Stevens, P.A.. 1975 Geology and soils. In: Peterken, G.F.; Welch, R.C., (eds.) *Bedford Purlieus: its history, ecology and management.* Abbots Ripton, NERC/ITE, 43-64. (ITE Symposium 7).

GEOLOGY AND SOILS

P. Stevens

Bedford Purlieus is situated on the edge of a dissected plateau which slopes gently eastwards towards the River Nene at Wansford. Two tributaries of the Nene run west-to-east through the site and the associated valleys together with a dry valley in the north dominate the geomorphology. Plateaux of limited size occur between these valleys but the majority of Bedford Purlieus is composed of extensive gently sloping (1^{o}-8^{o}) valley sides. The lowest and highest points are at about 160 ft. (49 m) and 230 ft. (70 m) O.D.

Geology

Fig. 12 is based upon the 1" geological map for Stamford (Sheet 157). A few alterations have been made from field observations to the drift geology, and mapping units termed Calcareous Tufa and Clay Colluvium have been added.

The solid geology is composed of the Jurassic Inferior Oolite and Great Oolite Series, dipping at less than half a degree to the east or east-south-east, causing the sequence of beds to crop out along the valley sides as bands running roughly parallel with the contours. In general, the lowest beds are exposed in the east, the highest in the west.

The geological succession represented within Bedford Purlieus is shown in Table 3.

Table 3. Geological succession within Bedford Purlieus

		Estimated thickness (metres)
Recent and Pleistocene	(Clay Colluvium	1-2
	(Calcareous Tufa	1-2
	(Glacial Sand and Gravel	<1.5
	(Chalky Boulder Clay	1-2
Jurassic Great Oolite Series	(Cornbrash	negligible
	(Blisworth Clay	3-4
	(Blisworth Limestone	3-4
	(Upper Estuarine Series	6-12
Jurassic Inferior Oolite Series	(Upper Lincolnshire Limestone	0-6
	(Lower Lincolnshire Limestone	4+

Horton, Lake, Bisson and Coppack (1974) describe the mode of formation of these beds. The Lincolnshire Limestone was deposited under turbulent conditions in shallow warm water. The Upper Lincolnshire Limestone fills channels cut into the underlying strata of the Lower Lincolnshire Limestone, thus accounting for the discontinuous nature of the former and possibly its absence in the south of Bedford Purlieus. The Lower Lincolnshire Limestone is a shelly, shell debris oolite limestone, forming hard, thick, grey beds when fresh, but weathering to

12. Geology

Glacial Sand & Gravel

Chalky Boulder Clay

Calcareous Tufa

Clay Colluvium

Cornbrash

Blisworth Clay (Great Oolite Clay)

Blisworth Limestone (Great Oolite Limestone)

Upper Estuarine Series

Upper Lincolnshire Limestone

Lower Lincolnshire Limestone

pale buff and cream flaggy limestone. The Upper Lincolnshire Limestone contains a much higher proportion of shell debris, but both limestones yield rich fossil faunas.

The period of carbonate deposition represented by the Lincolnshire Limestones was followed by a shallowing of the sea and the establishment of lagoonal marshes and coastal swamps. Deposition of the Upper Estuarine Series occurred, the boundary with the Lincolnshire Limestone being marked by an abrupt change from limestone to the sand of the thin basal ironstone bed of the Upper Estuarine Series. This Series shows very rapid vertical variations in lithology. The basal sand is succeeded by white silt stone, followed locally by a thin limestone band, then grey and green clays, the clays often being calcareous in nature.

The succeeding blue-hearted shelly, shell-detrital Blisworth (Great Oolite) Limestone marks a return to marine calcareous sedimentation. This limestone is fairly massive and hard, but is marked by the absence of oolitic particles.

Carbonate deposition gave way to the accumulation of mud, now forming the Blisworth (Great Oolite) Clay. This is predominantly a grey-green clay which separates, with abrupt boundaries, the Blisworth Limestone from the Cornbrash Limestone. The latter is a grey, hard shell-debris limestone weathering to yellowish brown and is only represented by a small tongue at the highest point of the wood.

Glacial deposits of two types are found in Bedford Purlieus. The Chalky Boulder Clay is generally accepted to be a drift deposited during the penultimate (Wolstonian or Gipping) glaciation. It is composed of olive green or brown clay with abundant stones, the latter being mainly sub-angular chalk, limestone and ironstone. Angular flints and rounded quartz, quartzite and sandstone pebbles also occur, the pebbles' characteristics suggesting derivation from the Triassic Bunter Beds. Chalky Boulder Clay occurs mainly on the higher ground in the south-west of the wood on the clays of the Blisworth Clay and Upper Estuarine Series and it appears to rest less commonly on the intervening Blisworth Limestone. Occasionally on slopes, decalcification has removed the chalk, causing the Chalky Boulder Clay to resemble the Jurassic clays, making characterization difficult.

The Glacial Sand and Gravel is of uncertain origin, but the similarity of the stones to those found in the Chalky Boulder Clay suggests a similar source. The Sand and Gravel is composed of brown loam or clay loam with characteristically abundant small fragments of ironstone, probably from a local source such as the Northampton Sand Ironstone, together with rarer flints and Bunter pebbles. It occurs as small patches mainly around the edge of the Chalky Boulder Clay.

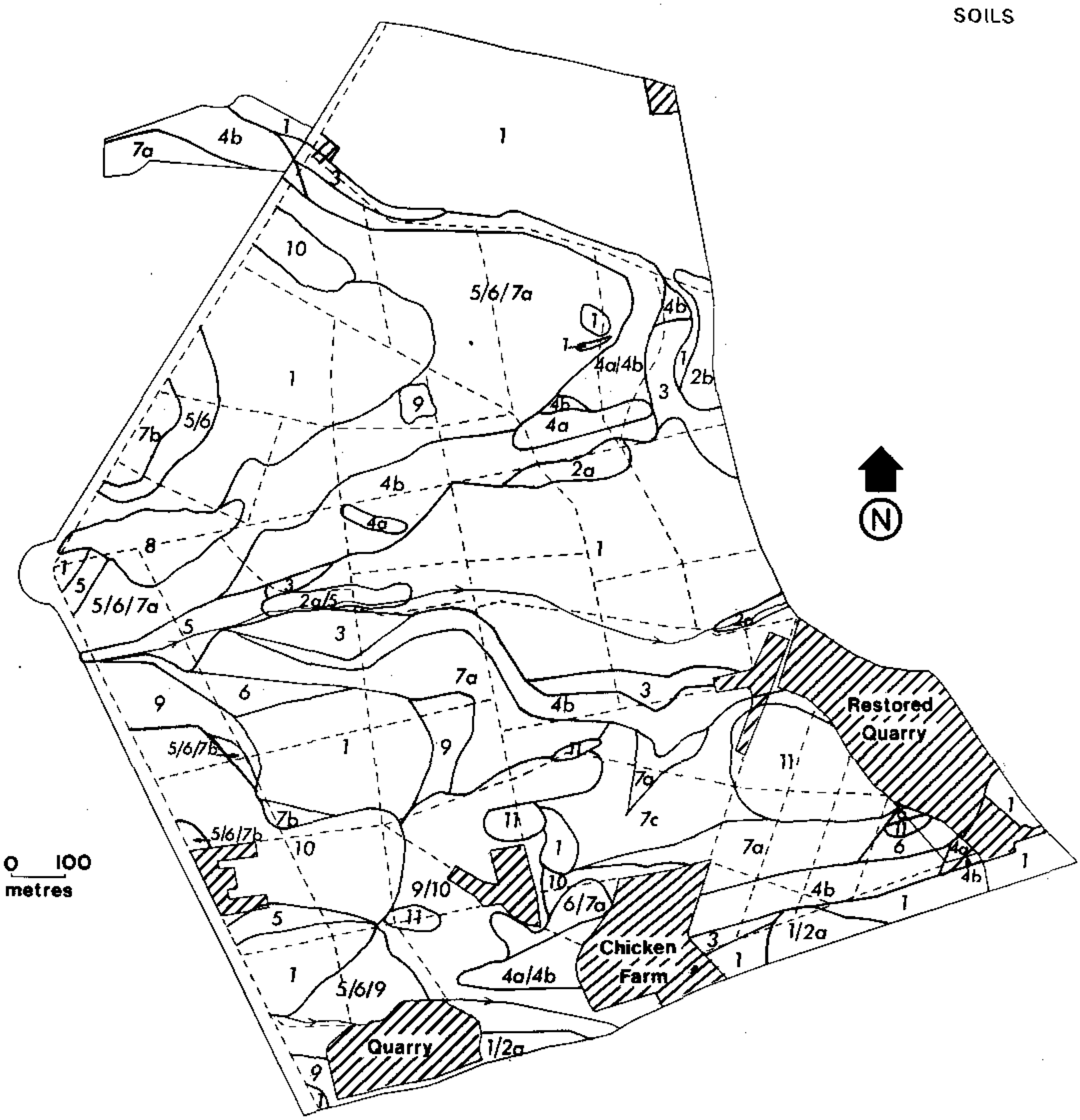
The Calcareous Tufa remnant was probably deposited post-glacially as a small patch at the base of the Blisworth Limestone outcrop and rests mainly on the upper argillaceous beds of the Upper Estuarine Series. It is described by Horton (1974) (pers. comm.) as consisting of 'small grains of structureless calcium carbonate in an extremely porous, almost uncemented material. Traces of plant fragments are present. It has probably accumulated as a deposit in a small lake below a spring.'

