THE SOILS OF THE BLACK ISLE

THE SOIL SURVEY OF SCOTLAND

The Macaulay Institute for Soil Research, Aberdeen

Plate 1. *Oblique air photograph of Chanonry Ness looking towards the western end of the Black Isle. On the promontory, the arable areas occur on the freely drained, undifferentated soils of the high raised beach whereas the golf course has been developed on the freely drained, undifferentiated soils of the low raised beach.*

Further west along the shoreline, the entrance to Munlochy Bay is guarded by conglomerate hills covered largely by freely drained podzols of the Kessock Association. Excepting the major alluvial hollows inland from Avoch and south-east from Munlochy, and the podzols developed on the conglomerate slopes of Drumderfit Hill, the bulk of the area is occupied by imperfectly drained podzols of the Millbuie Association; freely drained podzols occur where slight rises and crests improve the natural drainage. Aerofilms.

DEPARTMENT OF AGRICULTURE AND FISHERIES FOR SCOTLAND

Memoirs of the Soil Survey of Scotland

The Soils of the Black Isle

(Parts of Sheets 83, 84, 93 and 94)

By J. C. C. Romans
with contributions from J. S. Robertson, A. D. Walker, M. L. Berrow, B. D. Mitchell and P. D. Hulme

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Preface

The soils of the Black Isle were surveyed by J. C. C. Romans with the assistance of D. M. Lang, J. G. Cruickshank and W. R. Strachan, and the vegetation was surveyed by E. L. Birse and J. S. Robertson.

The standard and mineralogical analyses were carried out by the Department of Mineral Soils, and the trace element analyses by the Department of Spectrochemistry.

The memoir was written originally by J. C. C. Romans and revised and edited by A. D. Walker. J. S. Robertson wrote the chapter on vegetation, A. D. Walker the section on standard analytical data, M. L. Berrow of the Department of Spectrochemistry provided the section on trace elements, B. D. Mitchell, Department of Mineral Soils, the sections on mineralogy, and P. D. Hulme, Department of Peat and Forest Soils, the section on peat. The figures were drawn by A. D. Moir.

Copies of the field maps, scale 1:25 000, are kept at the Macaulay Institute for Soil Research, Aberdeen, where they may be inspected by appointment.

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Acknowledgements

Tabular material for the section on climate has been derived from publications of the Meteorological Office, and source material for the section on geology from publications of the British Geological Survey.

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1 Description of the Area

The Black Isle is a narrow peninsula in Easter Ross, about 32 kilometres long, lying between the Cromarty Firth and the Moray Firth (Fig. 1). Its western boundary, which has not been precisely defined, lies in the vicinity of Muir of Ord, but for the purposes of the account is the original A9 road between the county boundary at Tomich farm and Conon Bridge. The area is about 280 square kilometres, with a width of 13 kilometres in the broadest part, narrowing to 6 kilometres near Rosemarkie, and to less than 3 kilometres near Cromarty.

The main centres of population in the Black Isle are Muir of Ord, Conon Bridge, Avoch, Fortrose, Rosemarkie and Cromarty, and the smaller villages of North Kessock, Munlochy, Jemimaville, Culbokie and Tore (Fig. 2). Dingwall and Inverness are the nearest livestock markets serving the district, though seasonal sales are held at Muir of Ord. A small fishing fleet still operates from Avoch, and there is an expanding industrial estate at Muir of Ord. The nearest rail link serving the area is the main line north from Inverness through Muir of Ord and Dingwall to Wick and Thurso. The former branch line from Muir of Ord through Munlochy to Fortrose has been closed and partially dismantled for some years. An early proposal for a railway from Cromarty to Conon Bridge did not reach fruition, though traces of the levelled cutting can still be seen along the north coast near Cromarty. Local road transport requirements are met by the A832 road from Muir of Ord via Munlochy, Avoch, Fortrose and Rosemarkie, to Cromarty, together with the subsidiary B9169 and B9163 system along the north side of the Isle. There is an adequate crosslinking system of minor roads. With the construction of the new road bridge at Kessock, much of the traffic which previously proceeded north via Beauly and Muir of Ord takes advantage of the shorter route across the Black Isle.

PHYSICAL FEATURES

From a viewpoint north of the Cromarty Firth, the Black Isle stands out as a long, low peninsula with a broad central spine rising to between 150 and 240 metres. The smooth summit of Mount Eagle, now capped by the ITA television transmission tower, forms its highest point (Fig 2). At the west end,

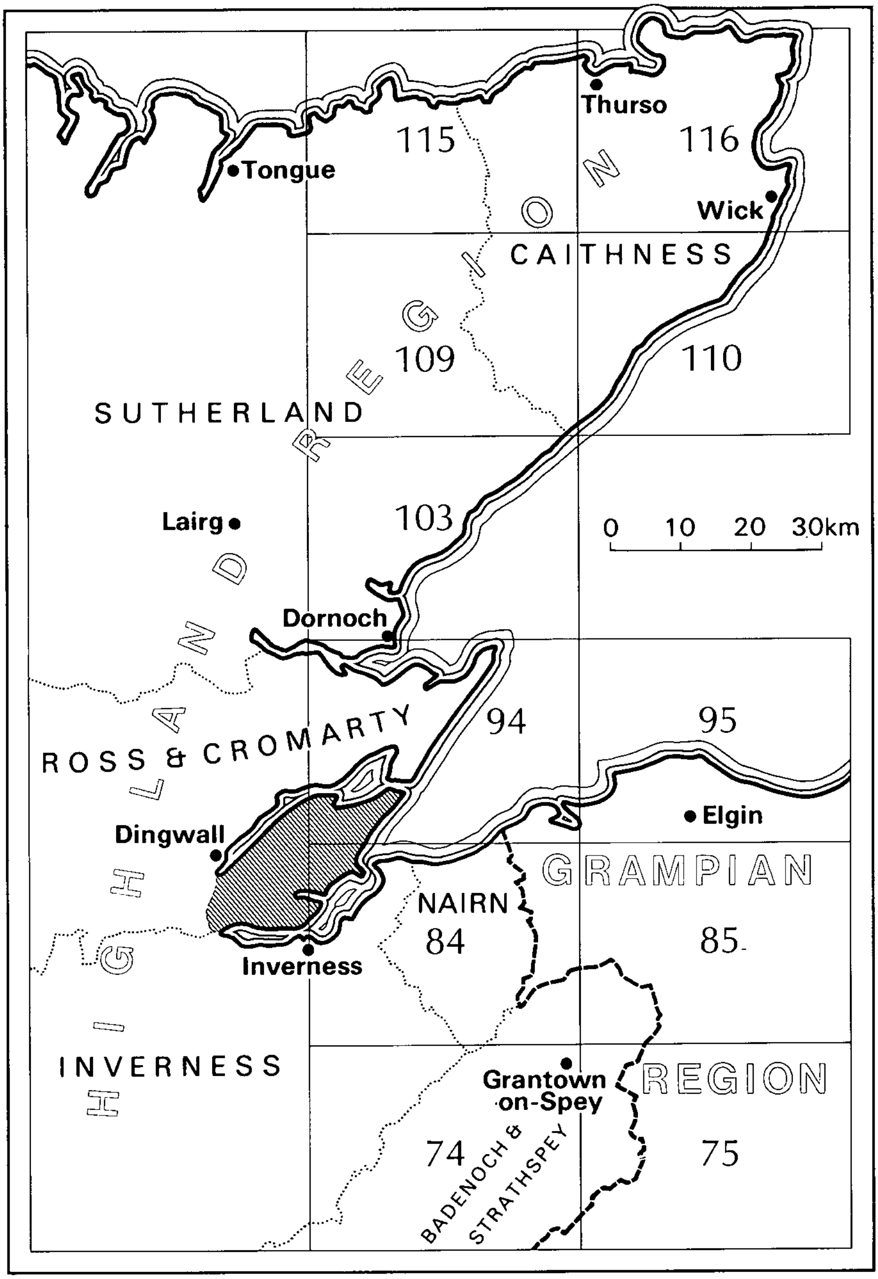

Figure 1. *Location of the area.*

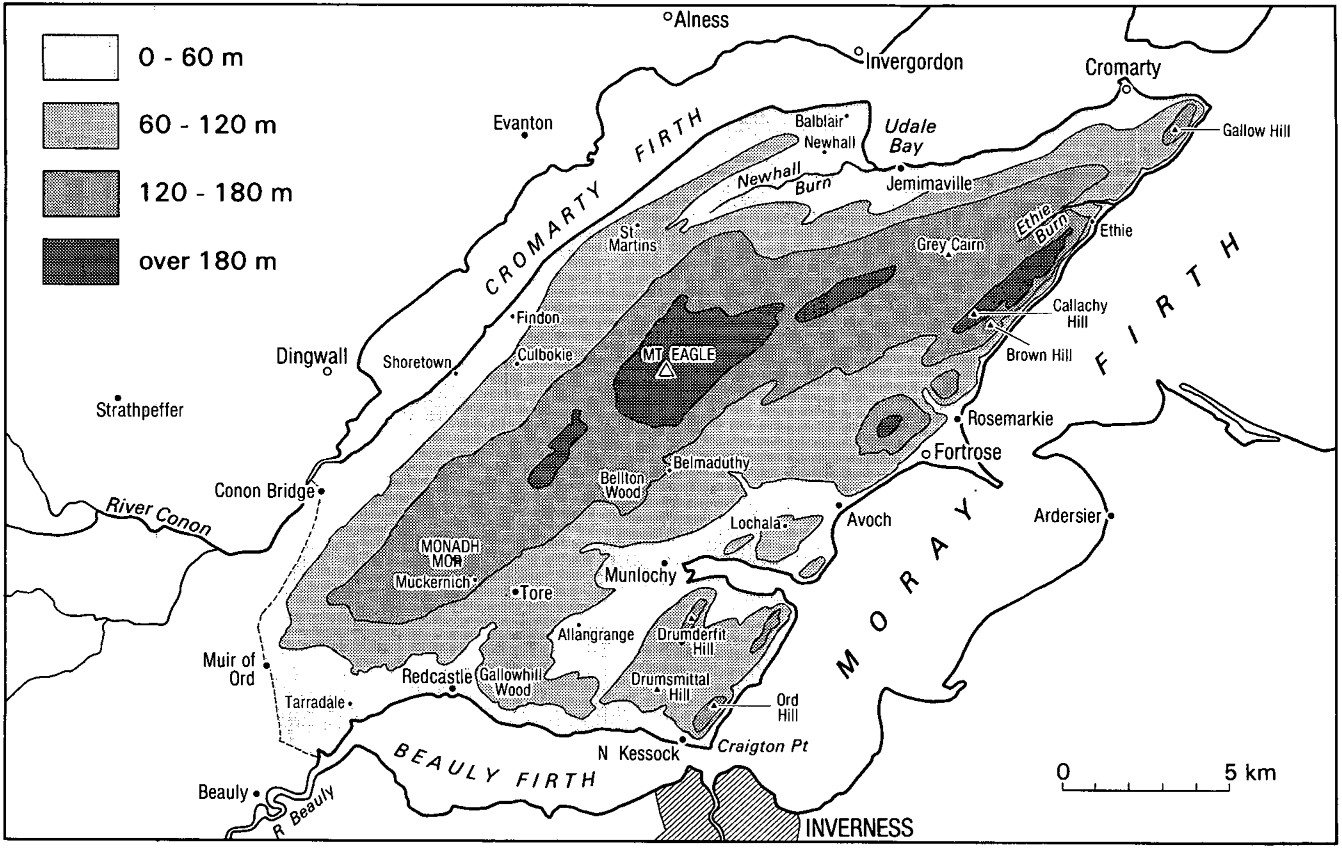

Figure 2. *Physical features.*

the ground falls away from the axial ridge towards the Cromarty Firth in a succession of gently sloping steps, although between St Martins and Balblair a broad valley separates the central ridge from a lower coastal rise, 90–120 metres high. This valley has its source in the Bog of Findon and runs down to the sea at Udale Bay. East of Udale, the central ridge narrows and gradually decreases in height to around 120 metres before petering out near Cromarty. From the north side of the ridge, the gently falling ground forms a vista towards Cromarty Bay of large, cultivated fields. The cliff-edge behind the low raised beach is dissected by many deeply incised gullies which have cut down through thick deposits of red sandstone till into the underlying soft, red sandstone.

The southern aspect of the Isle is entirely different and reflects the proximity of the Great Glen Fault. From Cromarty to Rosemarkie, there are steep cliffs, often 60–90 metres high, cut in Moine gneiss which forms the core of the narrow Ethie ridge upon which the BBC television transmission mast stands. From Rosemarkie westwards, the south side presents a tree-clad, rugged outline of hills and ridges cut through only by the Fairy Glen (at Rosemarkie), the Avoch Burn and Munlochy Bay. Inland, a succession of parallel north-east to south-west conglomerate ridges occupies the part of Knockbain and Avoch parishes south of the A832 road.

CLIMATE

The Black Isle shares the generally favourable climate conditions experienced in the Morayshire coastal lowlands which, before the relatively recent introduction of climatically tolerant cereal varieties, were sharply reflected in the pattern of arable agriculture. Wheat and barley were then cultivated extensively throughout Strathmore but were almost completely absent from Aberdeenshire and central Banffshire, appearing again along the shores of the Moray Firth and throughout the coastal lowlands of Easter Ross. In the second edition of *Great Britain: Essays in Regional Geography* (Ogilvie, 1930), it is remarked in respect of Easter Ross that 'considering the high latitude the climate is favourable and during the summer months Strathpeffer has a higher mean temperature than Aberdeen. Barley continues to be an important crop especially on the south coast of Inverness Firth and in the Black Isle. It is also of interest to note that the small area under wheat in Easter Ross gives one of the largest yields per acre in Scotland.' The winter temperatures at Strathpeffer are comparable with those of Aberdeen, but appear to be unfavourably affected by the valley location. Those for Inverness are appreciably higher (Table A).

The average annual rainfall (Fig. 3) at coastal stations in the Black Isle is about 650 millimetres (Table B), although the figures from a Forestry Commission rain-gauge at Blackstand Nurseries suggest that an average annual rainfall of approximately 800 millimetres may be expected on the central Millbuie ridge. It is unusual for rainfall to be below 35 millimetres in any month, even in a dry year. There are two relatively dry periods in the year, the first from March to June, and the second in September. July and August are frequently the wettest months, though, taking into account the higher evapo-transpiration in summer, the effects of the summer maximum may be less obvious than those of the longer and colder wet season from October to February.

In a comparison of average mean monthly temperatures (Table A), the pattern at Fortrose is very similar to that at Arbroath, a degree of latitude

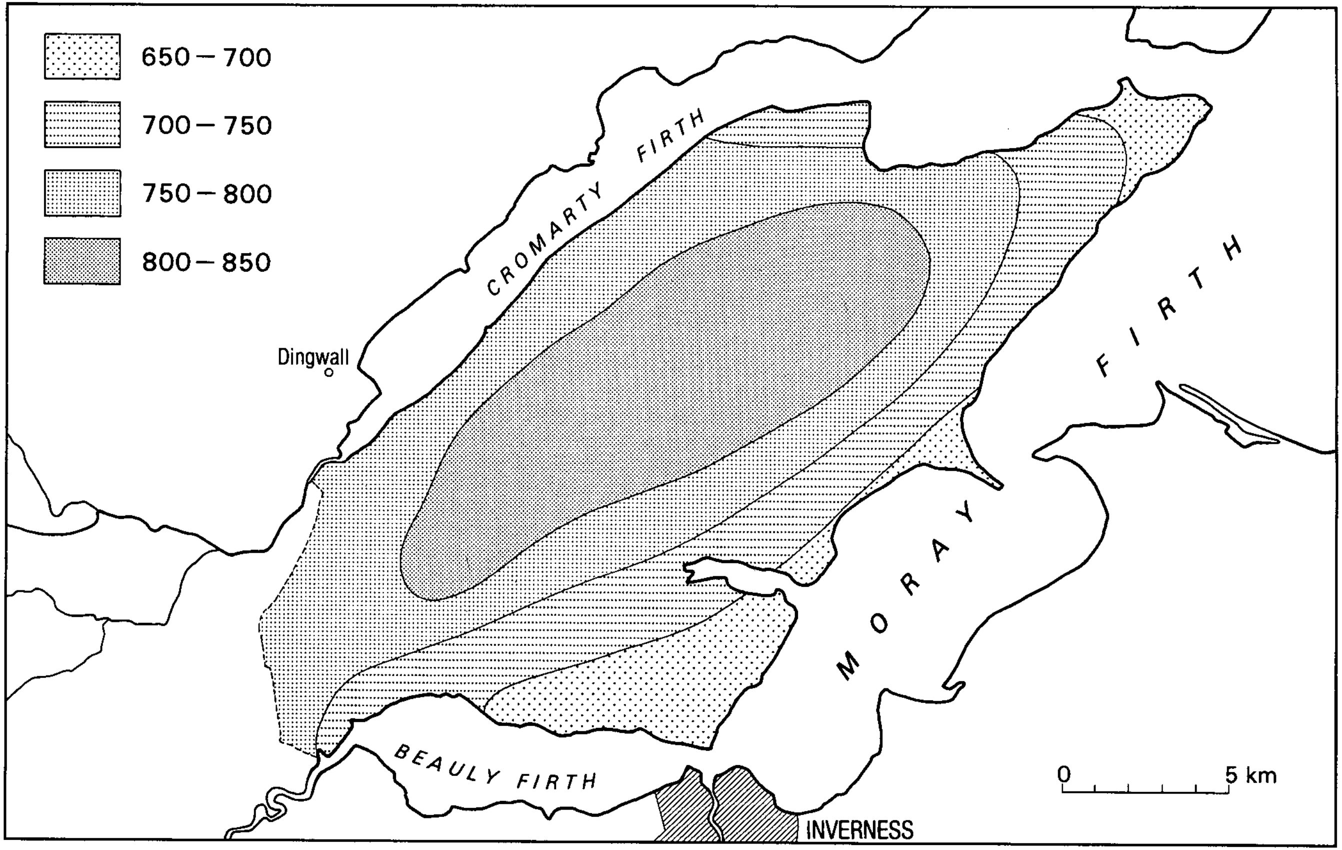

Figure 3. *Rainfall (mm, average annual).*

Table A Averages of temperature (°C)

	Fortrose-Chanonry Point 5 m			Fortrose 21 m			Inverness (Harbour Road) 4 m			Tarbatness 18 m			Strathpeffer 38 m			Inverness (Culduthel) 74 m			Arbroath 28 m			Aberdeen (Craibstone) 91 m		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
January	5.6	1.5	3.5	5.8	1.5	3.7	5.8	−0.2	2.8	4.9	1.5	3.2	5.3	−0.7	2.3	5.5	0.4	2.9	5.8	0.2	3.0	5.4	0.3	2.8
February	6.0	1.6	3.8	6.2	2.0	4.1	6.4	0.1	3.3	5.7	1.3	3.5	5.7	−0.3	2.7	6.0	0.5	3.2	6.6	0.7	3.7	5.8	0.6	3.2
March	7.8	2.9	5.3	7.7	3.1	5.4	9.0	1.9	5.5	7.5	2.6	5.1	8.1	1.1	4.6	8.2	1.9	5.0	8.4	1.9	5.1	7.7	1.4	4.5
April	10.0	4.5	7.3	9.8	4.9	7.4	11.6	3.7	7.7	10.0	4.2	7.1	10.7	2.7	6.7	10.6	3.5	7.0	11.1	3.5	7.3	9.7	2.8	6.2
May	12.3	6.8	9.5	12.2	7.1	9.6	14.1	6.1	10.1	11.8	6.7	9.3	14.1	5.0	9.6	13.4	5.8	9.7	13.4	5.6	9.5	12.4	4.9	8.7
June	15.1	10.1	12.6	15.1	9.8	12.5	16.7	9.4	13.1	14.7	9.5	12.1	17.3	7.8	12.6	16.2	8.6	12.4	16.4	8.3	12.3	15.7	7.4	11.6
July	16.5	11.6	14.1	16.6	12.0	14.3	17.9	11.1	14.5	16.2	11.1	13.7	18.4	10.3	14.4	17.6	10.8	14.2	18.2	10.5	14.3	17.5	9.9	13.7
August	16.4	11.6	14.0	16.7	11.7	14.2	17.7	10.8	14.3	15.6	11.2	13.4	17.7	9.9	13.8	17.4	10.7	14.0	17.8	10.3	14.1	17.1	9.5	13.3
September	15.1	10.3	12.7	15.0	10.5	12.8	16.1	8.9	12.5	14.6	9.7	12.1	15.2	7.5	11.4	15.3	8.7	12.0	15.9	8.5	12.2	15.1	7.8	11.4
October	12.2	7.8	10.0	11.8	7.5	9.7	12.8	6.2	9.5	11.8	7.4	9.6	11.7	4.9	8.3	11.8	5.9	8.9	12.5	6.0	9.3	11.4	5.3	8.3
November	8.5	4.5	6.5	8.7	4.9	6.8	8.6	2.6	5.6	8.0	4.0	6.0	8.0	1.9	4.9	8.5	3.0	5.8	9.1	3.2	6.1	7.8	2.6	5.2
December	6.0	2.9	4.7	7.1	3.3	5.2	6.8	1.3	4.1	5.9	2.5	4.2	6.4	0.5	3.4	6.6	1.7	4.2	6.9	1.7	4.3	6.0	1.3	3.7
Year	11.0	6.3	8.7	11.0	6.5	8.8	12.0	5.2	8.6	10.6	6.0	8.3	11.5	4.2	7.9	11.4	5.1	8.3	11.8	5.0	8.4	10.9	4.5	7.7
Period	1955–70			1931–60			1958–70			1949–70 (with gaps)			1901–80			1931–60			1931–60			1921–50		

Table B Averages of rainfall (mm)

Station	Altitude	Period	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Fortrose (Chanonry Point)	5 m	1955–70	50	42	37	40	52	51	62	79	55	63	57	61	649
Cromarty	6 m	1941–70	50	42	37	41	54	56	67	86	59	65	61	61	679
Allangrange	21 m	1941–70	60	53	44	49	56	55	69	84	64	74	67	75	750
Muir of Ord	46 m	1941–70	70	63	50	53	52	47	57	68	65	78	70	91	764
Blackstand	158 m	1941–70	61	51	45	49	64	64	78	100	69	78	71	75	805
Inverness (Harbour Road)	4 m	1958–70	49	42	37	41	51	53	65	85	57	63	59	61	663
Tarbatness	18 m	1916–50	47	34	29	36	45	41	60	57	52	61	50	45	557
Inverness (Culduthel)	74 m	1941–70	55	47	41	45	56	58	71	93	63	70	65	69	733
Arbroath	28 m	1911–60	58	47	41	39	54	43	69	62	63	73	64	56	669
Aberdeen (Craibstone)	91 m	1941–70	80	57	51	48	70	58	83	86	68	82	88	76	847

*Table C Average number of days with snow lying**

Station	Altitude	Period	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Fortrose (Chanonry Point)	5 m	1961–78	1.9	3.1	0.9	0.2	0	0	0	0	0	0	0.9	1.4	8.4
Inverness (Harbour Road)	4 m	1957–66	8	6	1	1	1	0	0	0	0	1	1	3	22
Tarbatness	18 m	1957–66	4	3	1	1	0	0	0	0	0	0	1	2	12
Arbroath	28 m	1911–60	3.0	3.3	1.8	0.1	0	0	0	0	0	0	0.4	1.6	10.2
Aberdeen (Craibstone)	91 m	1961–78	8.0	8.3	3.9	1.3	0.1	0	0	0	0	0.1	3.3	5.9	26.9

* A day with snow lying is counted when half or more of the ground surrounding the station is covered with snow at 09.00 hours G.M.T.

*Table D Average number of days of air frost**

Station	Altitude	Period	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Fortrose (Chanonry Point)	5 m	1961–78	6.3	8.4	2.9	1.9	0.2	0	0	0	0	0.1	2.1	5.1	28.0
Inverness (Harbour Road)	4 m	1956–66	15	13	7	4	1	0	0	0	<1	1	8	12	61
Tarbatness	18 m	1956–66	10	9	4	1	<1	0	0	0	0	<1	4	7	35
Arbroath	28 m	1911–60	13.9	11.8	4.2	1.8	0.1	0	0	0	0	0.1	4.4	10.3	46.6
Aberdeen (Craibstone)	91 m	1961–78	11.9	11.8	8.2	5.3	0.3	0	0	0	0.1	0.4	7.4	10.4	55.8

* Minimum air temperature 0°C or less.

	Average date of first and last air frost:	Extreme date of first and last air frost:
1	24 Nov. – 30 Mar.	26 Oct. – 27 May
2	27 Oct. – 24 Apr.	29 Sept. – 27 May
3	13 Nov. – 3 Apr.	5 Oct. – 6 May

further south, and both places are appreciably warmer than Aberdeen. In 1952, which had a colder than average early spring and winter, 99 days with ground frost were recorded at Arbroath and 97 at Inverness, with 124 at Aberdeen (Craibstone). The average number of frost days is, of course, considerably less, and figures for the nine-year period 1956–64 (Table D) strengthen the climatic analogy between Fortrose and Arbroath.

Under the system of climatic assessment developed for Scotland by Birse and Dry (1970), Birse and Robertson (1970), and Birse (1971), the central ridge of the Black Isle (excluding the summit of Mount Eagle) is described as fairly warm rather dry lowland, moderately exposed with moderate winters, whereas the greater part of the lower-lying coastal periphery is described as warm dry lowland, moderately exposed with fairly mild winters.

GEOLOGY

The Black Isle peninsula consists of a synclinal arrangement of sandstones and conglomerates of Middle Old Red Sandstone age, with two small blocks of Moine gneiss faulted-in on the southern coast between Cromarty and Rosemarkie (Fig. 4).

The stratigraphy of the sandstones and conglomerates has been described by Armstrong (1977) who assigned them to the Strath Rory Group; he also noted the occurrence of minor outcrops of Jurassic rocks on the foreshore at Ethie. The situation and limited extent of these latter rocks are such that they cannot be accommodated on the 1:63 360 soil map. Chesher (1977) reviews in detail the relationship of the Mesozoic strata with the Old Red Sandstones of the Orcadian basin. In the Rosemarkie inlier of Moine rocks, Harris (1977) has identified hornblendic Lewisian gneisses which alternate with the Moine psammites. Because of the complex and restricted distribution of such Lewisian rocks they have not been identified as forming a separate soil parent material within the 1:63 360 soil map.

The axis of the syncline runs from Tarradale along the Millbuie ridge, and through Mount Eagle towards Newhall. The uppermost strata in the sequence consist of about 760 metres of red, grey and yellow sandstones, grouped into the Millbuie Sandstone Series and outcropping in the northern and central parts of the Black Isle. They are underlain by a series of conglomerates with red sandstones and shales up to 2100 metres thick. These beds, which form the south-east part of the peninsula, outcrop with progressively steepening dip between Allangrange and Ord Hill. Dip angles up to 68 degrees have been recorded near Craigton Point; these, together with the straight line, coastal feature, reflect the presence of the Great Glen Fault.

Though sandstones and conglomerates are the most widespread rocks, subordinate calcareous shales, and 'fish beds' containing limestone nodules, are recorded. In addition, some of the sandstone beds are slightly calcareous and have contributed appreciable amounts of calcium carbonate to the derived glacial tills which overlie them. The pattern of calcareous sandstone, tufa and calcareous well water, calcareous till, and superficial deposits of marl and calcareous alluvium suggests that calcareous strata are more widespread in the Millbuie Sandstone Series, excepting the uppermost beds forming Mount Eagle, than in the underlying thicker conglomerate and sandstone series.

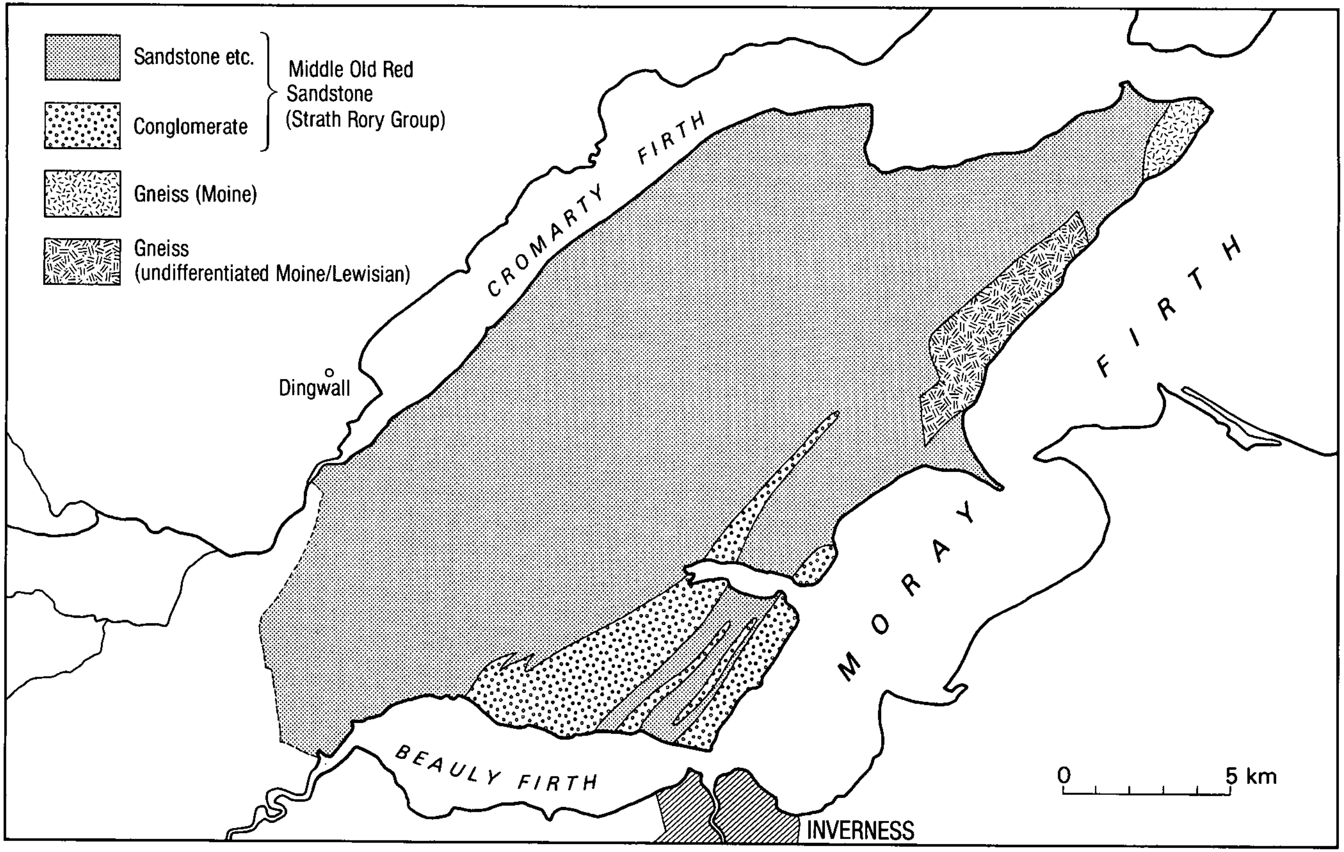

Figure 4. *Geology*.

GLACIAL DEPOSITS

The greater part of the Black Isle is covered by a mantle of glacial deposits which has been modified subsequently by the melting of stagnant ice and by solifluction.

Excluding Mount Eagle and the coastal ridges running parallel to the Great Glen Fault, most of the Isle is covered by a stiff, reddish brown till which may be overlain by a variable thickness of stony, coarse-textured, morainic material. At the western end of the peninsula, there may be 1.25 metres or more of the morainic material; between Culbokie and Bellton Wood the overlay is, on average, 60–80 centimetres thick, whereas to the east of Grey Cairn Wood towards Cromarty it is negligible. The detailed distribution of the morainic material is, of course, not as regular as the general outline suggests. Thin patches, overlying sandstone rock, are found at the western end where the ground rises steeply away from the gravel flats around Muir of Ord, and 'windows' in the moraine, through which the sheet till may be observed in inspection holes, are not infrequent in the central area. Over Mount Eagle and the coastal ridges, there is generally a thin cover of semi-residual drift or till which closely reflects the local lithology.

The compact, sheet till and the morainic material are both derived from Middle Old Red Sandstone strata, with little additional material other than erratic stones. The gradual thinning-out west to east of the morainic cover, the absence of any terminal moraine in the Grey Cairn Wood area, the presence of an extensive area of small kettleholes on the Millbuie ridge beside the peat moss of Monadh Mor, and the close similarity in mineralogical composition with the underlying till collectively suggest that the morainic cover is material melted out from the cleaner, upper ice during the decay of a stagnant ice-sheet. An examination of the distribution of polygonal frost-cracks supports this hypotheses. These frost-cracks have been noted in profiles and natural exposures throughout the Black Isle and extend generally to a depth of about 1.5 metres. When profile pits are opened, such rusty-edged, grey cracks can always be seen clearly in the reddish brown sheet till, but usually appear to be truncated by any overlying morainic material. However, in a few profiles (at Muckernich, Bellton Wood and Sunnybrae) they penetrate both till and overlay material. In those profiles where penetration of the overlay by the cracks is not evident, the maximum depth of crack penetration is still about 1.5 metres below the surface of the ground. The disappearance of the frost-crack pattern from the moraine veneer can be reasonably ascribed to the effects of later periods of cryoturbation and solifluction acting upon this coarse-textured material.

The distribution of erratics of granite and Inchbae gneiss, together with the overstep of the reddish brown sandstone till onto the Moine gneiss outcrops on the Cromarty peninsula and Nigg Hill (north of the Cromarty Firth), suggest that the sheet till and its morainic overlay were the melt products of a main ice-sheet moving across the Black Isle from slightly south of west to slightly north of east.

Till and the thin, semi-residual drifts on Mount Eagle and the coastal ridges account for about 86 per cent of the soil parent materials in this district. Fluvioglacial sands and gravels occupy less than 2 per cent of the area and are concentrated mainly at the western end of the Black Isle between Muir of Ord and the Beauly Firth, with some intermittent patches of gravelly moraine fringing the coast of the Firth as far east as Kessock. In addition, there are a few patches along the sides of the valley between Allangrange and

Munlochy, several small gravel mounds between Belmaduthy and Rives farms 2.4 kilometres north of Munlochy, and a few small mounds in the valley of the Newhall Burn on the north side of the Black Isle. High and low raised beaches corresponding to the nominal '100-foot' (30-metre) and '25-foot' (8-metre) platforms account for about 3 per cent of the area. High raised beach deposits are both more extensive and discontinuous. One of the larger patches occurs between Fortrose and Rosemarkie and appears to be the planed-down stump of a terminal or halt moraine upon which a spit and raised beaches have developed subsequently. Other high raised beaches are at Cromarty, Ferryton Point, and Findon along the north coast. A very narrow, not quite continuous, strip of low raised beach fringes the greater part of the Black Isle with the continuity most interrupted below the south-east cliffs between Cromarty and Rosemarkie.

2 Soils

Of the 23 soil series and one soil complex included in Table E, only the Millbuie and the Allangrange Series are more than 50 square kilometres in area. Of the remainder, only the Cromarty Series exceeds 20 square kilometres; 11 series cover between 1 and 11 square kilometres, and 9 occupy less than 1 square kilometre.

Analyses relating to 36 of the soil profiles described in the text are given in the appendix. For soil series and other units occupying less than 0.3 of a square kilometre analyses have not been included generally, but exceptions have been made in the cases of the Learnie and the Redcastle Series. Heights above Ordnance Datum of the profiles described are approximate only, having been taken from the 1:25 000 Ordnance Survey maps, by interpolation between contour lines where necessary.

Most of the freely and imperfectly drained soils are podzols. A long history of turf-cutting makes it difficult to substantiate whether, or not, some of the podzols that have a thin iron pan were once peaty podzols. As the thin iron pan occurs most frequently on the upper surface of a tough indurated layer, its practical importance should not be exaggerated.

The most important overall characteristic of the freely drained, semi-natural soils is the development, in response to the climatic conditions of low rainfall and high evapo-transpiration, of a podzolic profile; this is somewhat telescoped with relatively shallow A and B horizons because of an underlying indurated layer.

All the cultivated soils of the district are characterized by a tendency to have trace element deficiencies, particularly of cobalt, nickel and copper.

MILLBUIE ASSOCIATION

This is the most extensive soil association of the Black Isle. It occupies just under 186 square kilometres or about 66 per cent of the total area, extending eastwards from the Muir of Ord gravel flats to Udale Bay on the north side, and to Rosemarkie on the south side. The altitudinal range extends from the landward edges of the raised beaches to about 120 metres around the Kessock ridges, and 180 metres on the south-west and north-east sides of Mount Eagle. The greater part of the cultivated land lies below 150 metres, with the higher-lying moorland of the Millbuie Moor now, for the most part, under planted woodland.

Table E   Areas of soil map units (sq km)

Association	Podzols: Freely Drained		Podzols: Imperfectly Drained		Noncalcareous Gleys: Poorly Drained		Peaty Gleys: Very Poorly Drained		Complex		Totals	% area
	Series											
Millbuie	Allangrange	62.2	Millbuie	111.4	Roskill	6.0			Kinkell	6.2	185.8	66.0
Cromarty	Brucefield	1.0	Cromarty	23.8	Navity	0.5					25.3	9.0
Mount Eagle	Mount Eagle	10.9	Findon	8.6	Culbo	0.3					19.8	7.0
Ethie	Ethie	4.4	Gallow	1.3	Learnie	0.3					6.0	2.1
Kessock	Kessock	4.9	Redcastle	0.3							5.2	1.8
Corby	Corby	3.6	Leys	*	Mulloch	*					3.6	1.3
Boyndie	Boyndie	1.0	Anniston	0.3	Dallachy	*					1.3	0.5
Solifluction Deposits			Udale	7.3	Resolis	1.0	Clart	*			8.3	2.9
Totals		88.0		153.0		8.1		*		6.2	255.3	90.6
									Alluvium		9.8	3.5
									Mixed Bottom Land		6.7	2.4
									High Raised Beach		4.4	1.6
									Low Raised Beach		3.9	1.4
									Basin Peat		0.8	0.3
									Skeletal soils		0.5	0.2
											281.4	100.0

* less than 0.3 km^2

The parent material upon which the soils have developed is a stony, coarse-textured till derived from arenaceous Middle Old Red Sandstone strata. At the western end of the Isle, immediately north-east of Muir of Ord, there is some admixture of schist material, giving rise locally to soil profiles resembling those of the Ardvanie Association which has been mapped on the north side of the Cromarty Firth. Over the greater part of the Black Isle, non locally derived components of the parent material of the Millbuie Association are limited. The clay content of the morainic subsoil varies from 2 to 12 per cent and may be irregularly distributed through the solum, though not infrequently there is a low clay content near the base of the deposit. The relatively high clay contents (12–14 per cent) found occasionally in the cultivated, surface horizons of soils in this association suggests that the practice of spreading a compost of dung with estuarine silt, or till material dug from below the moraines, may have been common. The bulk of the morainic material appears to be locally derived, because the parent material is predominantly brown (Munsell Color 10YR5/3) over the outcrop area of the Millbuie Sandstone Series, with local yellowish brown (10YR5/4) or light yellowish brown (10YR6/4) variants, whereas over the red sandstones and conglomerates of the Redcastle–Avoch–Kessock triangle the soil parent material colour ranges from brown (7.5YR5/4) to reddish brown (5YR5/4).

