Organic Soils on Mt. Sprent, south west Tasmania: an analysis of correlations with local climate, microtopography and vegetation.

by

Kerry Lynn Bridle B.A. (Hons.)

Submitted in fulfilment of the requirements for the degree of Master of Environmental Studies

University of Tasmania
Hobart
December 1992

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university and contains no copy or paraphrase of material previously published or written by another person, except where due reference is made in the text.

Kerry Bridle

K.L. Bridle

ACKNOWLEDGEMENTS

So many people have helped with the initiation, development and completion of this thesis. It is difficult to know where to start.

Firstly, I would like to thank my supervisor and initiator, Jamie Kirkpatrick - for his time, effort, encouragement and support throughout the duration of this thesis.

Many members of the Department of Geography and Environmental Studies deserve a huge thank you, especially Pierre Horwitz, Manuel Nunez and Albert Goede, Roger Kellaway and Les Wood for their support of the thesis and myself. Denis Charlesworth provided help with the soils analysis. Kate Charlesworth allowed me to remove most of the contents of the Resource Centre library to my own bookshelf. Kerrie Green was always on hand with administrative problems.

Dave Somerville, Adrian Pyrke and Phil Barker taught me how to drive several computer packages. Mark Chladil and many volunteers lugged Campbell data loggers, star picketts and rain gauges up and down Mt. Sprent. Michael Askey-Doran climbed 'the hill' for four days duration collecting soil samples. Airlie Alam and Robert Slack proved to be extremely creative in manipulating my diagrams into something presentable, a big 'thank you' for your time.

Members of the Department of Parks, Wildlife and Heritage have been very supportive of this project. Michael Pemberton is thanked for his enthusiasm, peaty knowledge and advice. Tim Rudman proved to be a great help in tracking down the right person to talk to, while Jonathan Marsden-Smedley and Sally Bryant provided help in the field. John Grant and Mick Brown from the Forestry Commission were both approachable and helpful with their knowledge of peats. The Hydro-Electric Commission, the Bureau of Meteorology and the Department of Environment and Planning willingly provided data and maps. Thank you Derk for surveying the mountain, and thank you, Peter Cornish, for making the water wells.

A very special and sincere' thank you' must go to Ian Thomas and Phil Cullen who rarely shirked when various drafts of the thesis were offered to them. Their help and advice has been constructive, invaluable and much appreciated.

Adrian, Mary and Dominic are thanked for providing a relaxing home atmosphere during the final stages of this thesis, as are Lousie, Kathy, Jill, Jasmyn and Fiona for providing the same in Rooms 224 and 226 (long live Petticoat Parliament!).

Finally I would like to thank my family for their support, Boo for showing me the way south and Ben, who provided geological advice and, ultimately, a deadline - the light at the end of the tunnel!

I dedicate this thesis to George and Buff Bridle, whos' spirits, I hope, are flying high over Mt. Sprent in the beautiful south west!

ABSTRACT

Organic Soils on Mt. Sprent, south west Tasmania: an analysis of correlations with local climate, microtopography and vegetation.

Limited data are available pertaining to the peat soils on south west Tasmanian mountains or on the variability of peat soils over the lowland to alpine environmental gradient. This thesis describes organic soils on Mt. Sprent, a 'typical' mountain, in south west Tasmania and analyses their relationships with climate, vegetation and topography.

Climate data were collected using data loggers which recorded maximum and minimum air and surface temperatures, and relative humidity over a 30 month period. Rain gauges were located close to the data loggers. The climatic equipment was at four sites, at different altitudes ranging from 509 m to 1059 m.

Vegetation data were collected along altitudinal and topographic gradients, using a cover/abundance measure for 25 m^2 quadrats. The altitudinal data were collected for every 10 m increase in altitude, while the topographic data were collected along a grid system of transects laid out at four sites on the mountain.

Soils data were collected along the same topographic transects as the vegetation data. Soil depths were determined in the field, while physical properties were determined in the field and the laboratory.

Other environmental data were collected along the altitudinal and the topographic gradients. A total of 34 water table wells were located on the mountain, at each of the four topographic study sites and at the climatic stations.

Peat soils in south west Tasmania are shallow, with an average depth of 30 cm. Three types of peat were recognised: fibrous, intermediate and muck. These vary in their moisture content, organic content, degree of humification and depth. Where more than one peat type was found in a profile, shallow fibrous peats overlaid intermediate which in turn overlaid deeper muck peats.

Peat depth, moisture content and organic content decrease with altitude inferring climatic influences on the processes of peat formation and decay. Rainfall and relative humidity were found to be more than

adequate to support peat accumulation. The temperatures at the base of the mountain were higher than those reported in the literature for optimum peat formation. However, these temperatures were offset by very high rainfall and relative humidity values. By using evaporation data from a nearby village (12 km to the north east) and solar radiation values for the summit, evaporation rates for the mountain during summer were estimated. When compared to rainfall for the same period there was a moisture deficit at each station for February.

Vegetation varies with altitude and along topographic gradients. Buttongrass moorland, alpine heathland and alpine sedgeland occur in an altitudinal sequence. The deepest soils are found under the lowland buttongrass moorland vegetation, and the shallowest soils occur under the alpine vegetation. The four vegetation groups coincided with the four soil groups.

The amount of organic matter in the surface horizon was significantly related to vegetation type at two of the four sites, while soil depth related to vegetation type at three sites. Slope is an important correlate of peat depth at two of the four sites, while rock cover is important at three sites. The mean and modal water table depths are correlated with plant community distributions and the pH of the surface and lower soil horizons.

Factors affecting peat formation *viz.* depth and physical properties are interrelated to such an extent that it is difficult to determine the affects of a single factor. On the mountain, deeper peats occur at lower altitudes, in waterlogged conditions, and under buttongrass moorland vegetation. Fibrous peats are found under moorland, woody and alpine vegetation types in relatively well-drained areas. Reddish-brown fibrous peats occur under woody vegetation while buttongrass tends to produce black fibrous peats. Muck peats are found in areas of impeded drainage.

Higher temperatures experienced at lower altitudes may be offset to some extent by higher rainfall. A decrease in peat depth with altitude infers that climate affects the process of peat formation by affecting peat accumulation rates. A precipitation deficit during the summer months may be responsible for the shallow nature of the peats. Alternatively fire history and the relatively low productivity of the vegetation may also account for the shallow soils.

TABLE OF CONTENTS

Chapter 1 - PEAT FORMATION PROCESSES

1.1 INTRODUCTION

> 'From the physical and chemical points of view peat is a composite, multi-component, polyfractionate, semi-colloidal, high-molecular system with some characteristics of polyelectrolytes, and with much micromosaic heterogeneity.' (Lishtvan and Korol' 1975 in Botch and Masing 1983: 100)

In simpler terms, peat is an organic soil which consists of '...the accumulated remains of dead plants' (Clymo 1983: 159).

Peatlands (peat forming systems) cover approximately 4% of the Earth's total land area (Shotyk 1988). These ecosystems have been utilised, primarily in the northern hemisphere, as a source of fuel, for grazing livestock, as potentially viable agricultural land, for horticultural purposes, recreational pursuits and for whisky production. The demands placed on peatlands are increasing, along with an awareness of their ecological significance. While there is a large amount of ecological literature discussing the evolution and dynamics of peatland systems, there is less on the peat soils themselves.

Information on peatland systems and peat soils is heavily biased towards the northern hemisphere. While there are extensive peatlands in the southern hemisphere, these peats are not under as great a threat as the European systems.

1.2 FACTORS AFFECTING PEAT FORMATION

Peat forms where the accumulation of organic matter is greater than the rate of decomposition. Cool, wet, and acidic environments are conducive to peat formation, due to their influence on plant decomposition rates. Peats may spread either by the process of terrestrialisation or paludification (swamping) creating peatland systems.

There is a general acceptance in the international literature that peat soils have less than 20% inorganic matter with a minimum depth of 30 cm (Clymo 1983). Peat depth and the physical development of particular horizons are subject to many influences (Table 1.1) which include climatic (1-6), topographic (7-8), hydrologic (9-11) and biotic factors (12). Each of these factors affects the hydrological conditions of the peat-forming system.

Table 1.1 Favourable conditions for peat formation.

1) precipitation	high
2) number of rain days	high
3) atmospheric humidity	high
4) percentage of cloud cover	high
5) temperature range	low
6) mean temperature	low
7) angle of slope	low (0°)
8) topographic situation	basin
9) substrate permeability	low
10) substrate water pH and base-content	low
11) substrate-water aeration	low
12) nutrient status of vegetation	low

1.2.1 Climate

Some peatland systems are more climatically dependent than others. Blanket bogs are often termed tertiary or climatic peats (Farnham 1963, Moore and Bellamy 1973) as they rely heavily on nutrient inputs from rainfall, and occur in harsh climatic zones, generally western maritime areas. Blanket bogs cover undulating ground, relying on a high number of raindays, high atmospheric humidity and a low mean temperature and temperature range, to provide the moisture levels necessary to retain/accumulate organic matter (NCC 1988). Systems which are topographically determined, such as valley bogs, are not as heavily reliant on climate for growth and survival.

1.2.2 Biota

Vegetation affects the process of peat formation by providing the organic material from which peat is derived and by creating/sustaining an acidic environment in which the decomposition process is reduced. Different vegetation types have different rates of decay due to the internal structure of the plant (Clymo 1983) and to the palatability of plant remains to fauna and fungal breakdown (Coulson and Butterfield 1978). These relationships are distinguished by Birkeland (1974) as interrelationships between vegetation and soil morphology, and interrelationships between vegetation and soil chemistry.

Peat soils have been classified according to their botanical origin (Bohlin *et al.* 1989). In a global context, there are three major botanical groups of peats; moss peats, herbaceous (sedge) peats and wood peats (Farnham 1963, Kivinen 1977 in Clymo 1983). Peats formed from similar vegetation generally have comparable physical and chemical properties over a wide morphological range of geographically dispersed systems (Bohlin *et al.* 1989).

There is a degree of circularity involved in determining the interrelationships between vegetation and the physical characteristics of soil. *Sphagnum* moss is an 'acidophilous' plant which also promotes extreme values of acidity in the soil body (Goode and Ratcliffe 1977). Generally speaking, as *Sphagnum* spp. occupy extremely nutrient poor environments, plant decomposition rates are less than those found in base-rich environments. This may be reflected in the peat profile, where organic horizons under mosses may be more fibrous than under sedges due to their relative unpalatability to soil fauna (Rawes and Heal 1978).

Moorland plants tend to colonise nutrient deficient environments. These generally occur on weathering-resistant rock types such as quartzite, which provides a relatively impervious base inducing local ponding and eventually the accumulation of organic matter. Nutrient deficient environments may also occur over relatively fertile substrates in valleys where poor drainage leads to the accumulation of organic matter. As the layer of organic material increases, the plants colonising the surface will be further removed from the nutrient source. Therefore there should be a decrease in acidity down the soil profile.

1.2.3 Topography and Hydrology

Topography is a major contributor to the variability of soils in the landscape (Birkeland 1974). It influences the microclimate of a site, the hydrological conditions and the distribution of vegetation. Slope orientation (aspect) is well documented as having a great effect on plant distributions due to different microclimatic conditions and soil characteristics (Kirkpatrick and Nunez 1980). In the southern hemisphere sites on a south facing slope can be expected to favour peat formation more than those on a north facing slope. In southern Australia, this pattern may be enhanced by the frequency of fires being greater on the drier northerly slopes.

Slope angle also affects soil temperature, available moisture and drainage and therefore, the accumulation of organic matter. Where the incidence of the sun's rays is high, soils reach higher temperatures than on flat ground (Price 1971). This may occur over relatively short distances in response to microtopographic variation such as the leading edge of solifluction lobes. Position on a slope affects the amount of moisture received and retained. It is often the case that the deepest peats are found in valleys and basins while shallow peats occur on slopes (Taylor 1963, Moore and Bellamy 1973, Tallis 1973). Tallis (1973) found that variable peat depths were related to the subsurface topography of the site. Peat depth was inversely correlated to angle of slope where the angle was greater than 6-7°. No correlation was found on gentler slopes.

Topography affects the depth of the local water table due to its influence on drainage patterns. Because fibrous peats form above the regional water table and intermediate and muck peats form below it (Boelter and Verry 1977), topography indirectly affects the humification of the peat deposit (Malmer 1986).

A degree of circularity exists between soil type and hydrological conditions. The physical structure of the peat affects the hydrology of the mire system. Fibrous soils have higher hydraulic conductivities than amorphous soils (Carter 1986) though this is not necessarily applicable to all organic deposits (Mathur and Levesque 1985). Fibrous peats are relatively well drained, a condition which perpetuates further development of fibrous peats, given the right climatic and other conditions.

1.3 INTERACTIONS

Like mineral soils, peats form horizons and profiles which are the result of interactions with climate, topography, hydrology, vegetation, organisms and time (Jenny 1941 in Birkeland 1974). These factors may operate independently. However, the effects of each are difficult to disentangle. Interactions between the paramaters of climate, vegetation and topography may combine to create favourable conditions for the accumulation of organic matter in marginal areas for one parameter.

1.3.1 Climate and vegetation

Relationships exist between physical soil properties such as organic matter content, clay content and colour, and climate and vegetation (Birkeland 1974). Given similar environmental conditions, the amount of organic matter produced by plants increases with increasing temperature. At the same time the rate of decomposition also increases. Therefore, along an altitudinal gradient, one would expect a decrease in plant productivity and decomposition rates with an increase in altitude. As the rate of peat formation affects the type of peat formed, vegetation productivity and susceptibility to breakdown also affects the type of peat formed.

1.3.2 Climate and topography and hydrology

A combination of extremely high relative humidity values and rainfall evenly spread throughout the year may provide enough support for peats to develop on steep slopes (20°) (NCC 1988) or in tropical climates such as western Malesia (Anderson 1983). Therefore it is not necessary for soils to be waterlogged for peat formation to occur. Peats may accumulate on slopes where water is essentially free-draining, if the soil is not subjected to long periods of precipitation deficit.

1.3.3 Topography and hydrology

Hydrology is very much determined by topography, both the landforms of the region (subsurface) and the mire system (surface). The surface topography of raised bogs is much more important in the determination of hydrological conditions than the subsurface topography as the peat mass has developed in isolation from the ground water (Boelter and Verry 1977).

1.3.4 Topography, hydrology and vegetation

Relationships between topography and vegetation are closely related to relationships between hydrology and vegetation. Variability in slope, aspect and topographic position all affect hydrology and are reflected in the distribution of plant communities. Both pH and fluctuations in the water table level affect plant distributions and their transpiration rates (Boelter and Verry 1977, Goode and Ratcliffe 1977). Then the amount of moisture received and retained in the soil is partially dependent on topographic situation and plant transpiration rates.

Heinselman (1970) describes peatlands, which are classified according to hydrology, topography, botanical origin and thickness of peats and the natural vegetation. Malmer, (1986) notes that the vegetation often reflects changes in water properties, and that the peat accumulation rate in temperate regions is probably a result of differences in decay rate rather than in plant productivity rates. The degree of decomposition is very much related to plant type, local climate and hydrological conditions.

1.4 PEATS IN TASMANIA

Peatlands in Tasmania are not considered to be the most hospitable of environments, due to the difficulty of walking through boggy terrain on a cold, wet day while carrying a full-pack. Brown (in press) surmises the general feeling towards moorlands as being 'unappetising to the dry bushwalker'. It is not surprising therefore, that the peatlands of Tasmania are still not held in high esteem by the general population. Reports from the days of the pioneers highlight difficulties in transporting goods and themselves through vast tracts of heathy moorlands, and bush walking guide books today echo the same thoughts.

Peat covers approximately one seventh of Tasmania. The most extensive systems are located in the western half of the state, especially the south west. Attempts have been made to 'improve' this 'waste land' by aerating the soil in order to grow crops, graze cattle and plant pine forests

(Irby 1955). The following quotation illustrates the sentiments expressed on peat in the 1950's.

> This more or less inert mass, commonly known as peat, built up on the waterlogged land over the centuries by a type of plant life that possesses little power of transpiration, has created a matt of vegetable fibre that is in a state of arrested decomposition. Acids and toxins have formed inimical to the welfare of plant life of economic value to man, and his domestic animals...
>
> ...The soil must be rendered capable of what amounts to breathing. Life is the goal, the life of a living soil with its teaming hordes of aerobic and other bacteria...and all the rest of those factors essential to the welfare, even life itself of man and his domestic animals (Irby 1955:5).

The life creating processes to be applied to the soil were burning, ploughing, the addition of lime and a 'liberal dressing of superphosphate' (Irby 1955:7). Thankfully for telmaphiles, the experiment was not overly successful.

Peats in south west Tasmania cover wide areas of undulating terrain and so may be considered as blanket bogs (Jarman *et al.* 1988a, Pemberton 1989, Pemberton in press). It has been stated that blanket bogs *per se.* do not exist in Australia (Moore and Bellamy 1973, Campbell 1983). Tasmanian blanket peats are not acknowledged in the international literature, despite their ecological importance as extensive bogs in a globally marginal environment (Pemberton in press). If the strict definition of a peatland is adhered to then Tasmanian blanket bogs may be marginal. This is due to the shallow nature of typical peat horizons. The internationally accepted definition of peat (an organic soil greater than 30 cm deep) has been developed in the northern hemisphere where peats many metres deep are not unusual. However in Tasmania, 30 cm could be more accurately described as the average peat depth (Pemberton 1989, Balmer 1991).

Researchers in the northern hemisphere have used a combination of peatland morphology, nutrient status and botanical composition to classify peatland systems. They recognise bog, poor fen and fen, which are highly acidic (pH<4), acidic (pH 4-5) and acid to neutral (pH 5-7) respectively (Botch and Masing 1983). Particular plant communities are associated with these groups: bogs tend to be dominated by *Sphagnum* spp. and heath, while transitional fens and fens are dominated by sedges.

South west Tasmanian blanket peats have similar pH values as the oligotrophic bogs of the northern hemisphere. However, they are not strictly blanket bogs as they do receive nutrients from a source other than precipitation. The northern hemisphere classificatory system is not relevant to the Tasmanian case, as the sedge peats here are more nutrient poor than *Sphagnum* peats (Whinam 1990). They may be more appropriately classified as a poor fen or a sloping fen (Heinselman 1965), or as a blanket mire complex (Moore *et al.* 1984). Blanket mire complex appears to be the most appropriate term for Tasmania.

1.4.1 Origins

Tasmania has been affected by glacial processes but blanket bogs here are common on steep slopes, and are not confined to depressions, valleys or plateaux. Due to the extremely pyrogenic nature of buttongrass moorlands (the vernacular term for blanket bog vegetation), and a general acceptance of Jackson's (1968) model of ecological drift, blanket bogs in south west Tasmania are assumed to be pedogenic in origin (Campbell 1983). Aborigines and their burning practices are believed to have facilitated the spread of moorland communities (Jackson 1968). In a pollen analysis of a north east Tasmanian bog, Thomas (1991) found that the basal date of a peat/mineral soil interface correlated with Aboriginal occupation of the area (1660 $\pm$ 90 yrs, 2cm/100yrs). An accumulation rate of approximately 2cm/100 yrs was obtained for a valley bog in western Tasmania (van der Geer *et al.* 1991, 1.6 cm/100 yrs, Colhoun *et al.* 1992).

These rates are lower than those recorded for bogs in the northern hemisphere (5-6 cm/100 yrs) (Walker 1970).

Others argue that while the origin of these moorlands may be fire related in some areas, they may be topographically controlled in others (Pemberton 1989). In either case the present day climate must be supportive of the formation and continued presence of blanket bogs.

1.4.2 Climate

South west Tasmania is well known for its cold, wet, cloudy and humid weather, all of which are ideal for peat formation. Pemberton (1989, in press) states that a combination of these variables provides an anaerobic, acidic environment in which peat can develop. He also notes that impeded drainage is not a necessary component of peat formation as the large amount of rainfall received throughout the year keeps the surface layer of the peat moist and allows water tables to remain at high levels (Pemberton 1989).

Very limited climatological data are available for the south west. Meteorological stations are located on the edges of the region, at low altitudes. Estimates indicate rainfall of up to 3400 mm p.a. on the mountains (Figure 1.1), with low evaporation rates, low numbers of sunshine hours and high relative humidities (DPWH 1992). Mean maximum temperature in the warmest month (20°C for Strathgordon) appears to be relatively high when compared with values for blanket bogs in the northern hemisphere. However, the higher temperatures may be offset by the extremely high rainfall.

Studies have indicated by observation and by limited climatological data that there may be a precipitation deficit over the summer months, where the surface peat layer may dry out, crack and decompose (Richardson and Swain 1980, Jarman *et al.* 1988a, Pemberton 1989).

1.4.3 Floristics

Tasmania has representatives of all three botanical categories of peat, (moss, herbaceous and woody), although the sedge peats are the most dominant, covering approximately one seventh of the State (Jarman *et al.*

1988a) (Figure 1.2). In the northern hemisphere *Sphagnum* bogs are the most acidic peatlands, however in Tasmania, they are displaced in this role by sedge peatlands (Whinam 1990).

The sedge, *Gymnoschoenus sphaerocephalus* (species nomenclature follows Buchanan *et al.* 1989), commonly referred to as buttongrass, combined with various members of the Restionaceae (rush) family are characteristic of Tasmanian blanket bogs. In a general sense, buttongrass moorlands are considered to be at the opposite end of a continuum to *Sphagnum* bogs, this continuum being determined by fire frequency (Thomas 1991) and nutrient availability (Whinam 1990).

Relationships between vegetation type and soil colour have been reported. Jarman *et al.* (1982) found that soil colour could be related to vegetation type, with reddish fibrous peats developing under forests while black amorphous or fibrous peats occur under treeless vegetation.

While studies of the floristics of *Sphagnum* bogs (Whinam 1990), Blackwood swamps (Pannell 1992) and alpine moorlands (Gibson 1990) are reported in the literature, the amount of discussion given to physical characteristics of the peats underlying this vegetation is variable.

1.4.4 Topography

The depth of a peat profile is related to topographic sitution as it reflects moisture availability. Deeper peats are generally found in valleys and depressions while shallow peats are common on slopes. South west Tasmania is no exception with peats 1-2 m deep being recorded for valleys and shallow peats averaging 30 cm being recorded for slopes (Pemberton 1989, Pemberton in press).

There is no information on the direct effect of slope on soil type. Inferences are often made with respect to fibrous peats occuring on well drained slopes and ridges in contrast to muck peats which occur on poorly drained flats and depressions (Brown and Podger 1982, Pemberton 1989, Balmer 1990).

No information is available on differences in peat depth and type with aspect, although is is expected that differences do occur due to different microclimates being experienced on north and south facing slopes.

Information on the interrelationships between topography and soil are available as a result of botanical studies which have correlated environmental data with floristics.

1.4.5 Interrelationships

It has proven to be difficult to isolate any one factor which primarily determines variability in peat depth and type, or the distribution of plant communities in an area. Research suggests that these interrelationships between climate, vegetation, topography and soils are complex and highly variable. Confusing the picture even more are relatively unknown quantities such as fire history and local site history. While some work is available on the biota in peats such as the burrowing crayfish (*Parastacoides* spp.) little is known on other peat dwelling fauna. The crayfish themselves are possibly unique in the world of peat fauna, and are ecologically important to the moorland ecosystem, digging elaborate tunnels which aerate the soil and thus affect peat decomposition rates, and mixing inorganic material with organic material (Richardson and Swain 1990, Horwitz 1991, Wong 1991).

The distribution of Tasmanian *Sphagnum* peatlands are primarily influenced by climate, topography and soil nutrient levels. Temperature and moisture availability determine the distribution of particular geomorphic types, while topographically favourable areas in the form of depressions, record deeper peat depths than shelf or snowpatch mires (Whinam 1990).

Relationships were found to exist between vegetation, drainage and soils in alkaline pans in south west Tasmania (Brown *et al.* 1982). Vegetation varied primarily with acidity and depth to water table, however a secondary relationship was found between vegetation and humification and acccumulation of aerated peat. Bowman *et al.* (1986) agreed with Brown and Podger (1982) in their findings which related drainage

No information is available on differences in peat depth and type with aspect, although it is expected that differences do occur due to different microclimates being experienced on north and south facing slopes.

Information on the interrelationships between topography and soil are available as a result of botanical studies which have correlated environmental data with floristics (Brown *et al.* 1982).

1.4.5 Interrelationships

It has proven to be difficult to isolate any one factor which primarily determines variability in peat depth and type, or the distribution of plant communities in an area. Research suggests that these interrelationships between climate, vegetation, topography and soils are complex and highly variable. Confusing the picture even more are relatively unknown quantities such as fire history and local site history. While some work is available on the biota in peats such as the burrowing crayfish (*Parastacoides* spp.) little is known on other peat dwelling fauna. The crayfish themselves are possibly unique in the world of peat fauna, and are ecologically important to the moorland ecosystem, digging elaborate tunnels which aerate the soil and thus affect peat decomposition rates, and mixing inorganic material with organic material (Richardson and Swain 1990, Horwitz 1991, Wong 1991).

The distribution of Tasmanian *Sphagnum* peatlands are primarily influenced by climate, topography and soil nutrient levels. Temperature and moisture availability determine the distribution of particular geomorphic types, while topographically favourable areas in the form of depressions, record deeper peat depths than shelf or snowpatch mires (Whinam 1990).

Relationships were found to exist between vegetation, drainage and soils in alkaline pans in south west Tasmania (Brown *et al.* 1982). Vegetation varied primarily with acidity and depth to water table, however a secondary relationship was found between vegetation and humification and accumulation of aerated peat. Bowman *et al.* (1986) agreed with Brown and Podger (1982) in their findings which related drainage conditions to vegetation distributions and peat types i.e. structureless muck peats occurred in poorly drained sites, and fibrous organic soils on better drained sites.

In *Sphagnum* mires vegetation varies with respect to climate, nutrient availability and fire. Nutrient availability was reflected in the geology, peat depth and peat fertility (Whinam 1990). Data for alpine soils (Kirkpatrick and Dickinson 1984) and buttongrass moorlands (Bowman *et al.* 1986) shows that organic content is lower in recently burned plots.

While a strong case exists for interrelationships between vegetation and soils, Balmer (1990) found that the relationship is not applicable to all sites. In such a case, where there is little difference in the soils across a vegetation boundary, it is argued that fire history has altered the vegetation boundary.

Davis (1941) found that drainage, topography and vegetation were interrelated in the New Harbour region of south-west Tasmania. She reported that low water tables supported woodier communities whose soils had higher organic contents and moisture retention than the buttongrass community dominating areas of high water-tables. Bowman *et al.* (1986) found differences in vegetation distributions were related to a change in topography which in turn affected the level of the water table, and the physical characteristics of the soil.

Site history is as important as current site conditions. The initial formation of peats at a particular site, given the right climatic conditions, depends very much on the topography and drainage characteristics of the area. These factors while affecting vegetation patterns and peat formation, are affected by geomorphological processes such as glaciation. Additionally, recurring events such as fire also contribute to the vegetation/ soil mosaic (Brown and Podger 1982). The role of the Tasmanian Aborigines and their use of fire cannot be ignored (Thomas 1991).

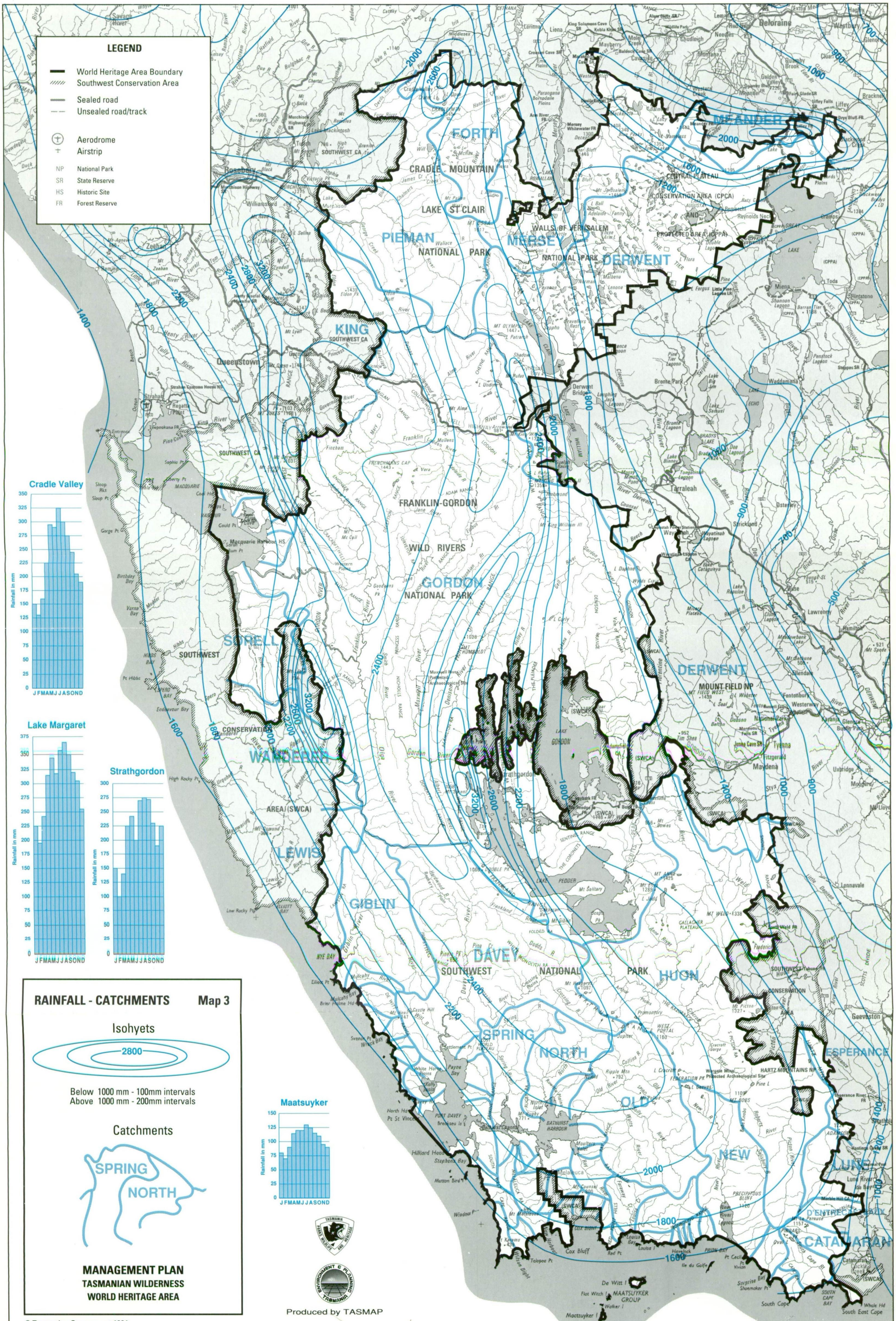

Figure 1.1 Rainfall in south west Tasmania Source: DPWH 1992

Reproduced with permission from DPWH and DEP

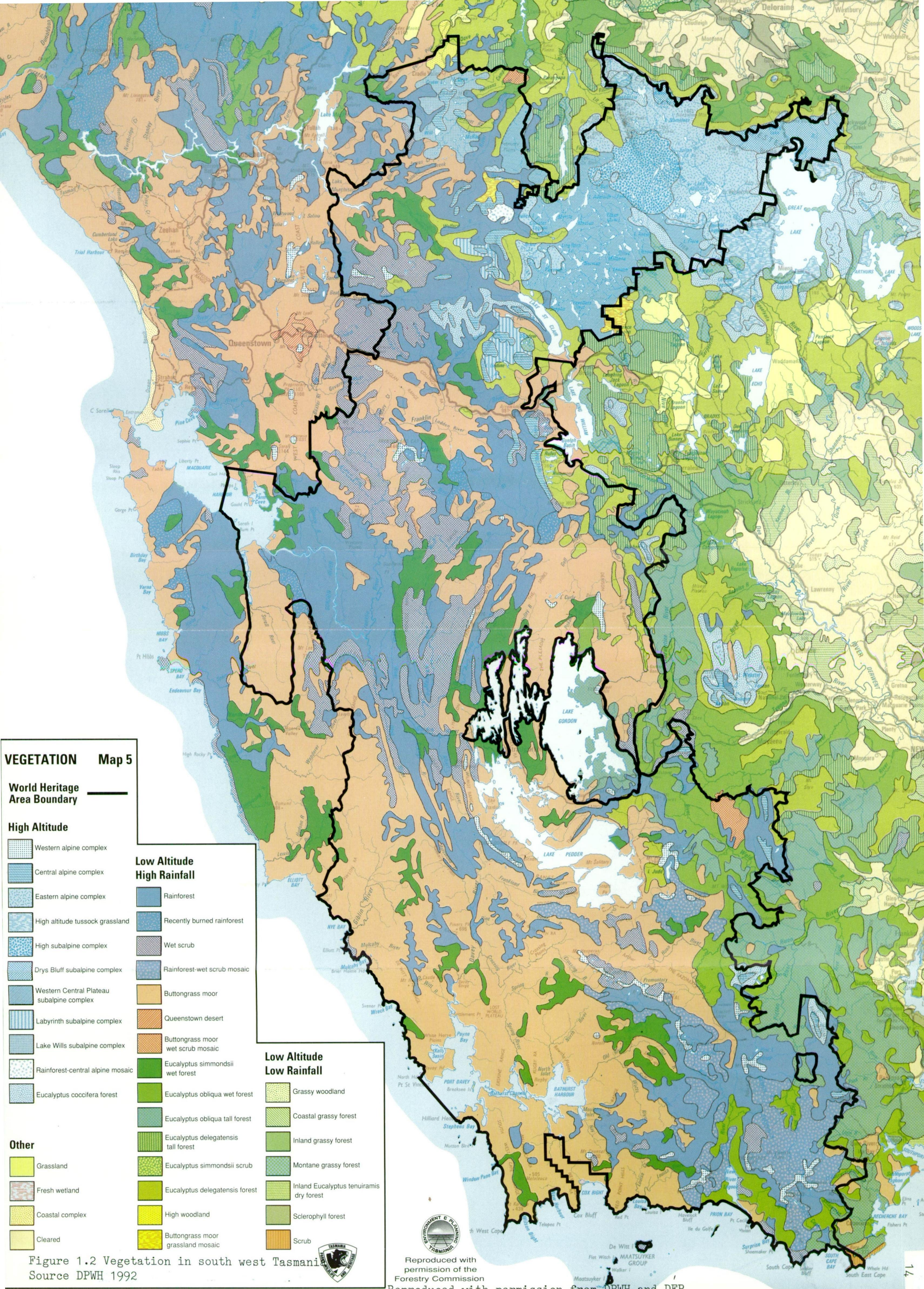

Figure 1.2 Vegetation in south west Tasmania
Source DPWH 1992

Reproduced with permission from DPWH and DEP

1.5 JUSTIFICATION

Research on the distribution, floristics and ecology of buttongrass moorlands in Tasmania (Kirkpatrick 1977, Gellie 1980, Brown and Podger 1982, Kirkpatrick and Brown 1987, Jarman *et al.* 1988 a,b, Balmer 1991, Horwitz 1991, Marsden-Smedley 1991, Wong 1991) generally omit data concerning the peat which underlies much of this vegetation type.