Clay Colluvium occurs on the western end of the main valley floor which runs W-E through the wood and is also found as isolated patches on valley sides. It is composed of uniformly coloured brown clay derived

Table 4. Soils of Bedford Purlieus

Soil Group	Classification according to Avery (1973)	Conventional British Classification	Texture and Parent Material
Soils on Lower Lincolnshire, Upper Lincolnshire, Blisworth and Upper Estuarine Limestone			
1.	Brown rendzina	Rendzina	Fine loamy; Lower Lincolnshire, Upper Lincolnshire, Blisworth and Upper Estuarine Limestones
2.	(a) Typical brown earth: uncultivated phase	Brown earth - high base status	)Fine loamy over clayey;)Lower Lincolnshire and)Upper Lincolnshire)Limestones))
	(b) Typical brown calcareous earth: cultivated phase	Brown calcareous soil	
Soils on Upper Estuarine Series Sand and Silt			
3.	Typical brown earth	Brown earth - low base status	Coarse loamy; Upper Estuarine Series basal ironstone bed sand
4.	Typical stagnogley soil:	Non-calcareous surface water gley:	
	(a) Mor phase	(a) Mor phase	Thin mor humus over fine silty; Upper Estuarine Series silt
	(b) Mull phase	(b) Mull phase	Fine silty; Upper Estuarine Series silt
Soils on Upper Estuarine Series and Blisworth Clays; and Clay Colluvium			
5.	Typical brown earth	Brown earth - high base status	Clayey; Clay Colluvium
6.	Stagnogleyic (typical) non-calcareous pelosol	Gleyed brown earth	Clayey; Upper Estuarine Series and Blisworth Clays
7.	Pelo-stagnogley soil:	Non-calcareous surface water gley:	
	(a) Upper Estuarine Clay phase	(a) Upper Estuarine Clay phase	Clayey; Upper Estuarine Series Clay
	(b) Blisworth Clay phase	(b) Blisworth Clay phase	Clayey; Blisworth Clay
	(c) Thin drift over Upper Estuarine Clay phase	(c) Thin drift over Upper Estuarine Clay phase	
Soil on Calcareous Tufa			
8.	Grey (non-humic) rendzina	Rendzina	Fine loamy; Calcareous Tufa
Soils on Glacial Drift			
9.	Stagnogleyic (typical) non-calcareous pelosol	Gleyed brown earth	Clayey: Chalky Boulder Clay
10.	Pelo-stagnogley soil	Non-calcareous surface water gley	Clayey; Chalky Boulder Clay
11.	Typical brown earth	Brown earth - high base status	Coarse loamy over fine loamy; Glacial Sand and Gravel

13. Soil map. For explanation see Table (4).



from the Blisworth and Upper Estuarine Series clays, together with a few pebbles throughout its depth, suggesting mixing of the clay with drift.

A very thin drift cover is noticeable in the top few centimetres of most soils. Pebbles of Bunter origin occur widely on the surface and loamy A horizons are commonly found in many clay soils in Bedford Purlieus. This may indicate either that drift was deposited over the entire area, or it may represent the remnants of a thicker drift removed by erosion. In compartments 47A, 47B, 48A and 49A this thin drift is considerably more conspicuous creating a "bridge" between the deeper drifts of Chalky Boulder Clay and Glacial Sand and Gravel in the west, and Glacial Sand and Gravel in the east.

Soils

No systematic soil survey has previously been undertaken. D.F. Fourt (pers. comm.) gave a brief general description of the soils present (1954). He identified a rendzina on limestone, good base status gleys and gleyed brown earths on Boulder Clay, and degraded brown earths on sandy deposits suggested as being fluvioglacial in origin. During the present work soils were mapped by free survey, involving observations with an auger at 850 sites (c. 4 observations per hectare) arranged as transects to cover the entire wood. The relatively high intensity of observations in relation to normal site soil surveys was considered necessary due to the rapid and marked changes in soils associated with the various geological outcrops. It also, it is hoped, allowed a relatively accurate mapping of the unpredictable but important patches of drift despite some difficulties in identification of decalcified Boulder Clay.

Eleven soil types were distinguished, of which three were further split into phases. Table 4 lists these soils and classifies them in terms of parent material and drainage according to the new system of Avery (1973) developed for use in the Soil Survey of England and Wales. The detailed criteria for classification in this system are unavailable at the time of writing and so slight alterations in nomenclature may be necessary eventually. Equivalent soil sub-group names from more conventional past British usage are also given. Table 4a shows how these different soils may be grouped according to drainage characteristics.

Table 4a

Drainage Class	Soil Groups
Free	1, 2(a), 2(b), 3, 5, 8, 11
Imperfect	6, 9
Poor	4(a), 4(b), 7(a), 7(b), 7(c), 10

When plotted on a map areas showing little variation in the soil characteristics, i.e. with only one soil type present, can be separated as simple mapping units. Areas with two or more soils become complex mapping units. Fig. 13 shows the distribution of soils in Bedford Purlieus.

The main characteristics of the soils identified are explained below, together with variations and profile descriptions of "typical" soils. Analytical data for samples taken from these "typical" soils are listed in Table 5.

Soils on Limestone

The various limestones support freely drained neutral to alkaline soils, mainly of fine loamy texture, and generally with very shallow profiles over solid or rubbly limestone. Plant litter is rapidly and completely incorporated into the mineral soil. Although two soils with deeper profiles are described, these are very limited in area.

1. Brown Rendzina

This soil is by far the most extensive limestone soil. The profiles are shallow and limestone is reached within 40 cm of the surface. They are dominated by fine loamy textures except where minor patches of sandy, silty or clayey drift are added. Soils on the Lincolnshire Limestone are extensively disturbed by relatively high populations of moles and earthworms, thus contributing to a well-developed structure and maintaining a high pH by mixing of limestone fragments with the soil materials. Lincolnshire Limestone soils are generally relatively brightly coloured - yellowish brown or strong brown - whereas Blisworth Limestone (and Upper Estuarine Series Limestone) soils tend to be dark brown or dark grey brown and shallower, with limestone often reached within 20 cm of the surface and with a pronounced fine crumb structure. A small but significant difference in the organic matter content may account for the colour variation. Intimate mixing of limestone with soil materials on the Blisworth and Upper Estuarine Series Limestone results in the whole soil matrix reacting vigourously with acid, whereas Lincolnshire Limestone soils differ in that distinct limestone fragments react with the acid, the soil matrix remaining inert.

