THE MACAULAY INSTITUTE FOR SOIL RESEARCH

REPORT NO. 4

THE SOILS OF CAITHNESS

1. Soil formation and distribution
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INTRODUCTION

The District of Caithness covers 1,774 square kilometres and has often been described as the 'Lowlands beyond the Highlands'. It is an apt description as much of the land is low-lying, non-rocky and very gently undulating; to many this landscape is featureless, flat and monotonous, but the wide open vistas, the clarity of the air and the bracing nature of the climate are all attributes which help give Caithness its unique character. Only in the extreme south does the scenery become 'Highland' in character, culminating in Morven (706 metres), the highest point in the District.

Agriculture is of the upland stock-rearing type and Caithness has long held a reputation for high quality Half-bred and North Country Cheviot ewe lambs. Grass is far and away the dominant crop and the area under barley and oats has declined steadily in the last decade. Because of the risks involved with late grain harvests, it is not surprising that conserved grass plays such a vital role in Caithness agriculture. Most grain grown is for home consumption, although some malting barley is exported if the quality is adequate. Some new crops such as oilseed rape have been recently introduced.

Much of the rough grazing is of low quality. Considerable areas have gone under forestry in the past five years and this trend is likely to continue.

1. SOIL FORMATION AND DISTRIBUTION

Soil develop as a result of complex physical, chemical and biological processes which take place in the mineral material at the surface of the earth. The interaction of these soil-forming processes differentiates the material into horizons; it is the nature and arrangement of these horizons which distinguish one soil from another. Although no two soils are identical, soils having profiles with a similar arrangement of horizons are classified as the same type.

Soil formation is governed by the interaction of several environmental factors including geology and parent materials, climate, relief, vegetation and time. In addition, Man has been responsible for altering some of the natural features of the soil. All these factors operate to a greater or lesser extent in Caithness, and are briefly described.

THE SOIL-FORMING FACTORS

Geology and parent materials

The properties of parent material which most affect soil formation are texture and mineralogical composition. The parent materials themselves vary according to the nature of the solid rock from which they are derived.

In Caithness sedimentary rocks are dominant, but igneous and metamorphic rocks, the oldest rocks of the District, occur in the west and south along the border with Sutherland. Progressively younger rocks are found towards the north and east, with the youngest rocks occurring at Dunnet Head, the most northerly point on the mainland.

The main geological groups and the rock types within them are indicated in Table 1.

In addition, there is a small area of diorite around Reay and an even smaller area of an ultrabasic igneous rock, scyelite, appropriately enough found near Loch Scye.

Glacial till is the most common type of parent material and varies according to the nature of the parent rock, but most common is a firm, dark grey material of sandy clay loam texture which extends over much of the arable land, from Forss in the south to Dounreay in the west. This till is derived from rocks of the Caithness Flagstones and is usually about one metre thick although considerably more where it forms infillings of valleys and bays. Shell fragments are common in the thicker till at depth and the material is calcareous (ie. lime-rich). The moderately fine texture and compact nature make the till relatively impermeable and as a result the soils developed on it have poor natural drainage. A shallow stony drift of coarser texture is less common, but widespread.

Tills with coarser textures are related to the coarser-grained rocks such as the granites, conglomerates and sandstones in the west and south. In contrast, a fine-textured till is derived from the mudstones of the Braemore area.

Peat is particularly extensive in the central, western and north-eastern parts of the District, as well as occurring locally elsewhere.

Table 1. Geology

Sedimentary Rocks		
Upper Old Red Sandstone	Dunnet Sandstones	Pink and yellow false-bedded sandstones
Middle Old Red Sandstone	John o'Groats Sandstones	Yellow and red calcareous sandstones
	Caithness Flagstones	Successive bands of limestones, calcareous flags, sandstones and mudstones
Lower Old Red Sandstone	Barren Group*	Arkoses, conglomerates, breccias, sandstones, mudstones
Igneous Rocks		
Helmsdale Granite		Adamellite
Strath Halladale injection complex		Moinian rocks intruded by sheets of granite, migmatites
Metamorphic Rocks		
Moinian		Quartzite, mica-schist, granulite

* Determination of the age of the Barren Group has been the subject of much research; the current view is that it is mainly of Lower Old Red Sandstone age. It is certainly the oldest group of the sedimentary rocks.

Moraines, associated with the later period of glaciation, are locally common and have a distinctive moundy landform. They are found in the Loch Shurrery and Loch Dorrery areas, near Wag in the Langwell Forest and in the valleys of the Thurso and Wick Rivers, and the material has generally a sandy loam or loamy sand texture.

Other types of parent material are not extensive and include:

(i) Stony frost-shattered debris on the hill summits. It extends down the hillsides in the form of scree.

(ii) Windblown shelly sand at Dunnet, Keiss and Sandside, and quartzose sand on the shores of some lochs.

(iii) Alluvium along the Wick and Thurso Rivers and on former loch sites such as at Syster, Lieurary and to the south of Castletown.

(iv) Isolated mounds and terraces of fluvioglacial sands and gravels along the Wick and Thurso Rivers.

There are some areas where drift cover is very patchy and rock crops out. Such areas include the Achavanich, Ben-a-chielt, Ulbster, Reay and Ben Dorrery districts, and the hills in the Langwell Forest.

Climate

The main elements of climate which affect soil formation are rainfall and temperature and the inter-relationship of the two. These provide the water for the leaching and gleying processes and the energy available for weathering and biotic activity.

The climate of Caithness is strongly influenced by three factors, namely a peninsular situation, an open, gently undulating topography and a high latitude. The winters are relatively mild when compared to some other regions at similar latitudes, but the summers are very cool in comparison to more continental regions. Gales are frequent and their effect is enhanced by the open landscape and the general lack of shelter.

The relationship between the various aspects of climate are very striking in Caithness. The relatively low rainfall - less than 900 millimetres per annum over much of the arable ground - is made to look comparatively excessive by the low evaporation rates associated with low summer temperatures and high relative humidities. In addition, there is a high number of days per year when measurable rain falls - about 250. These rather moist conditions help promote the removal of soluble salts from the surface layers of the soil and the accumulation of raw organic matter at the surface. While the climate of Caithness has helped to determine the overall nature of the soils, there is probably insufficient variation within the District to cause local soil differences, except on the summits of the higher hills.

To highlight both the similarities and differences in climatic conditions across the country, it is interesting to compare the mean July temperature at Wick with Cupar in Fife and over much of the West Midlands of England, two areas with rainfall similar to Wick. At Wick it is 12.9^{o}c, compared to 15.0^{o}C at Cupar and around 16.0^{o}C in the West Midlands.

Relief

Relief has a profound effect on climate and it is also inter-related with certain types of parent material. However, the most direct influence which relief has on soil genesis is through its effect on the water relationships of soil. Steep slopes or shedding sites are much more likely to have naturally freely drained soils than gentle slopes or receiving sites.

There is a general and, for the main part, gradual increase in altitude towards the boundary with Sutherland, although this pattern changes abruptly in the far south. The watershed rarely drops below 300 metres between Knockfin Heights and the Ord of Caithness, but is much lower in the north.

The larger part of the District consists of the Caithness Plain, underlain dominantly by rocks of the Middle Old Red Sandstone, with Moinian rocks and granite in the south and west. Much of the Plain is covered by till and subsequently by blanket peat. The land is mainly non-rocky and gently sloping, although in the south, between Thrumster and Houstry, the land is more rolling and dissected and drift cover is patchy. The non-rocky ground is mainly below 180 metres, whilst the slightly and moderately rocky land in the south is somewhat higher, rising to 287 metres on Ben-a-chielt.

