrema citrinescens, Micarea paratropa, Stereocaulon tornense, Trapelia mooreana)* and 7 undescribed taxa. In addition most of the 'unidentified taxa' mentioned in section 2•1•2 which are not well enough understood to be included in Table 3•1 also appear to have an oceanic distribution.

The vegetation of the British mountains is often considered to be either a depauperate outlier of that of the rest of Europe or intermediate between the high-latitude/low-altitude (arctic) and the low-latitude/high-altitude (alpine) types. From the above discussion it can be seen that the lichen vegetation of the hyper-oceanic mountains of western Scotland is distinctive and intrinsically important and deserves to be treated as a separate type which occurs nowhere else in Europe and possibly the world.

Table 3·4. Montane lichens considered to have either a pronounced Continental or Oceanic Distribution in the British Isles.

Continental

Alectoria ochroleuca
A. sarmentosa subsp. *vexillifera*
Bryoria nitidula
Cetraria ericetorum
C. nivalis
Cetrariella delisei
Cladonia maxima
C. stricta
Hypogymnia intestiniforme
Ochrolechia xanthostoma
Parmelia stygia
Pseudephebe minuscula
Umbilicaria hyperborea

Oceanic

Aspicillia recedens
Caloplaca obliterans
Catolechia wahlenbergii
Chromatochlamys confusum ad int.
Claurouxia chalybieoides
Coccotrema citrinescens
Collema glebulentum
Gyalideopsis scotica
Lecanora achariana
L. atromarginata
Lecidella aff. *asema*
?*Lemmopsis* sp.
Lithographa tesserata
Micarea paratropa
Phaeophyscia endococcina
Pilophorus strumaticus
Placopsis gelida s. lat.
Placynthium flabellosum
Porina guentheri
  var. *lucens*
Porpidia superba f. *sorediata* ad int.
Rhizocarpon anaperum
R. caesium ad int.
R. simillimum
Rinodina fimbriata
Ropalospora lugubris
  subsp. *sorediata* ad int.
Stereocaulon plicatile
S. tornense
Toninia thiopsora
Trapelia mooreana
Trapeliopsis wallrothii
Vestergrenopsis elaeina

Altitude - As shown above, altitude is only a rough guide as to the vegetation which will occur at a specific site; the effects of altitude are strongly modified by topography and continental position. However, it has the advantage of being an easily measurable parameter and, provided its inherent inaccuracies are taken into consideration, a very useful one.

The effects of increasing altitude have been discussed in section 1•4•2. Briefly these are:-

a) higher precipitation with a greater proportion falling as snow

b) lower temperatures and greater incidence of frosts

c) higher wind speeds

These combine to produce a much harsher climate than at lower altitudes. Of particular importance for lichen distribution is the lower temperature and greater incidence of frost which lichens, as a group, are more suited to survive than most other plants (cf. section 5•1•2). Consequently, lichens are particularly important in montane areas and form a high percentage of the plant bio-diversity.

An attempt has been made in Table 3•1 to assign all British montane lichens to the system of sub-zones characterized by vascular plant communities (Rodwell, 1991 onwards). As discussed in section 3•1•1, this works well for terricolous macro-lichens which form a structural part of the vegetation but less well for terricolous micro-lichens and all saxicolous ones.

As there are few, if any, 10km squares containing high- or mid-montane vegetation which do not also contain low-montane areas, 'dot-maps' of species assigned to the various montane sub-zones accurately reflect the distribution of high-ground. If this were not the case then the map for a low-montane species would not indicate all the area with land above this level. Consequently, the maps for low-, mid- and high-montane species show a progressive reduction in the areas covered, each one being contained within the former. This can be seen in Fig. 3•9 which show the maps for *Ophioparma ventosa* (upland/low-montane), *Cornicularia normoerica* (low-montane), *Pseudephebe pubescens* (mid-montane) and *Lecanora leptacina* (high-montane). The difference can also be seen between species of the same montane sub-zone but with different habitat requirements. *Pseudephebe pubescens* (Fig. 3•9c) grows on exposed siliceous rocks and is fairly widespread throughout the montane areas of the British Isles, whereas *Solorina crocea* (Fig. 3•10) is confined to damp soil, so is far more restricted in its distribution, tending to avoid the drier southern and eastern areas.