This soil can be correlated with the Sherborne Series of the Soil Survey of England and Wales, first described in Somerset and Gloucestershire by A.J. Low (1939) but first mapped in Dorset by K.L. Robinson (1948). Locally, Sherborne Series soils have been mapped by Thomasson (1971) on Inferior Oolite in East Leicestershire and by Burton (pers. comm.) a few miles North East of Bedford Purlieus for the Soil Survey Barnack Record (Sheet TF00E/10W).

A characteristic profile formed on Lower Lincolnshire Limestone shows:-

Depth (cm)	Horizon	
0-15	A	Yellowish brown (10YR 5/4) friable silty clay loam with weak subangular structure breaking to medium crumb; few subangular limestone fragments and rounded (Bunter) pebbles; earthworms seen; narrow undulating boundary.
15-26	B	Yellowish brown (10YR 5/8) firm silty clay with angular structure associated with common subangular limestone fragments; earthworms seen; sharp tongued boundary.
26-34+	B/C	Strong brown (7.5YR 5/8) clay filling spaces in limestone rubble.

Table 5 - Analytical Results for Bedford Purlieus Soils

Soil Number	Horizon	Horizon Depth (cm)	pH Soil/Water 2.5/1	Loss-on-ignition (%)	Organic Carbon (%) (From L.O.I.)	Total Nitrogen (%)	C/N	Textural Analysis (Avery 1973) % Clay <0.002 (mm)	% Silt 0.002-0.06 (mm)	% Sand >0.06 (mm)	Texture	Wet Bulk Density (g cm^{-3})	Exchangeable Cations (me/100 g) Ca	Mg	K	Mn	Cation Exchange Capacity (me/100g)	Extractable Iron Oxides (%) Potassium Pyrophosphate	Oxalic Acid	*Available* P_2O_5 (mg/100 g)**
1	A	0-15	7.65	9.5	3.9	0.39	10.1	24	70	6	silty clay loam	1.4	*	1.2	0.5	0.8	34	N.D.	N.D.	2.4
	B	15-26	7.80	4.9	1.9	0.18	10.3	35	55	10	silty clay	1.6	*	0.7	0.2	0.7	23	N.D.	N.D.	1.0
	B/C	26-34+	8.00	2.9	0.9	0.08	11.6	28	41	31	clay loam	1.9	*	0.8	0.2	1.0	21	N.D.	N.D.	0.7
2(a)	A	0-7	6.75	10.5	4.4	0.47	9.4	28	52	21	humose clay loam	1.3	18.4	0.9	0.9	0.7	38	N.D.	N.D.	1.0
	A/B	7-30	7.05	5.3	2.0	0.23	8.7	28	49	23	clay loam	1.5	*	0.5	0.4	0.8	28	N.D.	N.D.	0.2
	B	30-65	6.95	2.7	0.9	0.12	7.1	28	42	30	clay loam	1.8	14.2	0.5	0.3	0.7	18	N.D.	N.D.	0.1
3	A	4-22	5.65	4.5	1.7	0.17	9.7	13	45	42	sandy silt loam	1.6	3.8	0.5	0.3	0.4	14	N.D.	N.D.	0.5
	B1	22-44	5.15	1.2	0.1	0.04	3.3	12	46	42	sandy silt loam	1.6	1.6	0.1	0.1	0.5	8	N.D.	N.D.	0.1
	B2	44-50	4.70	0.8	0.0	0.02	-	7	13	70	sandy loam	1.7	0.8	0.1	0.0	0.4	3	N.D.	N.D.	0
	C	50-60+	4.90	0.5	0.0	0.01	-	18	27	55	sandy clay loam	2.1	3.1	0.4	0.1	0.5	8	N.D.	N.D.	0
4(a)	Oh/Ah	8-10	3.65	27.4	12.2	0.75	16.2	3	58	39	organic sandy silt loam	<1.0	3.4	0.6	0.8	0.7	69	0.14	0.18	0.5
	A	10-22	3.90	3.6	1.2	0.12	10.2	2	64	35	sandy silt loam	1.5	0.7	0.1	0.1	0.4	15	0.00	0.01	0.4
	Bg	22-34	4.00	0.3	0	0.02	-	3	83	14	silt loam	1.8	0.3	0.0	0.0	0.4	5	0.00	0.01	0.4
	Cg	34-50+	3.95	1.1	0.1	0.03	4.7	6	77	16	silt loam	>2.1	0.3	0.0	0.0	0.4	8	0.15	0.47	0.1
4(b)	A	0-15	4.00	12.0	5.1	0.42	12.2	17	67	16	humose silt loam	1.5	2.1	0.6	0.5	0.5	35	0.22	0.32	0.9
	Bg	15-35	4.00	3.7	1.3	0.13	9.9	18	72	10	silt loam	1.7	1.0	0.2	0.2	0.4	17	0.32	0.48	0.1
	Cg	35-80+	4.10	0.8	0.0	0.02	-	32	60	8	silty clay loam	2.0	0.7	0.1	0.1	0.4	8	0.03	0.26	0.1
5	Ah	0-2	7.15	13.6	5.8	0.66	8.8	44	48	8	humose silty clay	1.6	34.4	1.5	0.9	1.0	58	N.D.	N.D.	2.5
	A	2-18	7.05	8.9	3.7	0.34	10.8	51	41	7	clay	1.9	25.8	1.0	0.7	0.9	49	N.D.	N.D.	1.0
	Bt	18-48	6.95	4.0	1.4	0.15	9.6	46	47	7	silty clay	1.9	17.2	0.7	0.6	0.8	33	N.D.	N.D.	0.7
	B/C	48-70+	6.70	4.1	1.5	0.14	10.6	53	39	8	clay	1.8	20.0	0.6	0.7	0.8	35	N.D.	N.D.	0.3
6	A	3-13	6.25	11.0	4.7	0.47	9.9	41	55	4	silty clay	1.9	19.2	1.2	1.0	0.9	45	N.D.	N.D.	1.6
	B	13-38	6.15	5.4	2.1	0.23	9.1	42	50	8	silty clay	1.9	16.0	0.8	0.6	0.8	35	N.D.	N.D.	0.4
	B/C	38-48	5.95	4.6	1.7	0.20	8.5	44	58	8	silty clay	2.1	16.0	0.8	0.6	0.9	33	N.D.	N.D.	0.3
	Cg	48-60+	6.20	2.2	0.6	0.07	8.9	53	39	8	clay	2.1	16.6	0.9	0.8	1.0	28	N.D.	N.D.	0.3
7(a)	Ag/Bg	2-12	6.20	11.2	4.7	0.45	10.5	34	58	8	humose sandy silt loam	1.5	18.8	0.8	0.9	0.8	39	N.D.	N.D.	1.0
	Bg	12-22	5.50	6.2	2.4	0.29	8.4	40	60	1	silty clay	1.8	13.6	1.1	0.5	0.7	31	N.D.	N.D.	0.2
	Bgx	22-52	6.70	3.0	1.0	0.10	9.5	31	59	10	sandy silt loam	2.1	18.4	0.7	0.6	0.8	24	N.D.	N.D.	0.7
	Cgx	52-72+	7.80	1.0	0.1	0.03	4.7	58	37	5	clay	2.0	28.8	7.0	0.6	1.1	28	N.D.	N.D.	0.2
7(b)	Oh/Ah	0-2	4.60	42.3	18.9	1.41	13.5	N.D.	N.D.	N.D.	organic	<1.0	14.4	2.2	1.7	1.1	71	N.D.	N.D.	6.7
	Bg	2-9	4.20	10.6	4.5	0.35	12.7	53	42	5	clay	1.7	6.4	1.3	0.8	0.7	40	N.D.	N.D.	0
	C1gg	9-30	4.30	3.5	1.2	0.08	14.9	84	16	0	clay	1.7	14.1	3.3	1.5	1.0	N.D.	N.D.	N.D.	0
	C2gg	30-60+	4.40	3.2	1.1	0.04	27.0	86	14	0	clay	1.9	19.7	4.7	1.5	0.9	24	N.D.	N.D.	0
8	A1	0-25	8.00	10.6	4.5	0.59	7.6	18	54	28	humose sandy silt loam	1.2	*	0.6	0.4	1.1	38	N.D.	N.D.	9.1
	A2	25-42	8.30	7.8	3.2	0.45	7.0	21	53	27	clay loam	1.6	*	0.5	0.2	1.1	32	N.D.	N.D.	12.4
	C	42-52+	8.40	2.5	0.7	0.10	7.2	N.D.	N.D.	N.D.	-	<1.0	*	0.3	0.0	1.2	28	N.D.	N.D.	≫ 15.0
9	A	0-15	6.00	13.3	5.7	0.51	11.1	45	44	11	humose clay	1.7	29.6	1.2	0.9	1.0	52	N.D.	N.D.	0.7
	B	15-42	6.80	4.9	1.8	0.16	11.4	59	31	9	silty clay	1.9	*	0.9	0.9	1.1	40	N.D.	N.D.	1.0
	Cg	42-50+	7.80	2.0	0.5	0.06	8.2	42	37	22	clay	2.1	*	0.7	0.5	1.2	23	N.D.	N.D.	1.9
10	Ag	0-15	5.35	8.5	3.5	0.32	10.9	32	51	17	silty clay loam	1.7	10.8	1.4	0.8	0.7	29	N.D.	N.D.	0.5
	Bg	15-35	5.85	3.5	1.2	0.11	11.1	48	32	21	clay	2.1	16.8	1.4	0.6	0.8	28	N.D.	N.D.	0.4
	Cg	35-65+	7.90	3.7	0.4	0.05	8.6	53	32	15	clay	2.1	*	1.5	0.6	1.2	23	N.D.	N.D.	9.7
11	A	0-14	5.80	9.7	4.0	0.33	12.2	32	41	27	clay loam	1.7	10.7	1.1	0.5	0.6	28	0.21	1.37	2.9
	B	14-38	5.70	5.1	2.0	0.13	15.0	29	36	36	clay loam	>2.1	47.0	1.1	0.3	0.5	19	0.12	1.23	4.4
	B/C	38-50+	6.90	4.0	1.4	0.06	23.5	52	31	17	clay	1.9	16.8	0.9	0.4	0.7	29	0.01	1.21	0.4