The Caithness Plain merges gradually in the south and west with the Moine Plateau, a dissected upland region composed of Moinian rocks, migmatites and granites. The Moine Plateau, although comprising only a small part of Caithness, is an extensive region of the Northern Highlands. Only to the south of Braemore does the scenery become 'Highland' in character, but even here, there is much rolling moorland, albeit at a higher level than on the Caithness Plain. The steep wooded valleys of the Langwell and Berriedale Waters, with their grassy terraces and alluvial flats, provide a delightful contrast to the surrounding moor. However, the most conspicuous features are the tor-capped conglomerate hills of Morven, Smean and Maiden Pap, and the long resistant quartzite ridges of Scaraben, Creag Scalabsdale and Sal-vaich, all of which stand well above the general plateau level. The quartzite hills, in particular, are clothed in scree.

Vegetation

Vegetation is not considered to be an independent variable because it depends, in turn, on other factors such as climate and soil. Nevertheless, the type of vegetation does have an effect on the type of humus form developed; the ericaceous vegetation which is dominant in this area is associated with mor or peaty humus forms. The relationship between natural or semi-natural vegetation and soil type is well-marked in the uncultivated soils.

Time

The time factor relates to the length of time that the soil-forming processes have been operating. The Pleistocene glaciation destroyed the pre-existing soils and consequently the soils in Caithness today date from the end of the Ice Age. The majority of soils in Caithness are thus about the same age. Some younger soils developed on more recent deposits such as alluvium and windblown sand do not possess such well-developed profiles as soils on the older materials.

Man

Man can, through cultivation practices, change soils in several ways. Draining and ditching can change the soil-water regime, the addition of lime and fertilizer can alter the chemistry of soils, and ploughing can intermix the surface horizons, producing new ones. All these processes are in evidence in Caithness.

The cultivated areas of Caithness have mostly been broken in from peaty moorland and evidence for this is retained in the profiles of many soils. There is a gradation from the peaty soils of the moorland to the mineral soils of the arable land which retain little of their former character. In some areas however, the boundary between these two contrasting types is very sharp and coincides with fence lines.

It is the interaction of these environmental factors which is important, and that each is not operating in isolation. The combination of the cool moist climate, the large extent of slowly permeable parent material, and the gently sloping terrain results in soils with poor drainage being dominant. In addition, breakdown of plant remains at the surface is very slow, and organic matter accumulates; the vast extent of peat within the District is testimony to this.

SOIL TYPES

Before describing the range of soils present and their distribution, some important terms used by the Soil Survey of Scotland must be defined.

SOIL ASSOCIATION - a group of soils developed on similar parent materials.

SOIL SERIES - soils with a similar type and arrangement of horizons developed on similar parent material.

SOIL COMPLEX - a mapping unit used when the soil pattern on the landscape is too intricate for the individual soils to be shown separately.

In Caithness, thirteen soil associations have been identified and are listed in Table 2. The extent of the different associations, and the soil series and complexes within them, is very variable and only the more extensive and agriculturally important will be described in any detail in this account.

Table 2. The Soil Associations

	Soil Association	Parent Material
	Arkaig	Drifts derived from granulites and schists of Moinian age
	Berriedale	Drifts derived from sandstones and conglomerates of Lower and Middle Old Red Sandstone age
*	Braemore	Drifts derived from mudstones of Lower Old Red Sandstone age
	Canisbay	Drifts derived from strata of the Middle Old Red Sandstone John o'Groats Sandstones and Caithness Flagstones
*	Corby	Fluvioglacial sands and gravels derived from acid rocks
	Countesswells	Drifts derived from granites and granitic rocks
*	Dunnet	Weathered sandstones of Upper Old Red Sandstone age
	Durnhill	Drifts derived from quartzites of Moinian age
	Fraserburgh	Windblown shelly sand
	Kessock	Drifts derived from conglomerates of Lower and Middle Old Red Sandstone age
*	Shielton	Fluvioglacial sands and gravels derived from strata of the Caithness Flagstones
*	Strichen	Drifts derived from mica-schists of Moinian age
	Thurso	Drifts derived from sandstones, mudstones, calcareous flags and limestones of the Middle Old Red Sandstone Caithness Flagstones

* These associations cover very limited areas (5 square kilometres or less).

The soils of Caithness can conveniently be described under two headings (Figure 1):

1. The soils of the arable land
2. The soils of the hill ground.

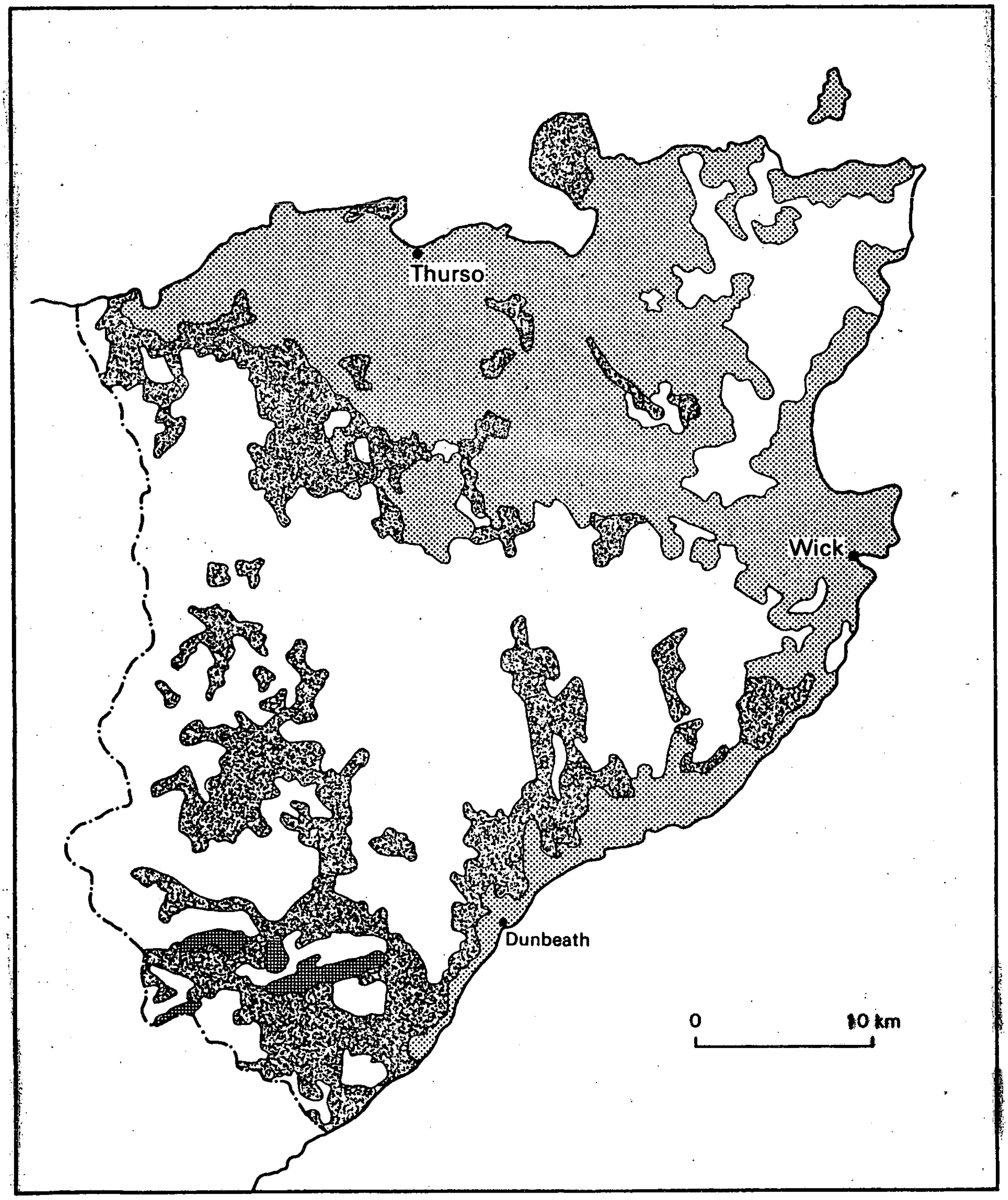
This approach does have the disadvantage of splitting soil associations between each section, but it does serve to group similar soil series from different soil associations in a logical and easily understood way.

