CHAPTER 15

SOILS OF THE SHALE OF THE PIETERMARITZBURG FORMATION, ECCA GROUP IN KWAZULU-NATAL

Location and Extent

The Pietermaritzburg Formation covers parts of northern and central KwaZulu-Natal. It is exposed south of Vryheid and in the Mfolozi and Mkuze valleys (Geological Survey, 1984)(Figure 15.1). South of the Tugela River the Pietermaritzburg Formation is located in two north-south stretching belts (Figure 15.1). For convenience of description these belts may be considered as lying on either side of the reported axis of the Natal monocline (King, 1940). The western boundary of this interior belt is determined by Ecca Group rocks of the Vryheid Formation. To the east lies the tillite of the Dwyka Formation. The boundaries of the Pietermaritzburg Formation are commonly determined by the numerous faults present within the monoclinal structure of the coastal hinterland (Geological Survey, 1988b, 1988c, 1988d). The eastern belt lies within the coastal belt at altitudes of between 50 and 300 metres. With the extensive faulting in the coast belt, the shales of the Pietermaritzburg Formation are bounded by the sandstones of the Vryheid Formation and the Natal Group, sands of the Berea Formation, and tillite of the Dwyka Formation. These changes in geology have important local influences of the soils, their classification and properties. The tillite occupies an area of approximately 908 650 hectares.

Geology and Geomorphology (Geology Symbol Abbreviation **Pp**)

In the north eastern area of the Karoo basin the soft blue Pietermaritzburg shales have long been recognised (SACS, 1980). They have also been known as the Lower Ecca Beds. However, the name Pietermaritzburg Formation has been assigned by the South African Committee for Stratigraphy (SACS, 1980). The unit consists almost entirely of shale and attains a maximum thickness of over 400m. The upper boundary is gradational and is probably best defined as a horizon above which the sand: shale ratio is greater than 0.5 (SACS, 1980). The name ceases to apply beyond the point in southern KwaZulu-Natal where the overlying Vryheid Formation pinches out (SACS, 1980). Here it is no longer distinguishable from the Volksrust Shale. This occurs in the areas of southern KwaZulu-Natal, (south of 30° 30') where the name Ecca Shale Formation is preferred.

The formation is described as dark grey shale, carbonaceous shale, siltstone and subordinate sandstone (Geological Survey, 1981; Geological Survey, 1988a, 1988b, 1988c, 1988d;).

Physiography and Drainage Features

In the KwaZulu-Natal northern interior basin exposures together with other Ecca Group rocks give rise to undulating lowlands and hills (Kruger, 1983). Exposures of the Pietermaritzburg Formation in the Mkuze, Mfolozi and Tugela River Valleys commonly occur on steep valley sides. However, south of the Tugela River are open undulating hills and valleys with many slopes being less than 5 percent. South of Pietermaritzburg undulating hills of moderate relief are again present, while in the Mzimkulu River Valley low mountains are present (Kruger, 1983). The

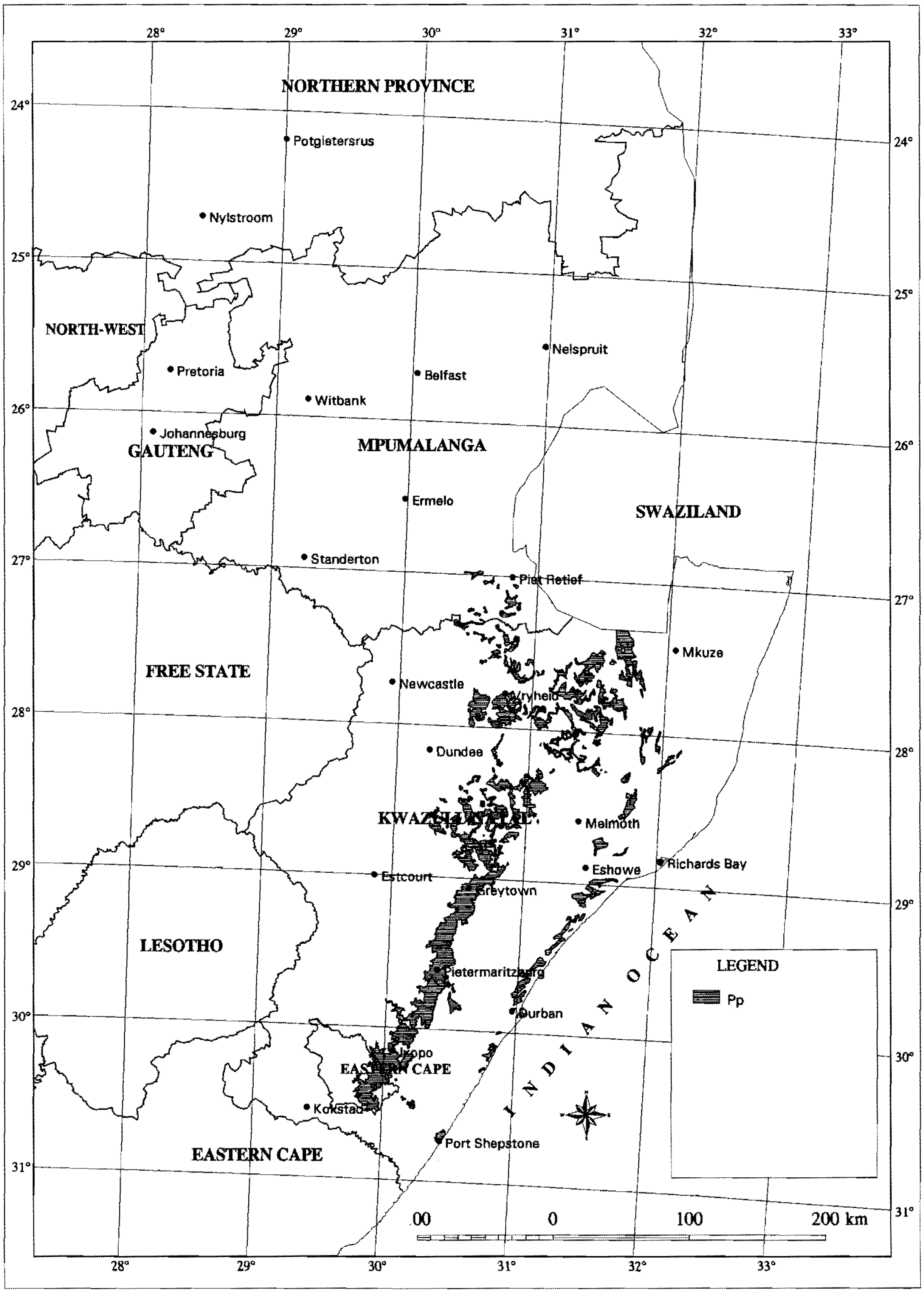

Figure 15.1. Location of the Pietermaritzburg Formation, Ecca Group in KwaZulu-Natal and Mpumalanga (after Geological Survey, 1984).

exposures of the Pietermaritzburg Formation along the entire coastal belt occur in highly dissected landscapes with limited flatter slopes.

Vegetation

In the northern KwaZulu-Natal Interior Basin the vegetation is dominated by Natal Central Bushveld with Natal Lowveld Bushveld in east of these interior basins (Low and Rebelo, 1996). The Tugela Valley has Valley Thicket, while Short Mistbelt Grassland covers the southern zones.

Soils

Eight major soil patterns are evident on the shales of the Pietermaritzburg Formation (Table 15.1). In three of these soil patterns red soils are dominant. In a further two soil patterns plinthic and duplex soils respectively are dominant. Lithosols comprise the major soils of two patterns, while margalitic black clays form the last pattern. It is interesting that each of these reflects in a uniquely different way the properties of the shale from which soil formation has taken place. The shales give rise to clay soils, and hence the freely drained red and yellow-brown soils of the apedal soil patterns. These soils are similar to those derived from the sedimentary rocks with a greater clay forming potential, and to those derived from dolerite. Iron and manganese concretions and iron coatings on stones and shale chips are characteristic of the plinthic landscapes, and contrast in morphology to the plinthite horizons of the interior basins developed from sandstone. The lithosols differ too, in that higher clay contents are recorded, often overlying hard horizontal shales, or the fractured and inclined shales with soil movement into the fractures. Finally, the margalitic soil pattern of Milkwood, Mayo and Bonheim soils, with the vertic soil forms of Arcadia and Rensburg, differs significantly from the soil patterns derived from other sedimentary rocks in KwaZulu-Natal and Mpumalanga Provinces. While margalitic and vertic soils are present on the sedimentary rocks they are usually directly associated with dolerite, or are located in bottomland positions where base materials and silica can accumulate. These soils show similarities to those of the basalts of the Letaba (Jl) and Bivane (Zb) Formations. The soils of the Pietermaritzburg Formation derived from shale thus show similarities to both the sedimentary rocks, particularly those of greater clay forming potential, as well as to the basic igneous rocks. This makes the soils developed from the shales of the Pietermaritzburg Formation rather unique.

The soil patterns derived from shale of the Pietermaritzburg Formation are listed below (Table 15.1). These include a red and yellow-brown apedal soil pattern where dystrophic soils are dominant, or occur together with mesotrophic soils. Another pattern has red apedal and red structured soils with dominantly eutrophic base status. In this pattern there are also calcareous Hutton soils, black clays (Bonheim, Mayo and Milkwood), duplex soils and lithosols. The plinthic soil pattern has Avalon, Westleigh, Longlands soils with mesotrophic and eutrophic base status. However, Hutton, Clovelly, Griffin and Shortlands soils comprise an appreciable component of the soils in this pattern. Plinthic soils commonly occur with duplex soils and lithosols where a lower effective rainfall is present. This is evident in the fourth soil pattern which is derived from the combination of seven land types (Table 15.1). The duplex soil pattern is dominated by Swartland and Valsrivier soils. A small proportion of the soils belong to the Estcourt form, having an E horizon, showing signs of soil wetness. The melanic black clay soil pattern is somewhat unique with dominant black clay soils lying directly over the shale. Examples where margalitic soils are dominant are located at Verulam and inland of

Table 15.1 Dominant soils and selected climatic information for soil patterns occurring on shale of the Pietermaritzburg Formation.

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rainfall mm	Evaporation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Red and Yellow-brown Dystrophic and Mesotrophic Apedal Soils										
Hutton	Hu17 Hu18	28				Ave	883	1483	2676	0.60
	Hu27 Hu28	7				Std	128	137	436	0.10
Clovelly	Cv16 Cv17 Cv18	13				Max	1284	1913	3916	0.90
Griffin	Gf12 Gf13	11				Min	606	1123	1674	0.39
Glenrosa	Gs16 Gs19	12								
Mispah	Ms10	9								
Total Area: 190 240 Ha			Means of 56 Land Types							
Broad Soil Pattern: Red Apedal and Red Structured Eutrophic Soils										
Hutton	Hu37 Hu38	35	Valsrivier	Va41 Va42	5	Ave				
	Hu36	6		Va12 Va22	4	Std				
	Hu47	3	Swartland	Sw31 Sw41	2	Max				
Shortlands	Sd21 Sd22	8	Bonheim	Bo41	4	Min				
	Sd31 Sd32		Mayo	My11Mw11	3					
			Milkwood							
			Mispah	Ms10	4					
Total Area: 39 330 Ha			Means of 10 Land Types							
Broad Soil Pattern: Red and Yellow-brown Apedal and Plinthic Soils (Dominantly Mesotrophic Base Status)										
Hutton	Hu27 Hu28 Hu17	15	Westleigh	We12 We13	4	Ave	794	1534	2467	0.52
	Hu37 Hu38 Hu36	3	Longlands	Lo12	2	Std	51	81	509	0.05
Clovelly	Cv27	13	Shortlands	Sd 21 Sd22	7	Max	845	1679	3016	0.58
Griffin	Gf22	3	Glenrosa	Gs16 Gs19	6	Min	684	1427	1146	0.42
Avalon	Av26 Av27 Av24	6	Mispah	Ms10 Ms11	8					
	Av36 Av37 Av34	4								
	Av16 Av17	2								
Total Area: 381 300 Ha			Means of 52 Land Types							
Broad Soil Pattern: Plinthic and Duplex Soils										
Avalon	Av26 Av16	7	Hutton	Hu27 Hu37	14	Ave	713	1495	2931	0.48
Westhleigh	We12 We13 We22	6	Shortlands	Sd11 Sd12	7	Std	60	128	166	0.06
Longlands	Lo12 Lo13 Lo22	5				Max	842	1576	3192	0.59
Swartland	Sw31 Sw32 Sw41 Sw42	8				Min	650	1158	2739	0.42
Valsrivier	Va31 Va31	4								
Estcourt	Es33 Es34 Es36	4								
Glenrosa	Gs16 Gs17	17								
Mispah	Ms10	7								
Total Area: 46 550 Ha			Means of 7 Land Types							

Table 15.1 continued. Dominant soils and selected climatic information for soil patterns occurring on shale of the Pietermaritzburg Formation.

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rain fall mm	Evaporation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Duplex Soils										
Swartland	Sw31 Sw32	18				Ave	754	1519	3503	0.50
	Sw41 Sw42	8				Std	95	162	684	0.05
Valsrivier	Va31 Va32 Va41	15				Max	922	1729	4292	0.56
	Va42					Min	634	1251	2678	0.43
Estcourt	Es34 Es36	3								
Glenrosa	Gs16 Gs17 Gs19	14								
Mispah	Ms10	4								
Total Area: 35 290 Ha			Means of 5 Land Types							
Broad Soil Pattern: Melanic Black Clay Soils										
Milkwood	Mw11	18	Swartland	Sw31 Sw41	6	Ave	835	1566	3272	0.54
Mayo	My11	4	Valsrivier	Va31 Va41	6	Std	150	162	546	0.08
Bonheim	Bo11 Bo21	12				Max	1055	1878	4230	0.66
	Bo31 Bo41					Min	620	1259	2415	0.37
Other	Ar30 Ar40	5								
Black	Rg10 Rg20									
Clays.										
Glenrosa	Gs16 Gs17 Gs19	17								
Mispah	Ms10	3								
Total Area: 59 570 Ha			Means of 15 Land Types							
Broad Soil Pattern: Lithosols without the presence of lime										
Glenrosa	Gs16 Gs17 Gs19	19	Hutton	Hu17 Hu22	11	Ave	781	1565	3018	0.50
	Gs10			Hu28		Std	97	169	543	0.07
Mispah	Ms10	17		Hu37 Hu38	4	Max	1043	1967	4300	0.61
Cartef	Cf12 Cf21	3	Shortlands	Sd12 Sd22	6	Min	657	1251	2373	0.33
Rock		9								
Total Area: 58 750 Ha			Means of 18 Land Types							
Broad Soil Pattern: Lithosols with the presence of lime										
Glenrosa	Gs16 GS17	19	Swartland	Sw31 Sw32	8	Ave	695	1678	3198	0.41
	Gs19 Gs29	1		Sw41 Sw42		Std	101	238	500	0.10
Mispah	Ms10	16	Valsrivier	Va31 Va41	3	Max	-	-	-	-
	Ms20	5				Min	615	1245	2415	0.33
Rock	Rock	8								
Total Area: 97 620 Ha			Means of 24 Land Types							

Scottborough, while similar margalitic soils are present in the Mpushini River valley, east of Pietermaritzburg. The lithosols can form in higher rainfall zones with correspondingly higher rates of soil formation. However, higher rates of erosion are also to be expected, as would be likely in steeper landscapes. The lithosols on Pietermaritzburg shale without the presence of lime, are associated with dystrophic (higher rainfall) through to eutrophic (lower rainfall) Hutton soils, and where correspondingly higher rates of ferralitic weathering can to be expected. They are also associated with Cartref soils. The inference is that the lithosols and Cartref soils are formed in a higher rainfall regime (Table 15.1), sufficient to give rise to an E horizon with soil wetness above slowly permeable shales. Effective rainfall is usually lower than is the case where ferralitic weathering to form Hutton or Shortlands soil is observed to be operative. The appropriate combinations of landsurface, relief and topography should also be operative to give rise to the E horizons or the ferralitic soils. Lithosols with the presence of lime were also noted. Lime was present in the Glenrosa, Mispah, Swartland and Valsrivier soils. Rainfall is lower than where either Hutton or Cartref soils are present (Table 15.1).

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles for Hutton, Griffin, Clovelly, Longlands, Estcourt, Swartland, Glenrosa, Mispah, Mayo, Milkwood, Rensburg and Shortlands were extracted from the database. The ranges in textural properties, (maximum and minimum values) for five particle size classes, dominant sand grade, and information on the luvic properties are presented (Table 15.2). These ranges are also presented graphically (Figure 15.2). The figure allows for overview comparison between

Table 15.2 Textural properties of soils of the Pietermaritzburg Formation derived from profile values.

Form	Hori zon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1	ClLm-SiCl-Cl	30-58	13-43	3-34	1-11	1-9	fi,co	NL5
	B1	ClLm-SiCl-Cl	33-74	5-49	1-38	1-16	1-40	fi,co	-
Griffin	A1	ClLm-SiCl-Cl	29-60	9-53	3-27	1-16	2-11	fi,co	NL4,EL1
	B1	ClLm-SiCl-Cl	35-65	11-50	1-32	1-13	1-14	fi,co	NL2,L2,EL1
	B2	SaClLm-SiCl-Cl	26-70	14-38	3-40	1-11	3-8	fi,co	-
Clovelly	A1	SiCl -Cl	48-72	19-39	2-15	1-2	1-4	fi,me,co	EL3,NL1,L1
	B1	SaCl-Cl	38-70	9-42	1-37	1-22	1-18	fi,co	EL3,NL2
Longlands	E1	Sa-SaLm-Lm	24-24	36-36	19-19	2-2	19-19	fi,me,co	EL5
	B1	SaClLm-ClLm-Cl	22-47	17-32	7-41	3-20	1-25	fi,co	L5
Estcourt	A1	SaLm-Lm	26-26	36-41	25-27	8-8	2-3	fi	EL3,NL2
	E1	LmSa-SaLm-Lm	24-26	37-38	24-26	7-9	2-3	fi,me	L5
	B1	Lm-Cl	23-51	10-38	16-27	6-14	2-12	fi,me,co	-
Swartland	A1	SaLm-Cl	1-56	4-37	4-51	1-26	1-57	fi,co	NL3,L2
	B1	SaClLm-SiCl-Cl	28-69	8-51	3-46	1-19	1-7	fi	NL5
Glenrosa/ Mispah	A1	SaClLm-ClLm-Cl	17-54	8-39	6-43	2-13	1-16	fi,co	-
Mayo	A1	SiCl-Cl	36-65	9-42	3-34	1-10	1-8	fi,co	EL5
	B1		25-64	5-34	4-31	2-12	1-13	fi,co	-
Rensburg	A1	Cl	70-70	16-20	8-11	1-1	1-2	fi	-
Shortlands	B1	Cl	47-75	18-27	1-15	1-10	1-5	fi	-

Luvic Properties: Explanation of symbols; L - Luvic, NL - Non-luvic, EL - Eluvic Properties. Numbers indicate relative dominance of property from occasionally (1) to dominantly(5).

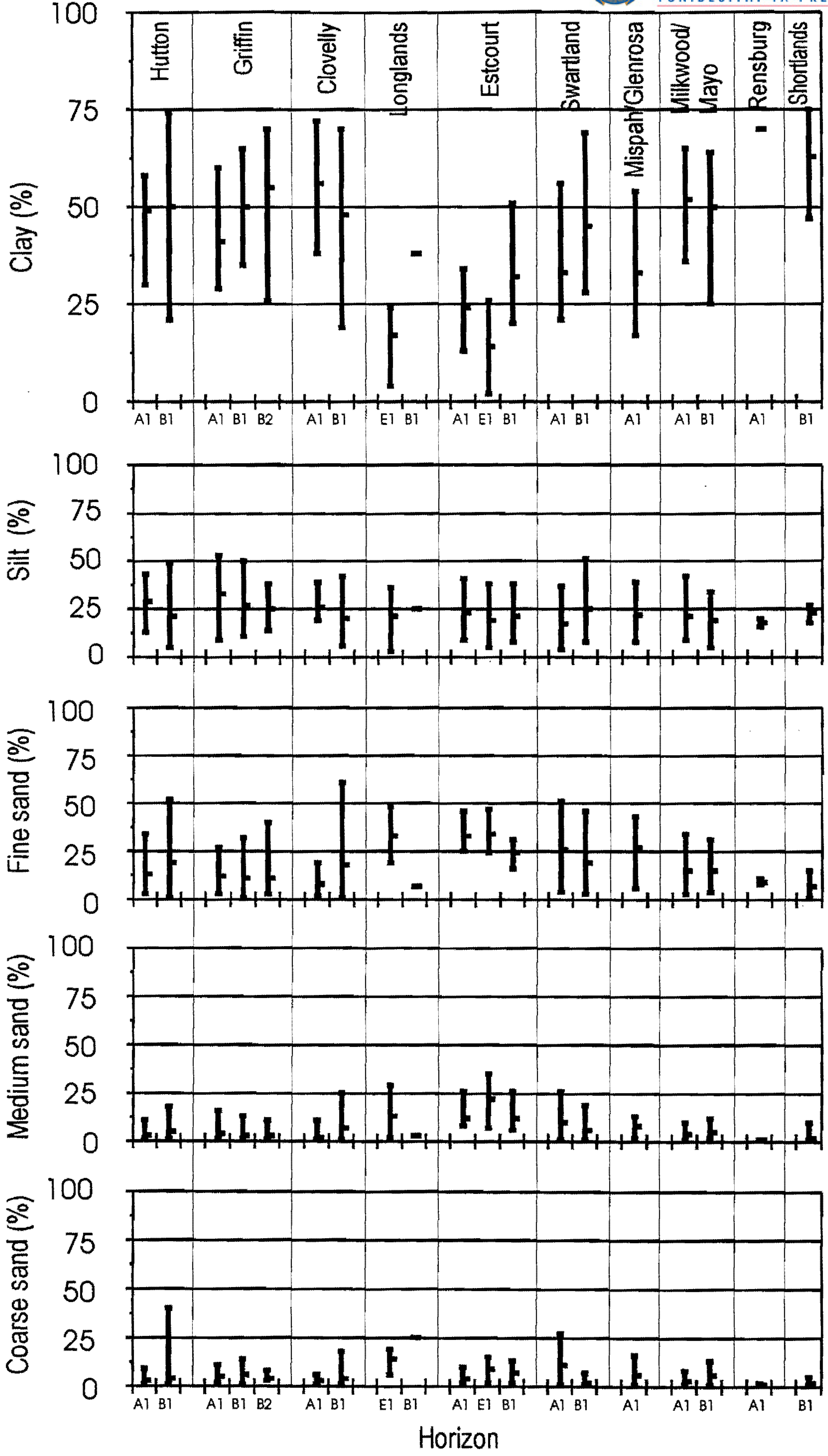

Figure 15.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Pietermaritzburg Formation. Maximum, minimum and mean values are shown for each horizon.

different soil forms over the particle size classes. It shows the clay nature of the red and yellow-brown apedal soils (Hutton Griffin, Clovelly), and of the melanic and vertic soils (Mayo, Rensburg) and red structured soils (Shortlands), and the sandy clay to clay nature of the Swartland and Mispah soils (Table 15.2, Figure 15.2). Maximum values for silt and fine sand values can be relatively high (Figure 15.2). Mean silt values generally are greater than those for fine sand. It is common to note fine gravel size shale chips in many of the soil profiles developed in semi-arid areas. These gravel chips are also reflected here in a small coarse and medium sand component (Table 15.2, Figure 15.2).

A review of the texture graphs (Figures 15.3 to 15.7) indicates that the textures of the majority of profiles are located in the clay class. Within this clay class however, there does appear to be a clustering of profiles with lower sand values (data reported in Table 15.4) and higher sand values (data reported in Table 15.5). These two natural clusters can be observed in the Griffin soils (Figure 15.3), in the B1 horizon of the Mayo soils (Figure 15.6), and in the Mispah soils (Figure 15.6). In the Clovelly soils (Figure 15.5) and in the Swartland soils (Figure 15.7) these clusters appear to merge together. It could be argued that these two clusters could be considered separately. This option has been chosen with data for the higher clay and silt values reported separately in Table 15.4, and for the somewhat lower clay and silt values reported in Table 15.5. In the Mispah and Swartland soils (Figures 15.6, 15.7) there is also a cluster of profiles with textures in the sandy clay loam class. Means and standard deviations of profiles are reported in Table 15.6. Threshold values for the separation of these data are reported in Table 15.3.

Table 15.3 Threshold values for the separation natural textural classes for the soils of the Pietermaritzburg Formation.

Natural Body based on texture	Threshold value	Natural Body represented in profiles of the following soils:	Dominant texture class	Data referenced in:
1 Clay texture, low sand	Total sand <25% (Corresponds to clay percentage >35%)	Hutton Griffin Clovelly Swartland Glenrosa / Mispah Mayo/Milkwood Rensburg Shortlands	Clay Silty clay loam	Table 15. 4
2 Clay texture, higher sand	Total sand between 25 and 50% (Corresponds to clay percentage >35%)	Hutton Griffin Clovelly Longlands Estcourt Swartland Glenrosa/Mispah Mayo/Milkwood	Clay	Table 15.5
3 Sandy clay loam texture	Total sand >50%	Swartland Mispah	Sandy clay loam	Table 15.6

Within the first clay group the Rensburg soils (Vertic A1 horizons, Table 15.4) have the highest clay percentage. The Mayo soils (Melanic A1 horizons) have, as expected, slightly lower clay percentages than the vertic soils. There is little difference between the Hutton, Griffin and Clovelly soils (Table 15.4), while the Mispah and Swartland (B1 horizons) have only slightly lower clay contents. There is thus limited variation over different soil forms within the single lithology.