N.D. Not determined

*Free $CaCO_3$ present.

**Interpretation of phosphate results is rather difficult due to uncertainty in the accuracy of this method. It is doubtful whether a truly satisfactory method exists.

2. (a) Typical brown earth - uncultivated

This deeper soil (with limestone reached at between 40 and 120 cm depth) occurs in some valley bottoms and valley side benches and probably results from accumulation of material derived from limestone soils upslope. However, decalcification of the upper horizons results in the absence of effervescence with acid, despite neutral pH values throughout. The profile is freely drained, but in the deepest profiles a hint of grey mottling in the generally bright brown B horizons may indicate slight drainage impedence, especially as clay textures prevail in the lower horizons of this soil.

Courtney and Webster (1973) summarise soil series associated with the Sherborne Series in Gloucestershire and Wiltshire. The Didmarton Series applies to the valley bottom site of one of the mapped areas, but the Shippon and Haselor Series might also be applied to some of the more extreme profiles occurring at this site.

The freely drained profile found in the valley bottom site is:-

Depth (cm)	Horizon	
0-7	A	Yellowish brown (10YR 5/4) friable stoneless clay loam with fine crumb structure; earthworms seen; diffuse even boundary.
7-30	A/B	Yellowish brown (10YR 5/6) friable stoneless clay loam with coarse angular structure breaking to weak crumb; earthworms seen; diffuse even boundary.
30-65	B	Strong brown (7.5YR 5/8) firm clay with a few angular limestone fragments; manganese concretions present in small clusters.
65+	C	Compact limestone rubble.

(b) Typical brown calcareous earth - cultivated

A small area of Bedford Purlieus is bare of trees and appears to have been cultivated in the recent past. It now supports rough grassland and a few shrubs. The soil profile in this area displays features which support the evidence of cultivation. The upper 25-40 cm is a uniformly brown, well structured material containing drift, pebbles and large angular limestone fragments from beneath. This cultivation horizon is continuous over this area, but the depth of the B horizon and limestone varies considerably. In places at the base of the B horizon limestone has weathered to form a layer up to 50 cm deep of loose oolith "sand".

The profile is calcareous throughout due to mixing during cultivation.

Depth (cm)	Horizon	
0-4	Ah	Grass root mat with dark brown (10YR 4/3) friable fine crumb-structured matrix; sharp undulating boundary.

Depth (cm)	Horizon	
4-35	Ap	Yellowish brown (10YR 5/6) friable slightly stony loam with loose fine subangular structure and common angular oolitic limestone fragments and Bunter pebbles; noticeable proportion of yellow coarse sand-sized ooliths; earthworms seen; diffuse even boundary.
35-70	B/C	Brownish yellow (10YR 6/6) tongues of friable stony loam similar to Ap horizon tonguing down into yellow (2.5Y 7/8) oolith sand; Bunter pebbles and angular limestone fragments in tongues; angular limestone fragments in the oolith sand; earthworms seen; diffuse even boundary.
70-90+	C	Yellow (2.5Y 9/8) stony oolith sand with a few angular limestone fragments.

Soils on Upper Estuarine Series Sand and Silt

3. Typical Brown Earth

The sand of the ironstone bed sand in Bedford Purlieus actually contains little ironstone. A few nodules occur at the extreme base close to the zone of contact with the Lincolnshire Limestone. The degree of iron-staining in the sand varies, causing a patchy appearance similar to the mottling characteristic of gley soils. However, this soil is freely drained and the coloration which varies from white through orange to black is not significant of present drainage conditions.

The depth of this sand bed is not sufficient for the development of a complete soil profile within sand or sandy loam material so that silt from the overlying silt beds or clay derived from the underlying limestone occur at the top and bottom respectively of most profiles. This accounts for the variety of textures - mainly sandy loam but also with sandy silt loams and sandy clay or sandy clay loams - within each profile. Soil structure is poorly developed. The soil is moderately acid (pH 4.5 to 5.5 throughout the profile) leading to a limited fauna and poorly developed soil structure. Litter accumulation results from the poor faunal population.

The boundary between this sandy soil and the more calcareous soils of the underlying limestone is often marked by the change from absence to presence of dog's mercury. Litter accumulation on this sandy soil contrasts with rapid incorporation into the limestone soils which also assists soil identification.

Depth (cm)	Horizon	
0-4	O1	Litter of sweet chestnut leaves.
4-22	A	Yellowish brown (10YR 5/4) stoneless friable sandy silt loam; coarse weak angular structure breaking to coarse weak crumb; earthworms seen.
22-44	B1	Brownish yellow (10YR 6/6) firm slightly stony sandy silt loam; few platy yellow sandstone fragments; single grain structure; earthworms seen; merging undulating boundary.

Depth (cm)	Horizon	
44-50	B2	Brownish yellow (10YR 6/6) firm slightly stony sandy loam; few platy yellow sandstone fragments; single grain structure; sharp broken boundary.
50-60+	C	Light grey (2.5Y 7/2) stoneless sandy clay loam with very pale brown (10YR 7/4) and reddish yellow (7.5YR 6/8) patches; massive structure.