It will be appreciated that the boundary drawn between the Millbuie and the Cromarty Associations is not very precise because of the gradual thinning-out, west to east, of the coarse morainic overlay upon the more compact, reddish brown till which forms the parent material of the Cromarty Association; the latter dominates the east end of the peninsula. As both soil parent materials are derived from the same strata and their essential differences are in clay content and physical consistency, there would be little justification on agricultural or mineralogical grounds for separating an intermediate parent material group—although it would be feasible to map one. The greater part of the soils in any such intermediate unit would lie east of a line from Ferryton Point to the junction of the B9160 and A832 roads, together with some of the smaller patches of the Cromarty Association which have been delineated in the eastern and central parts.

Three soil series and one soil complex have been distinguished. Freely drained podzols have been grouped within the Allangrange Series, imperfectly drained podzols within the Millbuie Series, and noncalcareous gleys within the Roskill Series. The Kinkell Complex, a patch of knob-and-kettle dead-ice terrain to the north-west of the Monadh Mor, includes soils of all three series together with wet, sandy alluvial soils and peat. The Allangrange and the Millbuie Series account for 93.5 per cent of the Association, with the remaining 6.5 per cent divided almost evenly between the Roskill Series and the Kinkell Complex.

ALLANGRANGE SERIES

The freely drained Allangrange Series covers about 62 square kilometres, about 34 per cent of the association area. It is the second most extensive series in the district, occupying just over 22 per cent of the Black Isle. Distribution is related both to topographic position and parent material variations, though principally to the former. It occurs widely on the rising ground at the west end of the peninsula between Muir of Ord and the Monadh Mor, with a north-eastern extension along the coastal slopes to Culbokie and Findon Mains and a similar, but more discontinuous, belt along the south-east slopes of the Millbuie Moor from Milton by Redcastle, through Tore, to Belmaduthy.

Additional areas are found along the coastal slopes between Avoch and Rosmarkie, and on the lower, north-eastern prolongation of Millbuie Moor between Mount Eagle and Grey Cairn Wood.

These freely drained soils are best developed on the thicker moraine which overlies the west end of the peninsula. As a minor constituent, there is also a narrow band of shallow soils, which is underlain by sandstone rock and which runs right around the western end of the Isle fairly close to the 91-metre contour on the west side of the B9162 road. Free drainage conditions are emphasized by a seasonal water shortage which was frequently acute before the installation of a regional piped water-supply, drawn from Loch Glass. This locality retains the highest concentration of small crofting units in the Black Isle. As the Allangrange Series is followed north-eastwards along the lower slopes of the Millbuie ridge, free drainage is related more and more to slope conditions, and less to the coarse texture of the solum. Shallow soils over sandstone occur sporadically and have been included within the series where they are not sufficiently extensive to warrent separation as a series of the Mount Eagle Association. Where the morainic overlay thins out to produce a parent material which is transitional to that of the Cromarty Association, freely drained profiles are not often formed, as the underlying, compact till usually causes some impedance to drainage. Some freely drained soils of this type are, however, found on top of the central ridge where it narrows to the east of Mount Eagle.

The soils of the Allangrange Series are podzols, which are frequently cultivated and occasionally possess a thin iron pan. Although the series extends over 62 square kilometres, not more than 5 square kilometres show any appreciable development of a thin iron pan. These podzols with thin iron pan are found on the high, central Millbuie ridge between Mount Eagle and Grey Cairn Wood. They were identified in about a third of the inspection holes dug in that area.

In the western part of the Black Isle, most of the land below 150 metres is now cultivated, and it is difficult to find a semi-natural soil profile that is really representative of the pre-arable state of the land. By taking an overall view of the soils examined, however, the limits of variation in horizon development can be reasonably defined.

The present-day surface organic horizons consist of 5–8 centimetres of litter and dark brown to black, fibrous raw humus with a little well-decomposed black humus at the base. They overlie a leached E horizon between 5 and 10 centimetres thick which is composed of dark grey, humose loamy sand with many bleached sand grains. The underlying yellowish brown stony, friable sandy loam Bs horizon is usually between 5 and 20 centimetres thick (extreme variations 1–25 centimetres), and sometimes shows very slight mottling and the impedance of drainage at the base, just above a strongly indurated, stony Bx horizon. This latter layer varies in thickness from a few to over 45 centimetres; the induration is strongest in the upper 7–10 centimetres and fades out gradually with depth. The C horizon of the profile consists either of stony, coarse sandy loam underlain by till or is wholly formed in the compact, reddish brown till which also forms the parent material of the Cromarty Association soils.

In this western district, all the semi-natural profiles examined have an indurated layer within 40 centimetres of the mineral soil surface, and in many it is within 25 centimetres of the surface. Some 60 to 70 per cent of the cultivated soils come into the 40-centimetre category. Another 10 per cent, which have the indurated layer at 60 centimetres or more, should probably be added, as they have agriculturally improved surface horizons 45 centimetres or more, thick which almost certainly reflect the addition of composted material. The effects of such additions are strikingly illustrated by the present condition of the arable lands of Muirends and Belmaduthy farms which are described in the *New Statistical Account of Scotland published in 1845* as having been enclosed and improved. On these farms, 80 per cent of the inspection holes revealed an indurated layer at 60 centimetres or more below the surface, and in 70 per cent of them the cultivated surface horizon was 45 centimetres thick or more. In only 10 per cent of these holes was the surface horizon less than 30 centimetres thick.

On the Millbuie ridge east of Mount Eagle, most of the soils are uncultivated and 90 per cent of the profiles examined have an indurated layer within 40 centimetres of the mineral surface; more than a third have one within 25 centimetres of the surface. The frequent, thin iron pan soils have been described as podzols rather than peaty podzols, because a well-developed peaty surface layer is rarely present. Whether the absence of a peaty surface layer reflects pedological development, or systematic turf stripping by past generations of crofters seeking domestic fuel, is somewhat uncertain, though the widespread practice of burning turf and the scarcity of peat mosses are mentioned frequently in the first and second Statistical Accounts; David Aitken's 1764 plan of Cromarty Estate shows many turf roads radiating westwards from Cromarty parish towards the area of Grey Cairn Wood.

The description of three representative profiles of the Allangrange Series at about 55 metres, 150 metres and 170 metres are set out below: their analytical data are in the Appendix. The first, Balgalkin, was taken from a water-supply tank excavation, and the site, though uncultivated, was by no means undisturbed. The second profile, at Newton of Ferintosh, was on arable land, and the third was taken from the kettlehole complex near Sunnybrae Croft. This last site formerly had a semi-natural vegetation of *Calluna* with scattered Scots pine trees but has been ploughed and planted by the Forestry Commission.

Profile description	Balgalkin (analysis No. 1, p. 106)
Site	Water-supply tank excavation about 1.2 kilometres south-east of Conon Bridge
Nat. Grid. Ref.	NH 553549
Altitude	55 metres
Topography	low mound
Drainage Class	free

Horizon	*Depth*	
Ap	0–15 cm	Very dark grey (10YR3/1) sandy loam; weak crumb; friable and loose; few small and medium stones; grass and broom roots present; no worms ; moist; no mottles; gradual, irregular change into
Bh	15–30 cm	Black (10YR2/1) and very dark grey (10YR3/1) sandy loam; this humus accumulation at the base of the Ap horizon is massive or is in narrow, horizontal bands
Bs		Discontinuous pockets of yellowish brown (10YR5/6) sandy loam; weak crumb; friable; few stones; common roots; no mottles; sharp change into
Bx	30–66 cm	Dark yellowish brown (10YR4/4) stony, coarse sandy loam; indurated, with coarse platy structure in the upper part of this horizon; abundant stones up to 20 centimetres, with occasional boulders; few roots in the upper few centimetres; no worms; moist; few rusty mottles; gradual change into

BC	66–94 cm	Brown (10YR5/3) stony, coarse sandy loam with some horizontal sandy streaks; firm; common stones; no roots; moist; few rusty mottles; sharp change into
C1	94–107 cm	Yellowish brown (10YR5/4) roughly stratified, stony, sandy loam and loamy sand; massive, breaking to single grain; friable; common small and medium stones; moist; a little rusty staining outlining grey patches; sharp change into
C2	107–150 cm	Brown (with pinkish cast) (7.5YR5/4) sandy loam; massive; firm; common stones; moist; some vertical, grey cracks with rusty edges present to 150 centimetres; few rusty mottles associated with weathered stones;
C3	150–218 cm	Brown (with pinkish cast) (7.5YR5/4) sandy loam till; massive; firm; common stones; no roots; no worms; moist; few rusty mottles associated with weathered stones and decreasing with depth; gradual change into
C4	218–259 cm	Brown (with pinkish cast) (7.5YR5/4) loam till; massive.
	Note	The erratic stones in the top 1.8 metres are mainly Moinian schists, with a few large sandstone erratics of Old Red Sandstone age and common smaller ones; below 1.8 metres, the erratics are mostly sandstones of Old Red Sandstone age.

Profile description — Newton of Ferintosh (analysis No. 2, p. 106)

Site	Small arable field lying immediately to the south-west of the farm steading
Nat. Grid. Ref.	NH 572528
Altitude	150 metres
Topography	gentle slope, 1° or less
Drainage Class	free

Horizon	*Depth*	
Ap	0–20 cm	Dark brown (10YR3/3) sandy loam; weak crumb; common schists and sandstones; common roots; worms present; moist; no mottles; sharp change into
Bs	20–25 cm	Yellowish brown (10YR5/4) sandy loam, with dark brown (10YR3/3)Ap horizon material penetrating down worm channels; weak crumb; friable; common stones; common roots; worms present; moist; no mottles; sharp change into
Bx	25–36 cm	Yellowish brown (10YR5/6) sandy loam; indurated; common schists and sandstones up to 40 centimetres; few roots; no worms; moist; few rusty mottles; sharp change into
B(x)	36–64 cm	Brownish yellow (10YR6/6) sandy loam; less strongly indurated; common stones; moist; sharp change into
C	64–112 cm +	Yellowish brown (10YR5/4) to brown (10YR5/3) stony sandy loam to loamy sand.

Profile description — Sunnybrae (analysis No. 3, p. 107)

Site	A small mound in the kettlehole complex
Nat. Grid. Ref.	NH 600553
Altitude	170 metres
Topography	small mounds scattered between kettleholes infilled with alluvium and peat
Drainage Class	free

Horizon	*Depth*	
L	0–1 cm	Loose litter of moss, lichen and heather fragments.
F	1–5 cm	Very dark greyish brown (2.5Y3/2) fibrous litter, loose above and felted below.
E	5–18 cm	Greyish brown (2.5Y5/2) to dark greyish brown (2.5Y4/2) sandy loam; massive; firm; few stones; common roots; no worms; dry; no mottles; sharp change into

Bh	18-19 cm	Very dark greyish brown (2.5Y3/2) colloidal humus accumulation varying from 0.5-1.5 centimetres thick; dry; sharp change into
Bs	19-23 cm	Olive-brown (2.5Y4/4) sandy loam; weak crumb; friable; common sandstone and schists; roots present; no worms; slightly moist to moist; sharp change into
Bx	23-51/ 63 cm	Light olive-brown (2.5Y5/4) to light yellowish brown (2.5Y6/4) coarse sandy loam; indurated; abundant stones of varying sizes with sandstones predominant over schists; no roots; slightly moist to moist; few mottles; gradual change into
C	51/63- 84 cm +	Light yellowish brown (2.5Y6/4) very stony, coarse sandy loam.

MILLBUIE SERIES

The imperfectly drained soils of the Millbuie Series cover about 111 square kilometres, or 60 per cent of the association area. They form the most extensive series of this district, comprising nearly 40 per cent of the Black Isle, and are widely distributed west of a line from Rosemarkie to Udale Bay, except on Mount Eagle, the Kessock ridges, and on the steep, western promontory above Muir of Ord. The series is particularly well developed on the flatter, central part of Millbuie Moor, but can be found wherever the morainic till lies on gently sloping ground or is underlain at no great depth by the compact, reddish brown till of the Cromarty Association.

This series is sufficiently extensive to reflect the general west to east trend of parent material variation described for the association as a whole, although the general development of some degree of drainage impedence is in itself, an indication that the shallower type of moranic deposit, less than 1 metre thick, occurs most often.

The soils of the Millbuie Series include imperfectly drained podzols with strongly developed and weakly developed indurated layers, and undifferentiated imperfectly drained soils without an indurated layer, together with their cultivated derivatives. Some of the podzols have a thin iron pan developed locally on the upper surface of the indurated layer, but more commonly there are some patchy, iron concretions in the strongly indurated, upper 8-10 centimetres of this horizon. Soils with a strongly developed indurated layer are found generally on those sites which initially had relatively good vertical or lateral drainage. For example, well-developed indurated layers are found more frequently along the crest of the low, coastal ridge between St Martins and Balblair than along the lower slopes, and along the broad Millbuie spine they tend to be associated with sloping sites and slightly high local spots. Site drainage difficulties are fairly general on the flat top where, once an indurated layer has been formed, water begins to accumulate in the solum during the winter and early spring months, awaiting removal by transpiration and evaporation during the warmer summer months. This leads gradually to the development of gleying in the Bs horizon and occasionally in the top of the indurated layer; the seasonally anaerobic conditions can lead to secondary mobilization of iron in the Bs horizon to produce the rusty concretions now frequent in the upper part of the Bx horizon. The gleying also affects the surface vegetation by reducing the already limited rooting zone above the indurated layer.

Generally, the semi-natural podzolic profile has a surface organic horizon consisting of about 10 centimetres of litter and very dark brown, partially decomposed fibrous litter, with a trace of well-decomposed, black humus at the base. The humus layer is seldom more than 1.5 centimetres thick and is underlain by an E horizon which is about 2.5 centimetres thick and consists of dark grey, humose sandy loam with prominent bleached sand grains. An indurated Bx horizon occurs frequently within 30 centimetres of the mineral ground surface, and is seldom more than 40 centimetres from the surface. On the high, central moor, the yellowish brown, friable sandy loam Bs horizon with ochreous mottling normally found between the E horizon and the indurated layer, is often replaced by a patchily coloured, humose horizon in which shades of grey, greyish brown and black predominate. This mixed horizon is interpreted as probably representing a long-term churning-up of the A, E and B horizons by the windthrow of mature trees before extensive settlement and deforestation of the Black Isle took place. Compact, reddish brown till generally forms the C horizon, but in soils transitional to the Cromarty Association, as in Grey Cairn Wood, the till can occur at the level of the indurated Bx horizon.

The descriptions of three profiles from this series are set out below. The first is an imperfectly drained podzol with a strongly developed indurated layer; the second is a cultivated podzol with a weakly developed indurated layer and the third is a cultivated, undifferentiated, imperfectly drained soil. This last profile is representative of the more reddish brown parent material found in the Redcastle–Avoch–Kessock area.

Profile description		Bellton Wood No. 1 (analysis No. 4, p. 107)
Site		Planted Scots pine woodland on the east side of the Munlochy to Culbokie road, opposite the Schoolhouse
Nat. Grid. Ref.		NH 632554
Altitude		130 metres
Topography		gentle slope, about 2° near profile pit
Drainage Class		imperfect
Horizon	*Depth*	
L	0–1 cm	Loose litter of moss, pine needles, and heather twigs.
F	1–5 cm	Very dark brown (10YR2/2) fibrous litter; frequent heather roots; no worms; moist; sharp change into
H	Trace	Black (5YR2/1) humus; sharp change into
E	5–8 cm	Very dark grey (10YR3/1), humose sandy loam with frequent bleached sand grains; weak sub-angular blocky; few stones; common roots; no worms; moist; no mottles; sharp change into
AB(g)	8–30 cm	Patchy, light brownish grey (2.5Y6/2), dark greyish-brown (2.5Y4/2), very dark greyish brown (2.5Y3/2), and black (2.5Y2/0), humose sandy loam, the dark patches containing considerable concentrations of humus; weak coarse subangular blocky; common stones, mostly schists and sandstones up to 15 centimetres; common heather and tree roots; no worms; moist; few rusty mottles; sharp irregular change into
Bf	30 cm	Thin iron pan; locally replaced by iron concretions in upper part of indurated layer.
Bx(g)	30–64 cm	Brown (10YR5/3 and 4/3) sandy loam; stongly indurated; common schists and sandstones up to 30 centimetres; few roots penetrating softer patches associated with pale brown, vertical cracks; no worms; moist; few yellowish brown (10YR5/8) mottles; gradual change into
B(xg)	64–76 cm	As for 25–58 centimetres but horizon less strongly indurated and with frequent yellowish brown and grey mottles; sharp change into
C	76–107 cm +	Dark brown (10YR4/3) sandy loam till; massive; very firm becoming firm below 100 centimetres; common sandstones and schists; no roots; no worms, moist; pale brown (10YR6/3), vertical cracks with yellowish brown (10YR5/8) edges.

Profile description	Tullich (analysis No. 5, p. 108)
Site	Field on south-east side of the public road opposite Tullich farm access road
Nat. Grid. Ref.	NH 653539
Altitude	50 metres
Topography	gentle, south-east slope overlooking Munlochy Bay
Drainage Class	imperfect

Horizon	*Depth*	
Ap	0–23 cm	Very dark greyish brown (10YR3/2) sandy loam; weak crumb; friable; common stones mainly schists; abundant roots; worms present; moist; no mottles; gradual irregular change into
Bs(g)	23–36 cm	Patchy, dark brown (10YR3/3) sandy loam; medium subangular blocky; common stones; few roots; worms present; moist; few rusty mottles; gradual change into
B(xg)	36–46 cm	Yellowish brown (10YR5/4) sandy loam; weakly indurated; common sandstones and schists; few roots; worms present; moist; some rusty and grey mottles; gradual change into
BC(g)	46–89 cm +	Brown (7.5YR5/4) and light brownish grey (10YR6/2) sandy loam; massive to weak subangular blocky; firm; common sandstones and schists; few roots in the upper part; no worms; common brownish grey and rusty mottles.

Profile description	Allangrange Station (analysis No. 6, p. 108)
Site	Field on west side of B9162 road about 460 metres south of Allangrange Station
Nat. Grid. Ref.	NH 610514
Altitude	75 metres
Topography	undulating lowland
Drainage Class	imperfect

Horizon	*Depth*	
Ap	0–23 cm	Dark brown (7.5YR3/2) sandy loam; medium subangular blocky; friable; common schists and sandstones up to 10 centimetres; roots common; worms present; moist; no mottles; sharp change into
Bs(g)	23–38 cm	Dark reddish brown (5YR3/4) sandy loam becoming reddish brown (5YR5/4) below; medium subangular blocky; friable; common sandstones and schists; roots frequent; worms present; moist; common grey and rusty mottles; gradual change into
C(g)	38–74 cm +	Reddish brown (5YR5/4) sandy loam; coarse subangular blocky; slightly firm; common sandstones and schists; few roots present to 60 centimetres; no worms; moist; common grey and rusty mottles.

ROSKILL SERIES

Though the poorly drained soils of the Roskill Series cover about 6.0 square kilometres and are more extensive than those of many series in the Black Isle, they constitute only about 3 per cent of the soils of the Millbuie Association. The series is best developed in the western half of the Black Isle between the B9162 road and Mount Eagle, particularly on the broad, central part of the Millbuie spine where it occupies flat areas without appreciable lateral drainage, and small local hollows.

The parent material variations are the same as those described for the Millbuie Series, with which the Roskill Series is always closely related in the landscape, but there has often been considerable re-sorting of the parent material by solifluction and slope-wash.

The soils of the Roskill Series are noncalcareous gleys, and occasionally include small patches of peaty gleys which are insufficiently extensive to distinguish as a separate series.

A cultivated profile of this series from the arable land of an old croft near Sunnybrae, within the area of the Kinkell Complex, is described below.

Profile description	Sunnybrae (analysis No. 7, p. 109)
Site	Old grassland on a croft 0.4 kilometres south-west of Sunnybrae farm
Nat. Grid. Ref.	NH 604551
Altitude	170 metres
Topography	hollow among mounds
Drainage Class	poor

Horizon	*Depth*	
Ap	0–25 cm	Very dark greyish brown (10YR3/2) sandy loam; coarse subangular blocky, breaking to fine crumb; few stones, mostly sandstones with some schists; many grass and *Juncus* roots; worms present; moist; yellowish brown (10YR5/6) mottles around root channels; sharp change into
Bg1	25–36 cm	Pale brown (10YR6/3) and brown (10YR5/3) sandy loam; weak coarse prismatic, breaking to coarse subangular blocky; common stones, mostly soft pieces of sandstone; few live roots; common brownish grey (10YR6/2) and brownish yellow (10YR6/8) mottles; gradual change into
Bg2	36–64 cm	Light brownish grey (10YR6/2) and greyish brown (10YR5/2) (with discontinuous, yellowish brown vertical streaks) sandy loam; weak prismatic, breaking to coarse subangular blocky; common stones, with pieces of soft rotten sandstone up to 25 centimetres; no live roots other than in the upper 3 centimetres, but a few dead roots; moist; light grey (10YR7/2) and yellowish brown (10YR5/8) mottles around old vertical root channels; gradual change into
Cg	64–132 cm +	Greyish brown (10YR5/2), light brownish grey (10YR6/2) and light grey (10YR7/2) sandy loam; nearly massive but with very weak prismatic traceable to about 100 centimetres; many soft sandstones and occasional schists; no live roots but soft, blackened, dead roots preserved in vertical root channels below 65 centimetres; no worms; moist to wet; water flowing into pit below 90 centimetres; prominent yellowish brown (10YR5/8 and 6/8) mottles around root channels.

KINKELL COMPLEX

The Kinkell Complex is a complicated area of small-scale knob-and-kettle topography covering about 6.2 square kilometres at the west end of Millbuie Moor; most of it lies east of the B9162 road. The area contains soils of the Allangrange, Millbuie and Roskill Series, with frequent small, scattered kettlehole lochs, many infilled with sandy alluvium or alluvium and peat. Until recently ploughed and planted by the Forestry Commission, the drier mounds carried Atlantic heather moor with scattered, stunted Scots pine trees. This was probably the last area of the Black Isle in which an appreciable remnant of semi-natural vegetation had survived relatively unmodified by human interference.

CROMARTY ASSOCIATION

This association occupies nearly 26 square kilometres and is the second largest in the Black Isle, covering about 9 per cent of the area. The greater part is found around Cromarty, though nearly 5 square kilometres have been mapped in separate areas north and south of the central Millbuie ridge. Additionally, there are some small patches further west, mostly between Bellton Wood and Muckernich. The association extends from below 25 metres, at the back of the raised beach cliff skirting Cromarty Bay, to nearly 180 metres in Grey Cairn Wood and on the northern slopes of Ethie Hill. A high proportion of the soils has been cultivated, and includes what has been long reputed to be the best arable land of the Black Isle.

A compact, reddish brown sandy loam till derived from Middle Old Red Sandstone strata, with only a thin overlay of coarser-textured material, forms the parent material of this association. Over most of the area mapped, the clay content ranges from 14 to 21 per cent within normal profile depth and, taking the Black Isle as a whole, the analyses suggest a gradual rise in the clay content from west to east. The characteristic compaction of this till is generally most marked within the upper 100 centimetres of the solum, particularly within the Cromarty peninsula east of Grey Cairn Wood, and the maximum clay content found in the compact part of the solum may be 15–25 per cent higher than that found at the base of the profile. This feature becomes gradually less marked in profiles from Grey Cairn Wood and localities further west, where an appreciable thickness of coarser-textured material is present in the upper part of the solum. It is very much reduced in profiles of the Millbuie Series where the till occurs under 75 centimetres, or more, of the coarser-textured material. There are indications that this accumulation of clay in the upper 100 centimetres of the solum has been accompanied by a similar but smaller increase of the silt and fine sand contents. Examination of soil thin-sections has shown that some oriented clay has been deposited in the larger pores, but the amounts of material deposited in this way are small and deposition of oriented clay in pores is known to extend to below 1.5 metres from the surface. It is probable therefore that periglacial, rather than pedological, processes have been responsible for the development of compaction in the solum, and that the base of the active layer was about 1 metre below the mineral surface at that time.

Till of the Cromarty Association shows little variation within the Black Isle, though it is rather paler at the west end than at the east end. The only distinctive variant encountered during the survey was a small patch of till derived from a noncalcareous mudstone and covering 0.3 of a square kilometre just north of Munlochy Bay on the northern slopes of Tourie Hill near Lochala farm. The clay content of this variant is comparable with that for the rest of the Cromarty Association, but the silt and very fine sand content are considerably higher. A fine sandy element in the field texture of adjoining soils, which have been included within the Millbuie Association, is also noticeable over a limited area on both sides of Munlochy Bay.

The cultivated, surface horizons of both the Millbuie and the Cromarty Associations are generally sandy loams, with a similar range of clay content. But, whereas only 3 out of the 8 surface soils of the Millbuie Association analyzed contained more than 12 per cent of clay, only one of the 6 surface soils of the Cromarty Association examined contained less than 12 per cent. Furthermore, it has been found that where over 12 per cent of clay is found in the plough layer of soils of the Millbuie Association, this is always greater than the clay content of any of the subsoil horizons, whereas the plough layer of a soil of the Cromarty Association always contains less clay than the finest of the subsoil horizons.

Three soils series have been distinguished, Freely drained podzols have been grouped within the Brucefield Series, imperfectly drained podzols within the Cromarty Series, and noncalcareous gleys within the Navity Series. The dominant Cromarty Series covers almost 24 square kilometres and makes up about 94 per cent of the association.

BRUCEFIELD SERIES

The series has developed only where convex topography and the natural porosity of the underlying strata, either separately or in conjunction, have provided naturally freely drained conditions.

Two patches of this series, on the north and south sides of Gallow Hill at Cromarty, and a third on the northern slope of Ethie Hill, are developed on steeply sloping sites on a relatively thin, sandstone-derived till which has overstepped the gneissic outcrops along the south coast of the Black Isle. A fourth, near Peddieston School, includes limited areas of very shallow soils over sandstone which are more closely related to the soils of the Mount Eagle Association than to those of the Cromarty Association. The remaining localities are in Grey Cairn Wood and near Mains of Raddery. These are relatively dry spots separated from rather larger, local patches of the Cromarty Series. They are generally freely to imperfectly drained, rather than freely drained. The patch of mudstone till at Lochala farm near Munlochy Bay, described above, has been included also within this series; there the soil drainage is similarly free to imperfect rather than free.

The soils of the freely drained Brucefield Series are podzols, most of which have their upper horizons disturbed by cultivation. In both types of profile, an indurated Bx horizon is usually formed between 25 and 35 centimetres below the mineral surface. In the semi-natural profile, the absence of any well-developed peaty surface layer could be readily accounted for by the intense, local fuel shortage described for Cromarty parish in the first and second Statistical Accounts of Scotland. The 'turf roads' shown on David Aitken's 1764 plan of Cromarty Estate support this belief. On the other hand, such freely drained sites would not normally support the widespread development of a peaty surface horizon. The present-day profile has a surface organic horizon of fibrous raw humus, rarely more than 5 centimetres thick, overlying a dark grey to black AE horizon about 10 centimetres thick with prominent bleached sand grains. Below the AE horizon and above an indurated layer, there is a brown to reddish brown friable Bs horizon up to 15 centimetres thick. In the cultivated soil, the A horizons and most of the Bs horizon are combined to form a dark brown sandy loam surface horizon, 20–25 centimetres thick, which directly overlies the indurated layer or is separated from it by 2–5 centimetres of the friable Bs horizon.

A freely drained, cultivated profile and a slightly imperfectly drained profile are described below.

Profile description		Cromarty Mains No. 2 (analysis No. 8, p. 109)
Site		Grassy edge of a cultivated field at east end of farm
Nat. Grid. Ref.		NH 802670
Altitude		90 metres
Topography		moderately steep (14°), north-north-west slope
Drainage Class		free
Horizon	*Depth*	
Ap	0–36 cm	Dark brown (7.5YR4/2) sandy loam; medium subangular blocky, breaking to fine crumb; friable; few stones; abundant roots; worms present; moist; no mottles; sharp change into

AB	36–48 cm	Dark brown (7.5YR4/2) with patches of brown (7.5YR5/4) sandy loam; medium subangular blocky, breaking to fine crumb; friable; common stones; roots common; worms present; moist; no mottles; sharp change into
Bs	48–56 cm	Dark brown (7.5YR4/4 to 3/4) sandy loam; medium subangular blocky; friable; common stones; few roots; worms present; moist; no mottles, sharp change into
B(x)	56–61 cm	Brown to reddish brown (7.5YR 4/4 to 5YR4/4) sandy loam; weak platy, breaking to weak angular blocky; weakly indurated; common stones; few roots; worms present; moist; no mottles; sharp change into
C	61–102 cm+	Brown to dark reddish grey (7.5YR 4/2 to 5YR4/2) sandy loam till; massive with vertical cracks 2.5 centimetres wide at top and infilled with brown (7.5YR4/2) loamy sand; very firm; common stones; very few roots; very occasional worms present to 70 centimetres; moist; few mottles.

Profile description	Lochala (analysis No. 9, p. 110)
Site	Grass field west of Lochala farm
Nat. Grid. Ref.	NH 638543
Altitude	80 metres
Topography	north-north-west side of a gently sloping 90-metre ridge
Drainage Class	free to imperfect

Horizon	*Depth*	
Ap	0–46 cm	Dark brown to brown (10YR4/3) fine sandy loam; angular blocky; friable; few stones, mostly small schist erratics; roots abundant in upper part and common below; worms present; moist; no mottles; sharp change into
Bs	46–53 cm	Brown (7.5YR4/4) fine sandy loam; medium to coarse platy; slightly firm, many stones, sub-angular to rounded schist erratics up to 10 centimetres; few roots; worm channels present; moist; some greyish and strong brown (7.5YR5/6) mottles; sharp change into
C	53–110 cm+	Reddish brown (5YR4/4) silty loam; massive with horizontal lamination to base of profile; firm; few stones, though these include some large erratics and small chips of reddish mudstone; few roots; worm channels penetrate to 90 centimetres; moist; vertical, greyish white, sand-infilled cracks penetrate to base of profile at about 110 centimetres; few faint rusty mottles persist to about 65 centimetres.

CROMARTY SERIES

This is the dominant series of the Cromarty Association, and with almost 24 square kilometres is the third largest association in the Black Isle. It is most extensively developed in the Cromarty penisula, with smaller areas between 0.6–2.6 square kilometres on the lower slopes of the central ridge, north east of Mount Eagle. Minor patches occur in the western half of the Black Isle, for example, near Tore, Findon and Belton Wood.

The topographic range within the Cromarty penisula is virtually that of the series as a whole. Slopes are gentle (1–2°) near the summit of the Millbuie Moor, increasing to moderate (4–5°) as the ground falls away towards Cromarty Bay. The lowest part of the declivity above the beach cliff is dissected by parallel gullies cut through the till into the red sandstone.

Most of the soils of this series have been cultivated, so that, on the oldest arable land between the A832 and Cromarty Bay, it is difficult to deduce from the present-day profile the appearance of the A and B horizons of the semi-natural precursor. The compact, somewhat gleyed, subsoil horizons have been long recognized. The Rev. Robert Smith, writing in *The Statistical Account of Scotland* (Sinclair, 1791–1799), noted that 'the soil about the town is fertile of a deep black mould; it is in general, however, remarkably wet, owing to a hardpan, or rocky substance in the bottom, which prevents the water from sinking beneath the surface. The soil in the country part of the parish is various; it is also in general, wet'. The semi-natural soils which remain are mostly in the Grey Cairn Wood, and are inevitably those least amenable to agricultural improvement because of limitations of altitude and exposure. They include imperfectly drained podzols with compact B and BC horizons, which may or may not be indurated, and undifferentiated, imperfectly drained soils. A thin iron pan has been occasionally recorded on the upper surface of the indurated Bx horizon, but this is generally not a feature of the series. David Aitken's Cromarty Estate map of 1764 shows moorland well-interdigitated with arable land on the lower ground, and the *New Statistical Account of Scotland* (1845), after describing the improved farms near Cromarty, records the remaining uncultivated land as 'moorish'. It comments that the western part of the parish is still 'broken into irregular map-like patches, divided from each other by little strips and corners of land not yet reclaimed from the waste' with the farm steadings 'composed of straggling groups of cottages built of undressed moor stones, and covered with turf'. It seems fair therefore to conclude that the greater part of these soils had podzolic A and B horizons before cultivation.

The profile descriptions of three soils of this series are given below. The first is representative of the best arable land of the series. The next, on old grassland not often ploughed, represents some of the ground most recently reclaimed. In the third profile, from Grey Cairn Wood, there is an appreciable thickness of morainic material overlying compact, reddish brown till of the Cromarty Association, and the soil is transitional between the Cromarty and the Millbuie Series. This profile showed also the relative impermeability of the compact, upper layers of the till and indicated the practical problems associated with the drainage of these soils. The profile was sampled in the month of September when the soil was rather dry, but once the compact till layers had been penetrated, water from the porous sandstone strata began to seep up through the C horizon into the pit.

Profile description		Cromarty Mains No. 1 (analysis No. 10, p. 110)
Site		Grass field immediately north-east of Cromarty Mains
Nat. Grid. Ref.		NH 792665
Altitude		70 metres
Topography		smooth, gentle to moderate slope (about 5°) falling towards the raised beach
Drainage Class		imperfect
Horizon	*Depth*	
Ap1	0–23 cm	Dark brown (7.5YR4/2) sandy loam; medium subangular blocky; friable; common stones mainly gneisses, schists and reddish sandstones up to 10 centimetres; grass roots abundant to common; worms present; moist; no mottles; gradual change into
Ap2	23–30 cm	Dark brown (7.5YR4/2) sandy loam, as above, but containing patches of subsoil material; grass roots common; sharp change into
B(xg)	30–38 cm	Brown (7.5YR5/4) sandy loam; slightly indurated; common stones, generally less than 5 centimetres; few grass roots; worm channels present in softer patches; moist; some grey and rusty mottles; gradual change into

BC	38–71 cm	Reddish brown (5YR5/3–5/4) loam; firm; common stones, mainly gneiss, schists and sandstones; few roots; no worms; moist; light grey (10YR7/1) vertical, irregular, cracks with yellowish brown (10YR5/6) edges and a few rusty mottles; gradual change into
C	71–97 cm	Reddish brown (5YR5/4) loam; massive but horizontally laminated; very firm; common stones; moist; a few light grey (10YR7/1) cracks penetrate this layer; some diffuse grey and rusty mottles; gradual change into
C(g)	97–107 cm +	Reddish brown (5YR5/4) sandy loam till; massive; becoming more stony; faint grey and rusty mottles becoming prominent with depth.

Profile description Bannans No. 1 (analysis No. 11, p. 111)

Site	Grass field just east of the A832 road near Kenny's Plantation
Nat. Grid. Ref.	NH 757639
Altitude	145 metres
Topography	broad, nearly flat, top of the Millbuie ridge
Drainage Class	imperfect

Horizon	*Depth*	
Ap	0–15 cm	Dark brown (7.5YR3/2) humose sandy loam; subangular blocky, breaking to fine crumb; firm; common stones, mainly schist, gneiss and sandstone up to 5 centimetres; grass roots abundant; no worms; moist; no mottles; sharp change into
Bf	15 cm	Discontinuous thin iron pan.
Bx(g)	15–36 cm	Brown (7.5YR5/4) sandy loam; indurated; common stone content as above; few roots penetrate soft patches in this layer; no worms; moist; some grey and rusty mottles; clear change into
BC(g)	36–48 cm	Reddish brown (5YR5/3) sandy loam to loam; firm; common sandstones and schists; few roots; gradual change into
BC	48–99 cm	Reddish brown (5YR5/4) loam; massive; very firm; common stones, including sandstones and schists, up to 30 centimetres; no roots; no worms; moist; vertical, grey cracks with rusty edges; some pinkish grey (5YR6/2) and rusty mottles; clear change into
C	99–127 cm +	Reddish brown (5YR5/4) sandy loam to loam; becoming softer with very weak horizontal laminations; common stones; no roots, some vertical, grey cracks extend to the base, together with diffuse, grey and rusty mottles.

Profile description Grey Cairn Wood (analysis No. 12, p. 111)

Site	Open moorland just over 0.8 kilometres south-west of Peddieston School
Nat. Grid. Ref.	NH 734631
Altitude	175 metres
Topography	gentle, convex slope (1–2°) with irregular micro-relief
Drainage Class	imperfect

Horizon	*Depth*	
L	0–1 cm	Loose litter of heather twigs, mosses and lichens.
F	1–4 cm	Very dark greyish brown (10YR3/2) and very dark brown (10YR2/2), felted, fibrous litter; many live heather roots; moist; sharp change into
Ah	4–13 cm	Very dark brown (10YR2/2) humose loam, speckled with bleached sand grains; massive, breaking to coarse subangular; slightly firm; few stones; common roots; moist; no mottles; sharp change into
AB	13–28 cm	Brown (7.5YR5/4), very dark brown (7.5YR3/2 and 10YR2/2), and black (10YR2/1) patchy-coloured, humose loam; massive, breaking to subangular; common stones, mainly subangular to

		rounded, quartz-schist and quartz-mica-schist erratics up to 30 centimetres long, and angular sandstones; common roots; no worms; moist; sharp wavy change into
Bs(m)	28-41 cm	Patchy, yellow to dark yellowish brown (10YR7/6, 6/4, 5/8, 4/4), coarse sandy loam; slightly cemented; common stones, schists and sandstones up to 30 centimetres; few roots in the upper part; no worms; slightly moist; sharp and diffuse rusty mottles; sharp irregular change into
Bx	41-51 cm	Light yellowish brown (10YR6/4) sandy loam; indurated; common stones; no roots; no worms; slightly moist; occasional small rusty mottles; sharp change into
BC	51-116 cm	Reddish brown (5YR4/3) loam till; massive with a weak laminated structure to about 65 centimetres with well-defined horizontal laminations below; very firm becoming firm with depth; common stones, mainly sandstones and schists up to 15 centimetres; no roots; no worms; slightly moist; few rusty mottles; well-defined light grey (10YR7/2) vertical cracks with yellowish brown (10YR5/6) edges which continue to the base of the profile; gradual change into
C	116-132 cm +	Reddish brown (5YR5/3) loam till; massive; water seeping from below.

NAVITY SERIES

The poorly drained soils included within this series cover less than 0.6 of a square kilometre, being found in localized wet spots within the Cromarty Series.

The parent material variations are as described for the association as a whole, excepting that the upper layers of the solum may consist in part of re-sorted, surface material.

The soils of the Navity Series are poorly drained noncalcareous gleys, though, in a few instances, it is possible that the soils formerly may have been peaty gleys or carried shallow peat.

The profile described below is an arable soil under old grassland with clumps of rushes.

Profile description	Bannans No. 2 (analysis No. 13, p. 112)
Site	Grass field about 90 metres west of the disused Bannans steading
Nat. Grid. Ref.	NH 763638
Altitude	130 metres
Topography	gentle slope on the north bank of the Ethie Burn
Drainage Class	poor

Horizon	*Depth*	
Ap	0-46 cm	Dark brown (7.5YR3/2) sandy loam; medium subangular blocky; few, small stones; roots abundant in top 15 centimetres, common below and few at the base; worms present; moist; diffuse rusty mottles around root channels; sharp change into
Bsg	46-56 cm	Brown (7.5YR5/4) sandy loam to loam; coarse prismatic, breaking to coarse subangular blocky; common stones, mainly schists and sandstones; few roots; vertical, grey cracks; sharp change into
Bg	56-77 cm	Brown (7.5YR5/4) and light brown (7.5YR6/4) loam; coarse subangular blocky; common stones; few roots; moist; light brown (7.5YR6/4) and strong brown (7.5YR5/6) mottles; vertical, grey cracks; gradual change into
Cg	77-122 cm +	Reddish brown (5YR4/3 to 4/4) loam till; weak coarse subangular blocky; common stones, up to 15 centimetres; few roots to 100 centimetres; moist; reddish brown (5YR5/3) and yellowish red (5YR5/6) mottles; vertical, grey cracks begin to die out at about 100 centimetres.