Within the second clay grouping, the clay and silt percentages values are displaced slightly lower for the Hutton, Griffin, Clovelly, Swartland and Mispah soils (Table 15.5). Increases in the fine sand values are evident. The Longlands and Estcourt soils show interesting, but similar properties (Table 15.5). Mean clay percentages are around 25 percent, while mean silt values are around 35 percent. The clay values are about half the value of the red and yellow-brown apedal soils, and the Mispah soils (Table 15.4 and 15.5). This can be assumed to be a reflection of the presence of the E horizon in these soils. It is also interesting that the clay percentages are lower than those for the Mispah soils. These clay and silt values are similar to those determined for Longlands, Kroonstad and Estcourt soils of the Volkrust Formation. It serves to confirm the important existence of these higher clay content E horizon soils which have not been extensively sampled. These clay and silt contents are about 1.5 to 2 times greater than those for the Longlands soils derived from the sandstone of the Vryheid Formation. The latter soils cover extensive areas of the KwaZulu-Natal interior basins and could be considered as the "expected and typical" Longlands soil. The Longlands and Estcourt soils from the Pietermaritzburg and Volksrust Formations serve to confirm the departure from the sandy Longlands and Estcourt soils (Table 15.5).

Mispah, Glenrosa and Swartland soils also have sandy clay loam texture (Table 15.6). Here silt values tend to be low, with higher values for fine, medium and even coarse sand.

The Hutton, Griffin and Clovelly soils, with high clay contents, have in general non-luvic B1 horizons (Table 15.2, Figure 15.8). The Griffin and Clovelly soils have a significant proportion of the profiles with the clay content in the B1 lower than that of the A1 horizon. The clay increases are as expected for the Longlands and Estcourt soils (Table 15.2) although derived from limited data sets. The clay increases for the Swartland soils, while being the largest within this group of soils, are less than initially expected (Figure 15.8).

Fine sands are generally dominant (Table 15.2, Figures 15.3 and 15.6). The presence of coarse sand (and probably also fine gravel fragments) in Figures 15.3 and 15.5 is indicative of fine shale derived gravel fragments, often with a hard iron coating, common in many of the soils derived from the shale of the Pietermaritzburg Formation.

Table 15.4 Means and standard deviations of five textural classes for soils of the clay and silty clay group of the Pietermaritzburg Formation.

Horizon	Depth	Clay		Silt		Fine Sand		Medium Sand		Coarse Sand		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
	mm	%		%		%		%		%		
Form: Hutton												
A1	378	52.9	4.2	32.4	9.8	8.2	6.0	1.3	0.4	3.6	1.9	7
B1	856	60.1	8.1	27.1	9.6	6.8	5.2	1.5	0.7	3.5	2.2	16
Form: Griffin												
A1	411	46.7	8.1	41.2	10.6	5.2	2.7	1.0	0.0	4.0	2.0	6
B1	638	54.7	7.5	29.7	8.8	7.2	5.2	1.5	1.0	6.3	4.0	13
B2	930	60.8	9.0	26.8	8.5	6.0	2.8	1.0	0.0	4.8	1.9	5
Form: Clovelly												
A1	297	58.6	6.8	26.6	6.2	6.9	4.5	1.1	0.4	3.0	0.9	7
B1	666	56.9	8.2	29.7	7.9	7.5	4.8	1.1	0.3	3.1	1.8	11
Form: Swartland												
A1	240	49.5	5.4	26.5	10.7	16.0	8.5	3.8	1.9	5.8	4.0	4
B1	240	49.5	5.4	26.5	10.7	16.0	8.5	3.8	1.9	5.8	4.0	4
Form: Glenrosa/Mispah												
A1	400	49.0	5.0	33.0	6.0	6.5	0.5	2.0	0.0	3.5	2.5	2
Form: Mayo/Milkwood												
A1	440	55.6	5.8	25.0	6.1	8.9	4.9	2.5	1.0	2.9	1.6	12
B1	666	53.7	8.9	21.0	9.2	7.3	3.3	2.3	0.4	4.0	2.1	6
Form: Rensburg												
A1	425	70.0	0.0	18.0	2.0	9.5	1.5	1.0	0.0	1.5	0.5	2
Form: Shortlands												
B1	937	63.4	9.2	23.4	3.1	7.9	5.3	2.5	3.4	2.3	1.4	8

Table 15.5 Means and standard deviations of five textural classes for soils of the clay and sandy clay group of the Pietermaritzburg Formation.

Horizon	Depth	Clay		Silt		Fine Sand		Medium Sand		Coarse Sand		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
	mm	%		%		%		%		%		
Form: Hutton												
B1	820	47.1	11.3	17.3	8.2	25.5	10.5	5.6	4.8	6.7	10.5	12
Form: Griffin												
A1	370	35.8	7.7	24.6	11.6	21.2	5.8	8.4	4.9	7.6	3.1	5
B1	610	42.4	5.2	20.2	6.4	23.6	4.8	7.2	3.7	4.6	2.1	5
Form: Clovelly												
B1	987	47.6	6.1	14.3	4.7	23.4	6.3	9.3	6.5	4.0	2.1	8
Form: Longlands												
E1	500	24.0	0.0	36.0	0.0	19.0	0.0	2.0	0.0	19.0	0.0	2
B1	1290	37.8	8.6	23.6	5.3	19.5	14.0	7.0	6.5	16.0	8.8	5
Form: Estcourt												
A1	350	26.0	0.0	38.5	2.5	26.0	1.0	8.0	0.0	2.5	0.5	2
E1	450	25.0	1.0	37.5	0.5	25.0	1.0	8.0	1.0	2.5	0.5	2
B1	840	35.0	12.3	24.8	12.8	23.3	4.3	9.3	3.0	6.5	4.2	4
Form: Glenrosa/Mispah												
A1	366	40.3	4.8	26.7	2.6	22.0	1.4	6.7	0.9	2.0	0.8	3
Form: Mayo/Milkwood												
A1	295	46.6	8.2	15.1	4.5	24.6	6.9	6.7	1.8	5.0	1.8	7
B1	650	50.8	7.4	17.0	8.3	20.5	3.5	6.0	0.7	6.8	0.8	4

Table 15.6 Means and standard deviations of five textural classes for soils of the sandy clay loam group of the Pietermaritzburg Formation.

Horizon	Depth mm	Clay % Mean	Clay % SD	Silt % Mean	Silt % SD	Fine Sand % Mean	Fine Sand % SD	Medium Sand % Mean	Medium Sand % SD	Coarse Sand % Mean	Coarse Sand % SD	Sample Size
Form: Swartland												
A1	0-296	20.4	11.3	9.8	4.5	34.8	16.1	15.6	6.3	16.0	20.7	5
B1	296	20.4	11.3	9.8	4.5	34.8	16.1	15.6	6.3	16.0	20.7	5
Form: Glenrosa/Mispah												
A1	168	26.3	5.2	18.4	7.9	35.5	3.5	9.3	3.3	9.1	5.1	8

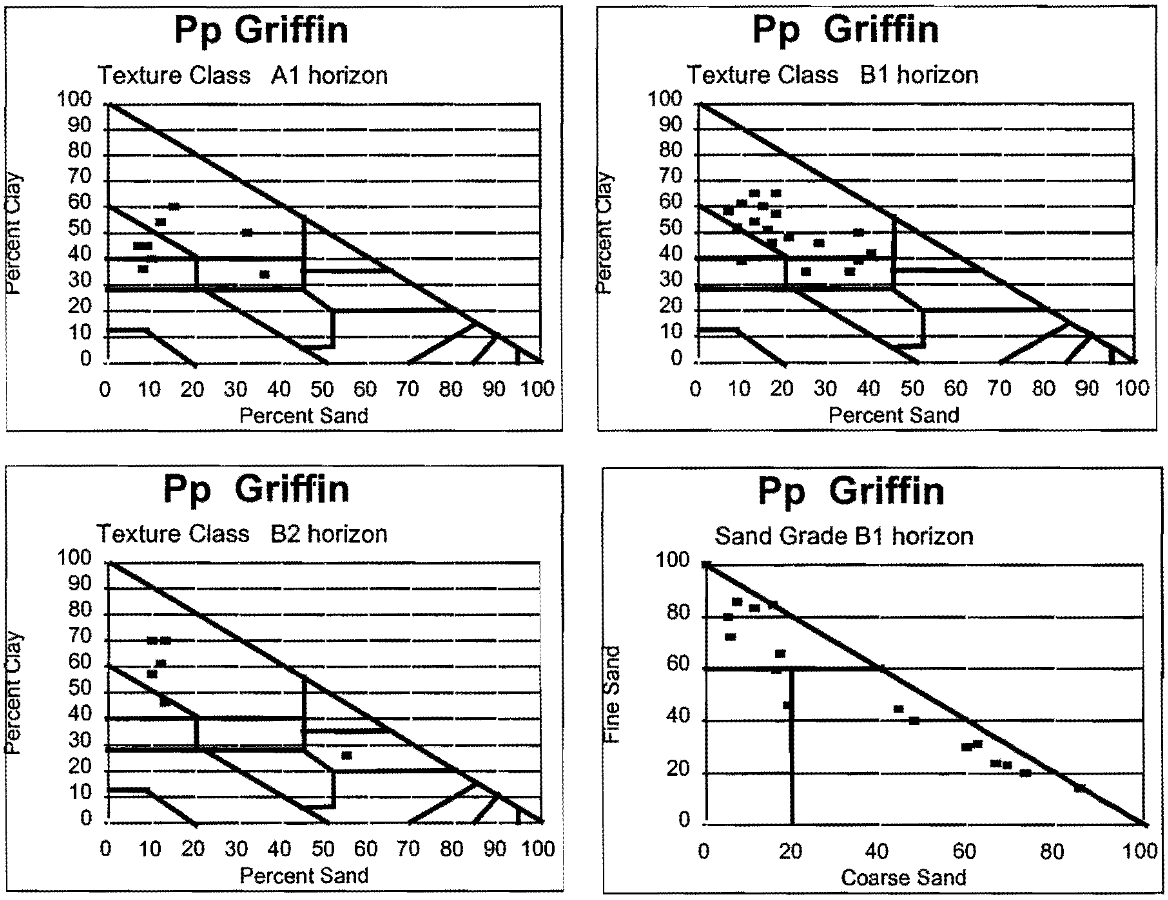

Figure 15.3 Distribution of soil textures, and sand grades, within soils of the Griffin Form.

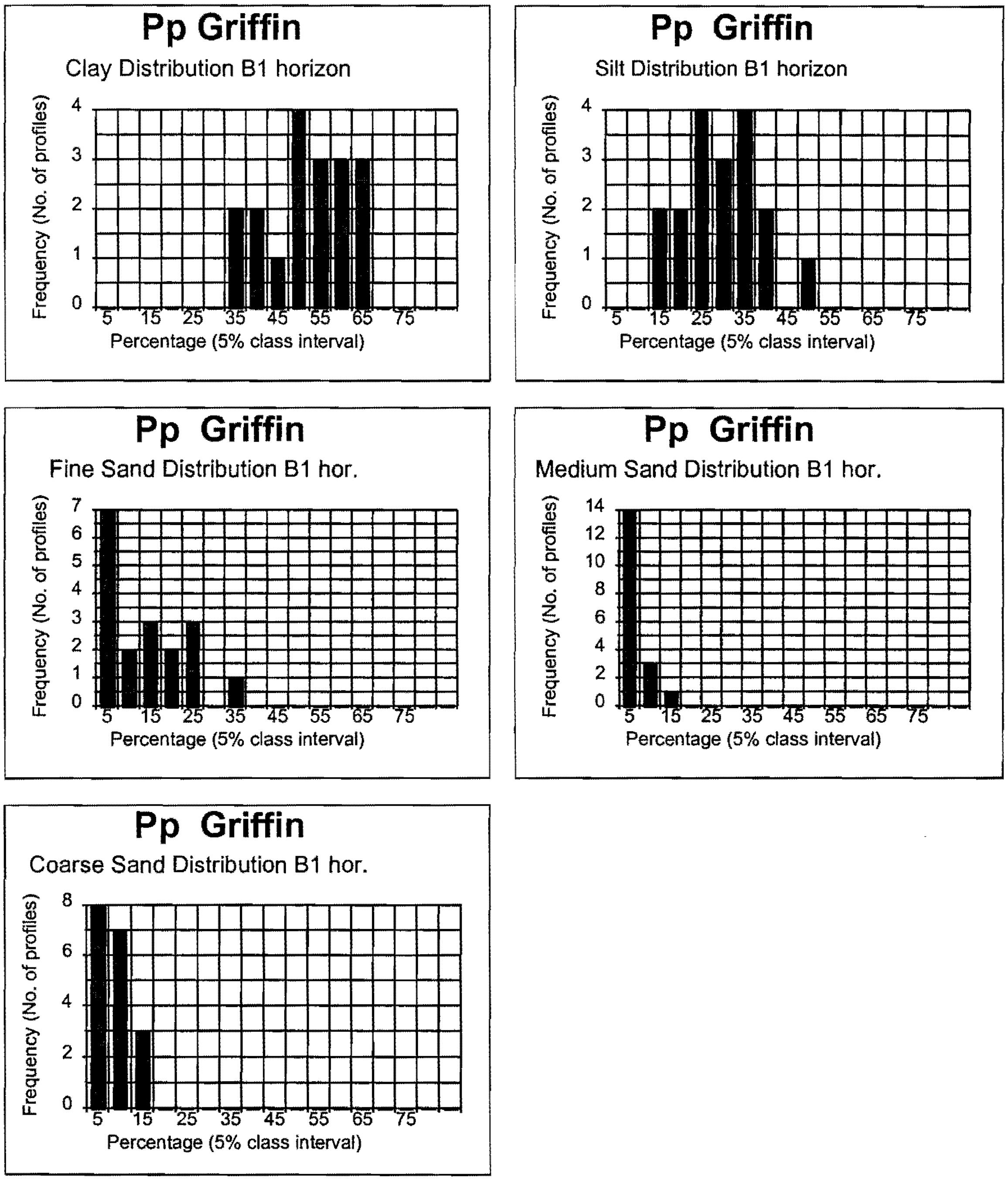

Figure 15.4 Distribution of clay, silt, fine sand, medium sand and coarse sand within soils of the Griffin Form.

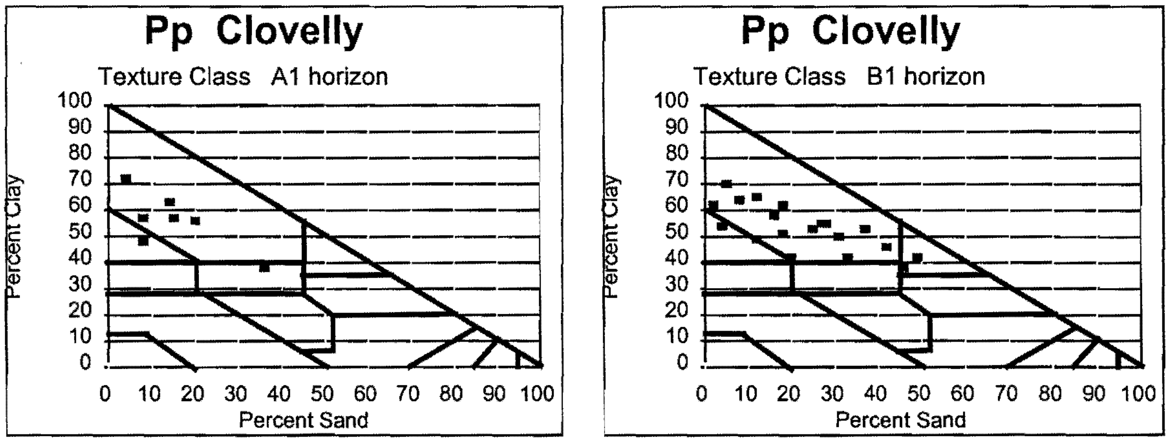

Figure 15.5 Distribution of soil textures within soils of the Clovelly Form.

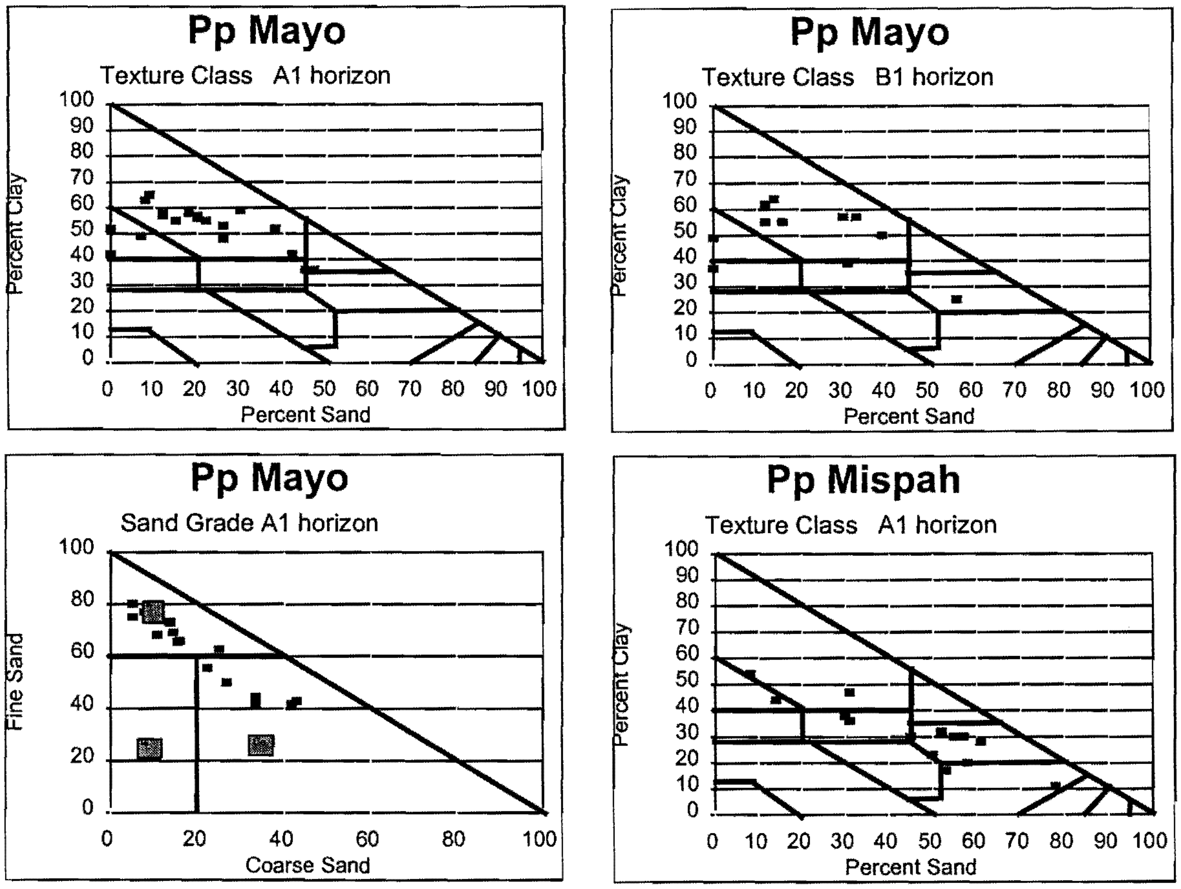

Figure 15.6 Distribution of soil textures, and sand grades, within soils of the Mayo and Mispah Forms.

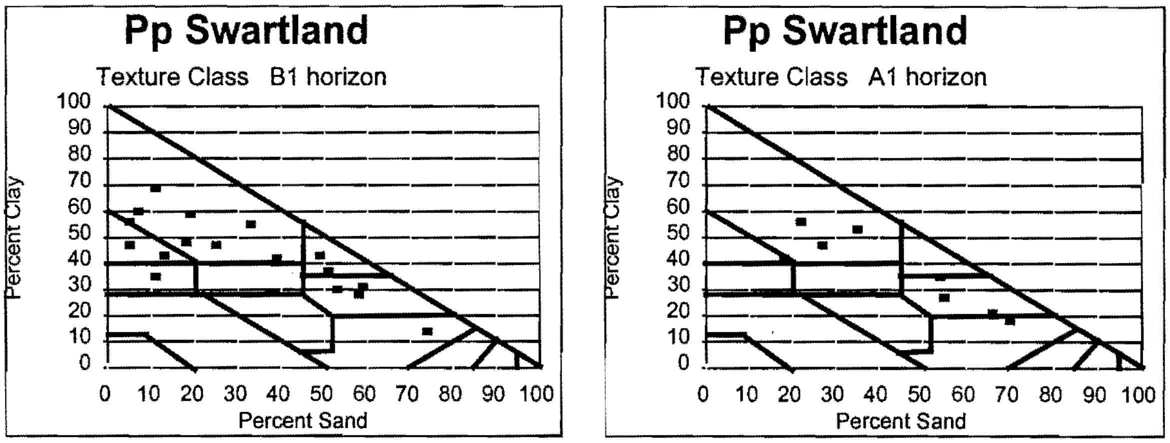

Figure 15.7 Distribution of soil textures within soils of the Swartland Form.

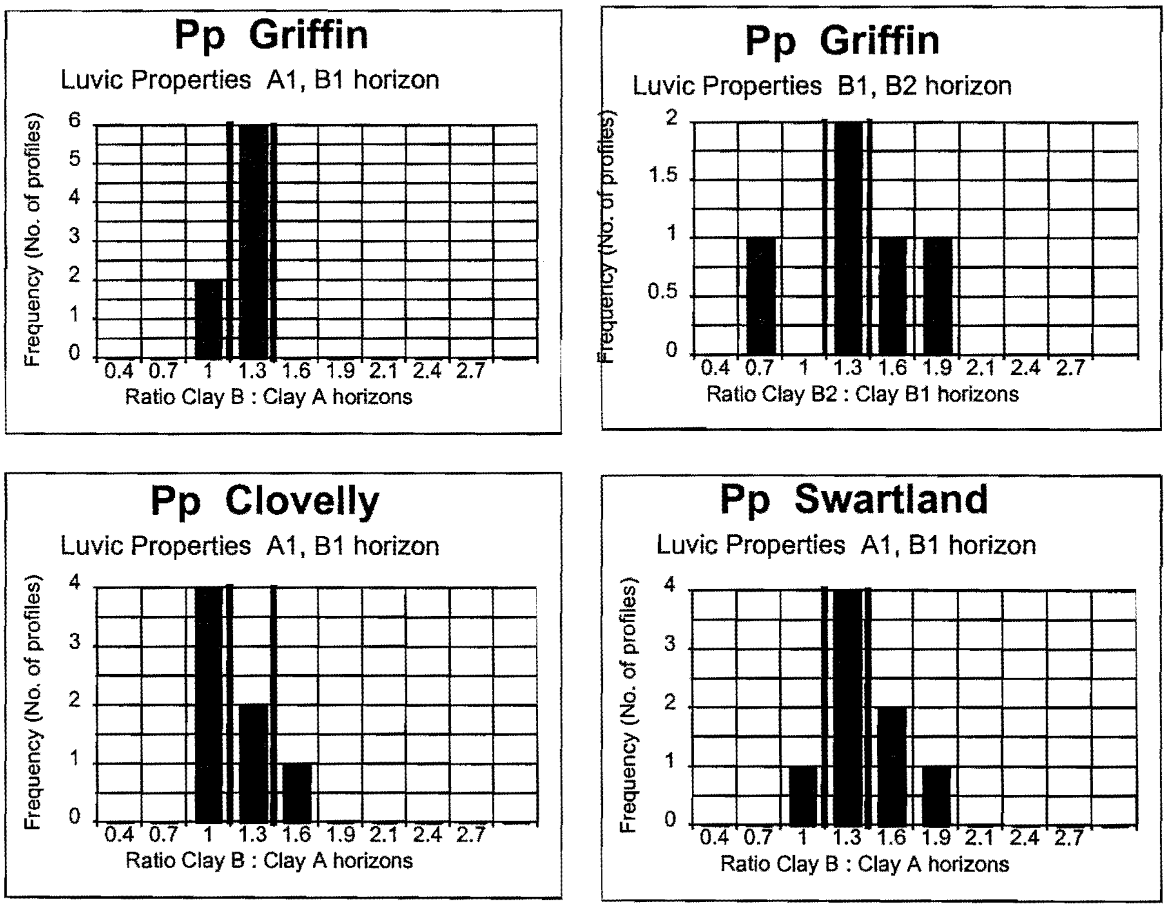

Figure 15.8 Luvic properties within soils Griffin, Clovelly and Swartland Forms.

CHAPTER 16

SOILS OF THE TILLITE OF THE DWYKA FORMATION IN KWAZULU-NATAL AND MPUMALANGA

Location and Extent

The Dwyka Formation covers extensive areas of north eastern KwaZulu-Natal stretching from the upper reaches of the Mkuze River and covering extensive areas of the interior valley basins of the Mfolozi and Buffalo River valleys (Geological Survey, 1984)(Figure 16.1). South of the Tugela River the Dwyka Formation is located in two north-south stretching belts (Figure 16.1). For convenience of description these belts may be considered as lying on either side of the reported axis of the Natal monocline (King, 1940). The western boundary of this interior belt is determined by Ecca Group rocks of the Pietermaritzburg Formation. To the east lies the sandstones of the Natal Group, and in some instances even the basement granites. The boundaries of the tillite are commonly determined by the numerous faults present within the monoclinal structure of the coastal hinterland (Geological Survey, 1988b; Geological Survey, 1988c; Geological Survey, 1988d). This belt of tillite occupies altitudes of between 700 - 900 metres. The eastern belt lies within the coastal plain at altitudes of between 50 and 300 metres. To the west lies sandstone of the Natal Group. The eastern boundary, often determined by faulting, comprises of shales, sandstones or red sands of the Pietermaritzburg, Vryheid and Berea Formations. These changes in geology have important local influences on the soils, their classification and properties. The tillite of the Dwyka Formation is also located in northern fringes of the Mpumalanga Highveld (Geological Survey, 1984). Soil profiles sampled from this area appear to have properties somewhat different to those of the main KwaZulu-Natal zone. The tillite occupies an area of approximately 834 500 hectares.