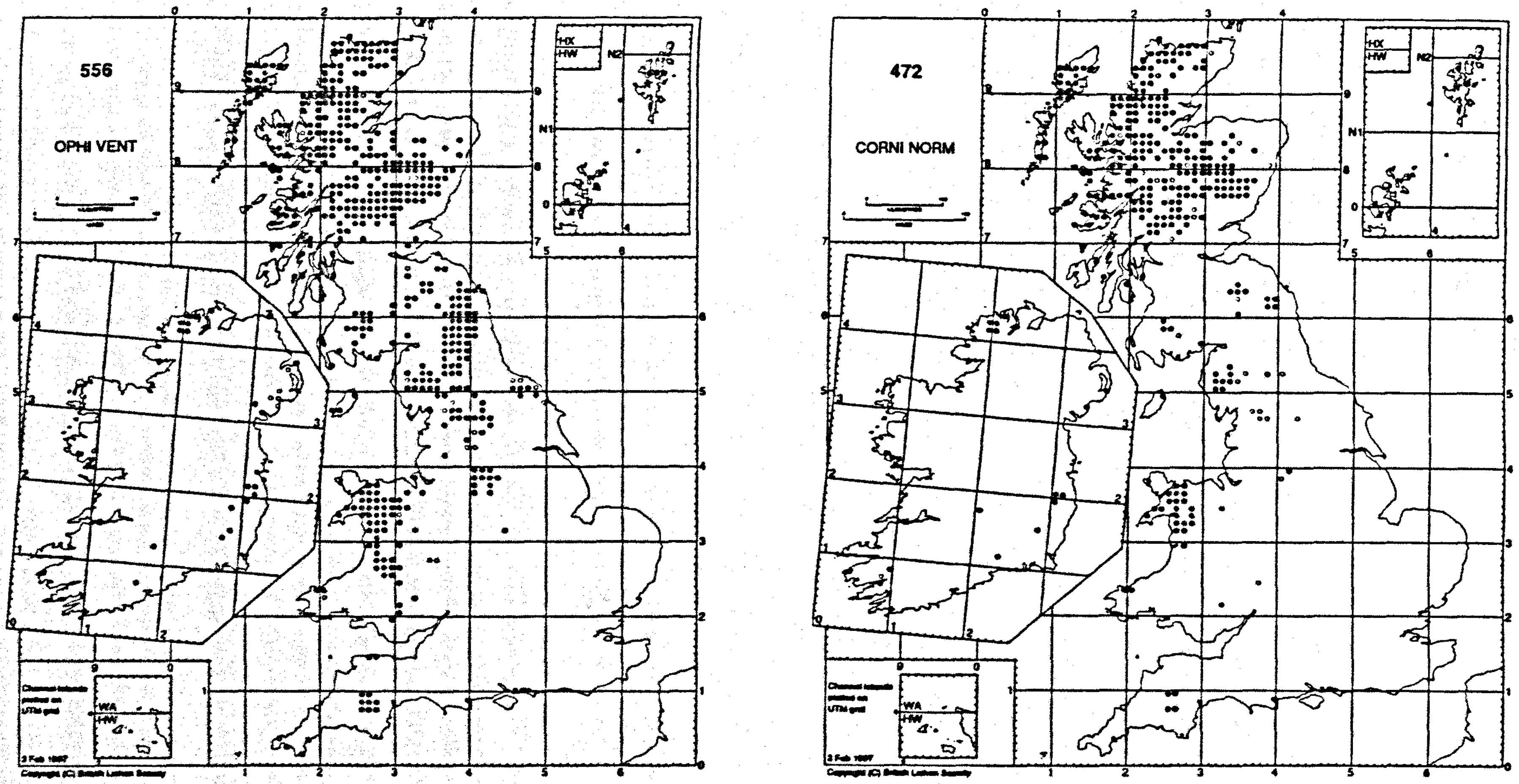

Figure 3-9. Distribution maps of lichens inhabiting montane sub-zones; a) *Ophioparma ventosa* (upland/low-montane, b) *Cornicularia normoerica* (low-montane).

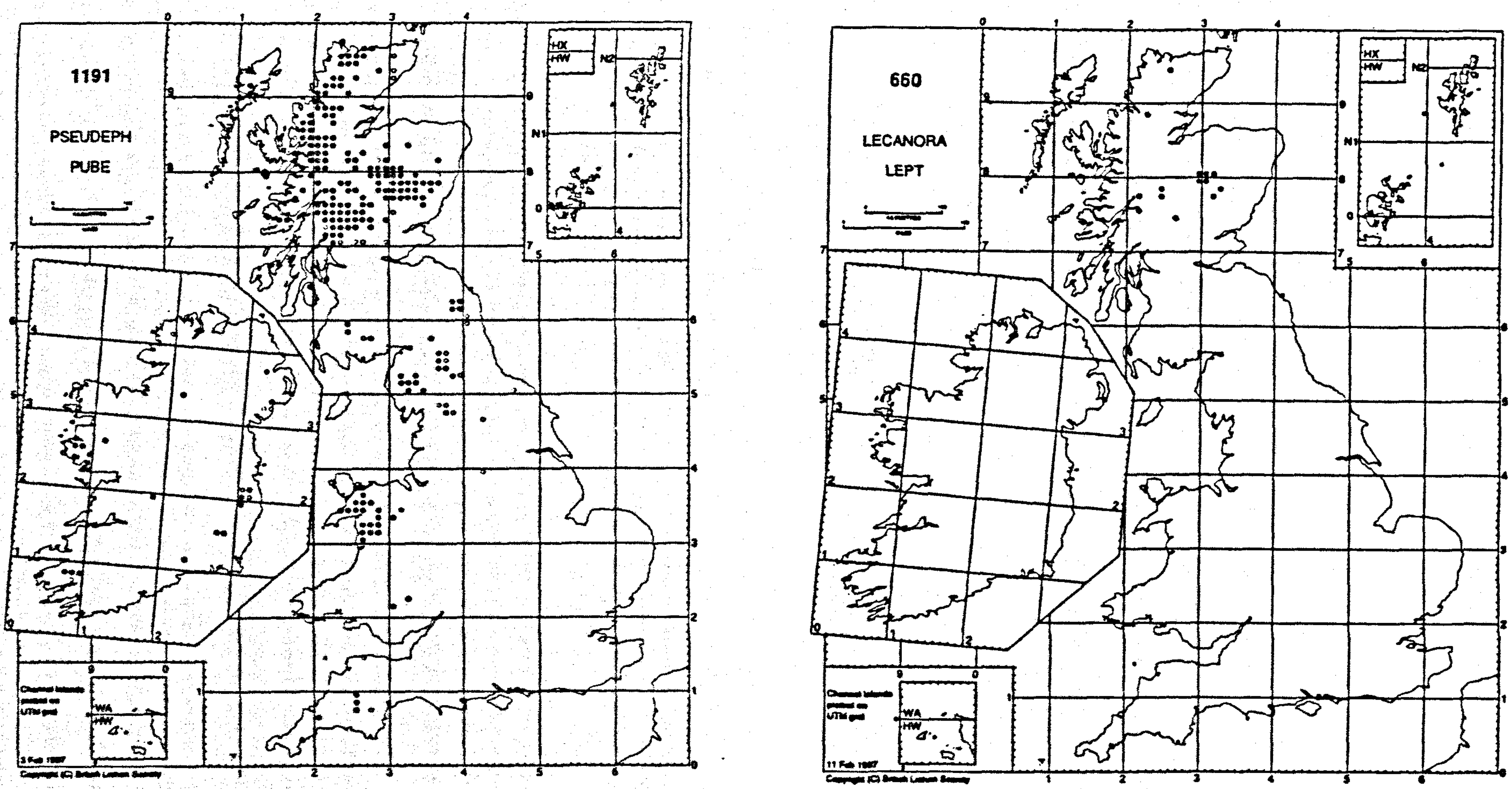

Figure 3-9. Distribution maps of lichens inhabiting montane sub-zones; c) *Pseudephebe pubescens* (mid-montane, b) *Lecanora leptacina* (high-montane).