MOUNT EAGLE ASSOCIATION

The Mount Eagle Association is the third largest association in the Black Isle, covering almost 20 square kilometres, or about 7 per cent of the total area. All the soils of the association are concentrated in a block stretching north-westwards from Mount Eagle down to the north shore, crossing on the way the rocky mounds and wet hollows around the Bog of Findon, and taking in the highest part of the coastal ridge between St Martins and Shoretown, before sweeping down to the cliff at the back of the low raised beach. The area has an altitudinal range from about 15 to over 240 metres. Land use within this association is divided about equally between agriculture and forestry, with most of the ground above 150 metres now planted by the Forestry Commission.

The soils are developed on a stony, semi-residual drift, usually 35–75 centimetres thick. This drift is very local in origin and shows considerable colour variations which reflect the underlying standstone strata, ranging from yellowish brown through brown to reddish brown. The strata belong, in the main, to the uppermost group of the Millbuie Sandstone Series. Extremely shallow patches of drift are common on the coastal ridge near St Martins, although a thicker solum occurs on the lower slopes around Mount Eagle near the boundary with the Millbuie Association. Along the north-west slope, between Culbokie Loch and Easter Culbo, at about the 90–120-metre level, this deeper drift is underlain locally by compact, reddish brown till of the Cromarty Association, giving rise to soils intermediate between the Millbuie and the Cromarty Associations. In view of their limited extent and location, these soils have been included within the Mount Eagle Association.

Three soil series have been separated. Freely drained podzols comprise the Mount Eagle Series, imperfectly drained podsols comprise the Findon Series and noncalcareous gleys form the Culbo Series. The Mount Eagle and Findon Series are both extensive, and account for over 98 per cent of the association. Gleys are restricted to small wet spots around springs on the hillslopes and to hollows in the Findon area. Around Bog of Findon, some limited areas of peaty gleys are included within the Culbo Series.

MOUNT EAGLE SERIES

This is the dominant series of the association, covering almost 11 square kilometres. It is widespread over the summit and southern slopes of Mount Eagle, and on the Shoretown–St Martins coastal ridge. On the high ground, the soils are podzols, some with a thin iron pan, the development of the thin iron pan reaching a maximum around the summit of Mount Eagle. Previously, these soils may have been peaty podzols, but virtually no trace of the peaty surface layer survives, and the description of the thin fibrous raw humus cover given in the *New Statistical Account* (p. 367) as a thin mossy or spongy layer is as true today as when it was written in 1845. The use of turf as a domestic fuel is probably a reasonable explanation of the present state of affairs. Alternatively, they may have been humus-iron podzols with an iron pan whose characteristic thick fibrous, surface organic L and F horizons have been compressed following deforestation. On the lower, coastal ridge, the soils are podzols some of which have profiles disturbed by cultivation. Thin iron pans are less common there than on Mount Eagle.

Whereas the mapping of this series has been restricted to the area described above, similar soils can be found locally near rock outcrops throughout the

Black Isle, generally as minor components of the Allangrange and the Brucefield Series.

Two profiles of the Mount Eagle Series are described below; the first is shallow and cultivated, and the second is developed on thin drift.

Profile description		St Martins (analysis No. 14, p. 112)
Site		Field on north side of B9163 road just west of St Martins Mains
Nat. Grid. Ref.		NH 638635
Altitude		100 metres
Topography		gentle 2° slope just off the crest of the coastal ridge
Drainage Class		free
Horizon	*Depth*	
Ap	0-22 cm	Very dark greyish brown (10YR3/2) sandy loam; weak crumb; friable and loose; common stones up to 10 centimetres; grass roots abundant; worms present; moist; no mottles; sharp change into
Bhs	22-25 cm	Very dark brown (10YR2/2) humose sandy loam with patches of dark yellowish brown (10YR4/4); weak crumb; friable and loose; few stones; common grass roots; worms present; moist; no mottles; sharp change into
Bf	25 cm	Root mat overlying strong, thin iron pan.
B(x)	25-38/46 cm	Yellowish brown (10YR5/4) sandy loam; weakly indurated; stones common; roots penetrate only in occasional soft patches; moist; no mottles; colour becomes gradually paler towards the base ; sharp change into
R	38/46 cm +	Yellowish brown sandstone.

Profile Description		Mount Eagle No. 1 (analysis No. 15, p. 113)
Site		0.8 kilometres east of the summit of Mount Eagle
Nat. Grid. Ref.		NH 658589
Altitude		215 metres
Topography		gentle slope just off the rounded top of Mount Eagle
Drainage Class		free
Horizon	*Depth*	
F	0-3 cm	Black (5YR2/1) fibrous litter with scattered sand grains.
AB	3-8 cm	Brown to dark brown (7.5YR4/2) sandy loam, with very dark brown (10YR2/2) humose loam at the base; weak subangular blocky; common stones, including schists and occasional granite erratics and some local sandstones; roots common; no worms; moist; no mottles; sharp change into
Bs1	8-21 cm	Patchy, yellowish red (5YR5/6) and reddish brown (5YR4/4) sandy loam; weak crumb; friable and loose; common stones, as above, but percentage of sandstones increasing; roots common; no worms; moist; few rusty mottles; sharp change into
Bs2	21-33 cm	Reddish brown (5YR4/4) sandy loam; subangular blocky; slightly firm; common stones, mostly sandstones; roots common above, few below; no worms; occasional rusty mottles; sharp change into
Bx	33-61 cm	Brown (10YR5/3) sandy loam; indurated; common stones; no root penetration except where layer is replaced laterally by shattered sandstone; no worms; moist; occasional rusty mottles; clear change into
R	61 cm +	Sandstone.

FINDON SERIES

Almost 9 square kilometres of imperfectly drained soils make up this series. The soils are found mainly on the north-west and north-east slopes of Mount Eagle and in the Findon area between Mount Eagle and the coastal ridge; they are mostly imperfectly drained podzols. Thin iron pan development is quite common on Mount Eagle, though the series lies generally outside the area in which the thin iron pan is most strongly developed. Thin iron pans are uncommon in the Findon area. Some undifferentiated imperfectly drained, cultivated soils occur between 90 and 120 metres on the north-west slope of Mount Eagle, where thicker soil profiles occur, intermediate in character between the Millbuie and the Cromarty Series.

Two soil profiles of this series are described below. One is a cultivated podzol and the other an uncultivated podzol with strong, thin iron pan on upper surface of the indurated horizon.

Profile Description		Crask (analysis No. 16, p. 113)
Site		Field north of Crask near Broomtown
Nat. Grid. Ref.		NH 617612
Altitude		95 metres
Topography		undulating ground, with rock-cored mounds
Drainage Class		imperfect
Horizon	*Depth*	
Ap	0–20 cm	Dark brown (10YR3/3) sandy loam; subangular blocky; friable; common stones, mainly schists and sandstones; grass roots common to abundant; worms present; moist; no mottles; sharp change into
Bs(g)	20–33 cm	Yellowish brown (10YR5/4) sandy loam; subangular blocky; friable; common stones, proportion of sandstones increasing; roots common to few; worms present; some diffuse grey and rusty mottles; sharp change into
B(x)	33–51 cm	Brown (10YR5/3) sandy loam; weakly indurated; common stones; few roots; no worms; moist; few rusty mottles; sharp irregular change into
R	51 cm +	Sandstone.

Profile Description		Mount Eagle No. 2 (analysis No. 17, p. 114)
Site		Forestry Commission plantation 1.9 kilometres east of the summit of Mount Eagle
Nat. Grid. Ref.		NH 662593
Altitude		205 metres
Topography		gentle 2° north-east slope
Drainage Class		imperfect
Horizon	*Depth*	
AE	0–13 cm	Very dark greyish brown (10YR3/2), humose sandy loam; weak subangular blocky; friable; common stones, mostly acid schists; roots common; no worms; moist; no mottles; gradual change into
Bs(g)1	13–28 cm	Patchy, dark yellowish brown (10YR4/4–3/4) sandy loam with some darker humus staining; subangular blocky; friable; common stones, mainly sandstones and schists; roots common above, few below; moist; diffuse grey and rusty mottles; gradual change into
Bs(g)2	28–43 cm	Brown (7.5YR4/4) sandy loam; subangular blocky; common stones; few roots; no worms; moist; few diffuse grey and rusty mottles; sharp change into

Bf	43 cm	Strong thin iron pan, replaced locally by iron concretions.
Bx(g)	43–76 cm	Brown (7.5YR5/4) sandy loam; indurated; common stones; few roots penetrate the more diffuse parts of the iron pan; moist; some diffuse, grey and rusty mottles; induration decreasing at the base of the layer, 2–5 centimetres above the underlying rock; sharp change into
R	76 cm +	Pink flaggy sandstone.

CULBO SERIES

This is one of the minor series in the Black Isle, covering only about 0.3 of a square kilometre. On the slopes of Mount Eagle, gleys are restricted to small patches around springs and seepages. Between Culbokie Loch and Bog of Findon in the source area of the Newhall Burn, the sandstone rock lies close to the surface and there is a concentration of such small, wet spots, springs and hollows.

The soil parent material is coarse textured and derived from sandstones; locally, it consists of a deposit of surface wash material whose derived soils also have been mapped within the Culbo Series because of their location and limited extent. The soils range from poorly drained noncalcareous gleys to very poorly drained peaty gleys.

ETHIE ASSOCIATION

Although around 6 square kilometres in area, the soils of this association are not widespread; they are concentrated in two separate localities. The greater part is distributed over the coastal ridges of Moine gneiss between Rosemarkie and Ethie Hill, with a small patch on the detached gneiss outcrops forming Gallow Hill and the Sutors of Cromarty. The ridges rise to between 150 and 210 metres, with the valley floors occurring between 90 and 150 metres. The lowest-lying ground is the steepland above the sea cliffs; it falls below 60 metres at Learnie and 30 metres near Cromarty.

The soil parent material is a thin drift, composed largely of sandstone-derived material which has been pushed over and between the coastal ridges of acid gneiss and has incorporated a proportion of the gneiss during its passage. As a result, it has a rather variable composition. On the ridges, the deeper drift is up to 75 centimetres thick and, at this extreme, closely resembles the parent material of the Millbuie Association, except that the basal layers incorporate much gneiss and overlie rubbly gneiss rockhead. Where the drift is thin (generally 45 centimetres), the solum is reduced to a stony, sandy loam in which angular chips of gneiss predominate. The material infilling the valleys between these ridges is of a rather different nature but, in view of the variability of the drift on the ridges and the limited extent of the valleys, there is little point in subdividing this otherwise convenient geomorphological unit. Down to depths of 1.5 and 2 metres, the valley floor material is colluvial, but it is underlain probably by reddish brown till of the Cromarty Association, as evidenced by small patches of the till found locally on the ridges. Often the pH value of the colluvium is extremely high (see analyses 23 and 24), and it is probable that there were formerly small, surface deposits of marl along the valley floor between Callachy Hill and Brown Hill. Similar deposits have been found in an analogous coastal locality near Geanies, located to the north of the Black Isle on Sheet 94 (Cromarty and Invergordon).

Plate 2. *Air photograph of the western end of the Black Isle, showing Beauly in the south-west, Muir of Ord in the western centre, and the River Conon in the extreme north-west. To the north-east, there is the characteristic, kettlehole-topography of the Kinkell Complex. Between Muir of Ord and the complex, an intensely chequered pattern highlights the crofting nature of the area; the soils are mainly freely drained, shallow podzols of the Millbuie Association. North-east from Kilcoy, these podzols are mainly imperfectly drained. Around Muir of Ord and south to the Beauly Firth, there are widespread sands and gravels on which have developed freely drained podzols of the Boyndie and Corby Associations. On either side of the Beauly Firth occur large expanses of mud-flats. From Tomich to Tarradale and around Spital Shore, there are extensive, areas of undifferentiated, mineral alluvial soils, whereas further east there is only a narrow fringe of undifferentiated soils of the low raised beach. At the extreme south-east lies the afforested slopes of Gallowhill which are covered largely by freely drained podzols of the Kessock Association.* SDD Crown Copyright.

Plate 3. *Air photograph of the Black Isle from Chanonry Point to Poyntyfield, due north from Fortrose; part of the Newhall Burn is shown in the extreme north-west. The soils on the extensively afforested, broad spine are freely drained and imperfectly drained podzols of the Millbuie Association. North-east of Rosemarkie, the coastal region is occupied largely by freely drained, shallow podzols of the Ethie Association; the area is dominated by Callachy Hill, Learnie Hill and Ethie Hill, all densely afforested. In the far north, the area is characterized by deeply incised gullies and by imperfectly drained soils developed on undifferentiated solifluction deposits whereas to the north-east the dominant soils are imperfectly drained podzols of the Cromarty Association. Apart from an outlier of till of the Cromarty Association around Killin, most remaining areas are covered by the widespread podzols of the Millbuie Association.* SDD Crown Copyright.

Most of the soils of this association are freely or imperfectly drained. The freely drained soils of the Ethie Series, which constitute over 70 per cent of the association area, are podzols. The imperfectly drained soils of the Gallow Series are divided into two groups; the hillslope soils are imperfectly drained podzols, whereas those developed on the valley colluvium are generally undifferentiated, imperfectly drained soils; pH values over 7 have been recorded in the lower half of a cultivated profile belonging to the latter group. The poorly drained soils of the Learnie Series, which form only about 5 per cent of the association, include both noncalcareous and calcareous gleys, the latter occurring in those valley floors which are believed to have contained small surface accumlations of marl.

ETHIE SERIES

The freely drained soils of the Ethie Series cover rather less than 4.5 square kilometres and occur between Cromarty and Rosemarkie; their distribution is virtually that of the association as a whole. The series is best developed on the summits and side slopes of the two parallel, discontinuous, coastal ridges between Ethie and Rosemarkie. The soils formed on deeper drift tend to be iron podzols with yellowish brown to brown B horizons, whereas the shallower soils with dark brown, or dark reddish brown to brown, Bh horizons are nearly equivalent to humus-iron podzols as described by Kubiena (1953). Naturally, the thin iron pan is not a feature of the soils of this series, and the raw humus is as scanty in this series as in any of the other semi-natural soils of the Black Isle. The surface organic horizon usually consists of 5–8 centimetres of litter and black, fibrous raw humus, with occasionally a trace of well-decomposed humus near the base. These surface organic layers are underlain by an E horizon from 5–15 centimetres thick. Despite variations in colour from light greyish brown to dark reddish brown, the actual percentage of organic matter in the E horizon is higher in the humus-iron podzol than in the iron podzol. Below the E horizon the shallow humus-iron podzol has a friable Bh horizon, 25–40 centimetres thick, which is dark brown or dark reddish brown above gradually becoming brown at the base where the solum merges into shattered rock. In the iron podzol, the yellowish brown Bs horizon may be thin and underlain by a paler, indurated Bx horizon below which the shattered gneiss occurs.

Four profiles of this series are described below. Two from Callachy Hill represent, respectively, an iron podzol (Profile 18) and a shallow humus-iron podzol (Profile 19). The third is a cultivated soil of this series with a shallow solum, and the fourth profile is a shallow humus-iron podzol from a roadside quarry section near the Sutors of Cromarty. It is noteworthy that in the E and upper part of the B horizons of the last profile, total phosphate, exchangeable potash and calcium values are appreciably higher than in any of the other semi-natural profiles of this series. This may be attributed partly to differences in altitude and leaching, but perhaps also to the more concentrated deposition of guano by sea-birds around Cromarty; the cultivated profile at Hillockhead, although containing rather more total phosphate and exchangeable calcium throughout the mineral solum than the Cromarty semi-natural profile, contains appreciably less exchangeable potassium. The values for the Cromarty profile have been confirmed in a duplicate profile taken nearby, but away from the quarry face.

Profile Description Callachy Hill No. 1 (Iron podzol). (analysis No. 18, p. 114)

Site	1.2 kilometres north-east of Flowerburn House
Nat. Grid. Ref.	NH 744608
Altitude	215 metres
Topography	moderate slope on south-east side of Callachy Hill
Drainage Class	free

Horizon	*Depth*	
L	0–3 cm	Undecomposed moss litter containing numerous sand grains; colonized by ants.
F	3–11 cm	Very dark brown (10YR2/2) fibrous litter containing bark fragments; abundant fine roots; litter more decomposed at base; sharp change into
E	11–16 cm	Reddish grey (5YR5/2) sandy loam, with dark humose horizontal streaks at the base; weak fine crumb; few small stones; abundant roots; no worms; moist; no mottles; sharp irregular change into
Bs1	16–30 cm	Yellowish brown (10YR5/6) and strong brown (7.5YR5/8), gritty fine sandy loam; medium crumb; few small stones; abundant roots; no worms; few rusty mottles; gradual change into
Bs2	30–36 cm	Brown to dark brown (7.5YR4/4) fine sandy loam; weak medium crumb, becoming subangular below; many stones, mainly schists and sandstones; common roots; no worms; moist; few rusty mottles; sharp irregular change into
Bx1	36–55 cm	Reddish yellow (7.5YR6/6), roughly stratified, loamy sand and sandy loam; indurated; many stones, mainly schists and sandstones; slight root mat above this layer but a few roots penetrate local soft patches; moist; no mottles; gradual change into
Bx2	55–76 cm	Reddish brown (5YR5/3) loam; indurated; many small stones, schists, sandstones and gneisses above, with gneisses becoming dominant towards the base, no roots; moist; no mottles; sharp change into
CR	76–107 cm	Rock rubble, comprising small, angular gneiss fragments with some gritty coarse sand.

Profile Description Callachy Hill No. 2 (Humus-iron podzol). (analysis No. 19, p. 115)

Site	0.8 kilometres north-east of Flowerburn House
Nat. Grid. Ref.	NH 741605
Altitude	215 metres
Topography	moderate slope on the south-east side of Callachy Hill
Drainage Class	free

Horizon	*Depth*	
L	0–3 cm	Loose litter composed mainly of moss, heather and a little grass.
F	3–6 cm	Very dark grey (5YR3/1) fibrous litter; common roots; no worms;moist; sharp change into
Ah	6–9 cm	Dark reddish brown (5YR2/2) humose sandy loam; weak crumb; loose; few small stones; common roots, no worms; moist; no mottles; sharp change into
AE	9–20 cm	Dark reddish grey (5YR4/2) humose sandy loam, black (5YR2/1) humus, and very dark reddish brown (5YR2/3) sandy loam in stratified layers 1–2.5 centimetres thick; massive, breaking to very fine crumb; few stones; roots common; no worms; moist; no mottles; sharp change into
Bh	20–30 cm	Patchy, dark reddish brown (5YR3/2) and brown (10YR5/3), humose sandy loam; weak crumb; loose; common stones; roots common to abundant; no worms; moist; gradual irregular change into

Bs	30–58 cm	Brownish yellow (10YR6/8) sandy loam with irregular patches of dark greyish brown humose sandy loam, particularly in the upper part; weak crumb; loose; abundant stones with a high proportion of gneisses; roots common; no worms; moist; sharp change into
R	58 cm +	Shattered gneiss.

Profile Description Hillockhead No. 1 (analysis No. 20, p. 115)

Site	Second field south of Hillockhead farm, on a south-south-east slope
Nat. Grid. Ref.	NH 746600
Altitude	105 metres
Topography	moderate slope on the seaward side of Brown Hill
Drainage Class	free

Horizon	*Depth*	
Ap	0–25 cm	Dark greyish brown (10YR4/2–10YR3/2 when moist) sandy loam; medium subangular blocky, breaking to fine crumb; few small stones; grass roots abundant; worms present; dry; no mottles; sharp change into
AB	25–41 cm	Greyish brown (2.5Y5/2–2.5Y3/2 when moist) sandy loam; coarse subangular blocky, breaking to fine subangular blocky; slightly firm; few small stones; common roots; worms present; dry; no mottles; sharp change into
Bs	41–48 cm	Greyish brown (2.5Y5/2–2.5Y3/2 when moist) sandy loam; subangular blocky; firm; a few small stones, including some angular gneisses; common roots; worms present; dry; few rusty mottles; sharp change into
R	48 cm +	Slightly undulating, shattered gneiss.

Profile Description Sutors of Cromarty (Humus-iron podzol) (analysis No. 21, p. 116)

Site	Roadside quarry just above the Drooping Cave
Nat. Grid. Ref.	NH 807672
Altitude	115 metres
Topography	a steeply sloping headland, about 11° at the profile site, and increasing steadily to 30° below the road.
Drainage Class	free

Horizon	*Depth*	
F	0–5 cm	Dark brown (7.5YR3/2) fibrous litter; loose; dry; roots abundant; sharp change into
E	5–18 cm	Dark brown (7.5YR3/2) humose sandy loam; crumb; loose and friable; few small gneissose stones; roots abundant; no worms; moist; no mottles; sharp change into
Bh	18–25 cm	Dark brown (10YR3/3) humose sandy loam; weak crumb; loose and friable; common stones, mainly angular gneiss chips; roots common; no worms; moist; no mottles; gradual change into
BR	25–43 cm	Brown (7.5YR4/4) fine sandy loam; subangular blocky; slightly firm: stones very abundant, almost gneiss rubble; common roots; no worms; moist, no mottles; gradual change into
R	43 cm +	Shattered gneiss.

GALLOW SERIES

The imperfectly drained soils of the Gallow Series occupy 1.3 square kilometres, with the soils distributed fairly evenly on hillslopes and in valleys. Near Cromarty, they cover most of the upper part of the Gallow Hill, and are quite well developed on the north-west and south-west slopes of Callachy Hill. The more colluvial facies of this series is present in the long, rather narrow, north-east to south-west valley between Callachy Hill and the coastal ridge.

The range in the parent material of this association has been fully discussed already (p. 31), and it remains to comment only that the Gallow Series is the sole series in which both main variations exist. Were these soils more extensive, they would justify separation into two distinct series.

The soils include imperfectly drained podzols and undifferentiated, imperfectly drained soils. On shallow sites, the trend is towards the humus-iron podzol rather than the iron podzol. Two profiles of this series are described below. The first, from Kinnock, is representative of the podzols of the hillslopes. The surface humus layers above the E horizon are similar to those of the Ethie Series, but there is an increasing tendency for an H layer to replace the lower part of the fibrous F layer. The E horizon may indicate the repodzolization of a shallow, formerly ploughed, surface layer after the planting of trees; the site is now rough grazing ground. The high loss on ignition and the high percentage organic matter figures in the upper part of the B horizon suggest a humus-iron podzol, in which the development of a thin, discontinuous iron pan may be, at least partially, responsible for the accumulation of organic matter. A thin iron pan, however, is generally not a feature of this series, and the development in this profile is not sufficiently advanced to impede roots.

The second profile is a cultivated, colluvial soil from Hillockhead farm. This soil is remarkable for a steady increase in pH value down the profile, pH 7 being exceeded below 90 centimetres.

Profile Description		Kinnock (analysis No. 22, p. 116)
Site		Cut woodland 0.8 of a kilometre south-south-west of Kinnock farm
Nat. Grid. Ref.		NH 728587
Altitude		120 metres
Topography		moderate slope on east side of the Rosemarkie Burn
Drainage Class		imperfect
Horizon	*Depth*	
F	0-3 cm	Fibrous litter with abundant roots.
FH	3-8 cm	Dark reddish brown (5YR3/2) humus; fine subangular blocky to fine crumb; abundant fine roots; clear change into
AE	8-23 cm	Greyish brown, (10YR5/2) to dark greyish brown (10YR4/2) sandy loam; medium to coarse subangular blocky; firm; few stones; common roots; clear change into
Bh(m)	23-28 cm	Dark reddish brown (5YR3/2) humose sandy loam; medium to coarse subangular blocky; firm; occasionally cemented; few stones; sharp irregular change into
Bf	28 cm	Discontinuous, thin iron pan.
Bs(g)	28-44 cm	Brown (7.5YR4/4) gritty sandy loam; medium subangular blocky; common stones; common fine roots; moist; strong brown and dark reddish brown, irregular mottles; sharp change into
Bx	44-51 cm +	Brown (7.5YR4/4) gritty loamy sand; strongly indurated with localized thin iron pan on upper surface; common stones; no roots.

Profile Description	Hillockhead No. 2 (analysis No. 23, p. 117)
Site	Roadside field north-west of Hillockhead farm
Nat. Grid. Ref.	NH 742604

Altitude		145 metres
Topography		moderate slope with a south-eastern aspect slopes
Drainage Class		imperfect

Horizon	*Depth*	
Ap	0-23 cm	Dark greyish brown (10YR4/2) sandy loam; medium subangular blocky, breaking to fine crumb; few small stones, mainly schists, gneisses and sandstones; roots abundant; worms present; moist; few fine, dark yellowish brown (10YR4/4) mottles; sharp change into
A	23-64 cm	Dark greyish brown (10YR4/2) sandy loam; weak coarse subangular blocky, breaking to fine crumb above, and fine subangular blocky below; few stones; roots common above, becoming few below; vertical worm channels present, generally 8-10 centimetres apart; moist; dark yellowish brown (10YR4/4) and yellowish brown (10YR5/8) mottles; gradual change into
Bs(g)	64-109 cm	Dark greyish brown (2.5YR4/2) merging down into olive-grey (5Y4/2) sandy loam; weak coarse subangular blocky, breaking to fine subangular blocky; few stones above but becoming common below 90 centimetres; no roots; worm channels present; moist; light olive-brown (2.5Y5/4) and olive (5Y5/6) mottles; sharp change into
BC(g)	109-117 cm	Brown (10YR5/3) sandy loam; massive; slightly firm; common stones, mainly of schists, gneisses, and sandstones; no roots; no worms; moist; few yellowish brown (10YR5/8) mottles; gradual change into
C	117-137 cm +	Yellowish brown (10YR5/4) coarse sandy loam; massive; common stones; no roots; no worms; moist; few yellowish brown (10YR5/6) mottles.

LEARNIE SERIES

With an area of about 0.3 of a square kilometre, this is a minor series, and is, for the most part, developed in wet colluvium on valley floors. The soil parent material has a high base status and probably overlies reddish brown till of the Cromarty Association at some depth. This material is closely allied to the valley floor deposits which have been included within the category of soils developed on undifferentiated solifluction deposits.

The soils include noncalcareous gleys, calcareous gleys and, very locally, peaty gleys. The only profile of this series sampled comes from Hillockhead farm. The site is on the valley floor, on old pasture studded with patches of *Juncus effusus*; pH 7 occurs above 50 centimetres, and pH 8 is exceeded below 90 centimetres from the surface.

Profile Description		Hillockhead No. 3 (analysis No. 24, p. 117)
Site		Valley floor between Hillockhead farm and Callachy Hill
Nat. Grid. Ref.		NH 743603
Altitude		140 metres
Topography		flat valley floor
Drainage Class		poor

Horizon	*Depth*	
Ah	0-3 cm	Root mat of *Juncus* and grass roots in brown (10YR5/3) sandy loam; fine crumb; some yellowish brown (10YR5/8) mottles around the roots.

Ap	3-18 cm	Brown (10YR5/3) sandy loam; coarse subangular blocky; few small stones, mainly schists, gneisses and sandstones; grass and *Juncus* roots common; occasional worms; moist; strong yellowish brown (10YR5/8) mottles around root channels; sharp change into
Bg	18-41 cm	Yellowish brown (10YR5/8), brownish yellow (10YR6/8), light yellowish brown (10YR6/4), and pale brown (10YR6/3) coarse sandy loam; coarse prismatic, breaking to weak coarse subangular blocky; stones common, mostly soft, rotten sandstones with some hard schists and gneisses; few roots; no worms; moist; ochreous mottles dominate the horizon; sharp change into
BCg	41-69 cm	Greyish brown (10YR5/2) sandy loam; very weak prismatic, breaking to weak coarse subangular blocky; common stones; few live roots; no worms; moist; some yellowish brown (10YR5/8) mottles; ochreous-stained root channels penetrate about 13 centimetres into this layer; sharp change into
Cg1	69-79 cm	Greyish brown (10YR5/2) loam speckled with brown (10YR5/3); massive; firm; common stones; no live roots, but the pores of dead rootlets have occasional very fine, yellowish brown mottles around them; gradual change into
Cg2	79-91 cm	As above horizon but becoming steadily wetter; old tree roots preserved in a soft damp condition from 79 centimetres to the base of the profile.
Cg3	91-132 cm +	Dark greyish brown (2.5Y4/2) to olive-grey (5Y4/2) sandy loam, becoming dark grey (5Y4/1) to olive-grey (5Y4/2) below 120 centimetres; below 120 centimetres the soil is wet and plastic.

KESSOCK ASSOCIATION

This is a distinctive, though not an extensive, association. The soils are distributed over about 5 square kilometres of steep, conglomerate ridges in the south-eastern parts of the Black Isle between Redcastle and Avoch. The coastal ridge fronting the Moray Firth is aligned north-east to south-west from Wood Hill to the Ord Hill by Kessock. Its crest rises gradually from 110 metres in the north-east to 170 metres above Kessock, and its tree-clad outline is dented only by the inlet of Munlochy Bay. A parallel, inner ridge runs from the Ord Hill on the north side of Munlochy Bay via Drumderfit Hill to Drumsmittal Hill. Further west, behind Redcastle, the more rounded, solitary mass of Gallow Hill reaches 150 metres.

The soil parent material is mainly a thin, coarse-textured, semi-residual drift, derived locally from the Middle Old Red Sandstone conglomerates. The drift has been largely eroded from the ridge-tops, leaving a veneer of soil broken by frequent, small, conglomerate outcrops. Around the slopes, it has accumulated as a rather thick colluvial mantle. The rock forming the ridge is a hard, brown or greyish brown, pebbly conglomerate distinctively different from the softer, redder conglomerates which form the parent rocks of the Tynet Association in Morayshire, but closely analogous to that found north of the Cromarty Firth, on Cnoc Fyrish near Evanton.

Most of the soils are freely drained podzols and have been placed in the Kessock Series. The remainder, which are imperfectly drained podzols, forms the Redcastle Series.

KESSOCK SERIES

This series accounts for 95 per cent of the association and is well developed on every conglomerate hill within the Avoch–Redcastle–Kessock– triangle.

On the ridge-tops the mineral soil is extremely shallow. Hard conglomerate rock often occurs within spade depth and is rarely more than 35 centimetres below the surface. On the side slopes there may be 35–50 centimetres of mineral soil and sometimes rather more; tree growth, particularly on the south-east slopes, is better than average for the Black Isle.

Most of the soils are semi-natural; a considerable proportion is now under planted woodland and only Drumderfit Hill is extensively cultivated, though there are some small crofts on the lower slopes of other ridges. The typical ridge-top soil has about 7.5 centimetres of litter and very dark brown to black, fibrous humus overlying an AE horizon which comprises about 8 centimetres of dark greyish brown, humose sandy loam. These AE horizons may directly overlie the conglomerate rock, but usually there is a limited development of a dark yellowish brown to dark brown sandy loam B horizon between the AE horizons and the solid rock. On the ridge-sides the A horizons are similar, but the Bs horizon may be 30–40 centimetres thick. Only occasionally is there an indurated B horizon above the rock. The description of a profile from Ord Hill follows.

Profile Description		Ord Hill–North Kessock (analysis No. 25, p. 118)
Site		Forestry Commission plantation on north-west slope of Ord Hill near Kessock
Nat. Grid. Ref.		NH 658487
Altitude		135 metres
Topography		steep ridge
Drainage Class		free
Horizon	*Depth*	
L	0–3 cm	Dark brown (7.5YR3/2) pine-needle litter.
F	3–8 cm	Dark brown (7.5YR3/2) litter with common heather roots.
E	8–21 cm	Very dark greyish brown (10YR3/2) sandy loam; massive; few stones; common roots; no worms; moist; no mottles; sharp irregular change into
Bhs	21–31 cm	Dark yellowish brown (10YR4/4) sandy loam; weak crumb; loose; common stones; common roots; no worms; moist; some patchy, dark humus staining; gradual change into
Bs	31–41 cm	Strong brown (7.5YR5/6) sandy loam; weak crumb; loose; common stones; common roots; no worms; moist; no mottles but some humus staining; sharp change into
Bh	41–54 cm	Brown to dark brown (7.5YR4/4) sandy loam; weak crumb; loose; common stones; roots common to few; no worms; moist; strong humus staining at the base; sharp irregular change into
R	54 cm +	Conglomerate.

REDCASTLE SERIES

This imperfectly drained series is restricted to a few small ridge-tops on Gallow Hill, Drumderfit Hill, and the coastal ridge, together with minor gullys and areas of seepage. The soils are generally shallow, and the drainage impedance results from the shallow, impervious conglomerate.

A profile excavated on the coastal ridge-top, overlooking Loch Lundie, is described below.

Profile Description	Lundie (analysis No. 26, p. 118)
Site	Cut-over pinewood, now covered by heather, grass, mosses and birch scrub

Nat. Grid. Ref.	NH 672503
Altitude	120 metres
Topography	flat-topped coastal ridge
Drainage Class	imperfect

Horizon	*Depth*	
L	0–2 cm	Dark brown (7.5YR3/2) litter.
F	2–8 cm	Black (5YR2/1) fibrous litter; abundant roots; sharp change into
E	8–9 cm	Very dark greyish brown (10YR3/2), humose loam; massive; no worms; moist; no mottles; sharp change into
Bs(g)	9–31 cm	Yellowish brown (10YR5/4) sandy loam; coarse subangular blocky; common stones, mainly conglomerate pebbles, schists, and sandstones; few roots (locally common in pockets, generally following course of rotted tree roots); no worms; strong brown (7.5YR5/6) mottles; sharp irregular change into
R	31 cm +	Conglomerate.

CORBY ASSOCIATION

This is a minor association occupying less than 4 square kilometres. The main part lies around Muir of Ord, with isolated areas along the southern coastline from Tarradale to Kessock.

The soils are developed on fluvioglacial gravels. These gravels are mainly moundy, with interspersed, wet peaty hollows on the north side of Muir of Ord, but extend for 1.6 kilometres or more to the south as a terraced flat with peat-infilled kettle-holes. The bulk of the gravels lies between 30 and 40 metres, with some mounds around the town reaching 45 metres. The discontinuous, terraced mounds, which extend along the coastline, generally lie between 8 and 25 metres but rise locally to about 45 metres and 60 metres near Kessock and Redcastle respectively.

Elsewhere within the Black Isle, fluvioglacial gravel deposits are extremely scarce and, though of no significance as soil parent materials, they are of local importance as sources of road-surfacing and building material. The known localities on the south side of the Black Isle include two elongated mounds in woodland about 0.8 kilometres south-west of Rhives farm at 70–90 metres, a single small mound in the valley south of Flowerburn Hill about 1.6 kilometres north-west of Rosemarkie at around 105 metres, a single mound at Muirhead farm 6 kilometres south-west of Cromarty at around 135 metres and a single mound 0.8 kilometres west of Tore at around 105 metres (on the north side of the B9162 road), now completely quarried away. On the north side, there are perhaps a dozen small gravel mounds strung out along the valley floor between Newmills and St Martins Mains at 40–70 metres.

Most of the soils are freely drained and have been included within the Corby Series. Imperfectly drained and poorly drained soils are grouped in the Leys and Mulloch Series respectively; both are of negligible extent with areas of less than 0.3 of a square kilometre. Most of this association has been cultivated, but in the semi-natural state the freely and imperfectly drained soils appear to have been humus-iron podzols. Owing to their limited extent, both poorly drained noncalcareous gleys and very poorly drained peaty gleys have been included within the Mulloch Series on the 1:63 360 soil map.

The soils of this association have long been cultivated wherever this was practicable, but at the present-day the flat land south of Muir of Ord is being developed increasingly for industrial use.

CORBY SERIES

The distribution pattern of the Corby Series is essentially that of the association as a whole. The parent material grades from mounds of poorly sorted coarse gravel on the north side of Muir of Ord to well-sorted, stratified gravels on the flat land to the south. These become increasingly interlayered with beds of coarse sand, and between Gilchrist Farm and Tarradale House merge gradually into outwash sands with gravel layers and lenses. The stones are mostly acid schists and quartzites with a small proportion of granites and granitic gneisses, and a few sandstones. The proportion of sandstones remains small, but is appreciably greater in the gravels near Kessock than in those near Muir of Ord.

The arable soils have a plough layer commonly 20–25 centimetres thick, but extending to 30 centimetres or more in some places. The shallower, cultivated soils are generally associated with an iron podzol profile with a strong brown Bs horizon, whereas the deeper soils are mainly humus-iron podzols with a darker brown, cemented, though permeable, B horizon.

The iron podzol usually has a strong brown to yellowish brown Bs horizon 15–20 centimetres thick, though this horizon shows considerable local variation in thickness; it may be friable or may show slight cementation in profiles intermediate between the iron podzol and the humus-iron podzol. The Bs horizon is, in turn, underlain by a yellowish brown to brown cemented Bm horizon 25–30 centimetres thick. There is usually a fairly rapid transition, below the cemented layer, into brown, loose, coarse sandy gravel.

The humus-iron podzol likewise has loose gravel at a similar depth below the surface. The B horizon is dark and cemented. Its colour ranges from dark brown, with very dark brown patches immediately below the Ap horizon, to brown and dark yellowish brown 13–15 centimetres lower down.

The humus-iron podzol described below is a soil formerly cultivated and now supporting an old grassland vegetation including *Agrostis canina, Anthoxanthum odoratum, Dactylis glomerata, Festuca ovina, Poa pratensis, Brachythecium rutabulum, Mnium undulatum, Pseudoscleropodium purum, Rhytidiadelphus squarrosus,* and scattered *Sarothamnus scoparius.*

Profile Description		Gilchrist (analysis No. 27, p. 119)
Site		Gravel pit on west side of B9169 road almost opposite Gilchrist farm access road
Nat. Grid. Ref.		NH 535494
Altitude		30 metres
Topography		gravel flat with kettleholes
Drainage Class		free
Horizon	*Depth*	
Ap	0–25 cm	Dark reddish brown (5YR2/2) humose sandy loam; fine crumb; very loose and friable; common stones; abundant fibrous roots; moist; no mottles; sharp change into
Bh	25–28 cm	Dark reddish brown (5YR3/2) sandy loam; weak medium subangular blocky: slightly firm; common stones; common roots; sharp change into
Bhm	28–41 cm	Brown to dark brown (10YR4/3) and very dark greyish brown (10YR3/2) loamy coarse sand; weak medium to coarse subangular blocky; cemented; abundant stones; common to few roots; moist; no mottles, but dark reddish brown to very dark grey (5YR3/2 to 3/1) humus staining of silt coatings on upper surfaces of pebbles; gradual change into

Bsm	41-64 cm	Dark brown (10YR3/3) and dark yellowish brown (10YR3/4 and 4/4) loamy coarse sand; cemented but with local darker, soft patches; abundant stones; few roots; no mottles but some possible manganese staining at 53-61 centimetres; gradual change into
C1	64-117 cm	Brown (10YR5/3) coarse sandy gravel; single grain; loose; no roots; moist; sharp change into
C2	117- 124 cm +	Yellowish brown (10YR5/4), slightly iron-stained, coarse sandy gravel.

LEYS AND MULLOCH SERIES

Neither of these series is of any practical importance as each occupies an area of less than 0.3 of a square kilometre.