Soils of the arable land

The arable land lies mainly below 100 metres and occupies much of the area north of a line from Reay to Wick, together with a narrow coastal strip from Wick as far south as Berriedale. Soils of the Thurso Association are dominant, reflecting the underlying geology, with some Canisbay Association soils in the John o'Groats district and Berriedale Association soils around Reay, Dunbeath and Berriedale.

Within the area covered by soils of the Thurso Association, Thurso Series, a noncalcareous gley, is most common. It is widely distributed and, after peat, is the most extensive soil in Caithness. Profile morphology consists of a dark greyish brown topsoil, usually 25-30 centimetres thick, overlying a compact, very slowly permeable greyish brown subsoil. The subsoil

Figure 1. Soil map



(arable shading)	Noncalcareous gleys; some podzols	Soils of the arable land
(hill shading)	Peaty gleys, peaty podzols; some peat	Soils of the hill land
(hill shading)	Subalpine and alpine soils, lithosols and rankers	Soils of the hill land
(blank)	Peat	Soils of the hill land

typically has grey sandy coatings on the faces of the structure units and yellowish brown and strong brown mottles within the units. The topsoil generally has a sandy silt loam texture, often with moderate or high levels of organic matter, whilst sandy clay loam textures are prevalent in the subsoil.

The ability of the topsoil to retain moisture and the proximity of an impermeable horizon to the surface contribute to the workability and trafficability limitations which are present in Thurso Series. Drainage is naturally poor and gravel infill up to the base of the topsoil is generally required for a drainage scheme to be efficient. Subsoiling across the drains should help the water to reach the drainage pipes more quickly, but care should be taken as to the conditions under which subsoiling is carried out and the depth at which the subsoiling tine is set. In many parts of Caithness, drainage is further hampered by the almost level terrain, restricting fall. Although the ability of poorly drained soils to retain nutrients and fertilizer inputs is greater than in freely drained soils, this tends to be outweighed by the physical limitations of low workability and trafficability.

Sibster Series is much less extensive, but constitutes some of the best land in Caithness. It is found on either side of the Wick River, at Noss and, less commonly, along the Thurso River. The essential difference between it and Thurso Series is the presence of a coarse-textured horizon between the topsoil and the impermeable subsoil. The thickness of this horizon is generally about 25 centimetres, but can be considerably more. The soil is thought to warm up earlier and more quickly in spring than Thurso Series soils and consequently plant growth usually begins a little earlier.

Bilbster Series includes podzols with free and imperfect drainage. It is widely scattered, being most common in the Halkirk, Castletown, Westfield and Latheronwheel districts. The soil profile consists of a dark brown sandy loam or sandy silt loam topsoil overlying a brown very compact stony subsoil. At the interface of these two horizons there are often traces of a thin iron pan indicating that these soils have been derived by cultivation from peaty podzols. Three phases of Bilbster Series based on the depth to bedrock are recognized: shallow phase (depth to bedrock less than 30 centimetres), intermediate phase, and deep phase (depth to bedrock greater than 100 centimetres). Rock outcrops are sometimes present and can preclude regular cultivation in a few areas. Although workability and trafficability on these soils is considerably higher than over much of arable Caithness, root development is often severely curtailed either by rock or the compact stony subsoil. The structure units in the compact subsoil are aligned parallel to the ground surface making root penetration very difficult. In contrast, the structure cracks in Thurso Series soils tend to 'open up' in dry years allowing roots to search for water at depth. Even in the moist Caithness climate grass can show signs of drought stress on Bilbster Series soils in dry years.

Comparative idealized soil profiles of the three arable soils of the Thurso Association are illustrated in Figure 2.

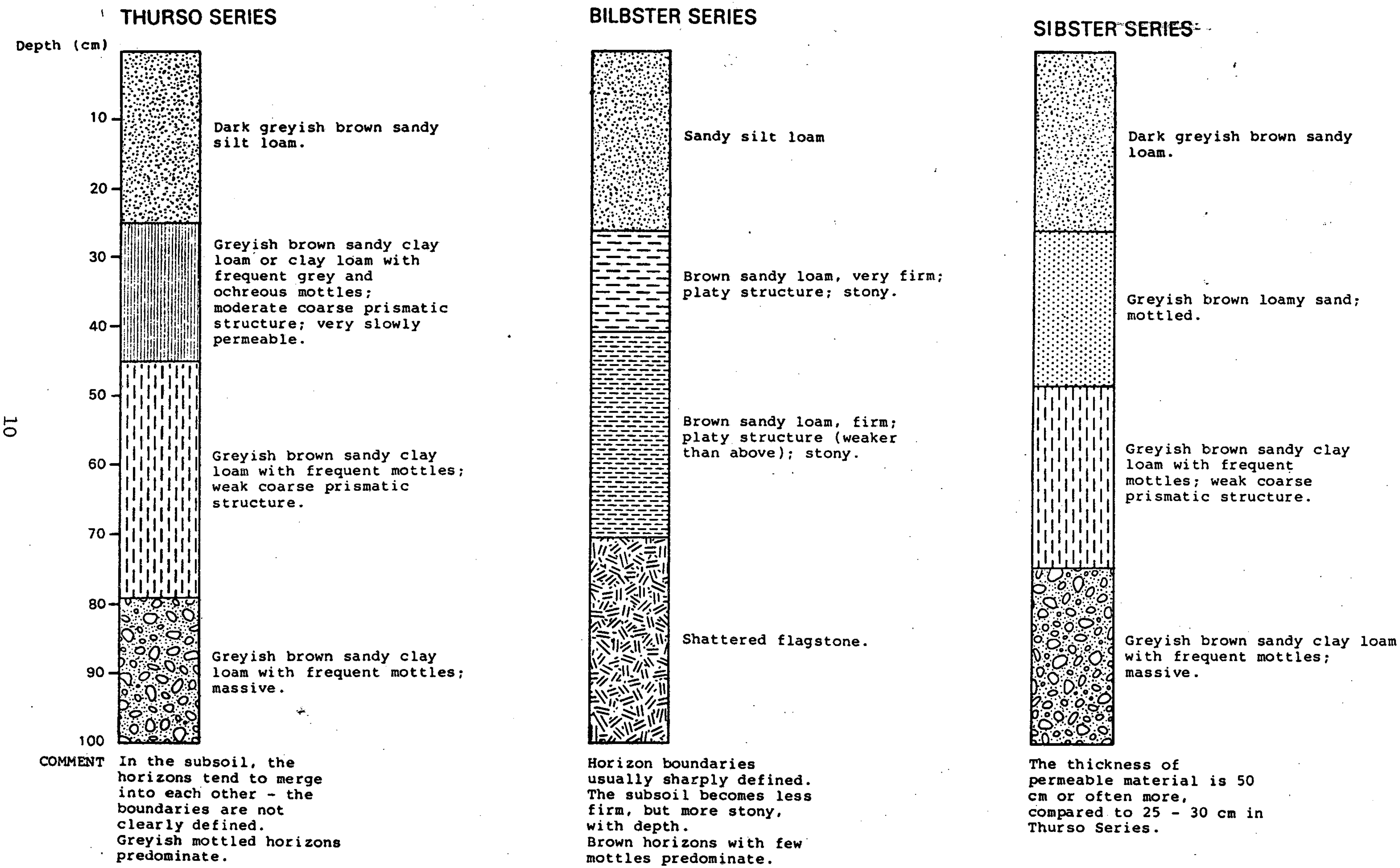


Figure 2. Thurso, Bilbster and Sibster Series profiles

Some small areas within the arable land show considerable soil variation and have been mapped as soil complexes. Within Ulbster Complex, found on a rock-controlled landform, Bilbster Series (shallow and intermediate phases) is the major soil component with poorly drained soils in the intervening hollows. Moundy morainic landforms are characteristic of Sordale Complex; Bilbster Series is again dominant, being found on the mounds, with poorly drained soils, and in some places peat, in the hollows between.