Geology and Geomorphology (Geology Symbol Abbreviation **C-Pd**)

The Dwyka Formation is the product of glaciation and is reported by Truswell (1977) as occurring throughout the former Gondwanaland continent. These glaciers were competent to carry fragments of any size, and much glacial sediment has been dumped as ill-sorted till, that has consolidated to form tillite. Since similar rocks may form as a result of landslides and submarine mudflows, the term diamictite is now commonly used in a non-genetic way for such ill-sorted sediment. Much of the Dwyka material is ill-sorted diamictite, a greenish or blueish rock with a dense argillaceous matrix in which coarse fragments of various sizes are set. Other materials in the overall unit include sandstones, conglomerates, argillaceous rocks, and some shales (Truswell, 1977). The Dwyka diamictite is locally up to 1 000 m thick in the south of the Karoo Basin. This thickness decreases rapidly northwards and in Mpumalanga the unit is preserved only in thin, erratically developed pockets.

The Dwyka Formation is described variously as comprising tillite, minor shale, dropstone-bearing shale, varved shale and sandstone (Geological Survey, 1981b; Geological Survey, 1988a; Geological Survey, 1988b; Geological Survey, 1988c).

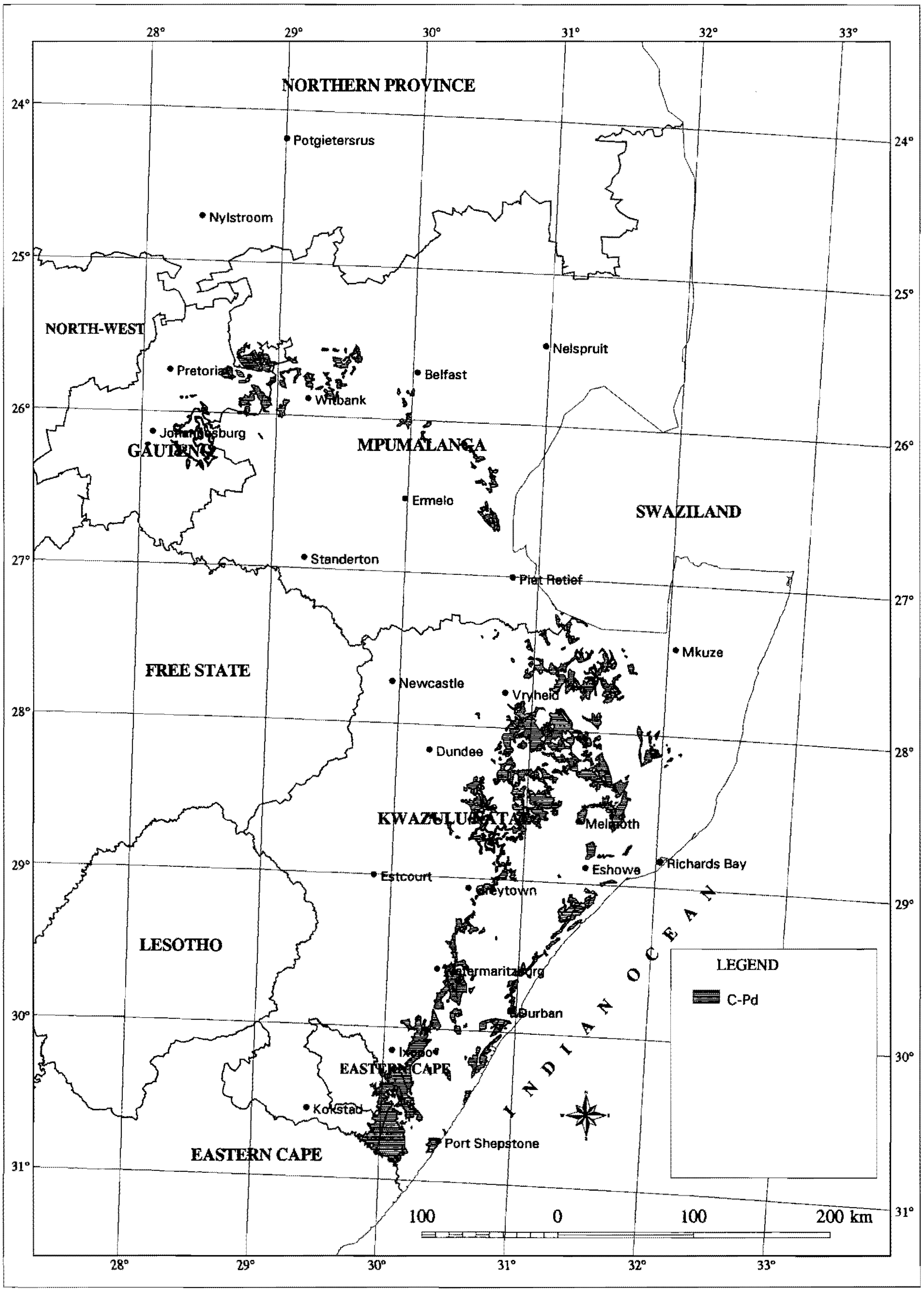

Figure 16.1. Location of the Dwyka Formation in KwaZulu-Natal and Mpumalanga (after Geological Survey, 1984).

Physiography and Drainage Features

The Dwyka Formation is exposed in a number of terrain morphological classes. In the KwaZulu-Natal Interior Basin undulating hills and lowlands are encountered with a relatively high proportion of slopes less than 5 percent (Kruger, 1983). These terrain classes commonly support plinthic and lithosolic soil patterns. Undulating hills and valleys of moderate relief are encountered in the Mistbelt Zone, commonly with red and yellow apedal soils located on these surfaces. The Dwyka Formation is extensively exposed in many of the river valleys. In the Mkuze, Mfolozi and Mkomazi River Valleys the terrain could be described as low mountains (Kruger, 1983), where lithosolic and duplex soil patterns are commonly present. Along the Coast Belt the Dwyka Formation is exposed, often with Basement Granites, in highly dissected hills and valleys. The Formation is also exposed on the northern fringe of the Highveld Plain where gentle to moderate slopes are present.

Vegetation

The vegetation over the greater part of the zones where tillite is exposed is described by Low and Rebelo (1996) as Coast Hinterland Bushveld. Natal Central Bushveld is present in the northern KwaZulu-Natal Interior, while Short Mistbelt Grassland occurs in the Mistbelt.

Soils

Six major soil patterns are present on the tillite of the Dwyka Formation (Table 16.1). These include a red and yellow apedal dystrophic soil pattern, a pattern comprising plinthic soils with red and yellow apedal soils, and a plinthic soil pattern. The remaining soil patterns comprise duplex soils and plinthic soils, and lithosols with and without the presence of lime.

The red and yellow dystrophic soil pattern is located on moist, undulating tablelands (Table 16.1). These tablelands are remnants of old landsurfaces and show deep weathering of the underlying material to give rise to a soft, friable to crumbly saprolite. Evidence of the original structure of the tillite material is preserved as sand and stone erratics within this saprolite material. These erratics, which have also undergone weathering, may range in size from the very fine whitish sand size particles to larger remnants of pebble, stone and boulder sizes. The data source (Land Type Survey Staff, 1986b; 1987a; 1988c; 1994a; 1994b; 1997b) gives dystrophic Hutton soils as dominant within this pattern (Table 16.1). However, Griffin and Clovelly soils are present as important components. Many Griffin profiles developed on tillite of the Dwyka Formation could be considered as modal benchmark sites for those soils exhibiting the sequence of horizons comprising of dark brown topsoils, over a bright yellow-brown horizon, over a red horizon. Topsoils commonly have elevated levels of organic carbon (>2%). It is significant that many of the Hutton profiles also show the yellow to red horizon sequence within the soil colours. Colours could range from yellowish red to dark reddish brown within the 5YR and 2.5YR hues. Similarly the Clovelly soils exhibit reddening of the third horizon, but within the yellow-brown colour ranges of 7.5YR and 10YR hues. The clear association of these characteristic highly weathered Hutton, Griffin and Clovelly profiles with the tillite can be readily established. Weathered remnants of stone sized erratics can be traced from the saprolite through the red apedal B horizon in many profiles. The uniform morphology and texture could be used to infer the associations between the red horizon and the surface horizons.

Table 16.1 Dominant soils and selected climatic information for soil patterns occurring on tillite of the Dwyka Formation.

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rain fall mm	Evaporation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Red and Yellow Apedal Soils										
Hutton	Hu17 Hu18	27	Glenrosa	Gs16 Gs17	9	Ave	954	1493	2593	0.64
	Hu16 Hu27 Hu28	5		Gs19		Std	179	210	200	0.16
Griffin	Gf12 Gf13	11	Mispah	Ms10	4	Max	1495	2141	3619	-
	Gf11	3	Katspruit	Ka10	3	Min	750	1201	1662	0.38
Clovelly	Cv17 Cv18	7								
	Cv16	4								
	Cv26 Cv27	1								
Total Area: 86 640 Ha			Means of 19 Land Types							
Broad Soil Pattern: Plinthic soils with Red and Yellow Apedal Soils										
Avalon	Av26	18	Clovelly	Cv26 Cv27	8	Ave	784	1544	2901	0.51
	Av27	2	Hutton	Hu17 Hu27	5	Std	24	6	81	0.01
Longlands	Lo12 Lo21	4	Griffin	Gf12 Gf22	3	Max	805	1552	3020	0.52
Westleigh	We22 We32	9	Oakleaf	Oa36	5	Min	750	1537	2824	0.49
Glenrosa	Gs16 Gs17 Gs19	19								
Mispah	Ms10	8								
Total Area: 5 480 Ha			Means of 3 Land Types							
Broad Soil Pattern: Plinthic Soils										
Longlands	Lo12 Lo22	9	Estcourt	Es33 Es34	5	Ave	698	1561	2959	0.45
	Lo11 Lo21	5		Es30 Es40		Std	58	36	313	0.04
Wasbank	Wa12 Wa22 Wa11	3	Valsrivier	Va30 Va40	3	Max	768	1620	3486	0.50
	Wa21		Sterkspruit	Ss23 Ss24	3	Min	606	1521	2678	0.39
Westleigh	We12 We22	4								
	We11 We21									
Avalon	Av36	4								
Glenrosa	Gs16 Gs17 Gs14	20								
Mispah	Ms10 Ms11	12								
Total Area: 28 850 Ha			Means of 5 Land Types							
Broad Soil Pattern: Duplex Soils and Plinthic Soils										
Swartland	Sw30 Sw31	10	Avalon	Av26	4	Ave	686	1551	2969	0.44
	Sw40 Sw41	3	Cartref	Cf12 Cf21	5	Std	42	108	372	0.05
Estcourt	Es34 Es36	5				Max	758	1786	3886	0.54
Sterkspruit	Ss24 Ss26	5				Min	650	1385	2610	0.37
Valsrivier	Va31 Va41	4								
Longlands	Lo12 Lo22	4								
	Lo11 Lo21	2								
Westleigh	We12 We22	6								
Glenrosa	Gs16 Gs17 Gs14	17								
Mispah	Ms10	7								
Total Area: 37 960 Ha			Means of 9 Land Types							

Table 16.1 continued. Dominant soils and selected climatic information for soil patterns occurring on tillite of the Dwyka Formation.

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rain fall mm	Evaporation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Lithosols without the presence of lime										
Glenrosa Mispah Cartref	Gs16 Gs17 Gs19 Ms10 Cf11 Cf12	43 10 9	Swartland Oakleaf	Sw31 Sw30 Oa36 (Soft B horizons)	5 4	Ave Std Max Min	827 132 1100 570	1543 217 2768 1229	3212 483 4230 2102	0.53 0.10 0.82 0.27
Total Area: 374 890 Ha			Means of 75 Land Types							
Broad Soil Pattern: Lithosols with the presence of lime										
Glenrosa Mispah Rockland Swartland Valsrivier	Gs16 Gs17 Ms10 Rock Sw31 Sw41 Va31 Va41	31 17 8 6 6	Swartland Valsrivier Sterkspruit	Sw31 Sw41 Va31 Va41 Ss24 Ss26	6 6 3	Ave Std Max Min	683 60 940 575	1640 91 1762 1342	3339 492 4081 2102	0.42 0.05 0.55 0.35
Total Area: 300 680 Ha			Means of 44 Land Types							

Subtle, but observable differences between the soils of the tillite of the Dwyka Formation and those of the Natal Group, and the Vryheid Formation are evident in the profile morphology and in the geomorphology. These differences closely follow the geological boundary and can be traced over all the soil patterns. The differences between the tillite of the Dwyka Formation and the shale of the Pietermaritzburg Formation are less evident in the highly weathered environments. However, soil differences are more evident in the subhumid environments with difference in dominant soil forms and properties. Differences below the soil solum are also noticeable with the tillite commonly giving rise to a crumbly, moderately weathered aggregate, which contrasts to the commonly hard horizontal shale plates.

Plinthic soils in association with red and yellow apedal soils occur on the fringes of the subhumid KwaZulu-Natal Interior Basins. This soil pattern occupies a relatively small area (Table 16.1). The higher effective rainfall could account for the formation of red and yellow soils in an environment where otherwise plinthic soils would be expected.

The plinthic soil pattern is located in the subhumid zone of the KwaZulu-Natal Interior Basins (Table 16.1). Plinthic soils with an E horizon (Longlands, Wasbank and Westleigh) are dominant, while the Avalon soils comprise on average only 4 percent of the plinthic soil unit. The Glenrosa and Mispah soils with characteristic profile morphology and properties are common on tillite in many of the KwaZulu-Natal Interior Basins. Duplex soils of the Estcourt, Valsrivier and Swartland Forms are subdominant to the plinthic soils and generally occupy the bottomland positions.

The duplex soil pattern comprises both calcareous and non-calcareous soils of the Swartland, Estcourt, Sterkspriut and Valsrivier Forms (Table 16.1). Glenrosa and Mispah soils are again dominant within the pattern, while Longlands, Westleigh and Cartref soils are also present. The duplex soils occupy a greater proportion of the upland and bottomland sites. It is probable that the shallower Swartland, Sterkspruit and Estcourt soils are derived directly from tillite. The deeper Valsrivier and Sterkspruit are probably derived from tillite colluvium, or from colluvium from adjacent soil zones. The properties of these soils are documented for implementation in land use applications. The formation of duplex as opposed to plinthic soils could to some extent be explained by their occurrence in a zone with a lower rainfall and greater evaporation and heat unit values (Table 16.1).

The lithosolic soil patterns are dominated by Glenrosa and Mispah soils (Table 16.1). In the pattern without the presence of lime, the higher rainfall regime is reflected in the E horizons of the Cartref soils, while the presence of Oakleaf soils (in upland topographic positions) is a reflection of a longer and more intense weathering regime. These Oakleaf soils may well be classified to the family of soils with a soft B1 horizon within the Glenrosa Form (Soil Classification Working Group, 1991). The rainfall at some of these localities with lithosolic soils is comparable to those of the red and yellow apedal soil patterns. It must be inferred that these are younger soil landscapes.

The lithosolic soil pattern with the presence of lime is dominated by Glenrosa and Mispah soils, with a greater proportion of rock. Lime is generally present in the bottomlands of the Swartland, Valsrivier and Sterkspruit soils (Table 16.1).

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles for Hutton, Griffin, Clovelly, Avalon, Longlands, Estcourt, Swartland, Inhoek, Glenrosa and Mispah Forms were extracted from the database. The data was plotted on textural triangle graphs (Figures 16.4 to 16.10) to establish the range of variation and any possible natural soil bodies. It was evident that the range stretches over a number of texture classes from sandy loam to clay. For the apedal soils (Griffin, Figure 16.4; Hutton, Figure 16.5) the cluster of profile points spans the whole range with no clear natural breaks. Within the profiles of Avalon (Figure 16.5), Glenrosa (Figure 16.6), Longlands (Figure 16.7), and Swartland (Figure 16.9) soils clearer evidence of clustering is apparent. It was also apparent that the textural properties of profiles derived from the tillite of the Interior Basins of KwaZulu-Natal differed from those on the northern fringes of the Mpumalanga Highveld. It was evident that a number of soil bodies could be drawn out from the dataset. Consequently the data were divided into three natural soil bodies as evident in the textural triangle graphs and their threshold values (Table 16.2) determined. These three textural groups are reflected in subsequent tables and figures. The first two textural groups are well represented by profiles from the dataset. However, the loam textural class is represented by only a limited number of profiles. The ranges in textural properties (maximum and minimum values) for five particle size classes, dominant sand grade, and information on the luvic properties are presented for the three natural soil bodies (Tables 16.3, 16.4 and 16.5). These ranges are also presented graphically (Figures 16.2 and16.3). The figures allow for overview comparisons between different soil forms over the particle size classes.

(Continued on page 222)

Table 16.2 Threshold values for the separation natural textural classes for the soils of the Dwyka Formation.

Natural Body based on texture	Threshold value	Natural Body as represented in profiles of the following soils:	Dominant texture class	Data referenced in:
1	Clay percentage >35% (Corresponds to Total sand<45%)	Hutton Griffin Clovelly Longlands Swartland Glenrosa / Mispah Inhoek	Clay Clay loam Sandy clay	Table 16.3
2	Clay percentage <35% (Corresponds to Total sand>45%)	Hutton Griffin Clovelly Avalon Longlands Estcourt Swartland Glenrosa/Mispah	Sandy loam Sandy clay loam	Table 16.4
3	Clay <35% Silt <30%	Longlands Glenrosa/Mispah	Loam	Table 16.5

Table 16.3. Textural properties of soils of the Dwyka Formation with clay loam to clay textural classes as derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1 B1 B2	Cl SaCl-ClLm-Cl ClLm-Cl	38-68 36-81 27-79	8-41 7-37 7-33	3-30 4-35 1-28	1-6 1-10 1-9	1-12 1-10 2-10	fi,me,co fi,me,co fi,co	NL - -
Griffin	A1 B1 B2	ClLm-Cl SaCl-ClLm-Cl Cl-ClLm	36-59 39-66 39-66	11-34 8-32 8-32	11-30 9-29 9-29	3-11 2-16 2-16	1-3 1-7 1-7	fi,me fi,me fi,me	NL4,L1 NL5 -
Clovelly	A1 B1 B2	Cl Cl-SaCl Cl	41-50 36-56 41-45	12-20 3-17 15-18	22-31 21-39 25-38	6-10 5-23 5-9	1-3 1-4 1-3	fi,me,co fi,me.cof i,co	NL5 - -
Longlands	A1 E1 B1	SaLm-SaClLm LmSa-SaLm-Lm Cl	16-29 12-39 44-59	32-35 29-39 21-26	21-34 19-39 11-15	7-8 5-7 2-3	5-7 5-5 1-4	fi,me,co fi,me,co fi,me,co	EL L -
Swartland	A1 B1	Cl ClLm-Cl	49-49 38-72	25-28 7-32	13-15 8-20	4-5 1-7	2-3 1-5	fi,me,co fi,me,co	L3,NL2 -
Glenrosa	A1 B1	Cl Cl	45-45 45-47	24-24 13-25	25-25 23-28	2-2 1-5	3-3 1-4	fi,me fi,me	- -
Inhoek	A1 B1	ClLm-Cl Cl	30-54 41-58	8-31 7-30	6-18 6-19	1-6 1-4	1-3 1-2	- -	- -

Luvic Properties: Explanation of symbols; L - Luvic, NL - Non-luvic, EL - Eluvic Properties. Numbers indicate relative dominance of property from occasionally (1) to dominantly(5).

Table 16.4 Textural properties of soils of the Dwyka Formation with sandy loam to sandy clay loam textural classes as derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1	SaLm-SaClLm	12-27	4-33	32-52	10-26	4-17	fi,me,co	L5
	B1	SaLm-SaClLm	14-34	3-26	26-47	3-46	1-26	fi,me,co	-
Griffin	A1	LmSa-SaClLm	9-24	6-20	32-59	7-38	3-14	fi,me,co	L5
	B1	SaLm-SaClLm	10-25	5-23	29-61	6-20	3-30	fi,me,co	L3,NL2
	B2	SaLm-SaClLm	10-25	5-23	29-61	6-20	3-30	fi,me,co	-
Clovelly	A1	LmSa-SaClLm	7-25	6-22	29-58	9-33	2-16	fi,me,co	L3,NL2
	B1	SaLm-SaClLm	8-32	2-22	27-56	8-30	6-30	fi,me,co	L3,NL2
	B2	SaLm	17-20	12-20	29-41	12-18	9-21	fi,me,co	-
Avalon	A1	LmSa-SaClLm	7-31	3-46	12-58	4-36	1-15	fi,me,co	L5
	B1	SaLm-SaClLm-SaCl	12-41	2-54	13-55	2-40	2-26	fi,me,co	NL3,L2
	B2	SaLm-SaClLm	15-35	9-19	35-52	6-19	3-15	fi,me,co	-
Longlands	A1	LmSa-SaLm	6-18	6-28	36-66	9-34	4-16	fi,me,co	EL3,NL1,L1
	E1	LmSa-SaLm	8-20	2-29	32-78	5-37	5-18	fi,me,co	NL2,L3
	B1	SaLm-SaClLm	12-32	7-28	22-46	6-24	5-18	fi,me,co	-
Estcourt	A1	LmSa-SaClLm	6-25	2-24	19-62	6-29	2-26	fi,me,co	EL3,NL2
	E1	LmSa-SaClLm	2-14	6-17	38-53	12-29	6-21	fi,me,co	L5
	B1	SaLm-SaCl	12-37	4-24	33-46	8-24	2-15	fi,me,co	-
Swartland	A1	SaLm-SaClLm	11-37	4-15	26-54	5-17	1-12	fi,me,co	L5
	B2	SaClLm-SaCl	22-43	7-20	26-47	6-18	1-11	fi,me,co	-
Glenrosa	A1	LmSa-SaLm-SaCl	10-39	4-25	27-72	3-26	1-26	fi,me,co	L4,NL1
	B1	SaLm-SaCl	13-39	11-27	25-63	4-20	1-15	fi,me,co	-

Luvic Properties: Explanation of symbols; L - Luvic, NL - Non-luvic, EL - Eluvic Properties. Numbers indicate relative dominance of property from occasionally (1) to dominantly(5).

Table 16.5. Textural properties of soils of the Dwyka Formation with loam texture class as derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Longlands	A1	Lm	13-29	31-35	21-37	7-13	4-7	fi,me	-
	E1	Lm	12-23	36-45	23-39	7-8	3-8	fi,me	-
	B1	Lm	25-25	41-41	26-26	4-4	4-4	fi,me	-
Glenrosa	A1	Lm	15-20	33-37	12-33	7-12	2-50	fi,me	-

Luvic Properties: Explanation of symbols; L - Luvic, NL - Non-luvic, EL - Eluvic Properties. Numbers indicate relative dominance of property from occasionally (1) to dominantly(5).

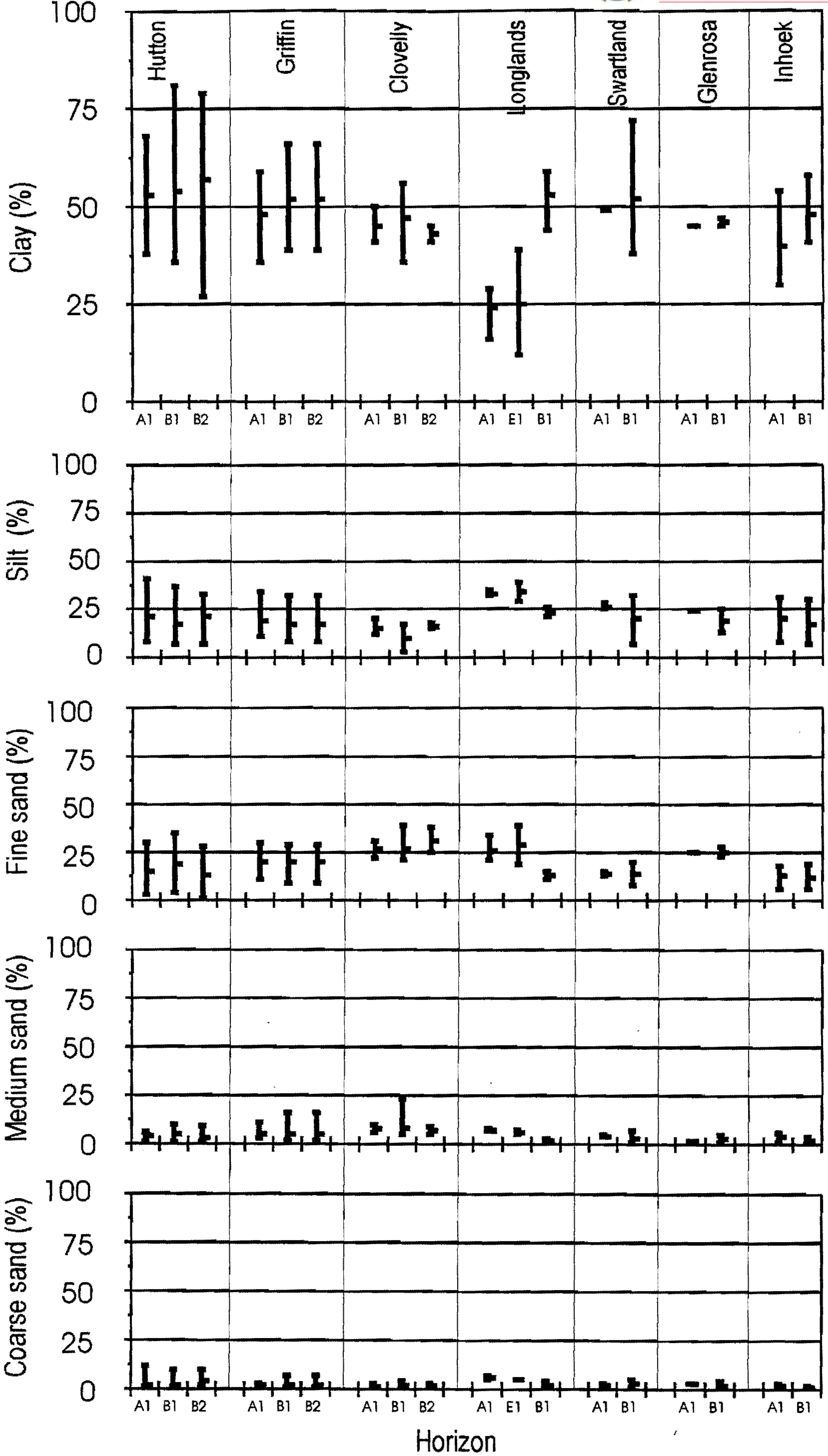

Figure 16.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Dwyka Formation with a sandy clay to clay texture. Maximum, minimum and mean values are shown for each horizon.