The Leys Series comprises imperfectly drained podzols, and is restricted on the 1:63 360 soil map to two small patches lying about 1.6 kilometres west of Kessock. The profile is similar to that of the Corby Series but has variable amounts of rusty mottling in the Bs horizon, which is generally rather less bright than the corresponding horizon in the freely drained soil. Cementation in the lower B horizon is less intense or absent, and there may be a little rusty mottling.

The Mulloch Series includes poorly drained noncalcareous gleys and some peaty gleys which the latter, had they been more extensive, would have been distinguished as the very poorly drained Mundurno Series. All these soils are found in depressions and kettleholes, and where the water-table is high near the edge of the gravels. The characteristic grey, or grey and rusty mottled, subsoils are often indicative of improved, former peaty gleys.

BOYNDIE ASSOCIATION

This association is limited to 1.3 square kilometres of outwash sands, the greater part being found about 2.5 kilometres south-east of Muir of Ord between Bellevue and Tarradale House. There are also some patches along the sides of the alluvial hollow running eastwards from Allangrange House into Munlochy Bay.

The soil parent material is fluvioglacial sand, or slightly stony sand, with occasional layers and lenses of gravel.

Three series have been distinguished, the freely drained Boyndie Series, the imperfectly drained Anniston Series and the poorly drained Dallachy Series. The soils of the Boyndie Series are humus-iron podzols and iron-podzols generally modified by cultivation. The soils of the Anniston Series are similar, but have slightly gleyed B horizons. The Dallachy Series includes noncalcareous gleys.

BOYNDIE SERIES

This is the dominant series in both the Tarradale and Munlochy areas, and most of the soils have thick surface horizons which have been improved to a depth of 45 centimetres, or more. The humus-iron podzol is more common than the iron podzol, though the dark brown humus-iron B horizon is frequently very weakly compacted in contrast with the strongly cemented Moray pan which is a feature of this series on Sheet 96 (Elgin) (Grant, 1960).

A typical profile is described below.

Profile Description		Bellevue (analysis No. 28, p. 119)
Site		Second field north-east of Bellevue
Nat. Grid. Ref.		NH 545489
Altitude		25 metres
Topography		gentle slope
Drainage Class		free
Horizon	*Depth*	
Ap	0-53 cm	Dark brown (7.5YR3/2) sandy loam to loamy sand; medium subangular blocky, breaking to fine subangular blocky and single grain; loose; few schist stones; common roots; worms present; moist; no mottles; sharp irregular change into
Bh	53-66 cm	Patchy, dark brown (10YR3/3 and 4/3) and dark yellowish brown (10YR4/4) loamy sand; weak medium subangular blocky, breaking to fine subangular blocky and single grain; loose; few stone; few roots; worms present; moist; no mottles; sharp change into
Bs	66-81 cm	Yellowish brown (10YR5/6) loamy sand to sand; very weak medium to fine subangular blocky, breaking readily to single grain; few stones; few roots; dark brown, vertical, worm channels present; moist; no mottles; sharp change into
C	81-109 cm +	Brown (10YR5/3) coarse sand; single grain; few stones; few roots to about 90 centimetres; no worms; moist; no mottles.

ANNISTON AND DALLACHY SERIES

Both these series are present in the Tarradale–Bellevue area but are not extensive.

The imperfectly drained soils of the Anniston Series are similar to those of the Boyndie Series, with a thick, cultivated surface layer overlying a rather paler B horizon in which there is some rusty mottling. The gleying may be due to the thinning-out of the sand deposit over an impervious substratum, or to the local concentration of a lateral seepage. The poorly drained Dallachy Series has been mapped only in a narrow strip along the edge of the raised beach at Bellevue where it has been used to accommodate outwashed sand which overlies the estuarine silty alluvium of the River Beauly.

SOILS DEVELOPED ON UNDIFFERENTIATED SOLIFLUCTION DEPOSITS

With an area of just over 8 square kilometres, this rather variable group of soils is the fourth largest in the Black Isle. They occur mostly along the lower valley slopes of the Newhall and Ethie Burns, though there is an eastward extension from the south bank of the Newhall Burn along the coastal slopes behind Jemimaville.

In the Newhall Burn area, the soils extend from an altitude of about 85 metres near Kinbeachie Loch to the cliff-top at the back of the low raised beach facing the Cromarty Firth. Along the Ethie Burn they lie between about 90–150 metres.

The soil parent material is derived from deposits of supraglacial material, moraine, and till of the Cromarty Association, with some incorporation of high raised beach deposits along the slopes above of the Cromarty Firth. The source rocks of all these superficial materials are, in the main, of Middle Old Red Sandstone age.

The material is generally coarse in texture, and rather vaguely stratified, with occasional better-defined bands and lenses of sandy material. The thickness of coarse material varies from about 35 centimetres at the upslope boundary to 0.9–1.2 metres along the valley floor. It is usually underlain by till of the Cromarty Association. Closely analagous parent materials south of the Moray Firth, and also derived from Old Red Sandstone strata, form the Brightmony Association; where the parent material is derived from Moinian strata, the derived soils are accommodated within the Dulsie Association.

The soils have been separated into imperfectly drained, poorly drained and very poorly drained categories. On the north side, in the valley of the Newhall Burn, most of the soils are imperfectly drained, and are cultivated. Small areas of poorly drained gleys have been distinguished near Newhall House, and occasional freely drained profiles occur on the slopes east of Newhall in the vicinity of the B9160 road; the latter are developed probably on patches of high raised beach sandy material. The valley of the Ethie Burn is much wetter, and poorly drained gleys are common; these are interspersed with small patches of very poorly drained peaty gleys distinguishable by their black organic surface horizons. In the outfall area of the valley, east of Bannans farm, the Ethie Burn channel is deeply incised and the fringes of the solifluction soils are imperfectly drained. The south-eastern part of the Ethie valley is in woodland and rough grazing, whereas the north-eastern part is mostly cultivated; recently, considerable improvements in land drainage have been effected in the latter area.

Over 85 per cent of these soils have been distinguished as imperfectly drained, and the rest are, for the most part, poorly drained. The areas of very poorly drained soils occupy less than 0.3 of a square kilometre.

Two profiles, one imperfectly drained and the other poorly drained, are listed below.

Profile Description		Braelangwell (analysis No. 29, p. 120)
Site		Grass field north-west of Braelangwell Mains, between the Braelangwell and Newhall Burns
Nat. Grid. Ref.		NH 690648
Altitude		30 metres
Topography		smooth, gentle slope 1° to 2°
Drainage Class		imperfect
Horizon	*Depth*	
Ap	0–28 cm	Brown to dark brown (7.5YR4/2) sandy loam; coarse subangular blocky; common stones, mostly hard schist erratics; common roots; worms present; moist; no mottles; sharp change into
Bs(g)1	28–36 cm	Pale brown (10YR6/3), greyish brown (10YR5/2), brown (10YR5/3) and yellowish brown (10YR5/4) loamy sand; weak coarse subangular blocky; firm; few stones; few roots; few dark brown worm channels; moist; greyish and yellowish brown mottles; sharp change into
Bs(g)2	36–64 cm	Light reddish brown (5YR6/4), brown (7.5YR5/4) and strong brown (7.5YR5/6) sandy loam to loamy sand; weak medium and coarse subangular blocky; common stones; few roots; no worms; moist; stong brown mottles which increase in size and frequency below 50 centimetres; sharp change into
C1	64–69 cm	Reddish brown (5YR5/4) loamy coarse sand; massive, slightly firm; no stones; no roots; no worms; moist; no mottles; sharp change into
C2	69–91 cm	Reddish brown (5YR5/4) roughly stratified, stony sandy loam and loamy sand; massive; common stones; no roots; no worms; moist; no mottles; gradual change into

C3	91–117 cm	Brown (7.5YR5/4) and light brown (7.5YR6/4) loamy coarse sand; massive; common stones; no roots; no worms; very moist *with water flowing from base of the horizon*; no mottles; sharp change into
C4	117–124 cm +	Reddish brown (5YR5/3) sandy loam to loam till of the Cromarty Association.

Profile Description — Muirhead (analysis No. 30, p. 120)

Site	Grass field immediately south-west of farm steading
Nat. Grid. Ref.	NH 753627
Altitude	130 metres
Topography	flat valley bottom with local, slight undulations
Drainage Class	poor

Horizon	*Depth*	
Ap	0–25 cm	Very dark greyish brown (2.5YR3/2) sandy loam to loamy sand; medium to coarse subangular blocky; common stones, mostly hard schists; roots common to abundant; worms present; moist; slight rusty mottles around roots; slight tendency for roots to form a mat on top of stones; sharp change into
Bg1	25–56 cm	Pale brown (10YR6/3) and light brownish grey (10YR6/2) loamy sand; weak coarse prismatic; few stones becoming common below 35 centimetres; few roots; a few worm channels; moist; occasional yellowish brown mottles; gradual change into
Bg2	56–84 cm	Light brownish grey (10YR6/2) and yellowish brown (10YR5/4) sandy loam; massive; common stones; few roots in upper 15 centimetres; no worms; moist, water seeping into profile pit at 65 centimetres; few yellowish brown mottles and ochreous staining around dead root channels; sharp change into
Cg	84–107 cm +	Light reddish brown (5YR6/4) and reddish yellow (5YR6/6) sandy loam; massive; common stones; no live roots; no worms; wet; strong reddish yellow mottles.

SOILS DEVELOPED ON ALLUVIUM

On the 1:63 360 soil map, alluvial soils cover rather less than 10 square kilometres, or some 3.5 per cent of the area of the Black Isle.

These soils have not been differentiated by texture, parent material, or degree of natural drainage, and they include those developed on small patches of silty estuarine alluvium at the western end of both the Beauly and the Cromarty Firths.

The largest individual patch of alluvial soil lies along the floor of a channel running from Allangrange House down to the head of Munlochy Bay; this channel continues in a north-east direction from the 100-foot (30-metre) level at Munlochy, past the site of Rosehaugh House, turning sharply south-eastwards through the coastal ridges to reach the sea at Avoch. Other parcels of alluvial soils are much smaller, and generally occupy long, narrow, north-east to south-west aligned strike hollows formed by glacial erosion of the underlying Middle Old Road Sandstone rocks. Most of the alluvial soils occur below 140 metres except for the small, silted-up kettleholes within the Kinkell Complex; many more are found south of the central ridge than north of it.

The soils are generally coarse or moderately coarse, ranging in texture from loamy sand to sandy loam and have been formed from parent materials derived from Middle Old Red Sandstone rocks. Localized patches with silty loam to silty clay textures occur amongst the coarser deposits in the Allangrange–Avoch channel, and occasionally elsewhere. At least two occurrences of finely laminated glacial silt exist. One of these recorded by the

Geological Survey as a potential brick clay (Eyles *et. al.*, 1946), is a reddish brown silty clay on the north side of the Rosehaugh–Avoch channel. The other is a very small patch of compact, laminated, brownish yellow silty clay loam in a waterpipe trench just outside the south-western border of the kettlehole complex at an altitude of about 150 metres (National Grid Reference NH 571528). This yellow deposit is of very limited extent, but has been probed with an auger to a depth of 3.6 metres.

The soils are mainly poorly drained mineral alluvial soils; most are noncalcareous, though locally, where small deposits of marl occur or were formerly present, they may be calcareous. A very high percentage of these soils is under cultivation, and the present drainage status reflects the management of the local water-table.

In Sinclair's *The Statistical Account of Scotland* (vol. 12, 1794) Mr Mackenzie of Allangrange, one of the local pioneers in land reclamation, is described as having 'recovered from 70 to 80 acres from a perfect morass', and in the *New Statistical Account* (vol. 14, 1845) it is noted that 'at Munlochy, similar improvements, to be executed by the tenant have been conditioned for on the renewal of leases, at rents proportionally moderate, . . . on conditon of his bringing into cultivation about twenty acres of wet land, at present lying waste, and of reclaiming from the sea, by raising proper embankments, between thirty and forty acres of excellent carse land'.

The improvement of alluvial soils in the Black Isle must date from that period, and the high standards achieved by the pioneering improvers are confirmed when inspection holes dug in the Allangrange–Munlochy area are compared with those in the scattered and smaller alluvial troughs. In the Allangrange–Munlochy area, about 70 per cent of the surface horizons were found to be between 20–30 centimetres thick with about 30 per cent between 35–60 centimetres. Elsewhere in the Black Isle, the comparable percentages are about 90 per cent and 10 per cent.

Two profiles are described below. The first, from Rosehaugh Estate, is typical of the widespread, coarser-textured material; similar poorly drained alluvial soils recorded subsequently on the 1:63 360 soil map of Cromarty and Invergordon (Sheet 94) were included within the Rockfield Series. The other profile is from the small patch of fine-textured, browish yellow, glacial silt found near the boundary south-west of the Kinkell Complex, and is similar to soils included subsequently within the Shandwick Series.

Profile Description		Rosehaugh (analysis No. 31, p. 121)
Site		Centre of Rosehaugh alluvial channel 0.8 kilometres south-west of Rosehaugh Mains
Nat. Grid. Ref.		NH 673547
Altitude		30 metres
Topography		flat alluvial channel
Drainage Class		poor
Horizon	*Depth*	
Ap	0–30 cm	Dark brown (10YR3/3) sandy loam; medium subangular blocky, breaking to fine crumb; few small stones; grass roots abundant; worms present; moist; no mottles; sharp change into
(B)gl	30–46 cm	Yellowish brown (10YR5/4) and dark yellowish brown (10YR4/4) loamy sand; weak subangular blocky; few medium, occasionally very large, stones; few roots; worms present; moist; greyish brown (10YR5/2) and strong brown (7.5YR5/8) mottles; sharp change into

(B)g2	46–61 cm	Strong brown (7.5YR5/6) sandy loam and very dark brown (10YR2/2) humose silty sandy loam; massive and stratified; few stones; no live roots; no worms; moist to very moist; greyish brown (10YR5/2) and strong brown mottles in the lighter-coloured bands; sharp change into
Cg1*	61–81 cm	Brown (10YR5/3) loamy coarse sand; massive; no stones; no live roots; no worms; moist to wet; well-developed, yellowish red (5YR4/6) vertical pipes around old root channels; sharp change into
Cg2	81–94 cm+	Greyish brown (10YR5/2) loamy coarse sand; massive; no stones; no live roots; wet; weakly developed, yellowish red pipes around old root channels in the upper part only.

* Formerly part of the permanently waterlogged subsoil, now exposed to intermittent oxidation following effective field drainage.

Profile Description Newton of Ferintosh No. 114 (analysis No. 32, p. 121)

Site	Near roadside fence of small field immediately to south-west of the farm buildings
Nat. Grid. Ref.	NH 571528
Altitude	150 metres
Topography	slight hollow
Drainage Class	imperfect

Horizon	*Depth*	
Ap	0–20	Very dark greyish brown (10YR3/2) sandy loam to loam; subangular blocky; few stones; roots common; worms present; moist; no mottles; irregular gradual change into
(B)(g)1	20–38 cm	Brownish yellow (10YR5/6) silty loam; angular to subangular blocky; no stones; common fine roots; worm channels present; moist; few grey mottles; gradual change into
(B)(g)2	38–53 cm	As above, but becoming firm; few roots; gradual change into
C	53–119 cm+	Brownish yellow (10YR6/6) silty clay loam; massive, finely laminated; firm; very few stones; no roots; no worms; moist; some greyish brown and strong brown mottles.

SOILS DEVELOPED ON MIXED BOTTOM LAND

This unit, about 6.7 square kilometres in area, includes small stream channels and gullies, the steeplands along valley sides, and cliffs. Both soil parent material and natural drainage are very variable. The soils are often immature and unstable.

The profile, quoted below, is taken from the steep, eroded south side of the Fairy Glen about 0.5 of a kilometre west of Rosemarkie; a pH value of 7.25 recorded at 20–30 centimetres below mineral ground surface is possibly an indication both of the relative immaturity of the profile and of the amount of calcium carbonate being leached and flushed from the till slopes above.

Profile Description Rosemarkie No. 1 (analysis No. 33, p. 122)

Site	South side of the Fairy Glen
Nat. Grid. Ref.	NH 731577
Altitude	45 metres
Topography	32° slope
Drainage Class	free

Horizon	*Depth*	
LF	0–2 cm	Surface litter and fibrous litter.
F	2–5 cm	Dark brown (7.5YR3/2) moderately decomposed litter with some mineral grains; abundant fine roots; sharp change into

A	5–20 cm	Dark brown (7.5YR3/2) sandy loam; subangular blocky; loose and friable; abundant stones; common roots; clear change into
BC	20–35 cm	Brown (7.5YR5/4) loamy sand; weak subangular blocky; common stones; common roots; gradual change into
C	35–58 cm +	Light reddish brown (5YR6/4), stony, sandy loam.

SOILS DEVELOPED ON RAISED BEACH DEPOSITS

Soils developed on raised beaches occupy rather more than 8 square kilometres around the Black Isle. They have been subdivided into low and high raised beach variants.

The low raised beach is very narrow and is almost continuous, except around the Sutors of Cromarty; it ranges from the present high-water mark to over 8 metres. There is quite often a slight break of slope, for 1 or 2 metres in extent, at the seaward edge, with a low cliff at the landward edge if the high raised beach is also present. On the south side of the Black Isle, where the high, rocky cliff-line leaves no lodgement for a high beach (excepting the terraced halt-moraine at Fortrose and the cliff-notches at North Kessock), the landward margin of the low raised beach is obscured intermittently beneath a deep talus.

The high raised beach is not continuous. It occurs at Redcastle, around the head of Munlochy Bay, between Fortrose and Rosemarkie, at Cromarty, south-westwards from Ferryton Point for about 5 kilometres and along the coastline north to Culbokie for about 4 kilometres The upper boundary is found usually between 15 and 30 metres and does not always coincide with that of the original beach deposits, as the latter may have been partially or completely affected by solifluction.

The soil parent materials of the high raised beaches are composed, almost invariably, of coarse sand and gravel or gravelly sand, often interbedded; large deposits of raw shingle do not occur. On the low raised beach, sandy and gravelly materials again predominate, though shingle may occur both as bars incorporated in the beach, for example, near Charlestown west of North Kessock, and as spits, for example, the small one at Kilmuir and the larger one at Chanonry Point by Fortrose. Patches of finer-textured material are not common, except at the west end of the Isle where the low raised beach merges into the estuarine alluvium around the mouths of the Rivers Beauly and Conon.

The greater part of the soils developed on the raised beaches is, or has been, cultivated, and semi-natural profiles are not available. It is evident from field inspection that the soils of the low raised beach have a relatively immature profile, whereas those of the high raised beach frequently show some development of a podzolic B horizon.

Though the soils of the raised beaches are, for the most part, freely drained, differences in natural drainage have not been delineated on the 1:63 360 soil map. Where imperfect drainage occurs on the low beach, it is usually associated with seepages from the cliff at the back of the beach, or with the transition to alluvium at the outfalls of the Rivers Beauly and Conon, of the Newhall Burn at Udale, and around the head of Munlochy Bay.

On the high raised beach, imperfect drainage occurs where the sandy beach deposits thin out and vertical drainage through the profile is impeded by an underlying, impervious platform of reddish brown till of the Cromarty Association. These conditions are found locally between Ferryton Point and Wester Cullicudden, and around the head of Munlochy Bay.

The soil profile on the low raised beach has a cultivated surface horizon which varies in thickness from 25–60 centimetres. The thicker horizons reflect earlier cultivation and improvement, and commonly occur close to centres of population, for example, at Cromarty and North Kessock. The subsoil is brown to reddish brown, roughly stratified, sandy and gravelly material with very little humus staining and a loose, single-grain structure, or is dark brown to dark reddish brown with strong colloidal humus staining of the soil fabric and weak crumb and single-grain structures. The dark-coloured, low raised beach soils are located generally on the south side of the Black Isle, but, despite their striking appearance, the humus content of the less than 2-millimetre fraction is only one per cent or less. These dark brown soils resemble brown earths and seem to be restricted to narrow fringes of low raised beach; they occur in places as far apart as Inverbervie and East Mathers on the Kincardineshire coast and Kilmory on the north side of the Island of Rhum. The subsoil pH value is usually more than 6, and the dark AB horizon may extend 0.9–1.2 metres below mineral ground surface. The development and maintenance of these soils is related probably to the steady replenishment of the soil base status in this unusual environment. Base-rich water may seep from the cliffs and talus at the back of the beach; additionally salt-spray, storm-tossed and applied seaweed, and shells may have contributed. The deposition of guano, may also be involved. When these ameliorating factors are combined on a narrow strip of beach where the annual precipitation is low, podzols are not usually developed.

The freely drained profile, described below, was taken from a low raised beach about 5 kilometres north-east of Rosemarkie. This beach was formerly used for the cultivation of potatoes, but has reverted to a rather base-rich, grassy vegetation with bracken (*Pteridium aquilinum*), bluebells (*Endymion non-scriptus*) and wild strawberries (*Fragaria vesca*), together with wild roses (*Rosa* spp.) and a few sloe bushes (*Prunus spinosa*).

Profile Description — Learnie (analysis No. 34, p. 122)

Site	Low raised beach below steep cliff at the north-east end of Learnie farm
Nat. Grid. Ref.	NH 768619
Altitude	less than 8 metres
Topography	gentle slope with a south-east aspect
Drainage Class	free

Horizon	*Depth*	
Ah	0–3 cm	A very thin bracken litter overlies dark reddish brown (5YR2/2) humose loamy sand; weak crumb to single grain; loose; no stones; common to abundant fine roots; small worms present; moist; no mottles; sharp change into
Aph	3–13 cm	Dark reddish brown (5YR3/2) humose loamy sand; very weak crumb and single grain; very few stones; common roots and some bracken rhizomes; no worms; moist; no mottles; gradual change into
Ap	13–38 cm	Dark reddish brown (5YR3/3) loamy sand; very weak crumb and single grain; very few small stones; a few fine roots and bracken rhizomes; no worms; moist; no mottles; merges into
AB	38–76 cm	Dark reddish brown (5YR3/4) loamy coarse sand; roughly stratified, some bands slighly humose; single grain with traces of very weak crumb; few angular stones; few roots and rhizomes in upper half; no worms; moist; few faint rusty mottles; gradual change into

BC	76–102 cm	Reddish brown (5YR4/4) coarse sand; single grain; common angular stones in lower half; roots apparently absent; no worms; a few rusty mottles; gradual change into
C	102–122 cm +	Reddish brown (5YR4/3) very stony coarse sand; single grain.

Soil profiles on the high raised beach usually have a thick, cultivated surface layer, which was recorded as 30 centimetres or more in 70 per cent of inspection holes in the Black Isle; the frequency rose to 100 per cent on the flat between Fortrose and Rosemarkie. Thereabout, 40 centimetres is nearer the norm, with up to 60 centimetres locally, and it is evident that these sandy, coastal soils were amongst those that attracted the earliest agricultural interest. There can be little doubt that the dark soils of the high raised beach provided a telling example of the virtues of shell lime and seaweed as fertilizers. Sinclair's *The Statistical Account of Scotland* (vol. 11, p. 336) indicates that the practice was already long established in Rosemarkie parish. 'The method of farming there, for time immemorial, has been remarkably uniform. It consists of a constant succession of barley, and though the lands be seldom or never rested, it is surprising how much they produce bearing commonly six or seven returns. When a quantity of seaware and tangle are thrown ashore (which often happens in a storm), the farmers, in spring especially, are very attentive in gathering it, and spreading it upon their land. . . . In the country part of the parish, the tenants . . . frequently sow oats in the same fields of several years running, which renders them less productive . . . about the burgh lands are rented from 30/- to 40/- per acre . . . and in the country good arable land draws from 15/- to 20/-.'

A dark brown to dark yellowish brown, somewhat cemented, B horizon is a frequent feature of soils on sandy, high raised beaches from Morayshire to the northern coastlands of Easter Ross, and the Black Isle is no exception. As on the lower raised beaches, low rainfall, and a small clay fraction low in weatherable minerals containing iron, combine to minimize the more obvious effects of leaching but in the absence of effective supplementation of the base status they cannot maintain a profile with brown earth characteristics. Such profiles may bear comparison with those of humus podzols.

The profile described below is a freely drained, cultivated soil.

Profile Description	Inch (analysis No. 35, p. 123)
Site	Field north of Inch farm steading approximately 2.4 kilometres west-south-west of Ferryton Point
Nat. Grid. Ref.	NH 674667
Altitude	25 metres
Topography	moderately sloping beach, with a north-north-west aspect
Drainage Class	free

Horizon	*Depth*	
Ap	0–25 cm	Dark reddish brown (5YR3/2) sandy loam to loamy sand; weak medium to coarse subangular blocky; common, rounded, hard stones up to 8 centimetres; abundant roots; worms present; moist; no mottles; clear change into
AB1	25–41 cm	Brown to dark brown (7.5YR4/2) loamy sand; weak medium subangular blocky, breaking readily to fine subangular blocky and single grain; common small, hard gravel; common roots; worms present; moist; no mottles; sharp change into
AB2	41–58 cm	Brown to dark brown (10YR4/3) gravelly loamy coarse sand; weak medium subangular blocky, breaking to single grain; common small stones; few roots; worms present; moist; no mottles; clear change into

B(m)	58-76 cm	Brown to dark brown (10YR4/3) stony, loamy coarse sand; slightly cemented; common stones up to 10 centimetres; few roots in upper 8 centimetres; no worms; moist; no mottles; gradual change into
BC(m)	76-86 cm	Yellowish brown (10YR5/4) loamy coarse sandy gravel; cementation gradually decreasing; gradual change into
C	86-102 cm +	Brown (10YR5/3) coarse sandy gravel; loose.

PEAT

In the Black Isle, peat covers less than 1 square kilometre. The only noteworthy deposit is a raised basin bog of approximately 40 hectares called the Monadh Mor which lies about 4 kilometres due north of Redcastle on the southern edge of the kettlehole complex of the Millbuie Association.

Monadh Mor has been used as a source of domestic fuel at various times and only 2 hectares remain uncut. Except for this small remnant of the raised bog surface, up to 2 metres depth of peat has been removed. In the cut-over areas, the peat has a maximum depth of 3 metres (average 1.5 metres) whereas in the uncut area depths of 4 to 5 metres were recorded. Here, the top 2 metres of peat are composed of almost pure *Sphagnum* peat of a low degree of decomposition below which, and throughout the cut-over areas, moderately to highly decomposed *Sphagnum–Eriophorum* (bog moss–cotton-grass) peat is predominant. The basal 20 to 30 centimetres of this deposit are characterized by sedge (*Carex*) remains and, locally, the peat is underlain by lake sediments. The *Sphagnum* and *Sphagnum–Eriophorum* peat is typically acid and pH values of 3.8 to 4.1 were obtained for the upper horizons.

Stunted pine trees, mostly less than 4 metres high, are scattered over the bog. Few plant species grow on the uncut area and heather (*Culluna*) and lichens are generally dominant. The cut-over surface now shows few signs of its former disturbance. Heather, cotton-grass and *Sphagnum* species are abundant and *Sphagnum*-carpeted wet hollows occur frequently. The lichen *Cladonia impexa* also is very abundant on the drier areas of the cut-over surface.

Within the kettlehole complex, adjacent to Monadh Mor, there are numerous small peat-filled depressions enclosed by mounds and ridges of gravel. These mires (poor fens and bogs) range from less than 0.1 hectare to several hectares in area and support a variety of vegetation types, including poor fen communities, characterized by plants such as water horsetail (*Equisetum fluviatile*), bottle sedge (*Carex rostrata*) and bog pondweed (*Potamogeton polygonifolius*), and bog communities similar to those on Monadh Mor.

Elsewhere in the Black Isle, there remain a few small patches of fen-type peat associated with alluvial soils. However, most small peat deposits are recorded as having been exhausted, due to cutting for fuel, during the period covered by Sinclair's *The Statistical Account of Scotland* (1791–98) and the *New Statistical Account of Scotland* (1845). 'Turf roads', shown radiating out from Cromarty towards the moorland area of Grey Cairn Wood on David Aitken's estate plan of 1764, are a testimony to the fuel shortage which led to the extensive stripping of peaty turf to supplement inadequate peat supplies.

SKELETAL SOILS

Small outcrops of the conglomerate, gneiss and sandstone, with or without a thin turf, are an occasional feature of the landscape of the Black Isle. In practice, mappable areas are restricted generally to the tops of the conglomerate ridges within the Redcastle–Avoch–Kessock triangle, and occupy less than 0.5 of a square kilometre. The typical conglomerate outcrop presents a glacially smoothed, hard outline with little effective lodgement for roots, though stunted Scots pine trees may struggle for survival in isolated soil pockets. The gneiss generally presents a more shattered surface and is covered with a thin skin of semi-residual, rather than skeletal soil. Sandstone outcrops also tend to disintegrate into a thin, dry, semi-residual soil.

3 Discussion of Analytical Data

During the period of the survey, soil samples were taken from profiles considered typical of the mapped units. Standard analytical determinations of loss on ignition, soil separates, exchangeable cations, percentage base saturation, pH, carbon, nitrogen, and total and readily soluble phosphorus were carried out on most samples. In a few selected profiles, the fine sand fraction was examined by gravimetric and optical methods. The clay mineral composition was determined by X-ray, differential thermal analysis and selective chemical dissolution techniques. Trace elements were determined by spectrochemical methods.

STANDARD ANALYTICAL DATA

Standard analytical data for 36 profiles are given in Appendix I, each profile being numbered for ease of reference. The following discussion is concerned with the values and trends of each constituent shown within the soil associations, major soil subgroups and soil series.

LOSS ON IGNITION

Loss on ignition measures the percentage mass lost when a sample of oven-dry (105°C) soil is heated at a high temperature (850°C) for two hours. This weight loss is due mainly to the oxidation of organic matter to carbon dioxide and water, to the loss of carbon dioxide from any free calcium carbonate present, and to the loss of water from the clay fraction. In coarse-textured soils the loss on ignition may be taken as an approximate estimate of the organic matter content.

Naturally, the highest values occur in the organic and organo-mineral horizons of the humus-iron podzols, both freely drained and imperfectly drained, for example, Nos 3, 4, 12, 15, 18, 19, 21, 22, 25 and 26. The values in the L, F and H horizons vary usually from 80 to 95 per cent but are occasionally as low as 45 and 18 per cent (Nos 26 and 21) in the basal organic horizon. Conversely, there is a marked reduction associated with cultivation, and in the Ap horizons values usually range from 3 to approximately 10 per cent, the majority being around 6 per cent, for example, Nos 1, 9, 16 and 28. Thereafter, these low values generally decrease with depth to between 1 and 5 per cent in the B horizon, and to less than 2 per cent in many C horizons, and to even less than 1 per cent in those C horizons developed in coarser-textured parent materials, for example, Nos 2, 6, 23 and 29. In those podzols which are uncultivated the trend is reversed in the upper B horizon and is presumably associated mainly with translocated organic matter which often forms a distinct Bh horizon. There, values range from around 10 to 18 per cent, for example, Nos 3, 19, 22 and 25. No data are available for peaty gleys but those for noncalcareous gleys, Nos 7, 13 and 24, reveal trends similar to those shown in the podzols which have been cultivated.

SOIL SEPARATES

Soil separates—sand, silt and clay—were determined by mechanical analyses, using the particle-size limits laid down by the International Scheme of Mechanical Analysis (sand 20–2000 μm, silt 2–20 μm and clay <2μm) and by the United States Department of Agriculture (U.S.D.A) (sand 50–2000 μm, silt 2–50 μm and clay <2μm). The relative proportion of these fractions present is referred to as texture; both sets of values are quoted in Appendix I. Texture is an important physical characteristic of soil, and greatly influences moisture retention and drainage, tillage properties and liability to poaching by stock and machinery; the type of soil structure and the base-exchange properties of the soil are also affected.

Additionally, the data provide a means of checking the validity of soil texture assessments made by hand in the field. Occasionally, the field texture of the sample differs from that derived from the results of particle-size analyses. This discrepancy, in many cases, is due largely to the presence of organic matter in the field sample. There can be a tendency also, to overestimate in the field the clay content of some mineral soils, particularly in the presence of coarse sand.

Most of the drifts forming the parent materials of soils in the Black Isle are moderately coarse-textured or coarse-textured. The latter textures are confined mainly to soils on material of fluvioglacial (Nos 27 and 28) and raised beach (Nos 34 and 35) origin, and to some basal horizons of shallow soils developed over rock (Nos 14, 19 and 23). Consistently high values of U.S.D.A sand, generally more than 90 per cent, and the corresponding extremely low values of clay and silt in the B and C horizons (Nos 27 and 28) are characteristic of the Boyndie and Corby Associations throughout the Moray Firth landward area; they are a reflection of the high degree of sorting that took place during their deposition under water.

Medium-textured soils are rare and such textures are confined mostly to a few horizons of the Cromarty Association soils (No 9) and, unusually, to the surface horizons of a cultivated, freely drained podzol of the Millbuie Association (No 2), They include also a cultivated, noncalcareous gley of the Ethie Association (No 24). Similarly, moderately fine-textured soils are apparently scarce, these textures being recorded in only the C horizon of No 10 (Cromarty Association) and in the B and C horizons of No 32, an alluvial soil. No finer-textured soils were recorded in the Black Isle except for the silty clay alluvial deposits in the Rosehaugh–Avoch channel.

The majority of soils in the Black Isle have sandy loam textures, predominantly in the water-worked and unmodified tills of the Millbuie and Cromarty Associations, and the locally derived drifts of the Ethie, Kessock and Mount Eagle Associations. Characteristically, the silt content of most of their horizons occurs in a narrow range of around 20–25 per cent whereas their clay contents range from 2–20 per cent, Within the C horizons of the Cromarty Association, however, the clay content is mainly between 16 and 20 per cent, and many of these horizons have textures closely approaching the limits of loam or sandy clay loam. Conversely, the lower end of the clay range is associated with horizons of the Kessock and Mount Eagle Associations, and some horizons of the Ethie and Millbuie Associations, especially the C horizons of the latter. In these soils, the textures vary between sandy loams and loamy sands with the former often approaching the limits of loamy sands; all these values reflect the coarser nature of the parent materials of such associations.

Levels of International silt in most soils of the Black Isle are approximately half the value of the U.S.D.A. silt with notable exceptions occurring in Nos 19, 20 (Ethie Association), 27 (Corby Association) and 28 Boyndie Association).

Although data are limited, the textures of noncalcareous gleys (Nos 7, 13 and 24) are not significantly finer than those of the podzols of the same association. They are mainly sandy loams without any discernible trend in the distribution of the soil separates. Though this contrasts with the situation found in other parts of Scotland, for example Aberdeenshire (Glentworth and Muir, 1963), the limited number of samples examined obviously restricts any definite conclusion.

EXCHANGEABLE CATIONS, PERCENTAGE BASE SATURATION AND pH

The cation-exchange capacity is a quantitative expression of the ability of a soil to take up, release and exchange one cation for another. The exchangeable ions are held primarily on the organic matter and the clay fractions which hold within their complex structure varying numbers of adsorbed cations, consisting of both hydrogen ions and metallic ions or bases. These adsorbed cations, many of which are plant nutrients, can be replaced to a greater or lesser extent by other cations, for example, by active hydrogen in nature or by metallic ions from applied chemical fertilizers. The unit used in expressing the magnitude of the exchange capacity is a milligramme-equivalent (m.e.) which is stated as 'one milligramme of hydrogen or the amount of any other ion that will combine with or displace it'. The results are expressed as m.e./100 g of soil. Cations normally estimated are calcium, magnesium, sodium and potassium. Together with hydrogen, which is determined separately, they are taken as an appropriate measure of the total exchange capacity. Thus, in most soils, the base-exchange capacity decreases with depth, accompanying the fall in organic-matter content, whereas in the non-organic horizons the higher base-exchange capacities are related usually to higher clay contents. However, in many coarse-textured soils, base-exchange capacities are extremely low (<5m.e. 100/g soil) beneath the surface horizons.

Percentage base saturation is determined by expressing the total exchangeable bases i.e. calcium, magnesium, sodium, and potassium as a percentage of the total exchangeable cations, including exchangeable hydrogen which is assumed to occupy that part of the exchange complex not carrying basic ions. For comparison, values of percentage base saturation are graded as follows:

low	<20 per cent
moderate	20–60 per cent
high	<60 per cent

Acid soils generally have a low percentage base saturation, whereas in neutral or near neutral soils, the base-exchange capacity is nearly or completely saturated. However, a soil with a low percentage base saturation but a high exchange capacity may have a greater content of the total exchangeable bases than a soil with higher percentage base saturation but lower exchange capacity.

Exchangeable calcium

Values of exchangeable calcium, as with most exchangeable cations, are at a maximum in surface organic horizons. In the L and F horizons of the podzols, Nos 3, 4, 12, 15, 18, 19, 21, 22, 25 and 26, such levels are normally very high (>8 m.e./100 g), ranging 8.23–17.9 m.e./100 g in L horizons with a single moderate value (3–8 m.e./100 g) of 6.86 m.e./100 g in No 12. The range is somewhat wider in the F horizons, varying mainly from moderate (4.37 m.e./100 g) to high (18.4 m.e./100 g) levels but with a single low value (<3m.e./100 g) of 2.11 m.e./100 g in No 18 (Ethie Association), and an extremely high value of 25.8 m.e./100 g in No 33, the latter developed in mixed bottom land deposits.

In the eleven humus-iron podzols listed in the appendix, all uncultivated and representing the Millbuie, Cromarty, Mount Eagle, Ethie and Kessock Associations, the values drop abruptly to very low levels in the Ah and E horizons, a characteristic of podzols especially where developed in acidic parent materials. Values are also very low throughout the remaining mineral horizons with a maximum value of 0.9 m.e./100 g (No 12) in the lower horizons and 0.81 m.e./100 g (No 22) in the upper horizons. For example, exchangeable calcium is below the lower limit of determination (0.01 m.e./100 g) in the E horizons and all underlying horizons of Nos 4, 17, 18 and 19. In No 26, a similar trend occurs below a low value of 0.93 m.e./100 g in the Ah horizon. Of the remaining podzol profiles, the values in the E and AE horizons of Nos 3, 12, 15, 21, 22 and 25, range 0.15–1.08 m.e./100 g. These values are succeeded by levels at or below the lower limit in at least some of the underlying horizons and all the basal horizons except those in Nos 12 (Cromarty Association) and 25 (Kessock Association).

Those podzols which have been cultivated, however, show the effect of liming with values in the Ap horizons being mainly moderate, although high levels occur in Nos 2, 5, 9 and 14, ranging 8.55–9.99 m.e./100 g; low values occur in only Nos 1, 8 and 11, (Millbuie and Cromarty Associations). Values in noncalcareous gleys are mainly moderate, ranging 3.33–6.46 m.e./100 g (Nos 7, 13 and 31) but with a low value of 1.82 m.e./100 g occurring in No 24 (Mount Eagle Association).

In most podzols which are cultivated, Nos 1, 2, 5, 6, 8, 9, 10, 11, 14, 16, 27, 28 and 29, there is a sharp downwards decrease in values below the Ap horizon, a decrease equally as abrupt as that from the surface organic horizons into the immediate underlying mineral horizons of the uncultivated podzols. As with those podzols that are uncultivated, this decrease is maintained through the B horizons into the C horizon in all profiles, except Nos 1, 9 and 11 (Millbuie and Cromarty Associations). Most of the profiles have moderately coarse textures, frequently at the coarser end of the range, and coarse textures in which the values are often near or below the lower limit of determination in the C horizon, for example, Nos 1, 2, 6, 8 and 27; occasionally exchangeable calcium is also below the limit of determination within a higher horizon; for example, No 1 (Bc), No 11 (Bx) and No 27 (Bs).