Information on Tasmanian blanket peats is extremely limited, especially with respect to spatial variation and interrelationships between vegetation, topography, soils and climate. Recent studies of buttongrass moorland communities highlight the need for research on peats such as: processes initiating formation, the rate of accumulation and loss (decay and erosion) of organic horizons, the age of deposits and physical properties of organic horizons (Jarman *et al.* 1988a, Balmer 1991, Pemberton in press).

1.6 SCOPE AND AIMS

The scope of this thesis is restricted to the determination of the spatial correlates of peat formation. The data gathered may lead to the provision of useful information for the management of organic soils in south west Tasmania and the development of hypotheses for further research into the climatic, vegetative and topographic parameters of blanket peats.

Thus, this project aims to describe in detail, variation in organic soils on a 'typical' mountain of south west Tasmania. Information is provided on relationships between the physical properties of organic soils and the environmental factors of climate, vegetation, topography and drainage over an altitudinal and topographic gradient.

Chapter 2 describes and classifies the soils of Mt. Sprent. Chapters 3, 4, and 5 explore climatic, vegetational and topographic correlates of peat depth and type. Chapter 6 discusses the interactive roles of all three parameters, and suggests hypotheses for further testing.

1.7 STUDY AREA

1.7.1 Location

Mount Sprent is located at 42°48'S 145°57'E and is the highest point on the Wilmot Range (1059 m), which adjoins the Frankland Range, creating a formidable barrier to the West Coast of Tasmania. The mountain is situated in the South West National Park and its ridgeline provides a border of the Tasmanian Wilderness World Heritage Area. The nearest settlement and meteorological station is at Strathgordon, 12 km to the north east (Figure 1.3).

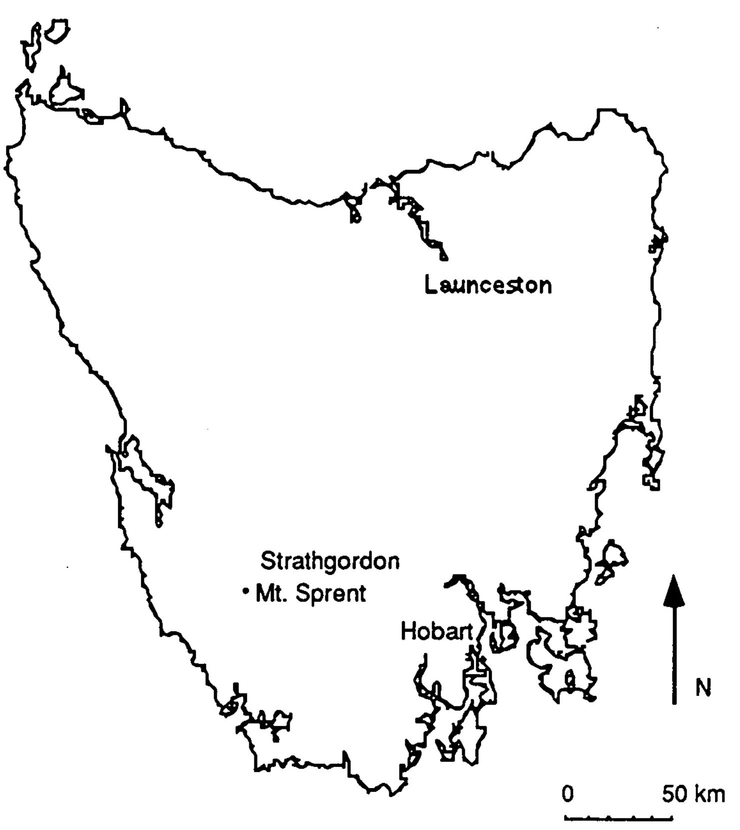

Figure 1.3 Location map of Mt. Sprent, south west Tasmania

Mt. Sprent is an ideal location in which to study ecological processes in the south west as it is easily accessible via the Serpentine Dam Road. It has been noted that the vascular flora and geology of the mountain are typical of mountains in the region (Pemberton 1989, Kantvilas and Jarman 1991) and so may provide an overview of processes affecting the region as a whole.

1.7.2 Geology and Geomorphology

The Frankland-Wilmot Range extends for approximately 30 km in a north-south direction and is between 2 to 5 km wide (Moscal 1981). The major rock type of the Wilmot Range is Precambrian quartzite. A deposit of pelite can be found south of the summit of Mt. Sprent (Boulter 1978) which traverses the study area (Figure 1.4). An amphibolite dyke is located due north of the summit, underlying a small saddle.

Despite the extensive glacial activity apparent on the adjoining Frankland Range, the Glacial Map of Tasmania (Derbyshire *et al.* 1965) does not show any glacial features for the Wilmot Range. However, Boulter (1978) suggests that the near vertical cliff face of Mt. Sprent could be the head of a discrete cirque, forming the shallow depression underneath it. It is acknowledged that ice reached down to an altitude of 350m (Derbyshire *et al.* 1965), but Boulter (1978) suggests that the limit was lower than this.

Boulter (1978) notes the highland features of post-glacial activity identified on the Frankland-Wilmot Range; cirques, aretes, hanging valleys, steep-sided fairly straight valleys and markedly stepped long profiles. These stepped long profiles are apparent on Mt. Sprent and are considered to have developed from glacial activity. Reduced vegetation cover combined with freeze/thaw activity to produce unstable slopes, resulting in the formation of solifluction sheets and landslip deposits (DPWH 1992).

1.7.3 Vegetation

Jarman *et al.* (1988a) produced a comprehensive classification of buttongrass moorland habitats for Tasmania. the following classificatory groups are applicable to Mt. Sprent:

B1. Standard Blanket Moor (graminoid heathland)
 a. Standard Peat
 b. Standard Pebbles
B4. Layered Blanket Moor
B14. Mountain Blanket Moor
 a. Common Mountain Moor
 b. Highland Standard Peat
B15. Mountain Copses
 a. Common Mountain Copses
 b. Dwarf Beech-Leatherwood Copses
BS2. Rocks
BP1. Alpine Lawns

Alpine communities may be classified according to Kirkpatrick (1983). The relevant communities to the mountain are:
Bolster Heath
Heath
Short Alpine Herbfield
Tall Alpine Herbfield

Botanical work has been carried out on the mountain, especially in relation to fire history (Jarman *et al.* 1988b) and fuel loads of buttongrass moorlands (Marsden-Smedley DPWH pers. comm.). Moscal (1981) created a vegetation map of the region. The most recent work has been on the distribution of lichens and bryophytes which includes a species list and community descriptions of the vascular plants found on the mountain (Kantvilas and Jarman 1991). The plant communities recognised in their study are:
1) Young *Leptospermum glaucescens* forest,
2) Buttongrass moorland, (B1)
3) *Nothofagus cunninghamii-Richea scoparia* scrub, (B15)
4) Alpine lawns and associated sedgelands, (BP1)
5) Sheltered rock sites,
6) Exposed rock sites,
7) Low altitude rock outcrops, (BS2)
8) Alpine rocks, and
9) Alpine heathland.

Of the vascular plant species recorded for Mt. Sprent, 63% are endemic to Tasmania Kantvilas and Jarman 1991). Most of the vegetation found on the mountain is fire adapted. The age of the last fire on the mountain is not known but it is hypothesised, due to the lack of fire sensitive vegetation and the abundance of fire resistant vegetation that the whole mountain has been affected by fires in the past. Jarman *et al.* (1988b) found that the stem age of woody vegetation on the mountain ranged from 22 to 29 years at 920m a.s.l. up to 31 to 59 years at 580m a.s.l.. Other ring counts from altitudes at and below 820m give an average age of 42 years since the last fire (Marsden-Smedley DPWH pers. comm.).

Results from preliminary analyses of these data suggest that there is a general increase in fuel-loads with altitude (Marsden-Smedley DPWH pers. comm.). Data from the DPWH harvested plots for three altitudes on Mt. Sprent substantiate this with the vegetation at 509m having an average fuel-load of 11.5 tonnes/hectare, and the vegetation at 820m recording 23.5 tonnes/hectare. This relationship may be explained by the structure of the vegetation at each site. Both sites are buttongrass moorland communities. However, the higher site records more woody species than the lower one. This suggests that either fire frequency is higher at lower altitudes or that plant decomposition rates are higher at lower altitudes.

Of the fire sensitive vegetation which remains, a small clump of deciduous beech (*Nothofagus gunnii*) survives on a highly protected shelf around the cirque head, and small pandani (*Richea pandanifolia*) are found near the rocky summit. Species of particular significance which inhabit the mountain are *Geum talbotanium*, and *Epacris navicularis* (nationally rare plants *sensu* Briggs and Leigh 1988) and *Richea curtisiae*, a local endemic.

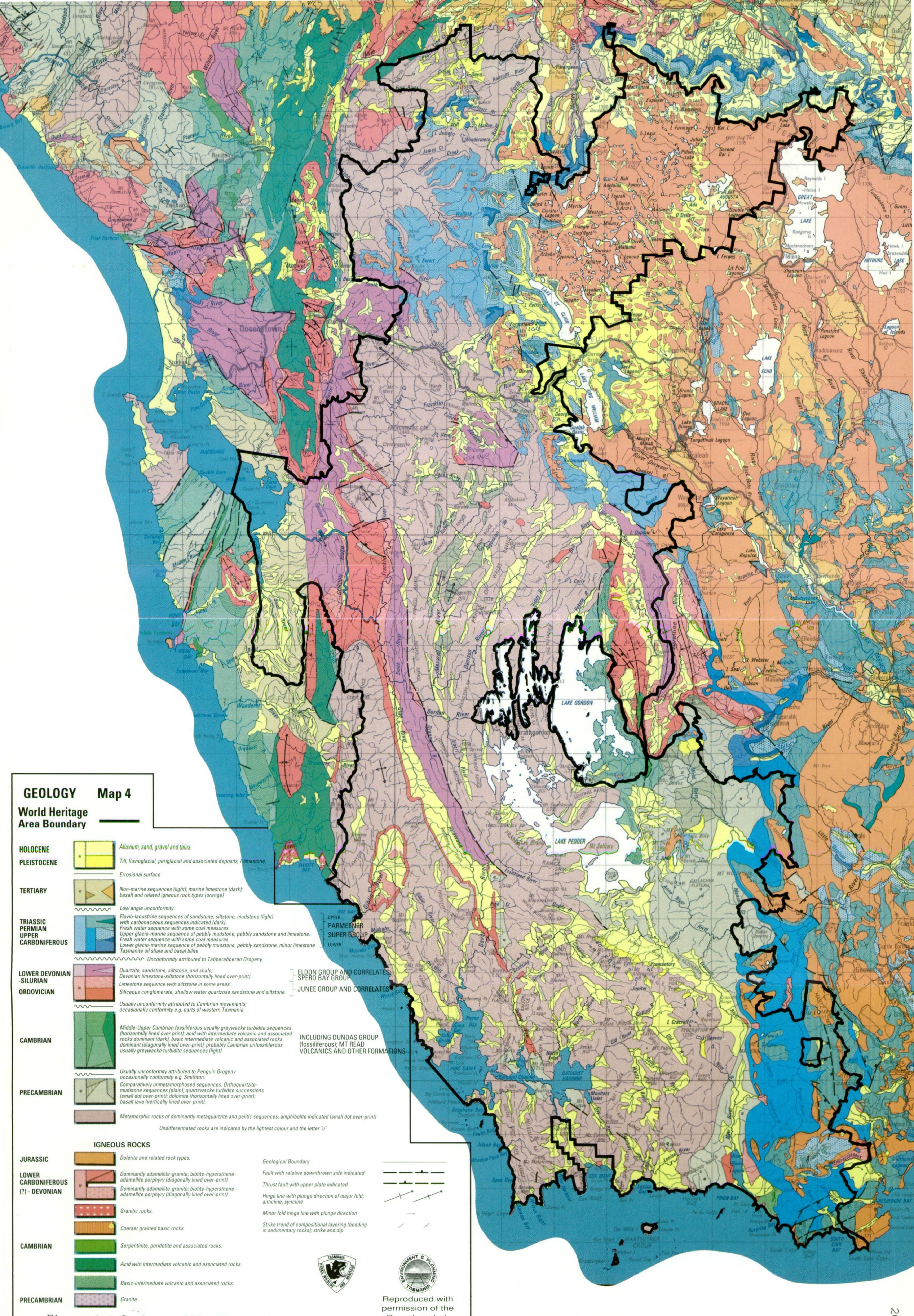

Figure 1.4 Geology of south west Tasmania

Source: DPWH 1992 Reproduced with permission from DPWH and DRP

Chapter 2 - ORGANIC SOILS OF MT. SPRENT

2.1 INTRODUCTION

Classifications of peats and peatlands are highly variable internationally, within Australia and within Tasmania. Variability in the methods used to classify peat soils has resulted in confusion in the literature. While literature is available comparing different techniques, standardisation of methods within Australia and Tasmania would enhance the comparability of the data collected. Nowhere in the literature has there been any detailed analysis of the effect of environmental variables on peat formation processes in Tasmania (Jarman *et al.* 1988a, Balmer 1990, Pemberton in press)

2.1.1 Non-Australian classifications of organic soils and horizons

Due to the complex nature and extreme geographic variability of peat soils, it has been difficult to create an internationally acceptable definition applicable for all interest groups (Boelter 1969, Jarrett 1982, Hanninen 1987). The US soil survey define peats as organic soils with less than 20-30% inorganic material (Andrejko *et al.* 1982), while Clymo (1983) states that an inorganic content of less than 20% is generally acceptable.

Peatlands can be classified with respect to one or more of the following criteria; morphology, floristics, topography, hydrology, stratigraphy, chemistry and physical peat characteristics (Moore 1984). The relative importance of a variable depends on the classification used. As floristics are relatively easily determined, classifications based on botanical composition take precedence in many studies of mire systems (Campbell 1983, Eurola *et al.* 1984). However, many of these studies do not detail the physical properties of the soil profile, an approach that is more common in economic surveys of peatlands (Jarrett 1982). Moore (1984) believes that classifications based on botanical composition and degree of humification are adequate for economic surveys, but are not appropriate for ecologically based studies. This view is not accepted by Farnham (1963) who believes that a 'useful' classification is a system based on relatively simple but specific morphological properties, easily identifiable by a field investigator.

The development of organic horizons is partially reliant upon hydrological conditions within the mire (peatland) system. Mire hydrologists have identified two organic horizons, the active upper layer or *acrotelm* and the inert lower layer or *catotelm* (Ivanov 1981). These horizons are differentiated by the position of the water table (Table 2.1).

Table 2.1 Characteristics of Mire Horizons

acrotelm	*catotelm*
contains an oscillating water table	has an invariable water content
has a high hydraulic conductivity	has a low hydraulic conductivity
is subject to periodic air entry	is not subject to air entry
is rich in peat-forming aerobic micro-organisms, and	is devoid of peat-forming aerobic organisms
has a live matrix of growing plant material	

(Ingram 1977)

The *acrotelm* is shallow and is usually less humified than the *catotelm* (NCC 1988), and may be absent in disturbed peatlands.

2.1.2 Australian Classifications

Northcote (1971) defined Australian peats as soils dominated by plant remains, with an organic content of greater than 20%. He defined two horizons: an O_1 horizon, consisting of undecomposed organic matter, and an O_2 horizon, consisting of organic material in various stages of decomposition. McDonald and Isbell (1984) adapted this classification to include P_1 and P_2 horizons. The prefix P represents organic soils which have been formed under water or in areas of excessive wetness.

The amount of organic content (20%) necessary for an Australian soil to be classified as a peat is very low compared to international definitions. Additionally, the peat must also reach a minimum depth of 30 cm in order to qualify as an organic horizon. This minimum depth is also accepted internationally, however organic profiles which are shallower than this and directly overlie bedrock or 'inert' substrates can now be classified as organic soils in Australia (Isbell 1992).

In an attempt to relate to non-Australian definitions, the new revised classification for Australian peats and organic horizons (Isbell 1992) follows those adopted by the Canadian and English and Welsh soil survey teams and is reproduced below.

The class of organic soils consists of:

soils that either

i) have more than 0.4m of organic materials within the upper 0.8m *or*

ii) have organic materials extending from the surface to a minimum depth of 0.1m, these either directly overlie rock or other hard layers, or overlie fragmental material such as gravel, cobbles or stones in which the interstices are filled with organic material.

Organic soils can then be divided up into horizons such as:

Soils that are more or less freely drained and never saturated for more than several days, (Aeric).

Soils in which the organic materials are dominated (= ca. 75% by volume) by fibric peat i.e. mainly well-preserved plant remains (fibres) whose botanical origin is easily identified, (Fibric).

Soils in which the organic materials are dominated by hemic peat i.e. the plant remains are intermediate in degree of decomposition between the less decomposed fibric peat and the more decomposed sapric peat of suborder 4, (Hemic).

Soils in which the organic materials are dominated by sapric peat i.e. strongly decomposed plant remains (fibre content less than about 15%) (Sapric).

Organic materials (peats) are defined as organic accumulations that are saturated with water for long periods (months per year) and have an organic content of 30% to 45%, or, are saturated with water for no more than a few days and have 50% or more organic carbon.

Spain *et al.* (1982) found loss-on-ignition (LOI) to be a good approximation of soil organic matter, as it is closely related to organic carbon levels. Therefore, it has been adopted in this study to represent soil organic content.

The LOI values quoted by Isbell (1992) are low when compared to non-Australian definitions of peat, but are appropriate when classifying shallow organic soils in south west Tasmania. While the internationally accepted cut-off for organic soils is 80% organic matter, many variations exist (summarised in Clymo 1983, and Jarman *et al.* 1988a). In countries such as England, where this cut-off has been adopted, researchers still call organic soils peats, even if these soils have organic contents of less than 80% (Charman 1992). This suggests that while researchers are aiming towards a global classification of peats, current classifications are not yet uniform.

2.2 TASMANIAN PEATS

Previous field classifications of Tasmanian organic soils have used McDonald and Isbell's (1984) classification, with the researcher allocating a soil to a P_1 or P_2 horizon, according to the amount of undecomposed organic matter (Pemberton 1989).

Numerous methods have been devised to determine degree of decomposition (humification) both in the field and in the laboratory. Field methods, while fast, are subjective and are reliant on the experience of the field officer (Farnham 1963, Chason and Siegel 1986). Values expressing degree of humification are applied to the soil by assigning a horizon to a category depending on the amount of material left in the hand after squeezing, the colour of the extracted water and the presence of identifiable plant remains.

Ecological research in peatlands in Tasmania has concentrated on the botanical variation in sites over relatively long environmental gradients. Very little work has been carried out on the variation of the physical properties of peats within a local area. It is proposed that peat depth is a function of growth rates and litter accumulation of plants, the rate of decomposition, and the impact of fire and erosion (Gellie 1980, Bowman *et al.* 1986, Pemberton 1988, 1989). Peat type is considered to be a result of species composition and drainage (Brown and Podger 1982).

Stephens (1962) classified the south west organic soils as moor podzol peats and moor peats. The latter soils are restricted to alpine areas. Both types are described as having a fibrous surface layer which 'metamorphoses' into an amorphous layer. These categories have been adopted by Nicolls and Dimmock (1965) who mapped the south west region as being covered by skeletal soils and moor podzol peats.

Brown and Podger (1982) described skeletal soils as a '...mosaic of bare quartzitic rock fragments and outcrop together with pockets of shallow silty peats' (1982: 660). However, these skeletal soils may be the product of repeated fires which have destroyed much of the organic layer (Pemberton 1989).

Moor podzol peats have two distinctive horizons, fibrous peats occurring on relatively well drained sites, and muck (amorphous, sapric) peats on areas of restricted drainage (Brown and Podger 1982). Tarvydas (1978) also commented on the apparent relationship between peat type and drainage, stating that dark grey muck peats are found on waterlogged ground, while reddish-brown fibrous peats are found on sloping ground.

Pemberton (1989) classified the organic soils of south-west Tasmania into two horizons; P_1, fibrous peat and P_2, muck peat (after McDonald and Isbell 1984) (Figure 2.1). Using a land-systems approach he delineated four groups of organic soils; *organic soils of coastal areas, organic soils of lowland depressions, organic soils on well drained slopes and ridges,* and *organic soils in sub-alpine and alpine areas.* The latter two groups are especially relevant to Mt. Sprent (Figure 2.1). Organic soils on well-drained slopes and ridges are typically shallower than organic soils in lowland depressions. They are generally between 30 and 60 cm deep and vary in colour according to drainage conditions. Reddish brown soils occur in better drained situations, while black soils dominate in poorly drained sites.

Organic soils in subalpine and alpine areas of south west Tasmania are restricted to sheltered positions in the lee of boulders or small crevices at high altitudes. At slightly lower altitudes or on more protected sites, shallow organic horizons develop (5 to 20 cm deep). These soils are generally light in colour (reddish brown) and are fibrous (Pemberton 1989).

Richardson (1985) in an analysis of lowland organic soils described profiles in which dark organic layers overlay sandier soils with a mean organic content of 41% (ranging from 17% to 76%). An analysis of his data showed a direct relationship between soil moisture content and organic content for saturated soils, while no relationship was determined for drier soils. Data for peat soils of the New Harbour region of the south west also showed a significant relationship between moisture content and organic content (Davis 1941).

Nicolls (1957) recorded an organic content of 43% for the upper horizon of organic soils in moorlands which decreased to 20% in the lower horizon. This finding is also supported by Maclean (1978) and Pemberton (1989).

Pemberton (1989) found that organic content decreased with altitude and with soil depth.

Data are available for organic soils on paired quadrats (burned and unburned) for lowland moorlands (Brown and Podger 1982, Bowman *et al.* 1986), and alpine heathlands (Kirkpatrick and Dickinson 1984). Organic content in soils from burned plots is less than in unburned plots, both in lowland and in alpine areas.

2.3 AIMS

The aim of this chapter is to describe variation in the soils of Mt. Sprent and to classify them according to their physical properties by using a standard internationally accepted method, that of the von Post Humification Scale (von Post and Granlund 1926 in Clymo 1983).

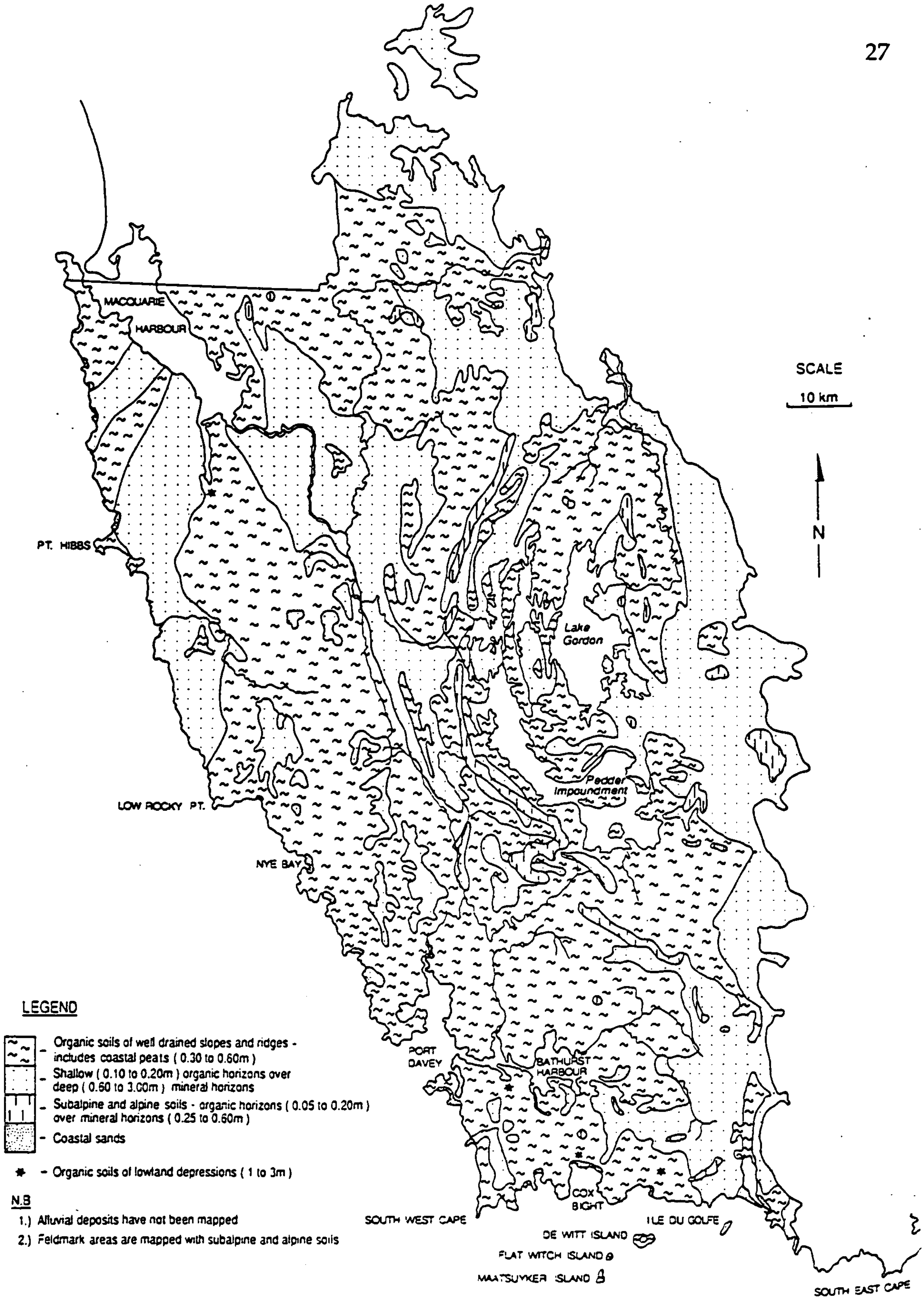

Figure 2.1 Organic soils of southwest Tasmania
Source: Pemberton 1989

2.4 METHODS

2.4.1 Field Methods

During the summer of 1989-1990, four sites were located at the altitudes of 620 m, 850 m (buttongrass moorland vegetation), 930 m and 1040 m (alpine vegetation). At each site a grid was laid out using tape measure and compass. The grid was made up of a number of intercepting transects consisting of continuous 25 m^2 quadrats (Figures 2.2 and 2.3) which covered vegetational and topographic variability within the site.

In addition five single transects, each 50 m in length, were located at altitudes of 580 m, 640 m, 720 m, 780 m and 840 m. Soil depths and profile information were collected from the sites. Attributes of the horizons were described in the field and organic and moisture contents were determined in the laboratory. These data were included in the analysis of the properties of horizons on the mountain.

The 1040 m site, consisted of one transect (8 soil samples), 70 metres in a NW direction. Five transects at the second site (930 m) were surveyed, ranging from 35 to 60 metres long in a NE or a NW direction. Data for the site at 850 m consisted of five transects varying from 25 to 100 metres in a NNW or an ENE direction. Finally, six transects were laid out in a grid pattern at 620 m. The transects were from 55 to 95 metres long in a WSW or a NNW direction. Table 2.2 lists the data collected and the technique used.

Table 2.2 Soil transect data collection and methods

Variable	Method
slope	clinometer
aspect	compass
soil depth	probe and soil pits
soil profile characteristics	soil pits

Soil depth was initially determined by using a steel probe, while a ruler was used to measure the depth of horizons in soil profiles. Soil depths were probed every 20 cm along the transects in order to assess the influence of subsurface topography.

Soil pits were dug wherever there was a change in conditions, i.e. with vegetation change, with an increase/decrease in rock cover, with a noticeable change in the feel or sound of the probing and with a change in slope. Each sample was representative of the soil for a particular sequence of horizons. For each pit the following data were recorded:
a) the type and depth of each horizon,
b) the degree of humification,
c) the colour, and
d) the presence and depth of gravels

Horizons were determined by the amount of discernible plant matter present, the amount of mineral soil present and by using the von Post humification scale where appropriate (von Post and Grunland 1926 in Clymo 1983). A Munsell soil chart was used to allocate soils to a particular colour.

The von Post Degree of Humification field method of determining decomposition has a scale ranging from 1 to 10, from H1 (unhumified) to H10 (highly humified) soils (Table 2.3). This method has been widely reported in the international literature and has been significantly correlated with other methods determining humification (Tolonen and Saarenmaa 1979, Paivanen 1973 in Ingram 1983, Hanninen 1987). Derivatives of this technique consisting of fewer, more general categories have been used especially for determining the economic value of organic soils (Farnham 1963, Barry 1979, LeMasters *et al.* 1982).

Charman (1992) outlined two 'reference' points which could be used to denote early peat growth: the first is the lowest horizon that illustrates a clear difference from a mineral soil by a rise in organic content. The second is the stage at which genuine organic deposits form, where the organic content is consistently at 95% or more. With this in mind, the determination of the depth of the organic soil is taken to be the total depth of any horizon which has an abundance of organic material. Therefore sandy organic soils are included with the three peat horizons in calculations of the depth of the organic soil horizon.

Only the depth of the gravel horizon was measured.

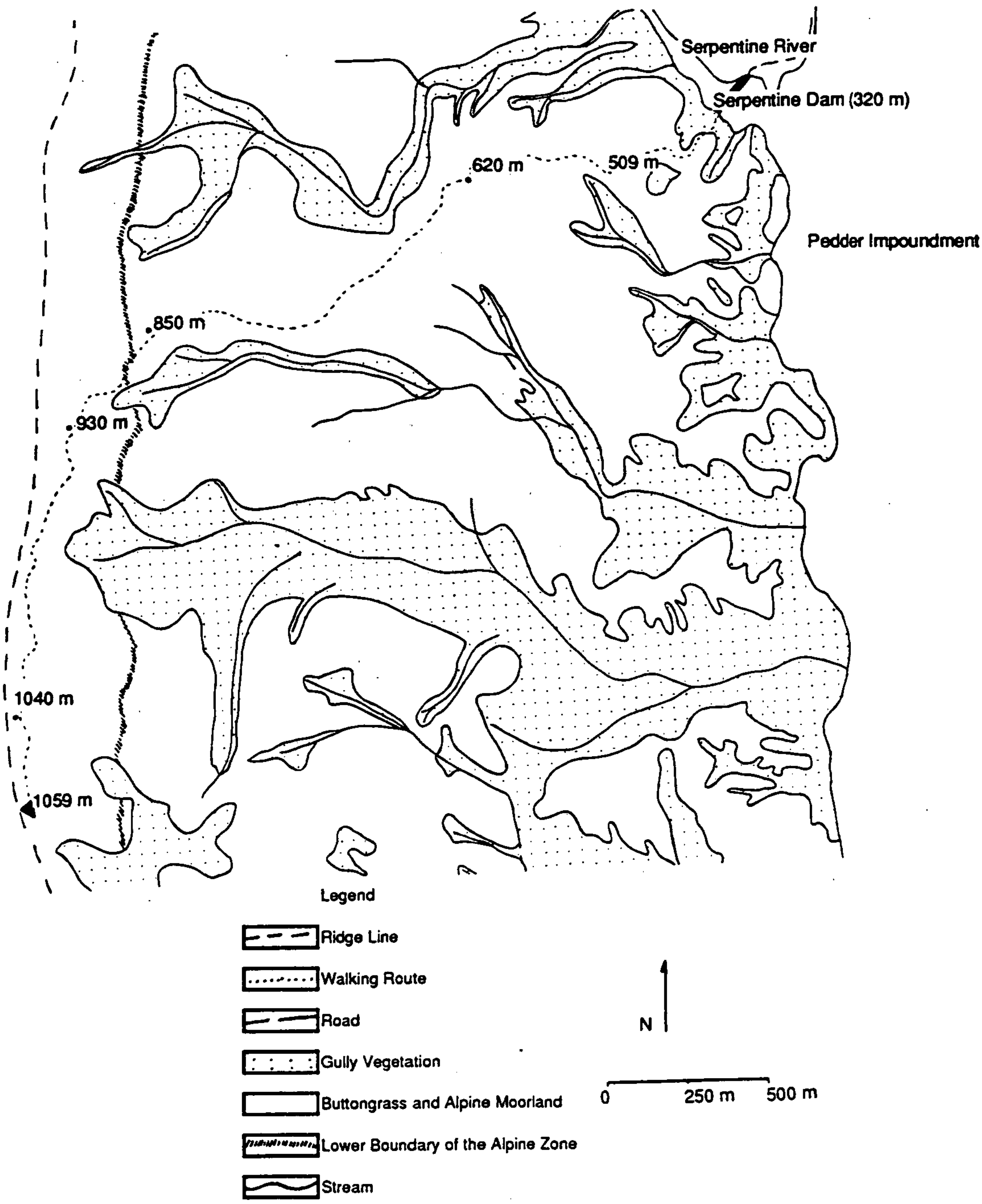

Figure 2.2 Location of sites on Mt. Sprent

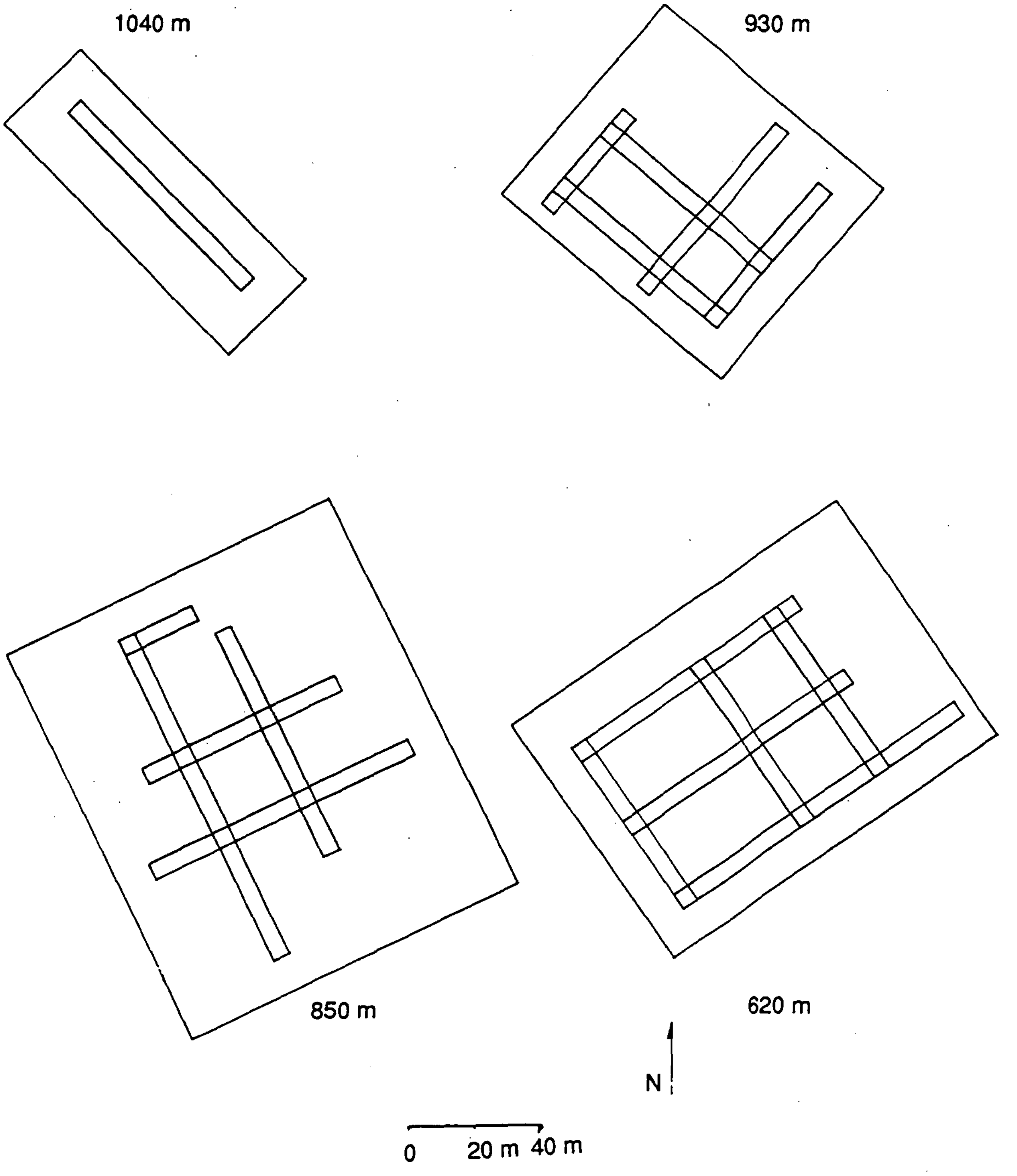

Figure 2.3 Location of transects at each site on Mt. Sprent

2.4.2 Laboratory Methods
Soils from each horizon were collected and placed in sealed plastic bags and stored in a freezer until laboratory analyses were carried out. The effect of freezing samples has been investigated by van Dijk and Boekel (1968). They concluded that the freezing of peat increased the soil's ability to store water. However, no conclusion was made with respect to the effects of freezing on peats with different degrees of humification. Stevenson (Dept. Geography, University of Newcastle-upon-Tyne, pers. comm.) believed that freezing peats not to be a problem as long as chemical analyses were not required. As each sample was treated in the same way, it was felt that the results were able to be compared from sample to sample, site to site. The soils were left to defrost over night. Samples weighed a minimum of approximately ten grammes. They were then weighed and placed into an oven at a temperature of 105°C for 24 hours. After this time the soils were reweighed, and the percentage moisture content of the sample was calculated.