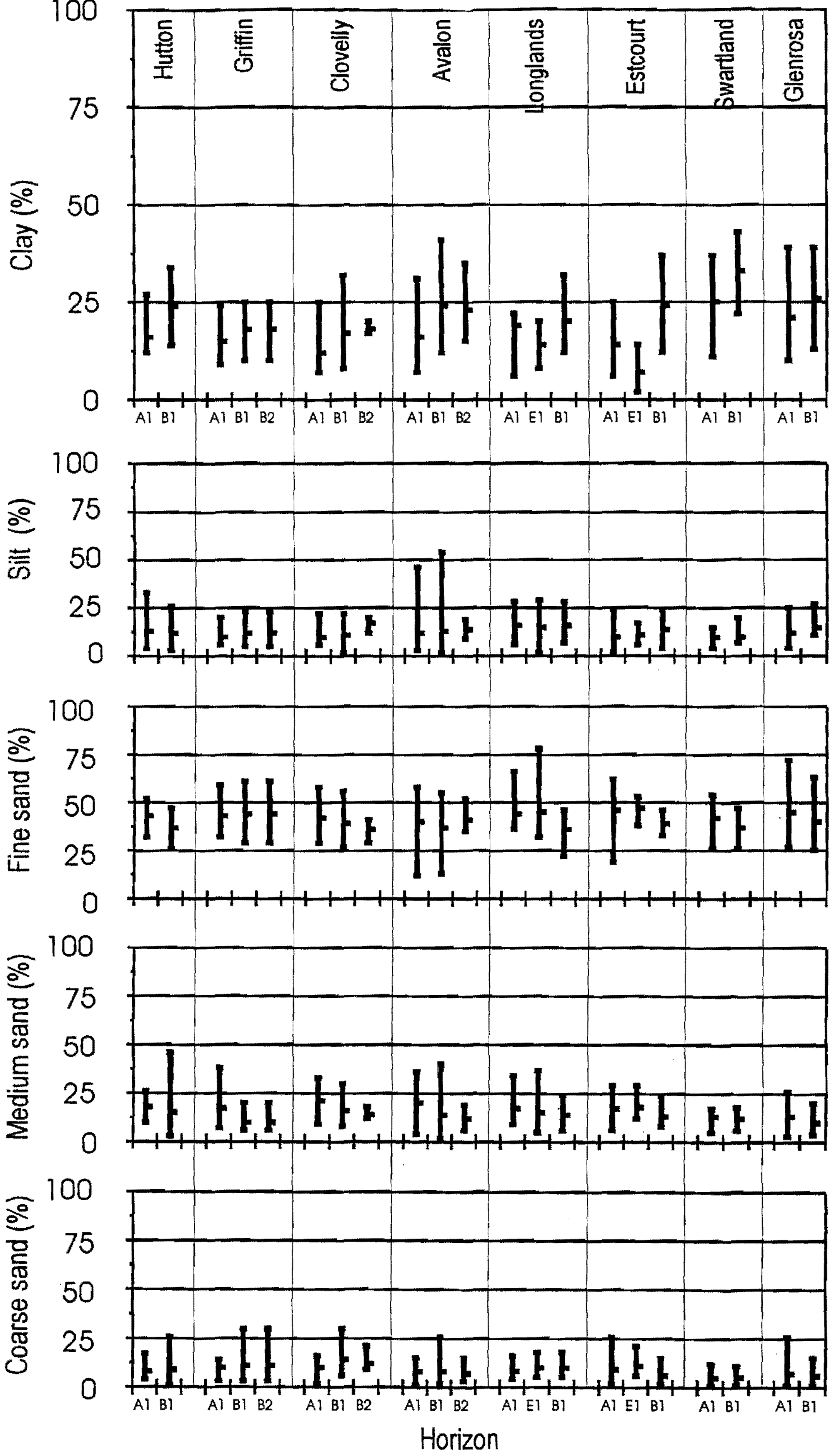

Figure 16.3 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Dwyka Formation with a sandy loam to sandy clay loam texture. Maximum, minimum and mean values are shown for each horizon.

Table 16.6 Means and standard deviations of five particle size classes for soils of the tillite of the Dwyka Formation with a clay loam to clay textural class.

Horizon	Depth	Clay		Silt		Fine Sand		Medium Sand		Coarse Sand		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
	mm	%		%		%		%		%		
Form: Hutton												
A1	0-443	53.8	8.6	21.1	9.4	15.0	6.1	4.0	1.4	2.5	2.9	13
B1	822	54.9	11.1	17.1	7.6	19.0	8.9	5.0	2.7	2.7	2.4	29
B2	894	29.0	57.3	29.0	21.8	29.0	13.3	29.0	3.5	29.0	4.8	4
Form: Griffin												
A1	401	48.7	7.4	19.6	7.0	20.2	7.8	5.6	2.6	2.0	0.7	9
B1	715	52.6	7.1	17.4	6.8	20.4	7.2	5.5	3.5	2.1	1.4	16
B2	715	52.6	7.1	17.4	6.8	20.4	7.2	5.5	3.5	2.1	1.4	16
Form: Clovelly												
A1	366	45.7	3.7	15.0	3.6	27.0	3.7	8.0	1.6	1.7	0.9	3
B1	860	47.7	6.6	10.5	3.6	28.7	5.8	8.4	5.1	2.2	0.9	10
B2	1200	43.0	2.0	16.5	1.5	31.5	6.5	7.0	2.0	2.0	1.0	2
Form: Longlands												
A1	400	24.3	5.9	33.0	1.4	26.0	5.7	7.3	0.5	6.0	0.8	3
E1	450	25.5	13.5	34.0	5.0	29.0	10.0	6.0	1.0	5.0	0.0	2
B1	1201	53.8	5.8	23.7	2.0	13.7	1.9	2.5	0.5	2.7	1.3	4
Form: Swartland												
A1	300	49.0	0.0	26.5	1.5	14.0	1.0	4.5	0.5	2.5	0.5	2
B1	809	52.8	10.7	20.4	8.7	14.0	4.6	3.9	1.7	3.0	1.6	11
Form: Glenrosa												
A1	200	45.0	0.0	24.0	0.0	25.0	0.0	2.0	0.0	3.0	0.0	1
B1	755	46.0	1.0	19.0	4.3	25.3	2.0	3.7	1.9	2.7	1.3	4
Form: Inhoek												
A1	446	40.2	8.3	20.0	8.8	13.3	5.3	4.3	2.4	2.0	0.8	6
B1	642	48.2	5.6	17.0	9.9	12.5	6.5	2.5	1.5	1.5	0.5	5

Table 16.7 Means and standard deviations of five particle size classes for soils of the tillite of the Dwyka Formation with a sandy loam to sandy clay loam textural class.

Horizon	Depth	Clay		Silt		Fine Sand		Medium Sand		Coarse Sand		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
	mm	%		%		%		%		%		
Form: Hutton												
A1	343	16.2	5.6	13.1	7.8	43.2	6.2	18.9	5.3	8.1	3.7	9
B1	819	24.6	5.5	12.4	7.1	37.2	6.3	15.7	9.2	9.0	6.8	20
Form: Griffin												
A1	346	15.5	5.4	10.6	4.3	43.8	8.4	17.4	9.5	10.5	4.2	8
B1	816	18.9	5.0	12.2	5.0	44.1	9.7	10.9	4.4	11.6	8.5	9
B2	816	18.9	5.0	12.2	5.0	44.1	9.7	10.9	4.4	11.6	8.5	9
Form: Clovelly												
A1	277	12.8	5.0	10.3	4.1	42.8	6.5	21.8	6.5	10.6	3.1	21
B1	754	17.5	7.0	11.3	5.1	39.0	8.2	16.8	6.2	14.2	6.7	27
B2	1180	18.5	1.1	17.3	3.1	36.5	4.6	14.0	2.5	12.5	4.9	4
Form: Avalon												
A1	316	16.9	6.1	12.1	10.9	40.7	11.1	20.3	9.1	8.9	4.1	15
B1	686	24.5	8.1	13.1	10.1	40.7	11.1	20.3	9.1	8.9	4.1	15
B2	1381	23.6	7.8	14.7	3.6	41.0	5.7	12.8	4.7	7.5	4.2	7
Form: Longlands												
A1	270	19.6	26.4	16.1	7.4	44.4	8.0	17.1	6.3	8.4	3.6	14
E1	584	14.2	4.5	15.6	9.1	45.9	13.3	15.8	7.9	10.3	4.3	20
B1	972	20.7	6.8	16.6	5.7	36.0	7.0	14.2	5.8	10.8	4.7	9
Form: Estcourt												
A1	335	14.2	5.4	10.7	5.3	46.5	11.9	17.9	6.5	9.0	6.9	13
E1	482	7.6	3.9	11.8	4.5	47.2	5.7	18.8	7.6	11.8	5.3	5
B1	822	24.6	.5	4.4	6.8	39.2	3.5	13.9	5.2	6.6	4.1	11
Form: Swartland												
A1	318	25.9	8.5	10.1	3.3	42.7	10.4	13.0	3.7	5.6	3.3	9
B1	620	33.1	7.1	10.8	3.9	37.4	6.2	12.3	4.0	5.2	2.6	10
Form: Glenrosa												
A1	323	21.3	6.8	12.7	5.2	45.1	10.5	13.3	5.8	7.6	5.7	31
B1	707	26.4	8.8	15.4	4.3	40.3	12.2	10.6	4.2	6.4	5.0	12

Table 16.8 Means and standard deviations of five particle size classes for soils of the tillite of the Dwyka Formation with a loam textural class.

Horizon	Depth	Clay		Silt		Fine Sand		Medium Sand		Coarse Sand		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
	mm	%		%		%		%		%		
Form: Longlands												
A1	425	21.2	6.0	32.8	1.6	30.2	6.1	8.3	2.1	5.5	1.0	6
E1	525	15.0	4.6	39.3	3.5	32.5	5.9	7.3	0.4	5.5	1.8	4
B1	1000	25.0	0.0	41.0	0.0	26.0	0.0	4.0	0.0	4.0	0.0	1
Form: Glenrosa												
A1	283	17.7	2.0	34.7	1.7	25.7	9.7	8.7	2.4	18.7	22.2	3

Examination of the textural properties of the Hutton, Griffin and Swartland soils gives a range of clay contents from between 10 to 70 percent (Figures 16.4, 16.5 and 16.9). The silt values commonly range from between 5 and 30 percent. Then there are a small number of profiles in the loam textural class (Figures 16.7 and 16.9). The separation of the clay and the sandy clay to sandy clay loam classes is clear in the Swartland B1 horizon (Figure 16.9). This separation is less apparent in the case of the B1 horizons of the Hutton (Figure 16.5) and Griffin soils (Figure 16.4). Since the range of variation is relatively large, threshold values for their separation at 35 percent clay and 45 percent total sand divide this range at a central point. For the Hutton, Griffin and Clovelly soils the clay textural class is encountered largely in KwaZulu-Natal, while the sandy loam class is largely present in Mpumalanga. However, there is some overlap to this general observation such that localities alone could not be effectively used in any separation of natural soil groupings.

In keeping with the format adopted elsewhere, the ranges in textural properties (maximum and minimum values) for five particle size classes, dominant sand grade, and information on the luvic properties are presented for each of the three natural soil bodies (Tables 16.3, 16.4 and 16.5). This information is presented graphically (Figures 16.2, 16.3). The figures allow for an overview comparison between different soil forms and over particle size classes. The irregularities in textural properties in tillite are to be expected. In the selection of the three groupings the range of variation is reduced. The means and standard deviations of five particle size classes, and for each of the textural groupings is presented (Tables 16.6, 16.7 and 16.8). When examining the textural data of soils derived from tillite of the Dwyka Formation, and when viewed in general terms, the range of variation is not much larger than that encountered in certain of the other sedimentary materials.

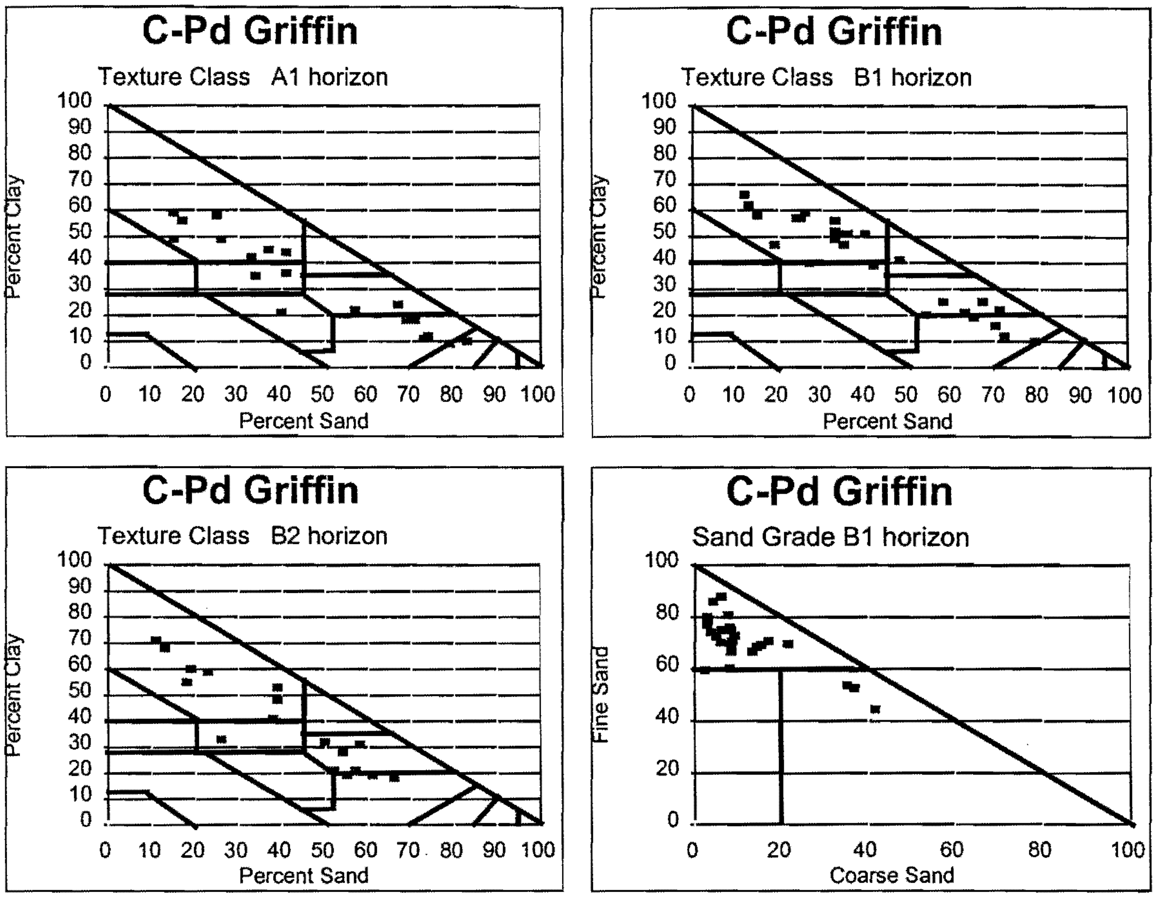

Figure 16.4 Distribution of soil textures, and dominant sand grade, within soils of the Griffin Form.

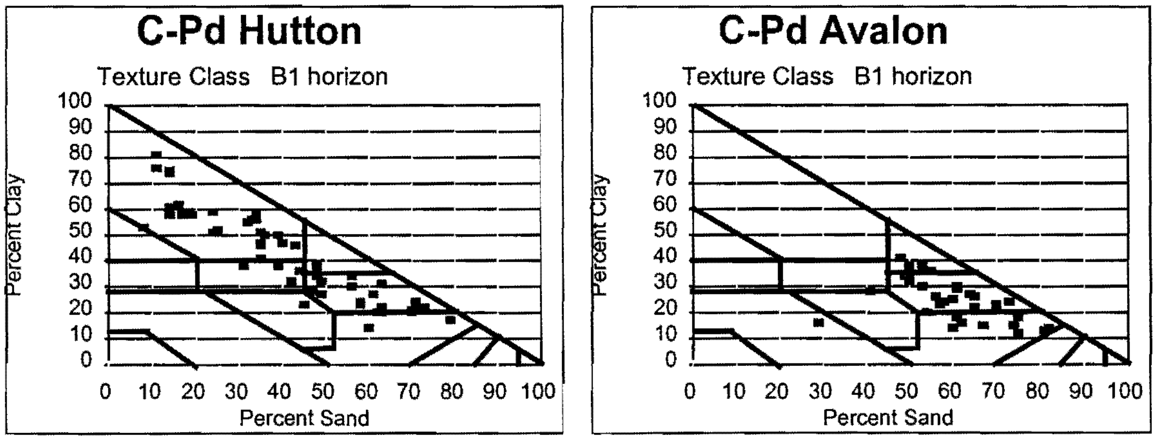

Figure 16.5 Distribution of soil textures within soils of the Hutton and Avalon Forms.

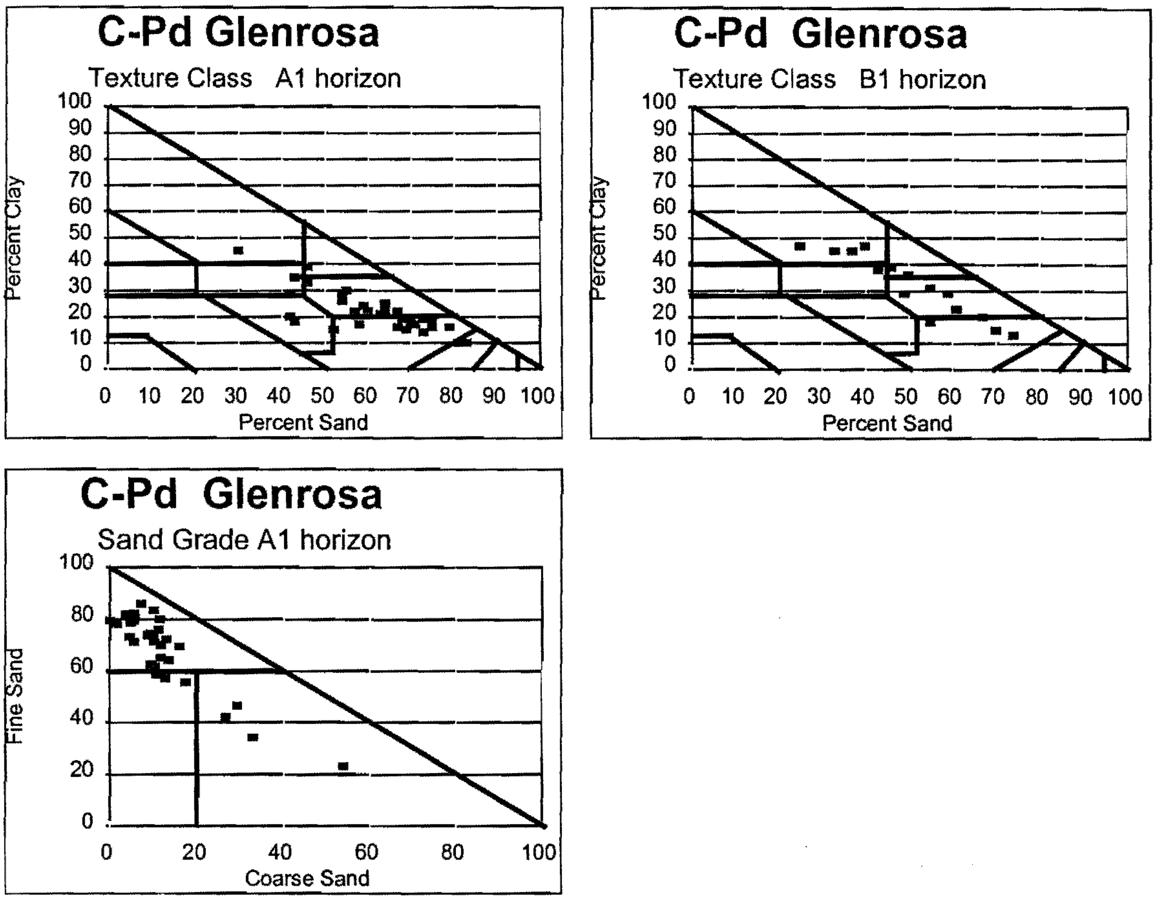

Figure 16.6. Distribution of soil textures, and dominant sand grade, within soils of the Glenrosa Form.

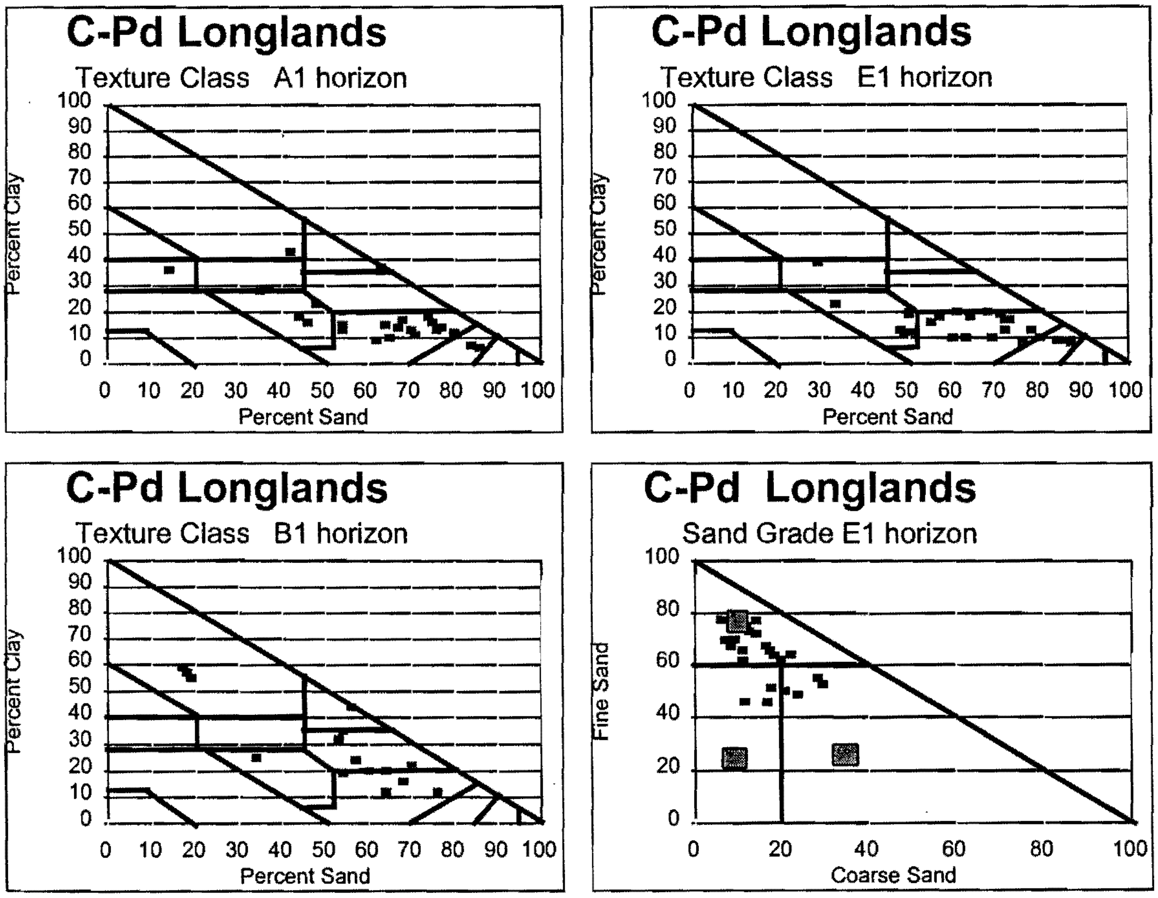

Figure 16.7. Distribution of soil textures, and dominant sand grade, within soils of the Longlands Form.