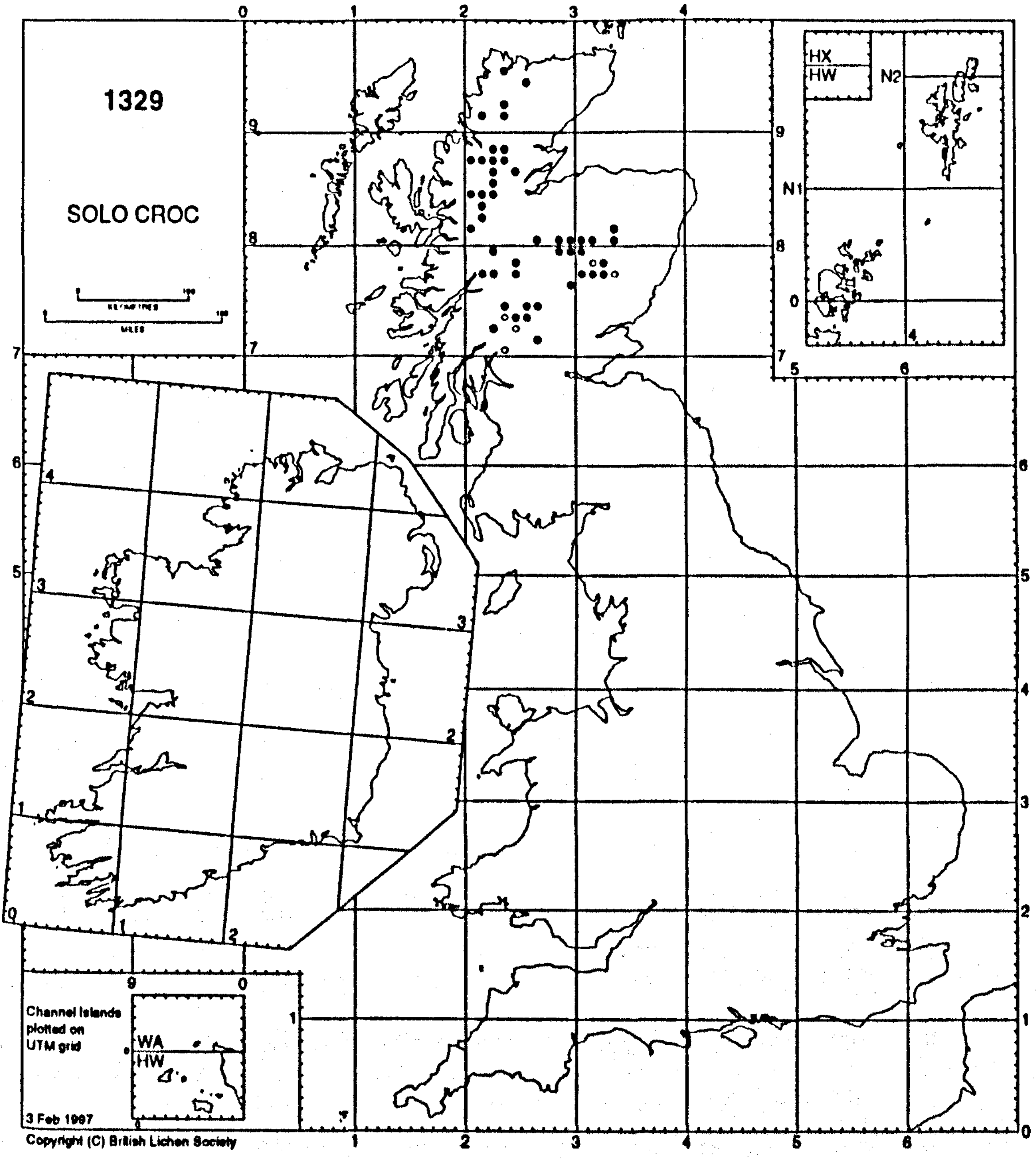

Figure 3-10. Distribution of *Solorina crocea*, a mid-montane lichen confined to damp soils.

Latitude - The main effect of increasing latitude is a decrease in temperature, although increasing day length during the warmer summer months may also be significant. The effects of this on lichen distribution are difficult to separate from those due to altitiude although species usually considered as montane in the British Isles which occur at, or near, sea-level in northern Scotland (e.g. *Brigantiaea fuscolutea*) fall into this catagory (Coppins *et al.* 1986). The position of others, which have been recorded in the British Isles only from high-altitude in Scotland and are absent from other montane areas further south, is less clear. All the high-montane (snow-bed) species of Table 3•1 fall into this group along with a number of mid-montane species, some of which are relatively widespread and frequent in Sotland (e.g. *Euopsis pulvinata, Lecidea luteoatra, L. paupercula, Pertusaria oculata, Rhizocarpon ?cyclodes, R. sublavatum* ad int., *Solorina crocea* and *Stereocaulon saxatile*) and their apparent absence from the other montane areas of the country is unexpected. The lower latitude of these other sites is probably a more important factor than their generally lower altitude although a combination of both factors may be involved.