Soils of the Canisbay Association are restricted to the crofting land on the north-east coast, from the Castle of Mey to Nybster. The soils are dominantly poorly drained cultivated peaty gleys of the Canisbay Series. The topsoil is typically very dark, due to the high organic matter content inherited from the former peaty surface horizon. It overlies a greyish brown, mottled, sandy clay loam subsoil which becomes reddish brown at depth. Clay loam textures occur locally. Like Thurso Series, these soils are naturally poorly drained and, if anything, the limitations are even more severe due to the greater water-retentive nature of the topsoil. The topsoil often has high levels of exchangeable calcium as a result of the addition of shell fragments over the years. This has the effect of both countering the natural acidity of the former peaty horizon, as well as helping to lessen the workability limitations of the soil. Like most arable soils in Caithness, high levels of exchangeable sodium are common, reflecting the high salt content of the air.

Soils of the Berriedale Association occur at the western and southern extremities of the arable land. Only two soils are found, with Ramscraigs Series, a freely or imperfectly drained soil, the most common. It is similar in many ways to Bilbster Series, but is distinguished from it by having redder colours in the subsurface horizons. It is most extensive around Sandside Bay, but also occurs in smaller areas between Dunbeath and Ousdale.

Dunbeath Series, a poorly drained noncalcareous gley, is less extensive, but is found beween Dunbeath and Ramscraigs and at Dounreay. The profile shows features typical of surface-water gleys developed on reddish parent materials. Gleying is most evident in the upper part of the profile where grey and brown colours predominate, whereas the reddish colours of the parent material are evident at depth, where gleying is weaker.

It is perhaps worthy of mention that there are numerous small areas of cultivated Thurso Association and Berriedale Association soils, as described above, which are well-detached from the main arable area. These indicate places which once supported a substantial rural population, but have long been uninhabited. These small pockets are most numerous in the valley of the Dunbeath River, around Dalemore on the River Thurso, the Shebster and Broubster districts and in the Achavanich area.

Two soil associations of minor extent are:
(i) The Fraserburgh Association at Dunnet, Keiss and Sandside Bay. The soil types include brown calcareous soils, calcareous regosols and calcareous gleys. These soils have high pH values and high levels of exchangeable calcium.
(ii) The Sheilton Association, which is restricted to very small areas of mounds and terraces of sands and gravels along the Wick and Thurso Rivers.

Alluvial soils show great variation in texture and drainage class, but in general the river alluvium in the arable area gives rise to loamy or sandy soils with imperfect or poor drainage. Lacustrine alluvium ie. occupying former loch sites, mainly comprises sandy soils with poor or occasionally imperfect drainage. Examples are found at Syster and near Castletown. Basin peat occupies similar localities in the landscape and good examples occur to the south of the road between Reay and Westfield.

Soils of the hill land

Although Caithness is often thought of as an agricultural oasis, only about one quarter of the land is cultivated. Much of the remainder has little or no agricultural potential, other than rough grazing, so it is very unlikely that the area under cultivation will increase to any great extent in the foreseeable future.

The hill land is dominated by deep blanket peat, and any account of Caithness describing any particular aspect of the natural environment could hardly fail to mention its extent and presence. Discounting the narrow areas of alluvial soils associated with streams and rivers, it is possible to walk from Duncansby Head to Knockfin Heights and not step on any soil but peat. However, other soils do occur, particularly as a fringe to the cultivated ground, in the Ben Alisky area and between the Berriedale Water and the District boundary.

The cool moist climate, the impermeable subsoils and the very gently sloping topography over much of the District are conducive to very slow decomposition of organic matter at the surface which causes the build-up of organic residues leading to peat formation. Much of the peat is 2-3 metres thick. Dubh lochans are locally common, particularly on Knockfin Heights; many of these have drained naturally, leaving a complex pattern of gullies and holes, with some lochans remaining.

As a resource, peat has been used as a domestic fuel for centuries and in some areas has been partially or completely removed. The largest areas of cut-over peat occur in the John o'Groats and Broubster areas. Efforts in the 1950s to establish a peat-fuelled power station at Braehour proved uneconomical when compared to more conventional fuels.

Peaty podzols and peaty gleys - both soils, by definition, having an organic surface horizon of less than 50 centimetres thick - are locally common. Again, soils of the Thurso Association are most extensive, although soils of the Arkaig, Berriedale and Countesswells Associations are also found. Particularly on rocky or moundy landforms, there is considerable lateral variation in soil type, and soil complexes are common.

Before describing in slightly more detail the distribution of different associations, it may be useful to illustrate the salient points of the two main soil types in the form of idealized profiles (Figure 3). The analogous soils in four main associations are listed below:

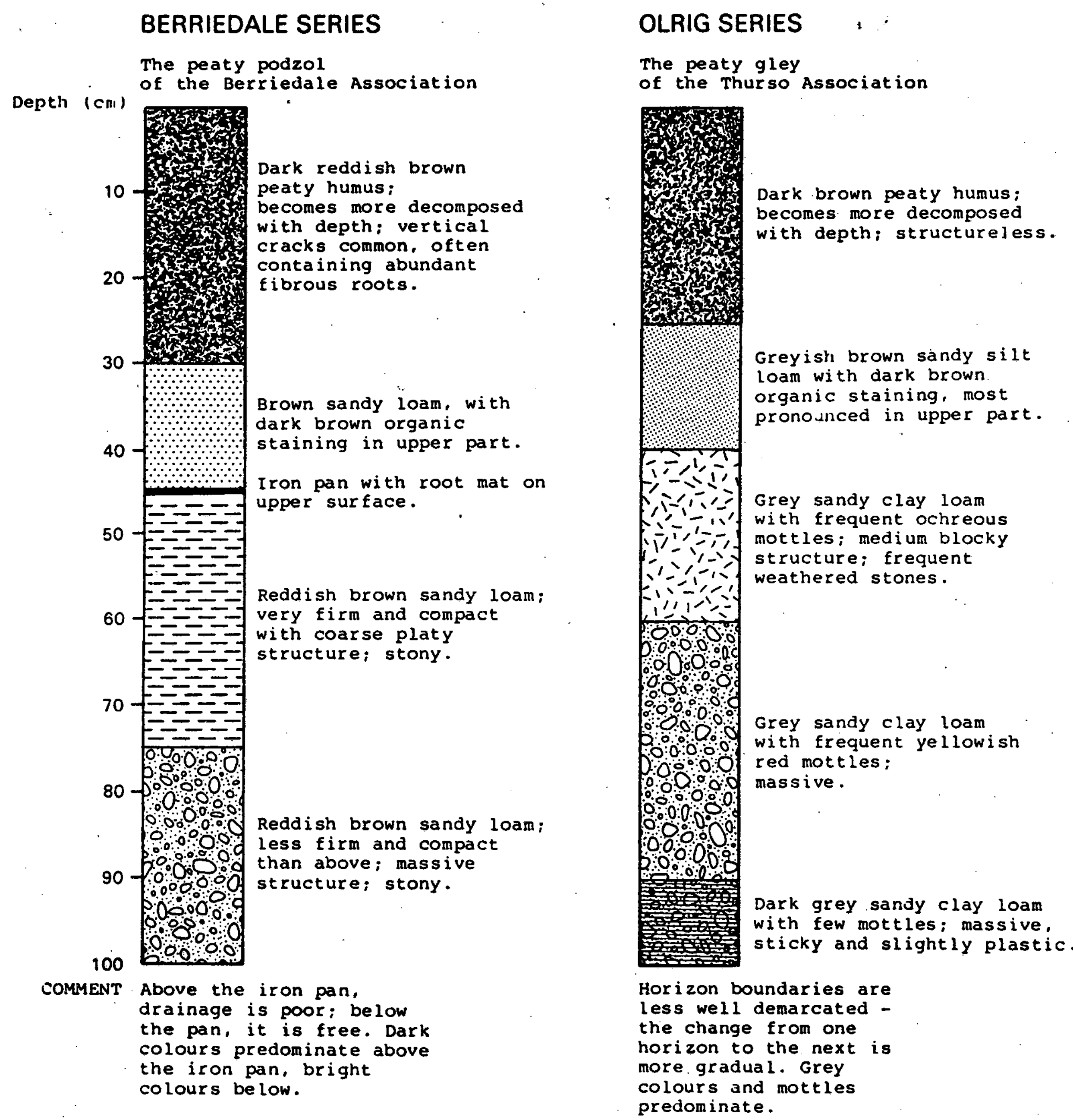


Figure 3. Berriedale and Olrig Series profiles

Soil Association	Peaty Podzol	Peaty Gley
Thurso	Camster Series	Olrig Series
Berriedale	Berriedale Series	Knockally Series
Arkaig	Kildonan Series	Badanloch Series
Countesswells	Charr Series	Drumlasie Series