In those shallow podzols developed over shattered rock and whether cultivated or not, Nos 14–22, 25 and 26 (Mount Eagle, Ethie and Kessock Associations), the minimum value occurs also in the basal horizon, usually a Bs or Bx horizon. Apart from No 20, which has a minimum of 3.52 m.e./100 g that probably reflects recent liming, the exchangeable calcium is below or near the lower limit of determination in the basal horizon.

Where the basal horizons of podzols are formed in unmodified till, as in the Cromarty Association, for example Nos 9, 11 and 12, occasionally in the Millbuie Association, for example No 1, and in solifluction deposits, for example No 29, the minimum occurs often above the basal horizon. The subsequent rise may be slight, for example No 11, or more significant, for example, No 9. Other profiles of the Cromarty Association, however, maintain the normal downward trend, for example, Nos 8 and 10. Values in most of these basal horizons are usually higher at 1–3 m.e./100 g than those in the other coarser-textured parent materials and are associated probably with the higher clay contents; such contents are normally around 20 per cent. But, in all the soils assigned to major soil subgroups, the value of exchangeable calcium in the C horizons exceeds the low range only in No 9, (3.05 m.e./100 g) a podzol, and in Nos 24 and 30 (20.0 m.e./100 g) and 6.78 noncalcareous gleys; the latter figures are extraordinarily high and may reflect the influence of calcareous sandstone. Within the B horizons, moderate values are restricted also and occur only in Nos 5, 7, 10, 20 and 23; apart from No 23, each is a single occurrence and all are less than 3.64 m.e./100 g.

The highest values in mineral soils (25.8 and 33.1 m.e./100 g) occur in mixed bottom land deposits associated with a steeply eroded gully near Rosemarkie.

Within the noncalcareous gleys, Nos 7, 13, 24 and 30, the levels of exchangeable calcium in the Ap horizons are mostly moderate but range 1.82–6.46 m.e./100 g. Thereafter, in Nos 7 and 13 there is a downwards decrease similar to that displayed in podzols with values dropping to low in the C horizons, ranging 1.06–1.35 m.e./100 g. In Nos 24 and 30, however, the minimum occurs in the upper Bg horizon. Values then rise steadily to a moderate level in the C horizon of No 30 (6.78 m.e./100 g) and an atypically high level of 20.0 in No 24.

Exchangeable magnesium

High values (>5 m.e./100 g) of exchangeable magnesium, as with exchangeable sodium and potassium, are confined to the surface organic horizons, where values range mainly between 5 and 10 m.e./100 g. Moderate values (0.3–5 m.e./100 g) of 0.50 and 2.70 m.e./100 g, however, occur atypically in the F horizons of Nos 18 and 21 (Ethie Association). The highest value of 12.6 m.e./100 g was recorded in the F horizon of No 19, also a humus-iron podzol of the Ethie Association.

Characteristically, values drop sharply to moderate and low levels (<0.3 m.e./100 g); in the Ah and E horizons of podzols the moderate levels, moreover, are at the lower range of the scale, all values ranging 0.11 to 0.93 m.e./100 g. In cultivated soils, mainly podzols but including noncalcareous gleys, Nos 7, 12, 24 and 30, topsoil values are dominantly moderate, 0.36–0.72 m.e./100 g with a few low values of 0.09–0.28 m.e./100 g. The highest values of a mineral horizon, 1.08–1.55 m.e./100 g were recorded in the Ap horizon of a profile developed in low raised beach deposits, No 34.

Regardless of association and in most podzols, the minimum value of exchangeable magnesium tends to occur in the B horizon, occurring almost equally in the Bs and Bx horizons. Only occasionally does the minimum value develop in the C horizon, for example Nos 7; 23 and 31; of the latter, Nos 7 and 31 are noncalcareous gleys. Unusually, the minimum occurs also in other horizons within the same profile; for example, in No 4, exchangeable magnesium is below the lower limit of determination (<0.02 m.e./100 g) in both the AB and B horizons. In No 8, it is at the limit of determination between the Bs and the upper C horizons, whereas in Nos 27 and 28 the exchangeable magnesium is below the lower limit in all horizons downwards of the Ap horizon except for a value of 0.06 m.e./100 g in the C2 horizon of No 27. The two latter profiles are formed in coarse-textured parent materials of, respectively, the Corby and Boyndie Associations. The minimum value in all profiles exceeds the low value range only in Nos 10, 13 and 23 where the values are barely moderate at 0.33, 0.33 and 0.31 m.e./100 g in the Bx, Bs and C1 horizons respectively.

In the 13 shallow profiles developed over rock (Mount Eagle, Ethie and Kessock Associations), the minimum value normally coincides with the basal horizon except in Nos 18, 19, 20, 24 and 25, though in Nos 19 and 25 the differences in values between the minimum value and that of the basal horizon are negligible. Outwith Nos 18, 23 and 24, the basal horizon is always a B horizon.

Generally, values increase below the B horizons in most profiles. In those of the Millbuie Association, excepting No 1, and in other profiles developed in coarse-and moderately coarse-textured parent materials, the rises are slight. Occasionally, where there are other C horizons in the sequence, the rise may be followed by an equally slight fall; this often accompanies a slight decrease in clay content. In the Cromarty Association, however, the basal horizons are associated with unmodified till which has a clay content of around 20 per cent. The values of exchangeable magnesium in such profiles frequently rise sharply and reach moderate values. A similar situation is found in No 1 (Millbuie Association) and Nos 29 and 30 (solifluction deposits) in which the basal horizon is formed in a comparable till.

Atypically, in Nos 23 and 24, an imperfectly drained podzol and a noncalcareous gley respectively, the values are moderate throughout. Both profiles are cultivated.

Exchangeable sodium

Except for the Ap horizon of No 27, which has also high associated values for carbon and loss on ignition, high values of exchangeable sodium (>0.25 m.e./100 g) are restricted in the Black Isle almost entirely to the L, F and H horizons of podzols. Values in these organic horizons range 0.25–1.73 m.e./100 g, with most between 0.60 and 1.00 m.e./100 g.

Below the organic horizon, values drop rapidly in the A and E horizons of the podzols to moderate values (0.05–0.25 m.e./100 g), ranging 0.05–0.17 m.e./100 g, though one high value (0.26 m.e./100 g) was recorded in the E horizon of No 21. In those podzols and noncalcareous gleys which are cultivated, values in the Ap horizons are also moderate, though most are at the lower end of the scale and below 0.10 m.e./100 g. The decrease continues rapidly downwards to the B horizons in all profiles.

Whereas the values in all Bh horizons, are within the moderate range, albeit all at the lower end of that scale, excepting an unusually high value of 0.20 m.e./100 g in No 21, values in the Bs and Bx horizons include both low (<0.05 m.e./100 g) and moderate values; the latter range mainly around 0.06–0.10 m.e./100 g. However, in 16 profiles from a total of 30 profiles assigned to major soil subgroups including 14 podzols and 2 noncalcareous gleys (Nos 7 and 30), the exchangeable sodium in the B horizons is below the lower limit of determination (<0.03 m.e./100 g) or was recorded at that limit, 7 of them in Bs horizons.

Occasionally, the decrease in values in the B horizon is maintained, often marginally, in the BC and C horizons. In 6 profiles, the minimum value for exchangeable sodium was recorded either as being below the lower limit of determination or at that lower limit in the basal C horizon; in one profile, No 11, the minimum value persists at the lower limit downwards from the Bx horizon. In another 2 profiles, Nos 5 and 13, minimum values of 0.07 and 0.06 m.e./100 g are maintained downwards from the BC and Bs horizons respectively. Minimum values for sodium were recorded also in the basal horizons of 10 out of the 13 shallow profiles (Mount Eagle, Ethie and Kessock Associations) developed over rock; usually the basal horizon in these instances is either a Bs or Bx horizon. These values vary from moderate (3 profiles) to low (7 profiles) with 5 of the latter at or below the lower limit. In 10 of the remaining profiles of the 30 profiles assigned to major soil subgroups, there was a slight rise in the C horizon; apart from two noncalcareous gleys, these profiles are humus-iron podzols. The basal values in 8 of these profiles are moderate, ranging 0.05–0.13 and are associated frequently with the slightly higher clay values found in unmodified till, for example, Nos 9, 10 and 12 (Cromarty Association).

The highest recorded value (1.73m.e./100g) occurs in the F horizon of No 12 whereas the highest value determined in a mineral horizon (0.43m.e./100g) is in the Ap horizon of No 27.

Exchangeable potassium

High values of potassium (>1.0 m.e./100 g) are confined within the soils of the Black Isle to the L, F and H horizons of podzols where values range 1.12–6.80 m.e./100 g. Exceptionally, however, one F horizon, No 18, has only a moderate value of 0.60 m.e./100 g. Values drop rapidly in the Ah and E horizons to mainly moderate values (0.1–1.0 m.e./100 g) ranging 0.10–0.52 m.e./100 g but including a few low values (<0.1 m.e./100 g) ranging <0.02–0.09, for example, Nos 3, 4, 12, 19 and 22. Indeed, in No 22 (Ethie Association), potassium is below the lower limit of determination in all horizons below the F horizon. A similar trend occurs also in No 4 (Millbuie Association) where the element is either at, below or marginally above the lower limit in all horizons below the E horizon.

In the podzols which are cultivated, values in the Ap horizons are mainly moderate and low with all the former values at the lower end of a range at 0.41–0.11 m.e./100 g, with most below 0.25 m.e./100 g; the low values range 0.05–0.09 m.e./100 g.

Low values dominate the Bs horizons of all podzols, except Nos 2 and 5 (Millbuie Association), and the Bg horizons of the noncalcareous gleys, Nos 7, 13 and 24; often these values are at or near the lower limit. Moderate values, however, occur as often as low values in Bh horizons. Towards the base of many B horizons in profiles developed over rock, (Ethie, Mount Eagle and Kessock Associations) there is frequently a rise in these low values though the rise is marginal. In many of these podzols, however the values decrease steadily downwards in Nos 14, 19, 20, 21 and 26 but are below the lower limit throughout No 22 as is also largely the case in the coarse-textured soils of the Corby and Boyndie Associations (Nos 27 and 28). In soils developed in till, the values in the BC and C horizons show no trend. Whereas those of the Millbuie Association are very low and comparable with those in the Bs horizon, those of the Cromarty Association are often moderate. These higher values are apparently closely related to the higher clay values of the unmodified till in such horizons. This clay content is usually around 20 per cent.

Exchangeable hydrogen

Values of exchangeable hydrogen show a general decrease down the profile, regardless of the major soil subgroup. These values, of course, are affected by texture, presence of organic matter, and in cultivated soils also by liming and fertilizer practice.

Widespread applications of lime and fertilizers in the Black Isle have raised the base status of most Ap horizons and consequently, values for exchangeable hydrogen in cultivated podzols and noncalcareous gleys are generally low. Such values range from 0.1 to 12.6 m.e./100 g. with unusually, a very high level in No. 27 of 34.9 m.e./100 g. They normally decrease rapidly downwards, often reaching the lower limit of determination in the C horizon; occasionally the minimum, often the lower limit of determination, occurs in the B horizon, for example, Nos 2, 9, 29 and 30, and sometimes in the BC horizon, for example, Nos 5, 6, 10, and 24. Where shallow profiles are developed over shattered rock the minimum, excepting Nos 14, 19 and 20, occurs in the basal horizon which is usually a Bx horizon; the minimum is often the lower limit of determination. Otherwise, values are rarely more than 6 m.e./100 g excepting No. 19 which has an atypically high value of 22.3 m.e./100 g. In most cases where the profile is deeper but the lower limit is not reached, the values of exchangeable hydrogen are very low in the C horizon , normally less than 4 m.e./100 g; exceptions include Nos 4 and 12 with values of 7.8 and 5.2 m.e./100 g respectively.

Occasionally, the typical downward decrease is interrupted by a subsidiary peak in the upper B horizon, usually associated with increased organic matter. This is characteristic of humus-iron podzols, for example, Nos 3, 12, 22 and 25. The peak occurs also in some cultivated podzols for example, Nos 5, 8 and 14.

Percentage base saturation

Base saturation obviously varies with past liming and fertilizer practice, and the vast majority of cultivated soils in the Black Isle, for example, Nos 2, 5, 9, 10 and 29, have a high percentage in the Ap horizon. In addition, the cultivated noncalcareous gleys, Nos 7, 24 and 30, and the poorly drained, mineral alluvial soil No 31, all show a steady increase downwards, resulting in the basal horizons being completely saturated. The only other trend discernible in cultivated soils is a tendency for the minimum percentage to occur in the B horizon. However, in the humus-iron podzols which have not been cultivated there is a characteristic pattern with a minimum consistently occurring in the B horizon. From moderate percentages (20–60%) in the L horizon, base saturation decreases in the F horizon to mainly low levels, ranging 2.6–19.8 but with atypical levels of 28 and 30 per cent in Nos 21 and 22. A sharp decrease follows in the AE or E horizon where percentages range 0.8–17.6 but are mainly less than 10. The decrease is maintained in the Bs horizon where the levels are normally very low ranging 0.6–4.0 per cent; slightly higher percentages, ranging 6.9–16.4 and 12.3, occur respectively in Nos 15 and 26.

The decrease is either maintained in the lower B horizon, normally a Bx horizon, for example, Nos 19 and 22, or, more usually, there is a sharp rise. This rise sometimes reaches saturation levels of 100 per cent in those shallow profiles where the basal sample was obtained from a Bx horizon resting upon shattered rock, for example Nos 15 and 17. In cultivated soils , the rise may continue into the C horizon and reach levels of around 50 per cent, these higher figures usually coinciding with the presence of unmodified till; it may even reach saturation where the horizon is formed from coarse material.

pH

The pH is an expression of the hydrogen ion concentration in the soil and was measured electrometrically in 1:2.5 soil suspensions in water.

A number of important soil properties and processes are correlated with and affected by the soil pH. Earthworm and other biotic activity is reduced under acid conditions and the natural plant communities are strongly influenced by the soil reaction. In addition, the availability of some plant nutrients, for example, manganese and boron, is affected markedly by pH as is the liability of plants to attack by some diseases.

In all the uncultivated humus-iron podzols, regardless of soil association, there is a similar and characteristic downwards increase in pH values. Because such soils are formed on parent materials derived mainly from acid rocks, have coarse and moderately coarse textures, and are strongly leached, these values are mainly low (<5.0). Within the surface organic horizons, values range usually from 3.6 to 4.2, the minimal value occurring frequently at the base of the F and FH horizons, for example, Nos 4, 12, 25 and 26. Although the maximum values occur always in the C horizons, the range is apparently narrow, usually between 4.8 and 5.0, for example, Nos 3, 4, 19, 21, 22 and 25. Exceptionally, values may rise to 5.3 and 5.4, for example, Nos 15 and 18; in both these cases shattered rock was encountered.

The pH values of cultivated soils, especially in the upper horizons, have been raised by liming and the present values simply reflect the current agricultural management. The values, which in the cultivated surface horizons vary between 4.6 and 6.9, either show no consistent trend or show a slight decrease downwards. These values are mainly medium (5.0–6.5). Only rarely are high values (>6.5) recorded and then usually in C horizons, for example Nos 23 and 24. The highest value of 8.4 occurred in the C horizon of the latter profile, a noncalcareous gley, where there was probably the influence of nearby pockets of marl. Other high values may be attributable to the translocation by ground-water of carbonates from calcareous strata within the underlying sandstone.

The lowest value recorded in the Black Isle was 3.4, and it occurred in the F horizon of a freely drained humus-iron podzol, No. 25.

CARBON AND NITROGEN

Determinations of carbon and nitrogen were made on the surface and upper horizons of the profiles. The carbon content of a soil is correlated closely with the amount of organic matter present, which is computed usually by multiplying the value for soil carbon by a factor (1.72). Amounts of soil nitrogen are used to determine the carbon to nitrogen ratio of the soil organic matter. This ratio is related to the degree of decomposition or humification of the residues which make up the soil organic matter. Thus, carbon:nitrogen ratios of about 8:1 to 13:1 indicate organic matter existing under conditions of high biotic activity leading to fairly rapid humification, and are characteristic of cultivated mineral soils in which the organic matter has been incorporated with the mineral horizons. Carbon:nitrogen ratios of 15:1 to 60:1 are typical of the mor humus and peats where the rates of decomposition are slow.

An important characteristic of soil horizons, in which the humus content is greater than 25 per cent, is their low bulk density. Such soils, although they may have a high content of nutrients or other elements as judged per unit weight of soil, have relatively lower amounts per unit volume compared with mineral horizons. This, together with the assumption that there is a limit to the volume of soil which any plant is able to exploit, helps explain why the raw humus and peaty horizons of humus-iron podzols, peaty podzols and peaty gleys are poor media for most plant growth and yet often have high contents of exchangeable bases and of phosphate per unit weight of soil.

The amount and nature of the organic matter in a soil has a major role in influencing the type and stability of soil structure; it is a major source of nitrogen as well as forming a reserve source of other plant nutrients. It is also the seat of much of the soil base-exchange capacity.

The highest values for both elements occur in the organic horizons of the humus-iron podzols. With few exceptions, the percentages of carbon and nitrogen decrease down the profile; the most noticeable variations are those concerning carbon in Nos 1, 12 and 25.

The levels of carbon in the L, F and H horizons of uncultivated podzols are, naturally, much higher than those of the surface horizons of cultivated podzols, mostly ranging 34–59 per cent. An abrupt decrease follows in the A and E horizons where values range 2–11 per cent with the majority less than 5 per cent. In cultivated soils, however, the range in the A horizons is slightly lower and varies between 1 and 5 per cent; most are less than 4 per cent although an unusually high level of 12 per cent occurs in No. 27. Most percentages thereafter decrease rapidly in the B horizons to values between 1 and 3 per cent, mainly less than 1 per cent; the few determinations made in the BC horizons are all less than 0.17 per cent.

Nitrogen values follow a similar trend, though the percentages are obviously much lower. Thus, in the L, F and H horizons of the podzols, the percentages are mainly above 1 per cent, ranging 0.43–1.69 per cent. A rapid decrease follows in the mineral horizons where the range is mostly 0.10–0.30 per cent throughout Ah, E and Ap horizons. Percentages continue to drop rapidly to the Bs and Bx horizons where most values range 0.03–0.10 per cent; in the BC horizon, the element is usually near the lower limit of determination at less than 0.01 per cent.

The carbon:nitrogen ratios, in accord with the generalizations outlined above, are very high in the L, F and H horizons of the podzols, ranging between 30:1 and 45:1, for example Nos. 12, 22 and 26, with an atypically low ratio of 18:1 in the F horizon of No. 21 and extremely high ratios of between 55:1 and

Plate 4. *Oblique air photograph looking eastwards across Cromarty to the Sutors of Cromarty. Immediately surrounding the town, are undifferentiated soils of the high and low raised beaches. On the slopes gently rising above the beaches are imperfectly drained podzols of the Cromarty Association; they are intensively farmed. At the Sutors of Cromarty, the steep slopes are covered by freely drained, shallow podzols of the Ethie Association; along the broad crest, the soils are imperfectly drained.* Aerofilms.

Plate 5. *Oblique air photograph of Munlochy looking towards the southern shore of the Moray Firth with the Ardersier spit prominent in the distant background. Flanking the eastern side of Munlochy Bay are the conglomerate Ord Hill and Wood Hill; they are covered by freely drained podzols of the Kessock Association. On the undulating ground around these hills and stretching towards Avoch, are mainly freely drained and imperfectly drained podzols of the Millbuie Association. Immediately north of Munlochy and below the road to Avoch, lie imperfectly drained, sandy and gravelly soils of the high raised beach. Seawards, these soils are replaced by imperfectly drained silty soils of the lower raised beach. They grade into the imperfectly drained alluvial soils of the Littlemill-Allangrange floodplain at the head of Munlochy Bay. Minor patches of saline alluvial soils intermittently fringe the shores of the bay.* Aerofilms.

67:1 in the L and F horizons of Nos 3 and 4. Most cultivated soils, however, have ratios of between 10:1 and 20:1 in the A horizons. These ratios may rise slightly in the B horizon of freely drained soils, for example, Nos 1, 2 and 8, or decrease slightly as commonly happens in imperfectly drained podzols which have been cultivated, for example, Nos 5, 6, 23 and 29.

Within uncultivated podzols, however, the carbon: nitrogen ratios in the A and E horizons vary between 14:1 and 42:1 (Nos 21 and 26), and those for the upper B horizons, usually Bh horizons, are also correspondingly higher, ranging between 12:1 and 33:1. In cultivated podzols atypically high ratios occur in the Bhs horizon of No. 1 and the Bhs horizon of No. 14. Excepting the Bx horizon of No. 14, the lowest ratios of all the B horizons occur, apparently, in the Bg horizons of the noncalcareous gleys, Nos 7, 13 and 24, where the ratios are between 4:1 and 7:1.

No ratios have been determined for C horizons though they would probably illustrate a continued and rapid decrease.

PHOSPHORUS

The soils have been analyzed for their total content of phosphorus, which is expressed as units of phosphorus pentoxide, and for readily soluble phosphorus. Plant nutrients added as fertilizers are changed to less-soluble forms by reaction with inorganic and organic components of the soil, and phosphorus, like other nutrients, exists in the soil in several forms differing in mobility and availability to plants. Therefore, the values for total phosphorus may give little indication of the amount of phosphorus available, whereas those for acetic-soluble phosphorus give an estimate of the phosphate fraction readily available as a plant nutrient.

Total Phosphorus

Low values of total phosphorus (<100 mg/g) are a feature of soils of the Black Isle and can be related to the dominant, moderately coarse textures. They occur in at least one horizon of every profile, excepting Nos 32 and 35; these profiles are developed respectively in alluvium and raised beach deposits. Indeed, outwith the L and F horizons of the humus-iron podzols where values are mainly medium (100–300 mg/g) but range 92–266 mg/g, and outwith virtually all cultivated A horizons, values are generally low in the deeper profiles In shallow profiles over shattered rock, where the lowest sample has been obtained usually from the base of the B horizon, values range from low (45–99 mg/g), for example, Nos 14, 15, 17, 22, 25 and 26, to medium (107–163 mg/g), for example, Nos 18, 19, 20 and 21.

Although most cultivated surface horizons have medium values, such values are generally on the low side (100–150 mg/g); a few higher values (156–195 mg/g) occur in Nos 9, 10, 20, 27 and 28. Only in Nos 27 and 35 do values exceed 200 mg/g. Atypically low values of 58 and 98 mg/g occur respectively on the surface horizons of Nos 1 and 24.

In humus-iron podzols, there is a distinctive trend where, excepting the Bh horizon of No. 21, the lowest values occur mainly in the Ah and E horizons, ranging 30–63 mg/g. Thereafter, slightly different patterns may occur. Often, there is a slight rise followed by a secondary minimum in the B horizon with values usually rising sharply in the basal part of the B horizon where it overlies shattered rock, for example, Nos 18, 19 and 22 in which values rise respectively to 179, 107 and 98 mg/g. Where the profiles are deeper, for example, in the Millbuie and Cromarty Associations, the rise in values at the base of the B horizon is followed by a slight fall in the C horizons.

In podzols of the Cromarty Association which have been cultivated, the C horizon is characterized by sandy loam and loam textures. The associated total phosphorus values usually show a minimum in the upper part of the horizon but increase downwards, often rapidly, for example Nos 9 and 10 which show rises respectively from 49 to 97 mg/g and from 58 to 106 mg/g. Within the coarser-textured soils of the Millbuie Association, however, the minimum values are also low (<100 mg/g) but occur normally in the B horizon and are followed by a rise in the C horizon, for example Nos 1, 2 and 6.

Readily Soluble Phosphorus

The amount of acetic-acid-soluble, or readily soluble, phosphorus in the soil is only a fraction of the total phosphorus present. High values (>10 mg/g) are found in surface organic horizons, but otherwise are restricted to a few cultivated horizons which have received fertilizers, Nos 10, 29 and 30, to most horizons of the noncalcareous gleys, Nos 7, 24 and 30, and occasionally to the BC and C horizons of humus-iron podzols, Nos 1, 2, 5, 8, 9, 12, 18, 23 and 29.

Although high values in the surface organic horizons of humus-iron podzols range mainly between 15 and 64 mg/g, a few lower values of 5.6–14 mg/g and an atypically low value of 3 mg/g (No. 21) occur in some F horizons. Values in the cultivated surface horizons of all the podzols, however, have a much narrower range. Most are of low (<3 mg/g) and medium (3–10 mg/g) with only a few high values which range up to 16 mg/g (No. 30). Immediately below the organic horizons of the humus-iron podzols there is a sharp decrease to low values, frequently below 1 mg/g; slightly higher values of 4.1 and 2.2 mg/g occur respectively in Nos 3 and 26. Normally, this decrease is continued in the B horizon where, in most podzols whether cultivated or not, the value is usually at a minimum. The minimum values are low, mainly less than 2 mg/g, and often less than 1 mg/g, except in Nos 2 and 28 where values are respectively 2.6 and 3.1 mg/g. Occasionally, as for example in Nos 4, 9, 11, 19 and 20, the minimum value occurs in an A, AB or AE horizon, though the difference between the minimum values and values in other horizons is often insignificant. Medium values in the B horizons are atypical and are generally associated either with the basal horizons of shallow profiles or indurated layers or both: the only high values occur in the Bx horizon of No. 12 and in the B horizons of No. 29.

Excepting Nos. 3 and 4, all values in the podzols rise in the C horizons to medium and, occasionally, high values; the latter range 11–27 mg/g although extreme levels occur in No. 29 where values rise from 33 mg/g in the B horizon to 56 mg/g in the C horizon.

In the noncalcareous gleys, values are usually very high in both B and C horizons, Nos 7, 24 and 30, though only medium values occur in No. 13. Extreme values in No. 30, ranging 16–92 mg/g are comparable to those found in surface organic horizons. A similar extreme range occurs in the imperfectly drained profile No. 29 which is developed also in solifluction deposits.

MINERALOGY

MINERALOGY OF THE CLAY FRACTION

The mineralogy of the upper and basal horizons of three freely drained profiles of the Allangrange Series of the Millbuie Association, developed on coarse-textured morainic drift derived from strata of Middle Old Red Sandstone age overlying till of Cromarty Association, was determined by X-ray diffraction and differential thermal examination. Kaolinite and dioctahedral mica were the principal clay minerals observed, kaolinite tending to predominate in the clay of the upper horizons and dioctahedral mica in the clay from the basal horizons. Small amounts of interstratified mica-vermiculite mineral occurred in most of the samples; quartz and feldspar were also present. The clay from the surface and C horizons of profile No. 10, an imperfectly drained soil of the Cromarty Association developed on till derived from sandstones of Middle Old Red Sandstone age, was also examined. The clay mineral suite again consisted of dioctahedral mica and kaolinite with some interstratified mica-vermiculite material. There was no change in the relative amounts of the principal clay minerals down the profile.

No evidence of poorly ordered alumino-silicate minerals was seen in the clays. More unusual, however, was the absence of accessory iron oxide minerals, both crystalline and X-ray amorphous.

MINERALOGY OF THE FINE SAND FRACTION

The fine sand fractions (0.075–0.150 millimetres) from four soil profiles from the Black Isle were separated for mineralogical analysis by optical methods. Three of the profiles were freely drained soils of the Allangrange Series of the Millbuie Association and the fourth was an imperfectly drained profile of the Cromarty Series of the Cromarty Association. The sand from an upper layer and the bottom layer of each profile was separated into heavy and light fractions using tetrabromoethane (specific gravity 2.95), and the number of grains of the minerals present are expressed on a frequency scale in Table F.

The proportion of heavy minerals was less than 2 per cent by weight in all but one of the horizons examined. Analyses of the light fraction showed a marked predominance of quartz, considerable amounts of potash feldspars and minor amounts of plagioclase and muscovite.

As in other Old Red Sandstone-derived soils, the heavy mineral fractions contain high proportions of hornblende, garnet, iron oxides and epidote. There are few significant differences between the profiles but it is noteworthy that apatite decreases upwards in each instance, The freely drained Belton Wood profile of the Millbuie Series contains an appreciable amount of sphene.

TRACE ELEMENTS

Only a small number of profiles were sampled on the Black Isle for trace element analyses. The amounts likely to be found in the dominant associations have been derived, therefore, from data for the same associations which occur in similar, adjacent areas, particularly those within the 1:63 360 soil maps for Sheet 84 (Nairn) to the south and for Sheet 94 (Cromarty) to the north.

Table F Minerals in the fine sand fraction (75–150 µm)

Association	Series	Profile No.	Depth (centimetres)	Light fraction (S.G.<2.95) Weight %	Quartz	Plagioclase	Potash Feldspars	Micas	Weathered Minerals	Heavy fraction (S.G.>2.95) Weight %	Apatite	Augite	Clinopyroxene	Biotite	Epidote	Garnet	Glass	Hornblende	Iron Oxides	Muscovite	Rutile	Sphene	Staurolite	Tourmaline	Zircon	Rock Particles	Weathered Minerals
Millbuie	Allangrange	1	30–41	97.29	9	2	5	3	3	2.71	2	0	0	0	5	7	—	7	5	—	0	2	—	2	1	2	0
			249–259	98.23	9	2	5	4	4	1.77	3	1	0	4	4	6	—	6	5	2	0	3	—	0	2	3	0
Millbuie	Allangrange	—	3–13	99.14	9	3	6	0	3	0.86	1	0	—	2	5	6	—	6	7	0	1	0	—	0	3	2	0
			86–94	98.42	9	1	6	3	2	1.58	2	0	—	3	5	6	—	7	6	0	—	0	—	0	3	4	1
Millbuie	Millbuie	4	15–25	98.51	9	2	6	3	2	1.49	0	—	—	1	5	6	—	7	5	2	0	4	—	—	3	1	0
			91–102	98.01	9	3	6	2	3	1.99	2	0	—	2	6	6	—	7	2	2	0	4	—	—	1	3	1
Cromarty	Cromarty	10	3–10	98.91	9	2	5	1	3	1.09	1	—	—	1	5	7	—	6	6	1	1	2	—	0	2	2	0
			97–107	98.85	9	1	5	4	3	1.15	4	0	—	0	5	6	0	6	6	0	0	3	0	1	2	4	0

Percentage	100–90	90–70	70–50	50–30	30–15	15–7	7–4	4–2	2–1	1–½	<½
Scale	10	9	8	7	6	5	4	3	2	1	0

Table G Mean total amounts of trace elements in B horizon samples (microgrammes per gramme in dry soil)

Association	Parent Material	Cobalt	Copper	Molybdenum	Manganese	Nickel	Lead	Titanium	Vanadium
Millbuie	Morainic till derived from arenaceous Middle Old Red Sandstone	<	3.3	<1	370	25	6	2750	30
Cromarty	Till derived from Middle Old Red Sandstone strata	2.3	4.8	1.0	344	23	11	2830	30
Mount Eagle	Shallow drift derived from Middle Old Red Sandstone strata	2.6	4.3	0.6	630	27	15	3000	49
Ethie	Shallow drift derived from Middle Old Red Sandstone strata and Moine gneiss	<3	2.2	0.9	350	15	9	3000	33
Corby	Fluvioglacial and morainic gravels	6	9	0.6	460	21	16	2930	38
Boyndie	Fluvioglacial sands	4	6	0.6	520	14	12	3500	31

The trace element contents of samples from 20 representative profiles have been determined spectrochemically using the methods described by Mitchell (1964), the results being expressed in microgrammes per gramme ($\mu g/g$). For the purposes of this report, the total trace element content in a profile has been assessed from the analyses of the B horizons. Unlike those of the overlying A horizons, the trace element contents of the B horizons are largely unaffected by additions of lime, fertilizers, manures, pesticides, herbicides, waste materials and trace element treatments. Also, whereas A horizons are modified by cultivation, and the A and E horizons of uncultivated profiles are modified by the accumulation of organic matter and by leaching, the B horizons of both cultivated and uncultivated profiles are comparable within one association. Therefore, the mean trace element content of the B horizons from a profile or group of profiles of the same association is referred to as the total content unless otherwise stated.

Table G lists the mean total contents of trace elements in the B horizons of soils of the Millbuie, Cromarty, Mount Eagle, Ethie, Corby and Boyndie Associations, calculated from the data available. No profiles of the Kessock Association have been analysed; the association covers a relatively small area and, because the parent material is a shallow drift derived from conglomerates of Middle Old Red Sandstone age, the total trace element contents of the soils should be similar to those of the soils of the Mount Eagle Association.

The levels of trace elements extractable by 0.43 M acetic acid (cobalt, nickel, lead and vanadium) and by 0.05 M EDTA (copper, manganese and zinc), especially from the upper horizons (0–25 centimetres), provide an indication of their availability for plant uptake and can be used for assessing the likelihood of deficiencies and excesses, and the consequent problems.

MILLBUIE ASSOCIATION

The parent material of the soils of this association is a stony, coarse-textured morainic till derived from arenaceous sandstones of Middle Old Red Sandstone age. Such soils cover about 60 per cent of the Black Isle, the imperfectly drained soils of the dominant Millbuie Series being particularly widespread.

Both the total cobalt content of less than 3 μg/g and the extractable contents of generally 0.1 μg/g or less are very low, and indicate the strong likelihood of cobalt deficiency affecting cattle and sheep unless supplements are given. Averaging 3.3 μg/g, total copper contents are also low, suggesting that copper deficiency could affect either cereal crops or grazing stock, or both.

Total contents of molybdenum less than 1, manganese 370, nickel 25, lead 6, titanium 2750 and vanadium 30 μg/g are all at the lower end of the normal range for these elements in soils. Such values reflect the dominantly coarse textures of the soils of the the Millbuie Association. The generally acid nature of these soils, however, indicates that manganese deficiency in crops is unlikely, unless the soils are over-limed.

CROMARTY ASSOCIATION

Compact, sandy loam till, derived from sandstones of Middle Old Red Sandstone age, forms the parent material of this association. The dominant soils are those of the imperfectly drained Cromarty Series which covers about 9 per cent of the Black Isle, especially around the town of Cromarty in the north-east.

The total cobalt contents of these soils are very low and range from less than 3 to 4 with a mean of 2.3 μg/g. Extractable cobalt contents are also generally low throughout the profiles, ranging in ploughed horizons from 0.12 to 0.60 with a mean of 0.28 μg/g. Cobalt deficiency affecting ruminant animals, therefore, could be anticipated on the freely drained soils of the Brucefield Series and on the imperfectly drained soils of the Cromarty Series. In one profile of the poorly drained Navity Series, mobilization of cobalt due to gleying has increased extractable cobalt levels to greater than 0.6 μg/g throughout the profile. Because the Ap horizon contains 1.0 μg/g, cobalt deficiency would be less likely on the poorly drained soils.

Values for total copper contents are also low, ranging from less than 3 to 8 with a mean of 4.8 μg/g. Likewise, extractable copper contents are generally low in the B and C horizons where levels are around 0.5 μg/g. However, in the upper horizons of cultivated profiles, where there is a maximum content of organic matter, these levels range from 0.6 to 3 μg/g and copper deficiency in cereal crops appears unlikely. Within the subsoil of one profile of the poorly drained Navity Series, the amount of extractable copper reaches 1.2 μg/g because of the gleying process.

Total molybdenum contents range from less than 1 to 3 μg/g with a mean of 1 μg/g; in the surface horizons of soils of the Cromarty and Navity Series there are, respectively, contents of 2 and 3 μg/g.

Showing little change with depth, total manganese contents range from 150 to 600 μg/g with a mean of 344 μg/g. Extractable manganese contents in cultivated horizons range from 20 to 50 μg/g and, because soil pH values are usually around 6 or less, manganese deficiency affecting crops would not be anticipated.

Total contents of the other elements, namely nickel 23, lead 11, titanium 2830 and vanadium 30 μg/g are generally low, reflecting the moderately coarse texture of the soils.

MOUNT EAGLE ASSOCIATION

The soils are developed on a shallow, stony, semi-residual drift derived from sandstones of Middle Old Red Sandstone age and their total trace element contents should be similar to those of the Cromarty Association. Soils of the freely drained Mount Eagle Series and the imperfectly drained Findon Series occupy about 7 per cent of the total land area of the Black Isle and are found in the central region, near Findon Forest.

The mean values reported in Table G show that soils of the Mount Eagle Association generally contain amounts of trace elements similar to those of the Cromarty Association and Milbuie , although they have slightly greater contents of manganese and vanadium. The low total cobalt and copper contents of 2.6 and 4.3 μg/g suggest the possibility of deficiencies of these elements affecting ruminant stock.

If cereal crops were to be grown, deficiency of copper causing 'blind ear' could arise. The likelihood of such problems is supported also by the values for the extractable contents of these elements. Extractable cobalt is very low throughout all the profiles whereas extractable copper contents in highly organic surface horizons of the profiles are 2.9, 1.7 and 1.5 μg/g; these values fall sharply in underlying mineral horizons to less than 0.25 μg/g. Amounts of manganese and zinc, extractable by EDTA, follow a similar pattern.

The mean total contents of molybdenum 0.6, manganese 630, nickel 27, lead 15, titanium 300 and vanadium 49 μg/g are near the middle or lower end of the normal range for these elements in soils.

ETHIE ASSOCIATION

The parent material of the soils of this association is a shallow drift derived from sandstones of Middle Old Red Sandstone age and Moinian gneiss. Soils of the dominant Ethie Series are freely drained and, together with the imperfectly drained soils of the Gallow Series, occupy around 6 square kilometres. The poorly drained soils of the Learnie Series are of minor extent.

These soils are very low in total cobalt and copper contents (Table G). Extractable contents of both elements are also low and suggest a high risk of deficiencies of the elements, particularly in the freely drained soils of the dominant Ethie Series.

Total contents of molybdenum 0.9, manganese 350, nickel 15, lead 9, titanium 3000 and vanadium 33 μg/g, reflect the lower end of the normal range for these elements in soils. Deficiencies of manganese affecting crops would not be anticipated because of the generally acid nature of these soils.

CORBY ASSOCIATION

Fluvioglacial gravels form the parent material of this association and occupy less than 4 square kilometres. They occur mainly in the south-west, south of Muir of Ord and on the southern coastline. Most of the soils are freely drained and have been included in the Corby Series; soils of the imperfectly drained Leys Series and of the poorly drained Mulloch Series are of negligible extent.

Throughout northern Scotland, soils of the Corby Association generally have rather low contents of cobalt and copper, respectively around 6 and 9 μg/g. This is a consequence of their derivation from acid igneous and metamorphic rocks. Five profiles, sampled from areas adjacent to the Black Isle, contain less than 3 to 4 μg/g total cobalt and less than 3 to 10 μg/g total copper in their upper horizons. With a range of 0.06 to 0.67 and a mean of 0.27 μg/g, the values of extractable cobalt contents strongly suggest a high risk of cobalt deficiency affecting ruminant animals.

The extractable copper contents in the upper horizons vary widely from less than 0.25 to 3.4 with a mean of 1.4 μg/g. Although these values suggest that copper deficiency in cereals is possible, it is generally unlikely considering the low pH values of the soils. There is, however, a risk of copper deficiency affecting stock, but this problem is not likely to be complicated by high amounts of molybdenum, the levels of which are usually less than 1 μg/g.

Though total manganese contents are rather low, averaging 460 μg/g, the generally acid nature of the soils results in a low risk of manganese deficiency in crops, unless induced by over-liming.

Mean total contents of the other trace elements in soils of the Corby Association are nickel 21, lead 16, titanium 2930 and vanadium 38 μg/g.