Conversely, some species (e.g. *Rhizocarpon reductum*) reach a high altitude in the mountains of North Wales (Fryday 1995, 1996) but are confined to lower altitudes in Scotland. *R. reductum* has been recorded from the area on Carnedd Llewelyn which supports the longest lying snow-bed in the British Isles outside of the Scottish Highlands where it performs its usual role as a colonising species of siliceous rocks. It also performs this function at low altitudes in the Scottish Highlands, but is almost unknown in the montane zone where it is replaced by *R. 'sublavatum'* ad int.

Geology - Studies of the factors affecting the distribution of montane vascular plants and communities usually find that geology has little influence, with the notable exception of base-rich rocks (Ferreira 1959, McVean & Ratcliffe 1962, Brown *et al.* 1993). The same is, in general, true for lichens (Foote, 1966, Yarrington & Green, 1966, Wong & Brodo, 1973, Hoffman *et al.* 1974, Armstrong, 1978, Bates 1978). Although the detailed investigation of an area usually reveals a correlation between different rock facies and the lichen vegetation (Degelius 1956, Wirth 1972, James, Hawksworth & Rose 1977, Pentecost 1980) these are related to petrological factors rather than the geology (age) of the rock . Pentecost (1980) suggests that the most important intrinsic factors responsible for this are the 'concentration of dissolved nutrients and inhibitory substances, porosity and water-holding capacity of the substratum, and microtopography.' Some species appear to grow more frequently on a particular rock type (e.g. sandstone, basalt, mica-schist) but this is a preference for the physical characters of the rock surface (texture) as they mostly show a preference for fine-grained, coarse or schistose rocks in general.

The mineral composition of a rock can have a significant effect on lichen distribution, most noticeably those which are rich in heavy-metal ions, especially copper and iron (Bates 1978, Purvis & James 1985, Purvis & Halls 1996). Lichens have also been used to separate rock types which are indistinguishable geologically in the field (Boyle *et al.* 1987).

The physical characteristics and chemical composition of a rock are far more important in determining the lichens it will support than its age or type and by far the most important character which significantly affects lichen distribution is its base content. Even here it has been suggested by Larson (1980) that other factors which separate basic rocks from siliceous ones (substrate solubility, texture, hardness and aspects of the rock's heat balance) may also be of importance in addition to chemical composition.

It appears to be primarily the degree of basicity and the physical characteristics of the rock which determine its lichen vegetation. Although *Lecanora frustulosa* has the centre of its British distribution on the Ben Lawers NNR, where it is comparatively frequent on calcareous mica-schist rocks, there are also recent records from calcareous conglomerate in Glen Coe and basalt at The Storr on the Isle of Skye. Another example is *Gyalideopsis scotica*, a British endemic species, first discovered overgrowing bryophytes on the epidiorite of Ben Hope in northern Sutherland but which has subsequently been collected from Cambrian limestone at Inchnadamph, fucoid-beds at Beinn Eighe, calcareous mica-schist on Ben Lawers and Caenlochan, calcite-felsitic tuffs in the Lake District, andesite in North Wales and calcareous Old Red Sandstone and Carboniferous limestone in the west of Ireland.

The distribution pattern of many calcicole lichens corresponds to the distribution of base rich rocks (e.g. *Agonimia tristicula*, Fig. 3•11). However, some species which are usually considered to be calcifuge show a distinct requirement for a base-enriched substratum as