The peaty soils of the Thurso Association generally occur as a fringe between the cultivated arable soils and the blanket peat or, less commonly, on the higher ground within the arable belt. Most common is Olrig Series and although widely scattered on the marginal land, it is most extensive between Mybster and Loch Calder and at Acharole. In some crofting areas such as Raggra, Sarclet, Slickly and Brabstermire the soils are cultivated and are essentially intergrades between peaty gleys and noncalcareous gleys - similar to Canisbay Series soils.

Although Camster Series, also split into shallow, intermediate and deep phases identical to those of Bilbster Series, is not extensive as a separate soil series, it is a major component of the three soil complexes comprising peaty soils and peat. They include:

1. Achavanich Complex, which occurs on stepped or ridged rocky topography, and is most extensive between Achavanich and Dunbeath, and in the Ulbster district. Drift cover is sporadic and usually thin. Camster Series is found on the steeper slopes and the crests of the ridges where drift cover is at its shallowest. Olrig Series and sometimes peat occur in the hollows and flats between the ridges.

2. Camster Complex has a more definite pattern, particularly in the Camster area itself. The intermediate and shallow phases of Camster Series are present on rock ridges which exhibit a strong north-south alignment and are separated by areas of deep peat. However, in the Loch of Yarrows area, towards the east, Camster Complex merges with the Achavanich Complex as the peat component becomes less extensive and the rock element becomes the main constituent of the landscape.

3. Dorrery Complex occurs on a moundy morainic landform and comprises the deep phase of Camster Series on the mounds with peat in the basins and hollows between. The complex is found on the west side of Loch Calder.

Soils of the Berriedale Association also occur as a fringe between the arable land and the extensive peat in the Reay and Berriedale district, but there are also tracts further inland, generally on the more undulating or sloping topography, where peat development is restricted. Berriedale Series is common between Borgue and Ousdale and on some of the steeper slopes of the valleys of the Dunbeath and Berriedale Waters. It is restricted inland to the Ben Alisky area and is not common in the north.

Knockally Series is similar to Olrig Series, but it has a reddish subsoil. Distribution is scattered, the largest areas being found in the West Shebster and Ramscraigs districts.

Berriedale Series, Knockally Series and peat are the major components of soil complexes which are found between Loch Shurrery and Sandside Bay, and as small scattered areas near Ben Alisky. Most extensive are Shurrery Complex, comprising peaty podzols and peat in a moundy morainic landform, and Bogaig Complex. They have broad similarities, but Bogaig Complex also includes peaty gleys and shallow peaty rankers and occurs on a gently undulating rock-controlled landform. Closely associated with the Berriedale Association are small areas of soils of the Kessock Association. They are found where the drift is derived solely from the conglomerates.

The Arkaig Association is most extensive in the Altnabreac-Loch More area and between the Scaraben range and the Langwell Water. In both areas, Kildonan Series, Strathnaver Complex (comprising peaty podzols and peat developed on moundy moraine) and Pollie Complex (a rock-controlled, although non-rocky, complex of peaty podzols, peaty gleys and peat) dominate the landscape. The soils and landforms of the Countesswells Association are very similar, with Charr Series and Glutt Complex, similar to Pollie Complex, most common. They are most extensive in the vicinity of Glutt Lodge and to the south of the Langwell Water.

As might be expected, all these soils with organic surface horizons, have low pH values, ranging from around 4 at the surface to 5 or slightly above in the parent material. Values for the exchangeable bases are high in the organic horizons, as is the cation exchange capacity, but both drop rapidly in the mineral soil.

The soils on the small cluster of hills in the south belong to the Kessock and Durnhill Associations. The scree slopes of Morven are dominated by peaty and podzolic rankers with occasional shallow peat on the lower slopes. Subalpine podzols (Smeorail Series) are present on the summit plateau. Smeorail Series is also found on Smean and Carn, often in close association with peat. Maiden Pap consists basically of peaty rankers and rock. Vegetation cover is patchy and very stunted on the summits where exposure is severe.

The Durnhill Association occurs on the long resistant quartzite ridges which comprise the Scaraben range and Creag Scalabsdale. Smaller areas are present on Cnoc an Eireannaich, Small Mount and The Child's Seat. There are two main soil complexes:

1. The steep scree slopes with peaty rankers, shallow peat and some podzolic rankers. These slopes are very similar to those on Morven.
2. The extremely bouldery summit ridges where shallow soils such as rankers and lithosols are most extensive. Subalpine and alpine podzols occur where the surface is less bouldery.

There are other less extensive, although geographically distinct, soil associations in the hill land. These include:

(i) The Dunnet Association on Dunnet Head. Peaty podzols (Dunnet Series) are the only soils present.
(ii) The Braemore Association, which occurs only in the Braemore area. Peaty gleys (Braemore Series) and noncalcareous gleys (Cam-leathad Series) are most extensive and are characterized by red fine-textured subsoils. The clay content of these soils is generally the highest of any in the District.

(iii) The Strichen Association, which is found immediately south of the Scaraben range. Gaerlie Series (peaty podzols) is most common and is distinguished from Kildonan Series by its finer texture. Fungarth Series (brown forest soils) and Annigathel Series (noncalcareous gleys) are very restricted.

Alluvial soils are found along the River Thurso and the Langwell and Berriedale Waters; freely drained sandy soils are most common.

FURTHER READING

Futty, D.W. and Dry, F.T. (1977). The Soils of the Country round Wick (Sheets 110, 116 and part 117). Memoirs of the Soil Survey of Great Britain: Scotland. Aberdeen: The Macaulay Institute for Soil Research.

Futty, D.W. and Towers, W. (1982). Northern Scotland: Soil and Land Capability for Agriculture. Aberdeen: The Macaulay Institute for Soil Research.

Soil Survey of Scotland 1:63 360 soil maps:
Latheron and Wick (Sheets 110 and 116 and part of Sheet 117)
Achentoul and Reay (Sheets 109 and 115) - in press.