Moisture content was determined by the following:

$$\% \text{ moisture content} = \frac{\text{sample wet weight} - \text{dry weight}}{\text{sample wet weight}} * 100$$

The samples were kept in sealed plastic bags, so it was assumed that water losses through the bag were negligible.

Loss-on-ignition (LOI) was used to determine the organic content of soils . A sample of oven-dried peat was weighed, then placed in a muffle furnace at 550°C for one hour (Walter 1974, Hakanson and Jansson 1983). The sample is then reweighed and the organic content (which is the inverse of ash content) can be determined by applying the following formula:

$$\% \text{ loss on ignition} = \frac{\text{wt. of air dried soil} - \text{wt. of combusted soil}}{\text{weight of air dried soil}} * 100$$

Organic content was determined by LOI for a portion (greater than 10 grammes) of all of the soil samples collected. The remainder of the samples were ground and sieved to less than two mm. These samples with distilled water 1:5 weight to volume and left to settle for 30 minutes, after which time, the pH value was recorded by a Microprosser pH/ion meter.

The field classification of soil horizons was checked against the organic contents determined by LOI. Horizons initially classified as peats were reassigned to an organic horizon if the organic content of the sample was not within the range denoted for a peat. Likewise organic horizons were reclassified as inorganic if percentage organic matter was less than 10%.

2.4.3 Statistical Analysis

The data from 185 horizons (89 samples) were combined with environmental and vegetation data for the transects into a spreadsheet. Multiple discriminant function analysis was used to determine differences in physical properties between soil horizons. The analysis computed a function which describes the maximum variation between groups. Using the chi-square test, it then compared the predicted groups with those identified by the researcher. The raw data were plotted and found to be unimodal. The data were log transformed and analysed using the statistical software package STATGRAF.

The soil data were classified according to horizon type and the following variables were used in the discriminant function analysis: moisture content, organic content, colour, degree of humification, pH, horizon depth, gravel depth and total depth of the soil profile.

The mean values for the soils data were collated for each horizon. Spearman-rank correlations were then calculated to relate the physical characteristics of the horizons to one another. Soils were compared between sites using Kruskall-Wallis one way ANOVA.

The data were reorganised into 89 samples which consisted of soil properties of the surface and bottom horizons. Of the 89 samples, a subset of 37 samples (91 horizons) were used for multivariate analyses. The data set was reduced to complete samples. It was decided that a sample be omitted if it included a missing cell rather than substituting an average value for the variable (Webster 1977).

Table 2.3 The von Post Humification Scale

H value	Description	Proportion of Dy	Plant Structure	Expressed Fluid	Peat Lost	Peat Retained in the Hand	
						Consistency	Colour
H1	completely unhumified	none		colourless/clear			
H2	virtually unhumified	none		yellow/brown/clear			
H3	little humified	small		noticeably turbid	none	not porridgey	
H4	poorly humified	modest		very turbid		somewhat porridgey	
H5	fairly humified - structure distinct	fair	plain but somewhat obscured	strongly turbid	some	very porridgey	
H6	fairly humified - structure less distinct	fair	indistinct but still clear		upto 1/3	very porridgey	
H7	quite well humified	considerable	much still visible		about 1/2	gruel-like	very dark
H8	well humified	large	vague		about 2/3	only fibrous matter + roots	
H9	almost completely humified	most	almost none visible		almost all	homogeneous	
H10	completely humified	all	none visible		all	porridge	

Source: von Post and Granlund (1926) in Clymo (1983)
Dy is a term used to describe structureless, dark brown humic matter which has no visible plant structure (Clymo 1983)

Multivariate discriminant function analysis was used to analyse the amount of variability in soils between sites. For the site data, colour and pH of the surface and lower horizons were not used due to missing values. However, depth of organic and mineral layers were included. The missing data cells were a result of both human and mechanical error (such as forgetting to measure moisture content for some samples, and faulty pH probes).

Relationships between individual variables were analysed by using the Spearman-rank correlation coefficient.

2.5 RESULTS

2.5.1 Horizon differentiation

In all, six types of horizon were recorded on the mountain (Table 2.4).

Table 2.4 Some physical characteristics of the soil horizons on Mt. Sprent.

1) P1 - a fibric organic horizon (organic content >30%, H value 1-3)
2) P2 - a hemic organic horizon (organic content > 30%, H value 4-6)
3) P3 - a sapric organic horizon (organic content > 30%, H value 7-10)
4) sandy organic horizon (organic content 10-30%)
5) sand (organic content < 10%)
6) clay

N.B. The gravel horizon is omitted as it is not considered to be a soil horizon.

Of the six horizon types recorded in the survey, only three (P1, P2, P3) had an organic content of greater than 30% (Table 2.5). The fibric horizon (P1) has the highest average moisture content (79%) and the highest organic content (67.7%). The degree of humification has a modal value of H3 (Table 2.5). It is the shallowest horizon with gravels sometimes present. The intermediate, hemic horizon (P2) has the second highest moisture content (77.4%) and organic content (60.6%). Humification has a modal value of H5. Gravels may be present within this horizon. The sapric, muck peat (P3) has the lowest moisture (74.6%) and organic contents (53.2%) of the three peat horizons. This horizon is well humified with a modal value of H8. It is the deepest horizon, averaging 19 cm.

As expected there is a large difference in the moisture and organic contents of the three peat horizons when compared with the inorganic horizons. Sandy organic soils have an average moisture content of 58% and an organic content of 19%. These horizons are relatively deep (14 cm) and are abundant at higher altitudes. Sandy organic soils and sands recorded the deepest gravel layers (4 cm).

Table 2.5 Characteristics of the six soil horizons recorded for Mt. Sprent.

Horizon Type	Moisture Content %	Organic Content %	pH	modal H value	Horizon Depth cm	Gravel Depth cm	n
Fibric peat (P1)	79.0	67.7	3.8	3	5.6	1.5	30
range	62.6-88.3	35.7-92.0	3.3-4.3		2.0-15.0		
Hemic Peat (P2)	77.4	60.6	3.8	5	7.0	2.6	47
range	63.8-89.2	30.6-94.8	3.3-4.2		3.5-20.0		
Sapric Peat (P3)	74.6	53.2	3.8	8	18.5	2.2	35
range	63.7-87.3	32.4-94.8	3.2-4.5		2.0-48.0		
sandy organics	58.2	19.0	3.8	8	14.2	4.1	53
range	38.2-83.7	10.0-28.2	3.3-4.3		4.0-40.5		
sands	39.6	6.6	3.8	9	10.9	3.7	17
range	31.3-50.0	2.8-9.7	3.3-4.6		3.0-33.0		
clay	42.1	18.4	4.0	8	10.2	0.0	3
range	25.2-59.0	4.1-32.1	3.5-4.3		7.0-13.5		

N.B. Values given are mean values unless otherwise stated.

Discriminant function analysis on the subset of 37 samples, found that the horizons were significantly different (Figure 2.4). The first function described 71.3% of the variability and had a chi-square value of 220.38 ($p = 0.0000$ for 32 d.f.). The second function was also significant, describing 25% of the variability (chi-square = 87.78, $p = 0.0000$ for 21 d.f.) The first coefficient separates the samples on the basis of organic and moisture contents and degree of humification (Table 2.6). These findings support the laboratory data by indicating that fibrous peats have the highest moisture contents and the shallowest horizons. The second coefficient separates the data on the basis of depth of horizon and total depth of the soil profile.

When the actual groups were compared to the predicted groups, the computer generated classification was in general agreement with the field and laboratory classification (Table 2.7). The intermediate peat has the most misclassifications (34%). Where intermediate peats occur in a profile they are usually between a fibrous and a muck peat. While there are obvious differences in the three horizons, the exact boundaries between them may be difficult to determine.

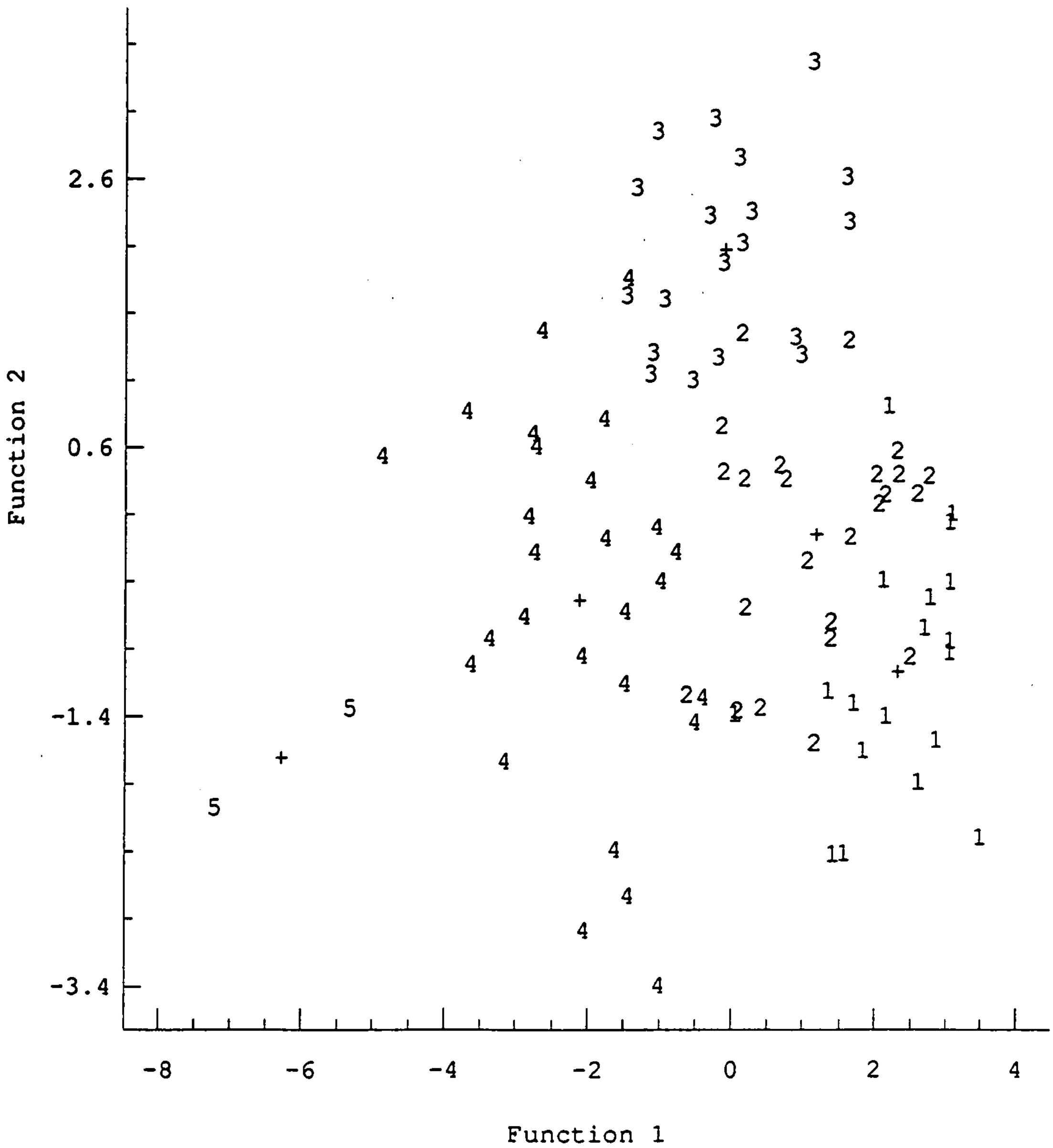

Figure 2.4 Discriminant function analysis of soil horizons from Mt. Sprent

Table 2.6 Standardised discriminant funtion coefficients for the soil horizons.

Variable	Coefficient 1	Coefficient 2
Moisture Content	0.37942	0.34408
Organic Content	0.63165	0.24047
pH	0.21107	-0.20591
Humification	-0.41731	0.50787
Colour	-0.13679	0.27091
Horizon Depth	-0.14043	0.79043
Gravel Depth	-0.05662	-0.04487
Total Depth	-0.05090	-0.52361

Table 2.7 Comparison of actual and predicted horizon classes by discriminant function analysis.

	Predicted Group					
Actual Group	1	2	3	4	5	Total
Fibric Peat	16	3	0	0	0	19
Hemic Peat	4	16	3	1	0	24
Sapric Peat	0	1	18	0	0	19
Sandy Organic Soil	0	0	1	26	0	27
Sand	0	0	0	0	2	2
Total	20	20	22	27	2	91

N.B. The three clay horizons were omitted from this analysis due to there being missing variables in these samples.

An analysis of individual variables showed that horizon type varied inversely with moisture content ($z = -8.245$, $p = 0.0001$), organic content ($z = -8.513$, $p = 0.0001$) and directly with depth of horizon ($z = 6.162$, $p = 0.0001$) and altitude ($z = 2.208$, $p = 0.0273$).

Moisture content and organic content are significantly correlated with each other ($z = 11.718$, $p = 0.0001$) and with horizon depth ($z = -2.583$, $p = 0.0098$, $z = -3.013$, $p = 0.0026$ respectively), colour ($z = -2.951$, $p = 0.0032$, $z = -3.814$, $p = 0.0001$), depth of gravel layer ($z = -1.979$, $p = 0.0478$, $z = -2.817$, $p = 0.0048$) and altitude ($z = -4.525$, $p = 0.0001$, $z = -4.044$, $p = 0.0001$).

2.5.2 Site differentiation

Eight samples were collected for the top site at 1040 m. This site consists of an extreme alpine environment with a number of relatively sheltered rocky areas and a very exposed saddle which receives the full force of the south-westerly winds.

The surface horizon is either an hemic peat, or a soil of sandy texture. The organic content of the organic horizons is comparatively low though is high enough to be considered a peat (30%, Table 2.8). The pH is lower than the other sites (3.6) and the colour is lighter (reddish-brown). The average depth of the surface horizon is shallow (5 cm). The lower horizons are organic sands, with correspondingly low moisture contents and low organic contents (17%). Colour is fairly uniform throughout the profile (reddish-brown). A mineral layer averages 2 cm in depth, overlying a gravel layer approximately 6 cm deep. The average soil depth of 21 cm contains a 13 cm organic layer, while the most common profile is a sandy organic horizon over gravels (Figure 2.5).

The second site, at 930 m, has a northeasterly aspect with slopes between 1° and 16°. Solifluction lobes are evident as are a number of rock outcrops. This site is essentially devoid of buttongrass (*Gymnoschoenus sphaerocephalus*) the dominant vegetation type at lower altitudes.

This site has an assortment of surface horizons ranging from fibrous layers to sandy organic soils. The site is dominated by amorphous sandy organic soils which have a mean organic content of 27%. The pH of the soil has an average value of 3.8. The average depth of the surface horizon is 18 cm. The horizon is highly humified with a value of H8, however, it cannot be classified as a peat as organic content is less than 30%. In general, if a fibric or a hemic organic soil is present as the surface horizon then it is usually accompanied by another (more humified) horizon. If a sapric (muck) peat is present then it is usually the only horizon. Organic content decreases with depth. Mineral horizons are shallow (1 cm) although there is a substantial gravel layer (5 cm). The average soil depth is 31 cm, 25 cm of which is organic (Figure 2.5).

Table 2.8 Soils characteristics of the surface and lower organic horizons for each site (89 samples)

Site	Modal Surface Horizon	Moisture Content %	Organic Content %	pH	H value	Horizon Depth cm
620 m	Fibric Peat	75.5	55.3	3.9	3	7.3
850 m	Sapric Peat	74.8	54.2	3.8	3	12.6
930 m	Sandy Organic	59.3	26.8	3.8	8	18.2
1040 m	Hemic Peat	63.9	30.5	3.6	3	4.8

	Modal Lower Horizon	Moisture Content %	Organic Content %	pH	H value	Horizon Depth cm
620 m	Sapric Peat	61.8	36.1	4.0	9	15.4
850 m	Sapric Peat	66.1	36.7	3.7	8	20.3
930 m	Sandy Organic	51.2	17.4	3.8	8	19.8
1040 m	Sandy Organic	52.1	16.8	3.8	8	8.8

	Organic Layer Depth cm	Mineral Layer Depth cm	Gravel Layer Depth cm	Total Depth of Profile cm	n
620 m	25.5	1.4	0.9	27	29
850 m	25.8	0.4	4.3	31	35
930 m	25.1	1.0	4.8	31	20
1040 m	13.0	1.8	6.0	21	5

N.B. The values given here are mean values unless otherwise stated.

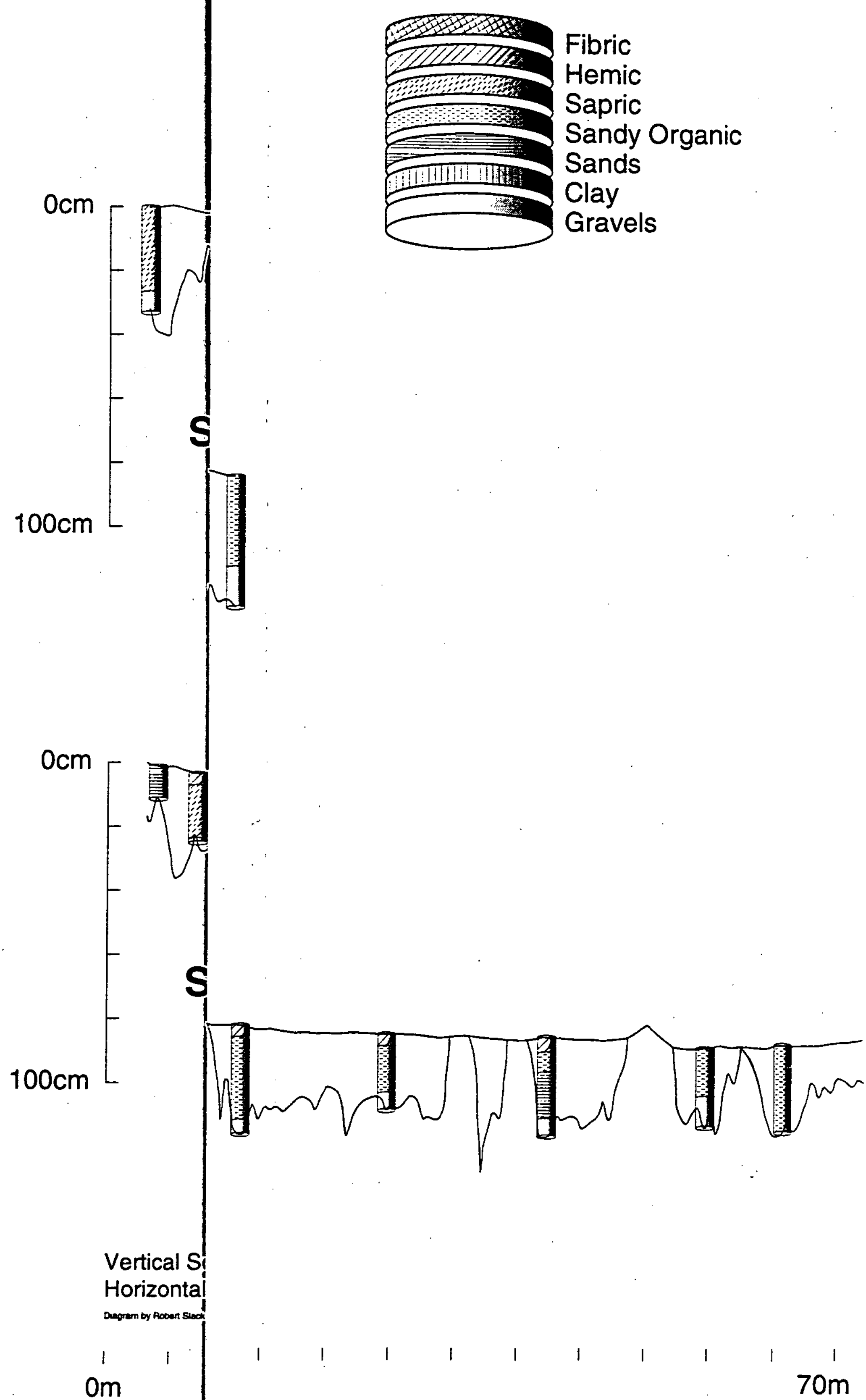
Fibric
Hemic
Sapric
Sandy Organic
Sands
Clay
Gravels
0cm
100cm
S
0cm
100cm
S
Vertical S
Horizontal
Diagram by Robert Slack
0m
70m

Figure 2

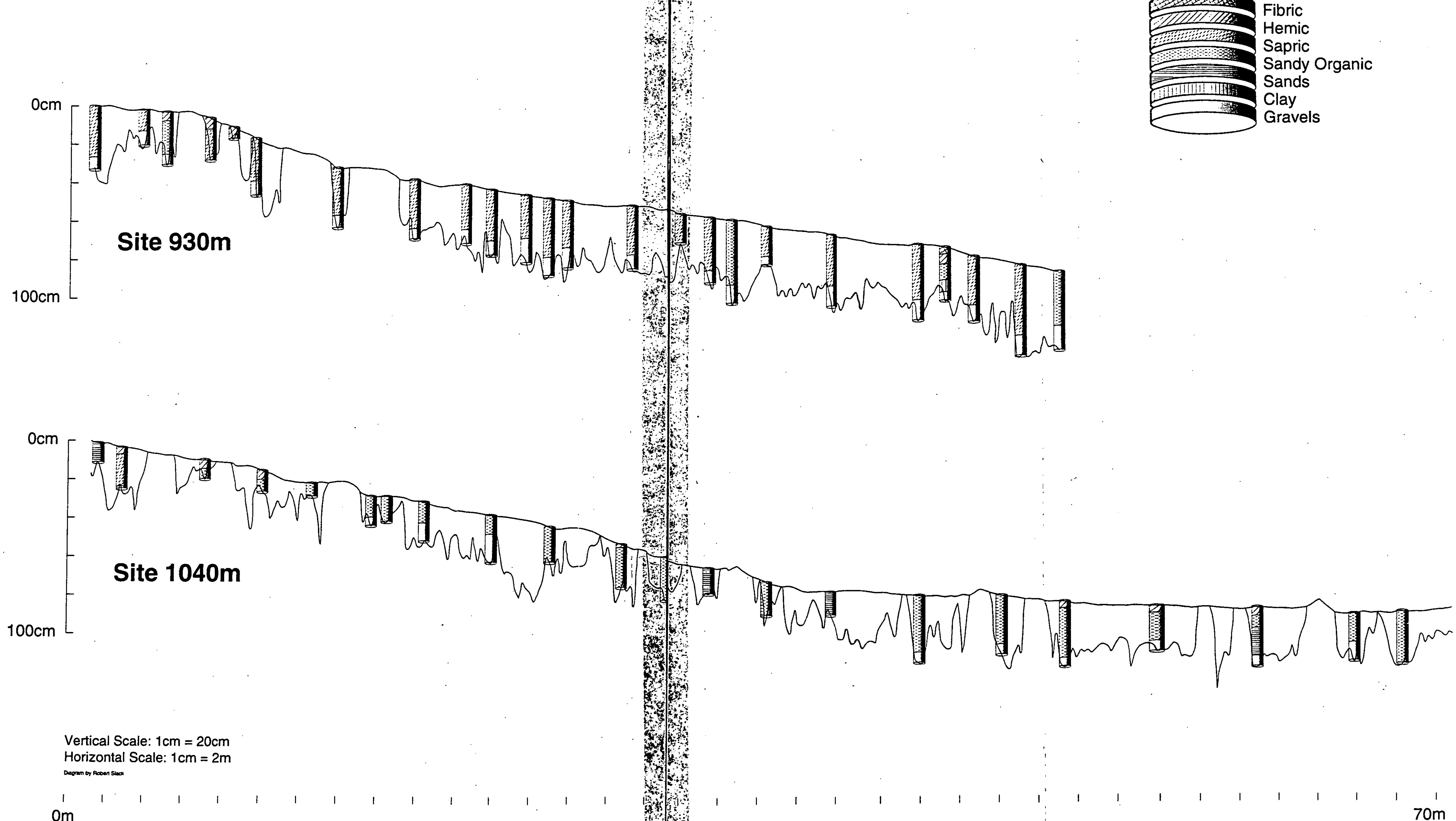

Figure 2.5 Topographic surveys and soil profiles for the sites at 930 m and 1040 m

The site at 850 m is a flat area which is waterlogged for most of the year. A shallow stream is present which flows even in the dry summer months. The site seems to receive moisture seeping from the steeply dipping, almost vertical rock faces to the WSW. It is suggested that the relative flatness of the area results in impeded drainage.

The uppermost horizon tends to be a sapric peat (organic content 54 %) with a slightly lower pH than the site at 620 m (3.8). The average depth of the surface horizon is 13 cm. The lower horizon is also predominantly a sapric peat (organic content 37%) although sandy organic horizons and sands are common. Colour (brownish-black) is fairly regular down the profile. The total depth averages 31 cm, 26 cm of which is organic. Any mineral layer present is very shallow (<1 cm) whilst the gravel layer averages 4 cm. The most common type of profile is a sapric peat overlying gravels (Figure 2.6).

Site 620 m is a relatively homogenous buttongrass moorland situated on a north-easterly facing crest. It is a gently sloping concave area with very little rock outcrop. In effect it is a miniature catchment with the head of the drainage system being located in the middle of the grid.

There is a dominance of fibrous, organic surface horizons (organic content 55%), with an average pH of 3.9 and an average surface horizon depth of 7 cm. A range of colours were found from dark reddish brown to brownish black. The lower modal horizon tends to be a sapric peat (organic content 36%). The average depth of soils at this site is 27 cm, 25.5 cm of which is organic. Sands and gravels are present though shallow (1 cm). The most common profile is a fibric over an hemic over a sapric peat. Degree of humification increases with depth (from avalue of H3 to H9) while organic content and moisture content decreases (Figure 2.6).

Figures 2.7 and 2.8 illustrate the relative values of organic and moisture content for the surface and the lower horizons at each site. There is a clear difference between the two lower sites (620 m and 850 m) and the two alpine sites (930 m and 1040 m). The site at 1040 m also has the shallowest organic horizon and the shallowest soils overall.

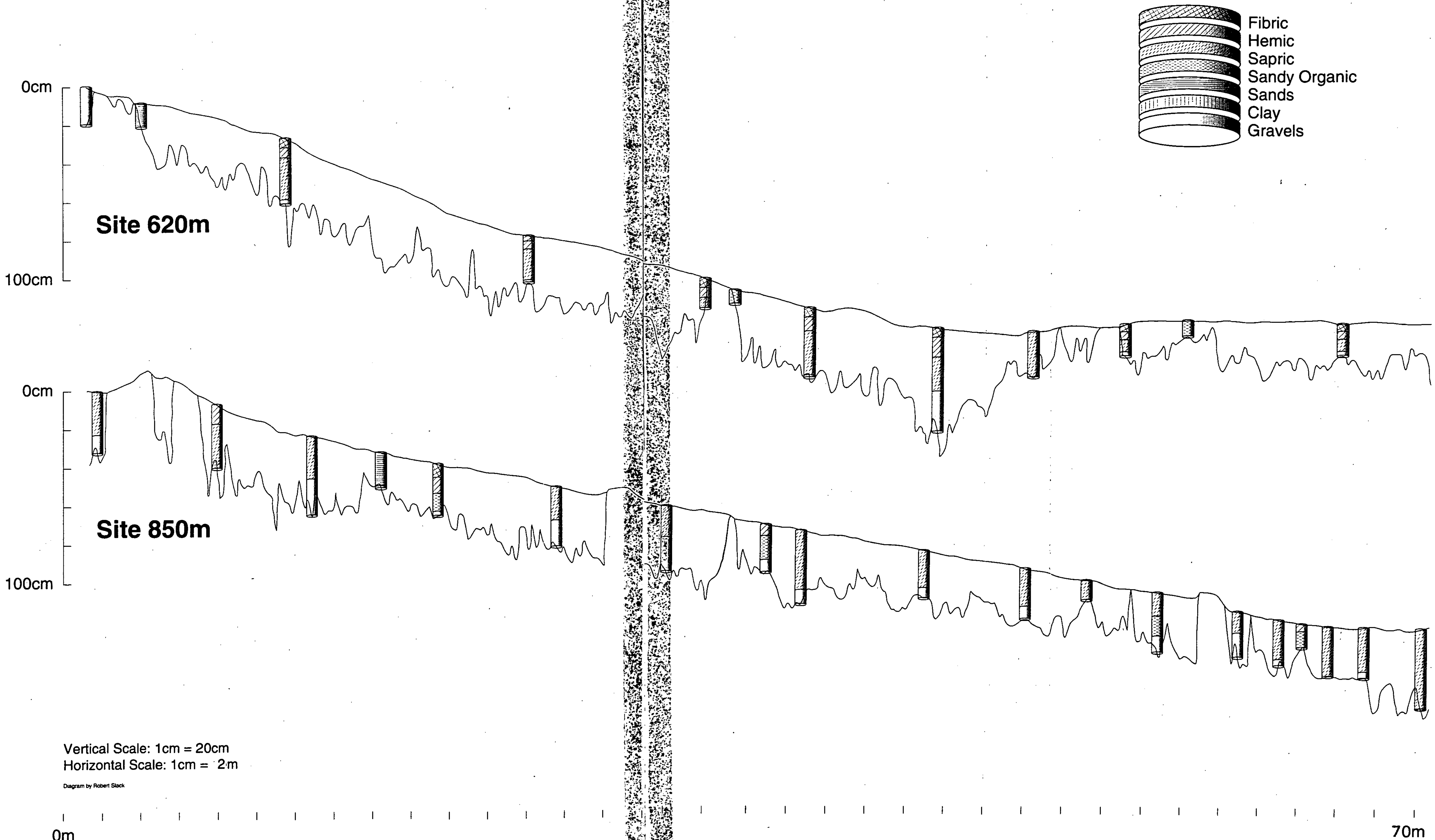

Figure 2.6 Topographic surveys and soil profiles for the sites at 620 m and 850 m

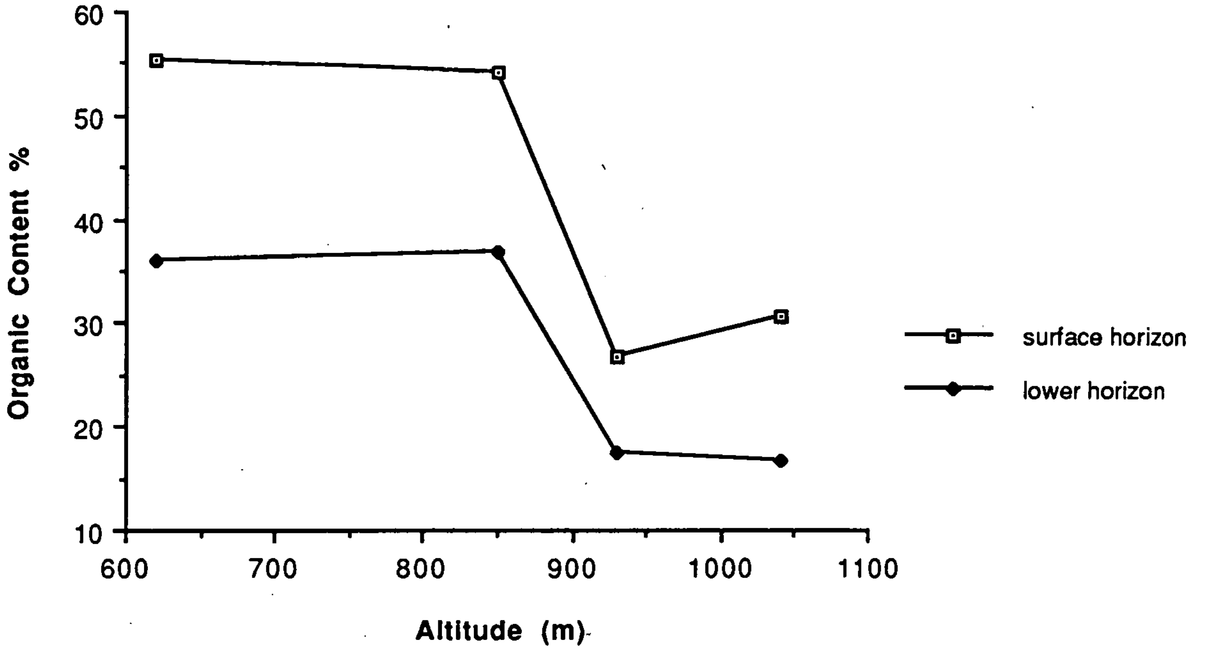

Figure 2.7 Organic content of the surface and lower organic horizons for each site on Mt. Sprent

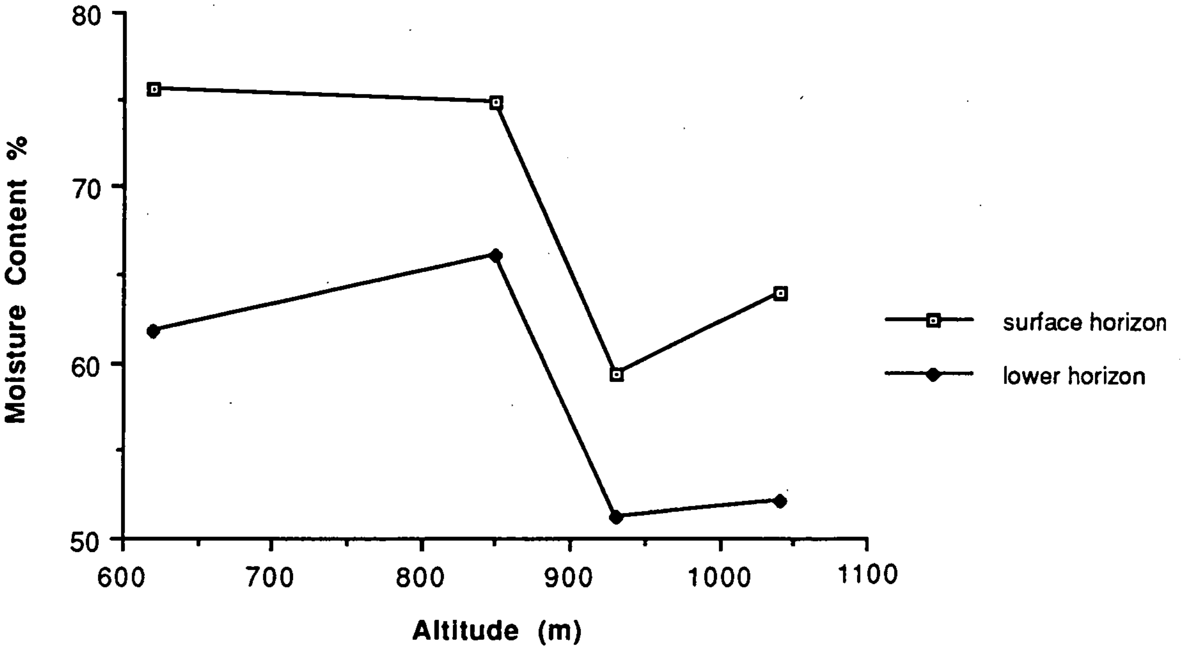

Figure 2.8 Moisture content of the surface and lower organic horizons for each site on Mt. Sprent

The least humified organic soils are the shallowest, and have the highest moisture holding capacity. Organic content is highly variable within and between horizons and sites. The presence of a fibrous horizon is not necessarily indicative of a high organic content. Sites with low organic contents (930 m and 1040 m) are those which have shallow horizons with relatively well developed sands or gravels as the lowest layer.