BOYNDIE ASSOCIATION

The parent material of the soils of this association comprises fluvioglacial sands which cover about 0.5 per cent of the area. Confined largely to an area south-east of Muir of Ord, the soils are dominated by those of the freely drained Boyndie Series.

Generally, soils of the Boyndie Association in nothern Scotland contain low amounts of cobalt and copper, around 4 and 6 μg/g respectively. In two profiles sampled in Nairnshire (Sheet 84), the cobalt contents were 3 or less than 3 μg/g throughout both profiles, whereas copper contents were 3 to 6 μg/g throughout, with 10 μg/g in the surface horizon of one profile. Extractable cobalt values in the A horizons were 0.1 to 0.3 μg/g which indicate a high risk of cobalt deficiency in ruminant animals. Similarly, extractable copper contents in A horizons were also around 1 μg/g, suggesting the probability of copper deficiency in cereals. Although there is also a risk of copper deficiency affecting ruminant stock, this problem would not be complicated by high amounts of molybdenum in the soil; contents of the latter in soils of the Boyndie Association are generally less than 1 μg/g.

Total contents of other elements in soils of the Boyndie Association are manganese 520, nickel 14, lead 12, titanium 3500 and vanadium 31 μg/g.

KESSOCK ASSOCIATION

Despite the lack of analyses of representative samples, problems of cobalt and copper deficiencies can be anticipated on soils of the Kessock Association because of the similarity of its parent material to that of the Mount Eagle Association.

As the soils of the Millbuie, Cromarty and Mount Eagle Associations are all derived from strata of Middle Old Red Sandstone age, the mean total trace element content for each of the elements listed in Table G are very similar. It appears, therefore, that problems of cobalt and, to a lesser extent, copper deficiency affecting ruminant stock are likely to be widespread in the Black Isle. Problems of boron deficiency in susceptible crops, such as the brassicaes, could arise also on the freely drained, sandy soils, particularly after liming. From the limited data available on selenium in Scottish soils, a deficiency of this element also might be anticipated in stock in areas of similar freely drained, moderately coarse and coarse-textured soils.

Some of the early experiments on the control of pining in sheep, by the administration of cobalt or by the use of cobalt-rich fertilizers, were carried out on farms in Ross-shire (Stewart *et al.*, 1941, 1942; Stewart, 1947). Most of the soils, on which pining in sheep was found, contained less than 5 $\mu g/g$ total cobalt.

SUMMARY OF ANALYTICAL METHODS

1 The soil separates (sand, silt and clay) were determined by a modification of the hydrometer method (Bouyoucos, 1927a, 1927b).

2 The exchangeable cations were determined in a neutral normal ammonium acetate leachate, calcium, sodium and potassium being determined by flame photometry (Ure, 1954) and magnesium by direct photometry (Scott and Ure, 1958).

3 Exchangeable hydrogen was determined by electrometric titration of a neutral normal barium acetate leachate (Parker, 1929). pH was determined in an aqueous suspension by means of a glass electrode.

4 Total carbon was determined by a wet combustion method using standard potassium dichromate solution (Walkley and Black, 1934).

5 Total nitrogen was determined by a semi-micro-Kjeldahl method (Markham, 1942).

6 Total phosphorus was determined by a colorimetric method using hydrazine sulphate, after fusing the soil with sodium carbonate (Muir, 1952).

7 Acetic soluble phosphorus was determined colorimetrically in a 2.5 per cent acetic acid extract (Williams and Stewart, 1941).

8 The mineralogy of the clay fractions was determined by differential thermal analysis and X-ray diffraction. Differential thermal curves were determined according to methods described by Mitchell and Mackenzie (1959). Diffraction patterns of the soil clays were obtained on film with a Raymax 60 X-ray generator.

9 The trace element determinations were made spectrochemically according to the methods described by Mitchell (1964).

4 Vegetation

The central spine of the Black Isle above the 150-metre contour is dominated by a wet, heathy vegetation and has been planted extensively with Scots pine. Dry moorland communities occur in the south where pine has been planted also and in a small area on the Sutors of Cromarty. Around the margin of the central ridge are local outcrops of calcareous sandstone, and occasional springs enriched with minerals. Broadleaved woodlands and other base-rich communities are found in association with these sites. The oakwood at Teandore is remarkable for the presence of *Paris quadrifolia* (herb Paris) whereas at Ballycherry, where the shallow peat is flushed with calcareous water, sedge mires have developed in which *Eriophorum latifolium* (broadleaved cotton-grass), *Carex capillaris* (hair sedge) and *C. lepidocarpa, Schoenus nigricans* (bog-rush) and *Saxifraga azoides* (yellow mountain-saxifrage) occur.

Below 150 metres, the land is cultivated extensively and there is very little rough grassland save for that found along the banks of the Ethie Burn. The most extensive area of vegetation on deep peat occurs in the kettlehole complex of Monadh Mor. Maritime communities are found along the coastline, especially near Fortrose and Rosemarkie, but they are either very disturbed or small in extent, and have not been recorded.

PLANT COMMUNITIES

WOODLAND

There are no examples of undisturbed natural forests, and trees are mostly planted, although certain sites such as the oakwood at Teandore may have been woodland for some time. Coniferous plantations, mainly of Scots pine, are most common but these were not sampled unless the tree canopy was mature and the underlying vegetation had achieved a degree of stability. Although oak and birch woodlands in this area are dominantly those of the eastern highland association which extends along the edge of the eastern Grampians and as far west as Glen Affric, small outliers of the southern association also have become established round the Moray Firth because of the equable climate. The two association areas overlap to a marked degree and elements from each are present in many of the stands. Mixed broadleaved woodland or elmwood is restricted to narrow, steep-sided gullies and mixed bottom land.

Class: Vaccinio-Piceetea Br.-Bl. apud Br.-Bl., Siss et Vl. 1939
Order: Vaccinio-Piceetalia Br.-Bl. apud Br.-Bl., Siss. et Vl. 1939
Alliance: not yet classified
Community: *Erica cinerea–Pinus sylvestris* plantations Birse et Robertson 1976, em. Birse 1980

Bell heather–Scots pine plantations

Old pine plantations with trees up to 100 years of age are a common feature of eastern Scotland north of the Highland Boundary Fault. The vegetation beneath the mature canopy is very similar to that of native pinewood and includes both *Goodyera repens* (lady's tresses) and *Listera cordata* (lesser twayblade). The field layer is usually sparse, but the ground layer is often total and consists of a deep carpet of mosses in which pine seedlings become established temporarily.

The typical subcommunity is the drier of the two quoted in the table and is found dominantly on freely drained humus-iron and iron podzols. Stands were recorded at Ferintosh (relevé 1), Ashley (2) and Lundie (3) and in Bellton Wood (4). The subcommunity with *Polytrichum commune* (hair moss) is found on soils with impeded drainage. A stand of this vegetation occurs in Bellton Wood on an imperfectly drained podzol (relevé 5). *Erica tetralix* (bog heather) is present in the field layer.

Table H

Relevé number	1	2	3	4	5	Constancy class
Serial no.	64031	64051	64053	64056	64055	
Grid reference	NH 599553	NH 625498	NH 669507	NH 635557	NH 636558	
Altitude (m)	160	61	137	137	140	
Aspect	WNW	NW	NW	SW	SW	
Slope (°)	6°	2°	8°	2°	3°	
Plot (m^2)	100	100	100	100	100	
Cover—						
tree (%)	60	45	50	40	50	
field (%)	1	2	8	1	60	
ground (%)	95	90	100	100	100	
Height—						
tree (m)	12	11	15	15	18	
field (cm)	–	8	15–46	5	46	
Major Soil Subgroup	HIP	HIP	HIL	IP	GP	
Climate	$O_2H_3B_3$	$O_2H_4B_3$	$O_2H_3B_3$	$O_2H_3B_3$	$O_2H_3B_3$	
Trees						
Pinus sylvestris	8	7	7	7	7	V
D. Community						
Erica cinerea	(X)	–	–	–	–	III

d. subcommunity						
Polytrichum commune	—	—	—	—	—	I
Erica tetralix	X	—	—	—	1	I
Ch. Order and Class						
Plagiothecium undulatum	1	5	—	1	6	IV
Goodyera repens	1	—	2	X	4	IV
Vaccinium myrtillus	—	—	—	—	—	III
Trientalis europaea	—	(X)	—	—	—	II
Rhytidiadelphus loreus	—	—	—	—	—	II
Vaccinium vitis-idaea	—	—	—	—	—	II
Listera cordata	—	—	—	—	2	+
Ptilium crista-castrensis	—	—	—	—	(X)	r
Sphagnum quinquefarium	—	—	—	—	—	r
Companion species						
Calluna vulgaris	(X)	X	(X)	(X)	8	
Dicranum scoparium	6	5	(X)	5	2	
Hylocomium splendens	7	6	5	8	8	
Hypnum jutlandicum	4	7	1	3	2	
Pleurozium schreberi	5	5	2	6	4	
Parmelia physodes	3	3	3	3	3	
Usnea spp.	3	—	—	2	2	
Lepidozia reptans	—	X	—	2	X	
Deschampsia flexuosa	—	3	4	—	—	
Rhytidiadelphus triquetrus	(X)	—	10	—	—	
Pinus sylvestris seedlings	—	1	—	1	—	
Cladonia cornuta	—	X	—	1	—	
Evernia prunastri	1	X	1	—	1	
Number of species	16	19	15	17	21	

Additional companion species
1 Betula pubescens seedling (X), Cetraria glauca X
2 Cladonia fimbriata X, Cladonia glauca X, Cladonia pyxidata X
3 Dicranum majus 3, Rhytidiadelphus loreus 1, Cladonia sp. 1, Usnea subfloridana 2
4 Cladonia digitata 1, Cladonia macilenta X
5 Dactylorchis maculata ericetorum X, Aulacomnium palustre 2, Cephalozia media X, Cladonia arbuscula 2, Peltigera sp (X)

Typical subcommunity (1—4)
Subcommunity with *Polytrichum commune* (5)

Class: Quercetea robori-petraeae Br.-Bl. et Tx. 1943
Order: Quercetalia robori-petraeae Tx. (1931) 1937 em. 1955
Alliance: Quercion robori-petraeae (Malcuit 1929) Br.-Bl. 1932
Association: Trientali-Betuletum pendulae Birse 1982

Eastern highland oakwood and birchwood

This association is differentiated from that of southern oakwood by the presence of *Luzula pilosa* (hairy woodrush) and *Trientalis europaea* (chickweed wintergreen).

Two subassociations have been separated, the first being dominated by oak and the second by birch. An example of the oakwood was recorded at Teandore on a freely drained humus-iron podzol (relevé 1). This stand, as indicated by the presence of *Stellaria holostea* (greater stitchwort), represents a slightly more base-rich element within the subassociation. The birchwood at Ashley (relevé 2) is not a typical example of the second subassociation as *Vaccinium vitis-idaea* (cowberry) is absent, but there is a strong heathy element in the form of *Vaccinium myrtillus* (blaeberry) which dominates the field layer. The soil there is an iron podzol.

Table I

Relevé number	1	2	Constancy class
Serial no.	64011	64052	
Grid reference	NH 548581	NH 623501	
Altitude (m)	50	55	
Aspect	NW	E	
Slope (°)	8°	3°	
Plot (m^2)	100	100	
Cover—			
tree (%)	60	50	
field (%)	70	75	
ground (%)	15	75	
Height—			
tree (m)	10	8	
field (cm)	30	36	
Major Soil Subgroup	HIP	IP	
Climate	$O_2H_3B_3$	$O_2H_4B_3$	
Trees			
Betula pendula (Ch. All.)	—	5	III
Betula pubescens	5	6	III
Quercus petraea/robur	7	—	II
Sorbus aucuparia	1	1	I
Fagus sylvatica	—	4	r
Lianes			
Lonicera periclymenum (Ch. All.)	3	—	r
D. Association			
Luzula pilosa	4	1	V
Trientalis europaea	2	X	IV
d. variant			
Stellaria holostea	3	—	I
Conopodium majus	—	—	I
Primula vulgaris	—	—	I
Lysimachia nemorum	—	—	r
d. subassociation			
Vaccinium vitis-idaea	—	—	III
Juniperus communis	—	—	II
Ch. Alliance, Order & Class			
Pteridium aquilinum	4	—	IV
Lathyrus montanus	—	—	III
Holcus mollis	7	—	II
Hypericum pulchrum	—	—	I
Teucrium scorodonia	—	—	I
Lonicera periclymenum	1	—	I

Companion species			
Deschampsia flexuosa	6	6	–
Potentilla erecta	X	X	–
Hylocomium splendens	1	8	–
Plagiothecium undulatum	2	X	–
Pseudoscleropodium purum	3	3	–
Rhytidiadelphus squarrosus	3	1	–
Rhytidiadelphus triquetrus	2	X	–
Lophocolea bidentata	2	5	–
Number of species	37	22	

Additional companion species

1 Betula pubescens seedlings 2, Quercus seedling X, Sorbus aucuparia seedling (X), Agrostis tenuis 3, Anthoxanthum odoratum X, Poa trivialis X, Carex sp. X, Luzula multiflora 1, Galium saxatile 1, Oxalis acetosella 5, Rumex acetosella 2, Veronica chamaedrys (X), Dicranella heteromalla X, Eurhynchium praelongum 2, Hypnum cupressiforme 1, Mnium hornum 3, Pohlia nutans X, Polytrichum longisetum 1, Thuidium tamariscinum 3

2 Vaccinium myrtillus 8, Calluna vulgaris (X), Fagus sylvatica seedling (X), Dicranum scoparium 1, Pleurozium schreberi 3, Evernia prunastri 2, Parmelia physodes 1, Hypnum jutlandicum 1

Typical subassociation (1)
  variant with *Stellaria holostea*
Subassociation with *Vaccinium vitis-idaea* (2)
  typical variant

Association: Lonicera—Quercetum (Birse et Robertson 1976) Birse 1984.

Southern Oakwood

In the Black Isle, southern oakwood is at the northernmost point of its range, its presence being encouraged by the prevailing climate of mild winters and warm, dry summers. It differs from the eastern association in the presence of *Lonicera periclymenum* (honeysuckle), either in the form of lianes or of dwarf shrubs, and the moss *Eurhynchium praelongum*. The association is found most often on brown forest soils of low base status.

The stand at Teandore (relevé 1) is an example of the subassociation with *Endymion non-scriptus* (bluebell) which is more western in its distribution. The canopy is dominated by *Quercus robur* (pedunculate oak) with an understory of *Corylus avellana* (hazel) shrubs and with *Lysimachia nemorum* (yellow pimpernel) and *Anemone nemorosa* (wood anemone) in the field layer. The soil is of moderate base status. The remaining stands can be related to the typical association of the drier east although they are not all good examples. The mosses *Rhytidiadelphus triquetrus* and *Hylocomium splendens* are present throughout. The stand at Drumsmittal (relevé 2) is dominated by *Quercus petraea* (sessile oak) whereas those at Rosemarkie (3) and Ballycherry (4 & 5) have canopies of birch, either *Betula pendula* or *B. pubescens*. The soils are all typical of the association with the exception of that at Rosemarkie which is of high base status.

Table J

Relevé number	1	2	3	4	5	Constancy class
Serial no.	64009	64054	64041	64046	64047	
Grid reference	NH 584579	NH 645488	NH 731577	NH 692634	NH 694637	
Altitude (m)	53	61	46	64	58	
Aspect	NW	SE	N	N	SE	
Slope (°)	5°	30°	32°	5°	23°	
Plot (m^2)	100	100	100	100	150	
Cover—						
tree (%)	70	60	30	50	30	
shrub (%)	40	—	—	—	—	
field (%)	30	75	25	50	80	
ground (%)	3	50	98	95	85	
Height—						
tree (m)	9	17	12	14	17	
shrub (m)	5.5	—	—	—	—	
field (cm)	8–25	20–56	13–38	15–48	20–66	
Major Soil Subgroup	BFS	BP	BFS	GBP	BP	
Climate	$O_2H_3B_3$	$O_2H_4B_3$	$O_2H_4T_1$	$O_2H_3B_3$	$O_2H_3B_3$	
Trees						
Betula pubescens	2	—	5	8	—	II
Quercus petraea	—	8	—	—	—	II
Betula pendula	—	—	5	—	6	I
Quercus robur	8	2	—	—	—	I
Fagus sylvatica	—	—	—	—	1	+
Betula pubescens odorata	—	—	—	—	2	—
Shrubs						
Corylus avellana	6	—	—	—	—	I
Sarothamnus scoparius	—	—	—	X	—	r
Juniperus communis	—	X	—	—	—	—
Ulex europaeus	—	(X)	—	—	—	—
D. Association						
Eurhynchium praelongum	2	4	—	—	—	IV
Lonicera periclymenum	(X)	(X)	—	—	3	IV
d. subassociation						
Endymion non-scriptus	4	—	—	—	—	III
d. variant						
Lysimachia nemorum	5	—	—	—		II
d. variant						
Stellaria holostea	—	(X)	—	—	—	II
d. subvariant						
Rhytidiadelphus triquetrus	—	3	6	9	2	II
Hylocomium splendens	—	2	6	2	2	I
Ch. Alliance, Order and Class						
Holcus mollis	—	4	—	—	6	V
Pteridium aquilinum	—	—	—	—	6	IV
Teucrium scorodonia	—	—	—	—	—	III

Hypericum pulchrum	—	X	—	—	1	I
Lathyrus montanus	—	—	—	(X)	—	+
Companion species						
Oxalis acetosella	1	1	4	4	4	
Veronica chamaedrys	X	4	X	1	2	
Viola riviniana	1	5	4	5	5	
Thuidium tamariscinum	1	4	7	—	8	
Pseudoscleropodium purum	—	1	1	6	6	
Agrostis tenuis	—	5	4	6	5	
Anthoxanthum odoratum	—	5	3	5	4	
Hypnum cupressiforme	X	1	—	—	2	
Mnium undulatum	1	—	—	X	2	
Festuca ovina	—	1	4	5	—	
Veronica officinalis	—	X	3	1	—	
Deschampsia flexuosa	—	5	X	—	1	
Lophocolea bidentata	—	1	2	—	4	
Galium saxatile	—	1	2	—	1	
Rhytidiadelphus squarrosus	—	4	—	1	2	
Potentilla erecta	—	(X)	—	3	2	
Geum rivale	X	—	(X)	—	—	
Rubus idaeus	X	—	X	—	—	
Ajuga reptans	(X)	—	—	1	X	
Trientalis europaea	2	—	—	—	(X)	
Fraxinus excelsior seedlings	—	(X)	1	—	—	
Poa pratensis	—	3	—	1	—	
Carex pilulifera	—	X	—	—	X	
Cerastium holosteoides	—	1	—	—	X	
Rumex acetosa	—	2	—	—	2	
Atrichum undulatum	—	1	—	—	X	
Dicranella heteromalla	—	2	—	—	1	
Holcus lanatus	—	—	1	X	—	
Luzula pilosa	—	—	2	2	—	
Plagiochila asplenioides	—	—	2	—	1	
Luzula multiflora	—	—	—	1	X	
Number of species	25	46	38	25	35	

Additional companion species

1 Poa trivialis X, Anemone nemorosa 5, Epilobium parviflorum (X), Taraxacum officinale X, Veronica serpyllifolia 3, Eurhynchium striatum 2, Fissidens bryoides 1, Isothecium myurum 1

2 Prunus avium seedling X, Quercus seedling X, Festuca rubra 2, Luzula campestris 1, Hieracium sp. X, Hypochoeris radicata 4, Senecio jacobaea X, Taraxacum sp. X, Bryum sp. 1, Ceratodon purpureus 1, Plagiomnium rostratum 1, Cladonia fimbriata X, Melampyrum pratense 5

3 Betula seedling X, Rubus fruticosus (X), Sorbus aucuparia seedling (X), Dryopteris filix-mas (X), Arrhenatherum elatius 1, Campanula rotundifolia (X), Fragaria vesca 1, Pohlia nutans X, Plagiochila asplenioides major X, Tritomaria quinquedentata 1, Cladonia sp. X, Peltigera sp. X, Rosa sp. (X), Dicranum majus 5, Dicranum scoparium X, Pleurozium schreberi 4

4 Carex flacca X, Cetraria glauca X, Evernia prunastri X, Fagus sylvatica seedling X

5 Agrostis canina 3, Cirriphyllum piliferum 3, Mnium hornum 1

subassociation with *Endymion non-scriptus* (1)
  variant with *Lysimachia nemorum*
typical subassociation (2—5)
  variant with *Stellaria holostea* (2)
    subvariant with *Rhytidiadelphus triquetrus*
  typical variant (3—5)
    subvariant with *Rhytidiadelphus triquetrus*

Class: Querco-Fagetea Br.-Bl. et Vl. 1937
Order: Fagetalia sylvaticae Pawl. 1928
Alliance: Carpinion betuli Oberd. 1953
Association: Querco-Ulmetum glabrae Birse et Robertson 1976 em. Birse 1984

Elmwood

This is the mixed deciduous woodland found most commonly on the base-rich soils in steep-sided gullies and in policies around mansion houses. The canopy can be a mixture of *Fraxinus excelsior* (ash), *Ulmus glabra* (elm), *Acer pseudoplatanus* (sycamore), *Quercus* species (oak) or *Betula* species (birch) and its dense cover induces a field layer that is dominated by shade-loving species. The soils are usually of moderate to high base status and the drainage may be any category between free to poor.

Both stands recorded there are representative of the typical subassociation. That at Teandore (relevé 1) has a canopy of oak (*Quercus petraea/robur) and Betula pubescens* (birch). The field layer is dominated by *Circaea lutetiana* (common enchanter's nightshade), and *Paris quadrifolia* (herb Paris) occurs also. The brown forest soil beneath the stand is of moderate base status and has a high level of exchangable calcium in the surface horizon. The second stand at Rosemarkie (relevé 2) is dominated by sycamore (*Acer pseudoplatanus*), with *Galium odoratum* (sweet woodruff) an abundant species of the field layer. The soil is a brown forest soil of low base status.

Table K

Relevé number	1	2	Constancy class
Serial no.	64010	64042	
Grid reference	NH 584579	NH 728583	
Altitude (m)	53	24	
Aspect	N	SW	
Slope (°)	4°	14°	
Plot (m^2)	100	100	
Cover—			
tree (%)	70	90	
shrub (%)	30	—	
field (%)	60	75	
ground (%)	3	10	
Height—			
tree (m)	11	15	
shrub (m)	6.1	—	
field (cm)	36	10–46	
Major Soil Subgroup	GBS	BP	
Climate	$O_2H_3B_3$	$O_2H_4T_1$	
Trees			
Fraxinus excelsior (Ch. Ord.)	—	1	IV
Ulmus glabra (Ch. Ord.)	—	—	III
Acer pseudoplatanus	—	9	II
Betula pubescens	7	2	II
Quercus petraea/robur	7	—	II

Alnus glutinosa	—	2	+
Fagus sylvatica (Ch. Ord.)	—	—	+
Prunus avium (Ch. All.)	—	—	r
Shrubs			
Corylus avellana	6	—	IV
Prunus padus	—	—	r
Lianes			
Lonicera periclymenum	2	—	r
d. subvariant			
Galium odoratum	—	6	+
Ch. Alliance			
Eurhynchium striatum	2	2	V
Endymion non-scriptus	—	—	IV
Stellaria holostea	—	4	r
Ch. Order and Class			
Dryopteris filix-mas	—	(X)	IV
Mercurialis perennis	—	—	IV
Fraxinus excelsior seedlings	—	2	III
Primula vulgaris	—	—	III
Circaea lutetiana	8	—	III
Lysimachia nemorum	1	—	III
Anemone nemorosa	2	—	III
Dryopteris borreri	2	—	III
Fissidens taxifolius	—	—	II
Carex sylvatica	—	—	II
Stachys sylvatica	—	X	I
Veronica montana	—	—	I
Circaea intermedia	—	—	I
Sanicula europaea	—	—	I
Crataegus monogyna seedlings	—	—	+
Scrophularia nodosa	—	—	+
Corylus avellana seedlings	—	—	+
Acer pseudoplatanus seedlings	—	—	+
Hedera helix	—	—	+
Fagus sylvatica seedlings	—	—	r
Rumex sanguineus	—	—	r
Polystichum lobatum	—	—	r
Adoxa moschatellina	—	X	r
Stellaria nemorum	—	—	r
Companion species			
Poa trivialis	X	1	—
Geranium robertianum	(X)	2	—
Geum urbanum	(X)	5	—
Oxalis acetosella	X	7	—
Veronica chamaedrys	(X)	X	—
Viola riviniana	X	1	—
Cirriphyllum piliferum	X	2	—
Eurhynchium praelongum	1	4	—
Hypnum cupressiforme	X	2	—
Thuidium tamariscinum	1	2	—
Number of species	25	34	

Additional companion species
1 Lonicera periclymenum (X), Agrostis tenuis X, Agrostis sp. X, Filipendula ulmaria (X), Paris quadrifolia 4, Rhytidiadelphus triquetrus X, Pseudoscleropodium purum X
2 Blechnum spicant X, Dryopteris dilatata (X), Dactylis glomerata (X), Luzula sylvatica (X), Ajuga reptans 2, Epilobium sp. X, Fragaria vesca (X), Glechoma hederacea 5, Silene dioica 1, Brachythecium rutabulum 3, Plagiomnium undulatum 2, Rhodobryum roseum X, Lophocolea cuspidata 2

typical subassociation (1, 2)
    typical variant
        typical subvariant (1)
        subvariant with *Galium odoratum* (2)

GRASSLAND

Very little semi-natural grassland occurs in the Black Isle as most of the land which is not planted is under cultivation or is remnant moorland. Rough pasture was recorded along the banks of the Ethie Burn and on the hill slopes near Kinnock; sedge mires of small extent occur at Ballycherry in association with springs.

Class: Nardo-Callunetea Prsg. 1949
Order: Nardetalia Prsg. 1949
Alliance: Nardo-Galion saxatilis Prsg. 1949
Association: Achilleo-Festucetum tenuifoliae Birse et Robertson 1976 em. Birse 1980

Bent-fescue grassland

This is the typical grassland association of dry, steep hill slopes which provides some of the best rough grazing in the Scottish uplands. The field layer is dominated by grasses, usually a mixture of *Festuca ovina* (sheep's fescue) and *Agrostis tenuis* (common bent-grass). The soils are predominantly brown forest soils of low base status.

Table L

Relevé number	1	2	Constancy class
Serial no.	64061	64062	
Grid reference	NH 728587	NH 772639	
Altitude (m)	122	107	
Aspect	NW	N	
Slope (°)	15°	23°	
Plot (m^2)	4	4	
Cover —			
field (%)	98	95	
ground (%)	40	65	
Height —			
field (cm)	8–23	20–41	
Major Soil Subgroup	GP	GBP	
Climate	$O_2H_3B_3$	$O_2H_3B_3$	
Ch. Association			
Veronica officinalis	–	X	III

D. Association			
Trifolium repens	—	(X)	IV
Viola riviniana	—	2	IV
Achillea millefolium	—	4	III
Ch. Alliance and Order			
Galium saxatile	X	2	V
Polygala serpyllifolia	—	—	II
Nardus stricta	—	—	II
Luzula multiflora	X	X	+
Viola lutea	—	—	+
Viola canina	—	—	r
Juncus squarrosus	—	—	r
Ch. Class			
Potentilla erecta	6	6	V
Carex pilulifera	—	—	III
Sieglingia decumbens	—	—	III
Plantago lanceolata	—	4	III
Hypnum jutlandicum	—	—	II
Calluna vulgaris	—	—	II
Erica cinerea	—	—	I
Empetrum nigrum	—	—	r
Euphrasia micrantha	—	—	r
Ptilidium ciliare	—	—	r
Pedicularis sylvatica	—	—	r
Botrychium lunaria	—	—	r
Carex binervis	—	—	r
Ulex europaeus	—	(X)	r
Companion species			
Agrostis canina montana	4	5	—
Agrostis tenius	5	5	—
Festuca ovina tenuifolia	5	5	—
Holcus lanatus	2	2	—
Rumex acetosa	X	X	—
Hylocomium splendens	5	6	—
Rhytidiadelphus squarrosus	6	5	—
Rhytidiadelphus triquetrus	1	1	—
Number of species	20	31	

Additional companion species

1 Vaccinium myrtillus 4, Deschampsia flexuosa, 3, Poa pratensis 1, Luzula pilosa 2, Bellis perennis (X), Cerastium holosteoides 1, Senecio jacobaea (X), Pleurozium schreberi 1

2 Blechnum spicant (X), Anthoxanthum odoratum 4, Festuca rubra 2, Carex panicea X, Angelica sylvestris X, Campanula rotundifolia X, Euphrasia nemorosa (X), Hypericum pulchrum (X), Lotus corniculatus 3, Succisa pratensis 3, Plagiomnium undulatum 3, Pseudoscleropodium purum 4, Thuidium tamariscinum 3, Lophocolea bidentata 4.

Both stands quoted in the table are related to the typical variant of the typical subassociation which is the most widespread form of the community. The first, from Ethie Burn (relevé 1), contains a heathy element. Both *Vaccinium myrtillus* (blaeberry) and *Deschampsia flexuosa* (wavy hair-grass) are present and the soil is a podzol and imperfectly drained. The second stand, near Kinnock (relevé 2), was recorded on an imperfectly drained brown forest soil.

Class: Caricetea nigrae (Nordh. 1936) Den Held et Westh. 1969
Order: Tofieldietalia Prsg. apud Oberd. 1949
Alliance: Eriophorion latifolii Br.-Bl. et Tx. 1943
Association: Caricetum hostiano-pulicaris (Birse et Robertson 1976) Birse 1980

Flea-sedge mire

A number of small sedge communities are found in flushed channels and depressions associated with base-rich springs. At Ballycherry, these springs contain such a high level of exchangeable calcium that, in places, calcium has been deposited as tufa on the vegetation. The stand of flea-sedge mire (relevé 1) is characterized by the presence of *Carex hostiana* (tawny sedge) and *C. pulicaris* (flea-sedge). *Eriophorum latifolium* (broad-leaved cotton-grass). *Schoenus nigricans* (bog-rush) and *Carex capillaris* (hair sedge), all basiphilous species, are present also. The soil is a poorly drained noncalcareous gley of high base status.

Association: Carici dioici-Eleocharitetum quinqueflorae (Birse et Robertson 1976) Birse 1980

Few-flowered spike-rush mire

This sedge mire is found often with the last-named community but in a slightly different position in the habitat, occurring in the wetter bases of the channels and depressions whereas flea-sedge mire colonizes the sides which are slightly better drained. Both stands were recorded at Ballycherry. The first (relevé 2) is an example of the more widespread subassociation and the soil is a peaty gley of moderate base status. The second (relevé 3) is related to the subassociation with *Saxifraga azoides* (yellow mountain-saxifrage) which is found in more calcareous sites; the soil is a noncalcareous gley of high base status with a pH value of 7.2 and 73.30 me/100g exchangeable calcium in the surface horizon.

Table M

Relevé number	1	Constancy class	2	3	Constancy class
Serial no.	64044		64043	64045	
Grid reference	NH 691636		NH 692633	NH 692633	
Altitude (m)	64		76	76	
Aspect	ESE		SW	N	
Slope (°)	2°		3°	4	
Plot (m^2)	4		4	4	
Cover --					
field (%)	80		85	80	
ground (%)	95		90	75	
Height --					
field (cm)	15–36		15–33	13–41	
Major Soil Subgroup	BG		PG	BG	
Climate	$O_2H_3B_3$		$O_2H_3B_3$	$O_2H_3B_3$	
Ch. Association A					
Carex hostiana	2	IV	–		III

Ch. Association B					
Eleocharis quinqueflora	5	II	3	—	V
Carex dioica	—	II	4	7	IV
d. subassociation					
Saxifraga azoides	—	I	—	[5]	II
Ch. Alliance and Order					
Carex pulicaris	2	V	—	(X)	I
Campylium stellatum	6	V	7	4	IV
Pinguicula vulgaris	X	IV	—	3	V
Fissidens adianthoides	1	IV	4	1	I
Drepanocladus revolvens	—	I	2	3	III
Bryum pseudotriquetrum	X	III	—	2	II
Triglochin palustris	—	II	—	X	II
Parnassia palustris	—	II	3	4	+
Taraxacum palustre	—	I	—	—	—
Riccardia multifida	1	I	—	3	r
Eriophorum latifolium	1	I	4	—	+
Tofieldia pusilla	—	+	—	—	I
Leiocolea muelleri	—	r	—	—	r
Schoenus nigricans	4	r	—	—	—
Sagina nodosa	—	+	—	(X)	—
Fissidens osmundoides	—	+	—	—	—
Pellia neesiana	—	+	—	—	—
Scorpidium scorpioides	—	—	X	—	IV
Selaginella selaginoides	3	IV	2	—	II
Sphagnum contortum	—	—	—	—	r
Leiocolea badensis	—	1	—	—	r
Ch. Class					
Carex panicea	—	V	4	[6]	V
Eriophorum angustifolium	—	III	1	3	IV
Carex nigra	—	III	—	—	II
Juncus articulatus	3	II	4	4	I
Riccardia pinguis	—	III	—	—	IV
Carex demissa	—	II	—	—	II
Carex echinata	—	II	—	—	I
Dicranum bonjeani	—	I	—	—	—
Agrostis canina canina	—	I	—	—	—
Viola palustris	—	+	—	—	—
Ranunculus flammula	—	r	—	—	I
Sphagnum auriculatum auriculatum	—	+	—	—	+
Hydrocotyle vulgaris	—	r	—	—	—
Juncus triglumis	—	+	—	—	r
Pedicularis palustris	2	—	2	X	I
Epilobium palustre	—	—	—	—	r
Acrocladium stramineum	—	—	—	—	r
Juncus acutiflorus	—	+	—	—	—
Companion species					
Equisetum palustre	3	—	4	5	—
Agrostis stolonifera	4	—	1	2	—
Festuca rubra	2	—	3	4	—
Molinia caerulea	4	—	4	3	—
Potentilla erecta	3	—	3	X	—
Succisa pratensis	7	—	5	4	—
Ctenidium molluscum	7	—	8	5	—
Erica tetralix	X	—	X	—	—
Dactylorchis spp.	(X)	—	X	—	—

Table M (cont.)

Relevé number	1	Constancy class	2	3	Constancy class
Euphrasia micrantha	2	—	2	—	—
Betula pubescens seedlings	(X)	—	—	4	—
Carex flacca	4	—	—	[6]	—
Prunella vulgaris	3	—	—	4	—
Veronica officinalis	X	—	—	X	—
Rhytidiadelphus triquetrus	2	—	—	1	—
Pinus sylvestris	—	—	(X)	3	—
Pellia fabbroniana	—	—	1	3	—
Carex lepidocarpa	—	—	5	3	—
Number of species	43		27	40	

Additional companion species

1 Festuca ovina 3, Nardus stricta 1, Poa pratensis X, Carex capillaris 1, Linum catharticum 1, Polygala sp. X, Ranunculus acris X, Ditrichum flexicaule 7, Drepanocladus vernicosus 5, Eurhynchium praelongum (X), Hylocomium splendens X, Pseudoscleropodium purum X, Lophozia ventricosa 2, Cladonia pyxidata X, Cerastium holosteoides X

2 Calypogeia fissa 1

3 Betula pubescens odorata 1, Juniperus communis 1, Ajuga reptans X, Plantago lanceolata X, Acrocladium cuspidatum 4, Cratoneuron filicinum 5, Philonotis fontana 1, Thuidium tamariscinum X, Lophocolea bidentata 2

Association A: Caricetum hostiano-pulicaris (Birse et Robertson 1976) Birse 1980
Typical subassociation, typical variant (1)

Association B: Carici dioici-Eleocharitetum quinqueflorae (Birse et Robertson 1976) Birse 1980
Typical subassociation, typical variant (2)
Subassociation with *Saxifraga azoides*, typical variant (3)

MOORLAND

Much of the area occupied formerly by moorland communities has been planted with coniferous trees and the underlying vegetation is in various stages of change depending on the density of the canopy. Small areas that have not been planted do still exist, the most extensive of these being on Monadh Mor. Dry moorland was recorded on the exposed headland of Sutors of Cromarty, moist and wet moorland at Ferintosh, and blanket bog on Monadh Mor.

Class: Nardo-Callunetea Prsg. 1949
Order: Calluno-Ulicetalia (Quantin 1935) Tx. 1937
Alliance: Ulicion gallii Des Abb. et Corillion 1949
Association: Carici binervis-Ericetum cinereae Br.-Bl. et Tx. (1950) 1952 em. Birse 1980

Atlantic heather moor

The association is widely distributed in the moorland regions of southern Scotland and at altitudes of usually 300 metres or less in northern Scotland. Both stands are examples of the typical subassociation, but that on the Sutors of Cromarty is part of the variant with *Vaccinium myrtillus* (relevé 1), drier vegetation on humus-iron podzols, whereas the stand at Ferintosh is related to the variant with *Molinia caerulea* (relevé 2). *Molinia* (flying bent) is absent but the presence of *Trichophorum cespitosum* (deer-grass) and the abundance of *Erica tetralix* (bog heather) form sufficient indication that the vegetation is moist heather moor. The soil is an imperfectly drained podzol.

Table N

Relevé number	1	2	Constancy class
Serial no.	64048	64035	
Grid reference	NH 806670	NH 599551	
Altitude (m)	122	160	
Aspect	NNW	W	
Slope (°)	13°	1°	
Plot (m^2)	4	4	
Cover—			
field (%)	80	70	
ground (%)	90	85	
Height—			
field (cm)	36	35	
Major Soil Subgroup	HIP	GP	
Climate	$O_2H_3B_3$	$O_2H_3B_3$	
Ch. Association			
Carex binervis	—	—	III
D. Association			
Agrostis canina montana	—	—	IV
Nardus stricta	—	—	III
Sieglingia decumbens	—	—	II
d. variant			
Trichophorum cespitosum	—	X	II
Molinia caerulea	—	—	II
Erica tetralix	—	7	I
Vaccinium myrtillus	5	—	I
Ch. Alliance and Order			
Calluna vulgaris	9	7	V
Erica cinerea	4	—	V
Antennaria dioica	—	—	I
Euphrasia micrantha	—	—	r
Ptilidium ciliare	—	—	r
Ulex gallii	—	—	r
Ulex europaeus	—	—	r
Sarothamnus scoparius	—	—	r
Lycopodium clavatum	—	—	r

Table N (cont.)

Relevé number	1	2	Constancy class
Ch. Class			
Hypnum jutlandicum	6	3	V
Potentilla erecta	—	—	V
Carex pilulifera	—	—	III
Luzula multiflora	—	—	II
Galium saxatile	—	—	II
Juncus squarrosus	—	—	I
Polygala serpyllifolia	—	—	I
Pedicularis sylvatica	—	—	+
Dactylorchis maculata ericetorum	—	—	+
Companion species			
Dicranum scoparium	2	1	—
Hylocomium splendens	4	8	—
Pleurozium schreberi	6	6	—
Cladonia glauca	2	1	—
Cladonia impexa	6	4	—
Cladonia squamosa	2	2	—
Parmelia physodes	4	4	—
Number of species	17	20	

Additional companion species
1 Deschampsia flexuosa 1, Pohlia nutans 3, Polytrichum juniperinum 1, Lophozia bicrenata X, Cladonia gracilis X, Cladonia pityrea X.
2 Plagiothecium undulatum 1, Rhytidiadelphus triquetrus 3, Cephaloziella hampeana X, Lophocolea bidentata 1, Lophozia ventricosa 1, Tritomaria exsectiformis 1, Cladonia bellidiflora X, Cladonia pyxidata, Cladonia scabriuscula X.