2. SOIL FERTILITY

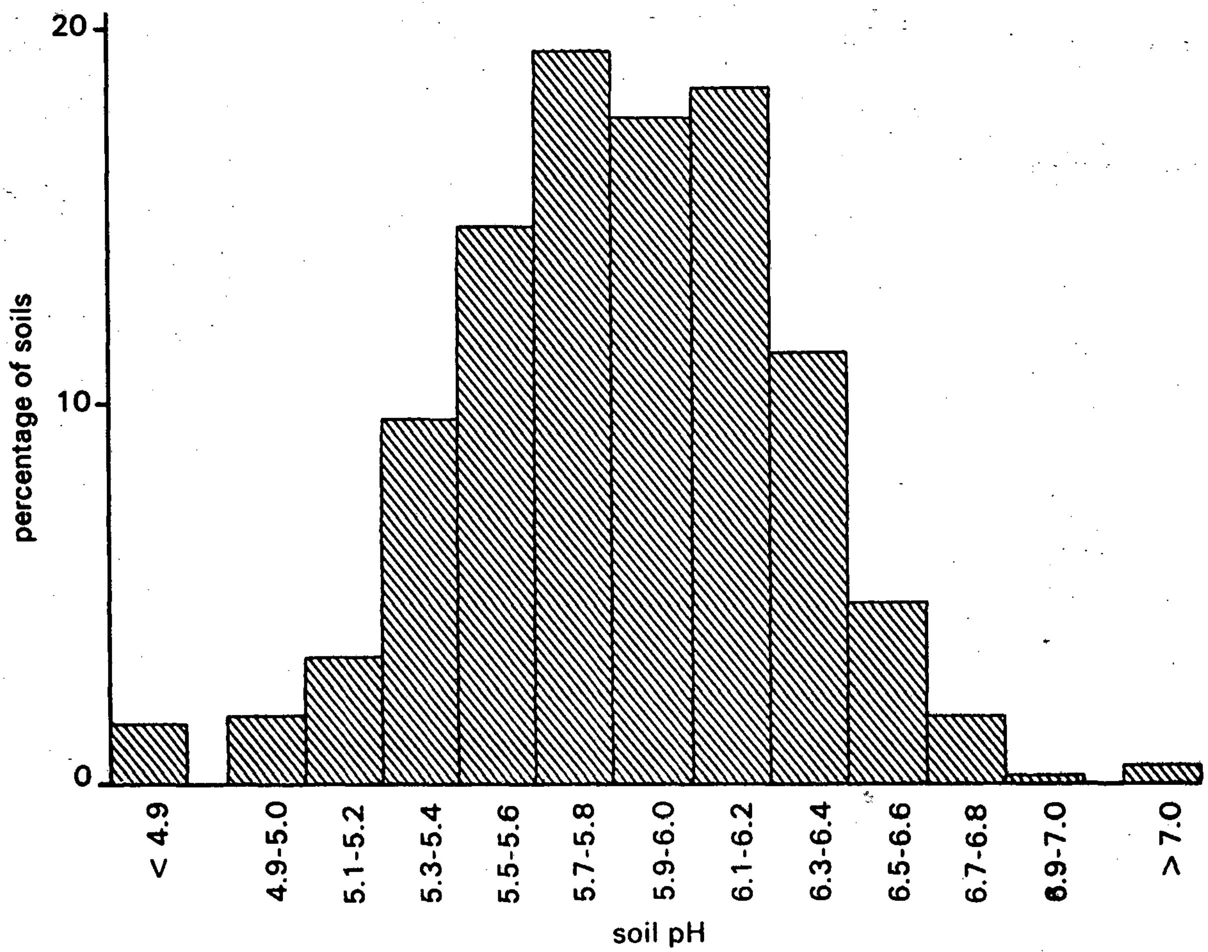
The lime status and macronutrient fertility of the soils of Caithness have been assessed using soil analyses carried out on over 850 fields. These fields were sampled between 1982-84 by staff of the North of Scotland College of Agriculture and analysed at the Macaulay Institute. Analyses were on samples submitted by College staff as a result of requests from individual farmers and not as a result of systematic sampling so there could be some bias in the results towards the more intensively farmed areas. Data on micronutrient levels are based on the analyses of approximately 400 fields.

The assessment of the availability of soil nutrients is based on the methods of extraction and interpretation reported in "Advisory Soil Analysis and Interpretation", The Macaulay Institute for Soil Research/Council of Scottish Agricultural Colleges Bulletin No. 1, 1985.

SOIL ACIDITY AND LIMING

Soil pH is a measure of acidity or alkalinity. The distribution of pH in mineral soils from Caithness is shown in Figure 4.

Figure 4. Distribution of pH in mineral soils



The desirable pH for grassland growing on mineral soils is 5.7 to 6.0. At pH values less than 5.5 the persistence and vigour of clover and ryegrasses are reduced. As the soil pH is increased above 6.0, manganese and cobalt in herbage decrease. A slightly higher pH range 5.9 to 6.2, is recommended for barley. Fifty-one per cent of the soils tested from Caithness were in the pH range 5.7 to 6.2. Eighteen per cent had pH values above 6.2. These were either developed on shelly sands of the Fraserburgh Association or soils which had been given over-generous amounts of lime or shell sand. The remaining 30 per cent of soils had pH values below 5.7 and would require more than maintenance applications of lime to bring their soil pH to a satisfactory level.

The average rate of the loss of lime from soil is likely to be between 0.3 and 0.4 tonne calcium oxide (CaO) per hectare per year, i.e. approximately 4 to 6 hundredweights calcium carbonate ($CaCO_3$) per acre. Highest losses are likely to occur where winter rainfall, nitrogen fertiliser usage, or soil pH is high, or where large infrequent dressings of lime have been applied. Loss from grassland will generally be less than from arable land under comparable rainfall and nitrogen use. However, losses of lime following the ploughing out of grass can be high because here organic matter is breaking down and nitrogen being released.

Much lower pH values can be tolerated without adverse effects on organic topsoils than on mineral soils. Most plant species, including clover, grow successfully on peat, with pH values of 5.0 and above. Soils of intermediate organic matter need only to be limed to pH 5.5. The pH of 80 per cent of soils with more than 60 per cent organic matter is below 5.0. These soils require lime before establishment of sown grass and clover.

MACRONUTRIENTS

Data are available for the macronutrients phosphorus, potassium, sulphur and magnesium, but not for nitrogen as there is no method at present of analysing soils to reliably predict their ability to supply nitrogen. However, soil nitrogen status is discussed.

Nitrogen

Nitrogen is the nutrient which, in the absence of fertilisers, most often limits the yield of crops. The main reserve of nitrogen in the soil is in the form of organic matter accumulated from fresh and old plant and animal remains. Caithness soils are well supplied with organic matter as a result of the mild, damp climate and an agriculture based on grassland. Nearly 80 per cent of the analysed soils contained between 6 and 15 per cent organic matter. When organic matter is broken down by soil bacteria and fungi some nitrogen is released. However, the amounts released are usually too small for the optimum growth of crops, and in the year of establishing grass nitrogen deficiency sometimes occurs. This results from the uptake of available soil nitrogen by bacteria breaking down organic matter; peaty soils are at greatest risk.

The soil nitrogen status depends among other factors on the number of years grass has been in the rotation, on the previous crop grown and the nitrogen fertiliser it received. Soils receiving large annual dressings of farmyard manure or slurry will usually have a high nitrogen status. If, however, slurry is applied in autumn or winter, a considerable proportion of the nitrogen will be washed out of the soil. A high nitrogen status can be expected in soils during the first two years after ploughing out grass more than 4 years old, which received more than 125 kg/ha of nitrogen per year or had a strong clover sward. A high nitrogen status can also be expected after a 2 year old ley grazed intensively and given over 250 kg/ha of nitrogen per year, a strong clover sward or after a grazed forage crop.

Nitrogen can be lost from the soil by leaching in drainage water and by denitrification to the atmosphere as well as by uptake by plants. Leaching and denitrification losses increase under wet conditions. Losses tend to be greater from grazed pastures than from arable soils, under similarly wet conditions.

Phosphorus

A shortage of phosphorus restricts the early growth of both grass and cereals, and delays ripening. The amount of clover in grassland is increased by phosphorus as is the feeding value of grass, hay and fodder crops. Swedes are among the more responsive crops to phosphorus additions. Phosphorus applied to seed potatoes gives quicker, early growth resulting in an increase in the quality and number of seed-sized tubers.