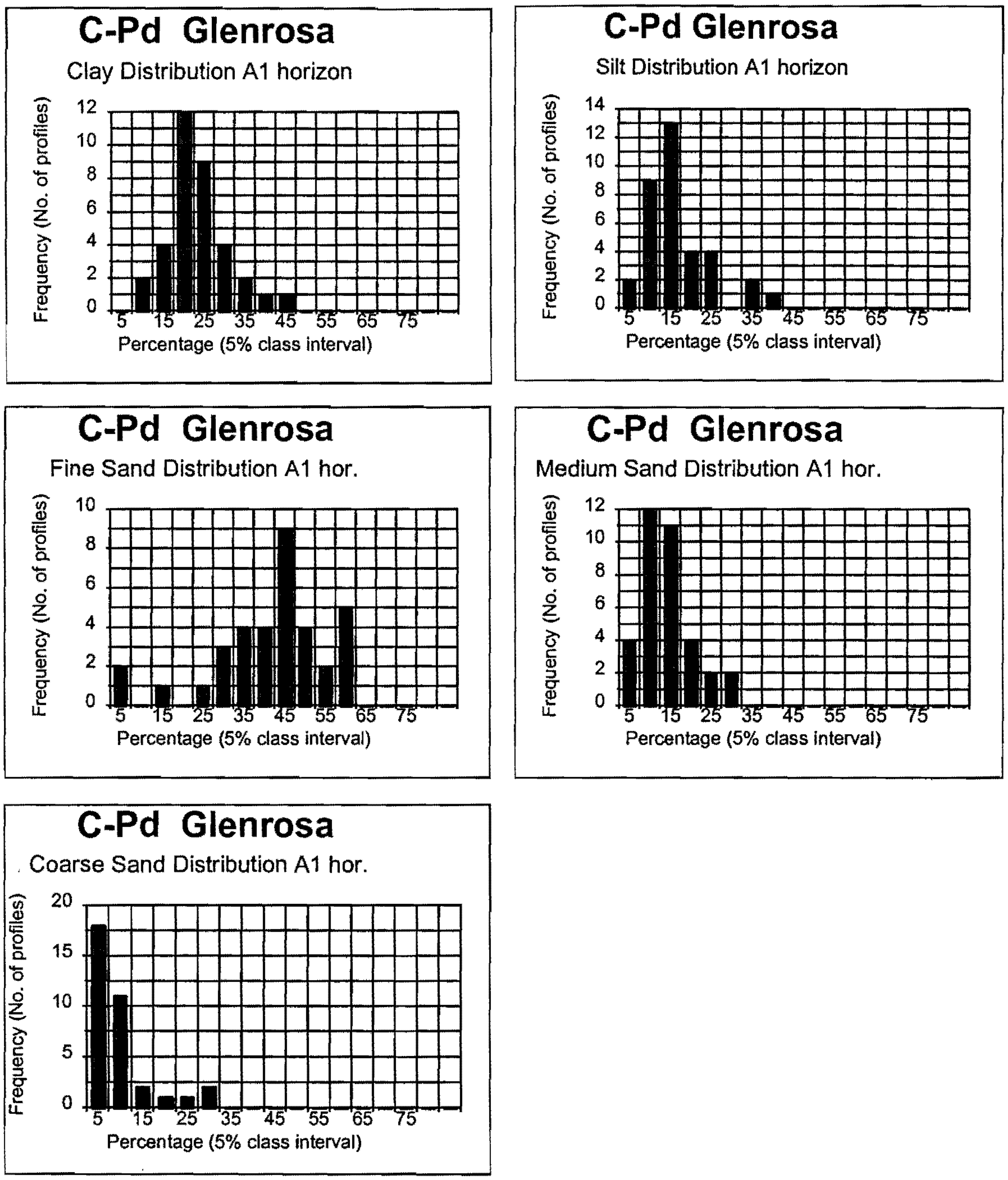

Figure 16.8 Distribution of clay, silt, fine sand, medium sand and coarse sand within soils of the Glenrosa Form.

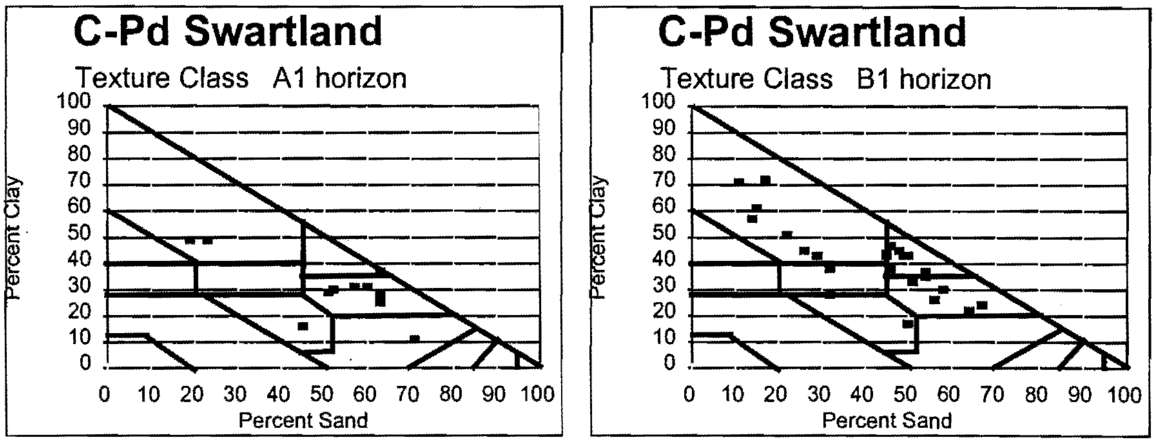

Figure 16.9 Distribution of soil textures within soils of the Swartland Form.

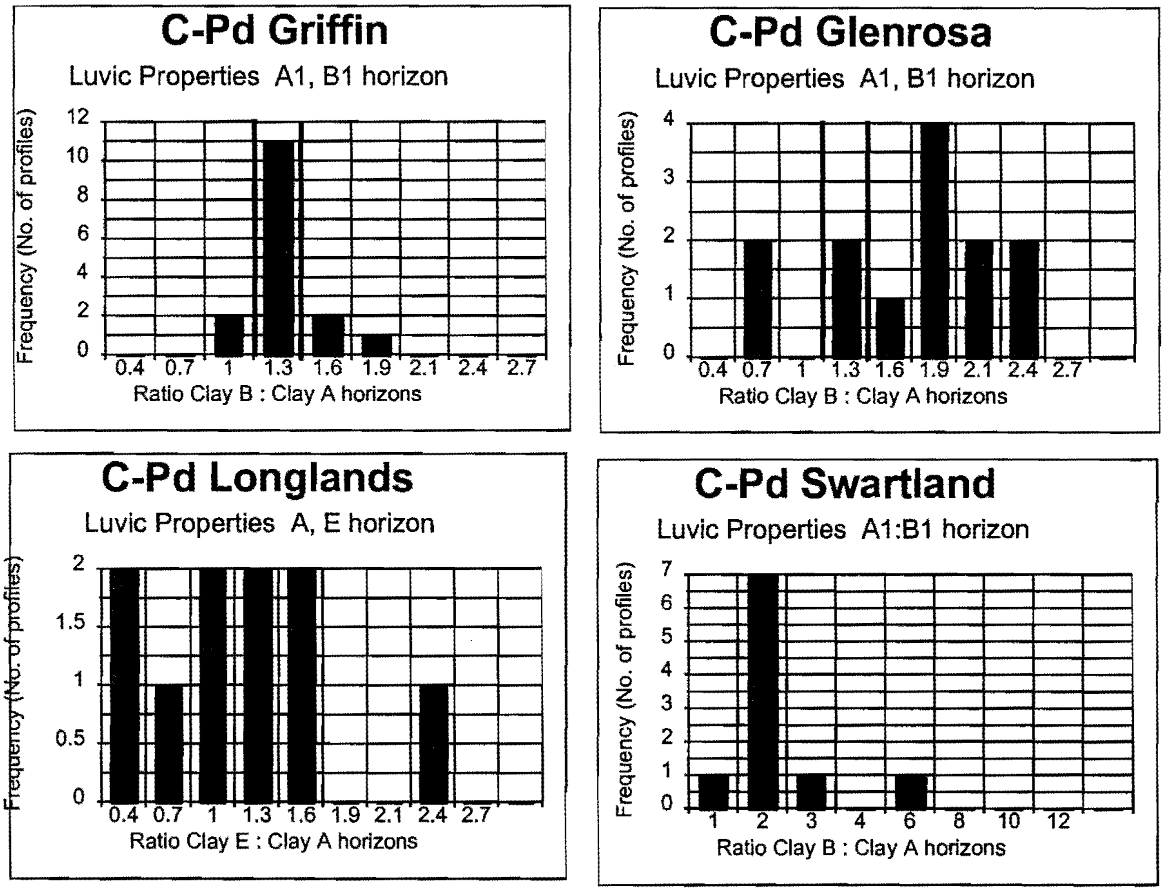

Figure 16.10 Luvic properties of soils of the Griffin, Glenrosa, Longlands and Swartland Forms.

CHAPTER 17

SOILS OF THE SANDSTONE OF THE NATAL GROUP IN KWAZULU-NATAL

Location and Extent

The Natal Group sandstones can be envisaged as lying in two essentially parallel belts in the coast belt and coast hinterland (Geological Survey, 1984). In the stratigraphic column the Natal Group rests on the basement granites, and below the tillites of the Dwyka Formation. Extensive faulting and down warping of the coast (Maud, 1968) has taken place giving rise to the sharp, but commonly irregular boundaries with these geological strata. Sandstones of the Natal Group are commonly exposed as flat to undulating tablelands, bounded by steep escarpments. The apparent uplifting of the geological stratigraphy of the province, and the reported monoclinal structure of the coastal belt, may be helpful in visualising the distribution and properties of soils derived from sandstones of the Natal Group. A clear description of this geomorphology is given by Van der Eyk, *et al.* (1969). The boundaries of these sandstones are thus strongly influenced by the resultant faulting and down weathering of the resultant strata. The northern extent of the Natal Group lies in the Mfolozi River valley north of Mtubatuba. The coastal extent of the Natal Group stretches southwards over the tablelands of Melmoth, Eshowe and Ndwedwe, through Durban to southern KwaZulu-Natal. In the interior stretching southwards from Kranskop through to the Oribi and Maringa Flats and into northern Pondoland are further occurrences of these sandstones. The eastern margins of these tablelands are often in elevated positions and experience a cool, misty climate with deeply weathered soils.

Geology and Geomorphology (Geology Symbol Abbreviation **O-Sn**)

The Natal Group rocks are predominantly greyish-white generally flat laying sandstones resting on the basement granite and gneiss (Geological Survey, 1980). They extend southwards from near the Mfolozi River into Pondoland. The Natal Group has been correlated with the Table Mountain succession in the South Western Cape, while associations with the Waterberg sandstone have also been suggested (SACS, 1980).

In the main outcrop area, which stretches from Hibberdene in the south to Eshowe in the north, five formations have been recognised (SACS, 1980). Three of these formations (Inanda, Mlazi and Eshowe Formations) contain largely felspathic and micaceous sandstone (SACS, 1980). They represent approximately 85% of the total reported thickness of the Natal Group and should dominate their surface extent. Their influence on the sandy through to sandy clay texture of the soils formed from Natal Group sandstone rocks is thus of important significance. The remaining two formations (Hibberdene and Mkunya Formations) are relatively thin and consist of white quartz sandstone. Should these formations be located on flat terrain, base poor and sandy Mispah, Cartref and Fernwood soils could be expected. South of Hibberdene the Natal Group is not known to be divisible into distinct lithostratigraphic units (SACS, 1989). The establishment of mappable lithostratigraphic units consisting essentially of a single rock type has proved difficult across the main outcrop area (SACS, 1980). Published maps give only the Natal group as a single unit.

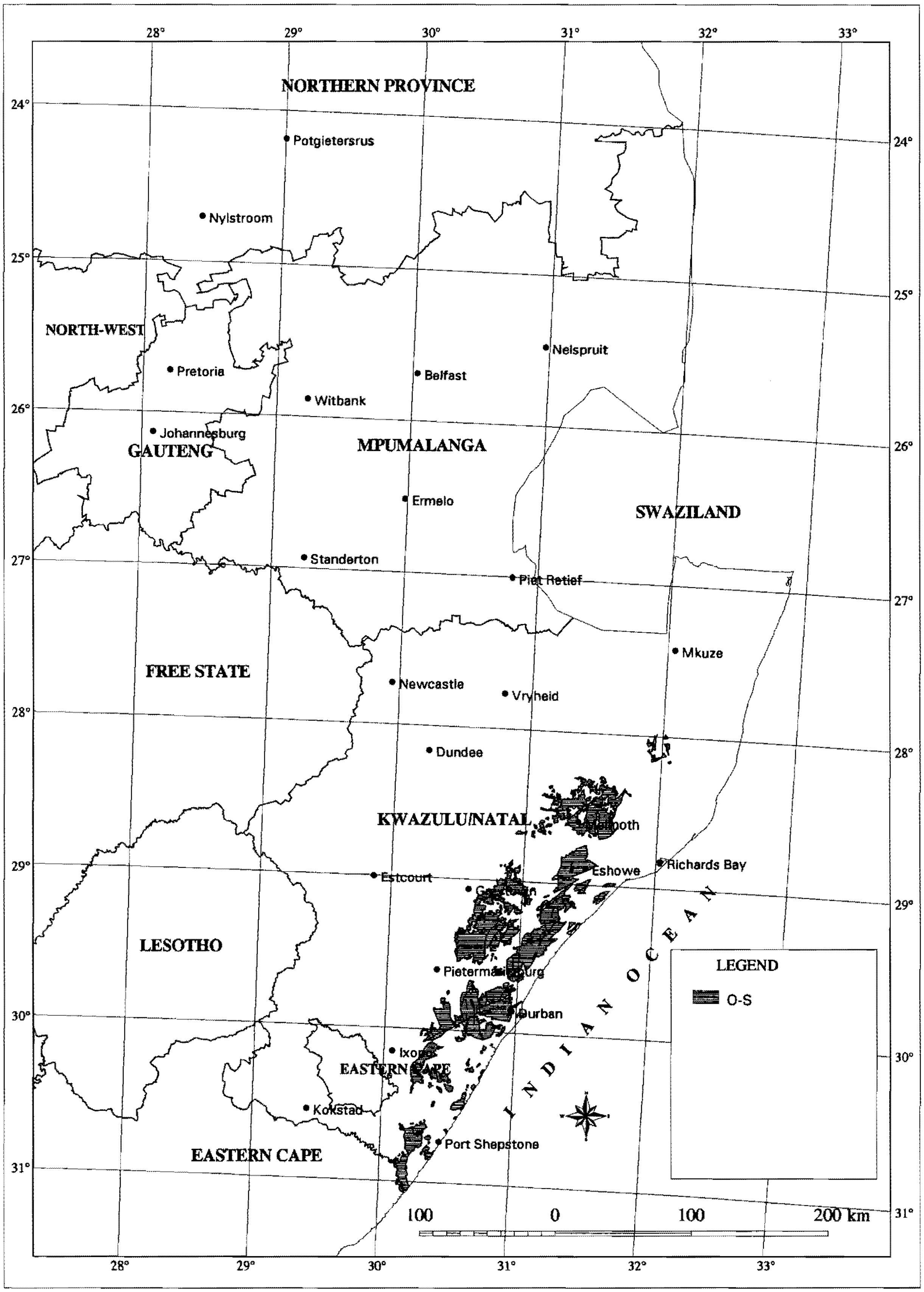

Figure 17.1. Location of the Natal Group in KwaZulu-Natal (after Geological Survey, 1984).

The Natal Group is described as comprising red-brown course to fine-grained arcosic sandstone, light-grey quartz arenite, micaceous sandstone, small pebble conglomerate, grit, subordinate siltstone and mudstone (Geological Survey, 1988c; Geological Survey, 1988d). In the northern Eshowe district the Natal Group sandstone assumes a maroon colour (Geological Survey, 1988b).

Many of the zones supporting thick humic soils are considered as of the African Surface (Partridge and Maud, 1987).

Physiography and Drainage Features

The terrain morphology of the exposures of the sandstones of the Natal Group varies from zones of relatively level land to steep low mountains. There are numerous examples of tablelands in the coast belt, the coast hinterland and in the interior where slopes of the order of 2 to 8 percent are common. These gentle sloping surfaces, usually with a favourable climate, form zones of high agricultural activity. Examples are the Eshowe and Ntumeni Plateaux in the north, the Sipepho Plateau in the central coastal zone, and the Oribi and Maringa Flats in the south. Incision of these sandstone surfaces has also given rise to undulating land of moderate relief, as encountered in the Melmoth and Kranskop Districts, in the interior at Bruyns Hill and Glenside, and in the south at Umbumbulu. The greater extent of the Natal group sandstones occurs on terrain of this nature. The level plateaux are usually bounded by steep escarpments zones. Examples of these escarpments are at Fields Hill west of Durban, and at Mtonjaneni over the Mfolozi Valley.

Vegetation

Vegetation of the plateaux is described as Short Mistbelt Grassland (Low and Rebelo, 1996). The vegetation of many of coast hinterland plateaus could be expected to support similar grassland, although it has been altered by agricultural activity. The vegetation of the drier river valleys is described as Coast-Hinterland Bushveld (Low and Rebelo, 1996).

Soils

Five major soil patterns are evident on the arcosic, micaceous and quartzitic sandstones of the Natal Group (Table 17.1). These include a red and yellow-brown apedal soil pattern where humic dystrophic soils predominate. Similar red and yellow-brown apedal soil pattern zones, but with orthic A horizons, are commonly located adjacent to but inland of these humic zones. Plinthic soils are not widespread on sandstones of the Natal Group. They do however, occur in a relatively narrow belt in the interior, in the Wartburg District (Land Type Survey Staff, 1994a), where E horizon soils are dominant. This is in contrast to other geology formations, notably the Vryheid Formation, where plinthic soils occupy relatively larger areas of the interior basins. Lithosols, comprising Glenrosa, Mispah and Cartref soils, without lime cover extensive areas of the interior valleys and of the coast belt. Lastly lithosols with duplex soils with the presence of lime are located in the drier interior valleys (Table 17.1).

The Natal Group sandstone commonly formed tablelands elevated above the surrounding countryside, and bounded by fairly steep scarps. Humic soils are widespread on those cool, moist and elevated tablelands that are first exposed to the easterly rain-bearing winds. Erosional

Table 17.1 Dominant soils and selected climatic information for Soils Patterns of the Natal Group.

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rain fall mm	Evaporation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Red and Yellow-brown Dystrophic Soils with a humic horizon										
Inanda	Ia10 Ia11	20	Glenrosa	Gs14 Gs17	21	Ave	1028	1515	3187	0.68
Kranskop	Kp10 Kp11	7	Mispah	Ms10		Std	129	109	367	0.08
Magwa	Ma10 Ma11	4				Max	1257	1789	4061	0.84
Nomanci	No10 No11	20				Min	760	1281	2534	0.52
Hutton	Hu16 Hu17	9								
Griffin	Gf11 Gf12	4								
Clovelly	Cv16 Cv17	3								
Total Area: 75 300 Ha			Means of 18 Land Types							
Broad Soil Pattern: Red and Yellow-brown Dystrophic Soils with an orthic horizon										
Hutton	Hu16 Hu17	36	Inanda	Ia10 Ia11	4	Ave	967	1536	3129	0.63
Griffin	Gf11 Gf12	8	Kranskop	Kp10 Kp11	2	Std	128	103	339	0.10
Clovelly	Cv16 Cv17	9	Magwa	Ma10 Ma11		Max	1156	1738	3859	0.76
			Nomanci	No10 No11	4	Min	640	1292	2469	0.37
Glenrosa	Gs14 Gs17	23								
Mispah	Ms10	4								
Total Area: 122 660 Ha			Means of 21 Land Types							
Broad Soil Pattern: Plinthic Soils with an E horizon										
Longlands	Lo21 Lo22	21				Ave	864	1550	2737	0.56
Wasbank	Wa21 Wa22	4				Std	54	135	226	0.07
Westleigh	We21 We22	9				Max	940	1787	3051	0.65
Avalon	Av24 Av26	6				Min	799	1421	2366	0.48
Glencoe	Gc24 Gc26									
Glenrosa	Gs14 Gs17	17								
Cartref	Cf21 Cf22	14								
Mispah	Ms10	8								
Kroonstad	Kd14 Kd17	3								
Total Area: 34 040 Ha			Means of 6 Land Types							
Broad Soil Pattern: Lithosols without the presence of lime										
Glenrosa	Gs14 Gs15 Gs16 Gs17	33	Hutton	Hu16	6	Ave	938	1556	3457	0.61
			Oakleaf	Oa16	4	Std	160	133	447	0.12
Cartref	Cf20 Cf21 Cf11 Cf31	23	Kroonstad	Kd14	3	Max	1409	1813	4456	-
						Min	570	1266	2469	0.37
Mispah	Ms10	10								
Total Area: 363 700 Ha			Means of 101 Land Types							
Broad Soil Pattern: Lithosols with duplex soils with the presence of lime										
Glenrosa	Gs14 Gs15 Gs16 Gs17	29	Swartland	Sw31 Sw41	4	Ave	724	1693	3808	0.43
			Valsrivier	Va31 Va41	4	Std	111	50	166	0.08
Cartref	Cf20 Cf21 Cf31	16	Kroonstad	Kd14	3	Max	980	1738	4081	0.62
Mispah	Ms10	19	Sterkspruit	Ss24 Ss26	1	Min	640	1592	3529	0.37
Rock	Rock	7								
Total Area: 33 320 Ha			Means of 9 Land Types							

stripping of the humic soils should also not have occurred to expose fresh to poorly weathered sandstone. These humic soils have very characteristic thick humic A horizons. Significant darkening of the A horizon to depths in excess of 600 mm, and even to 1 metre have been recorded. Inanda form soils dominate, (Table 17.1) where red apedal B horizons are present below the A horizons. Since it has been the usual practice not to give prominence to intergrades, the field pedologist must determine the lower boundary of the darkened A horizon. Increasing reddening of the profile over a diffuse boundary is commonly noted. Associated with this reddening are dark brown to yellow-brown colours in a transitional A/B horizon. This somewhat yellowish transitional horizon has usually not been assigned prominence and the diagnostic sequence of Humic A Horizon over Red Apedal B Horizon has been used. Where the thickness of the yellow horizon is greater, Kranskop and Magwa soil forms have been recognised (Table 17.1).

The thick humic A horizon soils occupy cooler, moist climate zones. The elevated levels of organic carbon of between 1.8 and 6 percent reflect these present climate features. They are considered as occupying the Early Tertiary erosion surfaces (Partridge and Maud, 1987). The deep weathering, low base status and the unusually thick A1 horizons with high organic carbon levels are considered as evidence of a long period of soil formation of these soils (MacVicar, Fitzpatrick and Sobczyk, 1984). Similar red and yellow-brown dystrophic apedal soils but with orthic A horizons are thought to occupy the Later Tertiary erosional land-surfaces (Partridge and Maud, 1987). It may be speculated that some measure of erosional stripping of the soil surface has taken place with removal of the organic matter rich soil horizons. The subsequent extent of accumulation of organic matter may be assumed to have been insufficient to develop the elevated levels of organic carbon over the larger A horizon depths.

The orthic A soil zones are located in slightly drier climates or at altitudes a little lower than corresponding humic zones. This may be illustrated below. At Melmoth the orthic soil group is located inland of the humic zones at Eshowe (and hence has a lower effective rainfall) and lower in altitude to an adjacent humic soil zone at KwaMagwaza. At Bruyns Hill and Glenside (north east of Pietermaritzburg) orthic topsoils are located in adjacent landscapes below the crest ridges which bear humic soils. Humic soils are not widespread on the Natal Group sandstones in the Kranskop area, although it is from this area that the thick humic Kranskop soil takes its name. Here orthic topsoils dominate. The orthic topsoil group has formed in the moist, humid climate capable of sustaining intensive arable cropping. The climate is nevertheless slightly drier than that of the humic zones. Casual observation would indicate that the humic soils are located where mist is frequently experienced. The fact of this drier climate is not well illustrated in Table 17.1 where climate statistics are derived over a wide geographical extent and with inherent variation. The differences could be better explained by referring to climate statistics of selected humic and orthic soil zones.

Within the humic soil zones Inanda, Kranskop, Magwa and Nomanci soils dominate (Table 17.1). Glenrosa and Mispah soils occupy subdominant proportions and are usually present on the steeper slopes, or associated with exposures of fresh sandstone, where erosional soil loss may be assumed to have taken place.

The red and yellow-brown apedal soil patterns with an orthic horizon show many similarities to those of the humic soils. Hutton, together with Griffin and Clovelly soils dominate (Table 17.1). Humic soils may occupy isolated remnant crest or lowland colluvial positions. These Hutton,

Table 17.2 Textural properties of soils of the Natal Group derived from profile values.