The humification of the surface horizon significantly varies with site ($H = 16.074$, $p=0.0011$). Moisture and organic content of the surface horizon are also related to site ($H = 18.226$, $p=0.0004$ and $z = 16.62$, $p = 0.0008$ repsectively).

Moisture and organic content of the lowest horizons decreases from 620 m to 1040 m ($z= -6.358$, $p= 0.0001$, $z = -7.135$, $p= 0.0001$ respectively).

No significant differences were found between sites in the depth of the gravel layer ($H = 6.958$, $p= 0.0733$), depth of mineral layer ($H = 5.142$, $p= 0.1617$), depth of organic layer ($H = 6.637$, $p= 0.0844$) or the total depth of the soil profile ($H = 0.3228$, $p= 0.3578$). Figure 2.9 shows that at the lower altitudes, organic soils dominate. However, there is an increase in altitude reveals a decrease in the dominance of organic material and an increase in the prominence of sands and gravel layers with altitude.

Plates 2.1 and 2.2 are examples of organic soils on Mt. Sprent. Plate 2.1 is a highly humified peat, at an elevation of 620 m underlying a buttongrass moorland community. Plate 2.2 is an hemic peat over a sapric organic soil. The presence of gravels near the surface may be attributable to the activities of the burrowing crayfish. The vegetation of this site (930 m) is alpine heath and has a much denser cover than the buttongrass moorland.

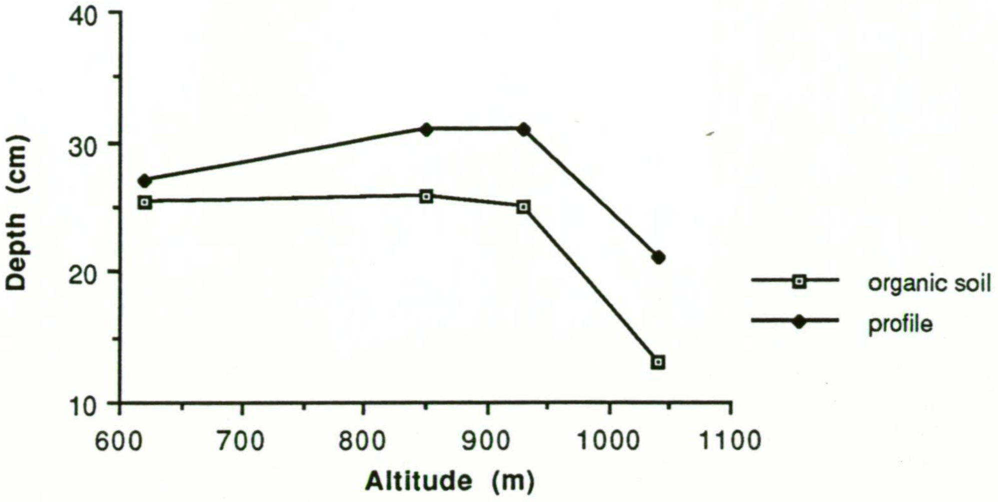

Figure 2.9 A comparison between organic soil depth and total profile depth at each site

Plate 2.1 Highly humified peat underlying buttongrass moorland.

Plate 2.2 Hemic peat overlying sapric organic soil underneath an alpine heath community.

2.6 DISCUSSION

The soils on Mt. Sprent are classified as peats because the organic horizons (P1, P2 and P3) have an average organic content of greater than 30-45%. These values, while lower than for other peat types (Whinam 1990), are comparable to those obtained for other organic soils of south west Tasmania (Davis 1941, Richardson 1985, Bowman *et al.* 1986, Pemberton 1989, Balmer 1990).

The majority of the soil samples from Mt. Sprent can be classified as organic soils as they consist of organic materials, greater than 0.1 m in depth, which directly overlie rock or fragmental material (Isbell 1992). Fibric (P1) hemic (P2) and sapric (muck P3) peats (Isbell 1992) are present although aeric peats are absent due to the consistently high rainfall experienced on the mountain.

There is a dominance of organic soils on the mountain with varying degrees of decomposition and organic content. The soils are consistent with the types recognised in the general land systems classification proposed by Pemberton (1989). However, they digress from this classification on the basis of organic content of the alpine soils. Pemberton (1989), using Northcote's (1971) definition of a peat, as an organic soil with an organic content of greater than 20%, classifies the alpine soils as peats. In the new Australian classification (Isbell 1992), peats are organic soils with an organic content of greater than 30-45%. Therefore alpine soils on Mt. Sprent and in south west Tasmania generally would be more accurately referred to as organic soils rather than peats.

The moisture content of a soil body is inversely related to bulk (dry) density (Klemetti and Keys 1982, Marachi *et al.* 1982) and ash content (inorganic content) (Landva *et al.* 1982). An inverse relationship exists between moisture content and the von Post humification scale (Klemetti and Keys 1982). These findings are supported in this study where moisture content decreases with increasing humification and with decreasing organic content.

The organic content of soils on Mt Sprent decreases with increasing humification. Although this is not necessarily the case for all peats, it appears to be a common feature in the limited literature concerning physical properties of shallow peat profiles (Goode and Ratcliffe 1977, Charman 1992). It is hypothesised that the decrease in organic content with depth is a result of the shallow nature of the soils and the presence of sands at the bottom of the profile which may have been intermixed with the organic soil through the activities of the burrowing crayfish (*Parastacoides* spp.) and by plant roots. The system as a whole receives the majority of its nutrient inputs from precipitation, however some input is received from upslope and from the physical weathering of the relatively infertile rocks.

These shallow peats may be of pedogenic origin rather than being purely climatic peats (*sensu* Taylor and Smith 1972, 1980). The geographical extent of buttongrass moorlands in Tasmania has been attributed to the effects of frequent fires (Jackson 1968, Bowman *et al.* 1986, Jarman *et al.* 1988a, Thomas 1991) although this is disputed by Pemberton (1989) who believes that some moorlands are present as an edaphic climax vegetation type. Rainforest and woodland communities are more fire sensitive than buttongrass moorlands (Jackson 1968). A decrease in the amount of woody vegetation may lead to a decrease in transpiration rates and an increase in height of the local water-table, all of which may result in the accumulation of peat soils. While organic soils are present under forests they are usually fibrous and shallow, overlying a mineral soil (Pemberton 1989). Therefore, the process of paludification (swamping) is considered to be of major importance in the formation of peats in Tasmania (Campbell 1983).

The variation in organic content between Tasmanian *Sphagnum* peats and buttongrass peats may be explained by the nature of the peat system itself and the depth of the peat soils. Generally, moss peats have a higher organic content than sedge peats (Klemetti and Keys 1982) which is explicable by taking into account the geomorphological context of the peat forming system.

Moss peats in Tasmania tend to occupy depressions such as kettleholes in moraine deposits which receive a relatively high nutrient load. Thus moss peats in these topographic situations have deeper organic soil horizons than sedge peats on sloping ground. There is a much greater contact between organic and mineral material in the shallow sedge peat. It is this contact with the substrate and the topographic position of the sedge peats receiving minerals from upslope, that determines the amount of mineral matter in the profile. Moss peats in similar topographic situations i.e. on slopes, have much lower organic contents than those in depressions (Whinam 1990).

In an international context, mires are often divided into low moor, transitional mires and high moor (Lishtvan and Tanovitsky 1979, Lishtvan and Korol' 1975 in Botch and Masing 1983). High moors have such characteristics as low pH values (from 2.5-3.6, and very high organic contents (96-98%). In contrast low moors have a pH range from 5-7 and organic contents of 93-94%. In this context the blanket bogs of Mt. Sprent may be more appropriately referred to as transitional mires (sloping fens) as they are highly acidic but have relatively low organic contents.

The organic content of alpine soils on Mt Sprent and in the south west generally (Pemberton 1989) are lower than those recorded for Mt. Field but higher than those recorded on Mt. Reid (Kirkpatrick and Dickinson 1984). Mt. Reid recorded highly acidic soils (3.8 on unburned sites) similar to values obtained on Mt. Sprent, while Mt Field recorded much higher values (5.4) (Kirkpatrick and Dickinson 1984). The south west consists mainly of quartzitic rock which is highly infertile compared to the dolerite of Mt. Field, indicating that geology has some input into the process of peat accumulation through plant productivity.

Individual soil properties vary significantly between the four sites on the mountain. On this basis, the soils are divided into lowland, subalpine and alpine soils. Sites at 1040 m and 930 m share some attributes (low organic contents) as do sites at 930 m and 850 m (depth of horizons) and 850 m and 620 m (similar organic contents). Thus, there is a gradational change in soils with altitude. These results lead one to conclude that there is a soil catena over an altitudinal gradient (after Corbett 1969).

Chapter 3 - CLIMATIC CORRELATES OF PEAT DEPTH AND TYPE

3.1 INTRODUCTION

Global and regional climates play a major role in the creation of habitats conducive to peat growth. Climatic factors are effective at a local scale but are somewhat disguised by the presence of other environmental factors such as topography and vegetation.

3.1.1 Macroclimate

Blanket bogs are extensive globally on the seaboards of temperate maritime regions (NCC 1988). These areas provide conditions, such as high rainfall, relative humidity and cloud cover and low evaporation rates which encourage the development of peat over undulating land.

South west Tasmania as a whole records slightly warmer temperatures than the suggested maximum for hill peat formation (less than 15°C in the warmest month) (NCC 1988). It has been suggested that peats form in the region due to the large amount of precipitation received and the high relative humidity levels (Pemberton 1989,) which effectively decrease the evaporation rate. This hypothesis is supported by research in other maritime regions where it is stated that conditions of 'extreme' rainfall (2500 mm for Scotland) can assist the formation of shallow peat on slopes of up to 20° or steeper (NCC 1988).

3.1.2 Mesoclimate

Morphology of particular peat forming systems are partially determined by, and rely on, climatic conditions for support and growth. Raised bogs and blanket bogs require much greater climatic support than valley bogs, due to their lack of contact with the groundwater supply.

Tasmania has a suitable climatic regime for the formation of blanket bogs (NCC 1988), and these bogs are the most widespread peat systems on the hills of south west Tasmania, inferring that climate plays a major role in peat formation in this region. Nevertheless, the large areas of blanket bog in south west Tasmania have been overlooked in the literature (Moore and Bellamy 1974, Campbell 1983, Costin 1986). Various hypotheses have been put forward as to why the peats are shallow, the most popular being that they are at their climatic limit for growth (Damman in Jarman *et al.* 1988a). It is suggested that a balance between peat accumulation and decay is achieved at around 30 cm depth (Balmer 1991).

3.1.3 Microclimate

A microclimatic model of peat formation may be composed of two parts: the first consisting of controls on temperature and the second, consisting of controls on moisture availability i.e. rainfall and evaporation. Variaiability in these factors may affect the depth and type of peat formed and the organic content of the peat by affecting accumulation and decay rates (Figure 3.1).

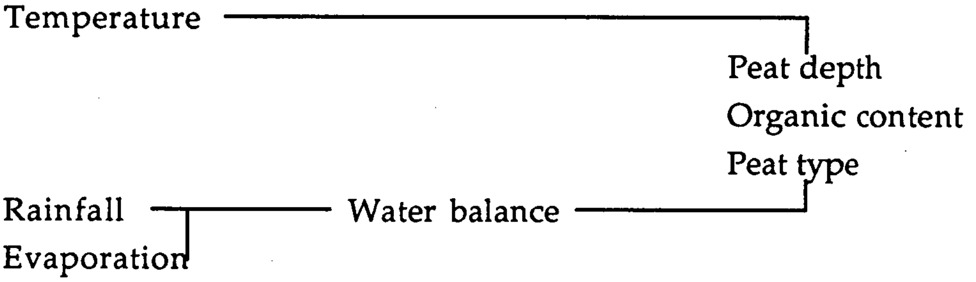

Figure 3.1. Simple model of climatic effects on peat formation.

For peat to accumulate in ombrotrophic conditions, precipitation needs to be greater than evaporation for most of the year (Boelter and Verry 1977). If evaporation exceeds precipitation, seasonal drying of the surface peat layer may occur (Richardson and Swain 1980), reducing the thickness of the organic layer and increasing erosion rates through shrinkage, fire and oxidisation (Jarman *et al.* 1988a,Pemberton 1988).

The amount of moisture in the soil affects both the movement of nutrients through the soil body and the actual process of soil formation (Oliver 1973). This is especially relevant to organic soils as the decomposition process is very much determined by the temperature and water content of the soil which affect microbial activity (Birkeland 1974, Wardwell *et al.* 1982). Variations in moisture content, temperature and microbial activity result in differences between organic horizons within and between sites. Schneider (1963) found that variability in the degree of decomposition in a profile was related to the amount of moisture in the upper layers of the profile.

Soil temperature decreases at a different rate to air temperature with increasing altitude (Barry 1981). Microclimates are affected by altitude with an increase in intensity of solar radiation being experienced, resulting in higher absolute surface temperatures at high altitudes than air temperatures (for clear skies). Mean annual ground temperature in the Alps was found to be greater than mean air temperature by 0.5°C at 600 m, 2.0°C at 1800 m and 2.9°C at 3000 m (Barry 1981). This would affect decomposition rates and may be reflected in the physical and chemical characteristics of the organic horizons. Physical and chemical properties of peats from ombrogenous (rainfed) bogs were found to vary with altitude (Gore 1963) possibly reflecting the influence of climate on plant productivity.

In a study of the distribution of Scottish moorland communities, it was found that soil type was related to altitude, slope and geology and that these differences were reflected in the distribution of plant communities (Nolan and Robertson 1987).

'Peaty rankers' (Nolan and Robertson 1987) appear to be very similar to the blanket peats in south west Tasmania in that they are characterised by an organic surface horizon up to 50 cm in depth and directly overlie hard noncalcareous bedrock or shattered rock. Peaty rankers are generally found in regions that experience low average temperatures and high mean wind speeds.

This chapter describes the climate of Mt. Sprent and relates its variability to soil properties.

3.2 CLIMATE IN THE STUDY AREA

3.2.1 Precipitation

The literature suggests that the amount of rainfall necessary for blanket bogs to form or be sustained is 1000 mm p.a (NCC 1988). Strathgordon records an average annual rainfall of 2486 mm (Bureau of Meteorology

1991) and estimated to be 3400 mm per annum on Mt. Sprent (DPWH 1992).

It is the distribution of rainfall rather than just total amount received which is important in the formation of peats (NCC 1988). Goode and Ratcliffe (1977) found that the number of wet days is more important in defining the limits of blanket bogs than rainfall *per. se* as wet days indicate distribution of rainfall. A wet day is any day which receives more than 1 mm of precipitation, with a minimum of 160 wet days correlating well with the distribution of blanket bogs.

Over a 10 year period Strathgordon received on average 189 wet days a year revealing a more than adequate distribution of rainfall. There was one year where the number of raindays was slightly less than the 160 day minimum (157 days). So while rainfall is more than adequate for most of the time, there are years when it may not be sufficient. In drought conditions, in which the surface peats dry out, oxidise and decompose, there may be a decrease in the thickness of the peat layer. (Jarman *et al.* 1988a)

3.2.2 Evaporation

Rainfall itself does not necessarily guarantee a habitat conducive to peat formation. Effective precipitation is more important in that it takes into account the effect of evaporation rates on moisture availability. The distribution of extensive blanket bogs in Britain has been related to an evapotranspiration surplus of 200 mm over spring and summer (April to September) (Stroud *et al.* 1987 in NCC 1988). If evaporation is greater than precipitation then organic matter will decompose quickly. Therefore it is important for evaporation values to be less than precipitation values in an ombrotrophic peat accumulating environment.

Evaporation depends on wind strength, the moisture deficit of the airstream, and on sunshine (Faircloth 1978). The mean annual record for open water (pan) evaporation for Strathgordon is the lowest in Australia. Estimates for evapotranspiration have been made by the HEC for 12 catchments in the south west region. It was estimated that approximately 71% of the mean annual rainfall for the region runs off into the sea with

29% being returned to the atmosphere by direct evaporation and transpiration by plants (Bosworth 1977).

3.2.3 Relative Humidity

Relative humidity is the ratio of the actual amount of water vapour present to the saturation amount (Bosworth 1977). High relative humidity levels are considered to be important in the formation of blanket bogs in marginal areas (Goode and Ratcliffe 1977, Clymo 1983). Stations bordering the south west region, generally record high relative humidity levels. Faircloth (1978) states that in the winter months mean humidity at 9 a.m. is about 81% with a mean maximum of 92%. The mean minimum for summer is about 71%. Humidities are generally lower in the afternoon with a mean minimum of 59%.

Long term average data (over 21 years) for Strathgordon are available showing high relative humidity values averaging from 76% to 89% for 9 a.m readings (Bureau of Meteorology 1991). In Ireland, where high humidity values contribute substantially to the peat forming environment, blanket bogs occur on slopes steeper than 20° (Clymo 1983). The south west of Tasmania has blanket bogs on slopes which are as steep and steeper.

3.2.4 Cloud Cover

The amount of sunshine measured in hours is the inverse measure of the average amount of cloud cover. Strathgordon records the least amount of sunshine in Australia, averaging about 7 hours per day in January and only 2 hours in June (Faircloth 1978, Bureau of Meteorology 1991). Cloud cover values have a mean minimum in the summer months and a mean maximum in winter.

This seasonal pattern is also reflected in the data for frequency of fog. There are on average 6-7 occurrences of fog in a month in the winter months compared with only 0.3-0.5 occurrences during summer (Faircloth 1978).

3.2.5 Temperature

According to the literature from the northern hemisphere, the best temperature regime for the optimum development of blanket bogs is a mean temperature of 9-15°C in the warmest month (NCC 1988). Strathgordon averages a mean minimum temperature of 10°C and a mean maximum of 20°C for February (Bureau of Meteorology 1991). It appears that the average temperature for the warmest month may be above that for optimum blanket bog development for some parts of the mountain, again possibly drying out the peat profile and reducing the depth of the organic layer.

3.3 CLIMATE ON MT. SPRENT

3.3.1 Methods

Until recently there were no climatic recording stations above 320 m in the south west of Tasmania. During 1989 members of the Department of Geography & Environmental Studies installed four climate stations on Mt. Sprent. The first station was located at the summit of the mountain at an altitude of 1059 m (Plate 3.1). The second station was installed at 930 m a.s.l. while the third station was located at 850 m a.s.l. The fourth station was located at an elevation of 509 m, at a break in the first steep rise from the Serpentine Dam (320 m). The elevation of the dam site and the summit of the mountain were known from previous surveys. The elevation of the three lower stations was determined with an altimeter.

There is an apparent sharp vegetational gradient on the south west mountains, where between the altitudes of 700 m and 900 m there is a noticeable change in the structure and floristics of the communities (Jarman *et al.* 1988a, Kirkpatrick.and Brown 1987). The data loggers were located with respect to the plant communities, above and below the 700-900 m zone and within it.

Each station consisted of a standard Bureau of Meteorology rain gauge and a Campbell data logger to record air and ground temperature and relative humidity for every minute of the day. From these data the daily maximum and minimum were extracted from the hourly readings. The station at the summit also recorded incoming solar radiation using a pyranometer. The data were stored on cassette tapes which were monitored every month when the rain-gauges were measured and emptied. Data were collected from March 1989 to June 1991.

Due to instrumental faults the data were incomplete. Over the two year period, 132 days of air and surface temperature data for all stations were retrieved. As the data were patchy, they were combined and analysed as a total data set for the station by season rather than by month. The humidity sensors were not well adapted to the climate on the mountain, resulting in a total data set of only 24 comparative days of data for all stations. Luckily these days all fall in the same month, February 1991, which at the very least allows for a comparison with Strathgordon for the driest month of the year.

Rainfall data were collected over the period February 1989 to June 1991. The rain-gauges used were standard copper rain-gauges supplied by the Bureau of Meteorology. Rainfall was measured for 29 consecutive months. Readings were taken as close as possible to the second of the month. Comparative data for Strathgordon were collated by summing the daily rainfall amounts in accordance with the length of time between rain gauge readings.

Additional rainfall data were supplied by the HEC for the Serpentine Dam site from July 1971 to October 1972. A comparison was made between the data for the dam site (at an altitude of 320 m) and the data for Strathgordon (also at 320 m a.s.l.) to determine the relationship between rainfall events at the two sites.

Evaporation values are not available for each station on the mountain, however they are available for Strathgordon. Comparisons between average monthly precipitation and evaporation values for Strathgordon were made over a 20 year period to determine the number of months where evaporation is greater than precipitation. As evaporation generally decreases with increasing altitude (Barry 1981), the value for Strathgordon may be used as an indicator of maximum evaporation for the sites on the mountain.

Plate 3.1 Climate station on the summit of Mt. Sprent (1059 m).

Net radiation values (Q^*) for the summit and Strathgordon were calculated using the following formula (Nunez 1978):

$$Q^* = K_d + L_d - K_u - L_u$$

where K_d = incoming solar radiation
K_u = reflected solar radiation
L_d = incoming long-wave radiation
L_u = outgoing long-wave radiation

An estimate of cloud cover for the mountain was extrapolated by using the sunshine data records from Strathgordon and the solar radiation data from the summit. The relationship between cloud cover, incoming solar radiation and number of sunshine hours can be determined by using the following equations:

$$K_d = K_{od}\,(0.26 + 0.5\ M/N)\ \text{cal cm}^{-2}\ \text{day}^{-1}$$

where K_{od} = extra terrestrial global radiation (cal cm^{-2} day^{-1})
M = measured sunshine hours
N = maximum sunshine hours

$$M/N = -1.206\ C + 1.271$$

where C = total daily cloud cover.

K_u was determined by approximating a regional surface albedo for the summit (Nunez *et al.* 1987). The vegetation chosen was scrub-heath sedgeland, southern Tasmania as it was the most appropriate description of vegetation on the summit of the mountain. The value of K_u was estimated to be 12% of the value of K_d.

With a value for cloud cover, outgoing long-wave radiation can be calculated using:

$$L_u = \varepsilon\sigma T_s^4 * 24 * 60 \text{ cal cm}^{-2} \text{ day}^{-1}$$

ε = surface emissivity
σ = Stefan Boltzmann constant = $8.13 * 10^{-11}$ cal cm^{-2} °K^{-4} min^{-1}
T_s = surface temperature (°K)

Surface temperature was assumed to approximate air temperature when averaged over a day (Paltridge 1975, in Nunez 1978), and so air temperature was used in the above equation. A mean surface emissivity of 0.95 was used as an approximation for Tasmania (Nunez 1978).

Incoming long-wave radiation was calculated by using a relationship for clear skies (Swinbank 1963, in Nunez 1978), and was adjusted for cloudy skies using an estimate of the amount of cloud cover received on the summit of the mountain.

$$L_d = 7.61 * 10^{-16} * T_A^6 * 24 * 60 \text{ cal cm}^{-2} \text{ day}^{-1} \text{ (for clear skies)}$$

L_d for cloudy days was assumed to increase by 12.4 cal cm^{-2} day^{-1} for each tenth of an increase in cloud cover (Paltridge 1975, in Nunez 1978).

Given all of the components of net radiation, a value for evaporation could then be determined for the summit of the mountain. Evaporation values obtained are only pertinent to the summer months, the most likely period of precipitation deficit. Net radiation and evaporation rates were determined for Strathgordon to test the validity of the method.

The raw data (rainfall, humidity and temperature) were plotted against altitude to illustrate the relative change between stations with altitude. An environmental lapse rate of 6°C/1000 m (Barry 1981) was added to the graphs of air temperature to compare actual gradients with expected gradients for the mountain.

To determine the actual rate of change of temperature against altitude, the temperatures measured for each station were compared to the nearest neighbour and divided by the difference in altitude that separated them, thus the following formula was applied:

$$\frac{\text{Temperature of Station A - Temperature of Station B}}{\text{Altitude of Station A - Altitude of Station B}} * 100$$

This equation gives a value for the change in temperature in degrees over a 100 m increase in altitude, which is an indicator of the steepness of the temperature gradient.

A paired-t test was used to determine whether the mean values of differences between stations were significantly greater than others. A probability of $p<0.05$ was accepted as the limit.

There is a general acceptance of the 'treeline' principle in the literature, where, on a global scale, trees are not found to grow successfully in areas where the mean maximum temperature for the warmest month is less than 10°C (Daubenmire 1954, Costin 1968). The air temperature of the summer season was calculated for each site, to see if there is a climatic constraint on vegetation growth on the mountain, which may influence peat production rates. The mountain is essentially treeless, however this may be caused by disturbance such as fire rather than the result of an adverse climate.

The number of frost days were determined by counting the days which experienced a temperature of less than 2.2°C (Bureau of Meteorology 1991).

3.4 RESULTS

3.4.1 Precipitation

As the data cover 29 months, they are presented in two graphs, one for autumn 1989 to summer 1990 (Figure 3.2), and one for autumn 1990 to summer 1991 (Figure 3.3). The corresponding data for Strathgordon (320 m) are also presented.

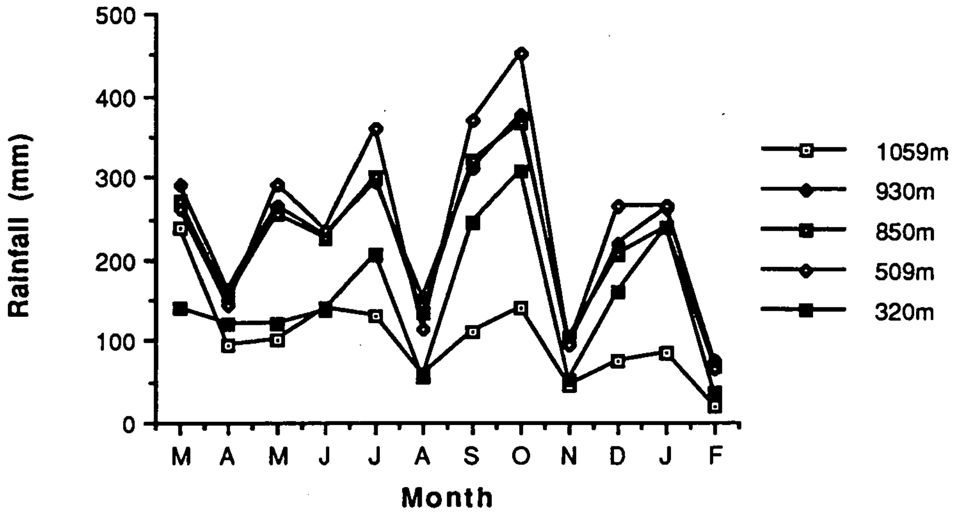

Figure 3.2 Monthly rainfall for each station on the mountain and for Strathgordon, March 1989 to February 1990

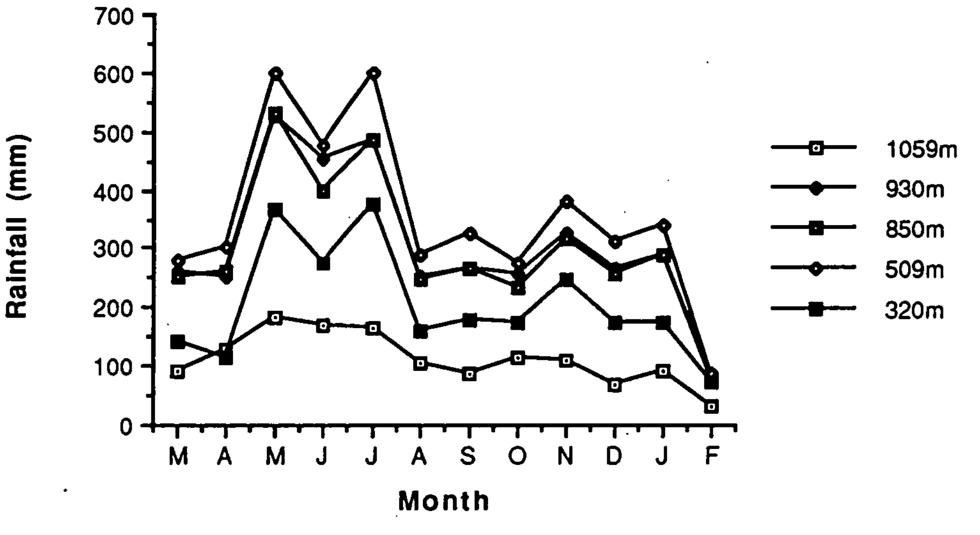

Figure 3.3 Monthly rainfall for each station on the mountain and for Strathgordon, March 1990 to February 1991

The two graphs reveal similar patterns with respect to the relationship between stations. The four lower stations all respond similarly to rainfall events. There is a very close relationship between stations 930 m and 850 m. The prominent feature of the summit station is that it has a subdued response to rainfall events.

It is interesting to note that while the lowest mountain rain gauge has the highest rainfall, Strathgordon, despite being regarded as one of the wettest parts of the State, is comparatively dry. When comparisons were made between the rainfall data for Strathgordon and the dam site at the base of the mountain, it was found that the dam site received a seasonal average of 20% more rainfall. Both sites are at the same altitude but are 12 km apart.

As the Strathgordon data react to rainfall events in much the same way as the stations on the mountain, it is not unreasonable to extrapolate the 189 wet days for Strathgordon as a minimum number of wet days for the mountain.

Using the data for Strathgordon, a comparison between evaporation and precipitation over a 20 year period showed that 9% of the months had a precipitation deficit i.e. evaporation values were higher than precipitation. This phenomenon occurred mainly in the month of February, when rainfall is at a minimum and temperature at a maximum. An average monthly evaporation rate for summer of 109 mm was determined for the summit. When this value was compared to the monthly precipitation for the summit, all of the summer months had precipitation deficits. During the summers of 1989-1991, the summit received between 20-93 mm of rain. If this evaporation estimate is compared to the other three sites, all three would have experienced a precipitation deficit in February 1989, 1990 and 1991. For the same period, Strathgordon had a precipitation deficit in February.

3.4.2 Relative Humidity

For the month of February 1991, the mean maximum relative humidity is fairly constant, varying from 94% to 96% (Table 3.1, Figure 3.4). However, a different pattern emerges for the mean minimum relative humidity values. There is a gradual increase in humidity from 509 m to 850 m which steepens to 930 m and decreases at the summit. The station at 509 m has the lowest mean minimum humidity of 67%.

Table 3.1 Summary statistics for climatic measurements taken at each of the four stations on Mt. Sprent.

	1059 m	930 m	850 m	509 m
Maximum air temperature (°C)	9.6	9.4	10.5	13.2
Minimum air temperature (°C)	4.3	3.6	4.4	5.7
Maximum relative humidity (%)	94.0	96.5	95.8	94.7
Minimum relative humidity (%)	71.1	74.9	72.7	67.4
Maximum surface temperature (°C)	7.3	8.6	9.8	13.4
Minimum surface temperature (°C)	3.6	3.6	4.9	6.0

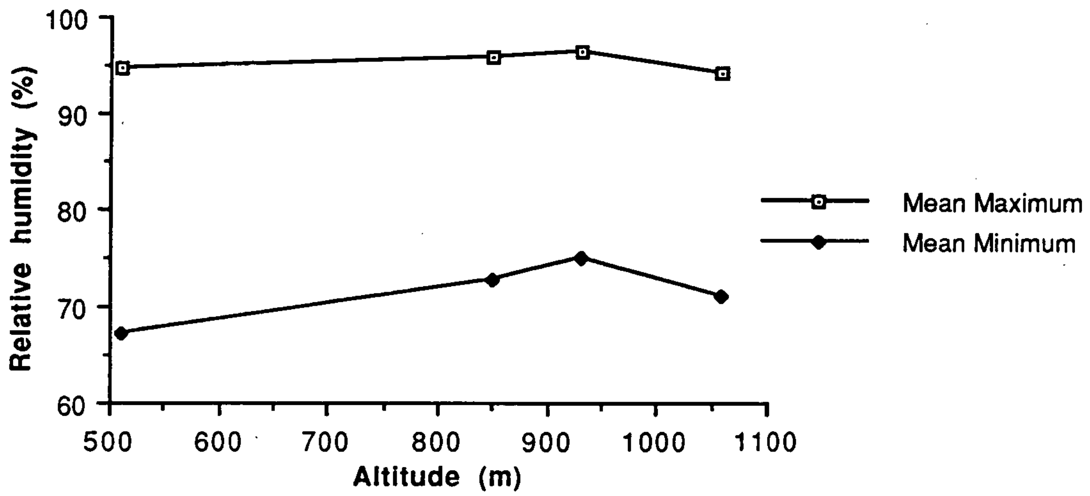

Figure 3.4 Mean maximum and minimum relative humidity for the stations on Mt. Sprent

Data for Strathgordon show an average humidity of 79% at 9 a.m (54% at 3 p.m.) (Bureau of Meteorology 1991). which is much lower than the value for the lowest site on the mountain.