Fifty-four per cent of the analysed mineral soils of Caithness were very low or low in phosphorus (Table 3). In these soils phosphorus at a rate

Table 3. Macronutrient status of mineral soils

Soil nutrient status	No. of samples as per cent of total			
	Phosphorus	Potassium	Sulphur	Magnesium
Very low	7	3	2	0
Low	47	34	26	2
Moderate	39	59	40	53
High	7	4	32	45

according to responsiveness, should be adjusted to give more than a maintenance application to each crop. Placement near to the seed will increase efficiency. In this way the problems of low soil phosphorus can be reduced and available soil phosphorus increases gradually with time. Soil phosphorus is relatively immobile and significant losses of added phosphorus by leaching do not occur from mineral soils but crops only use the phosphorus immediately surrounding the roots. Up to 20 per cent of crop requirement comes from the applied phosphorus fertiliser, the remainder from soil reserves.

Where soil phosphorus is low cereals usually give an economic response to fertiliser phosphorus. This is most efficient when combine-drilled with the seed. If this technique is not used an extra 30 kg P_2O_5/ha should be broadcast, preferably immediately prior to seed drilling. This ensures some fertiliser phosphorus is mixed with the soil and ends in the volume where roots grow. Where phosphorus is applied to ploughed land, cultivations which tend to move the soil and fertiliser into bands should be avoided as cereal growth and ripening may be uneven, resulting in yield loss. The most efficient method of phosphorus application for potatoes is placement in bands, 50 mm to the side and slightly below the level of the tuber. For swedes and turnips fertiliser should be broadcast after cultivation but just before ridging, thus ensuring it is concentrated in the centre of the ridge near the developing roots.

For grass sown in soils low in phosphorus, an application of 150-200 kg P_2O_5/ha worked into the seedbed, is justified as this ensures phosphorus is available for the establishment of a good root system. No phosphorus fertiliser has been found to be consistently superior to water soluble phosphate for grass during establishment. Water-insoluble rock phosphate is suitable for maintaining the phosphorus status of established grassland where the pH value is 6 or below and has not recently been limed. Even where a shortage of phosphorus in the soil does not reduce herbage growth the phosphorus content of the herbage may be decreased with adverse consequences for animal health. To maintain a content of at least 3g P/kg in herbage dry matter and moderate soil phosphorus levels, fertiliser applications of 150 kg P_2O_5/ha over 3 years are required even in grazed systems. A similar amount of phosphate is also required on peat soils where 60 per cent of those tested contained very low or low contents of plant-available phosphorus. The proportion of soils with either very low or low phosphorus status was rather similar for most series (Table 4).

Table 4. Phosphorus status of some soil series

Soil Assoc.	Soil Series	No. of fields as per cent of total Very low	Low	Moderate	High	No. of fields analysed
Thurso	Bilbster	6	62	31	1	137
	Thurso	6	48	39	7	348
	Sibster	12.5	37.5	50	0	8
	Olrig	26	44	28	2	39
Canisbay	Canisbay	0	44	35	21	34
Berriedale	Berriedale	10	0	55	35	20
Fraserburgh	Whitelinks	0	25	50	25	4
Corby	Corby	0	100	0	0	5
Alluvial	-	21	55	24	0	29

However, the naturally poorer draining Thurso Series was better supplied with plant-available phosphorus than the freer draining Bilbster. Most of the soils analysed had received fertilisers or manures at some time which may have reduced natural differences between soil types.

Potassium

Potassium deficiency in grassland soils can adversely affect yield response to nitrogen fertiliser and result in desirable species being replaced by weed grasses. Severe potassium deficiency in arable crops causes marked stunting of growth and in extreme cases premature death. Potatoes readily show shortages of potassium. High levels of soil potassium can result in luxury uptake by herbage and result in imbalances with other elements necessary for animal health.

Moderate soil potassium levels are desirable and nearly 60 per cent of the soils analysed were in this category (Table 3). Thirty-seven per cent of soils were classed as low or very low, perhaps reflecting the large amounts of potassium removed from the soil by conserved grass, potatoes and swedes. For example, 180 kg K_2O/ha may be removed in two cuts of silage, or in 30t/ha of potatoes. On grassland potassium fertilisers are best applied in increments throughout the growing season. The risk of hypomagnesaemia (grass tetany) is reduced by potassium applications made in mid season. Applications can include cattle slurries which are relatively rich in potassium.

Some soil series are better supplied than others with plant-available potassium (Table 5). A high proportion of the Canisbay and Berriedale

Table 5. Potassium status of some soil series

Soil Assoc.	Soil Series	No. of fields as per cent of total Very low	Low	Moderate	High	No. of fields analysed
Thurso	Bilbster	1	33	64	2	137
	Thurso	2	39	53	6	348
	Sibster	12.5	62.5	25	0	8
	Olrig	0	46	49	5	39
Canisbay	Canisbay	0	18	82	0	34
Berriedale	Berriedale	0	20	80	0	20
Fraserburgh	Whitelinks	0	50	25	25	4
Corby	Corby	0	60	40	0	5
Alluvial	-	4	38	48	10	29

Series soils contained moderate potassium levels, whereas a high proportion of Sibster, Olrig and Corby Series soils contained low potassium levels.

Nearly half of the soils with more than 60 per cent organic matter were low in potassium. These low potassium soils require about 100 kg K_2O/ha for establishment of direct sown grass/clover swards. Clover rapidly disappears from reseeded pastures on peat in the absence of potassium. Although significant amounts of potassium and nitrogen are recycled in urine, an annual maintenance application for grazing of about 60 kg K_2O/ha is thought necessary for the continued persistence and production of reseeded ryegrass and clover on peat.

Sulphur

The crops most prone to sulphur deficiency are brassicas such as swedes and oilseed rape and intensively managed grass. As well as reducing the yield of grass, sulphur deficiency can decrease the quality of crude protein in grass and depress the live-weight gains of sheep.

The soil sulphur status of fifty-eight fields were assessed. Twenty-eight per cent of the soils were poorly supplied with sulphur (Table 3). Where soil sulphur is low, fertiliser sulphur at a rate according to responsiveness may be applied as a solid, a flowable "liquid" or a powder in a water suspension. The three forms are in general equally effective when equal amounts of sulphur are applied. Where sulphur application is necessary for winter sown crops, it should be applied in spring because autumn seedbed dressings are likely to be washed out of the plough layer by winter rainfall. Sulphur in the atmosphere ensures there is always a small supply, but the extent of this contribution is variable and may not coincide with the crops' greatest need. When the prevailing winds come from the sea, coastal areas may receive 5 to 10 kg S/ha per annum as sulphate from sea spray.

Sulphur can be applied to grass either in spring at the same time as nitrogen and compound fertilisers, or for the second half of the grass-growing season. Grass sprayed with sulphur should not be grazed until the sulphur has been either washed off the leaves or diluted by new growth. Excessive sulphur can adversely affect metabolism of copper in ruminants, particularly where soil molybdenum is high.

The poorly draining Thurso Series soil was better supplied with sulphur than the freer draining Bilbster Series soil (Table 6).

Table 6. Sulphur status of Thurso and Bilbster Series

Soil Series	No. of fields as per cent of total Very Low	Low	Moderate	High	No. of fields analysed
Thurso	0	12	46	42	24
Bilbster	0	28	48	24	21

Magnesium

Forty-five per cent of the analysed mineral soils of Caithness were classed as high in available soil magnesium (Table 3), probably because magnesium limestone had been applied to these soils. Fifty-three per cent of the soils had moderate levels. Magnesium deficiency in agricultural crops is unlikely although the magnesium content of the herbage from moderate status soils may not be adequate in relation to animal health. Where lime dressings are required and soil magnesium is moderate, magnesian limestone would raise the magnesium content of soil and herbage. A higher proportion of soils of the Canisbay Association were high in magnesium status compared with the Thurso Association (Table 7).

Table 7. Magnesium status of some soil series

Soil Assoc.	Soil Series	No. of fields as per cent of total Very low	Low	Moderate	High	No. of fields analysed
Thurso	Bilbster	0	1	49	50	124
	Thurso	0	1	43	56	300
	Sibster	0	0	75	25	8
	Olrig	0	0	44	56	34
Canisbay	Canisbay	0	0	21	79	33
Fraserburgh	Whitelinks	0	0	100	0	4
Corby	Corby	0	20	60	20	5
Alluvial	-	0	0	23	67	21

All the soils tested with more than 60 per cent organic matter contained moderate or high levels of magnesium.