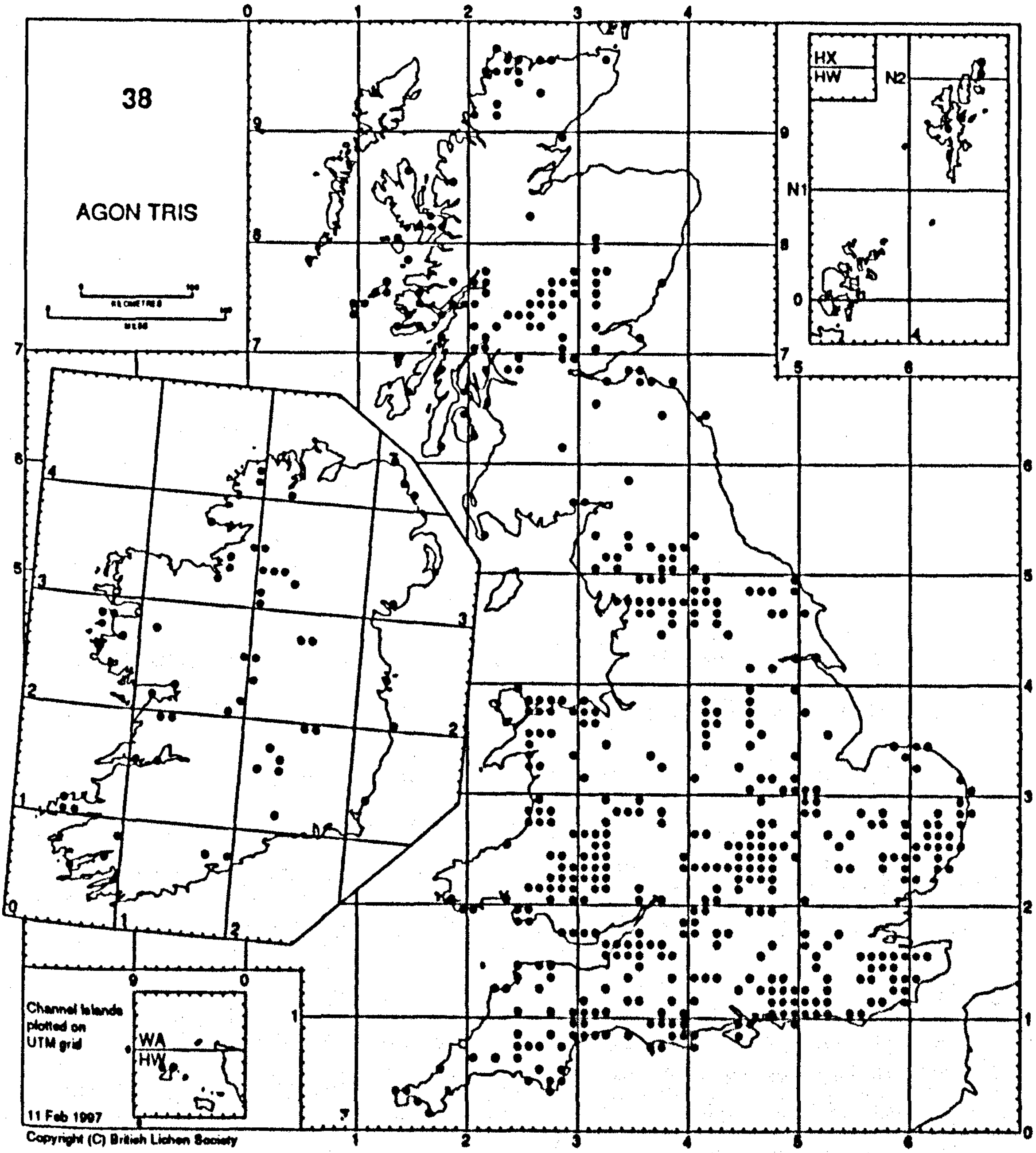

Figure 3-11. Distribution of *Agonimia tristicula*, a lichen restricted to base-rich substrata.

they approach the southern extremes of their range. This phenomenon also occurs in vascular plant distributions where species such as *Armeria maritima, Minuartia sedoides* and *Silene acaulis* are frequent in acidic montane heaths in Scotland but are restricted to more base-rich habitats further south. Ferreira (1959) attributes this to reduced root competition in montane heaths although this cannot be the case with lichens as they have no root system. McVean & Ratcliffe (1962) suggest that the increased incidence of wind-borne salt-spray in the north-west Highlands is responsible although this is also unlikely as the three plants also occur in montane heaths in the Cairngorms. It is more likely that some degree of nutrient enrichment is required to off-set the disadvantages for the plant of occurring in a sub-optimum habitat. A number of lichens which are fairly frequent in base-poor habitats in Scandinavia have been recorded only from substrata enriched by run-off from basic areas in the British isles. An example of this is *Nephroma arcticum* (see Appendix) but *Aspicilia melanaspis* and the recently discovered *Phylliscum demangeonii* are also good examples, both having been recorded in the British Isles only from upland quartzite rocks that are periodically inundated by a base-enriched stream in the north-west Highlands.

Other examples of this phenomenon are the apparent restriction of *Caloplaca nivalis* and *Micarea crassipes* in the British Isles to the calcareous mica-schists of the Ben Lawers range and the distribution pattern shown by species such as *Phaeophyscia endococcina* (Fig. 3•12) in the British Isles. This species, which is restricted to the upper surface of flat rocks by water, is frequent on both base-enriched and un-enriched rocks in the north-west Highlands, but further south has been recorded only from base-rich rocks on Ben Lawers, in the Caenlochan/ Glen Clova area and in the English Lake District.