Form	Hor izon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Humic Soils	A1	SaLm-SaClLm-ClLm-Cl	12-57	6-47	8-61	1-36	1-24	fi,me,co	NL3, L2
	A2	SaLm-SaClLm-ClLm-Cl	12-47	6-33	19-40	5-35	1-18	fi,me,co	-
	B1	SaLm-SaClLm-ClLm-Cl	6-73	3-34	6-44	1-32	1-50	fi,me,co	NL3, L1,EL1
	B2	SaLm-SaClLm-ClLm-Cl	10-64	8-9	14-73	5-35	2-18	fi,me,co	-
Inanda	A1	SaLm-SaClLm-ClLm-Cl	13-57	6-33	18-61	3-36	2-24	fi,me,co	NL3,L2
	A2	SaLm-SaClLm-ClLm-Cl	17-47	7-33	19-32	7-35	1-18	fi,me,co	-
	B1	SaLm-SaClLm-ClLm-Cl	6-51	3-33	16-34	2-32	1-23	fi,me,co	-
	B2	SaLm-SaClLm-ClLm-Cl	10-55	5-14	16-73	5-35	4-18	fi,me,co	-
Kranskop	A1	SaLm-SaCl-ClLm	12-36	6-47	8-43	4-26	2-17	fi,me,co	NL3,L2
	A2	SaLm-SaCl-ClLm	12-38	6-30	23-37	6-30	4-13	fi,me,co	-
	B1	SaLm-SaCl-Cl	13-73	5-34	6-44	1-26	1-20	fi,me,co	NL3,L2
	B2	SaLm-Cl	23-64	4-21	14-42	7-23	2-15	fi,me,co	-
Magwa	A1	SaLm-SaCl	18-40	6-19	18-44	5-34	2-21	fi,me,co	L3, NL2
	A2	SaClLm-SaCl	31-39	15-17	22-30	5-29	2-6	fi,me,co	-
	B1	SaClLm-SaCl	22-42	5-19	15-31	6-31	3-50	fi,me,co	-
Orthic Soils	A1	Sa-LmSa-SaClLm-Lm	6-45	2-41	8-54	1-34	1-30	fi,me,co	NL3, L2
	B1	Sa-SaClLm-Cl	7-65	1-97	6-50	1-38	1-27	fi,me,co	-
Hutton	A1	LmSa-SaCl-ClLm-Lm	9-45	2-41	8-54	1-31	1-24	fi,me,co	NL3,L2
	B1	LmSa-SaLm-SaCl-Cl	10-65	1-97	6-50	1-38	1-18	fi,me,co	-
Griffin	A1	SaLm-ClLm-Cl	17-42	9-40	15-37	7-33	2-15	fi,me,co	NL1,L1,EL3
	B1	SaLm-ClLm-Cl	15-60	9-31	16-40	8-32	1-14	fi,me,co	L5
	B2	SaCl-ClLm-Cl	36-47	16-24	15-23	10-21	3-11	fi,me,co	-
Clovelly	A1	SaLm-SaCl	6-36	6-24	19-41	16-34	5-30	fi,me,co	NL3, L2
	B1	SaLm-SaCl-Cl	7-63	8-19	16-38	5-31	2-27	fi,me,co	-
Oakleaf	A1	SaLm-SaCl	19-37	6-11	19-24	18-30	10-24	fi,me,co	-
	B1	Sa-SaClLm-Cl	4-75	5-14	13-53	3-31	1-21	fi,me,co	-
Eluvic Horizon Soils	A1	Sa-SaLm	3-17	2-23	22-46	16-46	7-38	fi,me,co	NL3, L1,EL1
	E1	Sa-SaClLm	3-27	1-13	19-77	21-47	2-38	fi,me,co	-
	B1	Sa-SaLm-SaCl-Cl	5-50	3-12	20-33	15-46	7-46	fi,me,co	-
Cartref	A1	Sa-SaLm	3-17	4-23	24-46	16-46	7-26	fi,me,co	EL3,NL1,L1
	E1	Sa-SaLm	3-17	3-13	28-44	24-47	2-31	fi,me,co	L3,NL2
	B1	Sa-SaLm	5-21	5-12	25-32	25-46	13-18	fi,me,co	-
Kroonstad	A1	Sa-SaLm	7-10	2-9	22-32	36-40	12-38	fi,me,co	EL4,NL1
	E1	Sa-SaClLm	5-27	1-10	19-77	21-41	3-38	fi,me,co	L5
	B1	LmSa-Cl	13-50	3-9	20-33	15-37	7-46	fi,me,co	-
Nomanci	A1	SaLm-SaClLm-Cl	12-51	6-38	9-40	1-31	1-24	fi,me,co	NL3,EL2
	A2	SaLm-SaCl	16-37	6-12	28-40	23-26	2-12	fi,me,co	-
Glenrosa Mispah	A1	LmSa-SaLm-SaCl-Cl	7-52	6-25	18-89	11-42	3-25	fi,me,co	-
	B1	LmSa-SaLm-SaCl-Cl	4-51	6-17	16-51	7-35	1-11	fi,me,co	-

Luvic Properties: Explanation of symbols; L - Luvic, NL - Non-luvic, EL - Eluvic Properties. Numbers indicate relative dominance of property from occasionally (1) to dominantly(5).

Griffin and Clovelly soils, while having dystrophic base status, will commonly have lower organic carbon levels and a thinner A horizon depth. Textural properties are similar, although mean clay percentages for the orthic group of soils are between five and ten percent lower than the humic group.

Soils of the plinthic pattern are located over a limited surface extent in the Wartburg District.

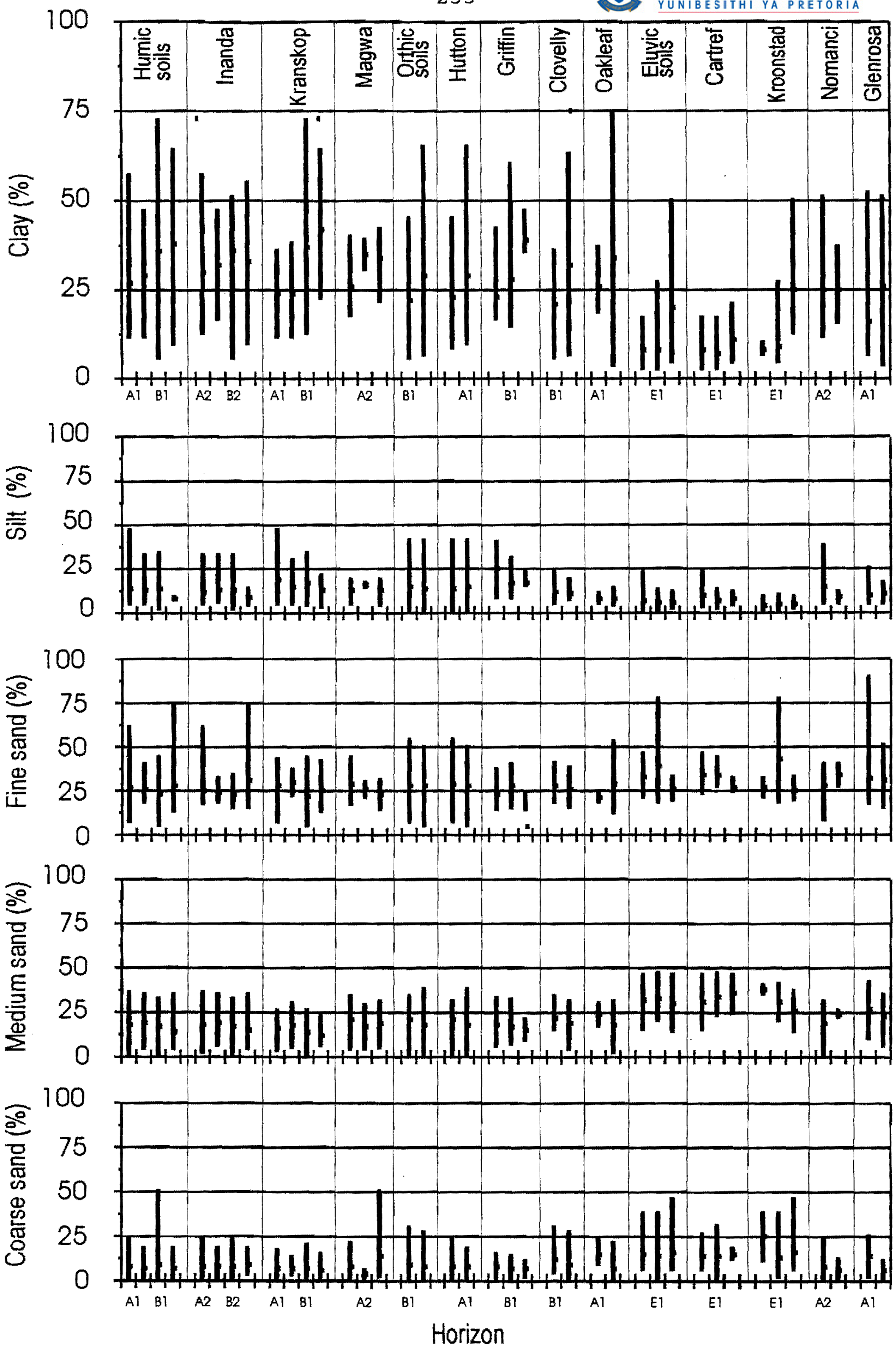

Figure 17.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Natal Group. Maximum, minimum and mean values are shown for each horizon.

Longlands, Wasbank and Westleigh soils are dominant (Table 17.1), together with other E horizon soils including Cartref and Kroonstad. Glenrosa and Mispah soils are also subdominant. Avalon and Glencoe soils with yellow-brown B1 horizons are estimated to occupy only small proportions of the landsurface (Table 17.1). This is somewhat in contrast to the soil pattern sequences of other sandstone geology formations where yellow-brown apedal soils occupy the moist subhumid zones, and E horizon soils occupy the drier subhumid zones. Furthermore, plinthic soils with maximal accumulation of iron and manganese oxides are widespread within the KwaZulu-Natal Interior Basins, and the Mpumalanga Highveld. Plinthic soils, and occurrences of ferricrete, are somewhat isolated in soils of the Natal Group sandstone (Land Type Survey Staff, 1988c; 1994a; 1994b). Occurrences of ferricrete, possibly of a relic nature, are present at the base of soil profiles at Wilsons Cuttings, Oribi Flats.

Grey coloured Glenrosa, Cartref and Mispah soils are dominant in the lithosolic soil patterns of the Natal Group sandstones. These soils have similar morphology and textural properties. Bleaching of the surface horizons, often not noted in the early profile descriptions, are common soil features. The transition from the A to E horizons is commonly gradual to diffuse and their classification is often subjectively based on the limited organic matter accumulation and on soil depth. In this soil pattern Kroonstad and Katspruit soils may occupy bottomland positions. An Oakleaf soil, possibly indicative of the initial stages of ferralitic weathering is sometimes present in certain upland sites.

In the semi-arid areas of the Mfolozi Valley similar lithosols are present, together with a greater proportions of rock. In addition, the bottomlands are occupied by duplex soils of the Swartland, Valsrivier and Sterkspruit forms. Lime is present in some of these duplex soils.

Physical Properties of Natural Soil Bodies: Textural Properties

The textural properties for soil profiles with thick humic A horizons, with orthic A horizons, and with Eluvial (E) horizons have been collectively extracted from the database and grouped by soil form. Their attribute values are given (Tables 17.2, 17.3). The textural properties of soil profiles from the Inanda, Kranskop and Magwa forms with thick humic A horizons have been reported separately after this Humic grouping. Textural properties of soil profiles from the Hutton, Griffin, Clovelly and Oakleaf forms are reported in the Orthic soil group. Similarly Cartref, and Kroonstad soils are reported in the Eluvial (E) horizon soil group. Finally textural properties for Nomanci, Glenrosa and Mispah are reported (Table 17.2 and 17.3). The trends for the respective individual soil forms within the Humic (Inanda, Kranskop and Magwa), Orthic (Hutton, Griffin, Clovelly and Oakleaf) and E horizon (Cartref, Longlands and Kroonstad) soil groups are similar. For brevity only the textural triangle graphs (Figures 17.3 to 17.6) for the Humic, Orthic and E horizon soils have been presented.

The ranges in textural properties, (maximum and minimum values) for five particle size classes, dominant sand grade, and information on the luvic properties are presented. (Table 17.2). These ranges are also presented graphically (Figure 17.2). The figure allows for overview comparisons between different soil forms over the particle size classes.

Soils with a humic A horizons have sandy loam through sandy clay loam to the lower end of the clay textural class as dominant in the A1 through to B2 horizons (Figure 17.3). There is little change in the minimum values for soils with a thick humic horizon (Table 17.2), with a

Table 17.3 Means and standard deviations of five textural classes for soils of the Natal Group.

Horizon	Depth	Clay		Silt		Fine Sand		Medium Sand		Coarse Sand		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
	mm	%		%		%		%		%		
Form: Humic Soils												
A1	562	27.8	9.9	14.7	8.6	27.5	8.1	18.7	8.0	8.4	5.4	76
A2	612	29.9	8.7	13.9	6.9	26.8	5.1	19.3	7.8	7.5	4.6	31
B1	1091	36.3	12.0	14.2	7.5	23.4	7.5	17.0	8.2	9.1	8.7	38
B2	1321	38.1	15.9	8.5	0.5	28.7	15.2	14.8	8.4	7.9	4.9	13
Form: Inanda												
A1	494	30.9	10.0	12.5	5.9	25.9	7.3	18.7	7.5	8.5	5.5	34
A2	607	32.0	8.1	13.9	7.2	24.5	3.3	19.0	7.3	8.1	5.1	19
B1	1153	36.2	10.2	13.1	7.3	23.7	4.7	17.6	8.0	8.0	5.6	21
B2	1283	33.2	16.4	9.0	2.9	31.8	19.1	15.8	10.1	9.8	5.0	6
Form: Kranskop												
A1	442	24.9	7.4	19.8	12.0	28.1	8.1	16.1	6.9	7.6	4.6	13
A2	564	24.7	8.4	15.4	7.2	30.1	4.5	18.7	8.4	7.6	2.8	7
B1	963	37.7	17.3	17.1	8.0	22.6	12.0	14.3	8.2	7.5	6.4	10
B2	1270	42.6	15.4	13.0	7.0	25.8	11.7	12.8	6.3	6.0	4.7	5
Form: Magwa												
A1	596	26.4	7.2	13.4	4.6	29.4	9.1	21.3	8.3	8.7	6.0	8
A2	630	35.0	4.0	16.0	1.0	26.0	4.0	17.0	12.0	4.0	2.0	2
B1	1091	34.6	6.5	13.0	5.7	23.6	5.8	19.1	7.6	14.6	14.9	7
Form: Orthic Soils												
A1	497	22.9	8.2	15.9	9.8	28.0	8.8	21.0	6.6	9.8	6.1	57
B1	900	29.6	12.1	14.9	13.1	28.0	8.1	18.8	7.2	8.8	4.8	67
Form: Hutton												
A1	479	23.3	9.6	14.4	10.1	29.7	9.9	21.2	7.3	8.7	6.1	29
B1	928	29.1	11.6	15.4	16.6	28.8	9.2	18.8	7.9	8.7	4.9	37
Form: Griffin												
A1	504	23.4	6.3	25.0	8.7	23.4	7.0	18.0	6.1	8.0	3.8	11
B1	842	28.4	12.7	17.8	7.5	28.0	5.9	17.8	6.1	7.9	3.8	14
B2	1292	39.0	4.2	17.6	2.8	20.3	3.3	15.1	3.4	7.6	2.2	7

Table 17.3 continued. Means and standard deviations of five textural classes for soils of the Natal Group.

Horizon	Depth	Clay		Silt		Fine Sand		Medium Sand		Coarse Sand		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
	mm	%		%		%		%		%		
Form: Clovelly												
A1	522	21.7	6.1	12.8	5.2	28.2	6.6	22.6	5.0	12.7	6.2	17
B1	886	32.0	12.2	11.4	3.7	26.1	6.6	19.6	6.1	9.9	5.3	16
Form: Oakleaf												
A1	356	26.3	7.7	8.7	2.0	21.7	2.0	24.0	4.9	15.3	6.2	3
B1	983	34.1	20.7	8.3	2.9	29.7	11.2	18.4	7.7	7.8	5.8	9
Form: Soils with an Eluvic Horizon												
A1	347	8.6	3.1	7.3	5.1	33.3	7.7	32.8	7.5	15.9	8.7	16
E1	818	8.5	6.0	6.1	3.7	39.4	14.4	33.2	7.9	14.0	9.6	15
B1	961	20.9	13.3	6.5	2.8	26.0	5.2	30.0	9.5	16.1	11.8	11
Form: Cartref												
A1	392	8.4	4.3	10.3	6.0	34.0	6.7	31.0	8.9	14.9	6.9	7
E1	907	7.6	4.7	7.3	3.8	34.4	5.2	34.9	8.7	14.3	8.6	7
B1	983	11.0	7.1	8.0	2.9	27.3	3.3	36.3	8.7	15.7	2.0	3
Form: Kroonstad												
A1	358	8.4	1.4	4.0	2.5	27.0	5.0	38.0	2.0	25.0	13.0	5
E1	740	9.3	6.9	5.1	3.3	43.8	18.0	31.8	6.8	13.8	10.4	8
B1	953	25.1	13.0	5.9	2.4	25.2	6.0	26.2	7.9	16.4	14.8	8
Form: Nomanci												
A1	733	25.3	10.7	15.5	9.5	28.8	8.3	19.5	8.7	8.5	5.5	21
A2	743	25.7	8.7	9.3	2.5	34.3	4.9	24.3	1.3	6.0	4.3	3
Form: Glenrosa/Mispah												
A1	369	16.6	10.1	10.2	4.9	32.3	14.6	27.4	7.3	14.1	6.9	20
B1	575	26.5	16.6	11.5	3.9	31.8	12.7	23.0	10.2	6.0	5.0	4

minimum value of around six to ten percent. There is however a progressive increase in the mean clay content with depth in the profile (Table 17.3) (for soils with a thick humic A horizon). This increase in clay content is substantially greater than in soils derived from the Vryheid Formation which shows similar patterns and properties for the corresponding textural triangle graphs. Silt values remain fairly constant down the profile, with maximum silt values around 35 percent (Table 17.2, Figure 17.3). Fine, medium and coarse sand fractions are represented in all soils (Figure 17.3) with about equal dominance of each of these fractions in humic soil profiles (Table

17.2, Figure 17.3). There are a few profiles with a loam to clay loam textural class (silt values greater than 30 percent). In view of the strong dominance of low to intermediate silt values, this observation was not expected.

The soils with an orthic A horizon show similar properties to those with a humic A horizon. Clay contents of the A1 horizon seem to be slightly lower than the corresponding humic soils (Table 17.3, Figure 17.5) with individual profiles within the loamy sand class. Silt values are also seldom in excess of 30 percent although individual profiles are within the loam class. Mean clay contents for the Hutton, Griffin and Clovelly soils do not show much difference with small increases down the profile (Table 17.3). There are a number of interesting Oakleaf profiles with slightly higher clay contents (and higher SD, Table 17.3) than the corresponding Clovelly soils which they closely resemble. The Oakleaf soils occur within a ferralitic weathering regime, but appear to have a youthful morphology. It is uncertain whether they have a greater reserve of weatherable minerals derived from variations in the parent sandstone.

The Cartref, Longlands and Kroonstad soils have substantially lower clay contents in the A1 and E1 horizons than the ferralitic soils (Table 17.2, Figure 17.2). Their clay contents are also lower than those of the Nomanci and Glenrosa soils (Tables 17.2, 17.3) although in a morphological sense they appear very similar. Cartref and Kroonstad soils are seldom present together with the red and yellow-brown apedal soils in the same landscape (Table 17.1). There is commonly a clear boundary between the Cartref and Kroonstad soils, and the ferralitic soils (Land Type Survey Staff, 1988c; 1994a; 1994b). They are invariably present on an erosional landsurface below the apedal soils. Rainfall is lower than in the red and yellow apedal soil zones, but may well be sufficient to sustain arable cropping. The reasons that weathering has proceeded to give rise to E horizons, with losses of iron and clay, from a parent material which has otherwise given rise to red and yellow freely drained sandy clay loams to sandy clays is uncertain. While the higher clay contents for the Nomanci soils are similar to that for the other humic soils, the higher mean clay contents for the Glenrosa soils were not expected. It would point to more intense eluvial horizon processes in the Cartref and Kroonstad soils than in the Glenrosa soils. Given their similarities in topsoil colour this speculation would require verification.

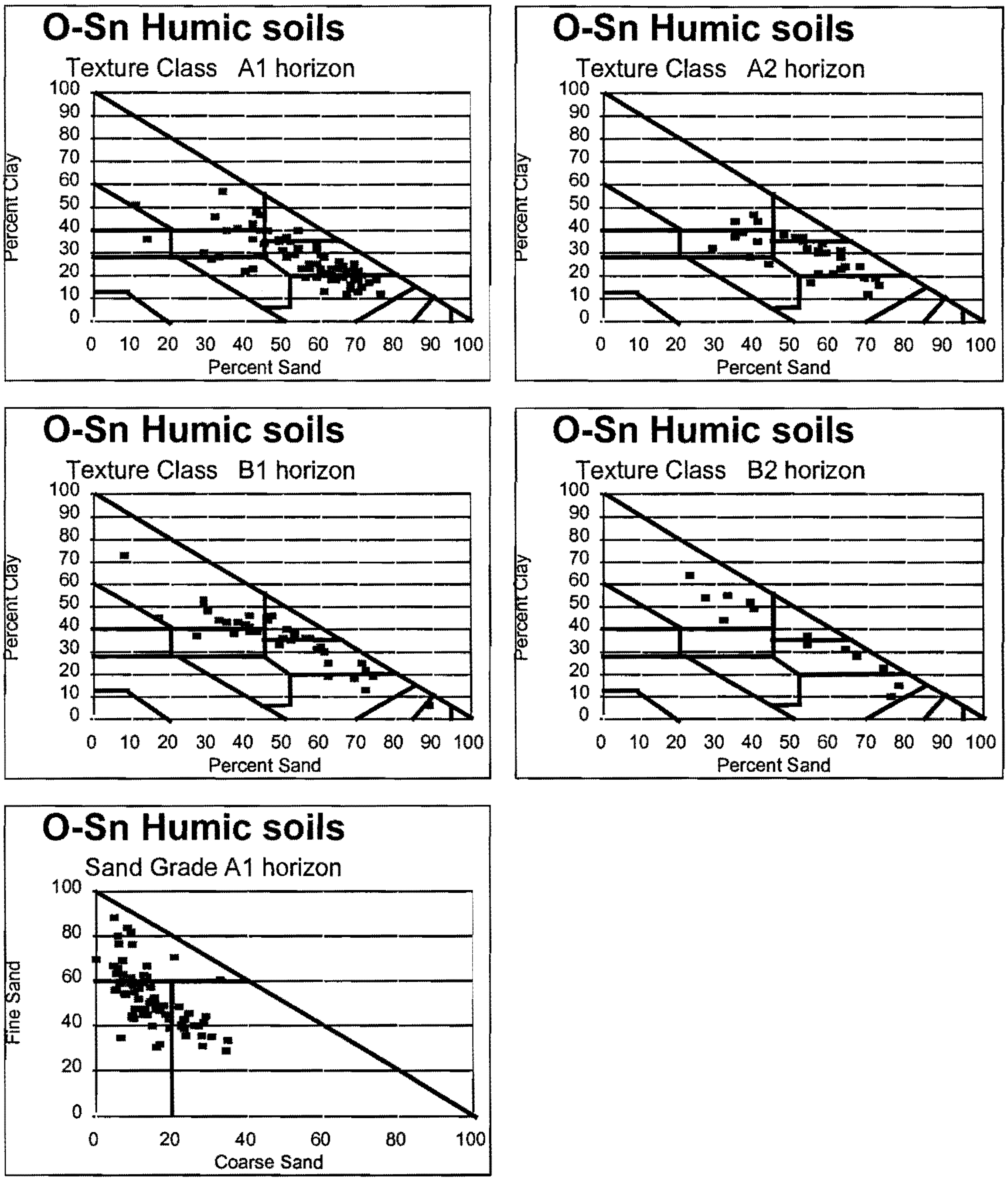

Figure 17.3 Distribution of soil textures, and dominant sand grade, for soils with humic A1 horizons, namely the Inanda, Kranskop and Magwa Forms.

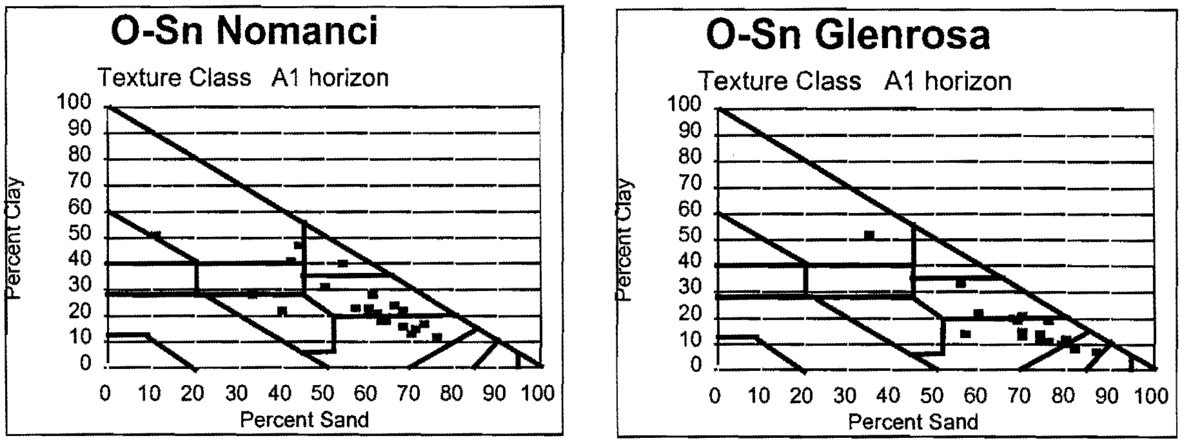

Figure 17.7. Distribution of soil textures within soils of the Nomanci and Glenrosa Forms.