3.4.3 Cloud cover

It is estimated that the summit receives 7-20% more cloud than the village, depending on the time of year. During winter, values between the two sites are much closer than in the summer months.

Net radiation at the summit is 8-17% less than Strathgordon.

3.4.4 Temperature

It is usual for air temperature to decrease with an increasing altitude (Barry 1981). However, this was not found to be the case on Mt. Sprent. While the general pattern is one of decreasing temperature with increasing altitude, there is an inversion illustrated by the anomalous temperature of the second station (930 m a.s.l.) which has a lower maximum and minimum air temperature than the summit. This inversion is not apparent in the figures for maximum and minimum surface temperature (Table 3.1, Figures 3.5 and 3.6).

There was a significant difference ($p < 0.05$) between the maximum air temperatures of all stations (Table 3.2). When the seasonal data were compared, the most numerous significant differences occurred between stations 850 m and 930 m. The presence of an inversion results in the second site experiencing a colder climate than 850 m and 1059 m.

The number of days below the treeline determinant of 10°C in the warmest month are given in Table 3.3 along with the number of frosty days. Stations 930 m and 850 m record a similar number of summer days where the daily maximum air temperatures is less than 10°C. The most frequent occurrence of frost at all stations is in the winter months while during summer, the number of frosty days decreases with decreasing altitude.

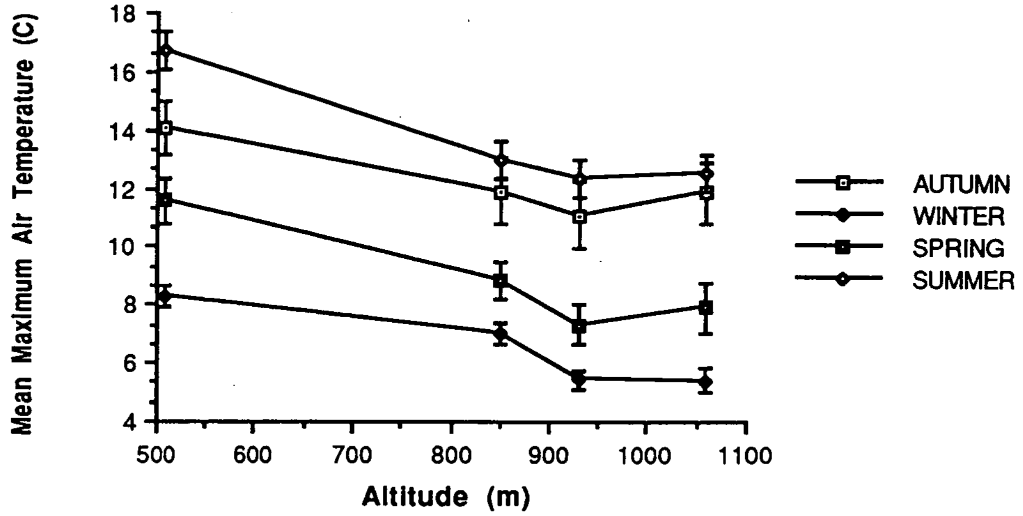

Figure 3.5 Seasonal mean maximum air temperatures for each station on Mt. Sprent

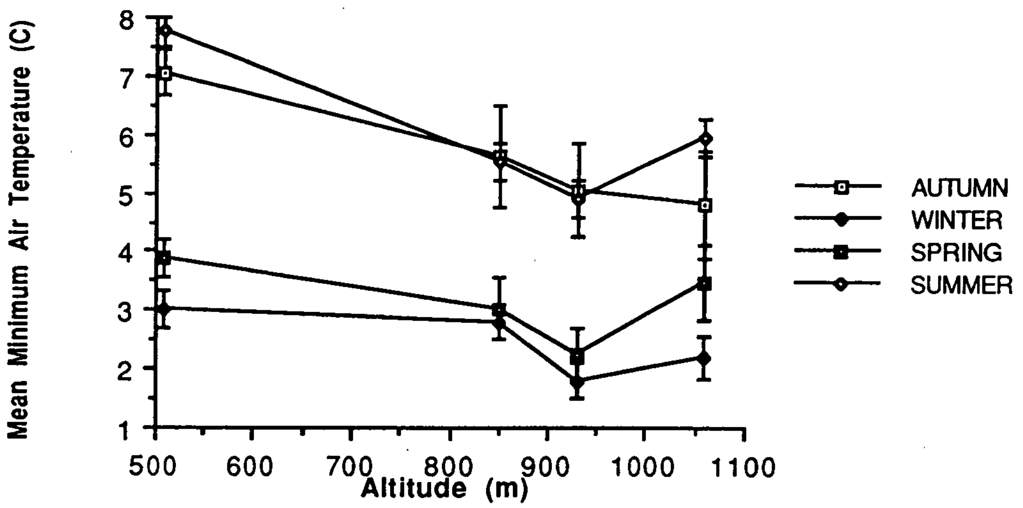

Figure 3.6 Seasonal mean minimum air temperatures for each station on Mt. Sprent

Table 3.2 Environmental lapse rates between each station on Mt. Sprent

	Mean of All Data	Seasonal Means			
		Autumn	Winter	Spring	Summer
Minimum Air Temperature					
509-850	0.39*	0.42	0.06	0.25*	0.65*
850-930	0.97*	0.74*	1.25*	0.99*	0.83*
930-1059	-0.57*	0.20	-0.30	-0.95*	-0.82*
Minimum Surface Temperature					
509-850	0.32*	0.03	0.68*	0.58*	0.06
850-930	1.71*	2.6*	-0.83	-0.89*	3.96*
930-1059	-0.02	0.17	0.43	0.15	-0.41*
Maximum Air Temperature					
509-850	0.79*	0.64	0.38*	0.81*	1.1*
850-930	1.37*	1.03*	1.99*	1.92*	0.86*
930-1059	-0.19	-0.61	0.02	-0.47	-0.16
Maximum Surface Temperature					
509-850	1.04*	0.91*	0.29*	0.25*	1.81*
850-930	1.55*	1.65	2.89	4.1	-0.12*
930-1059	1.05*	0.09	0.88*	0.86*	1.45*
Minimum Relative Humidity					
509-850	-1.57				
850-930	-2.76*				
930-1059	2.98				
Maximum Relative Humidity					
509-850	-0.33				
850-930	-0.87*				
930-1059	1.87*				

N.B * = significantly different values for each station ($p<0.05$)
Source (Kirkpatrick *et al.* in prep.)

Table 3.3 Percentage of days with air temperatures less than 10°C and frosty days (temperature less than 2.2°C) by season.

Maximum Air Temperature		Season		
	Autumn	Winter	Spring	Summer
% No. of Days < 10°C	n=14	n=41	n=17	n=60
1059m	36	100	59	33
930m	50	100	82	42
850m	50	95	71	38
509m	7	68	35	7
Minimum Air Temperature % No. of Frost Days				
1059m	36	100	100	48
930m	57	100	100	37
850m	29	98	59	23
509m	0	100	47	0

The third variable to be measured by the sensors was surface temperature. As expected, surface temperature decreases with increasing altitude, with the most variable temperatures occurring at the lowest station (Table 3.1, Figures 3.7 and 3.8). The steepest temperature gradient occurs between stations 930 m and 850 m (Table 3.3), mirroring the pattern illustrated by the air temperature readings. The minimum surface temperature values show a seasonal pattern with winter and spring values indicating lower temperatures at 850 m compared to its neighbouring stations, while summer and autumn values reveal a slightly lower temperature at 930 m (Table 3.4).

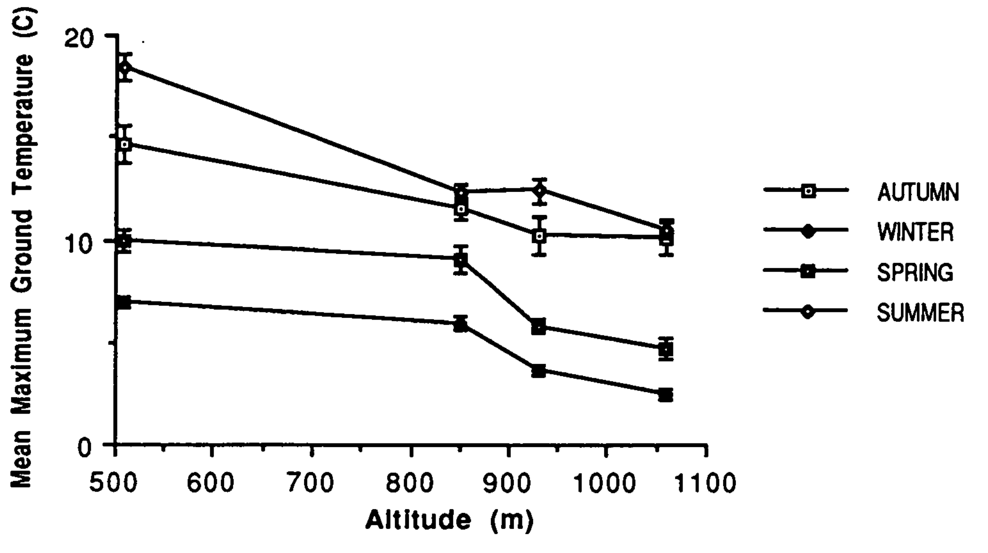

Figure 3.7 Seasonal mean maximum ground temperatures for each station on Mt. Sprent

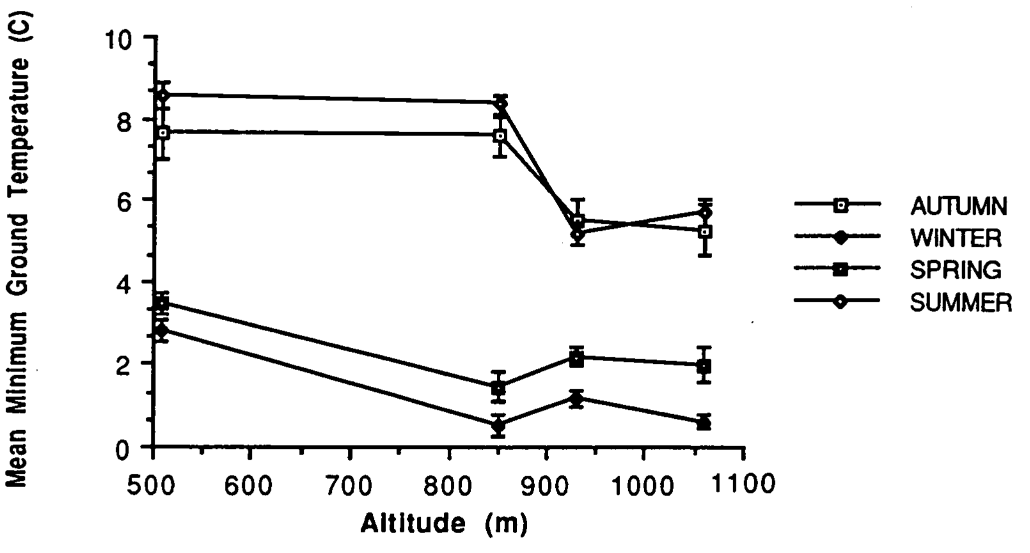

Figure 3.8 Seasonal mean minimum ground temperatures for each station on Mt. Sprent

Table 3.4 Percentage of days with ground temperatures less than 10°C and frosty days (temperature less than 2.2°C) by season

Maximum Surface Temperature	Season			
	Autumn	Winter	Spring	Summer
% No. of Days < 10°C	n=14	n=41	n=17	n=60
1059m	36	100	100	48
930m	57	100	100	37
850m	29	98	59	23
509m	0	100	47	0
Minimum Surface Temperature No. of Frost Days				
1059m	7	90	59	3
930m	0	83	53	5
850m	0	80	71	0
509m	0	34	18	0

3.5 DISCUSSION

3.5.1 Is the climate of Mt. Sprent suitable for peat formation?

Rainfall generally decreases from west to east across the State, and with increasing altitude (Gentilli 1972). The data from this study show that rainfall increases with altitude from 320 m to 509 m and then decreases. This may be explained by the presence of regional gradients caused by atmospheric circulation effects or moisture sources (Barry 1981) where the microscale wind flow is affected by the topography of the region.

Rainfall is variable from year to year indicating the influence of global climatic systems such as the Quasi-Biannual Oscillation (Allen 1991). Despite the variability in rainfall data over the 29 month period, the stations are fairly consistent with the data from Strathgordon indicating that rainfall events for the mountain can be predicted from the Strathgordon data.

Strathgordon, the Serpentine Dam site and the three lower sites on the mountain react similarly to rainfall events, while the station at the summit has a subdued response by comparison. The degree of exposure of the sites may provide an explanation for this result. The lower mountain stations are sheltered from the predominantly westerly weather, as they are located on north east slopes. Strathgordon is located approximately 12 km to the northeast of Mt. Sprent and is surrounded by low hills, again in a relatively sheltered position. The summit is subjected to the full force of the biting south westerly winds and driving, horizontal rain. It is acknowledged that the rain-gauges used are not suitable for the collection of horizontal rain, but, also as the summit is quite a narrow ridge then it is doubtful whether much of the horizontal rain lands. There are no trees or tall (greater than 1m) shrubs on the summit.

Evaporation

Data for Strathgordon indicates that evaporation may exceed precipitation on the mountain during summer months, creating adverse conditions for peat formation. An estimate of evaporation for the summit reveals a higher frequency of precipitation deficits. What can be concluded from the data is that stations on the mountain experience precipitation deficits comparable to those received in Strathgordon.

An important point to note is that it is the distribution of rainfall which is important with respect to drying of the peat surface. The surface peats may dry out within two or three days of no rainfall, which is not an uncommon occurrence during the summer months (Richardson and Swain 1980, Pemberton 1989).

Relative humidity decreases with increasing temperature, during the summer months and in the early afternoon. The variability in relative humidity values for the mountain stations may be reflecting the temperature variation. The greatest variation between maximum and minimum air temperature occurs at the station at 509 m, which would affect the humidity results.

The mean maximum air temperature for summer for all four stations is above 10°C which suggests that there is no climatically-controlled reason for the lack of trees on the mountain. As the data set is small, it is difficult to highlight any one factor as being responsible for the absence of trees, especially as past climatic conditions and disturbance may have played a role in forming the current vegetation patterns.

During autumn and winter the mean maximum air and surface temperatures show a marked decrease from 850 m to 930 m. This pattern is not apparent in summer and autumn where a steep lapse rate typically occurs. The temperature values for the station at 930 m are generally lower than for the summit, suggesting that the local climate at 930 m is affected by local site conditions, possibly a cold-air drainage trap.

Steep lapse rates are apparent in the values for minimum air and surface temperature. Colder minimum surface temperatures experienced during winter and spring at 850 m may be explained by the amount and duration of surface water present. This site is relatively flat and is the wettest site on the mountain (supported by soil moisture content values). During spring, the station at 850 m records the highest number of frost days (71%), possibly due to the presence of surface water. Vegetation cover at this site is not as dense as that at 930 m, which would also contribute to the cloder temperatures recorded. During summer and autumn the higher altitude sites receive frosts while the two lower stations are frost free.

The site at 509 m has a more than adequate annual rainfall with respect to hill peat formation, which may help offset the slightly higher than preferred air temperatures (8-17°C). Relative humidity is the lowest recorded for the mountain which may be due to the higher temperatures at this site combined with lower cloud cover values. Generally this site has the greatest capacity to dry out due to the relatively high temperatures and the lowest humidity values. Station 509 m receives the highest rainfall for the mountain and has a similar organic soil depth to higher sites, which indicates that the high precipitation values may offset higher temperatures, and so may allow an organic profile to develop.

At 850 m, the amount of rainfall is still more than adequate and relative humidity values are generally high. The mean air temperature range for the summer months is between 6°C and 15°C. Given that these temperatures relate to the summer season and not the warmest month, then these values may be a conservative estimate. On the whole the values are comparable with the temperatures associated with blanket bog (hill peat) formation in the northern hemisphere.

The second site at 930 m, again receives ample rainfall, and high relative humidity values. The air temperature range for the summer season lies between 5°C and 12°C. The maximum value lies within the preferred range, while the minimum value is slightly lower. It is thought that this site would be ideal for peat formation though maybe slightly less productive than the lower sites, due to the slightly lower temperatures experienced in the growing season.

At the summit, the amount of rainfall collected is more than enough to satisfy the parameters laid down for favourable conditions for peat formation. Relative humidities are high and average air temperatures during the summer months are not too different from site 850 m (6°C to 13°C). The amount of incoming radiation is available for this site and may be used to indicate cloud cover values. The limited data available suggest that the amount of cloud cover is 6-15% greater at the summit than at Strathgordon, adding to the humidity and overall 'wetness' of the area.

On the whole, all four sites on the mountain are able to support the accumulation of organic matter. There are many climatic differences between the four stations on the mountain. Sites may differ slightly in their ability to produce peat due to differences in temperatures and therefore plant productivity rates. The most numerous significant differences occur between the stations at 930 m and 850 m, inferring that the climatic environment at 930 m is markedly different to that at 850 m. The climatic differences between these two sites may be contributing to the sharp vegetation gradient seen on the mountain. They may also be contributing to differences in peat formation processes.

3.5.2 How do the soils data and the climate data overlap?

In the previous chapter, it was noted that; the soils at each site were significantly different to one another, organic content decreases with altitude and gravel depth increases with altitude. Can any of these findings be related to climatic variation on the mountain?

When the mean organic content values for each peat horizon are plotted, they form a pattern not unlike the one for maximum air temperature, in that site 930 m records a lower value than sites 1040 m and 850 m. This graph also reveals a pattern emulating the inverse graph of the seasonal rainfall for the four sites over two years. Seasonal rainfall is important in western Tasmania as the months of least rainfall events occur during the months experiencing high temperatures and high evaporation rates. It is suggested that mean maximum air temperature and seasonal rainfall could be useful indicators of the depth of the organic horizon.

It is noted that the mean rainfall measured for Mt. Sprent is much greater than that predicted on the regional rainfall map on page 13.

Physical weathering processes affecting soil formation increase in effectiveness with increasing altitude. Mineral and gravel horizons are more developed on the higher sites, resulting from such processes as freeze-thaw and frost heave which loosen the soil layer and shatter rocks. These processes may account for the decrease in organic content with altitude as the shallow organic horizons are readily mixed with the sand and gravel layers.

Climate affects peat formation processes in an indirect manner, through controlling plant production rates and by disturbing the physical environment. Thus the effects of climate (temperature and rainfall) on peats may be illustrated by the depth of the organic layer while the type of peat produced depends very much on local conditions such as vegetation and topography.

Chapter 4 - VEGETATIONAL CORRELATES OF PEAT DEPTH AND TYPE

4.1 INTRODUCTION

Research into peatlands internationally has concentrated on botanical features (both past and present) of the peat-forming system. Classifications of peatlands are often based on vegetation associations which are considered to be appropriate indicators of environmental gradients (Gore 1983, Moore 1984, NCC 1988) and have been used to classify Australian peatlands (Jarman *et al.* 1988a, Whinam 1990). However, natural scientists in Tasmania have expressed concern over the limited amount of information available on the interaction of vegetation and organic soils (Jarman *et al.* 1988a, Balmer 1990).

Information on altitudinal variation in vegetation and soils in south west Tasmania is limited. Researchers tend to have concentrated on areas within an altitudinal zone such as in lowlands or alpine areas, with transitions between plant communities in lowland areas dominating the literature (Bowman and Jackson 1981, Bowman *et al.* 1986, Balmer 1990). Information is available on the floristic variation along altitudinal gradients for south west Tasmanian mountains, but these works do not present any details on soil characteristics along the same gradient (Kirkpatrick and Brown 1987). A regional classification of organic soils is available for the south west (Pemberton 1989) which classifies the soils along altitudinal and topographic gradients, each group having distinctive vegetation associations.

Buttongrass moorlands in south west Tasmania are restricted in their altitudinal extent to elevations below 900 m a.s.l. (Kirkpatrick and Brown 1987, Jarman *et al.* 1988a). They considered this limitation to be climatically controlled. While altitude does not affect the plants directly, vegetation height and production generally decrease with increasing altitude thus less plant matter is available for peat formation. It is interesting to speculate whether there is also a change in the characteristics of the soil in the same altitudinal belt.

Depth and type of peat is often associated with vegetation type although the relationship is confused (Balmer 1990). As peat is derived from dead plant material, processes which affect the growth and decay of vegetation indirectly affect peat formation. An analysis of vegetation patterns may indicate processes affecting peat formation and horizon development. It is important to remember that peat accumulates slowly, therefore the present day vegetation can at best only be indicative of influences on the upper peat horizon.

Buttongrass moorland communities are associated with some of the deeper Tasmanian peats (Davies 1978). This suggests that peat accumulation rates decrease with increasing altitude as buttongrass vegetation is restricted to non-alpine environments. Rates of decomposition may also decrease due to the colder climate which reduces microbial activity (Dickinson 1983). However, Kirkpatrick and Gibson (1984) recorded peat depths of 1.15 m deep in string bogs. Thus, topographic situation is also a determining factor. A comparison of vegetation types in similar topographic situations may clarify the matter.

Changes in soil depth were reported to be partially responsible for the variation in floristics and species richness in rainforest communities (Kirkpatrick 1984). Correlations between vegetation type and soil type have been recorded (Tarvydas 1978, Bowman *et al.* 1986) where forests occur on reddish-brown soft fibrous peats in preference to dark grey muck peats. However, plant communities and particular 'indicator' species have been correlated with particular drainage conditions which influence the type of peat formed (Bowman *et al.* 1986, Brown and Podger 1982).

In a study of two moorland/woodland boundaries, Balmer (1990) found a relationship between the presence of buttongrass and soil type on one transect, yet on another a single soil type supported two plant communities. Her conclusion was that these vegetation boundaries were not directly related to any single physical environmental factor and so were likely to be formed by interrelationships between fire, vegetation and soil. However, she surmised that while there was an association between vegetation and organic soil horizons, the boundaries between vegetation types were not edaphically determined. Various authors have concluded that floristic changes in south west Tasmanian moorlands are correlated with such ecological gradients as a change in drainage conditions, soil pH and soil type (Jarman *et al.* 1988a, Brown *et al.* 1982, Kirkpatrick and Brown 1987).

Clearly then, the inter-relationships between vegetation and soils in south west Tasmania are complex. Attempts to differentiate the role of each have not been successful either due to the complexity of the situation and/or the inappropriateness of the techniques used.

The aim of this chapter is to determine any correlations that exist between vegetation patterns and soil depth and type.

4.2 METHODS

4.2.1 Data collection

Two sets of floristic data were collected in order to determine 1) altitudinal-related edaphic effects on plant distributions and 2) local topographic/edaphic effects on plant distributions.

The altitudinal transect

Floristic data for 55 25 m^2 quadrats of similar slope and aspect were collected at every 10 m increase in altitude from 509 m to the summit (1059 m). For each quadrat, cover/abundance scores were recorded for all vascular plant species (using the Braun-Blanquet scale cited in Mueller-Dombois and Ellenberg 1974) and soil depth at the centre and each corner of the quadrat were recorded using a probe. Species richness was also computed for each quadrat.

Species nomenclature follows Buchanan *et al.* (1989).

The individual site data

Floristic data were collected along the soil transects described in chapter 2 (620 m, 850 m, 930 m and 1040 m) (see Figures 2.2 and 2.3). The size of quadrats and the methods used were the same as for the altitudinal transect. In addition, average height of the dominant stratum was recorded for each quadrat. The median soil depth from the five probe depths was taken to be representative of soil depth over the quadrat.

The first site at 1040 m, consisted of a single transect, 70 m long, from which floristic data were collected for 14 quadrats. Vegetation data from 54 quadrats were collected at 930 m. Data were collected from 67 quadrats for 850 m, while data from 76 quadrats were collected from 620 m.

4.2.2 Data analysis

The data from the 55 altitudinal transect quadrats and those for the four sites at fixed altitudes were analysed using the same methods. The data sets were analysed separately.

The data were classified using the polythetic divisive classificatory program TWINSPAN. This program arranges data in an ordered two-way table by classifying individuals (samples) and attributes (species) (Hill 1979). Each group of sites is characterised by a group of differential species which favoured one side of a dichotomy (Jongman *et al.* 1987). The resultant two-way table of species by samples separates species/sample associations to a predetermined number of divisions. Classificatory groups were subjectively selected from the table on the basis of their floristic distinctiveness.

Cover-abundance values were used in the analysis and the pseudospecies cut levels were 0, 3, 15, 37.5, 62.5, 87.5.

A table of average values for each TWINSPAN group was collated using the soils data for each site described in chapter 2.

A table of percentage frequency values for each species in the TWINSPAN groups were computed and were used to describe the communities. Jaccard's Index of Similarity (Jongman *et al.* 1987) was applied to determine degree of similarity between the community groups along the altitudinal transect and within each site:

$$\text{Percentage similarity} = c/(a+b-c)$$

where c = the number of species in common between groups a and b, and a, b = the number of species in group a and group b.

Indirect gradient analysis (Jongman *et al.* 1987) was used to assign relative locations to each sample in ordination space with respect to major gradients. Ordinations of data from the 55 altitudinal quadrats, and from each of the four sites, was carried out using global non-metric multidimensional scaling (GNMDS). Dissimilarity indices were computed using the Bray-Curtis coefficient on community data which had been transformed by standardisation to unit maxima. This gave the smaller plants, (with smaller cover/abundance scores) equal weight as the larger plants. Minimum stress configurations were computed from 20 random starts (100 iterations). Results from the first minimum stress configuration were accepted.

The vector fitting option available in DECODA (Minchin 1990) was used to compute lines of best fit (vectors) from correlations between species ordination scores and environmental data. The resulting scores of the fitted vector are the maximum possible linear correlation. (Minchin 1990). The length of the vector indicates its relative importance in ordination space with the direction showing the direction of change within the ordination space.

Vector fits were computed using the Monte-Carlo approach (Minchin 1990), from 500 random permutations. A comparison between the scores of the vector fits in different dimensions (1-4) was made. If there was no loss of information between the results in two, three and four dimensions, the results from the two-dimensional ordination were used.

4.3 RESULTS

4.3.1 The altitudinal transect

Four community groups selected from the TWINSPAN classification were considered representative of the vegetation along the altitudinal gradient. The groups are as follows:

Community group 4: *Gymnoschoenus sphaerocephalus-Baeckea leptocaulis-Epacris corymbiflora*, heathy sedgeland (30 quadrats),

Community group 3: *Gymnoschoenus sphaerocephalus-Cenarrhenes nitida-Leptospermum nitidum-Monotoca submutica*, sedgy heathland (8 quadrats),
Community group 2: *Dracophyllum milliganii-Epacris serpyllifolia-Blandfordia punicea-Isophysis tasmanica*, alpine sedgy heathland (6 quadrats),
Community group 1: *Astelia alpina-Carpha curvata-Eucalyptus vernicosa-Nothofagus cunninghamii-Oreobolus oligocephalus*, alpine heathy sedgeland (11 quadrats).

Table 4.1 illustrates the percentage frequency of species in each quadrat for each TWINSPAN group. Mean values for altitude, soil depth and species richness are also presented at the end of the table.

Groups 3 and 4 are separated from groups 1 and 2 by the presence of the cyperaceous plant, buttongrass (*Gymnoschoenus sphaerocephalus*). This plant has been observed to be at its altitudinal limit between 700-900 m a.s.l. in the south west (Jarman *et al.* 1988a, Kirkpatrick and Brown 1987) and can be used as an indicator of the lowland/alpine boundary.

Group 4 is dominated by heathy-sedgeland species. Species faithful to this group are: *Epacris corymbiflora, Boronia citriodora* (shrubs), *Calorophus elongatus, Leptocarpus tenax* (graminoids), *Oschatzia saxifraga* and *Drosera pygmaea* (herbs). Species that occur in more than 80% of the quadrats in this group are: *Empodisma minus, Gymnoschoenus sphaerocephalus, Lepyrodia tasmanica, Milligania densiflora, Restio hookeri* (graminoids), *Baeckea leptocaulis, Bauera rubioides, Boronia citriodora, Epacris corymbiflora, Leptospermum nitidum, Melaleuca squamea* and *Sprengelia incarnata* (shrubs). This group of species typifies the Standard Blanket Moor and Wet Standard vegetation (Jarman *et al.* 1988a) or 'lowland buttongrass moorland' vegetation (Kantvilas and Jarman 1991). The deepest soils are found underneath this vegetation type (31 cm) and the altitudinal range of the samples in this community is between 510 m and 820 m a.s.l.. The average number of species in this community is 19.

Table 4.1 The percentage frequency of species in each TWINSPAN group for the altitudinal quadrat data

Species	TWINSPAN Groups			
	4	3	2	1
Actinotus bellidioides	73	25	-	-
Actinotus moorei	-	38	33	45
Actinotus suffocata	-	-	-	18
Agastachys odorata	77	75	83	18
Anemone crassifolia	-	-	50	82
Archeria serpyllifolia	-	-	-	27
Astelia alpina	-	-	83	100
Baeckea leptocaulis	93	75	50	-
Banksia marginata	27	13	-	-
Bauera rubioides	93	63	100	91
Blandfordia punicea	43	88	100	36
Boronia citriodora	83	-	-	-
Calorophus ater	30	-	-	9
Calorophus elongatus	20	-	-	-
Carpha curvata	-	-	50	73
Celmisia asteliifolia	-	-	17	55
Cenarrhenes nitida	17	75	67	9
Cyathodes parvifolia	-	-	-	64
Cyathodes petiolaris	-	-	-	27
Diplarrena latifolia	-	13	33	9
Diplaspis cordifolia	-	-	-	82
Donatia novae-zelandiae	-	-	-	27
Dracophyllum milliganii	27	75	100	73
Drosera arcturi	27	25	67	73
Drosera pygmaea	3	-	-	-
Ehrharta tasmanica	-	-	-	36
Empodisma minus	97	100	100	91
Epacris corymbiflora	100	-	-	-
Epacris serpyllifolia	7	88	100	91
Erigeron stellatus	-	-	-	18
Eucalyptus vernicosa	-	25	67	100
Eucryphia milliganii	-	25	33	36
Euphrasia collina	37	13	-	-
Euphrasia gibbsiae ssp. kingii	10	38	17	27
Euphrasia hookeri	-	-	-	9
Ewartia meredithae	-	-	-	9
Exocarpos humifusus	-	25	-	36
Forstera bellidifolia	3	-	-	45
Gahnia grandis	-	13	17	9
Gentianella diemensis	-	-	17	55
Gleichenia dicarpa	40	13	-	-
Gymnoschoenus sphaerocephalus	100	100	-	-
Helichrysum backhousii	-	-	50	82
Helichrysum pumilum	40	13	-	18
Isophysis tasmanica	10	38	83	55
Leptocarpus tenax	10	-	-	-
Leptospermum nitidum	80	100	17	-

Table 4.1 (cont.)

Species	TWINSPAN Groups			
	4	**3**	**2**	**1**
Lepyrodia tasmanica	80	38	-	-
Lycopodium laterale	73	63	50	-
Melaleuca squamea	97	88	83	-
Milligania densiflora	-	-	17	36
Mitrasacme montana	40	38	33	55
Monotoca submutica	23	100	83	64
Nothofagus cunninghamii	-	25	50	91
Olearia ledifolia	-	-	-	18
Olearia persoonioides	-	-	17	18
Oreobolus acutifolius	-	-	17	27
Oreobolus oligocephalus	-	-	17	82
Oschatzia saxifraga	3	-	-	-
Pentachondra pumila	13	25	33	73
Persoonia gunnii	-	38	33	64
Prionotes cerinthoides	-	-	-	9
Restio complanatus	73	13	-	-
Restio hookeri	87	25	-	-
Richea curtisiae	-	-	-	27
Richea milliganii	-	-	-	18
Richea scoparia	-	-	33	82
Schoenus calyptratus	3	38	67	55
Schoenus tenuissimus	67	13	-	-
Senecio pectinatus	-	-	-	9
Sprengelia incarnata	97	100	100	73
Stylidium graminifolium	40	25	-	-
Tasmannia lanceolata	-	-	-	73
Tetracarpaea tasmanica	-	-	-	9
Trochocarpa cunninghamii	-	-	-	9
Uncinia compacta	-	-	-	27
Xyris marginata	77	-	-	9
Mean Altitude	660	820	910	1000
Mean Soil Depth	31	27	27	22
Mean Species Richness	19	18	20	26
n=	30	8	6	11

Group 3 has no totally faithful species. This sedgy-heathland community is also dominated by buttongrass tussocks but numerous alpine plants are recorded, contrasting with group 4. Species that occur in more than 80% of the quadrats in this group are: *Blandfordia punicea* , *Empodisma minus*, *Gymnoschoenus sphaerocephalus* (graminoids), *Epacris serpyllifolia*, *Leptospermum nitidum*, *Melaleuca squamea*, *Monotoca submutica* and *Sprengelia incarnata* (shrubs). This community is quite diverse in that it includes not only those plants which are mainly found favouring higher altitudes (*Epacris serpyllifolia*, *Monotoca submutica*), but it also includes plants which flourish on better drained sites such as rocky outcrops (*Blandfordia punicea*). This community can be classified as Mountain Blanket Moor and Mountain Copses (Jarman *et al.* 1988a) or 'subalpine buttongrass moorland' vegetation and may also include 'low altitude rock outcrops' and '*Nothofagus cunninghamii*-*Richea scoparia* scrub' (Kantvilas and Jarman 1991). This group has the lowest species richness (with a mean of 18 species per quadrat). The samples in this group lie between 660 m and 900 m a.s.l.. The mean soil depth is 27 cm.

Group 2 is essentially alpine in composition. No buttongrass is present and the vegetation is composed mainly of low (less than 1 m) shrubs. There are no totally faithful species. Plants with percentage frequencies greater than 80% are: *Agastachys odorata*, *Bauera rubioides*, *Epacris serpyllifolia*, *Melaleuca squamea*, *Monotoca submutica*. and *Sprengelia incarnata* (shrubs), *Astelia alpina*, *Blandfordia punicea*, *Dracophyllum milliganii*, *Empodisma minus*, and *Isophysis tasmanica* (graminoids). This community could be described as Alpine Heath or Tall Alpine Herbfield (Kirkpatrick 1983). The altitudinal range for this group is between 880 m and 950 m a.s.l.. Species richness averages 20 per quadrat. The mean soil depth is 27 cm.