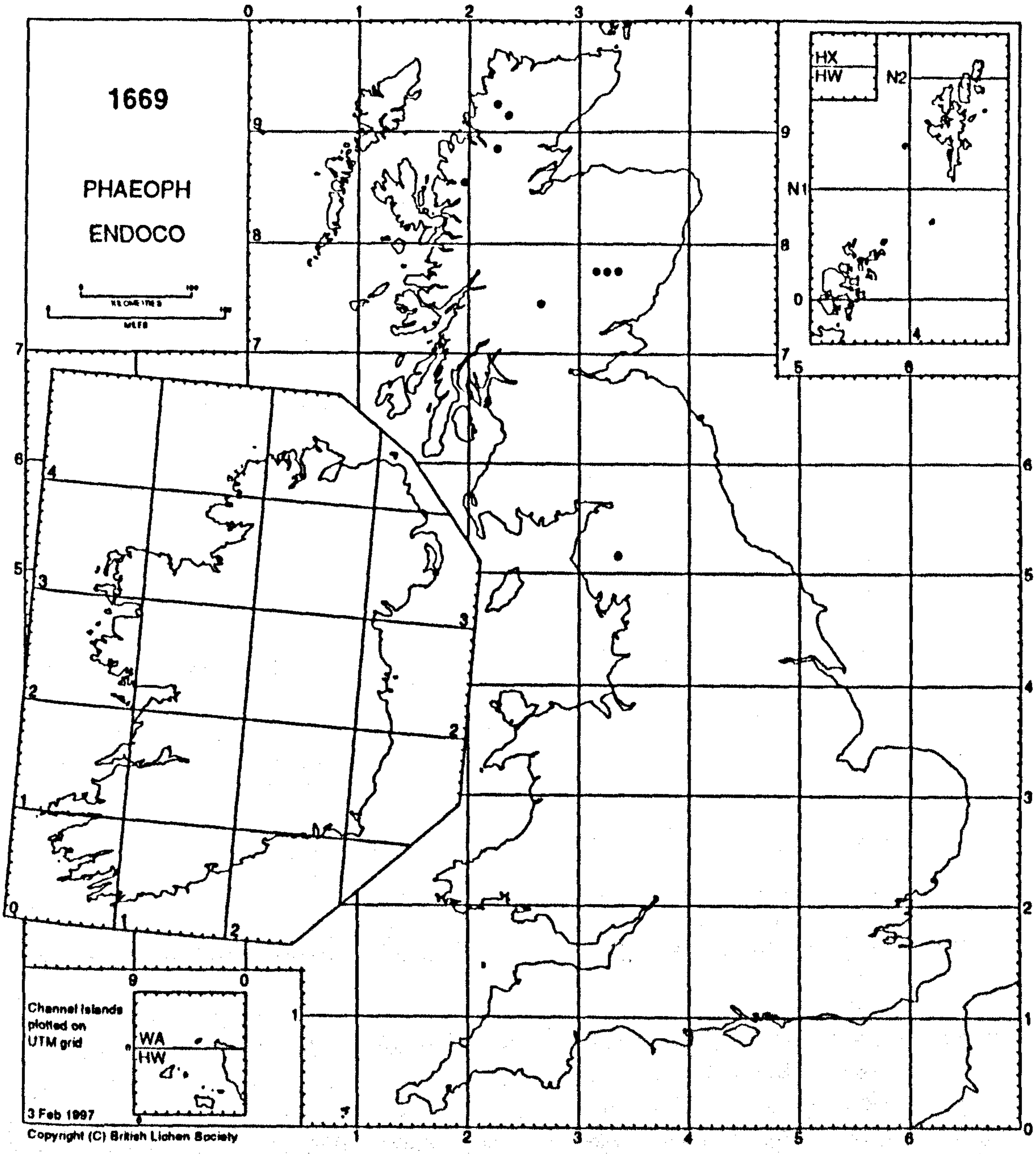

Figure 3-12. Distribution of *Phaeophyscia endococcina*, a lichen which occurs on acid rocks in the north-west Highlands but is restricted to base-rich rocks further south.

3•2•4 COMPARISON OF THE LICHEN VEGETATION OF BRITISH OCEANIC MONTANE AREAS

There has been no attempt to devise lists of indicator species for comparing different montane areas similar to those commonly used for woodland habitats and previous studies have used either the total number of montane species, or the number of rare species, recorded from an area to compare the relative importance of their lichen flora (Gilbert *et al.* 1982, Pentecost, 1987; Gilbert & Giavarini, 1993). As discussed above (section 3•1•1) this is refined here by dividing the montane zone into low-montane, mid-montane and high-montane sub-zones. This allows for a more detailed comparison of the lichen vegetation of different areas and highlights differences which may otherwise not have been apparent.

All the montane lichens included in Table 3•1 which have been recorded from North Wales, the Lake District, and Glen Coe are listed in Table 3•5. These three areas all have an oceanic climate, each reach a similar altitude and all have a similar geology, predominately acidic igneous rocks but with small areas of more basic substrata. However, there are significant differences in the altitudinal distribution pattern of their lichen vegetation.

The number of taxa from each of the three areas belonging to each of the eu-montane sub-zones defined in section 3•1•1 is plotted in Fig. 3•13 and these data presented as a percentage of the total resource for the sub-zone in Fig. 3•14. Fig. 3•13 shows the decreasing species diversity with increasing altitude in all three areas, with Glen Coe and North Wales having roughly similar values and the Lake District much lower ones, a pattern which is also apparent in Fig. 3•14. However, the greater importance of the mid-montane zone at Glen Coe compared to the other areas is clearly evident. This is best demonstrated in Fig. 3•14 which illustrates the relative importance of the individual zones in the three areas. Glen Coe and North Wales again have a similar low-montane flora but they then diverge with the mid- and high-montane floras of Glen Coe being of greater importance, whereas those of North Wales become progressively less important. In Glen Coe the mid-montane zone has the highest percentage of the resource recorded whereas in North Wales this is exceeded in importance by the low-montane zone.

Table 3·5. Montane lichens recorded from three oceanic areas of the British Isles

Taxon	North Wales	Lake District	Glen Coe
Low Montane			
Alectoria nigricans	x	x	x
Amygdelaria consentiens	x	x	x
Baeomyces placophyllus	x	x	x
Belonia calcicola	.	x	.
B. russula	x	x	.
Caloplaca obliterans	x	.	x
(*Catapyrenia cinereum*)	x	.	.
C. lachneum	x	.	x
Coccotrema citrinescens	x	.	x
Collema parvum	x	.	.
Cornicularia normoerica	x	x	x
Dermatocarpum arnoldianum	x	.	.
D. deminuens	.	x	.
D. intestiniforme	x	x	x
D. leptophyllodes	x	.	.
D. meiophyllizum	x	x	x
Epigloea medioincrassata	x	.	.
Fuscidea intercincta	x	x	x
F. kochiana	x	x	x
**F. 'poeltii* ad int.'	.	.	x
Gyalecta foveolaris	.	.	x
Gyalidea fritzei	.	.	x
Gyalideopsis scotica	x	x	.
Ionaspis cyanocarpa	.	.	x
I. odora	x	.	x
Koerberiella wimmeriana	x	x	x
Lecanactis abscondita	.	.	x
Lecanora achariana	x	x	.
Lecidea paupercula	.	.	x
L. pycnocarpa	x	x	x
Lecidella aff. *asema*	.	.	x
Lempholemma intricatum	.	.	x
L. radiatum	x	.	x

+aff. *L. isidioides*	x	.	.
Lithographa tesserata	x	x	x
Melanelia commixta	x	x	.
M. hepatizon	x	x	.
Miriquidica complanata	.	.	x
Ochrolechia frigida	x	x	x
(*Pannaria pezizoides*)	x	x	x
Peltigera elisabethae	x	.	.
P. venosa	x	.	.
Phaeophyscia endococcina	.	x	.
P. sciastra	.	x	.
Pilophorus strumaticus	x	.	x
Placynthiun asperellum	.	.	x
P. flabellosum	.	x	x
P. pannariellum	.	.	x
P. pluriseptatum	x	.	.
Polyblastia cupularis	x	x	x
P. efflorescens	x	.	x
P. inumbrata	x	.	x
P. melaspora	x	x	x
P. theleodes	x	x	x
P. wheldonii	x	.	.
Porpidia ochrolemma	x	.	.
P. superba	x	x	x
* 'f. *sorediata*' ad int.	x	.	x
Protoblastenia siebenhaariana	x	.	.
Psora decipiens	x	.	.
Pyrenopsis grumulifera	.	x	.
P. impolita	x	.	x
P. subareolata	x	x	x
Rhizocarpon intermediellum	x	.	x
R. lavatum	x	x	x
R. superficiale	x	.	.
Rimularia limborina	x	.	x
Ropalospora lugubris	x	.	x
* 'subsp. *sorediata*' ad int.	.	.	x
Staurothele succedens	x	.	x
Stereocaulon leucophaeopsis	x	x	x
Strigula stigmatella var. *alpestris*	x	x	.