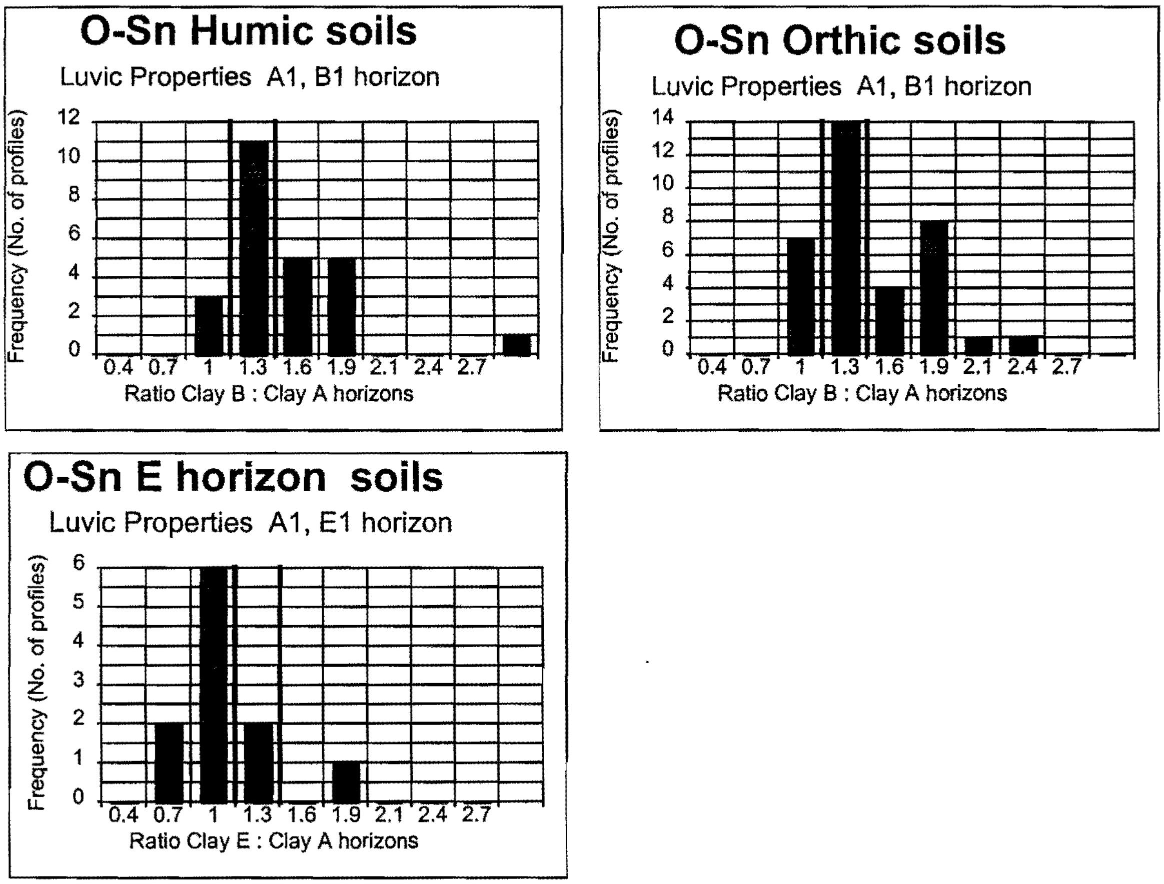

Figure 17.8 Luvic properties of soils with humic A1, orthic A1 and eluvial E1 horizons.

CHAPTER 18

SOILS OF GRANITIC ROCKS IN KWAZULU-NATAL AND SOUTHERN MPUMALANGA

Location and Extent

Granites in Southern Mpumalanga and in KwaZulu-Natal are essentially located in five broad zones and are of Swazian, Swazian to Randian, and Namibian ages (Geological Survey, 1984). The first three of these zones are located in the north of the study area and comprises an unnamed potassic granite of Swazian or Swazian-Randian age. Occurrences have been identified in the Piet Retief district, the Mfolozi River valley, and the Nkandla District (Figure 18.1). The remaining two major occurrences of granitic rocks in the study area have been collectively called the Mapumulo Metamorphic Group (Geological Survey, 1984) and are located in two north-south stretching belts in the KwaZulu-Natal Coast Hinterland (Figure 18.1). The first stretches from the Tugela River in the north to the Mgeni River in the south. The second lies to the south of the Mgeni River covering much of the Coast Hinterland of southern KwaZulu-Natal.

Granites occur over extensive areas of the Lowveld of Mpumalanga and the Northern Province (Figure 18.1) and have given rise to a range of soils complementary to those encountered in KwaZulu-Natal. To draw comparisons between the granitic soils in KwaZulu-Natal and that occurring elsewhere soil profiles from two additional granitic zones have been chosen. These are from the Goudplaats Gneiss located over large parts of the Northern Province (Figure 18.1), and a migmatite and gneiss of the Nelspruit Suite (Geological Survey, 1986) occurring in Mpumalanga.

The locations of the main granitic zones within KwaZulu-Natal are described below. The unnamed potassic granite (Symbol Z-Rg) is located in the southern parts of Mpumalanga and the northern interior basins of KwaZulu-Natal. The first of these exposures occurs from south of the Ngwempisi River in Mpumalanga, and stretches southwards into northern KwaZulu-Natal through the upper reaches of the Assegai, Pongola and Bivane River Basins. The towns of Piet Retief and Paulpietersburg are central in this zone. This region experiences a warm, and yet moist climate and is located at altitudes of between 800 and 1400 metres.

The second of these occurrences stretches over undulating terrain from the Nondweni River in the northern KwaZulu-Natal Interior Basin to south of the White Mfolozi River where undulating to steep terrain is encountered. Ulundi is located to the east of this granitic zone. The altitudes here range from 1100 metres in the interior to 550 metres in the Mfolozi River Valley. A sub-humid to a semi-arid climate is encountered. The symbol Zg has been used for this granitic zone in this text.

The third occurrence of potassic granite (Zg) is located in a steep zone east of Nkandla within the upper reaches of the Mhlatuze River. This zone is largely inaccessible with only limited soil information.

The northern exposures of the Mapumulo Metamorphic Suite, and its associated units, stretches over the coast hinterland basins of the Tugela, Mvoti and Mgeni Rivers (Geological Survey, 1984). They are described as comprising of gneiss and granulite. This zone could be described

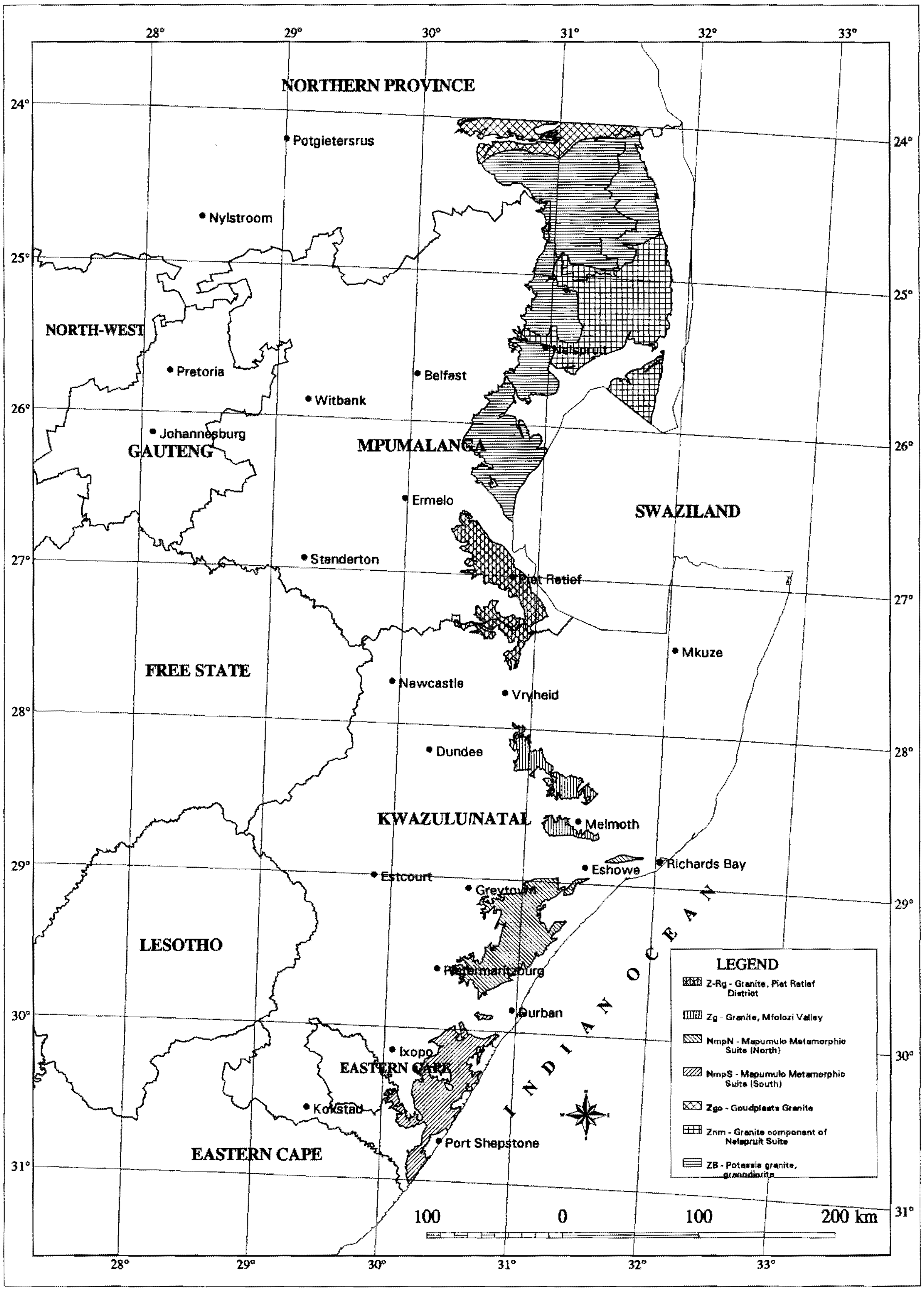

Figure 18.1. Location of granitic rocks in KwaZulu-Natal, Mpumalanga and Northern Province (after Geological Survey, 1984).

as experiencing a moist to a sub-humid climate within undulating to steep terrain. This granitic area is bounded in both the east and the west by sandstones of the Natal Group. There is a break in the exposures of these granitic rocks over an axis between Durban and Pietermaritzburg. To the south of this break granitic rocks are exposed in the Lovu, Mkomazi, Mtwalume and Mzimkulu River Valleys. Here the granites stretch right up to the coast, or are bounded by Quaternary sands, tillite of the Dwyka Formation and sandstone of the Natal Group. The granites are not exposed south of the KwaZulu-Natal border at the Mtamvuna River.

Geology and Geomorphology (Geology Symbol Abbreviation **Z-Rg**)

The 1970 Edition of the Geology map of South Africa (Geological Survey, 1970) records an extensive belt of migmatite, gneiss and ultrametamorphic rocks stretching from south of the Soutpansberg, and east of the Great Escarpment into Mpumalanga and Swaziland. The southern most occurrence of this unit (labelled AG2, Geological Survey, 1970) extends to Nondweni in the Mfolozi River Valley of KwaZulu-Natal. This zone was known as the Northern Cape and Transvaal Belt of metamorphism and granitization. South of the Mfolozi River the migmatite, gneiss and ultrametamorphic rocks were described in a single unit as the Natal Zone of metamorphism and granitization (labelled AG7: Geological Survey, 1970). Subsequent construction of the map legends on the 1984 Edition of the Geological Map of South Africa records a potassic granite and granodiorite (labelled ZB; Geological Survey, 1984) occurring over Central Mpumalanga and stretching further south in Northern KwaZulu-Natal to the Mfolozi and Mhlatuze Rivers. The Tugela Group was defined separately. The Mapumulo Metamorphic Suite now covered the greater part of the former Natal Belt of metamorphism and granitization and was now defined as comprising gneiss and granulite (Geological Survey, 1984). The location of the Mapumulo Metamorphic Suite is that shown in Figure 18.1. The Goudplaats Gneiss unit was also defined separately in the Northern Province (labelled Zgo) and comprises migmatite, gneiss and leucogranite (Geological Survey, 1984).

Mapping at the more detailed 1:250 000 scale records a number of granitic units. The medium to coarse grained biotite granite of Piet Retief District, labelled Z-Rg, is considered to be of Swazian to Randian age (Geological Survey, 1986c, Geological Survey, 1988a). The soils developed from this unit have been fairly extensively sampled and provide the most detailed soil information for this study area. To the south map legends (Geological Survey, 1988b) describe the units as granite and of Swazian age. The symbol Zg is used for recognition purposes. Specific descriptive or place names have not been recognised by the South African Committee for Stratigraphy (1980). Independent units within the Mapumulo Metamorphic Suite have been recognised from within the northern and southern zones (Geological Survey, 1988c, 1988d). Regrettably the number of soil profiles sampled from any single unit is limited and soil profiles have been collectively grouped as the Northern (NmpN) and Southern (NmpS) occurrences of the Mapumulo Metamorphic Suite (Nmp)(Figure 18.1). The profiles are derived largely from biotite gneiss (NmpN) (Geological Survey, 1988c) and coarse-grained porphyritic granite (NmpS) (Geological Survey, 1988d).

The unit of the Nelspruit Suite, labelled Znm, consists of potassic gneiss and migmatite (Geological Survey, 1986a, 1986b) (Figure 18.1).

Physiography and Drainage Features

Within the granitic areas of southern Mpumalanga Province moderately undulating plains are encountered. To the south the slopes of the Pongola Valley become steeper and undulating hills and lowlands are encountered (Kruger, 1983). This the only region within the study area on granite which has gentle to moderate slopes and consequently higher agricultural land use potentials. East of the town of Paulpietersburg the Pongola and Bivane Rivers fall into steeply incised valleys, where the terrain can be described as low mountains with only limited flatter land.

In the Nondweni District irregular undulating lowlands with hills are present, with slopes dominantly between 5 and 8 percent. However, these moderate slopes comprise only a limited area of generally shallow soils. Within the Mfolozi River Valley undulating hills and lowlands are encountered, with limited flatter slopes (Kruger, 1983).

The granitic areas of the Nkandla District comprise highly dissected low undulating mountains, drained by the Mhlatuze River. Similar highly dissected terrain with low undulating mountains are present in the valleys of the Tugela, Mvoti and Mgeni Rivers (Kruger, 1983). The dissection of the granitic areas to the south of Durban is less intense than to the north, although limited land with flatter slopes is present. Drainage is via the Lovu, Mkomazi, Mtwalume and Mzimkulu Rivers, and via numerous other smaller rivers and tributaries.

Vegetation

The vegetation of the granites exposed in the Piet Retief District is North-eastern Mountain Grassland, while in the Tugela Valley and of the Mapumulo Metamorphic Suite is Thicket and Coast-Hinterland Bushveld. In the south the vegetation where granite is exposed is Coastal Bushveld and Grassland (Low and Rebelo, 1996).

Soils

Three major soil patterns are evident on the granitic rocks of KwaZulu-Natal and southern Mpumalanga (Table 18.1). The first is a red and yellow apedal soil pattern with dominantly dystrophic soils. Recognisable within this dominantly red and yellow apedal soil pattern are similar, largely red apedal soil patterns where yellow soils are subdominant or absent, or where there are increasing proportions of lithosols, chiefly of the Glenrosa Form. Lithosols without the presence of lime occupy relatively large areas of the undulating to steep interior basin and coast hinterland. Lithosols with the presence of lime occupy restricted zones within the arid interior basins and on the dolomite and marble rocks of the Mzimkulu River Valley at Oribi Gorge.

Soil patterns with respectively red apedal Hutton soils with a sandy loam texture, plinthic soil patterns with Avalon, Longlands and Westleigh Forms, and duplex soil patterns comprising Sterkspruit, Valsrivier, Swartland and Estcourt Forms occur over extensive areas of north eastern Mpumalanga and Northern Province. They are generally located in geographic zones between the red and yellow apedal soil patterns and those of the lithosolic soil patterns. Their absence in KwaZulu-Natal can be attributed to differences in weathering intensity and weathering duration, and to differences in geomorphology and topography factors.

Table 18.1 Dominant soils and selected climatic information for soil patterns occurring on granitic rocks of the Piet Retief District (Z-Rg), Mfolozi District (Zg) within KwaZulu-Natal.

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rainfall mm	Evaporation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Red and Yellow-brown Apedal Soils (Piet Retief Granite Z-Rg1)										
Hutton	Hu17 Hu18	50	Glenrosa	Gs17 Gs18	7	Ave	900	1622	2961	0.55
	Hu27 Hu28	7				Std	124	164	440	0.08
Griffin	Gf12 Gf13	11				Max	1073	1479	2632	0.45
Clovelly	Cv17 Cv18	6				Min	701	1853	3584	0.63
Total Area: 52 160 Ha			Means of 6 Land Types							
Broad Soil Pattern: Red and Yellow-brown Apedal Soils with Lithosols (Piet Retief Granite Z-Rg2)										
Hutton	Hu17 Hu27	39	Avalon	Av16 Av17	12	Ave	850	1949	2166	0.43
Griffin	Gf12 Cv17	6	Glencoe	Gc16		Std	20	135	784	0.03
Clovelly						Max	873	241	3584	0.45
Glenrosa	Gs15 Gs18	16				Min	821	1853	1500	0.38
Cartref	Cf31	4								
Mispah	Ms10 Ms11	4								
Rock	Rock	8								
Total Area: 53 870 Ha			Means of 5 Land Types							
Broad Soil Pattern: Lithosols without the presence of lime (Piet Retief Granite Z-Rg3)										
Glenrosa	Gs15 Gs18 Gs16	43				Ave	781	1720	2673	0.45
	Gs17					Std	59	137	299	0.02
Cartref	Cf31 Cf32	8				Max	838	1853	3152	0.49
Mispah	Ms10	3				Min	700	1539	2418	0.43
Rock	Rock	17								
Total Area: 27 880 Ha			Means of 4 Land Types							
Broad Soil Pattern: Lithosols with the presence of lime (Mfolozi Granite Zg1)										
Glenrosa	Gs15 Gs18	30	Estcourt	Es15 Es34	8	Ave	737	1560	2924	0.47
	Gs14 Gs16 Gs17	9	Kroonstad	Kd15 Kd14		Std	179	81	382	0.05
Mispah	Ms10 Ms11	11	Swartland	Sw40 Va40	5	Max	1150	1710	3777	0.53
Cartref	Cf30 Cf31	8	Valsrivier			Min	594	1473	2721	0.39
Rock	Rock	6								
Total Area: 50 820 Ha			Means of 7 Land Types							

The red and yellow apedal soil pattern comprises dominantly sandy clay to clay dystrophic soils (Table 18.1, Piet Retief Zone, Z-Rg1). Soils are commonly deeply weathered where the solum grades to a soft red to pink saprolite. Stonelines of fine quartz gravel are commonly present within the solum, usually between the A and B horizons. The gravel may also be somewhat

Table 18.2 Dominant soils and selected climatic information for soil patterns occurring on granitic rocks of the Mapumulo Metamorphic Suite (NmpN, NmpS).

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rainfall mm	Evaporation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Red Apedal soils (dystrophic and mesotrophic) (Mapumulo Metamorphic Suite, NmpN1)										
Hutton Oakleaf	Hu17 Hu27 Hu26 Oa16 Oa17 Oa36	53 9	Glenrosa	Gs15 Gs18	17	Ave Std Max Min	883 - 1145 740	1571 - 1628 1534	3246 - 3759 2924	0.56 - 0.73 0.47
Total Area: 30 170 Ha			Means of 6 Land Types							
Broad Soil Pattern: Broad Soil Pattern: Lithosols with Red Apedal Soils of eutrophic base status (Mapumulo Metamorphic Suite, NmpN2)										
Glenrosa Cartref Rock	Gs15 Gs17 Gs18 Cf31 Cf21 Rock	40 5 6	Hutton Oakleaf	Hu36 Hu37 Oa16 Oa17 Oa36 Oa37	25 9	Ave Std Max Min	840 112 1030 635	1605 118 1813 1473	3452 480 4318 2924	0.53 0.08 0.66 0.38
Total Area: 188 840 Ha			Means of 21 Land Types							
Broad Soil Pattern: Red Apedal Soils (dystrophic and mesotrophic base status) (Mapumulo Metamorphic Suite, NmpS1)										
Hutton Glenrosa	Hu17 Hu18 Hu27 Hu28 Gs15 Gs18 Gs19	42 28				Ave Std Max Min	1027 - - -	1558- - - -	3692 - - -	0.66 - - -
Total Area: 26 230 Ha			Means of 5 Land Types							
Broad Soil Pattern: Lithosols with Red Soils of mesotrophic and eutrophic base status (Mapumulo Metamorphic Suite, NmpS2)										
Glenrosa Cartref	Gs15 Gs17 Gs18 Gs19 Cf31 Cf32	66 5	Hutton Oakleaf	Hu26 Hu27 Hu34 Hu35 Hu36 Oa34 Oa35 Oa36	19 5	Ave Std Max Min	942 184 1231 647	1500 83 1606 1281	3681 204 3958 2938	0.63 0.14 0.82 0.41
Total Area: 323 530 Ha			Means of 48 Land Types							
Broad Soil Pattern: Lithosols with Red Soils of eutrophic base status (Mapumulo Metamorphic Suite, NmpS3)										
Glenrosa	Gs18 Gs28	45	Hutton	Hu36 Hu37 Hu46 Hu47	17	Ave Std Max Min	790 - 878 703	1441 - 1466 1417	3197 - 3222 3173	0.54 - 0.47 0.61
Total Area: 22 990 Ha			Means of 2 Land Types							

dispersed through the profile and is usually attributed to physical weathering and fracturing of quartz veins within the granitic rocks. The proportion of yellow apedal soils derived from granitic rocks is at its highest values in the Piet Retief District (Table 18.1, Piet Retief Zone, Z-Rg1). Griffin soils are dominant over the Clovelly soils. The genesis of these yellow soils is probably the result of a high (> 950 mm per annum) rainfall and misty rainfall pattern and a moderate temperature regime. The proportion of yellow apedal soils on granitic rocks decreases in the escarpment zones of northern Mpumalanga and Northern Province.

Variants of the red and yellow apedal soil pattern in the Piet Retief District have Avalon and Glencoe soils as subdominant components (Table 18.1, Piet Retief Zone, Z-Rg2). Glenrosa and Cartref soils are also estimated to occupy subdominant proportions. Other variants occupying the crestland in the Mgeni and Mvoti Valleys (Table 18.2, NmpN1) have mesotrophic red apedal soils together with the dystrophic soils, while Oakleaf and Glenrosa soils are present in subdominant proportions. The presence of mesotrophic soils could be expected with a lower effective rainfall, and a possible shorter duration of weathering. Similarities to these soil patterns derived from granitic rocks in the Mzumbe and Oribi Gorge Districts are also evident (Table 18.2, Oribi Gorge Zone, NmpS1). Distinctions derived from differences in the geological naming and mineralogy of these largely biotite granites have given rise to only limited differences in the composition of the major soil patterns developed from these rocks. Indeed the ranges and means for textural properties of the Hutton and Glenrosa profiles also shows close similarities (Tables 18.3 and 18.4).

Glenrosa soils without the presence of lime are dominant in the lithosols soil patterns (Table 18.1). Cartref soils (Table 18.1, Piet Retief Z-Rg3), and eutrophic sandy loam Hutton and Oakleaf soils, and Cartref soils (Table 18.2, NmpN2, NmpS2) are subdominant.

Lithosols with the presence of lime occur in two Broad Soil Patterns. In the Mfolozi Zone lime is generally absent in the lithosolic soils of the upland terrain positions, but is present in Swartland, Valsrivier and Estcourt soils of the lowland positions (Table 18.1, Mfolozi Zone, Zgl). However, in the marble and dolomite rocks of the Oribi Gorge Zone lime is present in soils in both upland and bottomland positions (Table 18.2, NmpS3).

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles for Hutton, Griffin, Avalon, Longlands, Estcourt and Glenrosa Forms were extracted from the database for the granitic rocks of southern Mpumalanga and KwaZulu-Natal. The ranges in textural properties (maximum and minimum values) for five particle classes, dominant sand grade, and information on the luvic properties are presented (Table 18.3). These ranges are also presented graphically (Figure 18.2). The figure allows for an overview comparison between different soil forms and over particle size classes.