Typical subassociation, variant with *Vaccinium myrtillus* (1)
variant with *Molinia caerulea* (2)

Class: Oxycocco-Sphagnetea Br.-Bl. et Tx. 1943
Order: Sphagnetalia compacti Tx. (1970) 1972
Alliance: Ericion tetralicis Schwickerath 1933
Association: Narthecio-Ericetum tetralicis J. J. Moore (1964) 1968

Bog heather moor

Bog heather moor comprises wet moorland vegetation that is confined generally to the margins of peat mosses in the east but becomes much more extensive in the west. *Narthecium ossifragum* (bog asphodel) and *Erica tetralix* (bog heather) are usually outstanding species in the field layer from which *Eriophorum vaginatum* (cotton-grass) is absent. The typical subassociation is represented by a stand at Ferintosh (relevé 1) on a noncalcareous gley of moderate base status. The presence of *Molinia caerulea* (flying bent), *Potentilla erecta* (common tormentil) and *Polygala serpyllifolia* (milkwort) indicates that there is some flushing. The stand in Bellton Wood (relevé 2) has a high abundance of lichens in the ground layer and is a member of the subassociation with the lichen *Cladonia uncialis*. This subassociation is found generally in more exposed sites than the first and is characterized by the presence of *Racomitrium lanuginosum* (woolly fringe-moss) and *Cladonia arbuscula*, together with *C. uncialis*, in the ground layer. The soil is a noncalcareous gley of low base status.

Table O

Relevé number	1	2	Constancy class
Serial no.	64036	64057	
Grid reference	NH 599551	NH 634559	
Altitude (m)	158	137	
Aspect	NIL	W	
Slope (°)	0°	1°	
Plot (m^2)	4	4	
Cover—			
field (%)	95	40	
ground (%)	60	95	
Height—			
field (cm)	30	28	
Major Soil Subgroup	AG	AG	
Climate	$O_2H_3B_3$	$O_2H_3B_3$	
d. variant			
Molinia caerulea	5	—	III
d. subvariant			
Potentilla erecta	4	—	II
Polygala serpyllifolia	1	—	II
d. subassociation			
Cladonia uncialis	—	1	III
Racomitrium lanuginosum	—	1	III
Cladonia arbuscula	[5]	[4]	II
Ch. Alliance			
Erica tetralix	8	4	V
Trichophorum cespitosum	—	4	V
Sphagnum compactum	—	2	V
Gymnocolea inflata	—	—	I
Odontoschisma denudatum	—	—	+
Ch. Order and Class			
Sphagnum tenellum	—	X	III
Narthecium ossifragum	3	—	III
Sphagnum capillifolium	—	—	II
Mylia taylori	—	—	II
Pleurozia purpurea	—	—	II
Odontoschisma sphagni	—	—	I
Mylia anomala	—	—	I
Drosera rotundifolia	—	—	I
Cephalozia connivens	—	—	+
Aulacomnium palustre	5	—	+
Sphagnum rubellum	—	—	+

Table O (cont.)

Relevé number	1	2	Constancy class
Eriophorum vaginatum	—	—	+
Sphagnum plumulosum	2	—	+
Lepidozia setacea	—	—	+
Hypnum imponens	—	—	+
Lophozia porphyroleuca	—	—	r
Cephalozia leucantha	—	—	r
Sphagnum papillosum	—	—	r
Companion species			
Calluna vulgaris	4	7	—
Carex panicea	X	X	—
Dicranum scoparium	3	3	—
Hylocomium splendens	5	2	—
Hypnum jutlandicum	2	5	—
Pleurozium schreberi	5	6	—
Calypogeia fissa	3	2	—
Cladonia impexa	[5]	9	—
Number of species	34	23	

Additional companion species

1 Sorbus aucuparia seedling X, Agrostis canina montana 1, Deschampsia flexuosa 2, Nardus stricta 3, Carex echinata 5, Carex nigra 2, Carex sp. 2, Eriophorum angustifolium 4, Juncus kochii 1, Luzula multiflora (X), Dactylorchis maculata ericetorum X, Succisa pratensis (X), Acrocladium cuspidatum 1, Breutelia chrysocoma 1, Drepanocladus uncinatus 1, Rhytidiadelphus squarrosus 2, Sphagnum auriculatum inundatum 2, Lophocolea bidentata X.

2 Pinus sylvestris 5, Diplophyllum albicans 3, Lepidozia trichoclados X, Lophozia ventricosa X, Sphenolobus minutus 3, Cladonia pyxidata (X), Cladonia rangiferina [4], Cladonia squamosa X, Parmelia physodes 1.

Typical subassociation, variant with *Molinia caerulea,* subvariant with *Potentilla erecta* (1)
Subassociation with *Cladonia uncialis,* typical variant (2)

Order: Eriophoro-Sphagnetalia papillosi Tx. (1970) 1972
Alliance: Calluno-Sphagnion papillosi Tx. (1970) 1972
Association: Erico-Sphagnetum papillosi J. J. Moore (1964) 1968 em. Birse 1980

Blanket and raised bog

This is the most widespread association found on deep peat throughout Scotland. As mentioned above, Monadh Mor is the only extensive area of deep peat in the Black Isle and the stand recorded here is an example of the typical subassociation which is the common or lowland form. *Eriophorum vaginatum* (cotton-grass) and *Calluna vulgaris* (heather) are the only abundant species of the field layer, and the ground layer is dominated by the lichen *Cladonia impexa*. The practice of cutting-over and burning has altered the original surface of the moss, but there are some indications that the surface was slightly domed in places, a feature of mature development of basin peat.

Table P

Relevé number	1	Constancy class
Serial no.	64038	
Grid reference	NH 589534	
Altitude (m)	146	
Aspect	NIL	
Slope (°)	0°	
Plot (m^2)	4	
Cover—		
field (%)	40	
ground (%)	95	
Height—		
field (cm)	36	
Major Soil Subgroup	BPT	
Climate	$O_2H_3B_3$	
Ch. Association		
Odontoschisma sphagni	—	IV
Sphagnum papillosum	—	IV
Ch. Class		
Eriophorum vaginatum	7	V
Erica tetralix	—	V
Sphagnum capillifolium	—	IV
Trichophorum cespitosum	—	IV
Drosera rotundifolia	—	III
Mylia anomala	—	III
Sphagnum tenellum	—	III
Narthecium ossifragum	—	IV
Cephalozia connivens	3	II
Aulacomnium palustre	—	II
Mylia taylori	—	II
Sphagnum magellanicum	—	II
Lepidozia setacea	—	II
Lophozia porphyroleuca	2	II
Sphagnum plumulosum	2	I
Riccardia latifrons	—	I
Pleurozia purpurea	—	I
Sphagnum rubellum	—	I
Polytrichum alpestre	—	+
Vaccinium oxycoccus	—	+
Sphagnum imbricatum	—	r
Carex pauciflora	—	r
Calypogeia sphagnicola	—	r
Gymnocolea inflata	—	r
Hypnum imponens	—	r
Andromeda polifolia	—	r
Sphagnum compactum	—	r

Table P (cont.)

Relevé number	1	Constancy class
Cephalozia leucantha	X	r
Sphagnum fuscum	—	r
Cephalozia macrostachya	—	r
Dicranum bergeri	—	r
Companion species		
Calluna vulgaris	5	—
Empetrum nigrum	(X)	—
Erica tetralix	1	—
Eriophorum angustifolium	3	—
Galium saxatile	X	—
Dicranum scoparium	1	—
Hypnum jutlandicum	3	—
Hylocomium splendens	1	—
Mnium hornum	2	—
Plagiothecium undulatum	2	—
Pleurozium schreberi	3	—
Pohlia nutans	2	—
Sphagnum cuspidatum	1	—
Calypogeia fissa	4	—
Lepidozia sp.	4	—
Sphenolobus minutus	(X)	—
Cladonia deformis	(X)	—
Cladonia glauca	1	—
Cladonia impexa	9	—
Cladonia pyxidata	2	—
Parmelia physodes	4	—
Number of species	26	

Typical subassociation
typical variant (1)

Class: Scheuchzerietea palustris den Held, Barkman et Westh. 1969
Order: Scheuchzerietalia palustris Nordh. 1936
Alliance: Rhynchosporion albae W. Koch 1926
the *Eriophorum angustifolium–Sphagnum cuspidatum* Community Birse 1980

Common cotton-grass pool

This is a community of deep pools in blanket peat, usually associated with blanket bog vegetation and comprising open stands of *Eriophorum angustifolium* (common cotton-grass) rooted in a submerged mat of the moss *Sphagnum cuspidatum*. The stand was recorded on Monadh Mor.

Table Q

Relevé number	1
Serial no.	64039
Grid reference	NH 589534
Altitude (m)	146
Aspect	NIL
Slope (°)	0°
Plot (m^2)	1
Cover—	
field (%)	20
ground (%)	98
Height—	
field (cm)	23
Major Soil Subgroup	WPT
Climate	$O_2H_3B_3$
Ch. Alliance	
Sphagnum cuspidatum	9
Companion species	
Eriophorum angustifolium	5

THE RELATIONSHIP BETWEEN SOILS AND VEGETATION

There is a clear relationship between soils and the plant communities that grow on them. However, some vegetation is found on a wide range of soil types where some other factor in the environment is exerting the dominant influence on its distribution. Also, several different communities can be found on one soil type, but this can be due, in part, to the action of management on the vegetation; for example, different management policies can result in woodland, moorland or grassland on a particular type of site.

In the following account, the genetic soil groups and variants distinguished in the Black Isle are among those described by Birse and Robertson (1976). They are considered in terms of the plant communities associated with them, both in the context of data collected from the whole of Scotland and of stands recorded locally from within the survey area. Some indication of the properties of these soils is given, again within a general Scottish context, but notable local examples are quoted when they occur. The subdivisions of the subgroups are based principally on those levels of base saturation which appear to exert a critical influence on the form of vegetation that is present (Birse and Robertson, 1976). Soils of very small extent and variants of subgroups have not been mapped and therefore do not appear in the legend of the 1:63 360 soil map. They are, however, included in this description because of the distinctive plant communities that are found on them and are discussed under the subgroup to which they belong. The chemical properties of the soil profiles from the Black Isle stands are listed in Table S.

BROWN EARTHS

Brown earths are not infrequent within the Black Isle but are of small extent, being confined to steep valley slopes where colluviation has occurred and to local pockets subjected to lateral seepage of calcuim-rich spring water. Because of their limited extent, they are not shown on the soil map.

Brown Forest Soils—moderate or high base status (BFS)
These soils are defined as having a base saturation of over 50 per cent in the surface of the A horizon, but generally the values recorded are well above this figure and, in some instances, the horizon is fully saturated. The soils are freely drained apart from a few profiles with slightly impeded drainage.

The dominant plant communities in Scotland are broadleaved woodland —most often elmwood (Querco-Ulmetum glabrae), pastures and herb-rich bent-fescue grassland (part of Achilleo-Festucetum tenuifoliae). The Black Isle stands are of southern oakwood with bluebell and of grassy southern birchwood (parts of Lonicero-Quercetum).

Brown Forest Soils—low base status (BP)
Brown forest soils with a base saturation of less than 50 per cent in the surface of the A horizon are considered to be low base status soils. Base saturations of less than 10 per cent have been recorded from several sites throughout the country and, in most cases, the values are under 30 per cent. A thin, but well-developed, black humus horizon is present in places overlying the surface mineral horizon. The soils are freely drained.

The typical communities of these soils are the associations of broadleaved woodland—mainly oak and birchwood, some pastures, common bent-fescue grassland (part of Achilleo-Festucetum tenuifoliae) and herb-rich heather moors. Locally, the stands are those of elmwood (Querco-Ulmetum glabrae), of grassy southern oakwood and of grassy southern birchwood (parts of Lonicero-Quercetum).

Brown Forest Soils With Gleying—moderate or high base status (GBS)
This group of soils is characterized by having levels of base saturation of 40 per cent or more in the surface of the A horizon and by the gley features in the B and C horizons. The soils are imperfectly drained.

The related plant communities are those that occur also on the freely drained brown forest soils. A stand of elmwood (Querco-Ulmetum glabrae) at Teandore is the only local record of vegetation on this soil type. The soil has a surface pH value of 6.0 and an exchangeable calcium level of around 12.0 m.e./100 g of soil.

Brown Forest Soils With Gleying—low base status (GBP)
Imperfectly drained brown forest soils of low base status are defined as having base saturation levels of less than 40 per cent in the surface of the A horizon and gley features in the B and C.

The vegetation found commonly on these soils is the same as that occurring on the freely drained, low base status group. Grassy southern birchwood (part of Lonicero-Quercetum) and common bent-fescue grassland (part of Achilleo-Festucetum tenuifoliae) were both recorded on typical soils in the area.

PODZOLS

These acid soils form the most extensive group in the Black Isle and, in the upland area, are generally planted with Scots pine (*Pinus sylvestris*) and other conifers. Most of the stands are on soils of the Millbuie Association.

Iron Podzols (IP)
The iron podzols have low base saturation levels of 30 per cent or less in the surface of their mineral horizons. A well-developed F or FH horizon is present usually, but there is no H horizon. The B horizon is iron-enriched and there is no humus staining. The soils are freely drained.

Associated plant communities are native pinewood, acid oakwood and birchwood. Long-established coniferous plantations are common also. A stand of eastern highland birchwood (part of Trientali-Betuletum pendulae) and of bell heather–Scots pine plantation (the *Erica cinerea–Pinus sylvestris* Community) were recorded in the area.

Humus-Iron Podzils (HIP)
The humus-iron podzols are much more extensive than the last-named subgroup. Their properties are similar to those listed for that subgroup with the exception of the nature of the B horizon which has a clearly recognizable humus-enriched subhorizon, and the presence of an H horizon.

Besides the woodland communities of the iron podzols, this subgroup is found also beneath species-poor grasslands and dry heaths. Local stands of eastern highland oakwood (part of Trientali-Betuletum pendulae), dry bell heather—Scots pine plantations (part of the *Erica cinerea–Pinus sylvestris Community*) and dry Atlantic heather moor (part of Carici binervis-Ericetum cinereae) were recorded on these soils.

The soil beneath one'stand of planted pine is shallow on rock and has been termed a shallow or lithic phase of the subgroup (HIL).

Humus-Iron Podzols—imperfectly drained (GP)
These imperfectly drained podzols have levels of base saturation of less than 20 per cent in the surface of the A or E horizon.

The plant communities are those that are found also on the freely drained podzols but there is a tendency for the wetter elements of the associations to be present. Thus, the Black Isle stands are represented by moist bell heather—Scots pine plantation (part of the *Erica cinerea–Pinus sylvestris* Community) and moist Atlantic heather moor (part of Carici binervis-Ericetum cinereae). A stand of common bent–fescue grassland (part of Achilleo-Festucetum tenuifoliae) was recorded also.

GLEYS

Noncalcareous Gleys—moderate or high base status (BG)
Those gleys with levels of base saturation of 30 per cent or more in their surface horizons are considered to be moderate or high base status soils. Values are generally much higher than the threshold figure and the majority of the soils have levels of over 60 per cent. Drainage is poor or very poor.

The characteristic communities on these soils are species-rich rush pastures and sedge mires and, to a lesser extent, elmwood (Querco-Ulmetum glabrae). Stands of flea-sedge mire (Caricetum hostiano-pulicaris) and few-flowered spike-rush mire (Carici dioici-Eleocharitetum quinqueflorae) were found at Ballycherry where the site is flushed with calcareous spring water. The surface horizon of the soil beneath the first stand has a pH value of 6.6 and an exchageable calcium level of 25.1 m.e./100 g of soil, whereas in that of the second stand, the values are 7.2 and 66.0 m.e./100 g of soil respectively. A stand of bog heather moor (Narthecio-Ericetum tetralicis) was recorded on a gley at Ferintosh.

Noncalcareous Gleys—low base status (AG)
Noncalcareous gleys of low base status have levels of base saturation of less than 30 per cent in the surface horizon. Drainage is poor or very poor.

Although the vegetation associated with the low base status gleys is dominantly that of species-poor rush pasture (part of Potentillo-Juncetum acutiflori), stands of flying bent grassland (part of Junco squarrosi-Festucetum tenuifoliae), moist Atlantic heather moor (part of Carici binervis-Ericetum cinereae) and bog heather moor (Narthecio-Ericetum tetralicis) also occur on these soils. The northern subassociation of bog heather moor was recorded at Ferintosh.

Peaty Gleys (PG)
Poorly or very poorly drained soils with well-developed organic surface horizons are classed as peaty gleys. Base saturation within the surface horizons ranges widely from 30 per cent or less to almost total saturation. However, these soils were not mapped because of their limited extent.

The plant communities commonly found on the peaty gleys with high values of base saturation are willow scrub, flush alderwood (the *Crepis paludosa–Alnus glutinosa* Association), sedge mires and species-rich rush pastures. The stand from the Black Isle is that of few-flowered spike-rush mire (Carici dioici-Eleocharitetum quinqueflorae). It occurs on the site at Ballycherry influenced by calcareous spring water and the level of exchangeable calcium present in the surface horizon of the soil is 62.6 m.e./100 g.

PEATS

Basin Peats (BPT)
Levels of base saturation in peat in the early stages of basin infill are usually moderate or high, but those in the latter stages, prior to the formation of a true raised bog, are usually much lower. The peat in the Black Isle is derived largely from bog mosses (*Sphagnum* species) and cotton-grasses (*Eriophorum* species) with some stems of ericoid plants. The state of decomposition of these plants varies greatly and layers of almost unaltered *Sphagnum* occur.

The characteristic vegetation of low base status, unflushed peat is the blanket bog association (Erico-Sphagnetum papillosi). The Monadh Mor stand is an example of the common or lowland subassociation. The level of base saturation within the peat surface is less than 20 per cent. On the peat surface are small, sparsely-vegetated, water-filled channels which are classed as common cotton-grass pools (the *Eriophorum angustifolium– Sphagnum cuspidatum* Community).

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Appendix I Standard Analytical Data

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
1.	Millbuie Association; Allangrange Series. Balgalkin (p. 16). Sample Nos 134451–60																		
Ap	3–13	6.3	67	25	80	12	8	0.91	0.43	0.05	0.18	10.5	13.0	4.6	3.61	0.15	23.5	58	2.2
B_{hs}	18–28	8.0	69	25	81	13	6	0.77	0.22	0.06	0.13	16.6	6.6	4.7	4.45	0.14	33.0	67	1.3
B_x	30–41	3.2	69	24	82	11	7	0.15	<0.02	<0.03	0.04	7.7	2.6	5.0	1.20	0.03	44.5	60	0.6
Bc	76–86	0.9	67	26	79	14	7	<0.01	<0.02	<0.03	0.06	3.4	2.3	4.9	0.17	0.01	13.1	76	5.6
C1	97–104	1.6	77	19	86	10	4	<0.01	<0.02	<0.03	0.02	2.2	1.8	4.9	—	—	—	80	7.6
C2	109–119	0.5	69	27	85	11	4	0.15	<0.02	<0.03	0.02	3.4	5.3	5.0	—	—	—	92	11.9
C2	135–145	1.4	55	29	69	15	16	0.60	0.46	0.06	0.08	3.6	24.9	5.3	—	—	—	89	4.8
C3	155–165	1.1	59	29	71	17	12	0.76	0.54	0.06	0.08	2.4	37.7	5.5	—	—	—	72	5.4
C3	188–198	1.0	63	27	78	12	10	0.60	0.33	0.05	0.06	2.7	28.0	5.4	—	—	—	114	8.6
C4	249–259	0.8	66	23	77	12	11	1.36	1.34	0.06	0.09	2.2	57.0	6.3	—	—	—	77	26.4

— indicates not determined

2.	Millbuie Association; Allangrange Series. Newton of Ferintosh (p. 17). Sample Nos 134440–44a																		
Ap	3–10	9.3	56	31	71	16	13	9.91	0.09	0.12	0.21	1.8	85.1	6.4	3.40	0.21	16.3	146	6.3
B_s	20–25	3.8	61	28	75	14	11	2.58	<0.02	0.05	0.31	1.5	66.8	6.2	1.20	0.05	22.2	79	2.6
Bx1	25–36	2.1	66	23	78	13	9	1.36	<0.02	0.06	0.04	<0.1	100	6.5	0.27	0.04	7.5	72	4.9
Bx2	41–51	1.1	74	21	84	11	5	0.91	<0.02	0.04	0.04	0.5	65.5	6.4	—	—	—	60	5.5
C	66–76	0.8	78	20	90	8	2	0.15	0.08	0.03	<0.02	<0.1	100	5.9	—	—	—	90	27.2
C	102–112	0.8	80	18	90	8	2	0.15	<0.02	<0.03	<0.02	<0.1	100	5.8	—	—	—	99	24.2

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates: % Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Exchangeable Cations m.e./100g: Ca	Mg	Na	K	H	% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
3.								Millbuie Association; Allangrange Series. Sunnybrae (p. 17), Sample Nos 144511–19											
L	0–1	94.0	—	—	—	—	—	15.9	9.87	0.51	5.21	29.3	51.8	—	56.8	0.85	66.5	181	64.4
F	1–5	55.6	—	—	—	—	—	5.25	5.23	0.55	1.97	82.4	13.6	3.7	34.7	0.57	60.9	146	23.8
E	5–10	8.0	79	19	91	7	2	0.61	0.55	0.10	0.34	36.4	4.2	3.8	4.70	0.14	33.8	46	4.1
E	13–18	5.7	71	22	82	11	7	0.15	0.14	0.05	0.09	30.8	1.4	4.1	3.15	0.08	38.4	41	0.3
B_h	18–19	17.9	76	21	86	11	3	0.16	0.37	0.12	0.20	50.1	1.7	4.4	—	—	—	83	0.1
B_s	19–23	6.4	64	25	76	13	11	<0.01	0.05	0.05	0.05	6.3	2.3	4.8	—	—	—	46	< 0.1
B_x	23–30	2.6	68	21	78	11	11	<0.01	<0.02	0.03	0.03	7.1	0.8	4.9	—	—	—	47	< 0.1
B_x	41–51	3.0	65	20	73	12	15	0.46	0.04	0.03	0.03	1.6	26.5	5.0	—	—	—	65	< 0.1
C	76–85	2.0	68	18	76	10	14	<0.01	0.03	0.04	0.05	2.7	4.3	4.9	—	—	—	56	< 0.1

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H	% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
4.								Millbuie Association; Millbuie Series. Bellton Wood No. 1 (p. 19), Sample Nos 147785–93											
L	0–1	83.0	—	—	—	—	—	8.23	5.62	0.61	2.94	48.2	26.5	4.2	48.5	0.89	54.6	151	40.4
F	1–5	92.0	—	—	—	—	—	5.66	10.4	0.95	1.18	146.4	11.0	3.5	49.5	0.87	57.2	119	11.3
E	5–8	5.6	64	24	77	10	12	<0.01	0.18	0.08	0.08	16.3	2.0	4.2	2.14	0.08	26.3	34	0.6
AB(g)	20–30	5.7	72	23	84	11	5	<0.01	<0.02	0.05	<0.02	16.3	0.3	4.7	2.19	0.06	36.5	52	0.1
Bx(g)	30–38	2.3	64	24	73	15	12	<0.01	<0.02	0.04	0.02	9.5	0.6	4.9	—	—	—	82	1.6
Bx(g)	49–59	2.9	72	22	82	12	6	<0.01	<0.02	0.04	<0.02	9.1	0.4	5.0	—	—	—	85	1.6
B(xg)	66–76	2.0	75	21	84	12	4	<0.01	<0.02	0.03	<0.02	8.7	0.3	5.0	—	—	—	71	1.5
C	76–84	2.0	63	23	73	13	14	<0.01	0.05	0.05	0.04	10.1	1.4	5.1	—	—	—	71	2.2
C	96–107	1.9	65	19	74	10	16	<0.01	0.14	0.06	0.04	7.8	3.0	5.0	—	—	—	75	2.4

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
5.	Millbuie Association; Millbuie Series. Tullich (p. 20), Sample Nos 139363–67																		
Ap	3–13	8.0	63	25	73	11	12	9.81	0.72	0.11	0.33	1.8	86.1	6.6	4.10	0.25	16.4	139	5.1
Bs(g)	23–33	4.9	68	22	78	12	10	3.21	0.26	0.11	0.27	5.5	41.0	5.9	2.34	0.19	12.7	104	3.7
B(xg)	38–46	2.5	68	21	77	12	11	1.37	0.11	0.08	0.21	3.6	33.0	5.9	—	—	—	83	1.8
BC	61–71	2.0	66	25	78	13	9	0.61	0.10	0.07	0.26	<0.1	100	5.7	—	—	—	84	3.6
BC(g)	79–89	1.0	66	30	81	15	4	0.30	0.10	0.07	0.21	<0.1	100	6.0	—	—	—	113	10.6

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H	% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
6.	Millbuie Association; Millbuie Series. Allangrange Station (p. 20), Sample Nos 139300–04																		
Ap	3–8	6.1	78	13	80	11	9	5.05	0.10	0.06	0.13	3.4	61.2	6.0	2.80	0.17	16.4	133	6.1
Bs(g)	25–36	2.9	75	19	84	10	6	0.76	<0.02	0.03	0.07	2.9	22.9	5.6	0.80	0.08	9.9	48	0.4
BC(g)	48–58	1.1	80	17	88	9	3	0.15	<0.02	<0.03	0.04	<0.1	100	5.7	—	—	—	58	2.0
C(g)	71–81	0.7	77	19	87	9	4	0.30	0.02	<0.03	0.04	<0.1	100	5.5	—	—	—	63	5.5
C(g)	97–104	0.5	79	19	88	10	2	0.15	0.05	<0.03	0.04	<0.1	100	5.4	—	—	—	70	5.2

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates % Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Exchangeable Cations m.e./100g Ca	Mg	Na	K	H	% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
7.	Millbuie Association; Roskill Series. Sunnybrae (p. 21), Sample Nos 144520–25																		
Ap	3–13	7.3	69	21	77	13	10	6.46	0.28	0.08	0.09	4.8	59.2	5.8	3.58	0.19	19.0	130	0.6
Bg1	28–36	1.5	70	22	82	10	8	3.18	0.21	0.03	0.05	1.9	64.7	6.1	0.26	0.02	12.4	49	6.1
Bg2	46–53	1.4	60	30	82	8	10	2.72	0.23	0.03	0.07	2.1	58.8	6.3	0.12	0.02	6.0	48	16.7
Cg	71–79	1.4	81	13	86	8	6	2.56	0.33	0.03	0.05	<0.1	100	6.2	—	—	—	52	13.0
Cg	97–107	0.6	87	11	93	5	2	1.35	0.19	<0.03	0.03	<0.1	100	6.2	—	—	—	58	15.5
Cg	122–132	0.7	86	11	92	5	3	1.35	0.18	<0.03	0.05	<0.1	100	6.3	—	—	—	58	15.5

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates % Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Exchangeable Cations m.e./100g Ca	Mg	Na	K	H	% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
8.	Cromarty Association; Brucefield Series. Cromarty Mains No. 2 (p. 23), Sample Nos 207650–56																		
Ap	3–13	6.2	68	18	77	9	14	2.68	0.52	0.19	0.07	8.0	30.2	5.3	2.97	0.26	11.6	122	2.9
AB	36–43	4.6	65	20	76	9	15	1.67	0.07	0.09	<0.02	8.8	17.2	5.4	2.39	0.14	17.7	84	2.2
Bs	48–56	4.9	69	20	81	8	11	1.22	0.02	0.07	<0.02	11.7	10.1	5.2	2.13	0.11	18.7	77	1.9
B(x)	56–61	4.7	68	19	76	11	13	0.77	0.02	0.05	<0.02	13.8	5.7	5.0	—	—	—	89	2.6
BC	61–66	1.5	71	16	79	8	13	<0.01	0.02	0.03	<0.02	4.1	1.2	5.1	—	—	—	78	11.1
C	81–89	2.0	71	16	77	10	13	<0.01	0.02	0.03	<0.02	2.1	2.3	5.3	—	—	—	73	10.9
C	94–102	1.8	71	10	73	8	19	<0.01	0.03	0.04	0.03	2.2	4.3	5.1	—	—	—	77	8.9

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
9.	Cromarty Association; Brucefield Series. Lochala (p. 24), Sample Nos 139351–56																		
Ap	3–13	5.6	48	32	63	17	17	8.55	0.50	0.07	0.11	<0.1	100	6.6	1.85	0.17	10.8	156	5.3
Ap	36–43	4.3	56	27	68	15	15	3.67	0.24	0.05	0.06	<0.1	100	6.0	1.83	0.15	12.6	147	1.5
Bs	46–53	3.0	63	24	70	17	13	1.22	0.06	0.03	0.04	<0.1	100	5.9	0.77	0.07	10.9	129	6.2
B/C	56–64	2.8	51	29	62	18	20	1.37	0.14	0.04	0.06	2.6	38.5	6.0	—	—	—	101	6.3
C	79–86	2.2	43	38	60	21	19	3.05	0.67	0.06	0.11	3.9	49.7	5.6	—	—	—	49	5.5
C	102–112	3.1	50	32	65	17	18	2.74	0.71	0.13	0.17	3.8	49.9	5.6	—	—	—	97	18.6

— indicates not determined

10.	Cromarty Association; Cromarty Series. Cromarty Mains No. 1 (p. 25), Sample Nos 137688–93																		
Ap	3–10	5.6	64	23	75	12	13	6.32	0.57	0.05	0.41	2.4	75.1	6.1	2.22	0.15	14.7	183	12.7
Ap	23–30	4.7	66	21	76	11	13	5.77	0.67	0.06	0.36	1.5	82.6	6.3	1.77	0.16	10.9	186	6.8
B(xg)	30–38	2.8	64	21	74	11	15	3.64	0.33	0.03	0.37	1.0	80.8	6.5	0.75	0.06	12.3	91	5.0
Bc	48–56	1.4	59	22	70	11	19	2.58	0.33	0.08	0.33	0.7	82.0	6.6	—	—	—	67	3.8
C	71–81	1.7	57	23	68	12	20	2.27	0.59	0.10	0.18	1.0	75.8	6.3	—	—	—	58	1.8
C(g)	97–107	2.0	55	24	67	12	21	1.98	1.04	0.08	0.15	1.9	63.5	5.5	—	—	—	106	6.1

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates: % Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Exchangeable Cations m.e./100g: Ca	Mg	Na	K	H	% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
11.	Cromarty Association; Cromarty Series. Bannans No. 1 (p. 26), Sample Nos 137707–14																		
Ap	3–10	9.9	69	24	83	10	7	1.08	0.34	0.10	0.22	12.6	12.1	5.1	4.71	0.23	20.8	103	1.0
Bx(g)	18–28	2.6	57	23	67	13	20	<0.01	0.12	0.03	0.18	2.3	12.7	5.6	0.28	0.03	9.7	70	2.7
Bc(g)	38–46	2.5	57	24	67	14	19	<0.01	0.21	0.03	0.14	4.1	8.4	5.4	0.16	0.03	5.5	41	1.1
BC	61–69	2.3	55	26	65	16	19	<0.01	0.21	0.03	0.14	3.8	9.2	5.2	—	—	—	62	2.4
BC	76–84	2.2	59	23	68	14	18	0.23	0.50	0.03	0.15	3.8	19.5	5.1	—	—	—	66	3.4
C	99–107	1.8	59	23	69	13	18	0.15	0.29	0.03	0.15	2.6	19.2	5.1	—	—	—	73	3.3
C	117–127	1.9	65	19	73	11	16	0.30	0.83	0.03	0.14	3.4	27.5	5.4	—	—	—	72	6.3

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H	% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
12.	Cromarty Association; Cromarty Series. Grey Cairn Wood (p. 26), Sample Nos 144485–94																		
L	0–1	96.9	—	—	—	—	—	6.86	4.16	0.76	2.06	55.4	20.0	3.8	55.8	1.56	35.7	103	25.4
F	1–4	90.9	—	—	—	—	—	9.60	6.28	1.73	1.59	91.3	17.4	3.6	55.3	1.01	34.9	179	15.2
Ah	4–10	8.4	73	22	87	8	5	0.15	0.15	0.08	0.04	19.0	2.2	4.0	2.30	0.17	13.7	44	0.6
AB	13–21	11.7	64	29	78	15	7	<0.01	0.11	0.10	0.06	24.5	1.1	4.7	5.97	0.15	40.9	85	0.2
Bs(m)	31–38	2.5	87	11	91	7	2	<0.01	0.03	<0.03	<0.02	6.0	0.8	5.1	0.71	0.03	22.9	71	0.1
Bx	43–48	1.5	69	23	78	14	8	<0.01	<0.02	<0.03	0.07	4.4	2.0	5.1	—	—	—	96	13.0
BC	51–59	1.7	64	17	71	10	19	0.45	0.45	0.06	0.15	6.7	14.2	5.3	—	—	—	59	6.2
BC	71–79	1.6	64	17	73	8	19	0.76	0.59	0.05	0.14	6.4	19.4	5.4	—	—	—	78	5.1
BC	97–107	1.5	68	16	77	7	16	0.76	0.55	0.05	0.18	6.2	19.9	5.3	—	—	—	77	5.9
C	122–132	1.4	69	14	75	8	17	0.91	0.53	0.09	0.21	5.2	25.1	5.1	—	—	—	70	19.6

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
13.	Cromarty Association; Navity Series. Bannans No. 2 (p. 27), Sample Nos 137715–20																		
Ap	3–10	6.5	64	22	75	11	14	3.53	0.46	0.10	0.14	7.1	37.4	5.4	3.40	0.23	15.0	120	1.8
Ap	30–41	5.4	62	22	72	12	16	5.19	0.34	0.10	0.05	5.3	51.5	6.0	2.34	0.20	11.5	54	1.2
Bsg	48–56	2.8	64	20	72	12	16	2.74	0.33	0.08	0.06	1.8	64.5	6.1	0.67	0.10	6.9	17	3.0
Bg	66–74	2.1	64	21	73	12	15	2.21	0.67	0.06	0.05	2.2	57.7	6.1	—	—	—	27	3.3
Cg	94–102	1.7	74	16	81	9	10	1.67	1.08	0.06	0.08	2.0	58.9	5.8	—	—	—	48	3.6
C(g)	112–122	1.7	65	21	74	12	14	1.06	0.45	0.06	0.05	3.7	30.6	5.4	—	—	—	39	4.7

— indicates not determined

14.	Mount Eagle Association; Mount Eagle Series. St Martins (p. 29), Sample Nos 139330–33																		
Ap	3–13	6.8	67	23	78	12	10	9.99	0.38	0.07	0.08	<0.1	100	6.9	3.49	0.16	21.3	125	3.5
Bhs	22–25	6.2	74	21	83	12	5	1.67	0.05	0.05	0.05	7.2	20.2	5.7	2.71	0.04	63.0	81	1.8
B(x)	25–36	1.0	80	15	86	9	5	0.30	<0.02	0.04	0.04	1.7	17.9	5.8	0.42	0.14	2.9	52	0.9

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
15.			Mount Eagle Association; Mount Eagle Series. Mount Eagle No. 1 (p. 29), Sample Nos 139318–23																
F	0–3	76.8	—	—	—	—	—	8.18	7.84	0.64	2.04	84.0	18.2	3.8	45.6	1.14	40.0	155	15.9
AB	3–6	8.2	73	23	88	8	4	0.76	0.63	0.22	0.18	11.9	13.1	4.4	4.32	0.15	28.2	63	2.5
Bs1	11–21	3.6	65	24	77	12	11	0.15	0.09	0.07	0.02	4.4	6.9	4.9	1.15	0.04	28.1	127	1.0
Bs2	23–33	2.6	67	24	77	13	9	0.18	<0.02	0.05	0.02	1.3	16.4	5.1	—	—	—	69	0.8
Bx	46–56	1.6	65	27	76	16	8	<0.01	<0.02	0.03	0.05	<0.1	100	5.3	—	—	—	82	1.6

— indicates not determined

16.			Mount Eagle Association; Findon Series. Crask (p. 30), Sample Nos 139337–39																
Ap	3–13	6.9	63	22	73	12	15	3.20	0.13	0.05	0.11	6.0	37.7	5.7	3.05	0.18	16.9	142	6.2
$B_s(g)$	20–30	3.7	66	22	75	13	12	0.46	<0.02	<0.03	0.04	1.2	30.8	5.3	1.03	0.08	13.7	63	0.7
B(x)	38–48	2.1	66	23	77	12	11	0.15	<0.02	<0.03	0.06	<0.1	100	5.4	—	—	—	45	0.6

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
17.	Mount Eagle Association; Findon Series. Mount Eagle (p. 30), Sample Nos 139324–29																		
AE	3–10	5.6	72	22	82	12	6	<0.01	0.11	0.05	0.10	12.3	2.1	4.4	2.92	0.13	22.3	49	0.6
Bs(g)1	15–25	3.7	64	30	80	14	6	<0.01	<0.02	0.04	0.03	3.8	1.8	4.9	1.23	0.06	21.9	61	0.6
Bs(g)2	30–38	2.8	78	16	85	9	6	<0.01	<0.02	0.04	0.02	<0.1	100	5.0	0.69	0.05	14.1	74	0.6
Bx(g)	43–53	1.6	62	30	75	17	8	<0.01	<0.02	0.03	0.03	<0.1	100	5.2	—	—	—	72	1.0
Bx(g)	64–74	1.4	66	25	77	14	9	<0.01	<0.02	0.03	0.03	<0.1	100	5.2	—	—	—	83	2.2

— indicates not determined

18.	Ethie Association; Ethie Series. Callachy Hill (p. 35), Sample Nos 135199–205																		
F	3–11	87.7	—	—	—	—	—	2.11	0.50	0.67	0.60	147.6	2.6	3.6	51.0	1.51	33.7	120	13.6
E	11–16	6.0	73	20	85	8	7	<0.01	0.31	0.09	0.11	12.3	4.0	3.9	3.58	0.14	25.8	51	1.9
Bs1	17–28	5.4	65	26	79	12	9	<0.01	0.05	0.03	0.02	5.1	1.7	4.7	1.63	0.13	12.4	107	0.7
Bs2	30–35	3.1	64	24	75	13	12	<0.01	0.04	0.03	<0.02	3.3	2.1	4.9	0.91	0.06	15.4	95	0.8
Bx1	38–48	1.5	74	20	86	8	6	<0.01	0.02	0.04	<0.02	1.7	3.5	4.9	—	—	—	87	1.9
Bx2	61–71	1.9	59	22	72	9	19	<0.01	0.33	0.05	0.09	2.6	15.5	5.3	—	—	—	66	2.1
CR	94–104	4.0	71	20	79	12	9	<0.01	0.14	0.03	<0.02	1.6	9.6	5.4	—	—	—	179	10.6

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
19.	Ethie Association; Ethie Series. Callachy Hill No. 2 (p. 35), Sample Nos 135193–98																		
F	3–6	82.4	—	—	—	—	—	10.1	12.6	1.19	1.79	103.8	19.8	4.0	48.2	1.69	28.6	230	36.0
Ah	6–9	16.1	79	19	94	5	1	0.61	0.55	0.16	0.17	15.1	9.0	4.1	6.02	0.23	25.7	50	0.7
AE	9–20	18.7	74	24	88	10	2	<0.01	0.16	0.05	0.06	34.5	0.8	4.5	11.1	0.30	36.6	81	0.6
Bh	20–30	10.9	72	25	85	12	3	<0.01	0.14	0.07	0.06	24.6	1.1	4.6	5.26	0.31	17.0	67	0.7
Bs	30–38	12.7	79	18	91	6	3	<0.01	0.07	0.05	0.05	24.8	0.7	4.9	—	—	—	99	0.9
Bs	50–58	13.1	63	32	82	13	5	<0.01	0.08	0.05	0.05	22.3	0.6	4.9	—	—	—	107	0.7