Thelidium fumidum	.	.	x
Trapelia mooreana	x	x	x
Umilicaria proboscidea	x	x	x
Vestergrenopsis elaeina	x	.	x
Total	**57**	**34**	**51**

Mid Montane

**Adelolecia pilati* 'subsp. *pachythallina*' ad int.	.	.	x
Allantoparmelia alpicola	x	x	x
Bryonora curvescens	.	.	x
Catillaria contristans	x	x	x
Cecidonia xenophana	.	.	x
Cladonia bellidiflora	x	x	x
Euopsis pulvinata	.	x	x
Frutidella caesioatra	x	.	x
Lecanora frustulosa	.	.	x
Lecidea berengeriana	.	x	x
L. hypnorum	x	x	x
L. limosa	.	.	x
Lecidoma demissum	x	x	x
Lepraria neglecta	x	.	x
Lopadium pezizoideum	.	.	x
+*Melaspilea* sp.	.	.	x
Micarea cinerea (anamorph)	x	x	x
M. marginata (anamorph)	.	.	x
M. submilliaria	x	.	.
Parmelia stygia	.	.	x
Pertusaria oculata	.	.	x
Polyblastia terrestris	x	.	x
**Porpidia* '*confluenta*' ad int.	.	.	x
P. contraponenda	x	x	x
**P.* '*striata*' ad int.	x	.	x
Protothelenella corrosa	x	x	x
P. sphinctrlnoidella	x	.	.
P. sphinctrinoides	x	.	x
Pseudephebe pubescens	x	x	x
Rhizocarpon alpicola	x	x	.
R. anaperum	x	.	x

**R.* '*colludens* subsp. *rufoatrum*' ad int.		.	.	x
**R.* '*sublavatum*' ad int.		.	.	x
Sporastatia polyspora		x	.	.
S. testudinea		x	.	.
Staurothele aeolata		.	.	x
Stereocaulon plicatile		x	.	x
S. saxatile		.	.	x
S. spathuliferum		.	.	x
S. tornense		x	.	x
Thamnolia vermicularis		x	x	x
Thelopsis melathelia		x	.	x
Toninia fusispora		x	.	x
Total		**25**	**13**	**38**
High Montane				
Lecanora leptacina		.	.	x
Micarea paratropa		.	.	x
Miriquidica griseoatra		.	.	x
Toninia squalescens		.	.	x
Total		**0**	**0**	**4**
Total	**297**	110 (28•6)	67 (16•4)	123 (32•4)
Low Montane	**172**	57 (33•1)	34 (19•8)	51 (29•7)
Mid Montane	**103**	25 (24•3)	13 (12•6)	38 (36•9)
High Montane	**12**	0 (0)	0 (0)	4 (33•3)

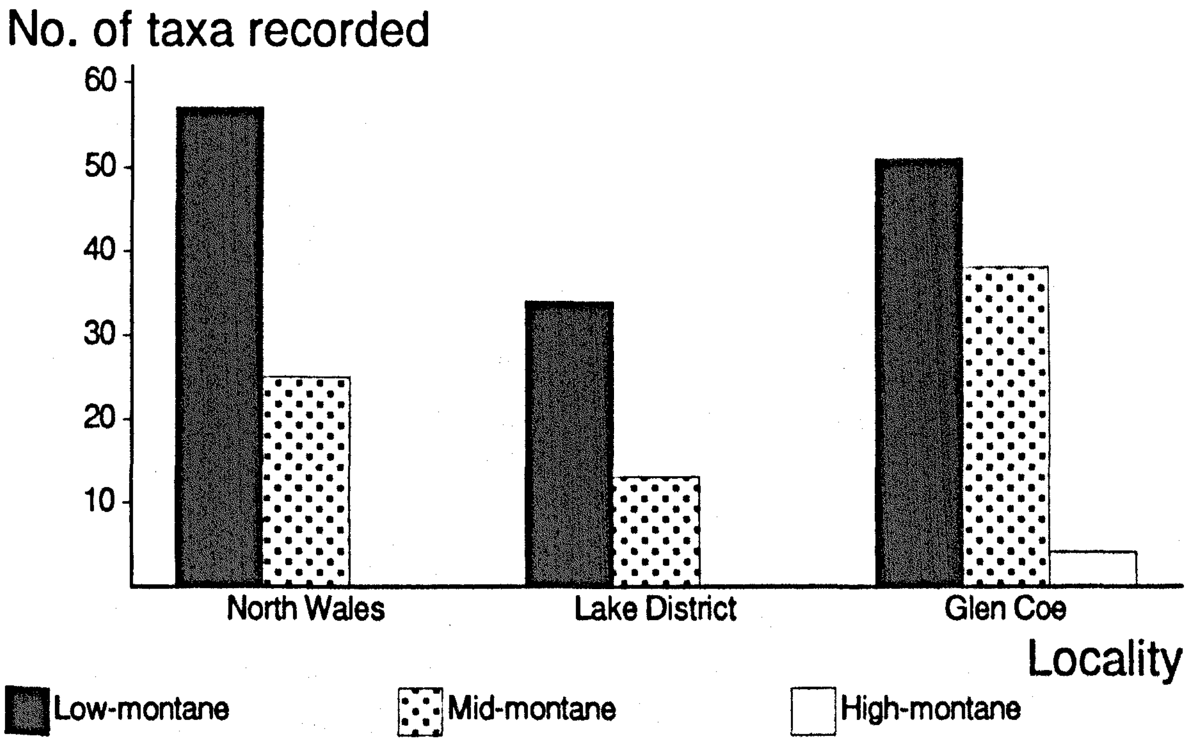

Figure 3•13. The number of taxa belonging to each of the montane zones recorded from Glen Coe, The Lake District and North Wales