4. Typical Stagnogley Soil

The Upper Estuarine silt occurs as a relatively hard massive pale grey or white siltstone. The massive nature appears to impede drainage in the soils formed on this material, causing extensive strong brown mottling. However, the latter seems too intensive for the degree of water saturation which might be expected even under the wettest conditions in this profile. The soils are strongly acid (pH <4.5) throughout, and have exceptionally low levels of most plant nutrients due, it seems, to initially low levels in the parent material and not to leaching. Two phases have been identified, depending upon the degree of accumulation or incorporation of surface organic matter, the volume of which is related mainly to the density of bracken. Until recently there was no published information about soils on the Upper Estuarine silt. Burton, 1974 (pers. comm.) has recently mapped such soils for the Barnack sheet (TF 00E/10W) and a Soil Survey Record will appear in the near future.

(a) Mor phase

Certain areas of Bedford Purlieus support very dense, vigorous bracken beneath oak and sweet chestnut woodland and upon a cleared area in C 33. An accumulation of between 2 to 30 cm of bracken litter, humified at its base to a black amorphous material, characterises this soil. The only evidence of incorporation of this organic debris into the mineral soil below is the black staining of the otherwise pale grey-brown structure faces in the upper mineral horizons. The upper contrasting black organic and pale grey mineral horizon of this soil give the appearance of a classic podzol profile. However, no significant humus or iron accumulation in the B horizons has been observed or discovered using analytical methods. The grey coloration is due to parent material, and the ochreous mottling due to drainage impedence, gleying being the main process operating.

Depth (cm)	Horizon	
0-4	O1	Matted litter of bracken fronds.
4-8	Of	Mat of decomposing bracken fronds.
8-10	Oh/Ah	Very dark greyish brown (10YR 3/2) loose stoneless sandy silt loam composed of distinct small patches of organic and mineral material; single grain structure; sharp smooth boundary.
10-22	A	Pinkish grey (10YR 6/2) stoneless sandy silt loam with brown (7.5YR 5/2) structure faces due to humus staining; very firm, structures large and ill-defined - almost massive; merging smooth boundary.

Depth (cm)	Horizon	
22-34	Bg	Light orange (10YR 7/1) silt loam with large distinct brownish yellow (10YR 6/6) mottles; extremely firm massive structure with hard stone-like grey silt stones; merging smooth boundary.
34-50+	Cg	Light grey/grey (10YR 6/1) silt loam with large distinct brown/dark brown (7.5YR 4/4) and very dark grey brown (10YR 3/2) mottles; extremely firm massive structure becoming hard at depth.

(b) Mull Phase

Incorporation of organic matter into the soil forming a mull humus type results in a finer structured soil A horizon. Soil pH remains extremely acid even in the A horizon, and mottling characteristics indicate similar drainage conditions to the mor phase.

Depth (cm)	Horizon	
0	O1	Few birch leaves.
0-15	A	Very dark brown (10YR 2/2) loose slightly stony silt loam with yellow (2.5Y 8/8) inclusions from Bg horizon: few Bunter pebbles; medium weak angular structure breaking to fine moderate crumb; merging tongued boundary.
15-35	Bg	Yellow (2.5Y 8/8) very firm silt loam with common large light grey (2.5Y 7/0) mottles; coarse strong angular structure; merging smooth boundary.
35-80+	Cg	Light grey (2.5Y 7/0) very firm silt loam with common large brownish yellow (10YR 6/8) mottles; coarse strong prismatic structure with thin silt cutans between structures due to translocation.

Soils on Upper Estuarine Series and Blisworth Clays ; and Clay Colluvium

5. Typical Brown Earth

This freely drained soil in clay displays remarkably uniform profiles. The heavy textured parent material and nature of the sites at which this soil occurs suggest that the profiles should be poorly drained. The reason for the free drainage, despite the receiving site in the main stream valley, is considered to be the underlying limestone, but this reason cannot be applied to those freely drained profiles encountered higher up the valley sides.

Colour, structure and stone content are relatively constant throughout, even in the deepest profiles (>120 cm). The inclusion of Bunter pebbles and other erratics indicates considerable mixing of the clay during movement and/or deposition, thus creating a uniform parent material, which has been little altered by soil profile development. The soil reaction is slightly acid to neutral, possibly as a result of flushing or by mixing of limestone with the clay at some stage. This soil has not been correlated with any established Soil Series.

Depth (cm)	Horizon	
0	O1	Few elm leaves; moss growing on soil surface.
0-2	Ah	Very dark grey brown (10YR 3/2) friable slightly stony humose silty clay; few Bunter pebbles; coarse moderate angular structure breaking to medium moderate crumb; earthworms seen; narrow undulating boundary.
2-18	A	Dark brown (10YR 3/3) firm slightly stony clay; few Bunter pebbles; coarse moderate angular structure breaking to medium moderate angular; earthworms seen; diffuse even boundary.
18-48	B1	Yellowish brown (10YR 5/4) firm slightly stony silty clay; few Bunter pebbles; coarse moderate angular structure breaking to fine moderate angular; earthworms seen; diffuse even boundary.
48-70+	B/C	Dark yellowish brown (10YR 4/4) firm slightly stony clay with few Bunter pebbles; coarse moderate angular structure breaking to fine moderate angular.

6. Stagnogleyic (typical) non-calcareous pelosol

This imperfectly drained soil represents the least poorly drained of a range of soils with impeded drainage formed in Upper Estuarine clay and Blisworth Clay or silty clay. Imperfect drainage is indicated by extreme mottling at between 40-80 cm depth, mottling being absent in the top 40 cm. The cracking characteristics of the clay contribute to the strongly developed but coarse structure with prismatic units prevailing in the lower B horizon. The soil is typically non-calcareous, with pH values between 5.5 and 6.5, but calcareous bands occur in the Upper Estuarine Series clay leading to some profiles producing a calcareous reaction, especially at depth. A calcareous reaction is occasionally encountered at the surface where lime-rich water runs down from limestone outcrops immediately upslope.

Depth (cm)	Horizon	
0-3	O1	Loose litter of oak, hazel, hawthorn leaves overlying moss.
3-13	A	Very dark grey brown (2.5Y 3/2) friable slightly stony silty clay with a few ironstone fragments; medium moderate subangular structure; white fungal mycelium between structures; earthworms seen; merging even boundary.
13-38	B	Brown/dark brown (10YR 4/3) firm slightly stony silty clay with a few ironstone fragments; coarse strong angular structure; white fungal mycelium between structures; earthworms seen; merging even boundary.
38-48	B/C	Brown (10YR 5/3) very firm silty clay with a very coarse strong prismatic structure; earthworms seen; merging even boundary.

Depth (cm)	Horizon	
48-60+	Cg	Greenish grey (5GY 5/1) extremely firm clay with abundant large distinct yellowish brown (10YR 5/8) mottles; very coarse strong prismatic structure; earthworms seen.

7. Pelo-stagnogley soil

This is a poorly drained, intensively mottled soil. Shrinkage of the clay when dry causes cracking and a well developed structure in B horizon. Three phases have been identified. The Blisworth Clay poorly drained soils have a noticeably higher clay content (roughly 80%), moderate to extremely acid reaction (pH 4-5), and poor incorporation of litter into the mineral soil, whereas the Upper Estuarine Clay has between 50 and 65% clay, neutral to slightly acid reaction (pH 5.5-7.0) and normally rapid complete litter incorporation.

(a) Upper Estuarine Clay phase

Organic material is relatively deeply incorporated into the mineral horizons, resulting in a dark brown A horizon with small rusty mottles. Below this, there is strongly mottled brown, blue, grey or greenish clay to silty clay, normally with prismatic structure. The profile is slightly acid throughout, but calcareous bands in the clay account for high pH values and effervescence with acid in some B and C horizons. Surface horizons are also occasionally flushed by lime-rich water from limestone outcrops upslope. Small amounts of drift are incorporated into the upper horizons, tending to lighten the texture.