— indicates not determined

20.	Ethie Association; Ethie Series. Hillockhead No. 1 (p. 36), Sample Nos 144508–10																		
Ap	3–13	4.8	64	23	75	12	13	4.93	0.24	0.12	0.13	3.6	60.1	6.1	2.40	0.16	15.5	156	6.8
AB	25–33	4.3	66	22	75	13	12	3.66	0.21	0.04	0.09	3.4	53.8	6.0	1.95	0.14	14.2	152	5.3
Bs	43–48	4.4	65	22	74	13	13	3.52	0.32	0.06	0.07	6.0	39.9	5.9	—	—	—	163	8.0

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
21.	Ethie Association; Ethie Series. Sutors of Cromarty (p. 36), Sample Nos 137702–06																		
L	Trace	71.5	—	—	—	—	—	11.1	7.59	1.48	6.80	24.1	52.8	5.2	34.2	1.10	31.0	234	43.3
F	0–5	18.3	69	24	85	8	7	4.37	2.70	0.60	0.94	20.1	30.0	5.0	7.91	0.43	18.4	154	3.1
E	8–18	10.7	69	20	81	8	11	1.08	0.72	0.26	0.43	11.6	17.6	4.9	4.98	0.24	21.2	127	1.3
Bh	18–25	7.9	66	22	79	9	12	0.39	0.30	0.20	0.24	8.5	11.8	5.0	3.21	0.16	19.8	90	0.8
BR	30–43	4.8	56	23	67	12	19	<0.01	0.12	0.12	0.05	5.8	4.8	5.0	1.24	0.07	17.5	113	0.7

— indicates not determined

22.	Ethie Association; Gallow Series. Kinnock (p. 37), Sample Nos 193042–46																		
FH	3–8	81.4	—	—	—	—	—	18.4	7.25	0.72	1.45	71.4	28.0	4.2	47.7	1.27	37.7	266	32.4
AE	16–21	8.3	68	23	83	8	9	1.07	0.46	0.09	<0.02	13.8	10.5	4.2	4.61	0.15	32.9	41	1.4
Bh(m)	23–26	12.8	69	23	84	8	8	0.81	0.37	0.08	<0.02	30.9	3.9	4.4	—	—	—	46	0.8
Bs(g)	33–41	5.5	71	18	79	10	11	<0.01	0.07	0.04	<0.02	9.0	1.2	4.8	—	—	—	49	0.8
Bx	44–51	1.0	71	17	78	10	12	<0.01	0.02	0.04	<0.02	5.4	1.1	4.9	—	—	—	98	8.2

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
23.								Ethie Association; Gallow Series. Hillockhead No. 2 (p. 37), Sample Nos 144501–07											
Ap	3–13	6.3	85	12	90	7	3	4.31	0.54	0.10	0.13	9.2	35.6	5.9	2.30	0.14	15.9	136	5.7
A	25–33	4.0	69	22	78	13	9	3.83	0.50	0.08	0.09	4.5	50.3	6.3	1.60	0.11	14.4	112	2.7
A	43–51	2.9	61	20	72	9	19	3.36	0.50	0.09	0.05	2.9	57.8	6.5	1.11	0.11	9.8	106	2.7
Bs(g)	69–76	2.4	64	18	74	8	18	3.50	0.62	0.09	0.05	2.6	62.1	6.8	—	—	—	86	3.0
Bs(g)	89–99	2.2	68	16	76	8	16	3.49	0.62	0.10	0.05	2.5	63.1	7.0	—	—	—	95	1.7
BC(g)	109–117	1.5	68	15	73	10	17	3.49	0.71	0.12	0.07	<0.1	100	7.0	—	—	—	49	1.0
C	130–137	0.8	84	15	94	5	1	1.96	0.31	0.06	0.03	<0.1	100	7.1	—	—	—	43	10.6

— indicates not determined

24.								Ethie Association; Learnie Series. Hillockhead No. 3 (p. 38), Sample Nos 144495–500											
Ap	3–13	4.3	50	34	65	19	14	1.82	0.41	0.15	0.17	6.9	27.1	5.5	1.66	0.11	14.7	98	5.5
Bg	20–33	1.3	63	24	72	15	13	1.35	0.28	0.04	0.03	3.4	33.4	6.9	0.11	0.03	3.9	60	16.1
BCg	43–51	1.2	71	18	78	11	11	1.81	0.32	0.04	0.05	<0.1	100	7.3	0.04	<0.01	10.0	68	24.5
Cg1	69–76	1.2	70	17	77	10	13	2.88	0.37	0.04	0.13	<0.1	100	7.5	—	—	—	101	59.4
Cg2	97–107	1.7	76	21	88	9	3	10.6	0.40	0.06	0.18	<0.1	100	8.3	—	—	—	95	42.2
Cg3	122–132	2.6	66	27	77	16	7	20.0	0.58	0.06	0.26	<0.1	100	8.4	—	—	—	102	5.3

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
25.	Kessock Association; Kessock Series. Ord Hill-North Kessock (p. 40), Sample Nos 139345–50																		
L	0–3	93.8	–	–	–	–	–	17.9	5.00	0.92	2.49	63.6	29.2	3.9	58.8	1.59	36.9	157	21.3
F	3–8	89.0	–	–	–	–	–	11.3	9.26	1.24	1.12	112.9	16.9	3.4	51.4	1.56	32.9	134	10.2
E	8–18	6.2	69	24	82	11	7	0.46	0.50	0.14	0.13	12.0	9.3	4.0	3.57	0.15	24.5	30	0.7
Bhs	23–31	10.8	75	20	86	9	5	< 0.01	0.14	0.11	0.12	13.5	2.7	4.8	4.82	0.16	29.8	48	0.5
Bs	33–41	15.5	77	20	87	10	3	< 0.01	0.06	0.09	0.06	12.0	1.7	4.8	–	–	–	65	0.4
Bh	49–54	9.4	72	23	85	10	5	0.16	0.09	0.13	0.08	11.1	4.0	4.9	–	–	–	65	0.4

– indicates not determined

26.	Kessock Association; Redcastle Series. Lundie (p. 40), Sample Nos 139340–44																		
L	0–2	92.9	–	–	–	–	–	11.0	6.65	0.78	3.97	61.7	26.6	4.1	53.8	1.19	45.3	196	35.7
F	2–8	45.1	–	–	–	–	–	4.83	9.46	0.64	1.16	66.2	19.5	3.8	26.4	1.00	26.3	92	5.6
E	8–9	13.2	66	29	82	13	5	0.93	0.93	0.17	0.35	25.4	8.6	4.1	8.07	0.19	41.6	56	2.2
Bs(g)	11–16	6.1	59	34	77	16	7	<0.01	0.04	0.03	0.09	4.3	3.6	4.7	2.57	0.08	32.5	58	0.3
Bs(g)	21–31	3.5	69	26	83	12	5	<0.01	0.02	0.03	0.08	0.9	12.3	4.8	1.27	0.05	24.9	53	0.4

– indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates: % Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Exchangeable Cations m.e./100g: Ca	Mg	Na	K	H	% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
27.	Corby Association; Corby Series. Gilchrist (p. 42), Sample Nos 207637–44																		
Ap	3–10	20.8	70	24	85	9	6	4.41	0.57	0.27	0.19	34.9	13.5	5.1	12.1	0.57	21.4	224	1.9
Ap	18–25	17.1	80	14	89	5	6	1.91	<0.02	0.43	0.08	30.6	7.3	5.3	9.33	0.47	22.4	175	1.7
Bh	28–38	5.3	91	3	92	2	6	0.24	<0.02	0.08	0.04	10.1	3.4	5.5	1.47	0.11	14.0	98	1.4
Bhm	46–53	2.9	92	2	93	1	6	<0.01	<0.02	0.04	0.04	5.8	1.4	5.2	1.14	0.11	10.0	62	1.6
Bsm	53–64	2.9	91	4	93	2	5	<0.01	<0.02	0.06	0.04	6.0	1.6	5.2	–	–	–	63	1.1
C1	76–84	1.1	96	1	96	1	3	<0.01	<0.02	0.03	<0.02	3.3	0.9	5.5	–	–	–	96	2.7
C1	104–117	0.9	96	2	97	1	2	<0.01	<0.02	<0.03	<0.02	2.6	0.8	5.7	–	–	–	83	3.9
C2	117–124	1.6	93	3	94	2	4	<0.01	0.06	0.05	<0.02	3.4	3.1	5.8	–	–	–	84	2.4

– indicates not determined

28.	Boyndie Association; Boyndie Series. Bellvue (p. 44), Sample Nos 207632–36A																		
Ap	3–10	4.5	71	18	80	9	11	3.83	0.39	0.15	0.25	8.4	35.5	6.2	2.08	0.20	10.5	195	9.6
Ap	30–38	3.7	72	16	79	9	12	3.23	0.09	0.06	0.07	8.0	30.1	6.0	1.97	0.16	12.5	169	4.2
Bh	53–61	2.6	84	7	88	3	9	0.92	<0.02	0.05	<0.02	8.8	9.9	5.8	1.06	0.12	9.1	167	3.1
Bs	69–76	1.5	93	1	93	1	6	0.46	<0.02	0.06	<0.02	5.6	8.6	5.7	–	–	–	110	3.1
C	81–89	1.1	95	1	95	1	4	0.23	<0.02	0.03	<0.02	3.3	7.2	6.0	–	–	–	83	3.9
C	102–109	0.9	96	2	97	1	2	0.23	<0.02	0.03	<0.02	2.7	8.9	5.7	–	–	–	73	3.3

– indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
29.	Soils developed on Undifferentiated Solifluction Deposits; imperfectly drained. Braelangwell (p. 45), Sample Nos 207663–69																		
Ap	3–13	3.1	73	17	84	6	10	3.80	0.36	0.05	0.09	1.6	73.0	5.9	1.19	0.11	10.5	114	10.9
Bs(g)1	28–33	0.9	74	16	81	9	10	2.24	0.16	0.03	0.03	<0.1	100	6.5	0.49	0.05	9.6	83	32.6
Bs(g)2	36–43	0.7	76	17	86	7	7	1.66	0.12	<0.03	<0.02	<0.1	100	6.5	0.24	0.03	9.2	80	30.8
Bs(g)2	51–58	0.5	84	12	92	4	4	1.20	0.02	<0.03	<0.02	<0.1	100	6.5	—	—	—	79	33.9
C1	64–69	0.4	84	10	93	3	4	0.75	0.03	<0.03	<0.02	<0.1	100	6.3	—	—	—	74	28.8
C3	97–104	0.4	72	23	86	9	5	0.90	0.15	<0.03	0.02	<0.1	100	6.7	—	—	—	97	48.5
C4	117–124	0.8	63	22	74	11	15	2.72	0.55	0.04	0.11	<0.1	100	6.8	—	—	—	94	56.0

— indicates not determined

30.	Soils developed on Undifferentiated Solifluction Deposits; poorly drained. Muirhead (p. 46), Sample Nos 207657–62																		
Ap	3–13	4.5	79	12	86	5	9	4.56	0.42	0.07	0.07	2.1	70.6	5.7	2.60	0.20	13.1	165	16.1
Bg1	25–33	0.9	85	9	91	3	6	0.90	0.03	0.01	<0.02	<0.1	100	5.9	0.49	0.05	9.4	73	15.9
Bg1	48–56	0.9	69	24	82	11	7	1.21	<0.02	<0.03	<0.02	<0.1	100	6.0	0.45	0.05	8.8	95	30.3
Bg2	61–69	1.2	58	31	69	20	11	2.24	0.25	0.03	0.05	<0.1	100	6.2	—	—	—	116	91.8
Bg2	79–84	1.3	59	21	69	11	20	3.17	0.04	0.05	0.12	<0.1	100	6.4	—	—	—	106	55.6
Cg	97–107	1.2	71	18	76	13	11	6.78	0.53	<0.03	0.04	<0.1	100	7.7	—	—	—	75	18.5

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
31.	Alluvium; poorly drained. Rosehaugh (p. 47), Sample Nos 139357–62																		
Ap	3–13	3.6	80	14	86	8	6	3.95	0.11	<0.03	0.08	2.7	61.1	6.0	1.67	0.13	12.5	116	6.0
Ap	20–30	2.9	83	11	88	6	6	3.33	0.18	0.03	0.08	0.4	89.2	6.1	1.28	0.08	16.0	77	3.0
(B)g1	33–41	2.5	93	5	94	4	2	1.81	0.18	0.03	0.04	<0.1	100	6.5	0.38	0.04	8.8	53	2.8
(B)g2	51–61	3.5	72	19	85	6	9	6.08	0.27	0.07	0.06	1.0	86.4	6.4	—	—	—	54	1.6
Cg1	71–81	0.5	96	4	97	3	<1	1.05	0.15	<0.03	0.02	<0.1	100	4.2	—	—	—	62	1.7
Cg2	84–94	0.5	96	4	99	1	<1	0.45	0.11	<0.03	<0.02	2.9	16.4	6.4	—	—	—	96	0.8

— indicates not determined

32.	Alluvium (glacial silt); imperfectly drained. Newton of Ferintosh No. 114 (p. 48), Sample Nos 134445–50																		
Ap	3–10	7.2	41	38	58	21	21	6.56	0.37	0.10	0.02	3.6	65.9	6.2	2.99	0.14	21.2	148	2.5
(B)(g)1	23–33	4.9	21	51	47	25	28	3.34	0.35	0.07	0.02	1.6	70.7	5.8	0.62	0.03	18.8	131	0.9
(B)(g)2	41–51	4.7	22	48	47	23	30	2.44	0.36	0.05	0.10	2.5	53.8	5.4	—	—	—	139	1.8
C	64–74	4.6	19	53	47	25	28	1.52	0.23	0.04	0.09	2.3	44.9	5.0	—	—	—	149	0.5
C	91–97	4.2	14	54	40	28	32	1.22	0.23	0.05	0.12	3.0	35.3	5.0	—	—	—	155	0.9
C	109–119	3.1	24	50	45	29	26	0.91	0.25	0.03	0.09	2.7	32.0	5.1	—	—	—	132	0.7

— indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
33.	Mixed bottom land. Rosemarkie No. 1 (p. 48), Sample Nos 191561–64																		
F	2–5	57.6	–	–	–	–	–	25.8	5.22	0.44	1.26	45.9	42.1	4.4	20.1	1.18	17.1	130	20.3
A	15–20	2.0	79	13	85	7	8	7.0	0.23	0.04	0.03	0.5	93.1	6.3	1.14	0.12	9.8	46	12.2
BC	25–35	1.5	81	8	86	3	11	17.5	0.16	0.04	0.10	<0.1	100	7.3	–	–	–	49	8.6
C	51–58	1.7	78	14	86	6	8	33.1	0.26	0.04	0.14	<0.1	100	7.8	–	–	–	54	5.0

– indicates not determined

34.	*Low Raised Beach; freely drained. Learnie* (p. 50), Sample Nos 137694–701																		
L	Trace	20.4	88	10	96	2	2	15.8	8.26	0.25	2.08	9.5	73.4	6.0	6.98	0.36	19.5	183	21.7
Ah	0–3	7.5	94	5	95	4	<1	4.44	1.55	0.10	0.52	1.7	79.7	6.2	3.77	0.28	13.3	143	9.1
Aph	3–13	4.3	95	4	96	3	1	2.28	1.08	0.10	0.35	0.7	83.7	6.0	1.46	0.16	9.0	152	4.2
Ap	25–36	3.2	96	3	97	2	1	0.92	1.13	0.05	0.18	0.3	88.4	5.8	1.67	0.09	18.8	123	2.6
AB	46–56	1.1	97	3	98	2	<1	0.43	0.21	0.05	0.05	<0.1	100	6.1	–	–	–	135	4.3
AB	69–76	0.9	97	3	98	2	<1	0.20	0.15	0.03	0.03	<0.1	100	6.2	–	–	–	121	7.8
BC	91–99	1.1	98	2	98	2	<1	0.20	0.17	0.03	0.03	<0.1	100	6.2	–	–	–	99	4.4
C	112–122	1.7	97	3	98	2	<1	0.55	1.00	0.03	0.03	<0.1	100	6.5	–	–	–	146	5.4

– indicates not determined

Horizon	Depth (centimetres)	% Loss on Ignition	Soil Separates					Exchangeable Cations m.e./100g					% Saturation	pH	% Carbon	% Nitrogen	C/N	mg/100g Total P_2O_5	mg/100g Read. Sol. P_2O_5
			% Sand U.S.D.A.	% Silt U.S.D.A.	% Sand Inter.	% Silt Inter.	% Clay	Ca	Mg	Na	K	H							
35.								High Raised Beach; freely drained. Inch (p. 51), Sample Nos 207645–49											
Ap	3–13	6.9	66	20	76	10	14	7.36	0.49	0.10	0.17	8.0	50.4	5.7	3.30	0.27	12.1	249	7.4
AB1	28–36	3.9	76	11	80	7	13	2.44	0.41	0.07	0.03	6.3	32.0	5.7	1.40	0.14	10.1	200	2.1
AB2	43–51	4.2	78	12	84	6	10	3.37	0.29	0.14	0.04	8.0	32.4	6.0	—	—	—	202	2.7
B(m)	64–71	2.3	82	11	88	5	7	1.22	0.06	0.08	<0.02	7.0	16.2	5.7	—	—	—	150	4.7
C	91–102	1.6	90	4	92	2	6	0.76	0.03	0.07	0.03	3.6	19.8	5.8	—	—	—	148	7.6

— indicates not determined

36.								Peat. Monadh Mor (p. 52), Sample Nos 191558–60											
	3–13	90.7	—	—	—	—	—	11.3	12.8	1.16	0.29	131.8	16.2	3.8	54.2	1.16	47.1	45	5.5
	23–36	95.3	—	—	—	—	—	9.94	15.9	1.46	<0.02	124.0	18.1	4.0	56.1	0.96	58.5	15	2.3
	51–61	91.2	—	—	—	—	—	9.82	15.6	1.50	0.17	110.9	19.6	4.1	—	—	—	14	1.6

— indicates not determined

Appendix II Methods and Definitions

SOILS

SOIL CLASSIFICATION

The system of soil classification used in this bulletin is described in many of the Soil Survey of Scotland's previous publications. It is based principally on the recognition of typical examples of soil subgroups rather than on the definition of properties discriminating between groups; such types of classification are typological, as opposed to definitional (Butler, 1980).

SOIL PROFILE DESCRIPTIONS

The standard terms used in the descriptions of soil profiles are listed and defined briefly. They are mainly those of Soil Survey Staff (1951) and Hodgson (1974).

Slope

The terms used to describe slope are: gentle (0–3°), moderate (3–7°), strong (7–11°), moderately steep (11–15°), steep (15–25°) and very steep (>25°).

Drainage class

Drainage class is assessed from profile morphology, particular attention being paid to the amount of grey and ochreous mottling present. In general, well-drained soils have horizons with a uniform colour and little or no mottling, whereas soils with impeded natural drainage have ochreous or grey mottling, or both. The drainage classes recognized are: free, imperfect, poor and very poor.

Colour

The names and notations of the soil colours are those of the *Munsell Soil Color Charts* (Munsell Color Company, Inc., 1954).

Texture

Soil texture is a measure of the relative amounts of sand, silt and clay present in the mineral soil material of less than 2 millimetres in diameter. The textural class names are ascertained from the triangular diagram (Fig. 5) used in conjunction with the range of grain sizes established by the United States Department of Agriculture (U.S.D.A.).

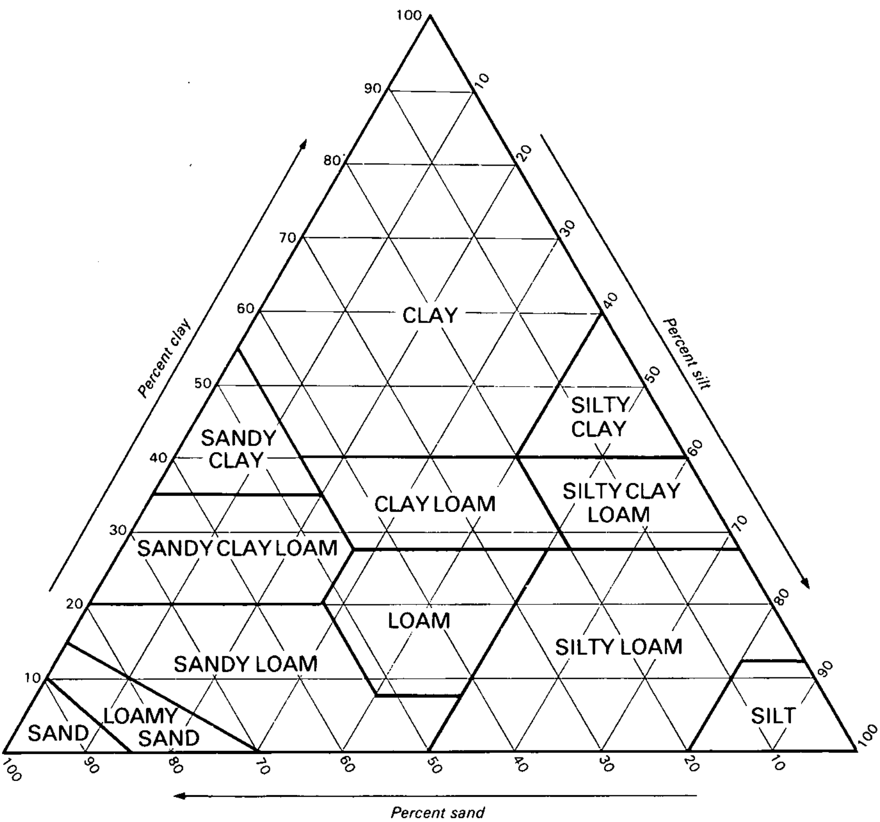

Figure 5. *Percentages of clay (<2 μm), silt (2–50 μm) and sand (50–2 000 μm) in the basic soil textural classes.*

Stones

Terms describing frequency are: none (0 per cent volume), few (1–5 per cent), common (5–15 per cent), many (15–35 per cent), abundant (35–70 per cent) and very abundant (>70 per cent). Sizes of stones are: very small (<6 millimetres diameter), small (6 millimetres–2 centimetres), medium (2–6 centimetres), large (6–20 centimetres), very large (20–60 centimetres) and boulders (>60 centimetres). Shape can be rounded, subrounded, subangular, angular or platy (tabular).

Structure

Structure is the aggregation of the primary soil particles into compound units (peds). Grade, size and shape are described. Grade refers to the degree of development: terms are structureless, weak, moderate and strong; soil horizons which are structureless are either massive or single-grain.

There are four main shapes of structure unit, each with five size classes.

Angular and subangular blocky structures have peds with three axes of about equal length. Neighbouring peds interlock. Sizes are very fine (<5 millimetres diameter), fine (5–10 millimetres), medium (10–20 millimetres), coarse (20–50 millimetres)., and very coarse (>50 millimetres).

Crumb and granular structures also have peds with three axes of about equal length, but the peds do not interlock with their neighbours. The size ranges are very fine (<1 millimetre diameter), fine (1–2 millimetres), medium (2–5 millimetres), coarse (5–10 millimetres) and very coarse (>10 millimetres).

Prismatic structures have units in which the vertical axis is distinctly longer than the two horizontal axes. The sizes are very fine (<10 millimetres diameter), fine 10–20 millimetres), medium (20–50 millimetres), coarse (50–100 millimetres) and very coarse (>100 millimetres).

Platy structures have units with the vertical axis much less than the two horizonal axes. Sizes are very fine (<1 millimetre thick), fine (1–2 millimetres), medium (2–5 millimetres), coarse (5–10 millimetres) and very coarse (>10 millimetres).

Consistence

Consistence is an expression of the degree of cohesion of the soil material. A different set of terms is used for each moisture state.

Consistence when wet is described in terms of plasticity (non-plastic, slightly plastic, plastic or very plastic) and stickiness (non-sticky, slightly sticky, sticky or very sticky).

Consistence when moist can be loose, very friable, friable, firm, very firm or extremely firm.

Consistence when dry (uncommon in Scottish soils) is either loose, soft, slightly hard, hard, very hard or extremely hard.

Cementation

Soil material can be cemented by substances such as calcium carbonate, humus, silica or compounds of iron, manganese or aluminium. The degree of cementation is described as weak, medium or strong.

Induration

Indurated horizons are compact, brittle, and are more resistant to vertical than to horizontal disruption. The terms for describing the degree of induration are weak, medium and strong.

Roots

The terms for describing size are: very fine (<1 millimetre diameter), fine (1–2 millimetres), medium (2–5 millimetres), coarse (5–10 millimetres) and very coarse (>10 millimetres).

Kind can be fleshy, fibrous or woody.

Root frequency, determined by estimating the number of very fine or fine roots in a 10 × 10 centimetres area of the vertical face of the soil profile, is described as: none (0 roots per 10 × 10 centimetres), few (1–10), common (10–25), many (25–200) or abundant (>200).

Horizon boundary

The boundaries between soil horizons are described as sharp (<2 centimetres), clear (2–5 centimetres), gradual (5–12 centimetres) or diffuse (>12 centimetres).

SOIL HORIZON SYMBOLS

Master horizons

Master horizons are represented by capital letters. Arabic figures are used as suffixes to indicate vertical subdivision (e.g. C1, C2).

Transitional horizons with properties of two master horizons are shown by the combination of two capital letters e.g. AE, EB, BC.

In layered parent materials Arabic numerals are used as symbol prefixes when it is necessary to distinguish lithological or textural contrasts (e.g. 2C when the C horizon differs from the material in which the solum (A and B) is presumed to have formed).

L Fresh annual litter, normally loose, plant structures obvious.

F Decomposed litter, only some of the original plant structures obvious.

H Well-decomposed organic matter formed under aerobic conditions. Plant structures not visible. May be mixed with some mineral matter. (Mor humus).

O Peaty material formed under wet, anaerobic conditions.

A Mineral horizons formed at or near the surface that show an accumulation and incorporation of organic matter or which have a morphology acquired by soil formation but lack the properties of E or B horizons.

E Eluvial horizons underlying an H, O or A horizon from which they can be normally differentiated by a lower content of organic matter and lighter colour—particularly when dry. Usually they show a concentration of sand and silt fractions with a large component of resistant minerals resulting from a loss of clay, iron or aluminium.

B A mineral horizon in which there is little or no obvious rock structure and having one or both of the following:

(i) alteration of the original material involving solution and removal of carbonates; formation, liberation or residual accumulation of silicate clays or oxides; formation of granular, crumby, blocky or prismatic peds; or (normally) some combination of these:

(ii) illuvial concentration of silicate clay or iron, aluminium or humus.

C A mineral layer of unconsolidated material from which the solum is presumed to have formed.

R Underlying consolidated bed-rock sufficiently coherent when moist to make hand digging with a spade impracticable.

Subhorizons

A lower case letter may be added to the capital letter to qualify the master horizon designation. More than one letter can be used if necessary, e.g. Bhs 1 indicates the first of two B horizons enriched in humus and sesquioxidic material. Symbols may be bracketed if the feature development is weak.

b Buried (e.g. Ab).
f Sharply defined thin iron pan.
g Horizon with gley features.
h Accumulation of organic matter in a mineral horizon (e.g. Ah or Bh).
m A cemented horizon, other than a thin iron pan.
p Disturbed by ploughing.
s Accumulation of sesquioxidic material.
t Accumulation of illuvial clay.
w Alteration *in situ* in accordance with section (i) of the description of the B horizon.
x Indurated layer, compacted but not cemented.

VEGETATION

Recording of the vegetation in the field was based on the methods laid down by Poore (1955a, 1955b) and modified by Birse and Robertson (1976). The survey did not attempt a quantitative estimation of the plant communities in the area, but was restricted to an analysis of the main vegetation types in selected sites. The relevés (vegetation records) so collected were compared with the phytosociological tables used in the classification of Scottish vegetation by Birse and Robertson (1976) and by Birse (1980, 1984). Some of the Black Isle relevés were used in the construction of these major tables. Others, which were not included, are listed in the floristic tables of the account under the associations to which they are related most closely.

In Chapter 4, each community or association is placed within its appropriate class, order and alliance and a brief note on each of the relevés is given. This is followed by the floristic table of the relevés recorded in the Black Isle in which all the character and differential species of the classification are quoted, together with those companion species that occur in the local stands. A table of the site characteristics of each stand of vegetation is given also. A further section deals with the relationship between the major soil subgroups and the plant communities.

A more comprehensive account of the associations and their relief, climate, soils, morphology, status and distribution is given in the publications on classification mentioned above.

FLORISTIC TABLES

The cover/abundance value for each species within each relevé is given according to the Domin scale (Poore 1955b). The ratings for the scale are:—

Cover about 100 per cent	10
Cover greater than 75 per cent	9
Cover 50–75 per cent	8
Cover 33–50 per cent	7
Cover 25–33 per cent	6
Abundant, cover about 20 per cent	5
Abundant, cover about 5 per cent	4
Scattered, cover small	3
Very scattered, cover small	2
Scarce, cover small	1
Isolated, cover small	X

(X) indicates a species outside the sample area but still considered to be part of the community or association.

[ ] indicates that the two species so bracketed share the same cover/abundance values due to difficulties in indentification, for example, the vegetative forms of the sedges *Carex flacca* and *C. panicea*.

In woodland stands, the tree and shrub seedlings of the field layer are considered as separate species from the adult trees and shrubs.

The presence of species within the associations of the classification is given by the scale:—

Constancy class V	80–100 per cent
IV	60–79 per cent
III	40–59 per cent
II	20–39 per cent
I	0–19 per cent

In the larger tables, constancy class I is subdivided further into I = 10–19 per cent, + = 5–9 per cent, r = <5 per cent.

Individual species names for vascular plants follow those of Clapham, Tutin and Warburg (1962), as do the bulk of the common names. Mosses follow those of Smith (1978), liverworts follow Paton (1965), and lichens follow James (1965).

Abbreviations used in the table are:

D., d.	differential species
Ch.	character species
All.	Alliance

SITE CHARACTERISTICS TABLES

Abbreviations used for the major soil subgroups (GSG):

BFS	— brown forest soil–moderate or high base status
BP	— brown forest soil–low base status
GBS	— brown forest soil with gleying–moderate or high base status
GBP	— brown forest soil with gleying–low base status
HIP	— humus-iron podzol–freely drained
IP	— iron podzol
HIL	— humus-iron podzol–shallow phase

- GP — humus-iron podzol–imperfectly drained
- BG — noncalcareous gley–moderate or high base status
- AG — noncalcareous gley–low base status
- PG — peaty gley
- BPT — basin peat–low base status (dystrophic)
- WPT — subaqueous peat

Other abbreviations used:

- T — tree layer
- S — shrub layer
- F — field layer
- G — ground layer
- Climate — abbreviations after Birse (1971)

The height of the field layer is given often as two components—the general height, then the height of inflorescences and ferns.

Additional abbreviations used in table R:

- MBL — mixed bottom land
- S2 — undifferentiated solification deposits, imperfectly drained

Plant community codes and common names:

- VP1 — bell-heather–Scots pine plantations
  - VP1A — dry bell-heather–Scots pine plantations
  - VP1B — moist bell-heather–Scots pine plantations
- QR3 — eastern highland oakwood and birchwood
  - QR3A — eastern highland oakwood
  - QR3B — eastern highland birchwood
- QR4 — southern oakwood
  - QR4A — southern oakwood with bluebell
  - QR4B — grassy southern oakwood
  - QR4D — grassy southern birchwood
- F1 — elmwood
  - F1B — typical elmwood
- T1 — flea-sedge mire
- T3 — few-flowered spike-rush mire
- N3 — bent–fescue grassland
  - N3C — common bent–fescue grassland
- CU1 — Atlantic heather moor
  - CU1B — dry Atlantic heather moor
  - CU1C — moist Atlantic heather moor
- SC1 — bog heather moor
  - SC1A — common bog heather moor
  - SC1B — northern bog heather moor
- ES1 — blanket bog
  - ES1A — common (lowland) blanket bog
- SP2 — common cotton-grass pool

In Table S, two values each for exchangeable calcium, exchangeable magnesium and total phosphorus are given. The first is the uncorrected value but the second has been corrected according to the amount of organic matter present. This has been done because the specific gravity of organic soil material is less than that of mineral soil material and a correction factor must be applied if the levels of the different nutrients are to be compared realistically. This factor is $_{x+100}$ where x is the percentage of organic matter.

The correction factor is based on the fact that the specific gravity of soil organic matter is approximately 1.35 and an average specific gravity of soil mineral material is 2.70 (the specific gravity of granite).

The surface horizon is taken to be the first mineral horizon (A or E) unless a well-developed H horizon is present, in which case its values are quoted instead. The values for L, F or FH horizons are not considered. The horizon properties quoted for peat in the table were derived from samples taken at approximately 20-centimetre intervals down the profile.

Table R Plant communities, soils and localities

Serial number	Plant community	Genetic soil group	Soil association	Grid reference	Locality
WOODLAND					
64037	VP1A	HIP	Millbuie	NH 599553	Ferintosh
64051	VP1A	HIP	,,	NH 625498	Ashley
64053	VP1A	HIL	,,	NH 669507	Lundie
64056	VP1A	IP	,,	NH 635557	Bellton Wood
64055	VP1B	GP	,,	NH 636558	Bellton Wood
64011	QR3A	HIP	,,	NH 584581	Teandore
64052	QR3B	IP	,,	NH 623501	Ashley
64009	QR4A	BFS	,,	NH 584579	Teandore
64054	QR4B	BP	MBL	NH 645488	Drumsmittal
64041	QR4D	BFS	,,	NH 731577	Rosemarkie
64046	QR4D	GBP	Millbuie	NH 692634	Ballycherry
64047	QR4D	BP	MBL	NH 694637	Ballycherry
64010	F1B	GBS	Millbuie	NH 584579	Teandore
64042	F1B	BP	MBL	NH 728583	Rosemarkie
GRASSLAND					
64061	N3C	GP	Ethie	NH 728587	Kinnock
64062	N3C	GBP	S2	NH 772639	Ethie Burn
64044	T1	BG	Millbuie	NH 691636	Ballycherry
64043	T3	PG	,,	NH 692633	Ballycherry
64045	T3	BG	,,	NH 692637	Ballycherry
MOORLAND					
64048	CU1B	HIP	Ethie	NH 806670	Sutors of Cromarty
64035	CU1C	GP	Millbuie	NH 599551	Ferintosh
64036	SC1A	AG	,,	NH 599551	Ferintosh
64057	SC1B	AG	Cromarty	NH 634559	Bellton Wood
64038	ES1A	BPT	Peat	NH 589534	Monadh Mor
64039	SP2	WPT	,,	NH 589534	Monadh Mor

Table S Soils, plant communities and site characteristics

Major soil group	Brown earths								Podzols									
Soil subgroup and variants	BFS		BP			GBS	GBP		IP		HIP				HIL	GP		
Plant community	QR4A	QR4D	F1B	QR4B	QR4D	F1B	QR4D	N3C	QR3B	VP1A	QR3A	VP1A	VP1A	CU1B	VP1A	VP1B	N3C	CU1C
Serial number	64009	64041	64042	64054	64047	64010	64046	64062	64052	64056	64011	64051	64037	64048	64053	64055	64061	64035
Altitude – m	53	46	24	61	58	53	64	107	55	137	50	61	160	122	137	140	122	160
Aspect	NW	N	SW	SE	SE	N	N	N	E	SW	NW	NW	WNW	NNW	NW	SW	NW	W
Slope	5°	32°	14°	30°	23°	4°	5°	23°	3°	2°	8°	2°	6°	13°	8°	3°	15°	1°
Drainage	P(PH)	P	P	P	P	PPH	PPH	PPH	P(PH)	P	P	P	P(PH)	P(PH)	P	PPH	PPH	PPH
pH – surface horizon	5.9	6.3	5.4	4.8	5.2	6.0	5.3	4.7	4.0	3.8	4.3	3.7	3.9	4.2	3.8	4.1	4.2	3.8
Base saturation %																		
– surface horizon	74.2	93.1	33.1	18.7	19.4	77.6	39.4	21.9	18.3	11.5	27.1	10.1	10.7	24.7	13.7	19.4	19.4	19.1
– B horizon	61.5	100.	21.3	1.9	10.9	78.5	89.4	15.4	3.2	1.2	2.4	0.7	0.8	12.2	1.2	1.1	1.1	21.6
– C horizon	–	100.	31.7	2.5	–	86.1	100.	33.8	4.1	3.2	–	0.8	0.8	2.8	–	2.9	2.9	–
Exchangeable Ca (m.e./100 g)	8.13	6.96	2.43	1.53	1.07	12.77	2.44	2.46	10.63	5.98	4.02	6.01	6.03	13.90	6.23	13.68	3.68	14.17
surface horizon	7.80	6.82	2.33	1.42	1.03	11.88	2.34	2.21	6.27	3.05	3.46	3.05	3.26	7.23	3.18	6.98	6.98	7.79
Exchangeable Mg (m.e./100 g)	1.41	0.23	0.31	0.67	0.31	1.67	0.72	0.65	5.56	8.83	2.23	6.19	3.62	8.34	8.54	5.64	5.64	7.97
surface horizon	1.35	0.23	0.30	0.62	0.30	1.55	0.69	0.59	3.28	4.50	1.92	3.16	1.95	4.34	4.36	2.88	2.88	4.38
Carbon: Nitrogen ratio – surface	11.1	9.8	12.2	18.2	13.6	11.7	16.2	16.4	26.5	45.9	18.3	36.4	35.0	39.8	33.8	36.4	36.4	42.0
Total P_2O_5 (mg/100 g)	55	46	54	95	42	76	54	110	276	162	113	129	140	162	108	179	179	153
surface horizon	53	45	52	88	40	71	52	99	163	83	97	66	76	84	55	91	91	84

Major soil group	Gleys					Peat	
Soil subgroup and variants	BG			AG	PG	BPT	WPT
Plant community	T1	T3	SC1A	SC1B	T3	ES1A	SP2
Serial number	64044	64045	64036	64057	64043	64038	64039
Altitude – m	64	76	158	137	76	146	146
Aspect	ESE	N	NIL	W	SW	NIL	NIL
Slope	2°	4°	0°	1°	3°	0°	0°
Drainage	PH-HP	PH-HP	PH	PH	PH-HP	–	–
pH – surface horizon	6.6	7.2	4.6	3.9	5.8	3.8	–
Base saturation %							
– surface horizon	93.4	100	30.5	2.7	83.0	16.2	–
– B horizon	100	100	55.9	2.4	100	18.1	–
– C horizon	100	100	47.1	5.6	100		–
Exchangeable Ca (m.e./100 g)	30.24	73.30	3.44	0.67	62.64	11.27	–
surface horizon	25.10	65.97	2.92	0.34	40.72	5.86	–
Exchangeable Mg (m.e./100 g)	3.70	1.69	0.99	0.87	12.86	12.77	–
surface horizon	3.07	1.52	0.84	0.44	8.36	6.64	–
Carbon: Nitrogen ratio – surface	15.6	17.2	20.8	37.3	18.6	47.1	–
Total P_2O_5 (mg/100 g)	69	87	71	179	69	45	
surface horizon	57	78	60	91	45	23	

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