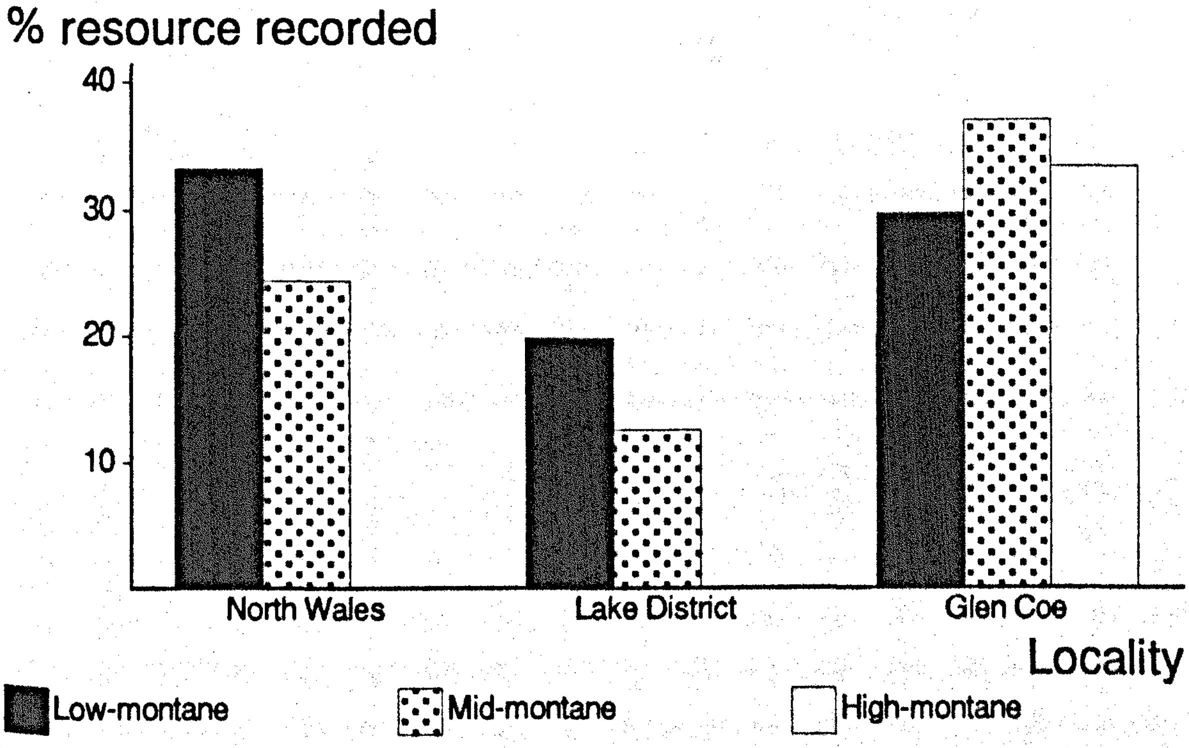

Figure 3•14. The number of taxa belonging to each of the montane zones recorded from Glen Coe, The Lake District and North Wales expressed as a percentage of the total resource for that zone.

The most significant difference is the importance of the high-montane zone at Glen Coe, which appears to be totally absent from the other areas. However, this result must be treated with caution as the total resource for this zone is very small (12 taxa) and further work may reveal a small element of this zone in North Wales which would greatly alter the assessment.

There are two possible reasons for the greater importance of the mid- and high-montane zones at Glen Coe, increased latitude or increased oceanicity. Glen Coe is 400km north of North Wales and 300km north of The Lake District and, as discussed in section 3•2•2•3, the resulting decrease in temperature will benefit a number of boreal/Arctic species which will be unable to colonise the warmer areas further south. Oceanicity is also a factor to be considered as, although all three areas are on the western side of the British Isles, both North Wales and The Lake District are sheltered from the most extreme effects of an oceanic climate by the bulk of Ireland to the west (cf. Fig 1•2). However, Glen Coe is situated to the north of Ireland and experiences a more oceanic climate. As a consequence, montane plants are able to extend their range into lower altitudes (McVean & Ratcliffe 1962, Birse 1971, Birks 1988, Ratcliffe & Thompson 1988) which results in montane plants occurring over a wider area, more habitats being available to them and, consequently, a higher proportion of species of the mid- and high-montane zones being present. In fact both factors probably play a part, the effects of which are inseparable.

The restricted occurrence of mid-montane conditions and the absence of high montane ones in North Wales and The Lake District cause a progressive decline in the diversity of the lichen vegetation with increased altitude. Glen Coe has far more species not recorded from any of the other two areas and many of these are mid- or high-montane species. Lichens recorded from high altitude in Glen Coe but not seen in the other two areas include *Bryonora curvescens, Micarea marginata, Pertusaria oculata, Rhizocarpon 'sublavatum'* ad int., *Stereocaulon saxatile* and *S. spathuliferum.* In addition the area of longest snow-lie on Carnedd Llewelyn yielded only four species not seen elsewhere in North Wales (i.e. *Frutidella caesioatra, Protothelenella corrosa, Rhizocarpon anaperum* and *Stereocaulon tornense*) and these are better considered as facultative snow-bed species (i.e. mid-montane) than true snow-bed specialists (i.e. high-montane) as they are frequent on damp summit plateaux in the oceanic regions of the western Scottish Highlands.