This soil can be correlated with the Denchworth Series mapped originally by Kay (1934) and now recorded from Jurassic clays in many parts of England. Denchworth Series includes soils which are non-calcareous throughout or calcareous only in the C horizon. Profiles which are calcareous in both the B and C horizons, and occasionally throughout the profile correspond to the Evesham Series. These two Series occur in a random manner and as such cannot be separated for mapping purposes.

Depth (cm)	Horizon	
0-2	Ol	Oak leaves.
2-12	Ag/Bg	Dark brown (10YR 3/3) greasy stoneless sandy silt loam with common fine distinct rusty mottles; coarse moderate angular structure breaking to medium moderate subangular; earthworms seen; merging undulating boundary.
12-22	Bg	Dark brown (10YR 3/3) sticky stoneless silty clay with common medium distinct yellowish brown (10YR 5/8) mottles; coarse moderate angular structure; earthworms seen; merging undulating boundary.
22-52	Bgg	Olive (5Y 5/3) sticky stoneless silty clay with common medium distinct greenish grey (5BG 5/1) and common large distinct yellowish brown (10YR 5/8) mottles; coarse moderate angular structure; merging undulating boundary.

Depth (cm)	Horizon	
52-72+	Cgg	Olive (5Y 4/3) plastic clay with common medium faint dark bluish grey (5B 4/1) mottles; large prismatic structure with a hint of slickensiding on some structure surfaces.

(b) Blisworth Clay phase

This phase is very similar to the Upper Estuarine clay phase. The main difference is the higher clay percentage (c. 80%) leading to even poorer drainage conditions with extensive, very bright mottling to within a few centimetres of the surface. The soil was not found to be calcareous in any profiles examined. This soil again corresponds with the Denchworth Series.

Depth (cm)	Horizon	
0-2	Oh/Ah	Very dark grey brown (2.5Y 3/2) partially decomposed organic debris mixed with mineral material and a few Bunter pebbles; very friable; very fine weak crumb structure; earthworms seen; sharp wavy boundary.
2-9	Bg	Dark greyish brown (10YR 4/2) firm clay with brownish yellow (10YR 6/6) ped faces and a few medium distinct reddish yellow (7.5YR 7/8) mottles; medium moderate angular structure; earthworms seen; sharp wavy boundary.
9-30	C1gg	Light olive grey (5Y 6/2) very firm clay with olive grey (5Y 5/2) ped faces and abundant large prominent strong brown (7.5YR 5/8) mottles; very coarse strong angular structure; earthworms seen; merging wavy boundary.
30-60+	C2gg	Light grey/grey very firm clay with abundant large distinct reddish eyllow (7.5YR 6/8) mottles; coarse prismatic structure.

(c) Thin drift over Upper Estuarine Clay phase

There is a significant contribution of coarse loamy pebbly drift to the upper 30 cm of this soil formed in Upper Estuarine Clay. Drainage is poor and mottling occurs to within about 10 cm of the surface. At about 50 cm depth unmottled blue-grey clay occurs. This is parent material colouring and indicates reducing conditions for a considerable proportion of the year as mottling would otherwise be expected. This addition of drift to the surface may improve the surface drainage compared with 7(a), but the significance of this is doubtful. Analytical data for this soil is not available.

Depth (cm)	Horizon	
0	Ol	Few oak leaves.
0-12	A	Dark grey brown (10YR 4/2) sandy clay loam with a few Bunter pebbles and angular flints; sticky, medium subangular structure; merging wavy boundary.

Depth (cm)	Horizon	
12-50	Bg	Light yellowish brown (10YR 6/4) sandy silt loam with abundant greenish grey (5BG 6/1) mottles, a few Bunter pebbles and angular flints; sticky, medium subangular structure; merging wavy boundary.
50-70+	C	Bluish grey (5B 6/1) sticky clay with a few Bunter pebbles at top of horizon; massive structure but with abundant roots.

Soil on Calcareous Tufa

8. Grey (non-humic) rendzina

The porous calcareous tufa provides an extremely well drained parent material, despite the receiving site below the outcrop of the Blisworth Limestone. The profile is deep and remarkably uniform with dark brown friable crumb-structured fine loamy A horizon, highly porous with organic matter intimately incorporated throughout. Small lumps of white tufa are included throughout, especially in the lower half of the A horizon resulting in a slightly lighter coloration. The whole profile is highly calcareous with pH values higher than 8.0. Moles and earthworms are abundant, the large number of mole hills and the nature of the material which they bring to the surface providing an accurate method of mapping this soil. A striking feature is the large number of empty snail shells to be found scattered on the ground surface and throughout the A horizon. Occasional shells were observed in the tufa itself. Investigation would decide whether the snails have been living recently in the soil or are fossils of snails contemporary with the deposition of the tufa in a freshwater environment.

At the base of the A horizon, there is an abrupt boundary with the tufa. There is surprisingly little mixing of the A horizon with the tufa below.

Soils on calcareous tufa have been mapped under different series names in other parts of the country but have not yet been described from the region around Bedford Purlieus.

Depth (cm)	Horizon	
0-25	A1	Dark brown (10YR 3/3) friable humose sandy silt loam; medium weak subangular structure breaking to fine moderate crumb; few small fragments of soft tufa; common snail shells present; earthworms seen; merging smooth boundary.
25-42	A2	Brown (10YR 5/3) friable clay loam; medium weak subangular structure breaking to fine moderate crumb; common small fragments of soft tufa; common snail shells; earthworms seen; sharp wavy boundary.
42-52+	C	White (10YR 8/2) firm porous calcareous tufa with a few small dark brown A horizon inclusions; massive structure but readily broken into fine crumb structure; few snail shells.

Soils on Glacial Drift

Drainage in the heavy textured Chalky Boulder Clay soils is impeded, especially on plateaux areas where the bulk of this deposit occurs, due to poor lateral and vertical water movement in the soil profile. On slopes, lateral drainage is relatively significant and the Chalky Boulder Clay thinner, resulting in imperfect rather than poor drainage. Well developed structure in the upper horizons has helped leaching and decalcification. Chalk fragments are usually found within 4.0 cm of the surface in the poorly drained profiles, but at greater depth in the imperfectly drained equivalents. Flint and Bunter pebbles remain scattered throughout the profiles.

9. Stagnogleyic (typical) non-calcareous pelosol

This imperfectly drained soil is restricted to the edges of the Chalky Boulder Clay deposit or on slopes. Chalk is restricted to depths greater than 40 cm in the profile, the upper 40 cm being non-calcareous, despite pH values between 6 and 7, and thus justifying the "non-calcareous" qualification in the name. The soil has freely drained A and B horizons, but the C horizon is extremely mottled.

This soil corresponds to the chief variant of the Ragdale Series described by Thamasson (1971) in Leicestershire.

Depth (cm)	Horizon	
0	01	Few oak leaves.
0-15	A	Very dark grey brown (2.5Y 3/2) firm slightly stony clay; few small and medium angular and rounded flints; medium weak angular structure breaking to fine weak angular structure; earthworms seen; merging even boundary.
15-42	B	Yellowish brown (10YR 5/4) firm slightly stony silty clay; few small and medium angular flint and rounded flint and ironstone fragments; coarse weak angular structure breaking to medium weak subangular; earthworms seen; merging even boundary.
42-50+	Cg	Light olive brown (2.5Y 5/6) sticky gritty clay with common medium faint ochreous mottles; small rounded chalk fragments, small angular flint, ironstone and oolitic limestone fragments; massive structure; earthworms seen; water running into bottom of pit.