MICRONUTRIENTS

Data are available for the micronutrients copper, molybdenum, cobalt and manganese. Liming reduces the availability of manganese and cobalt from the soil, has no effect on copper uptake but increases the uptake of molybdenum. Molybdenum limits copper absorption by ruminants, and so may induce the symptoms of copper deficiency. Changes in soil pH, or addition of cobalt and copper to the land since the soils were analysed will have changed their micronutrient status.

Copper

Copper deficiency occurs in cereals grown on soils which are naturally very low in copper. Early growth is normal but near the end of tillering the tips of young leaves turn yellow or white, are often stiff and brittle and may bend at right angles to the stem. Some leaves twist into spirals. Ears may have white tips and do not fill with grain.

The extent to which the copper content of herbage is influenced by the soil differs markedly between plant species. Clovers have a higher concentration of copper than grasses when grown in soils of moderate copper status. Conversely, clover frequently has a lower concentration of copper than grasses when grown in soils of low or very low copper status.

Table 8. Copper status of some soil series

Soil Assoc.	Soil Series	No. of fields as per cent of total Very low	Low	Moderate	High	No. of fields analysed
Thurso	Bilbster	2	12	84	2	117
	Thurso	3	9	86	2	182
	Sibster	0	10	90	0	10
	Olrig	11	22	67	0	18
Canisbay	Canisbay	10	38	52	0	61
Berridale	Ramscraigs	0	70	30	0	10
Fraserburgh	Fraserburgh and Whitelinks	72	14	14	0	7
Peaty*	Peaty*	84	10	3	3	30

* In this table soils containing more than 35 per cent organic matter are classified as peaty irrespective of the depth of the organic horizon.

Most fields of the Thurso Association soils appeared adequately supplied with copper for cereals (Table 8). Copper deficiency in cereals is expected in most fields of the Fraserburgh and Whitelinks shelly sands, peaty soils, and soils of the Berriedale Association in the Reay district.
There is also a risk of copper deficiency in cereals in some fields of the Canisbay Series soils, especially in the John o' Groats district. Copper deficiency in cereals can be eliminated by working into the soil by normal cultivations 5 kg/ha of copper, in the form of a copper salt. This treatment maintains an adequate level of copper for cereals for at least 10 years as copper is not readily leached from the plough layer.

Copper that is applied to the soil produces only a marginal increase in the copper concentration in herbage, especially if the sward contains little or no clover, because copper transport from roots to tops in grass is poor. Soil treatments are, therefore, not effective in controlling copper deficiency in cattle and sheep. However, where soil copper status is very low during improvement of hill pastures, it may be worthwhile to apply copper in order to enhance slightly the copper concentration in the herbage.

Even on soils of moderate copper status, such as the majority of fields of the Thurso Association, summer herbage is unlikely to contain more than 8 mg/kg of copper in the dry matter, and so may not meet the copper requirement of cattle. Copper deficiency in cattle and sheep may be induced by the overgrazing of autumn pasture and a consequent increase in soil iron ingestation, or by the intake of herbage with an above normal concentration of molybdenum.

Molybdenum

Liming acid soils increases the availability of soil molybdenum, which may lead to molybdenum-induced copper deficiency in ruminants. Clover takes up soil molybdenum more readily than grasses, so that applications of nitrogen tend to decrease the molybdenum concentration of mixed swards by decreasing the proportion of clover. Where herbage molybdenum concentration is high there is a large increase from June to October. However, low molybdenum levels are desirable (Table 9).

Table 9. Molybdenum status of some soil series

Soil Assoc.	Soil Series	No. of fields as per cent of total				No. of fields analysed
		Low	Moderate	High	Excessive	
Thurso	Bilbster	72	28	0	0	50
	Thurso	57	33	9	1	125
	Olrig	0	17	33	50	6
Canisbay	Canisbay	84	4	12	0	24
Berriedale	Ramscraigs	100	0	0	0	8
Peaty*	Peaty*	85	5	5	5	20

* In this table soils containing more than 35 per cent organic matter are classified as peaty irrespective of the depth of the organic horizon.

Low soil molybdenum levels were found in most of the Berriedale Association soils and the peaty soils that were analysed. More than one-quarter of the Bilbster soils contained moderate molybdenum levels, where autumn herbage is expected to contain 1.5 to 3.5 mg/kg of molybdenum in the dry matter. This concentration of molybdenum can induce copper deficiency in ruminants. Soils with a high molybdenum status were found in some fields of the poorly draining gleys of the Thurso, Olrig and Canisbay Series, where autumn herbage is expected to contain between 3 and 8 mg/kg of molybdenum. The high molybdenum contents of Canisbay soils were found in the Auckingill district. Three of the six analysed Olrig Series soils contained an excessively high molybdenum level, where molybdenum concentration of autumn herbage is expected to be greater than 5 mg/kg.

Molybdenum should not be applied to soil or pasture as it is readily taken up by herbage, particularly clover, and even small increases in herbage molybdenum can adversely affect copper metabolism in ruminants. The severity of this molybdenum effect increases as the herbage concentration of sulphur increases.

Cobalt

Severe cobalt deficiency in sheep and cattle is well known as "pine", and is expected to occur where soil cobalt status is very low. In order to reduce the risk of cobalt deficiency, soil cobalt status needs to be moderate or high (Table 10).

Table 10. Cobalt status of some soil series

Soil Assoc.	Soil Series	No. of fields as per cent of total Very Low	Low	Moderate	High	No. of fields analysed
Thurso	Bilbster	12	6	25	7	117
	Thurso	11	39	39	11	188
	Sibster	0	50	30	20	10
	Olrig	5	24	24	47	21
Canisbay	Canisbay	13	31	47	9	68
Berriedale	Ramscraigs	0	90	10	0	10
Fraserburgh	Fraserburgh and Whitelinks	100	0	0	0	6
Peaty*	Peaty*	28	38	22	12	32

* In this table soils containing more than 35 per cent organic matter are classified as peaty irrespective of the depth of the organic horizon.

Cobalt deficiency is commonly found on freer draining, stony and coarse-textured soils. This is demonstrated in Caithness where about 70 per cent of the fields analysed from the Bilbster Series soils were found to have a very low or low cobalt status. Conversely, the naturally poorer draining, finer-textured Thurso Series and the peaty gleys of the Olrig and Canisbay Series were found to be better supplied with plant-available cobalt.

Liming soils to pH values above 6.0 reduces the availability of soil cobalt to herbage and the cobalt status of shelly sands of the Fraserburgh and Whitelinks Series are very low.

Cobalt sulphate applications to dormant grassland or ploughed land are usually effective in raising the cobalt concentration in herbage to a satisfactory level. One application of 2 kg/ha of cobalt sulphate should be sufficient for 3 or 4 years on acid mineral soils and for at least 5 years on organic and peaty soils. Animals given access to treated pasture for 50 per cent of grazing time should perform satisfactorily. Thus, one quarter of the grazing has to be treated every second year in order to maintain at least half the pasture adequately supplied with cobalt. The shell sands are likely to require 4 to 6 kg/ha to give the same benefits. Cobalt sulphate should not be applied in the same year as lime.

Manganese

Manganese deficiency in oats (Grey Speck) is common on shelly sands and other soils with pH values greater than 6.3. The symptoms of manganese deficiency can also be seen in barley, particularly in patches of high pH within fields. Manganese deficiency is aggravated in dry, poorly consolidated seedbeds. In apparently deficient fields normal manganese uptake, shown as greener growth, can occur in wheel tracks. In spring-sown cereals the appearance of manganese deficiency can be delayed by sowing into a firm seedbed and combine drilling a NPK fertiliser containing the acidifying ammonium nitrate. As manganese deficiency is due to reduced soil availability at high pH, soil applications are not worthwhile.

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