Group 1 contains alpine plants of both well drained and poorly drained areas. There are many species which cover a wide altitudinal range although their densities vary. Eighteen species are unique to this TWINSPAN community, three of which occur in more than 80% of the quadrats. The faithful species highlight the alpine nature of this group; *Actinotus suffocata* (herb), *Donatia novae-zelandiae* (cushion herb), *Archeria serpyllifolia*, *Cyathodes parvifolia*, *C. petiolaris*, *Helichrysum* *backhousii, Richea curtisiae, Tasmannia lanceolata* (shrubs), *Ehrharta tasmanica* var. *tasmanica* (grass), and *Uncinia compacta* (graminoid). This group includes two of Kirkpatrick's (1983) community groups; Bolster Heath and Alpine Heath. It has the highest species richness (with a mean of 26 species per quadrat) and lies on the shallowest soils (22 cm). Its altitudinal range is between 940 m and 1050 m a.s.l..

Group 4 and group 3 are the most similar in terms of Jaccard's coefficient of similarity, sharing 64% of the species listed for both groups (see Plate 4.1). Groups 3 and 2 have a percentage similarity of 53% while groups 2 and 1 have a percentage similarity of 54%. As expected groups 4 and 1 are the least similar sharing 25% of species recorded.

The ordination of the quadrat data illustrates the floristic relationships between the four TWINSPAN groups (Figure 4.1). The four communities are separated along the first ordination axis. There is an overlap between TWINSPAN communities 4 and 3 and 3 and 2. However group 1 is very distinct from the other three.

The vector fits for soil depth, altitude and species richness are significant ($p < 0.05$) (Table 4.2). The communities are separated primarily by altitude and soil depth which are inversely correlated.

The relationship between vegetation group, soil depth and altitude can be seen in Figure 4.2 where soil depth values are plotted against altitude. Groups 4 and 1 are strongly defined as they occur at opposite ends of the gradient, Group 4 has the deepest soils at lower altitudes, while Group 1 has the shallowest soils at higher altitudes. Groups 3 and 2 have similar mean soil depths (27 cm). These two groups span a wide range of soil depths, though Group 3 tends towards deeper soils whilst Group 2 tends towards the shallow ones. Soils at lower altitudes have an average depth of greater than 30 cm.

Plate 4.1 Buttongrass moorland communites cover the lower slopes of Mt. Sprent up to an altitude of 870 m. This photograph was taken at an elevation of 840 m.

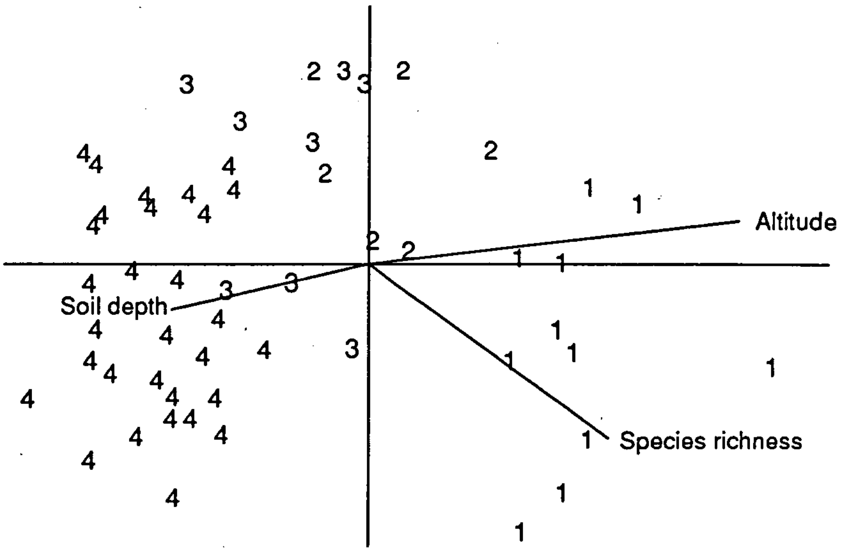

Figure 4.1 Ordination scores, TWINSPAN groups and vectors for the 55 altitudinal quadrats

Table 4.2. The length, significance and direction of vectors fitted to the two-dimensional ordination of the altitudinal data set.

Variable	n=	max R	probability	axis 1	axis 2
altitude	55	0.8723	0.000***	0.9909	0.1344
soil depth	55	0.4222	0.003**	-0.9838	-0.1794
species rich	55	0.7134	0.000***	0.7234	-0.6904

*** = highly significant

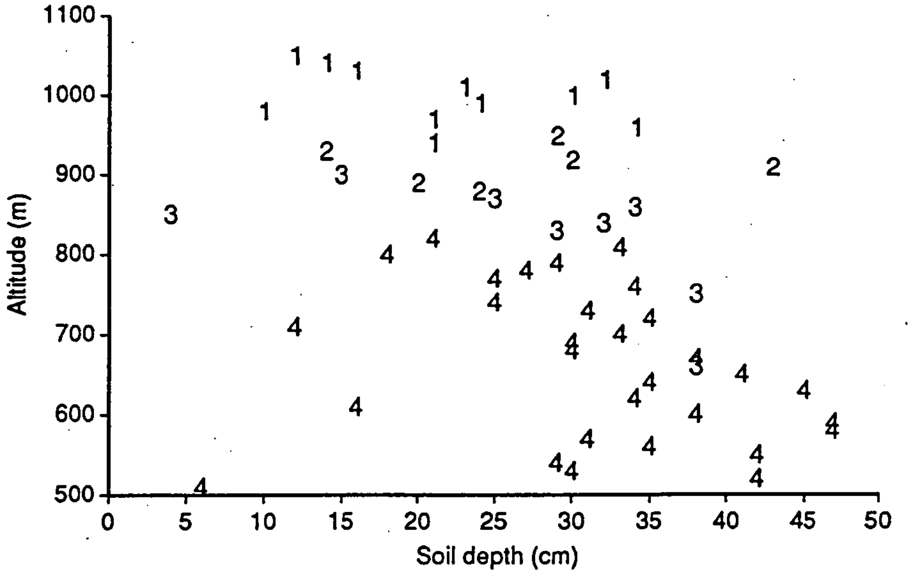

Figure 4.2 Soil depth by altitude and TWINSPAN group for the 55 altitudinal quadrats.

4.3.2 The individual site data

Two or three communities were found to be discernible at each site in the field and these seemed to reflect position in relation to a moisture gradient. The TWINSPAN groups and the GNMDS and vector fitting process support this observation.

At the lowest site, at 620 m, the TWINSPAN classification identifies three main vegetation groups (Table 4.3), two being local variations of *Gymnoschoenus sphaerocephalus* heathy sedgeland (Wet Standard Blanket Moor and Standard Blanket Moor *sensu* Jarman *et al.* 1988a), and the third (only 5 quadrats) can be described as Standard Pebbles (Jarman *et al.* 1988a). The third group can be identified by the preference of *Blandfordia punicea* (lily) and a concentration of shrubby species such as *Cenarrhenes nitida, Monotoca submutica* and the herbs *Euphrasia collina* and *Stylidium graminifolium.* These plants appear in better drained, rockier sites, such as rocky knolls. The average soil depth recorded under this community is 16 cm, however, the dominant stratum is generally taller (55 cm) than those in groups 1 and 2 (48cm and 49 cm respectively).

The 'wetter' community groups, 1 and 2, are divided by the preferences of two herbs, the insectivorous *Drosera arcturi* and *Helichrysum pumilum* for the first group and *Stylidium graminifolium* (herb), *Gleichenia dicarpa* (fern), and the graminoids *Calorophus ater* and *Schoenus tenuissimus* for the second group. The herb *Utricularia dichotoma* is faithful to group 1. This plant tends to occupy poorly drained bare ground, similar to those sites occupied by *Drosera arcturi*. *Calorophus elongatus* (cord rush) is faithful to group 2. The second group intergrades with both the first and third groups, having intermediate values for soil depth (group 1 has an average soil depth of 28 cm compared with 24 cm for group 2). Groups 1 and 2 have the highest percentage similarity in terms of species composition (94%) while groups 1 and 3 and 2 and 3 have 74% of their species in common.

The ordination diagram (Figure 4.3) shows a split between group 3 and groups 1 and 2 along the first axis. The community groups are not easily separated along the second axis, which corresponds closely to soil depth.

One soil characteristic other than soil depth can be correlated significantly (although weakly) to the ordination of species. The depth of the gravel layer ($r = 0.49$, $p = 0.04$) decreases from group 3 to group 1.

Organic contents of the surface horizons of TWINSPAN groups 1 and 2 (57% and 55% respectively) are much lower than group 3 (68%). The soils beneath the taller vegetation has a higher organic content in the surface horizon than those of the other two groups.

Table 4.4 shows differences in soil properties between the groups.

Table 4.3 Percentage frequency of species in each TWINSPAN group at 620 m

Species	TWINSPAN GROUPS 1	2	3
Boronia citriodora	100	100	100
Empodisma minus	100	100	100
Gymnoschoenus sphaerocephalus	100	100	100
Baeckea leptocaulis	100	96	100
Helichrysum pumilum	100	81	60
Epacris corymbiflora	98	100	100
Restio complanatus	98	100	100
Actinotus bellidioides	98	96	60
Sprengelia incarnata	98	88	100
Bauera rubioides	96	100	100
Oschatzia saxifraga	96	100	20
Lepyrodia tasmanica	96	96	60
Xyris marginata	93	92	100
Leptospermum nitidum	91	100	80
Melaleuca squamea	91	92	80
Lycopodium laterale	87	85	20
Restio hookeri	84	96	100
Agastachys odorata	78	73	100
Drosera arcturi	64	19	20
Mitrasacme montana	60	65	100
Euphrasia collina	51	54	100
Schoenus tenuissimus	33	81	60
Stylidium graminifolium	27	65	100
Leptocarpus tenax	20	31	20
Gleichenia dicarpa	13	58	-
Calorophus ater	7	31	-
Monotoca submutica	4	8	100
Banksia marginata	4	4	-
Utricularia dichotoma	2	-	-
Lepidosperma filiforme	2	4	-
Calorophus elongatus	-	8	-
Blandfordia punicea	-	-	100
Cenarrhenes nitida	-	-	40
Gahnia grandis	-	-	20
Persoonia gunnii	-	-	20
Mean soil depth (cm)	28	24	16
Mean species richness	20	21	22
Mean average height	48	49	55
n=	45	26	5

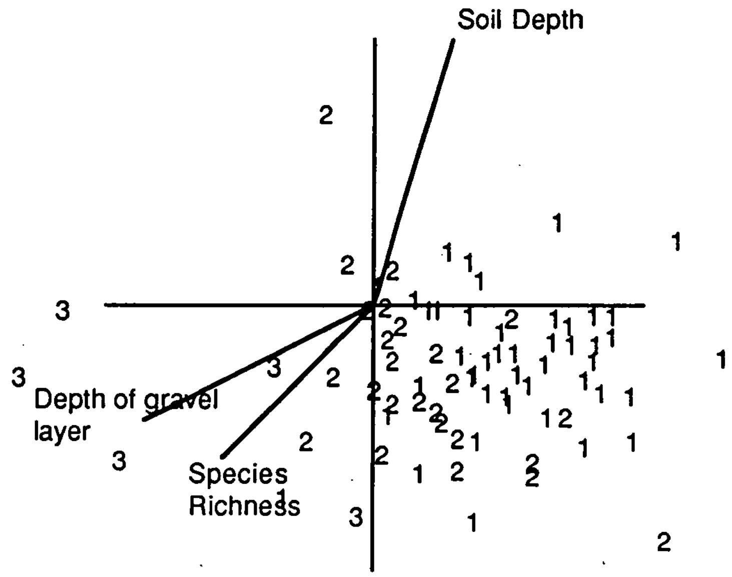

Figure 4.3 Ordination scores, TWINSPAN groups and vectors for the site at 620 m.

Table 4.4 Soil physical properties for each TWINSPAN group at 620 m

Physical properties	TWINSPAN Groups		
	1	2	3
Surface Horizon			
Modal surface horizon	P1	P1	P1
Mean moisture content (%)	79.6	72.7	80.7
Mean organic content (%)	56.9	54.6	68.4
Mean pH	3.9	3.9	3.9
Modal humification	H3	H3	H3
Mean Depth (cm)	7.7	6.3	7.0
Bottom Horizon			
Modal bottom horizon	P3	P3	Sand
Mean moisture content (%)	64.3	64.2	54.7
Mean organic content (%)	38.9	36.3	33.8
Mean pH	3.8	4.1	4.0
Mean humification	H9	H9	-
Mean Depth (cm)	14.6	15.4	19.0
Mean depth of organic layer (cm)	25.1	22.9	35.0
Mean depth of mineral layer (cm)	0.8	2.4	4.0
Mean depth of gravel layer (cm)	0.9	1.0	1.5
n =	11	8	3

N.B. Bottom horizon refers to soil horizons. Therefore gravels are not included.

At 850 m, the TWINSPAN classification delineated three communities, separated by their relative 'alpineness' and preference for rocky sites (Table 4.5). The communities are initially separated by the presence of *Blandfordia punicea* (lily), *Schoenus calyptratus* (graminoid), *Cenarrhenes nitida* and *Eucalyptus vernicosa* (shrubs). The alpine community (group 3) may be described in terms of the category 'Mountain Copses' (Jarman *et al.* 1988a).

The non-alpine communities (group 1 Standard Peat and group 2 Common Mountain Moor, *sensu* Jarman *et al.* 1988a) are differentiated by average height of the dominant stratum and by diversity, with group 1 having a shorter mean vegetation height and a lower species richness than group 2. Groups 1 and 2 share 89% of their species with each other and 74% with group 3.

The ordination diagram (Figure 4.4) shows the distinctiveness of the three TWINSPAN groups. Species richness is the strongest vector separating the groups.

The TWINSPAN groups are not easily separated along the second axis. The closest measured environmental correlate to this direction of change is soil depth. Further divisions of the existing TWINSPAN groups subdivide the communities into groups which record deeper average soil depths and those which record shallower depths.
The following soils data significantly correlate with the species ordination scores: organic content of the surface horizon ($r = 0.6002$, $p = 0.024$) and colour ($r = 0.5275$, $p = 0.014$), and organic content ($r = 0.7462$, $p = 0.000$) of the lower horizon. Average values for each TWINSPAN group in Table 4.6 reveal a distinct difference between group 3 and groups 1 and 2 with respect to organic content and moisture content.

Group 3 has the tallest vegetation, the shallowest soils and the highest species richness. It also records the highest organic content for both the surface and the lowest horizons. Group 2, the intermediate group, has the deepest surface and lower horizons and organic horizons and the deepest gravel layer.

Table 4.5 Percentage frequency of species in each TWINSPAN group at 850 m

Species	TWINSPAN GROUPS 1	2	3
Dracophyllum milliganii	100	100	100
Gymnoschoenus sphaerocephalus	100	100	100
Melaleuca squamea	100	100	100
Sprengelia incarnata	100	100	100
Bauera rubioides	100	100	75
Lycopodium laterale	100	95	83
Leptospermum nitidum	100	90	83
Lepyrodia tasmanica	100	90	50
Empodisma minus	97	100	100
Epacris serpyllifolia	97	100	100
Isophysis tasmanica	97	100	100
Drosera arcturi	97	85	100
Baeckea leptocaulis	89	95	58
Actinotus bellidioides	89	55	25
Calorophus ater	89	30	17
Helichrysum pumilum	86	60	33
Agastachys odorata	78	90	100
Xyris marginata	70	55	17
Euphrasia collina	65	85	75
Mitrasacme montana	54	65	75
Persoonia gunnii	32	45	67
Stylidium graminifolium	30	35	33
Monotoca submutica	19	75	100
Cenarrhenes nitida	16	25	92
Pentachondra pumila	11	65	67
Mitrasacme sp. *nova*	11	30	25
Blandfordia punicea	8	70	100
Schoenus calyptratus	8	40	92
Actinotus moorei	5	60	83
Schoenus tenuissimus	3	50	8
Exocarpos humifusus	3	20	58
Diplarrena latifolia	3	20	25
Restio hookeri	3	10	17
Restio complanatus	3	5	-
Epacris corymbiflora	3	-	8
Utricularia dichotoma	3	-	-
Carpha curvata	-	5	-
Astelia alpina	-	5	25
Eucalyptus vernicosa	-	-	67
Nothofagus cunninghamii	-	-	42
Olearia persoonioides	-	-	33
Helichrysum backhousii	-	-	25
Richea milliganii	-	-	17
Richea scoparia	-	-	8
Tasmannia lanceolata	-	-	8
Tetracarpaea tasmanica	-	-	8
Trochocarpa cunninghamii	-	-	8
Mean soil depth (cm)	27	27	21
Mean species richness	20	23	25
Mean average height	41	49	58
n =	37	20	12

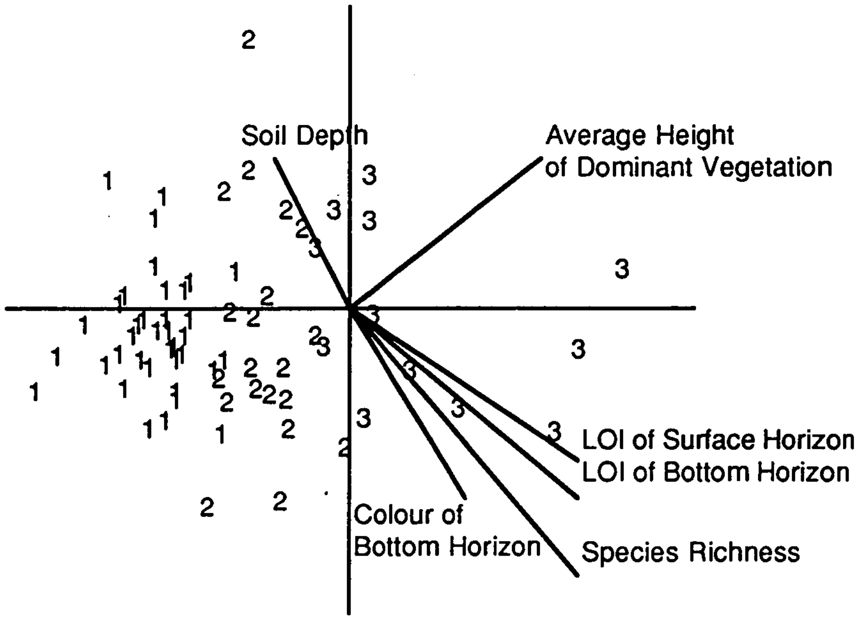

Figure 4.4 Ordination scores, TWINSPAN groups and vectors for the site at 850 m.

Table 4.6 Soil physical properties for each TWINSPAN group at 850 m.

Physical properties	TWINSPAN Groups		
	1	2	3
Surface Horizon			
Modal surface horizon	P2	P3	P2
Mean moisture content (%)	73.3	74.4	79.8
Mean organic content (%)	50.1	48.0	68.9
Mean pH	3.8	3.8	3.8
Modal humification	H3	H6	H5
Mean Depth (cm)	10.3	15.4	8.5
Bottom Horizon			
Modal bottom horizon	P3	P4	P3
Mean moisture content (%)	64.9	61.4	77.7
Mean organic content (%)	30.2	29.6	57.0
Mean pH	3.7	3.7	3.7
Mean humification	H8	H7	H7
Mean Depth (cm)	15.3	30.4	15.9
Mean depth of organic layer (cm)	21.8	36.9	21.6
Mean depth of mineral layer (cm)	0.3	0.7	0.0
Mean depth of gravel layer (cm)	2.3	6.6	2.8
n=	7	6	4

The alpine sedgy heathland at 930m has three TWINSPAN communities (Table 4.7). The analysis classified the vegetation according to the alpineness of the vegetation and then along a moisture gradient. The non-alpine groups are divided into two communities. Group 1 (Mountain Copses) favours slightly better drained areas and has a dominance of species such as *Agastachys odorata* and *Eucalyptus vernicosa* (shrubs). The average vegetation height in this group is 45 cm compared to 34 cm and 37 cm for groups 2 and 3 respectively. Group 2 (Highland Standard Peat) has a dominance of the following species *Actinotus suffocata, Helichrysum pumilum* (herbs) and *Xyris marginata* (graminoid) and can be found in wetter areas. Groups 1 and 2 have similar mean soil depths (30 cm) and number of species per quadrat (23 and 21 respectively).

Group 3 (Mountain Copses) is characterised by the presence of *Anemone crassifolia* (herb), *Helichrysum backhousii, Tasmannia lanceolata , Nothofagus cunninghamii* and *Richea scoparia* (shrubs). It occupies sites with the shallowest soils (14 cm). Groups 1 and 3 are the most similar in terms of species composition sharing 70% of the total number of species recorded for both groups. Groups 1 and 2 and 2 and 3 share 65% and 64% of their species respectively.

The ordination diagram (Figure 4.5) shows species richness to be the strongest vector separating the species. Soil depth is inversely related to species richness. Correlations between vegetation and soils at this site include: depth of the surface horizon ($r = 0.6182$, $p = 0.014$) and the depth of the gravel layer ($r = 0.6056$, $p = 0.016$). Species richness correlates inversely with depth of organic layer ($z = -2.605$, $p = 0.0092$).

No data on the soil physical properties are available for community group 1. Group 3 generally has a less humified surface horizon than group 2 (see Table 4.8). Organic content in both groups is relatively low. However, it is more uniform under the vegetation in Group 3. Gravels are present in group 2 and absent in group 3.

Table 4.7 Percentage frequency of species in each TWINSPAN group at 930 m.

Species	TWINSPAN GROUPS 1	2	3
Dracophyllum milliganii	100	100	100
Empodisma minus	100	100	100
Isophysis tasmanica	100	100	100
Epacris serpyllifolia	100	100	92
Melaleuca squamea	100	100	92
Sprengelia incarnata	100	100	92
Drosera arcturi	100	97	92
Oreobolus oligocephalus	100	97	75
Agastachys odorata	100	43	75
Eucalyptus vernicosa	100	38	92
Bauera rubioides	80	100	100
Carpha curvata	80	100	50
Schoenus calyptratus	80	84	100
Actinotus moorei	80	54	83
Lycopodium laterale	60	97	92
Baeckea leptocaulis	60	95	83
Euphrasia collina	60	59	83
Astelia alpina	60	38	75
Forstera bellidifolia	60	35	50
Blandfordia punicea	60	16	33
Diplarrena latifolia	60	5	-
Milligania densiflora	60	5	-
Xyris marginata	40	95	33
Helichrysum pumilum	40	68	67
Calorophus ater	40	57	25
Pentachondra pumila	40	32	50
Persoonia gunnii	40	30	83
Mitrasacme montana	40	30	33
Leptospermum nitidum	40	19	17
Richea scoparia	40	-	58
Actinotus suffocata	20	57	25
Cenarrhenes nitida	20	22	50
Monotoca submutica	20	19	75
Donatia novae-zelandiae	20	19	8
Schoenus tenuissimus	20	3	8
Nothofagus cunninghamii	20	-	67
Olearia persoonioides	20	-	17
Gahnia grandis	20	-	-
Actinotus bellidioides	-	16	58
Exocarpos humifusus	-	11	-
Gymnoschoenus sphaerocephalus	-	11	-
Centrolepis monogyna	-	8	-
Mitrasacme sp. *nova*	-	8	-
Anemone crassifolia	-	8	100
Restio hookeri	-	5	25
Helichrysum backhousii	-	3	75
Tasmannia lanceolata	-	3	67
Erigeron stellatus	-	3	17

Table 4.7 (cont.)

Species	TWINSPAN GROUPS 1	2	3
Abrotanella forsteroides	-	3	-
Oreobolus acutifolius	-	3	-
Stylidium graminifolium	-	3	-
Trochocarpa gunnii	-	3	-
Cyathodes parvifolia	-	-	42
Tetracarpaea tasmanica	-	-	25
Gentianella diemensis	-	-	17
Abrotanella scapigera	-	-	8
Archeria serpyllifolia	-	-	8
Gleichenia alpina	-	-	8
Mean soil depth (cm)	30	30	14
Mean species richness	23	21	27
Mean average height	45	34	37
n=	5	37	12

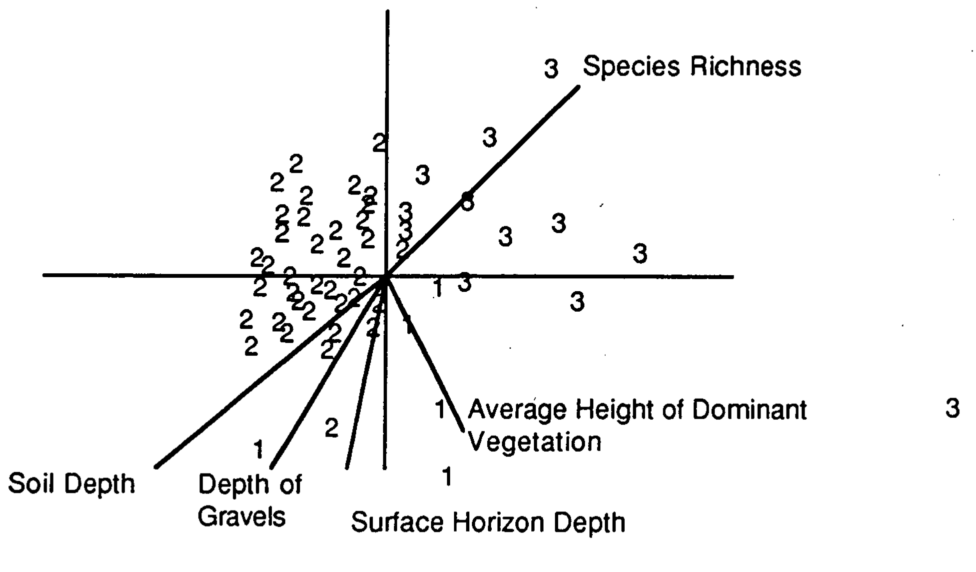

Figure 4.5 Ordination scores, TWINSPAN groups and vectors for the site at 930 m

Table 4.8 Soil physical properties for each TWINSPAN group at 930 m.

Physical properties	TWINSPAN Groups 2	3
Surface Horizon		
Modal surface horizon	4	2
Mean moisture content (%)	58.8	66.2
Mean organic content (%)	27.4	29.3
Mean pH	3.8	3.9
Modal humification	8	4
Mean Depth (cm)	22.3	13.0
Bottom Horizon		
Modal bottom horizon	4	4
Mean moisture content (%)	47.8	65.9
Mean organic content (%)	14.9	26.2
Mean pH	3.8	3.8
Mean humification	9	8
Mean Depth (cm)	19.7	16.3
Mean depth of organic layer (cm)	26.9	18.0
Mean depth of mineral layer (cm)	0.0	0.0
Mean depth of gravel layer (cm)	7.1	0.0
n=	10	3

Only two floristic groups were selected at 1040 m (Plate 4.2, Table 4.9). The first group is defined by the presence of *Gentianella diemensis* (herb) and *Actinotus moorei* (rosette herb). This group includes many woody plants such as *Nothofagus cunninghamii* and *Richea scoparia* (shrubs). It can be classified as alpine heath as defined by Kirkpatrick (1983). The average soil depth for this group is 9 cm. The average vegetation height is 40 cm and mean species richness is 30.

The second group is determined by the presence of *Epacris navicularis* (low shrub), and can be classified as bolster heath (Kirkpatrick 1983). It has a large cover of cushion plants and is on the flatter, wetter sites. It differs from the community at 930 m by the presence of plants such as *Celmisia asteliifolia, Epacris navicularis, Helichrysum backhousii* and *Richea curtisiae* . The average soil depth for this group is 21 cm. Mean vegetation height is 3 cm and species richness is 23 per quadrat.

These two communities are very distinctive and as a result soil characteristics are easily related to vegetation (Figure 4.6). The vectors correlating with vegetation are: moisture content of the surface horizon (r = 0.9796, p = 0.036), organic content (r = 0.9731, p = 0.022) of the surface horizon and the depth of organic layer (r = 0.9952, p = 0.000).

The type of lower horizon is related to species richness (z = 2.062, p = 0.0392), and average vegetation height correlates with the depth of the gravel layer (z = -2.219, p = 0.0265). Group 1 has tall vegetation, and shallow soils which have very low organic contents throughout the profile (8.5%-14.6%) (see Table 4.10).

Plate 4.2 Vegetation at 1040 m. Note the shrubby communities are best developed on the slopes, in the lee of boulders.

Table 4.9 Percentage frequency of species in each TWINSPAN group at 1040 m.

Species	TWINSPAN Groups 1	2
Actinotus suffocata	100	100
Carpha curvata	100	100
Donatia novae-zelandiae	100	100
Drosera arcturi	100	100
Oreobolus oligocephalus	100	100
Drosera pygmaea	100	83
Eucalyptus vernicosa	100	83
Anemone crassifolia	100	67
Astelia alpina	100	67
Diplaspis cordifolia	100	67
Richea scoparia	100	67
Helichrysum backhousii	100	33
Dracophyllum milliganii	88	100
Isophysis tasmanica	88	100
Sprengelia incarnata	88	100
Epacris serpyllifolia	88	50
Tasmannia lanceolata	88	33
Actinotus moorei	88	-
Gentianella diemensis	88	-
Ewartia meredithiae	75	100
Cyathodes parvifolia	75	67
Bauera rubioides	75	-
Erigeron stellatus	75	-
Nothofagus cunninghamii	75	-
Helichrysum pumilum	63	-
Monotoca submutica	63	-
Euphrasia hookeri	63	83
Celmisia asteliifolia	63	50
Persoonia gunnii	63	33
Pentachondra pumila	50	50
Blandfordia punicea	50	-
Schoenus calyptratus	50	-
Abrotanella scapigera	38	-
Mitrasacme montana	38	-
Mitrasacme sp. *nova*	38	-
Trochocarpa gunnii	38	-
Lycopodium laterale	38	33
Xyris marginata	25	83
Forstera bellidifolia	25	67
Richea curtisiae	25	67
Olearia persoonioides	25	17
Exocarpos humifusus	25	-
Epacris navicularis	13	100
Eucryphia milliganii	13	17
Archeria serpyllifolia	13	-
Baeckea leptocaulis	13	-
Milligania densiflora	13	-
Abrotanella forsteroides	-	83
Calorophus ater	-	33

Table 4.9 (cont.)

Species	TWINSPAN Groups 1	2
Cenarrhenes nitida	-	17
Euphrasia collina	-	17
Euphrasia striata	-	17
Gahnia grandis	-	17
Mean soil depth (cm)	9	21
Mean species richness	30	23
Mean average height	40	3
n=	8	7

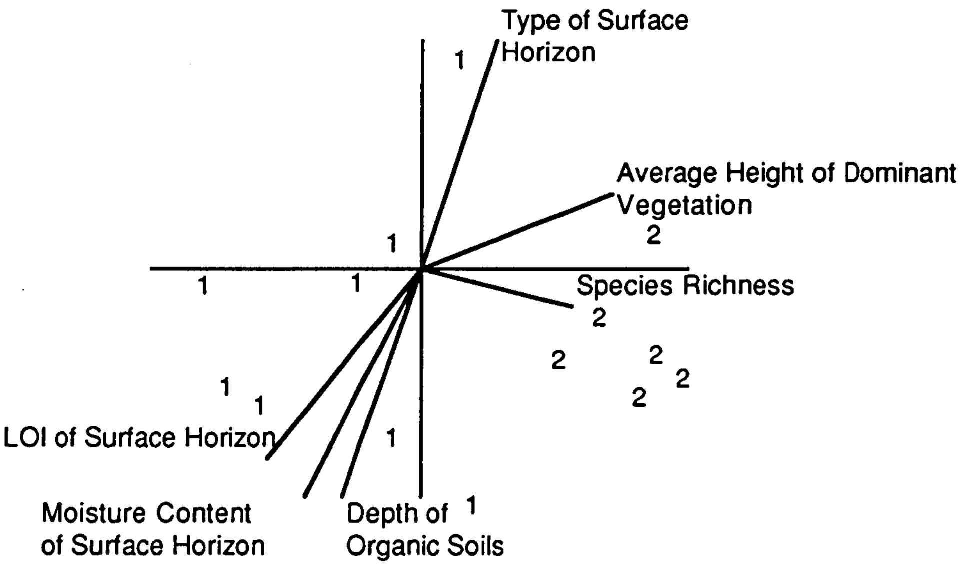

Figure 4.6 Ordination scores, TWINSPAN groups and vectors for the site at 1040 m.

Table 4.10 Physical properties of soils at 1040 m.

Physical properties	TWINSPAN Groups	
	1	2
Surface Horizon		
Modal surface horizon	P2	sandy organic
Mean moisture content (%)	48.6	74.2
Mean organic content (%)	14.6	41.0
Mean pH	3.5	3.7
Modal humification	3	4
Mean Depth (cm)	5.0	4.5
Bottom Horizon		
Modal bottom horizon	sand	sandy organic
Mean moisture content (%)	39.0	60.8
Mean organic content (%)	8.5	22.4
Mean pH	3.8	3.9
Modal humification	-	8
Mean Depth (cm)	4.5	13.0
Mean depth of organic layer (cm)	5.0	18.3
Mean depth of mineral layer (cm)	4.5	0.0
Mean depth of gravel layer (cm)	0.5	9.7
n =	3	2

4.4 DISCUSSION

Soil depth varies with vegetation over an altitudinal gradient. Plant associations are differentiated first and foremost by altitude, and then by soil depth. The TWINSPAN community groups are well differentiated along an altitudinal gradient, but are not so well defined along the soil depth vector.

On Mt. Sprent, buttongrass dominates the non-alpine areas, shrubs dominate the alpine sheltered areas and cushion plants dominate the exposed alpine areas. These vegetation distributions are similar to those documented by Davis (1978). Buttongrass, hypothesised to be the most prolific peat former (Davis 1978), occurs at lower altitudes. One would expect productivity to decrease with altitude, therefore the most productive peat formers are likely to be the buttongrass moorlands. So do the sites with buttongrass moorland vegetation record the deepest organic soils?

Average soil depth decreases from 620 m to 1040 m. However, mean values for soil depth at 930 m and 850 m are identical. Jaccard's Coefficient of Similarity reveals that TWINSPAN groups 3 and 4 are the most similar, 64% of the species recorded are present in both communities. The least similar in terms of plant associations are groups 2 and 3 with 53%. One can conclude from this that soil depth does vary with vegetation along an altitudinal gradient, but other factors are influencing the variable soil depth as two sites with relatively different species compositions record the same soil depths.

For the individual sites, soil depth was found to significantly differentiate the plant communities at three of the four sites. Generally vegetation occurring on rock outcrops recorded shallower soil depths than those on the flats. These plant communities recorded a greater number of shrubby species, more fibrous horizons and higher organic contents than those in more poorly drained situations. While this information can be gleaned from looking at the average values for each TWINSPAN group, the relationships were not significant in the vector fitting process. More localised data needs to be collected in order for these relationships to be tested fully.