10. Pelo-stagnogley soil

In the poorly drained Chalky Boulder Clay soils, chalk is encountered between 30 and 80 cm depth from the surface, and the A and B horizons are less deep. There is mottling throughout the profile. The profile is slightly acid in the A and B horizons, but neutral in the C where chalk occurs.

The Ragdale Series (Thomasson 1971) corresponds closely to the majority of profiles with $CaCO_3$ below 40 cm depth, and a mixed variant of the Ragdale Series applies to the profiles with $CaCO_3$ within 40 cm of the surface.

Depth (cm)	Horizon	
0	Oh	Few oak leaves.
0-15	Ag	Brown/dark brown (10YR 4/3) plastic slightly stony silty clay loam; few very fine faint ochreous mottles

Depth (cm)	Horizon	
		and a few medium rounded Bunter pebbles; medium moderate subangular structure breaking to fine weak crumb; earthworms seen; merging even boundary.
15-35	Bg	Olive grey (5Y 5/2) plastic slightly stony clay with common medium distinct yellowish brown (10YR 5/8) mottles; small rounded Bunter pebbles and shelly limestone fragments, and small angular flints; coarse moderate angular structure; earthworms seen; merging even boundary.
35-65+	Cg	Light brownish grey (2.5Y 6/2) plastic slightly stony clay with light grey/grey (5Y 6/1) ped faces and common medium distinct reddish yellow (7.5YR 6/8) mottles; small subangular and rounded chalk fragments, small angular flints, and small angular and subangular oolitic limestone fragments; massive structure; earthworms seen.

11. Typical Brown Earth

This freely drained, well structured friable soil is characterised by the abundance of fine gravel-sized ironstone in a clay loam matrix. The parent material is Glacial Sand and Gravel and the soil occupies an area capping a low hill in the south east of Bedford Purlieus. The ironstone is considered to contribute to the strong brown "rusty" coloration of the crumb-structured soil matrix. Coloration and structure are relatively uniform throughout the profile, although where the drift thins over Upper Estuarine Limestone or Clay, a lithological boundary occurs at depth.

This soil has not been correlated with any existing published soil series.

Depth (cm)	Horizon	
0	Oh	Few oak leaves.
0-14	A	Dark yellowish brown (10YR 4/4) very stony friable clay loam with abundant subangular, rounded and platy ironstone fine gravel with a few medium and large rounded Bunter pebbles; fine moderate crumb structure; earthworms seen; diffuse even boundary.
14-38	B	Strong brown (7.5YR 5/8) very stony friable clay loam with stones as above; medium weak angular structure breaking to medium weak crumb; earthworms seen; diffuse even boundary.
38-50+	B/C	Strong brown (7.5YR 5/8) massive very stony plastic clay with ironstone gravel as above but no Bunter pebbles.

Discussion

A wide variety of lowland soils is represented in Bedford Purlieus. The main influence is that of geology, contributing parent materials with a range from highly calcareous limestones and tufa through to highly acid silt and sand. Textures and drainage characteristics range from poorly drained heavy clays to freely drained sandy loams. Local relief and porosity of underlying strata act on the clay soils resulting in a spectrum of drainage classes from poor to free. As can be seen from Figures 12 and 13, geological and some soil boundaries follow a similar trend, reflecting the geological influence on the soils. Other soil boundaries do not correspond with geological boundaries. These reflect drainage differences, textural variation within the Upper Estuarine Series outcrop, effects of cultivation, depth of profile and they also separate complex mapping units from simple units.

During field mapping it was observed that certain plant species were associated with specific soil types or groups of soil types, and that some species were correspondingly absent. As might be expected ash and lime are generally confined to limestone soils, whereas sweet chestnut and bracken occur mainly on the acid silt and sand doils of the Upper Estuarine Series. Dense bracken and a deep litter is associated with certain areas of the silt outcrop. Dog's mercury is widespread and abundant on soils of high base status. It is absent from the Blisworth Clay and acid silt and sand soils but is found in isolated clumps on the flushed imperfectly and poorly drained Upper Estuarine Series clays, sparsely scattered on Chalky Boulder Clay soils and abundant on the soils formed on limestone, Clay Colluvium, Calcareous Tufa and Glacial Sand and Gravel.

As might be expected Deschampsia cespitosa is restricted mainly to soils with imperfect or poor drainage either due to preference or exclusion from more freely drained sites. The main exception is the freely drained brown earth formed on Clay Colluvium in the valley bottom site which supports a large population of this plant. The receiving site ensures an influx of water which passes readily through the soil. However, seasonal waterlogging is conceivable, thus explaining the occurrence of this species in this site. The imperfectly and poorly drained Upper Estuarine Clay and Chalky Boulder Clay soils support Deschampsia cespitosa at varying densities, but the poorly drained Blisworth Clay supports only scattered tufts of the grass.

Although some generalisations can be made relating plant species with soil types from direct observation, it was considered possible that a map showing the distribution of pH values for these soils would be of greater use for these relationships. A soil core sampling programme was therefore undertaken utilising a rough grid system based upon ride intersections. At about 250 points, 0-10 cm and 10-20 cm samples were taken for pH testing. The resulting values were plotted and two maps produced (Figs. 14 and 15), one of each depth of sample. These maps again generally reflect parent material, but minor variations between the two pH maps, the geology and soils maps may reflect the influence of vegetation, land-use history or thin surface drift.

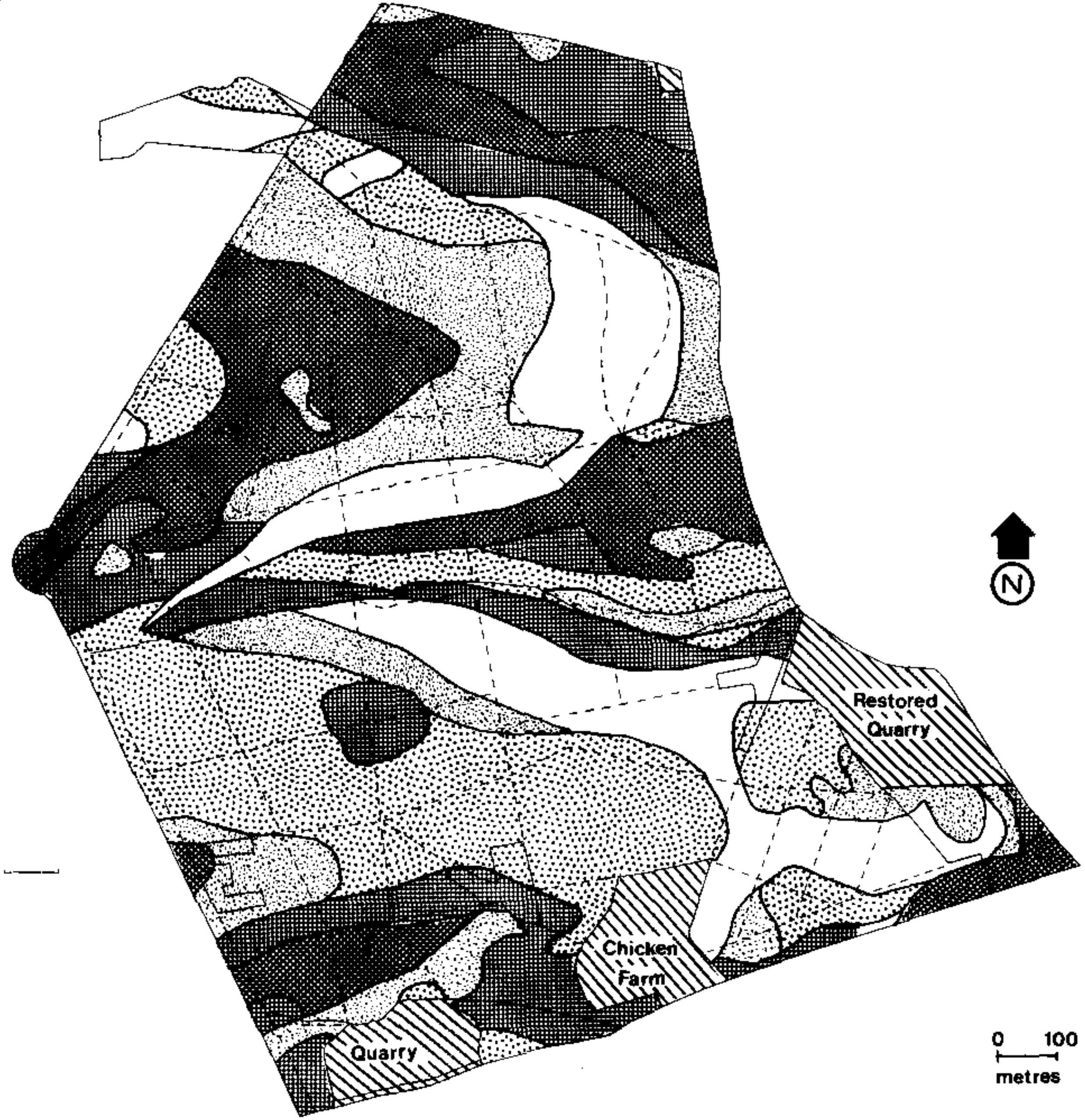
Conservation and Management Requirements

The mineral resources of the wood are relatively valuable. Lincolnshire Limestone has been quarried extensively adjacent to Bedford Purlieus and the reconstituted land of Compartment 50A is a restored limestone quarry. Considerable areas within Bedford Purlieus would probably be considered suitable for limestone extraction. At the recently closed quarry near Hunting Gate, Upper Estuarine Series silt was removed for use as a refractory material. The silt band crops out in Bedford Purlieus and can be traced by the incidence of small pits, obviously man-made and not of recent origin, for extraction of the silt. This product is probably still of economic value.

14. Distribution of pH at 0-10 cm depth.

Soil pH 0-10cm

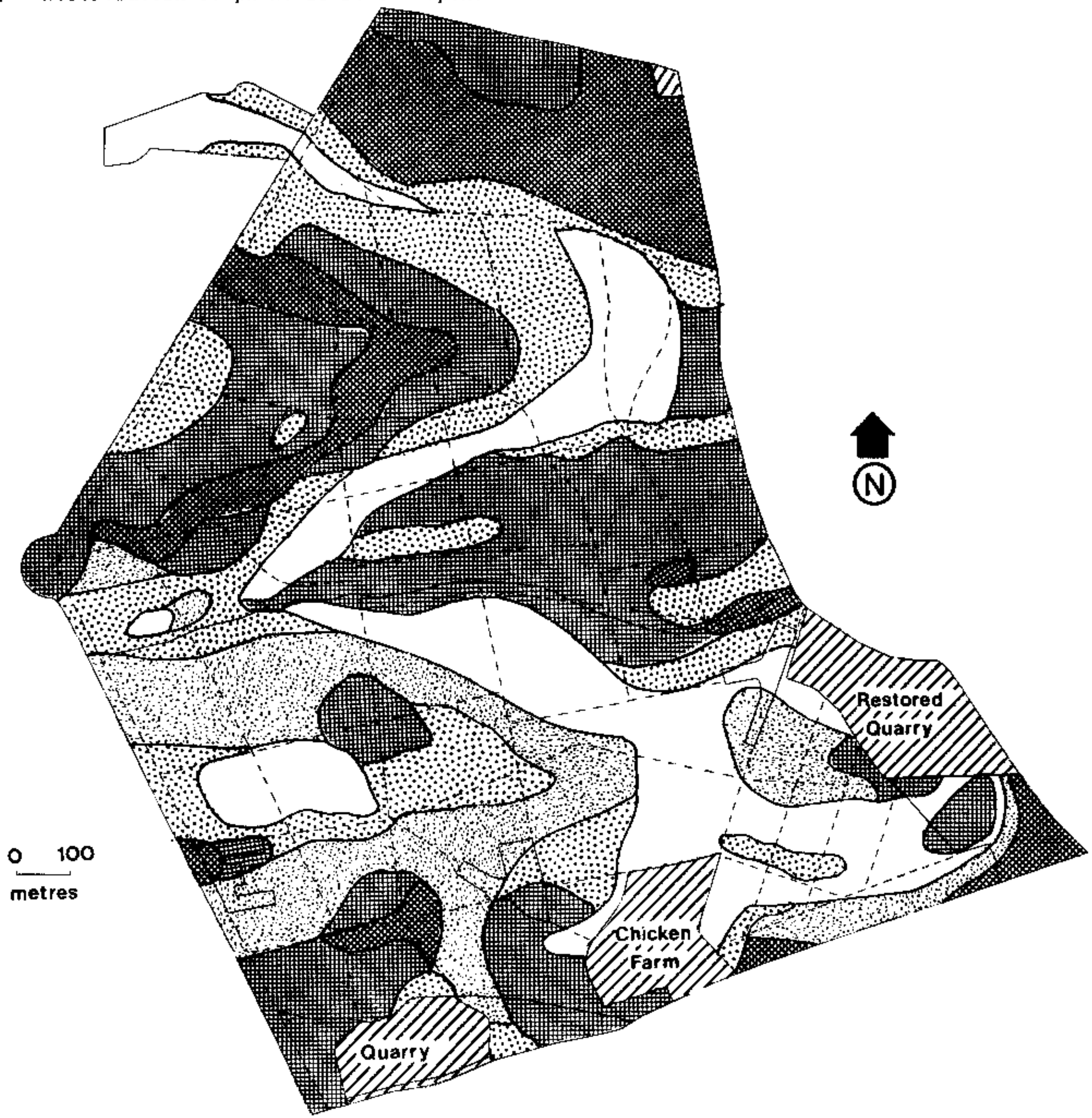
Soil Reaction	pH (in water)
Strongly Acid	< 4·5
Moderately Acid	4·5 - 5·5
Slightly Acid	5·5 - 6·5
Neutral	6·5 - 7·5
Alkaline	> 7·5
Areas not sampled	



15. Distribution of pll at 10-20 cm depth.

Soil pH 10 - 20 cm

Soil Reaction	pH (in water)
Strongly Acid	< 4·5
Moderately Acid	4·5 - 5·5
Slightly Acid	5·5 - 6·5
Neutral	6·5 - 7·5
Alkaline	> 7·5
Areas not sampled	



The whole of Bedford Purlieus may be considered as a valuable site for soil conservation. The soils present are now only rarely found in an uncultivated form, especially in this area of eastern England but should be compared to those of Castor Hanglands N.N.R., five miles to the ENE, which is situated mainly on the same geological formations so that similar soils might be expected there.

Bedford Purlieus displays a considerable variety of soils for such a small area, obviously a factor explaining the diversity of the wood's flora. Observations suggest that only one small area has been cultivated in the past. On a national basis, the limestone, Chalky Boulder Clay and Upper Estuarine clay soils are relatively common and widely distributed. However, the Upper Estuarine silt, Glacial Sand and Gravel and Calcareous Tufa soils are more localised and rare, especially the latter two. The silt soils present several opportunities for research, including assessment of the drainage status throughout the year, and investigation of any tendency towards podzolisation.

The age of the Calcareous Tufa is believed to be post-glacial, but further work to confirm this could be undertaken. The site of this deposit has obviously provided a popular habitat for snails, judging by the numbers of empty shells above and below the soil surface.

The very high ironstone content of Glacial Sand and Gravel is unusual. Further work could be done to decide the age of this drift in relation to the Chalky Boulder Clay and other drifts in the region.

The uncultivated nature of the soils should be preserved. The present management of opening-up rides and some compartments appears to have little lasting effect on the soils, although use of heavy machinery on the clay soils might cause structural deterioration leading to compaction and drainage problems of a more permanent nature.

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