The depth of the gravel layer was found to be important in the location of plant communities at two sites (620 m and 930 m) while organic content was also differentiated under plant communities at two sites (850 m and 1040 m).

While there are relationships between plant communities and soil physical properties, these relationships are not consistent from site to site. Soil depth is the most consistent variable in differentiating between plant associations, but may be reflecting drainage or topographic conditions imposed on the vegetation and the soil rather than being caused by the vegetation itself.

Chapter 5 - TOPOGRAPHICAL CORRELATES OF PEAT DEPTH AND TYPE

5.1 INTRODUCTION

Topographic elements such as degree of slope, position on slope, slope morphology, aspect and geomorphological activity are important components in the peat formation process as they affect the amount of moisture, sunlight and nutrients received and retained by the peat body. These elements interact in a complex manner with climate and vegetation to create variability in the depth and type of peat formed. Information regarding the effect of topography on peat type is discussed indirectly in the literature concerned with mire hydrology and is briefly summarised here.

5.1.1 Slope

Extensive blanket bogs may occur on sloping ground up to an angle of 25°-30° (Moore and Bellamy 1973, Goode and Ratcliffe 1977). Slopes greater than this may support peats in regions of extreme climate such as humid temperate maritime areas (NCC 1988). However, peats on slopes are generally much shallower than those on flats or in depressions, and are subject to severe erosion after disturbance (Pemberton 1989).

5.1.2 Position on slope

Position along a slope is an important determinant of soil nutrient levels and moisture availability. Soil nutrient and moisture levels are generally higher at the base of slopes, due to inputs from upslope, than soils located on the upper reaches of slopes. Organic soils on slopes in south west Tasmania are commonly referred to as being 'well-drained' while those on the flats and in the valleys are 'waterlogged' (Brown and Podger 1982, Jarman *et al.* 1988a, Pemberton 1989).

5.1.3 Drainage

Drainage is primarily determined by slope and it is a highly significant variable in the formation of peat. It affects soil aeration, the mineral nutrient supply and growth and decay rates of vegetation, (Heinselman 1970, Wildi 1978 in Ingram 1983, Malmer 1986).

Both the mean water table level and fluctuations in water table depth are ecologically important in peatlands, and variations may be expressed in the distribution of plant communities (Ingram 1983, Tallis 1983, Moore *et al.* 1984). The acrotelm (active, upper layer of peat) and the vegetation in a local mire system are known to be related to its hydrology (Ingram 1983).

The ecological significance of water table fluctuations in peats has been reported in literature on zoological studies of burrowing crayfish (Richardson and Swain 1980). The distribution of *Parastacoides* and *Engaeus cisternarius* reflects drainage conditions, with upper, heath dominated slope, inhabited by *Engaeus* being better drained than lower, buttongrass dominated slopes. However data are not available on the variation in peat depth and type along the slope.

Fluctuations in water table depths in drained buttongrass moorlands have been found to be more variable than undrained moorlands. Both types showed variability with seasonal conditions (Horwitz 1991). Can this finding be extended to variation in water table depths between 'naturally' better drained sites as opposed to 'naturally' poorly drained sites?

5.1.4 Geomorphological processes

It has been suggested that past glacial and peri-glacial geomorphological processes have created the stepped long profiles in south west Tasmania (Boulter 1978, DPWH 1992). A combination of glacial processes, reduced vegetation cover, and freeze/thaw activity are hypothesised to have produced unstable slopes, solifluction sheets and landslip deposits (DPWH 1992).

The process of soil creep has also been referred to in explanations of short, steep stepped features in the landscape. Soil creep, while retarded in fibrous organic soil, may be more active in amorphous organic soils especially during periods of excessive wetness combined with little vegetation cover. Bog 'flows' or 'bursts' are well documented in Ireland where they are hypothesised to have formed under such conditions. The water content of the peat increases the weight of peat to such an extent that it is forced downslope by gravity (Colhoun *et al.* 1965, Colhoun 1966, Taylor 1983). Similar conditions occur in Scotland where burning and grazing have decreased vegetation cover and increased susceptibility to 'tears' (NCC 1988).

Terracette formations are documented for south west Tasmania (Macphail and Shepherd 1973). They are said to be formed by the process of soil creep and occur on slopes of 20°-30°, supporting shallow skeletal soils along the slope and 'deeper, wetter, peaty soils' lower down slope. Similar features are present on the north east facing slope of Mt Sprent as are stepped long profiles (Boulter 1978). While these features have been recorded, no research has been carried out on the interrelationship between the surface and subsurface topography and peat depth.

5.1.5 Aspect

Aspect has a major contribution to peat formation processes as it intensifies the moisture regime. Northerly aspects are drier than southerly ones (in the southern hemisphere). This implies that the accumulation of organic matter may be prevalent on southerly facing slope (due to the moister environment) or conversely that the accumulation of peat is more rapid and therefore more fibrous on the 'drier' northerly facing slopes. While moisture availability is not considered to be problematic in south west Tasmania, the difference in moisture retention between opposing aspects may be sufficient to produce differences in the type of peat formed. Aspect affects soil temperatures which may then influence soil microbial activity and oxidisation rates.

5.1.6 Interrelationships between topography and organic soils in Tasmania

Data on topographic variation in Tasmanian peats is limited and is generally collected as additional, environmental data for botanical studies. Whinam (1990) found a relationship between geomorphic class and peat depth. Peat depths for shelf mires were generally less than peat depths for moisture retaining kettleholes. These microhabitats also affect the distribution and productivity of plants, the peat formers.

Local variability in peat soils has primarily been explained from a botanical stance, where it is hypothesised that vegetation patterns reflect changes in drainage (Brown and Podger 1982, Pemberton 1989), topography (Brown *et al.* 1982, Bowman *et al.* 1986, Pemberton 1989) and soil type (Tarvydas 1978).

The general consensus is that drainage is the most important factor in differentiating organic soil types, with vegetation distributions reflecting changes in the drainage gradient (Brown and Podger 1982, Bowman *et al.* 1986). In laboratory experiments on *Sphagnum* moss, it was found that the amount of moisture available affected the degree of humification of the plant (Whinam 1990), thus affecting the structure of peat produced. In south west Tasmania, muck peats are generally found in areas of restricted drainage while fibrous peats are located along drainage lines and slopes with lower water tables (Brown and Podger 1982, Pemberton 1989).

This chapter attempts to relate microtopographic variation to peat characteristics by using three methods: 1) topographic surveys of the sites; 2) the distribution of plant communities as indicators of topographic change and water table fluctuations; 3) surface and subsurface surveys of transects orthogonal to terracette and stepped long profile features.

5.2 METHODS

5.2.1 Data collection

Soils and vegetation data collected for the four sites located at altitudes 620 m, 850 m, 930 m, and 1040 m (discussed in chapters 2 and 4) were used. For each transect the variables of slope (using a clinometer), aspect (using a compass) and percentage rock cover (by visual estimation) were added to the above data. Values for these data were determined over a 25 m^2 quadrat (as was the vegetation and average soil depth).

In order to determine any relationship between drainage and soil physical characteristics, 34 perforated plastic pipes were installed at different altitudes on the mountain. The pipes were placed in the peat to bedrock. A plastic lid covered the top of the pipe to prevent rainwater from distorting the readings. Water table depth was measured by placing a light coloured stick into the well and measuring the level of contact. Water table levels were recorded from 13 to 40 times for each well depending on the date of installation and position on the mountain. Where possible the wells were located along a transect (Figure 5.1), however for those which were not included in the transect data, individual quadrat data (soils, vegetation and topography) were collected.

Two wells were located at 509 m. Five wells were located at 620 m. Seven wells were located at 850m, while fifteen wells were installed at 930 m. The site at 1040 m had four wells and the final well was installed at the summit, at 1059 m.

A survey of the terraces was undertaken by measuring the topographic regularity of the steps in relation to subsurface topography and peat depth. Six transects were located at different altitudes on the mountain, each being representative of the steps (terraces). Each transect was laid out as a long profile, orthogonal to the direction of step formation. Soil depths were taken every 20 cm along the transect which varied from 40-50 m in length. The depths were recorded by using a steel probe. Slope was determined (using a clinometer) and the profiles were plotted to determine any patterns between soil depth and subsurface and surface topography.

The transects were located at 580 m, 640 m, 780 m, 840 m (buttongrass moorland) and 930 m (alpine heathland).

5.2.2 Data Analysis

The topographic data relating to the four sites (620 m, 850 m, 930 m, 1040 m) were correlated with the soils data (from chapter 2) by using the Spearman Rank Correlation Coefficient. Aspect was coded from 1 to 5, from the driest north west facing slopes to the wettest south east facing slopes (Kirkpatrick and Nunez 1980). The topographic data were fitted to the species ordinations outlined in chapter 4 and were compared to the vectors of soil physical properties.

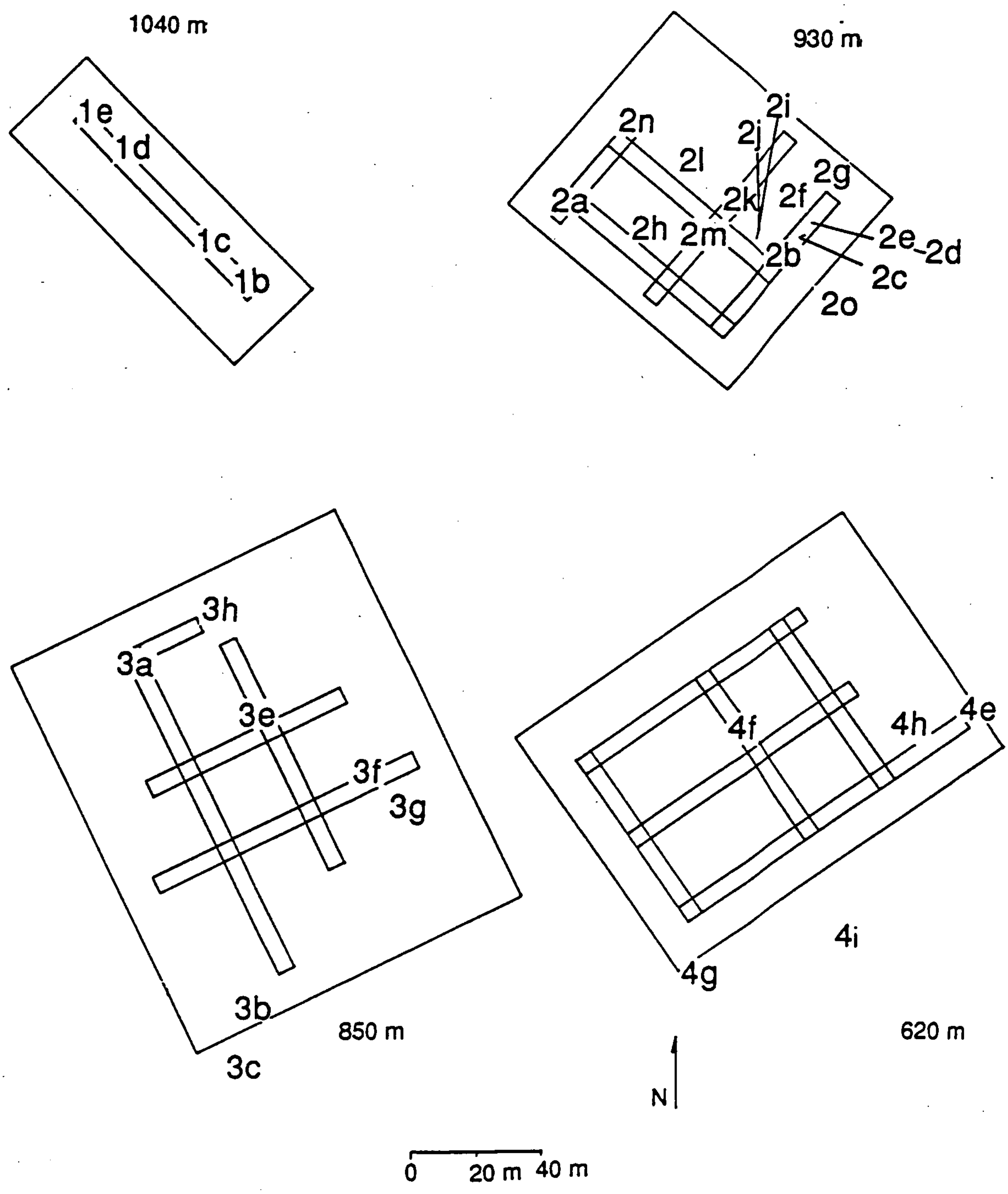

Figure 5.1 Location of water table wells at each site on Mt. Sprent.

N.B. Additional wells are located at the summit (1a at 1059 m) and at 509 m (4a and 4b). Well 3d was lost during the data collection stage, while wells 4c and 4d never existed.

Data for the water wells were collated in a spreadsheet and descriptive statistics were computed for each well. After vector fitting all of the water table variables, the mean and modal water table depths and the range of depths were found to be useful summaries of the water table data and so were used to compare drainage, plant communities and soil properties. All of the other water table variables were highly correlated with these three.

The water table data were analysed as a complete data set i.e. they were not analysed site by site due to the low number of samples at some sites. Vegetation data for the water well quadrats were ordinated using GNMDS and vectors of the soils, topography and drainage were fitted to the species ordination. (The procedure followed is outlined in chapter 4 methods).

Mean values of the drainage data for each of the TWINSPAN groups at each site were computed. These values were then compared to the mean values for soils and topography to determine the existence of any general patterns between community groups.

Data for the long profiles were plotted up to determine any visible patterns between soil depth and surface and subsurface topography. Trend lines were fitted to the profiles in order to determine the general underlying pattern of subsurface topography, reducing the 'noise' factor. Organic content of the soil samples was determined by the weight loss on ignition method described in chapter 2.

5.3 RESULTS

5.3.1 Correlations between topography and soils data

Table 5.1 illustrates the significant relationships between soil physical properties and topographic variables for each site.

By far the most consistent, significant correlation from site to site is that of rock cover and soil depth. Soil depth increases with decreasing rock cover. Other soil variables correlate significantly with rock cover but these relationships are not transferable from site to site. Gravel depth correlates with rock cover at one site and slope at two sites. However the relationship between slope and gravel depth is not consistent between sites. At 620 m, gravel layers are deeper on flatter areas, whereas they are shallower on flatter areas at 1040 m. Soil pH of the surface and lower horizons is related to slope and rock cover.

Table 5.1 Significant correlations (Spearman rank, $p<0.05$) between soil properties and topographic variables for each site on Mt. Sprent.

Edaphic Variable	Topographic Variable	Sites 620 m	850 m	930 m	1040 m
Gravel Depth	Slope	•			X
pH (s, l)	"		X		
Moisture content (s)	"				X
Horizon Type (l)	"				•
Humification (s)	Aspect	•			
Humification (l)	"	X			
Soil Depth	Rock Cover	X	X	X	
pH (s, l)	" "	•			
Mineral Depth	" "	•			
Organic Content (l)	" "		•		
Horizon Type (l)	" "			X	
Gravel Depth	" "			X	
Moisture Content (l)	" "			•	

Note: s, l refer to surface or lower horizon; X indicates an inverse relationship between the variables, while • indicates a direct relationship.

While many of the soil variables are significantly correlated with topographic variables, the relationships are not necessarily applicable at each site.

At 620 m, deeper gravel layers are found under soils on steep slopes. Higher pH values, shallow soil profiles and relatively deep mineral layers (sands) are recorded for rockier sites. Less humified surface soils occur on north facing (dry) slopes, while the lower horizon tends to be more humified (indicating the presence of a peat as opposed to a sandy organic layer).

At 850 m, soils on steeper slopes are more acidic than those on flat ground while soils in rocky areas are generally shallow with organic lower horizons.

At 930 m, soil properties are related to rock cover. The type of lower horizon and depth of gravel layer vary inversely with rock cover ($z = -0.562$, $p = 0.0314$, $z = -2.088$, $p = 0.0368$ respectively) while the moisture content of the lower horizon varies directly with rock cover ($z = 2.646$, $p = 0.0081$). Areas of high percentage rock cover support shallower, more organic soils with correspondingly high moisture contents and shallow gravel layers.

At 1040 m topographic variability in the soils data is related to slope. The moisture content of the surface horizon ($z = -1.964$, $p = 0.0495$) and the depth of gravel ($z = -2.2$, $p = 0.0278$) decrease with increasing slope. Soil depth is not significantly related to any topographic variable, and no soil variables are significantly related to rock cover.

5.3.2 Correlations between soils, topography and vegetation ordination scores

Table 5.2 reveals that soil depth and rock cover are as strongly related to species ordination scores as they are to each other. Approximately half of the significant relationships are also noted in Table 5.1 for the same sites. This indicates that strong interrelationships exist between soils, vegetation and topography.

A relationship between vegetation and soil physical propertiesis indicated in Table 5.2. The main difference between the two tables is that the correlations which are not highlighted in the previous table (Table 5.1) are those which relate soil characteristics (especially of the surface horizon) with vegetation. Therefore, correlations between topography and soils data relate mainly to depth of soil, while correlations between topography, vegetation and soils data relate to soil physical characteristics.

Table 5.2 Significant correlations (Spearman rank, $p<0.05$) between soil and topographic variables and ordination scores of the vegetation for each site on Mt. Sprent.

Topographic and Edaphic Variables	Sites 620 m	850 m	930 m	1040 m
Slope		•		⊡
Rock Cover	☒	⊡	⊡	
Aspect	☒	X		
Soil Depth	⊡	☒	☒	
Gravel Depth	☒		☒	
Top Horizon Type		X		•
Top Moisture Content				☒
Top Organic Content		•		•
Top Horizon Depth			X	
Lower Organic Content		⊡		
Lower Colour		•		
Organic Depth				X

Note: X is indicative of an indirect relationship while • denotes a direct relationship; ☒ ⊡ represent variables which are significantly correlated with topographic and soils data at the same site as those in Table 5.1.

5.3.3 Correlations between soils, topography, vegetation and drainage data

The only soil and topographic variables to correlate significantly to mean and modal water table depth are pH of the surface horizon ($z = -2.501$, $p = 0.0124$, $z = -1.985$, $p = 0.0471$).

The ordination diagram (Figure 5.2) of species data for the water wells reveals that the community groups (identified in chapter 4) are separated with respect to altitude and drainage conditions. There is an obvious relationship between the vectors of mean/modal water table depth and soil depth and depth of gravel.

Soil depth is inversely related to percentage rock cover, mean and modal water table depth and the vegetation variables of species richness and average height. Soil depth is directly related to gravel depth.

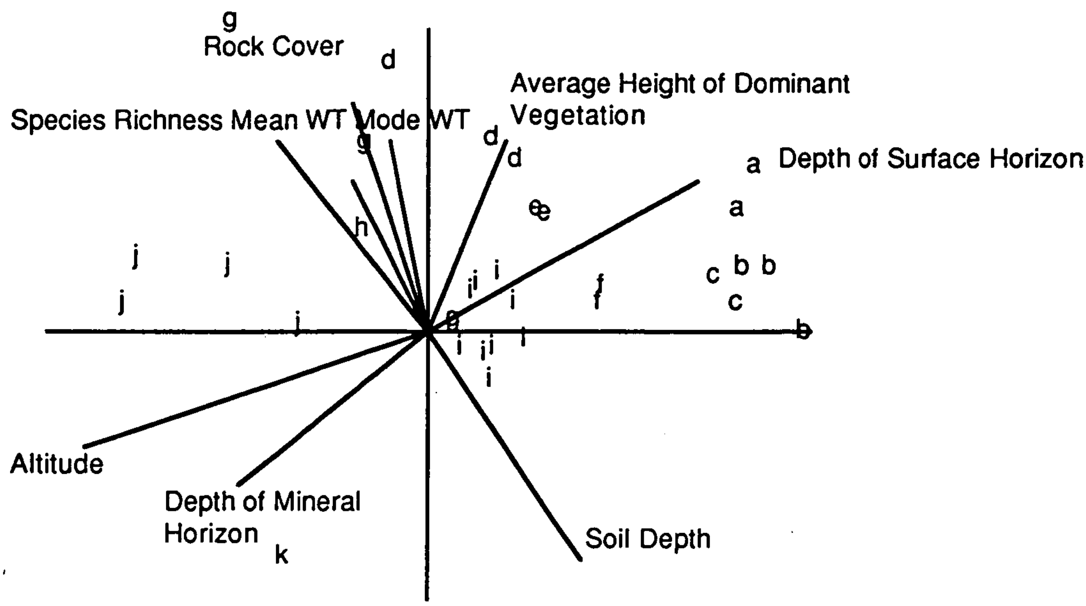

Figure 5.2 Ordination scores, TWINSPAN groups and vectors for each water table well

N.B. a,b,c are TWINSPAN groups 1,2,3 for the wells at 509 and 620 m
c,d,e are TWINSPAN groups 1,2,3 for the wells at 850 m
f,g,h are TWINSPAN groups 1,2,3 for the wells at 930 m
i,j are the TWINSPAN groups 1,2 for the wells at 1040 m and 1059 m.

Colour of the surface horizon is inversely related to the range of water table depths and average vegetation height. Light coloured horizons tend to be located in soils with variable water table levels and under taller vegetation.

Strong relationships exist between drainage conditions and plant community distributions and soil characteristics. Rock cover is the only topographic variable measured which correlates with the species ordination scores. Rock cover can be used as an indicator of drainage, rocky sites having lower water tables than non-rocky sites.

The mean and modal water table depths are presented in Table 5.3 along with the significant mean data for soils, vegetation and topography for each TWINSPAN group at each site. From this table one can surmise that rock cover, soil depth, average vegetation height, species richness, depth of surface horizon and the mean and modal water table depth all vary between the community groups, i.e. within sites. Colour of the surface horizon and pH vary with altitude i.e. between sites and are therefore not necessarily directly related to microtopographic drainage conditions as reflected in plant community distributions.

Table.5.3 Water table depths and soil physical properties for each well by TWINSPAN group

	620 m			850 m			930 m			1040 m	
TWINSPAN groups	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**
Mean Rock Cover (%)	5	8	27	5	7	16	1	3	25	17	11
Mean Soil Depth (cm)	28	24	16	27	27	21	30	30	14	9	21
Average Height of Dominant (cm)	48	49	55	41	49	58	45	34	37	40	3
Species Richness	20	21	22	20	23	25	23	21	27	30	23
Mean Depth Surface Horizon (cm)	8	6	7	10	15	19	-	22	13	5	5
Mean pH Surface Horizon (cm)	3.9	3.9	3.9	3.8	3.8	3.8	-	3.8	3.9	3.5	3.7
Mean Water Table Depth (cm)	7	9	7	5	13	19	19	10	14	12	3
Modal Water Table Depth (cm)	0	0	8	2	7	20	9	6	7	14	0

5.3.4 Terraces

From field observation there appear to be two main forms of step formation, terracettes, or sheep tracks, as described by Macphail and Shepherd (1977) and stepped long profiles, noted by Boulter (1978).

The terracettes occur on very steep slopes, averaging 20°. Steps on steeper slopes are closer together than those on gentler slopes. Immediately behind (upslope) of the step, the soils are deeper, while at the bottom of the step they are much shallower (Figure 5.3, Plate 5.1).

The stepped profiles are fairly regular in appearance and occur on shallower slopes (approximately 10°) than the terracettes. Again distance from step to step is dependent on slope angle. Sedgy vegetation occurs along the tread while heathy, woodier vegetation occupies the riser. Soil depth on the riser is generally less than on the tread and lies directly on rock rather than being underlain by gravels. Soil depth increases immediately behind the rock and is much shallower at the base of the slope (Figure 5.3, Plate 5.2).

5.4 DISCUSSION

It was expected that slope, as a control of internal and external drainage, would strongly correlate with soil physical properties. However this was not the case. Slope was significantly related to soil properties at three sites, although the relationship between slope and these soil variables was not consistent between sites. Slope was measured over the distance of a 25 m^2 quadrat which may include small depressions or a steep slope for 2.5 m of the transect followed by a very flat area. Soil samples were taken from both, but were allocated the same slope measurement which would disguise any influence of slope on soil properties.

Aspect was not a significant determinant of soil characteristics (except at one site). This may have been due to the four sites being located on the north east facing slope of the mountain. While there was variation in aspect along the transects, the sites were relatively small. Therefore local variation in climate, determined by local topography would probably affect the whole site. The site at 620 m recorded a relationship between degree of humification and aspect. The humification of the surface horizon was lower (i.e. the organic soils were more structured) on drier (north facing) slopes. This finding is supportive of previous results which found that fibrous organic soils indicate a fast peat accumulation rate, in a relatively well drained site (Lee *et al.* 1988).

Rock cover is a reliable indicator of soil depth at three of the four sites. No major trend applicable to each site could be determined between any soil characteristic and rock cover. Correlations between rock cover and soil properties are important at 930 m and 620 m, where the amount of rock present relates to the type of horizon present and the depth of mineral and gravel layers. It is suggested that these variables also illustrate the role of drainage in affecting soil properties and formation processes. As none of the attributes are important at all the sites, it is hypothesised that while rock cover does influence soil properties, it is not the major influence. Rock cover is presented as being a useful indicator of drainage conditions, with sites recording high rock cover being relatively well drained.

Comparison of correlations for soils and topographic data and soils, topographic and vegetation data reveal that there is a strong interrelationship between the three data sets. Neither topography nor vegetation can be seen as playing the major role affecting peat formation processes. The data suggest however that vegetation has an impact on soil physical properties of the surface horizon i.e. the horizon most likely to have been derived from present day vegetation.

Soil depth, depth of gravel layer and pH are inversely related to mean and mode water table depths. None of the other soil characteristics are significantly correlated to the water table data despite studies. Drainage in peats is extremely complex with water table levels fluctuating within centimetres of a measuring pipe. The water table data collected in this study were sufficient to show a relationship between vegetation and drainage but not to show relationships between peat and drainage.

While significant relationships between soil properties and drainage characteristics are few, drainage and vegetation type are related. Thus the distribution of plant communities may be used to identify areas of differential drainage patterns.

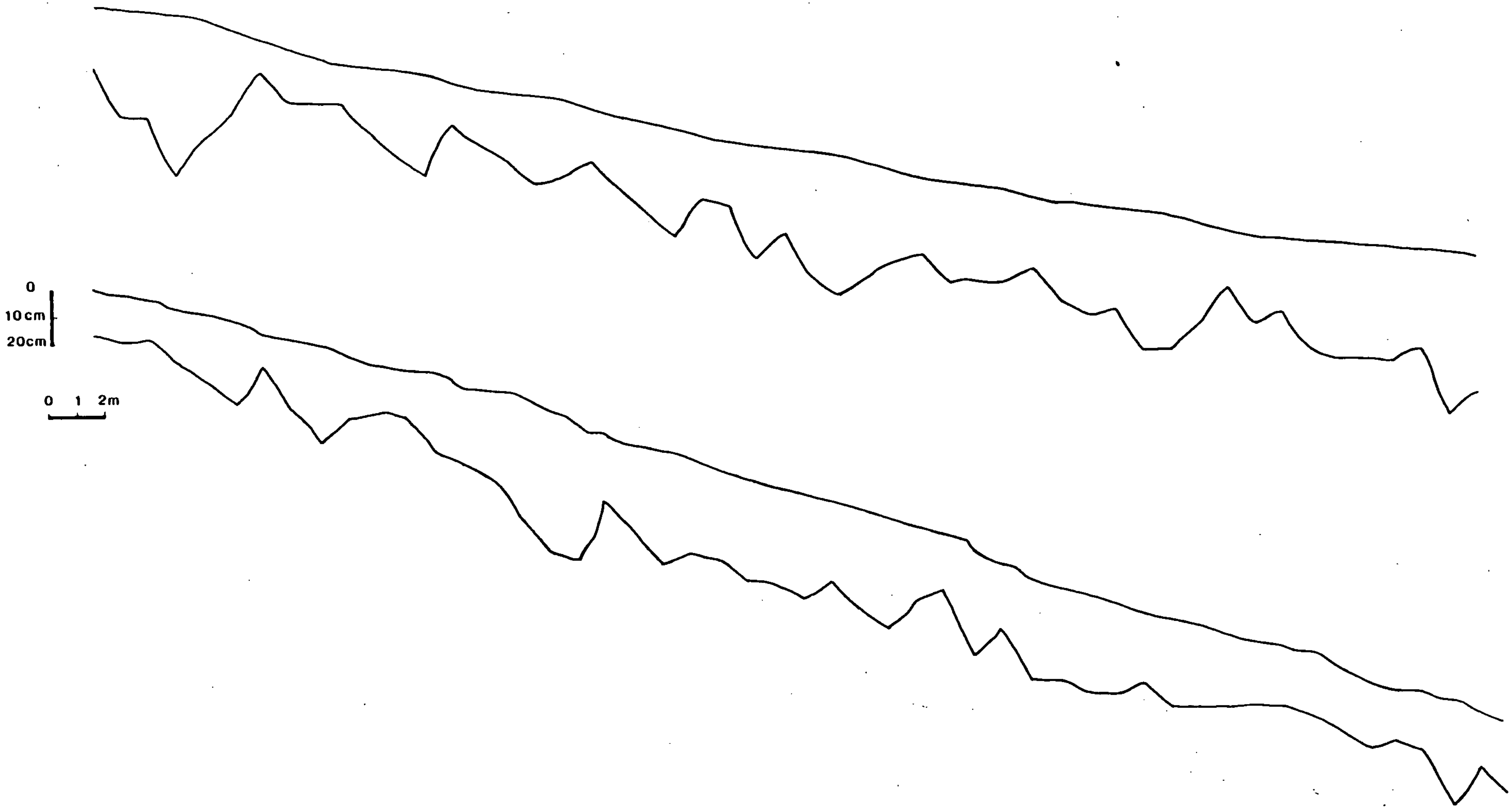

Figure 5.3 Surface and subsurface topography and soil depth of terraces on Mt. Sprent

Plate 5.1 Terraces at 640 m altitude

Plate 5.2 Terraces at 930 m altitude

5.4.1 Terraces and stepped profiles

The terracettes described by Macphail and Shepherd (1973) occur on steep slopes (20°) on Mt. Sprent. It is suggested by these two authors that the formations result from soil creep, an extremely slow process given the relatively well covered slopes. The steps are very narrow and may result from the gravitational force enhanced by steepness of slope, where the vegetation is not strong enough to hold the peat in situ. Further analysis on particle size and root structure is needed to expand this hypothesis.

As with the terracettes, soil depth on the risers of the stepped long profiles is generally less than on the tread and lies directly on rock rather than being underlain by gravels. Soil depth increases immediately behind the rock and is much shallower at the base of the slope. A suggestion for this development of deeper peat immediately behind the rock relates to the moisture availability in the soil and microscale depositional processes. Deeper peats may form behind the outcrop due to a damming effect. If the rock prevents the movement of runoff downslope then the site immediately behind the outcrop will be wetter than if drainage was unrestricted. Also organic material may accumulate behind the rock creating deeper profiles. At the foot of the riser, sands and gravels are common, as the lighter organic material has been washed downslope. Further along the tread the moisture content and deposition will increase as rainwater is intercepted and dammed by the next rock outcrop. As moister environments are more conducive to peat formation, the areas close to impeded drainage have deeper organic soils. Plant distributions on the stepped profiles support this hypothesis as sedgy plants dominate on the tread (moister environment) while woody, heathy plants dominate on the rise (better drained environment). Evidence in the form of particle size analysis and C^{14} dating is needed to test this hypothesis.

It is also suggested that the form of the rocks, i.e. their initial distribution may be related to periglacial processes and that the peat has developed since their formation. Thus peat depth is determined by the subsurface topography, but is locally determined by variation in moisture availability/retention and the down slope deposition of organic matter.

Chapter 6 - DISCUSSION

It is difficult to place Tasmanian blanket peats in any morphological classification presented for the northern hemisphere. These peats are not dominated by mosses, yet they record the highest levels of acidity of any vegetation type in the state. They receive most of their nutrients from rainfall. This is a result of the peats developing on relatively infertile, slow-weathering, quartzitic bedrock, which releases very few nutrients to the environment. The relative major-ion composition of Lake Pedder (now inundated by the Pedder Impoundment) was similar to sea water (Buckney and Tyler 1973) suggesting that limited nutrients were added in solution from runoff. The term which best describes the south west Tasmanian peats is 'blanket bog complex' (Moore *et al.* 1984) as it accounts for variations in water shedding and water receiving environments and therefore water chemistry over undulating terrain.

6.1 ORGANIC SOILS ON MT. SPRENT

The organic soils on Mt. Sprent may be classified as peat soils according to the Australian classification (Isbell 1992) as they have an organic content of greater than 30%, and are dominated by organic materials for a minimum depth of 0.1 m. In an international context they are shallow but are comparable in depth to some blanket peats in the northern hemisphere (Taylor 1983, Moore *et al.* 1984). Limited data are available on peats of similar depth around the world making comparisons through the literature difficult. A classification of Scottish moorland soils (Nolan and Robertson 1987) suggests that there is a similarity between peaty rankers and the hill peats of south west Tasmania. They may also be comparable to the 'Magellanic Tundra' complex (Pisano 1983) as the vegetation is of Gondwanic origin and thus is similar to that found in the south west of the state. However, little information on the peats is presented in the document, other than that they are shallow and directly overlie rock. Comparisons between Tasmanian peats and their South American counterparts may be interesting and useful in a classification of southern hemisphere peatlands.

The soils on the mountain can be divided into two groups: organic soils of slopes and ridges and alpine soils (*sensu* Pemberton 1989). The alpine soils are not peats as they do not have an average organic content of 30% or more. In this study they are classified as sandy organic soils. While there is a large proportion of mineral soil in the profile, there is also a large amount of organic matter present.

The 'organic soils of slopes and ridges' may be better defined as 'highland moorland soils', as they also occur in depressions and flats between the slopes and ridges, and yet are not 'organic soils of lowland depressions' (Pemberton 1989). They are organic throughout the profile, usually resting on shallow sands or gravels or directly overlying rock. Organic content averages 50% in the surface horizon.

The mean organic content of 68% in the surface horizon, is well below values recorded for international blanket peats (Clymo 1983) though comparable to other studies in south west Tasmania (Richardson 1985, Bowman *et al.* 1986). An explanation of this may be found in the bioturbation of the soil by burrowing crayfish (predominantly *Parastacoides* spp.). The amount of material transplanted by the burrowing activities of crayfish is substantial and would account for the relatively low organic contents recorded.

There is a sequence of soil physical characteristics down the profile which are generally found on the mountain and elsewhere in the state, with fibric overlying hemic overlying sapric peats. All three horizons need not be present at any one location. Generally if a sapric peat is the surface horizon then it is the only organic horizon present. This horizon sequence is widespread on the mountain and is in agreement with other research in the state (Pemberton 1989, Horwitz 1991). Limited information for shallow peats in the northern hemisphere suggests that humification increases with peat depth (Charman 1992). This is not necessarily the case for deeper peats where fibrous layers have been recorded under amorphous horizons (Goode and Ratcliffe 1977).

6.1.1 Correlates of peat formation on Mt. Sprent (and south west Tasmania)

The peats are differentiated along an altitudinal gradient. While the amount of rainfall received is variable over the mountain, it is evenly spread throughout the year.

This study indicates that precipitation deficits do occur (mainly in February) which would have some impact on moisture availability, oxidisation of the organic layer and decomposition of organic matter. However the relationship is not straightforward as deeper peats are found at the warmer, wetter sites at lower altitudes. These sites may be expected to dry out more quickly due to higher temperatures, lower relative humidities and thus higher evapotranspiration rates. However, plant productivity may also be high at these sites, offsetting to some extent the negative effects of warmer conditions on peat formation.

The geology is consistent within the description of Precambrian metamorphics, generally highly silicious quartzites which release few nutrients to the environment with weathering. The aspect of the sites on the mountain which follow the track, is north-easterly facing, a relatively warm, dry slope in the southern hemisphere. Slope is generally steep but variable over the range of the mountain.

Vegetation varies with altitude, and like the soils, may be divided into two main groups, alpine heath and sedgeland and buttongrass moorland. Moorland vegetation dominates along the lower slopes of the mountain which intergrades and is quickly replaced by alpine heathland and sedgeland. The boundary between the two main vegetation types lies between 850 m and 930 m, the limit of buttongrass (*Gymnoschoenus sphaerocephalus*) tussocks. This boundary is reported by other researchers in the state (Kirkpatrick and Brown 1987, Jarman *et al.* 1988a).

Temperature (both air and ground) decreases with altitude. The steepest lapse rate for air and ground temperature occurs between the two sites at 850 m and 930 m, which corresponds with the floristic and edaphic boundaries. Given the likelihood that the change in vegetation is reacting to a change in climate, are the different soils predominantly a result of a change in climate or are they a result of a change in vegetation?

Soil depth decreases with altitude, with the change in climate and between plant communities. The initial separation of the altitudinal quadrats is into four community groups, each having a species composition based on the altitudinal range of the samples. Thus Group 4 has the highest proportion of alpine plants while Group 1 has none. Although the species composition of the groups is different, median soil depths between the two middle groups are identical (27 cm). This indicates the complex interaction between a number of factors in the peat formation process as two different plant communities record similar soil depths. Therefore, peat formation, in terms of climate and moisture availability must be favourable at both sites irrespective of vegetation type.

Soils data from pits at the four individual sites also show a decrease in soil depth with altitude. Again the middle two sites have similar mean soil depths, but the lower three sites have almost identical organic layer depths. While on the surface, it appears that all three sites share similar peat forming properties, this is somewhat deceptive. The organic contents of soils are much higher at the two lower sites (620 m and 850 m) than at 930 m.

The finding that moisture content is related to degree of humification and organic content is in agreement with other studies both internationally and locally (Boelter 1969, Landva *et al.* 1982, Richardson 1985). Moisture content and organic content of the alpine soils are less than that of the moorland soils.

A comparison of soil physical characteristics between two similar plant communities at different altitudes may provide an insight into the role of climate in peat formation processes.

Two similar vegetation types located at different altitudes (850 m and 930 m), are in similar topographic situations i.e. around rock outcrops. The percentage similarity of species between the two groups is 63%. The mean and modal water table depths at the two sites are below the surface (from 14 - 20 cm) (see Table 6.1). The modal surface horizon at each site is a moderately humified hemic peat. Despite recording similar types of surface horizon (hemic peats), the moisture and organic contents are very different.

Table 6.1 A comparison of soils data for rock outcrops at 850 m and 930 m

	850 m	930 m
rock cover	16%	25%
mean water table depth	19 cm	14 cm
surface horizon	hemic peat	hemic peat
moisture content	80%	66%
organic content	69%	29%
pH	3.8	3.9
humification	H5	H4
surface horizon depth	9 cm	13 cm
depth of organic layer	22 cm	18 cm
total soil depth	35 cm	18 cm

It is important to note here that the difference between the two sites is also apparent in the make up of the soil profile. The rock outcrop community at 850 m has a better defined, more variable soil profile than 930 m, which tends to be dominated by a single, fairly uniform, organic horizon. Where other horizons are present, they are shallow.

The indication is then that climate ultimately determines variability in soil depth and type on the mountain.

When organic content is plotted against mean maximum temperature of the growing season (Figure 6.1), there is a linear correlation between the sites, with organic content increasing with increasing temperature. This pattern occurs up to a threshold value of 13 °C, 55% organic content, above which organic content is constant. This suggests that climate affects the type of peat formed through its effect on plant productivity and decomposition rates.

Warmer temperatures, combined with high rainfall, provide a regime conducive to relatively high accumulation rates (2 cm/100 yrs. for Tasmania, Thomas 1991, Colhoun *et al.* 1992). This would also explain the presence of more fibrous peats at lower altitudes, if they are an indicator of rapid peat growth.

It appears that climate is the dominant factor affecting peat formation. However, at a local scale, it is a different case as there is considerable variation over short distances at individual sites.

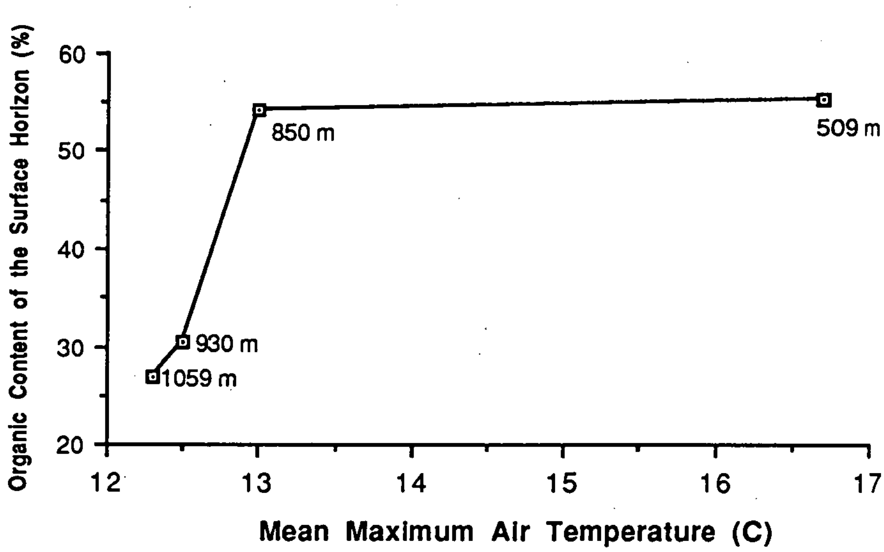

Figure 6.1 The relationship between mean maximum air temperature for the growing season and organic content of the surface horizon, by altitude.

6.2 MICROSCALE VARIABILITY IN PEAT DEPTH AND TYPE

Peat depth and type varies with different topographic situations and drainage conditions. Vegetation type also appears to have some influence on the physical properties of the peat formed. Humification of the surface horizon and its moisture and organic content are generally differentiated between community groups within an altitudinal gradient. Heathier communities tend to have higher organic contents with correspondingly high moisture contents and relatively undecomposed surface horizons.

One would not expect the current vegetation to influence the characteristics of the lower peat horizon, given the expected age of the peat and the presumably erratic fire history of the region.

The preference/tolerance of particular plants for certain environmental conditions such as well drained sites, would be reflected to some extent by peat depth. Sites which are most conducive to peat formation are those occupying poorly drained situations. On Mt. Sprent these sites tend to be dominated by graminoids, while the woody plants dominate the better drained areas.

Amorphous peats in Tasmania have often been associated with buttongrass moorlands. If one assumes that the peat underlying the vegetation is of a similar age, then the peat under woody vegetation should be less humified than that under sedgy vegetation. This was not found to be the case on Mt. Sprent as fibrous peats were found under both woody and sedgy communities. This can be explained in a number of ways: the peat is not of similar age, i.e. the accumulation rate of woody peats is different to that of sedge peats; the distribution of plant communities and peat type reflects localised disturbances; or decomposition rates are similar between vegetation types.

While all sites on the mountain showed some evidence of fire, the sites at lower altitudes had much fewer fire sensitive species and more fire scars, such as burnt buttongrass tussocks, relatively thick tea-tree stags and severely eroded peat with exposed gravel surfaces. Stem counts of vegetation on the mountain indicate that the last severe fire was approximately 40 years ago on the lower slopes (Jarman *et al.* 1988b, Marsden-Smedley DPWH, pers. comm.). However, evidence at the sites suggests that milder fires occurred more recently. Fire sensitive species such as *Richea scoparia* occur in sheltered rock outcrops at lower altitudes, suggesting that these sites may have peats of a greater age than those in exposed areas. In this case the woodier vegetation types which inhabit the rock outcrops, may be supported by older peats, which would account for the lack of a relationship between humification and vegetation type. Only dating of deposits from each site will provide an answer to this.

The hypothesised role of rock cover as a protector against fire becomes more feasible when topographic considerations of the variability in peat depth and type are taken into account. Of the environmental variables measured, percentage rock cover is the best indicator of variation in soil depth at three of the four sites. While rock cover is a good indicator of soil physical properties, these relationships are not consistent between sites. It is suggested that rock cover is an allegory for drainage conditions as it reflects both vegetation patterns and soil physical characteristics.

The analysis of fluctuations in water table levels is extremely informative, highlighting the interrelationships that exist between soils, vegetation and topography. Rock cover is a good indicator of variability in water table depth and both of these factors are indicative of soil depth. Rocky sites generally have shallower soils with deeper water tables. Relationships between soil physical properties and other variables are not well defined. Colour of the surface horizon is correlated with water table level, where lighter coloured soils are found under deeper water tables. This also coincides with the distribution of woody vegetation.

Drainage is believed to be the controlling influence on peat formation processes at a local scale as it incorporates the factors of topography, vegetation and microclimate and causes variability in the depth and type of peat formed. Drainage is also presumed to be important in the distribution of peat fauna (burrowing crayfish) (Wong 1991) and is critical in determining the natural spread of the destructive soil pathogen *Phytophthora cinnamomi* . Further analysis of small scale drainage patterns may reveal more information on the complex interaction between peats and many biotic and abiotic variables, such as peat formation rates under different moisture regimes, with or without the aid of burrowing crayfish.

6.3 CONCLUSION

The work presented here is a baseline study, providing avenues of interest for further research. Regional climatic variation and its effects on peat formation and decomposition rates is an interesting area of research. How does the summer precipitation deficit affect rates of peat decomposition? How much do the water tables rise/fall with each rainfall event? How does this affect the soil respiration rate? Are woody plants more or less productive in terms of peat formation than sedges? Do sedges decompose at a faster rate than woody plants? These questions while useful in themselves would also benefit other researchers in peatland studies such as zoologists studying burrowing crayfish or land managers who wish to conduct fuel reduction burns without burning the peat.

The most obvious next step is to concentrate on peat accumulation and decomposition rates. How old are south west Tasmanian blanket peats? Successful dates and stratigraphies have been obtained for western Tasmanian valley bogs, but attempts to date the blanket peats have been thwarted, possibly by the activities of burrowing crayfish. The peats are shallow but a comparison of dates from relatively sheltered sites, such rock outcrops, may provide useful information on the origins of these peatlands. Are they a result of Aboriginal burning practices, removing forested land, raising the local water tables, providing a moist environment for the accumulation of organic matter?

Are south west Tasmanian blanket peats in equilibrium or are they in a state of decay? Both hypotheses have been posed by researchers in order to account for the shallow nature of the profiles (Damman in Jarman *et al.* 1988a, Pemberton 1989).

One of the most interesting aspects of this study, is the complexity of interrelationships between drainage, biota and peat. The extreme variability in peat soils at a local scale, is intricately related to both the flora and fauna, which in turn are controlled to some extent by drainage characteristics. This study has shown, and others have inferred that minor variations in the composition of plant communities is very much related to drainage, as are the distributions of species of burrowing crayfish. Peatland hydrology is complex. However, more detailed analysis on water table fluctuations in different peat types in different situations may provide details on the biotic role in peat formation processes.

REFERENCES

Allen K.J. (1991) An EOF and Spectral Analysis of Tasmanian Rainfall. Honours thesis. University of Tasmania, Hobart.

Anderson J.A.R. (1983) The tropical peat swamps of western Malesia. In A.J.P. Gore (ed.) Ecosystems of the World 4B, Mires: Swamp, Bog, Fen, and Moor: Regional Studies. Elsevier Scientific Publishing Co., Amsterdam.

Andrejko M.J., Fiene F. and Cohen A.D. (1982) Comparison of ashing techniques for determination of the inorganic contents of peats. In P.M. Jarrett (ed.) Testing of Peats and Organic Soils. ASTM Special Technical Publication 820, Philadelphia.

Balmer J. (1990) Two moorland boundaries. Tasforests **1**, 133-141.

Balmer J. (1991) Buttongrass Moorland Vegetation. In J. B. Kirkpatrick (ed.) Tasmanian Native Bush: A Management Handbook. Tasmanian Environment Centre, Hobart.

Barry R. (1981) Mountain Weather and Climate. Methuen, London.

Barry, T.A. (1979) A simple field classification of peat types in the raised type bogs (hochmoore) of Ireland. Proc. Inter. Symp. on Classification of Peat and Peatlands: Finland **1979**, 200-216.

Birkeland P.W. (1974) Pedology, Weathering and Geomorphological Research. Oxford University Press, London.

Boelter D.H. (1969) Physical properties of peats as related to degree of decomposition. Soil Sci. Soc. Am. Proc. 33, 606-609.

Boelter D.H. and Verry E.S. (1977) Peatland and water in the Northern Lakes. General technical report NC-31. USDA, Minnesota.

Bohlin E., Hamalainen M. and Sunden T. (1989) Botanical and chemical characterization of peat using multivariate methods. Soil Sci. **147**, (4) 252-63.

Bosworth P. (1977) A Collation of Meteorological Information for south west Tasmania. South West Occasional Paper No. 2. South West Tasmania Resources Survey, Hobart.

Botch M.S. and Masing V.V. (1983) Mire Ecosystems in the U.S.S.R.. In A.J.P. Gore (ed.) Ecosystems of the World 4B, Mires: Swamp, Bog, Fen, and Moor: Regional Studies. Elsevier Scientific Publishing Co., Amsterdam.

Boulter C.A. (1978) The structural and metamorphic history of the Wilmot and Frankland Ranges, south west Tasmania. PhD thesis. University of Tasmania, Hobart

Bowman D.M.J.S. and Jackson W.D. (1981) Vegetation succession in south west Tasmania. Search. **12**, (10) 358-362.

Bowman D.M.J.S., Maclean A.R. and Crowden R.K. (1986) Vegetation-soil relations in the lowlands of south west Tasmania. Aust. J. Ecology. **11**, 141-153.

Briggs J.D. and Leigh J.H. (1988) Rare or Threatened Australian Plants. ANPWS Special publication no. 14, Canberra.

Brown M.J. (in press) Buttongrass Moorland Ecosystems. In S.J. Smith (ed.) Tasmanian Wilderness - World Heritage Area Values. Roy. Soc. Tasm., Hobart.

Brown M.J., Crowden R.K., and Jarman S.J. (1982) Vegetation of an alkaline pan-acidic peat mosaic in the Hardwood River Valley, Tasmania. Aust. J. Ecol. **7**, 3-12.

Brown M.J. and Podger F. (1982) Floristics and fire regimes of a vegetation sequence from sedgeland-heath to rainforest at Bathurst Harbour, Tasmania. Aust. J. Botany. **30**, 659-676.

Buchanan A.M., McGeary-Brown A. and Orchard A.E. (1989) A census of the vascular plants of Tasmania. Tasmanian Herbarium Occassional Publication No. 2. Tasmanian Herbarium, Tasmanian Museum and Art Gallery, Hobart.

Buckney R.T. and Tyler P.A. (1973) Chemistry of some sedgeland waters: Lake Pedder, south west Tasmania. Aust. J. mar. Freshwat. Res.. **24**, 267-273.

Bureau of Meteorology (1990-1991) Monthly Weather Reviews. Hobart.

Campbell E.O. (1983) Mires of Australasia. In A.J.P. Gore (ed) Ecosystems of the World 4B, Mires: Swamp, Bog, Fen, and Moor. Regional Studies. Elsevier Scientific Publishing Co., Amsterdam.

Carter V (1986) An overview of the hydrologic concerns related to wetlands in the United States. CAn. J. Bot. **64**, 364-74.

Charman D.C. (1992) Blanket mire formation at the Cross Lochs, Sutherland, northern Scotland. Boreas **21**, 53-72.

Chason D.B. and Siegel D.I. (1986) Hydraulic conductivity and related physical properties of peat, Lost River Peatland, northern Minnesota. Soil Sci. **142**, (2) 91-99.

Clymo R.S. (1983) Peat. In A.J.P. Gore (ed) Ecosystems of the World 4A, Mires: Swamp, Bog, Fen, and Moor. General Studies. Elsevier Scientific Publishing Co, Amsterdam.

Colhoun E.A. (1966) The debris-flow at Glendalough, Co. Wicklow and the bog-flow at Slieve Rushen, Co. Cavan. Irish Nat. Journ. **15**, 199-206.

Colhoun E.A., Common R. and Cruickshank M.M. (1965) Recent bog flows and debris slides in the north of Ireland. Sci. Proc. Roy. Dub. Soc. **2**, 163-174.

Colhoun E.A., van der Geer G. and Fitzsimons S.J. (1992) Late quaternary organic deposits at Smelter Creek and vegetation history of the Middle King Valley, Western Tasmania. J. Biogeogr. **19**, 217-227.

Corbett J.R. (1969) The Living Soil:the processes of soil formation. Huntingdale Press, West Como.

Costin A. B. (1968) Alpine ecosystems in the Australasian region. In W.H. Osbourne and H.E. Wright (eds.) Arctic and Alpine Environments Indiana University Press, Bloomington.

Costin A. B. (1986) Genesis of Australian alpine soils. In B.A. Barlow (ed.), Flora and Fauna of Alpine Australasia. C.S.I.R.O., Melbourne

Coulson J.C. and Butterfield J. (1978) An investigation of the biotic factors determining the rates of plant decomposition on blanket bog. J. Ecology. **66**, 631-650

Daubenmire R. (1954) Alpine timberlines in the Americas and their interpretation. Butler Univ. Bot. Stud. **11**, 119-136

Davies J.B. (1978) Alpine and subalpine communities of the Mt. Field National Park and Mt. Rufus. Honours thesis. University of Tasmania, Hobart.

Davis C. (1941) Preliminary survey of the vegetation near New Harbour, South-west Tasmania. Pap. Proc. Roy. Soc. Tasm. **1940**, 1-10

DPWH (1992) Tasmanian Wilderness World Heritage Area Management Plan. Department of Parks, Wildlife and Heritage, Tasmania, Hobart.

Derbyshire E.D., Banks M.R., Davies J.L. and Jennings J.N. (1965) Glacial Map of Tasmania. Roy.Soc. Tasm. Special Publication No. 2, Hobart.

Dickinson C.H. (1983) Micro-organisms in peatlands. In A.J.P. Gore (ed) Ecosystems of the World 4A, Mires: Swamp, Bog, Fen, and Moor. General Studies. Elsevier Scientific Publishing Co., Amsterdam.

Eurola S., Hicks S. and Kaakinen E. (1984) Key to Finnish mire types. In P.D. Moore (ed.) Eurpoean Mires. Academic Press, London.

Faircloth P. (1978) The Climatic and Hydrological Resources: An Overview South-west Working Paper No. 2. South-west Tasmania Resources Survey.

Farnham, R.S. (1963) Classification of peat in the USA. Proc. 2nd International Peat Congress **1**, 115-132.

Gellie N.J.H. (1980) Fire Ecology of Buttongrass Moorlands Bulletin No. 6, Forestry Commission, Tasmania, Hobart.

Gentilli J. (1972) Australian Climatic Patterns. Nelson, Melbourne.

Gibson N (1990) The environments and primary production of cushion species at Mt. Field and Mt. Wellington, Tasmania. Aust. J. Bot. **38**, 229-243.

Gore A.J.P. (1963) Comparative ecological studies on peats at two different altitudes in northern England. Proc. 2nd International Peat Congress **1**, 139-149.

Gore A.J. P. (1983) Introduction. In A.J.P. Gore (ed) Ecosystems of the World 4A, Mires: Swamp, Bog, Fen, and Moor. General Studies. Elsevier Scientific Publishing Co., Amsterdam.

Goode D.A and Ratcliffe D.A. (1977) Peatlands. In D.A. Ratcliffe (ed.) A Nature Conservation Review. Vol. 1. Cambridge University Press, Cambridge.

Hakanson and Janson (1983) Principles of Lake Sedimentology Springer-Verlag, Berlin.

Hanninen P. (1987) Comparison between the von Post degree of humification and fibre content method and physical and chemical properties of different grain sizes of peat. Proceedings of the Symposium of 1987 Wetlands/Peatlands Conference. 71-75.

Heinselman M.L. (1965) String bogs and other patterned organic terrain near Seney, Upper Michigan. Ecology **46**, 185-188.

Heinselman M.L. (1970) Landscape evolution, peatland types, and the environment in Lake Agassiz Peatlands Natural Area, Minnesota. Ecological Monographs. **40**, (2) 235-261

Hill M.O. (1979) TWINSPAN - A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell University, New York.

Horwitz P. (1991) The Conservation Biology of *Engaeus spinicaudatus*, a threatened crayfish from north eastern Tasmania. Unpublished report produced for the Australian National Parks and Wildlife Service, Canberra.

Ingram H.A. (1977) Soil layers in mires: function and terminology. J. Soil Science. **29**, 224-227.

Ingram H.A.P. (1983) Hydrology. In A.J.P. Gore (ed) Ecosystems of the World 4A, Mires: Swamp, Bog, Fen, and Moor. General Studies. Elsevier Scientific Publishing Co., Amsterdam.

Irby L.G. (1955) Conquest of the Buttongrass Plains and Heathlands of Tasmania. Department of Agriculture, Hobart.

Isbell (1992) A classification system for Australian soils. (2nd approximation) Tech. Rep. 1/1992. CSIRO Division of Soils, Canberra.

Ivanov K.E. (1981) Water movement in mirelands. Translated by A Thomson and H.A.P. Ingram. Academic Press, London.

Jackson W.D. (1968) Fire, air, water and earth - an elemental ecology of Tasmania. Proc. Ecol. Soc. Aust. **3**, 9-16.

Jackson W.D. (1976) Ecological Drift - an argument against the continued practice of hazard reduction burning. In The Role of Fire in the Management of Tasmania's National Parks and the South-west Area. Proceedings of a Symposium. University of Tasmania, Hobart

Jarman S.J. and Crowden R.K. (1978) A Survey of Vegetation from the Lower Gordon River and Associated Catchments. South-west Occassional Paper No. 12. South-west Tasmania Resources Survey, Hobart

Jarman S.J., Crowden R.K and Brown, M.J. (1982) A descriptive ecology of vegetation in the lower Gordon River Basin, Tasmania. Pap. Proc. Roy. Soc. Tasm. **116**. 165-177.

Jarman S.J., Kantvilas G. and Brown M.J. (1988a) Buttongrass Moorlands in Tasmania. Research Report No. 2. Tasmanian Forest Research Council Inc., Hobart

Jarman S.J., Kantvilas G. and Brown M.J. (1988b) A Preliminary Study of Stem Ages in Buttongrass Moorlands. Research Report No. 3. Tasmanian Forest Research Council Inc., Hobart.

Jarrett, P.M. (ed.) (1982) Testing of Peats and Organic Soils. ASTM Special Technical Publication 820, Philadelphia.

Jongman, R. H., ter Braak, C. J. F. and van Tongeren, O. F. R. (1987). Data Analysis in Community and Landscape Ecology. Pudoc, Wageningen.

Kantvilas G. and Jarman S.J. (1991) Lichens and bryophytes of the Tasmanian World Heritage Area: 1. Mount Sprent. In M. R. Banks *et al*. (eds.) Aspects of Tasmanian Botany: A tribute to Winifred Curtis. Roy.Soc. Tasm., Hobart.

Kirkpatrick, J. B. (1977) Native vegetation of the West Coast region of Tasmania. In M. R. Banks and J. B. Kirkpatrick (eds.) Landscape and Man: The interaction between man and environment in Western Tasmania. Proceedings of a symposium organised by the Royal Society of Tasmania, Hobart.

Kirkpatrick J.B. (1983) Treeless plant communities of the Tasmanian High Country. Proc. Ecol. Soc. Aust., **12**, 61-77.

Kirkpatrick J.B. (1984) Altitudinal and successional variation in the vegetation of the northern part of the West Coast Range, Tasmania. Aust. J. Ecol., **9**, 81-91.

Kirkpatrick J.B. and Brown M.J. (1987) The nature of the transition from sedgeland to alpine vegetation in South-west Tasmania. i) Altitudinal vegetation change on four mountains. J. Biogeogr., 14, 539-549.

Kirkpatrick J.B. and Dickinson K.J.M. (1984) The impact of fire on Tasmanian alpine vegetation and soils. Aust. J. Bot. **32**, 613-629.

Kirkpatrick J.B and Gibson N. (1984) Dynamics of a Tasmanian bolster heath string fen Vegetatio. **58**, 71-78.

Kirkpatrick J.B. and Nunez M. (1980) Vegetation-radiation relationships in mountainous terrain: eucalypt-dominated vegetation in the Risdon Hills, Tasmania. J. Biogeogr., 7, 197-208.

Klemetti V. and Keys D. (1982) Relationships between dry density,moisture content, and decomposition of some New Brunswick peats. In P.M. Jarrett (ed.) Testing of Peats and Organic Soils. ASTM Special Technical Publication 820, Philadelphia.

Landva A.O., Pheeney P.E. and Mersereau D.E. (1982) Undisturbed sampling of peat. In P.M. Jarrett (ed.) Testing of Peats and Organic Soils. ASTM Special Technical Publication 820, Philadelphia.

Lee G.B., Bullington S.W., and Madison F.W. (1988) Characteristics of histic materials in Wisconsin as arrayed in four classes. Soil Sci. Am. J. **52**, 1753-1758.

LeMasters, G.S., Bartelli, L.J. and Smith, M.R. (1982) Characterization of organic soils as energy sources. In P.M. Jarrett (ed.) Testing of Peats and Organic Soils. ASTM Special Technical Publication 820, Philadelphia.

Lishtvan and Tanovitsky (1979)Actual problems pertaining to efficient use and protection of peat deposits. Proc. Inter. Symp. on Classification of Peat and Peatlands: Finland **1979**, 318-329.

Maclean A.R. (1978) Mineral nutrients in soils and vegetation of sedgeland and heathland communities in south west Tasmania. Honours thesis. University of Tasmania, Hobart.

McDonald R.C. and Isbell R.F. (1984) Soil Profile. In R.C. McDonald *et al.* (eds.) Australian Soil and Land Survey. Inkata Press, Melbourne.

Macphail M.K. and Shepherd R.R. (1973) Plant communities of Lake Edgar, South-west Tasmania. Tasm. Nat. **34**, 1-23.

Malmer N (1986) Vegetational gradients in relation to environmental conditions in northwest European mires. Can. J. Bot. **64**, 375-383.

Marachi N.D., Dayton D.J. and Dare C.T. (1982) Geotechnical properties of peat in San Joaquin Delta. In P.M. Jarrett (ed.) Testing of Peats and Organic Soils. ASTM Special Technical Publication 820, Philadelphia.

Marsden-Smedley J. (1991) The ecology of moorland-copse boundaries in south west Tasmanian oligotrophic environments. Honours thesis. University of Tasmania, Hobart.

Mathur S.P. and Levesque M. (1985) Negative effect of depth and saturated hydraulic conductivity of histosols. Soil Science **140**, 462-466.

Minchin P. (1990) DECODA- Database for Ecological Community Data, version 2.02. Australian National University, Canberra.

Moore P.D. (1984) The Classification of Mires: an Introduction. In P.D. Moore (ed.) European Mires. Academic Press, London.

Moore P.D. and Bellamy D.J. (1973) Peatlands. Elek Science, London.

Moore P.D., Merryfield D.L. and Price M.D.R. (1984) The Vegetation and Development of Blanket Mires. In P.D. Moore (ed.) Eurpoean Mires. Academic Press, London.

Moscal T. (1981) Natural History Case Studies from South West Tasmania: Vol.3 The Frankland, Wilmot and Arthur Ranges. Occasional Paper No. 14. South West Tasmania Resources Survey, Hobart.

Mueller-Dombois D. and Ellenberg H. (1974) Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York.

Munsell Munsell Soil Colour Charts Munsell Colour Co. Inc, Baltimore.

Nature Conservancy Council (1988) The Flow Country: The peatlands of Caithness and Sutherland. N.C.C., Peterborough.

Nicolls K.D. (1957) A reconnaissance of the Corinna-Pieman Heads area, Tasmania - Soils. Pap. Proc. Roy. Soc. Tasm. **91**, 17-21.

Nicolls K.D. and Dimmock G.M. (1965) Soils. In J.L. Davies (ed.) Atlas of Tasmania. Mercury Press, Hobart.

Nolan A.J. and Robertson J.S. (1987) Regional trends in dry and moist Scottish moorland vegetation in relation to climate, soils and other ecological factors. J. Ecology. **75**, 1145-57.

Northcote K.H. (1971) A Factual Key for the Recognition of Australian Soils. 3rd Edition. Rellim Technical Publications, Glenside.

Nunez M. (1978) The radiation index of dryness in Tasmania. Australian Geographical Studies. **16**, 126-135.

Nunez M., Skirving, W. J. and Viney N. R. (1987) A technique for estimating regional surface albedos using geostationary satellite data. Journal of Climatology. **7**, 1-11.

Oliver J. E. (1973) Climate and Man's Environment: An Introduction to Applied Climatology. John Wiley & Sons, New York.

Pannell J.R. (1992) Swamp Forests of Tasmania. Forestry Commission, Tasmania, Hobart.

Pemberton M. (1988) Soil erosion between Birchs Inlet and Elliot Bay, south west Tasmania. Pap. Proc. Roy. Soc. Tasm. **122**, 109-114.

Pemberton M. (1989) Land Systems of Tasmania. Region 7- South-west. Department of Agriculture, Hobart.

Pemberton M. (in press) Physical environment: Soils. In S.J. Smith (ed.) Tasmanian Wilderness - World Heritage Area Values. Roy. Soc. Tasm., Hobart.

Pisano E. (1983) The Magellanic tundra Complex. In A.J.P. Gore (ed) Ecosystems of the World 4B, Mires: Swamp, Bog, Fen, and Moor. Regional Studies. Elsevier Scientific Publishing Co., Amsterdam.

Price L.W. (1971) Vegetation, microtopography, and depth of active layer on different exposures in subarctic alpine tundra. Ecology. **52**, 638-647.

Ratcliffe D (1977) Peatlands. In D Ratcliffe (ed.) A Nature Conservation Review: Volume 1. CUP, Cambridge.

Rawes M. and Heal O.W. (1978) The blanket bog as part of a Pennine Moorland. In O.W. Heal and D.F. Perkins (eds) Production Ecology of British Moors and Montane Grasslands. Ecological Studies 27. Springer-Verlag, Berlin

Richardson A.M.M. (1983) The effect of the burrows of a crayfish on the respiration of the surrounding soil. Soil Biol. Biochem. **15**, (3), 239-242.

Richardson A.M.M. (1985) Investigation into the Metabolism and Nutrient Dynamics of Peat Soils from South-west Tasmania, using Laboratory Microcosms. Unpublished report to the Forest Ecology Research Fund, Hobart.

Richardson A.M.M. and Swain R. (1980) Habitat requirements and distribution of *Engaeus cisternarius* and three subspecies of *Parastacoides tasmanicus (Decapoda: Parastacidae)*, burrowing crayfish from an area of South-western Tasmania. Aust. J. Mar. Freshwater Res. **31**, 475-484.

Schneider S. (1963) Chemical and stratigraphical investigations of high-moor profiles in north west Germany. Proc. 2nd International Peat Congress **1**, 75-90.

Shotyk, W. (1988). Review of the inorganic geochemistry of peats and peatland waters. Earth Science Reviews. **25**, 95-176.

Spain A.V., Probert M.E., Isbell R.F. and John R.D. (1982) Loss-on-ignition and the carbon content of Australian soils. Aust. J. Soil Res. **20**, 147-152.

Stephens C.G. (1962) A Manual of Australian Soils. CSIRO Australia, Melbourne.

Tallis J.H. (1973) Studies on southern Pennine peats v: direct observations on peat erosion and peat hydrology at Featherbed Moss, Derbyshire. J. Ecol. **61**, 743-751.

Tarvydas R.K. (1978) Soils. Lower Gordon River Scientific Survey, H.E.C., Tasmania.

Taylor J.A. (1963) Preliminary report on the peat deposits of Wales. Proc. 2nd International Peat Congress **1**, 37-48.

Taylor J.A. and Smith R.T. (1972) Climatic peat - a misnomer? Proc. 4th Inter. Peat Congress. **4**, 471-84.

Taylor J.A. and Smith R.T. (1980) The role of pedogenic factors in the initiation of peat formation, and in the classification of mires. Proc. 6th Inter. Peat Congress. 109-118.

Thomas I. (1991) The Holocene archaeology and palaeoecology of northeastern Tasmania, Australia. PhD thesis. University of Tasmania, Hobart.

Tolonen K. and Saarenmaa L. (1979) The relationship of bulk density to three different measures of the degree of peat humification. Proc. Inter. Symp. on Classification of Peat and Peatlands: Finland **1979**, 227-238.

van der Geer G., Fitzsimons S.J. and Colhoun E.A. (1991) Holocene vegetation history from King River railway bridge, western Tasmania. Pap. Proc. Roy. Soc. Tasm. **125**, 73-77.

van Dijk H. and Boekel P. (1968) Effects of drying and freezing on certain physical properties of peat. Proc. 2nd International Peat Congress **2**, 1051-1062.

Walker D. (1970) Direction and rate in some British post-glacial hydroseres. In D. Walker and R.G. West (eds.) Studies in the vegetational history of the British Isles. CUP, Cambridge.

Walter, E.D. Jr. (1974) Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparision with other methods. Jour. Sed. Petrology **44**, (1), 242-248.

Wardwell R.E., Charlie W.A. and Doxtader K.A. (1982) Test method for determining the potential for decomposition in organic soils. In P.M. Jarrett (ed.) Testing of Peats and Organic Soils. ASTM Special Technical Publication 820, Philadelphia.

Webster R. (1977) Quantitative and numerical methods in soil classification and survey. Clarendon Press, Oxford.

Whinam J. (1990) A Study of the Ecology of Tasmanian *Sphagnum*Peatlands. PhD. thesis. University of Tasmania, Hobart.

Wong V. (1991) Interactions between burrowing crayfish and the plant community of buttongrass moorlands. Honours thesis. University of Tasmania, Hobart.