The textural properties, expressed as maximum and minimum values (Table 18.3), and mean values (Table 18.4) for the Hutton and Griffin soils in the Piet Retief district show similar ranges. The profile textures lie dominantly in the sandy clay loam, through sandy clay to clay classes (Table 18.3, Figures 18.3 and 18.4). Silt values of the A1 and B1 horizons are less than 20 percent, showing a small increase in the B2 horizon where weathering may be assumed less intense (Table 18.4). The Piet Retief granite represents a relatively large uniform body of medium to coarse grained biotite granite (Geological Survey, 1988a, symbol Z-Rg). Soil formation has taken place in a warm, moist environment, giving rise to deeply weathered kaolinitic sandy

Table 18.3 Textural properties of soils of the granitic rocks of KwaZulu-Natal derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Granite of the Piet Retief District (Z-Rg)									
Hutton	A1 B1 B2	SaLm-SaClLm-Cl SaClLm-SaCl-Cl Lm-SaClLm-ClLm-Cl	13-63 28-72 19-59	6-23 2-42 12-42	9-38 6-37 11-28	4-22 1-25 4-17	2-22 1-21 2-16	fi,me,co	NL2,L3 NL1,EL4 -
Griffin	A1 B1 B2	SaClLm-Cl SaClLm-SaCl-Cl Cl	30-52 28-59 41-53	10-24 6-29 10-46	11-22 12-34 6-18	5-20 1-21 1-10	2-14 1-27 1-10	fi,me,co	NL3, L1, EL1 NL5 -
Avalon	B1	SaClLm-Cl	35-51	7-13	20-40	8-11	6-6		-
Longlands/ Estcourt	A1 E1 B1	LmSa LmSa SaLm-Lm	10-12 4-12 8-35	9-14 8-9 12-21	25-26 9-25 23-28	16-16 15-16 6-18	31-38 36-62 11-32	co co	EL L -
Glenrosa	A1 B1	SaLm-SaClLm-Cl SaLm-SaClLm-Lm	17-54 17-46	6-40 14-24	6-43 15-39	11-23 9-15	1-19 8-17	me, co fi, co	-- -
Mapumulo Metamorphic Suite (NmpN)									
Hutton	A1 B1	SaLm-Lm-Cl SaLm-ClLm-Cl	13-58 34-65	10-38 10-30	9-36 11-25	7-25 2-18	7-13 4-14	co me, co	L4,NL1 -
Mapumulo Metamorphic Suite (NmpS)									
Hutton	A1 B1 B2	Lm-SaClLm-Cl Lm-ClLm-Cl SaClLm-Cl	12-51 15-61 29-61	6-35 14-34 20-25	4-73 3-32 6-26	3-15 2-14 2-11	1-21 2-17 6-15	fi, co fi, co co	NLl3, L1, EL1 -

Luvic Properties: Explanation of symbols; L - Luvic, NL - Non-luvic, EL - Eluvic Properties. Numbers indicate relative dominance of property from occasionally (1) to dominantly(5).

clay to clay soils. The sample set of the Hutton and Griffin soils (comprising 55 analyses from the B1 horizons) could represent central reference values for soil textures derived from biotite granite in moist, highly weathered environments. It is interesting to note that the textures are dominantly of the sandy clay to clay classes. Despite the presence of quartz in the parent rock, the high component of weatherable biotite mica provides the higher potential for clay formation. The sand grades are clustered with medium and coarse sand dominant (Table 18.3, Figures 18.3 and 18.4). Despite this dominance of coarse and medium sand, the percentage values of these sand grades are generally less than 10 and 15 percent respectively (Table 18.4). Hutton soil profiles with luvic and non-luvic properties were analysed in approximately equal proportions (Table 18.3).

The Hutton profiles sampled from the Mapumulo Metamorphic Suite of both northern and southern KwaZulu-Natal have very similar properties to those from the granite of the Piet Retief District (Z-Rg). Profiles from the Mapumulo Metamorphic Suite in northern KwaZulu-Natal have been sampled from two unnamed units comprising megacrystic biotite granite and biotite gneiss (Symbol NmpN, Geological Survey, 1988c). In southern KwaZulu-Natal Hutton profiles have been sampled from six units including those described as comprising medium to coarse grained granite, biotite gneiss, hornblende gneiss, and quartz feldspar gneiss and migmatite

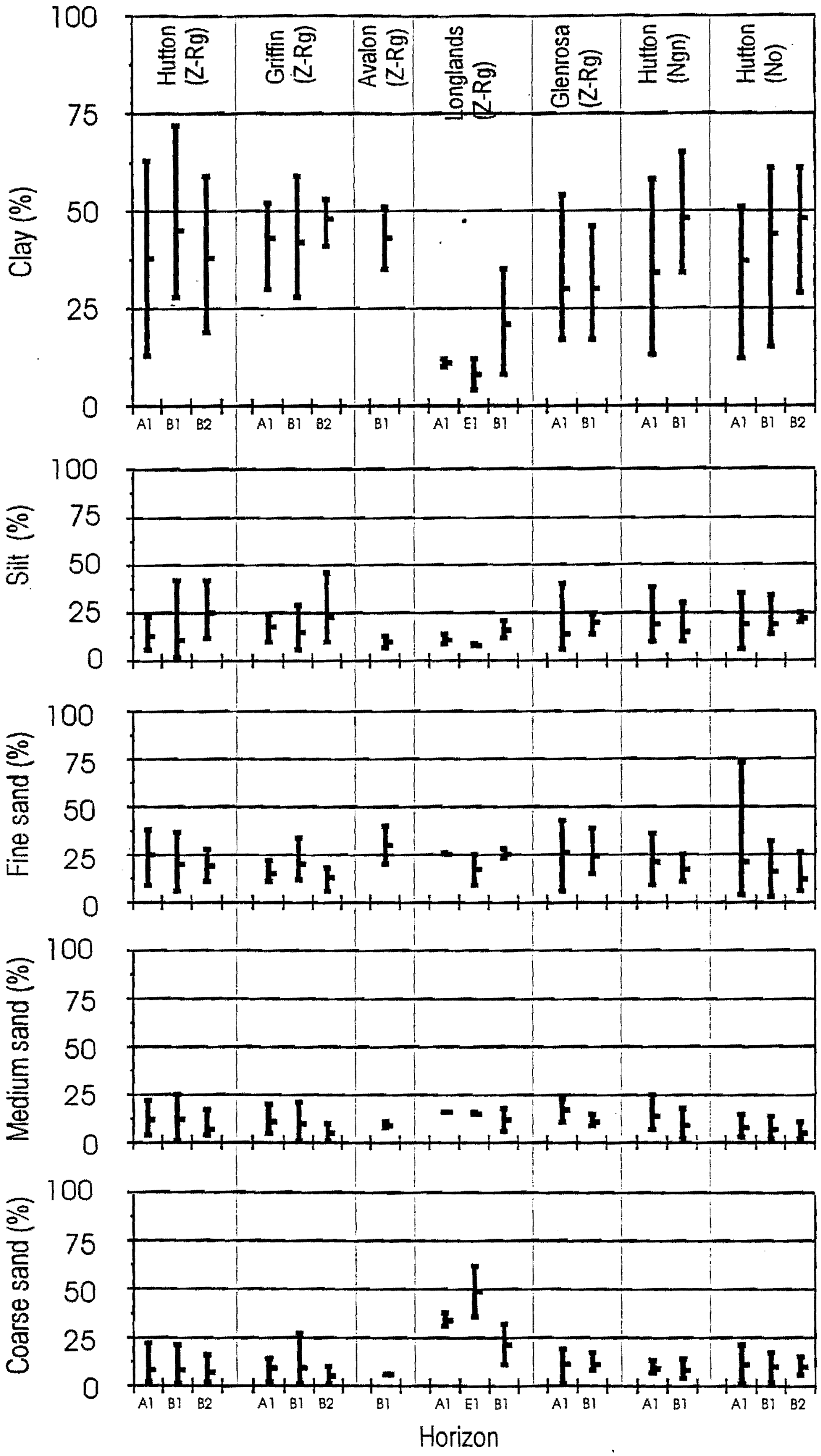

Figure 18.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of granite from KwaZulu-Natal. Maximum, minimum and mean values are shown for each horizon.

Table 18.4 Means and standard deviations of five textural classes for soils of the granite from KwaZulu-Natal.

Horizon	Depth mm	Clay % Mean	Clay % SD	Silt % Mean	Silt % SD	Fine Sand % Mean	Fine Sand % SD	Medium Sand % Mean	Medium Sand % SD	Coarse Sand % Mean	Coarse Sand % SD	Sample Size
Form: Hutton (Granite of the Piet Retief District, Z-Rg)												
A1	270	38.2	14.5	13.7	4.6	25.4	8.3	12.4	5.1	8.4	4.9	12
B1	696	45.4	10.5	11.3	8.1	20.4	6.1	12.3	6.6	8.9	4.6	40
B2	942	38.8	12.4	25.0	9.4	19.2	5.1	7.8	4.2	7.8	4.2	9
Form: Griffin (Granite of the Piet Retief District, Z-Rg)												
A1	340	43.8	8.4	18.2	5.0	15.2	4.3	11.0	5.2	9.2	4.1	6
B1	660	42.9	9.7	15.1	6.7	20.2	7.0	10.6	5.9	9.5	6.3	15
B2	1025	48.8	4.7	23.0	14.0	13.3	4.5	5.5	3.6	5.8	4.3	4
Form: Avalon (Granite of the Piet Retief District, Z-Rg)												
B1	625	43.0	8.0	10.0	3.0	30.0	10.0	9.5	1.5	6.0	0.0	2
Form: Longlands/Estcourt (Granite of the Piet Retief District, Z-Rg)												
A1	325	11.0	1.0	11.5	2.5	25.5	0.5	16.0	0.0	34.5	3.5	2
E1	595	8.0	4.0	8.5	0.5	17.0	8.0	15.5	0.5	49.0	13.0	2
B1	1455	21.5	13.5	16.5	4.5	25.5	2.5	12.0	6.0	21.5	10.5	2
Form: Glenrosa (Granite of the Piet Retief District, Z-Rg)												
A1	275	30.4	12.2	14.7	10.9	26.7	11.8	17.0	4.2	11.3	5.2	7
B1	780	30.6	9.8	20.0	2.8	24.4	9.0	11.3	2.2	11.7	2.5	7
Form: Hutton (Mapumulo Metamorphic Suite, NmpN)												
A1	500	34.0	18.5	19.7	13.0	21.0	11.2	14.0	7.9	9.3	2.6	3
B1	1011	48.6	9.0	15.7	6.1	17.4	3.8	9.3	4.8	8.0	3.4	9
Form: Hutton (Mapumulo Metamorphic Suite, NmpS)												
A1	460	37.4	11.7	19.4	7.2	21.4	17.4	8.5	3.4	11.4	5.7	14
B1	915	44.5	13.2	19.5	5.8	16.6	10.1	7.5	3.9	10.7	3.7	13
B2	1112	48.8	11.9	22.5	2.5	12.5	8.0	5.8	3.6	10.8	3.5	4

(Symbol NmpS, Geological Survey, 1988d). Generally there are insufficient profiles sampled from each geological unit (Geological Survey, 1988c, 1988d) to list these texture data separately. The texture values of component units of the Mapumulo Metamorphic Suite (Tables 18.3 and 18.4) are grouped to give composite mean values. The sampled profiles are all of the Hutton Form and of dystrophic or mesotrophic base status and with kaolinitic weathering. The soil forming factors of climate and time are assumed reasonably constant. There does not appear to be differences in textural properties resulting from these differences in geological materials.

The texture properties of the Avalon soils sampled from this area fall within the same textural range as determined for the Hutton profiles (Tables 18.3 and 18.4). As the sample size is small, these data should not be extrapolated to other plinthic zones on granitic rocks.

The textural properties of the Longlands and Estcourt soils (those soils with an E Horizon) are sharply different to those of the Hutton soils (Tables 18.3 and 18.4). Although the sample size is limited (the reason for grouping of Longlands and Estcourt soils) the textures of the A1 and E1 horizons are of the loamy sand class. Coarse sand is dominant. The texture class for the B1 horizons of the Longlands and Esctourt soils are loamy sand and clay loam respectively (Table 18.3).

The texture range of the Glenrosa soils is relatively large (Table 18.3). Whilst the central class is sandy clay loam, profiles with clay and with sandy loam classes were also determined (Figure 18.6). Sand grades are both medium and coarse.

The range of soil forms that have been sampled is somewhat limited, with sampled profiles drawn largely from only the Hutton, Griffin and Glenrosa Forms. Profile values are grouped per soil form and district on the assumption of there being relative uniformity within a restricted locality with respect to parent material, weathering intensity and topography. This is reflected in the texture and base status data. The Hutton and Glenrosa profiles from the Piet Retief District (Z-Rg), and those of the Mapumulo Metamorphic Suite (NmpN, NmpS) have developed essentially clay and sandy clay textures (Table 18.3). The very limited sample set of soils having an E horizon have coarse loamy sand textures (Table 18.3). While this data is characteristic of the granite soils of KwaZulu-Natal, it does not represent the broader picture. The range of soil forms and textural properties is known to be greater than this.

Granites and granodiorites cover extensive areas of the Lowveld of Mpumalanga and Northern Province. Granitic rocks extend from the Crocodile River in southern Mpumalanga to the Soutpansberg in Northern Province. Their extent is bounded in the east by the Lebombo Mountain Range and approximately by the escarpment in the west. The 1: 1 million geological map of South Africa (Geological Survey, 1970) describes this map unit as the Transvaal Belt of granitization and metamorphism. Subsequent editions (Geological Survey, 1984) describe a number of units including the Nelspruit, Kaap Valley and Mpulusi Granites in the south, an unnamed granite in the central belt, and the extensive Goudplaats Granite in the north. Soil profiles sampled from this extensive granitic body include red and yellow apedal soils, plinthic soils, duplex soils and lithosols. A selection of Hutton and Glenrosa profiles from this sample set has been chosen to reflect the greater range of soil textures in these two soil forms. The Hutton soils from the Goudplaats Granite (Symbol Zgo) (Geological Survey 1985c, Geological Survey, 1986a) have a textural range from loamy sand through to clay (Table 18.5, Figure 18.8), while those for the Glenrosa soils are dominantly sand through sandy loam to sandy clay loam. Two Glenrosa profiles were measured to have a clay texture (Figure 18.8). Sand grades range from fine to coarse. The range for the Hutton and Glenrosa soils on the gneiss component of the Nelspruit Suite (Symbol Znm) (Geological Survey, 1986b) is much narrower (Table 18.5, Figure 18.8), and reflects essentially soil texture clusters in the sand to sandy loam classes. Individual profiles of the Hutton Form were recorded in the clay class (Table 18.5, Figure 18.8).

Table 18.5 Textures of Hutton and Glenrosa soils derived from granitic rocks of the Goudplaats Granite and Nelspruit Suite.

Form	Horizon	Texture Class	Sand Grades
Goudplaats Granite (Zgo)			
Hutton	A1	LmSa - Cl	fi, me, co
	B1	LmSa - Cl	me, co
Glenrosa	A1	Sa - Cl	fi, me, co
	B1	LmSa - Cl	fi, me, co
Nelspruit Suite (Znm)			
Hutton	A1	Sa - Cl	co
	B1	Sa - SaLm, Cl	co
Glenrosa	A1	Sa - LmSa	co

The Hutton soils in the Piet Retief District have developed in a humid climate, while those from the Nelspruit District have developed in a semi arid climate. Soils from the Goudplaats Granite occur over a wider range of climatic conditions. This would suggest a relationship between estimates of climate and soil texture properties. The sum of exchangeable cations (S/clay Ratio) or the cation exchange capacities (CEC/clay Ratio) expressed as a ratio of the clay content are commonly measured parameters expressing weathering intensity and climate (Soil Classification Working Group. 1991, ISSS, ISRIC, FAO. 1998, Soil Survey Staff. 1999). Graphs of the clay percentage against S/clay Ratio reveals an interesting trend (Figure 18.9). The graphs are for Hutton soils derived from granitic rocks from KwaZulu-Natal, Mpumalanga and Northern Province. The dystrophic soils (S/clay Ratios < 5) are concentrated in the clay region, with an absence of sandy textures. S/clay ratios of greater than 15 (eutrophic soils) have clay percentages less than 35 percent (sandier than sandy clay loam), while S/clay ratios of greater than 40 have textures sandier than sandy loam. The trend for the CEC/clay ratio plotted against clay percentage is very similar.

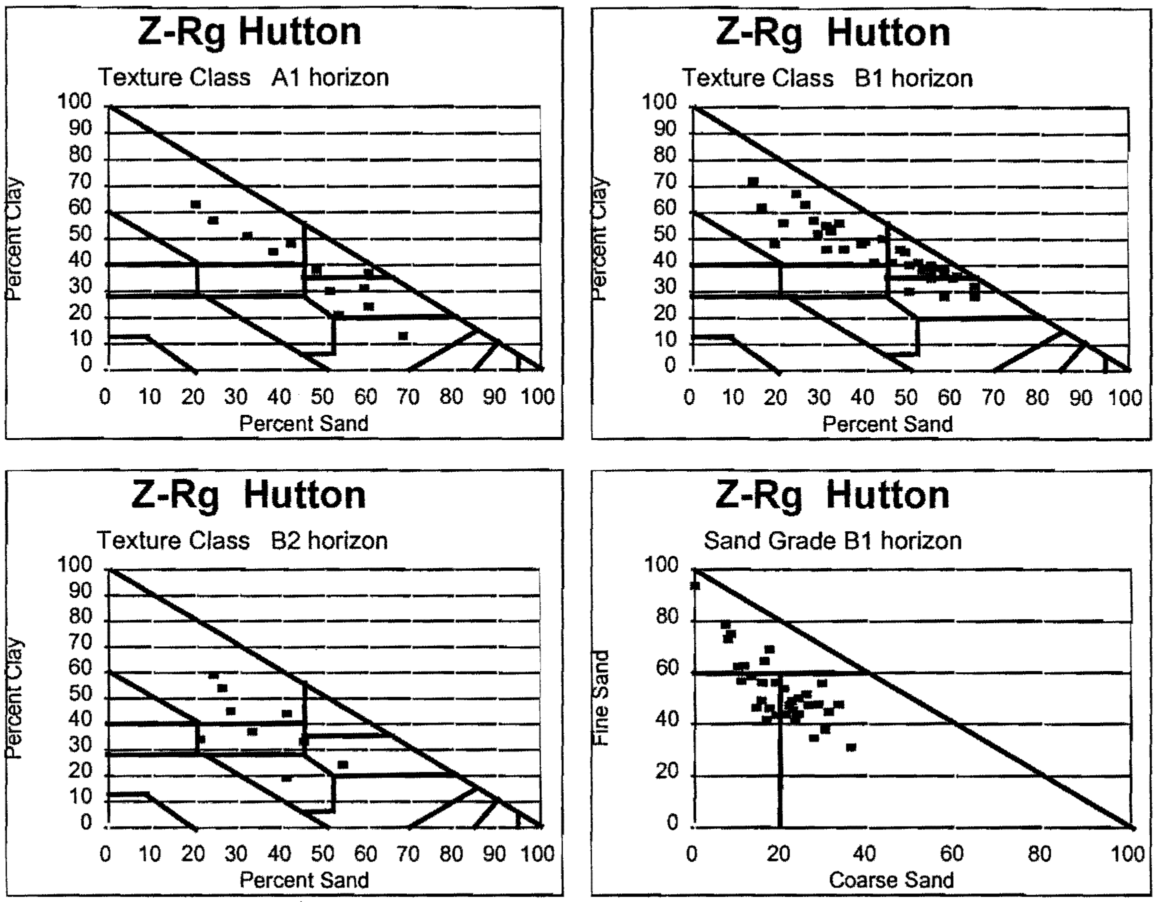

Figure 18.3. Distribution of soil textures, and dominant sand grade, within soils of the Hutton Form.

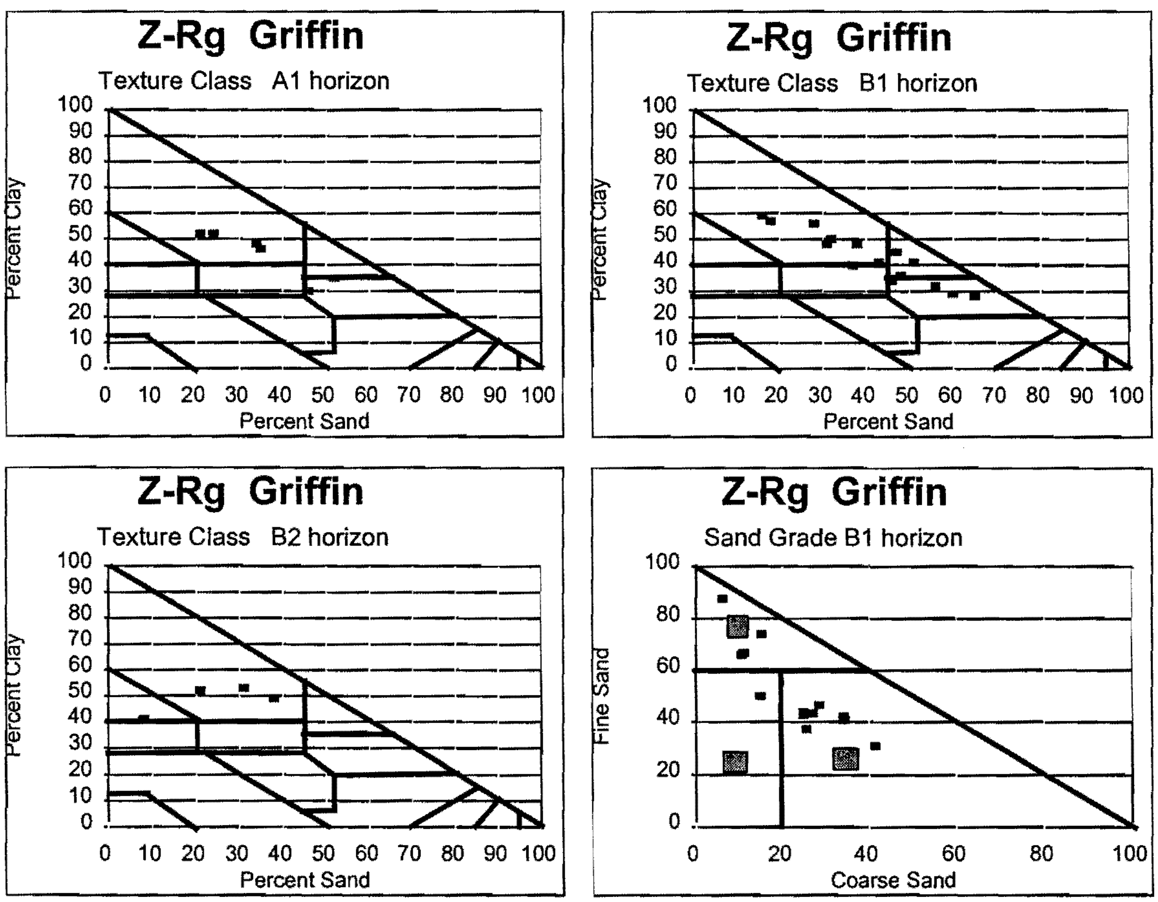

Figure 18.4. Distribution of soil textures, and dominant sand grade, within soils of the Griffin Form.

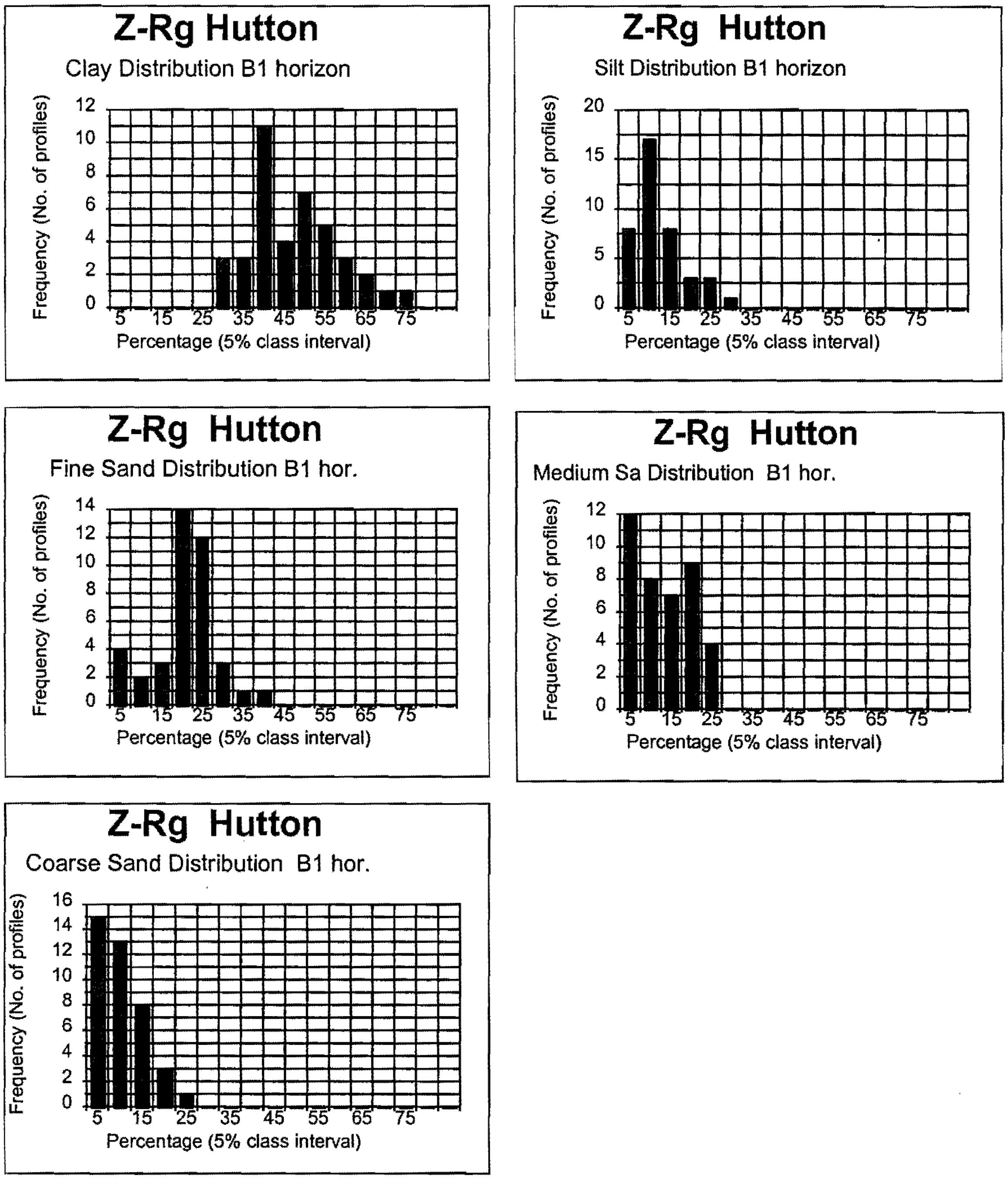

Figure 18.5 Distribution of clay, silt, fine sand, medium sand and coarse sand within soils of the Hutton Form.

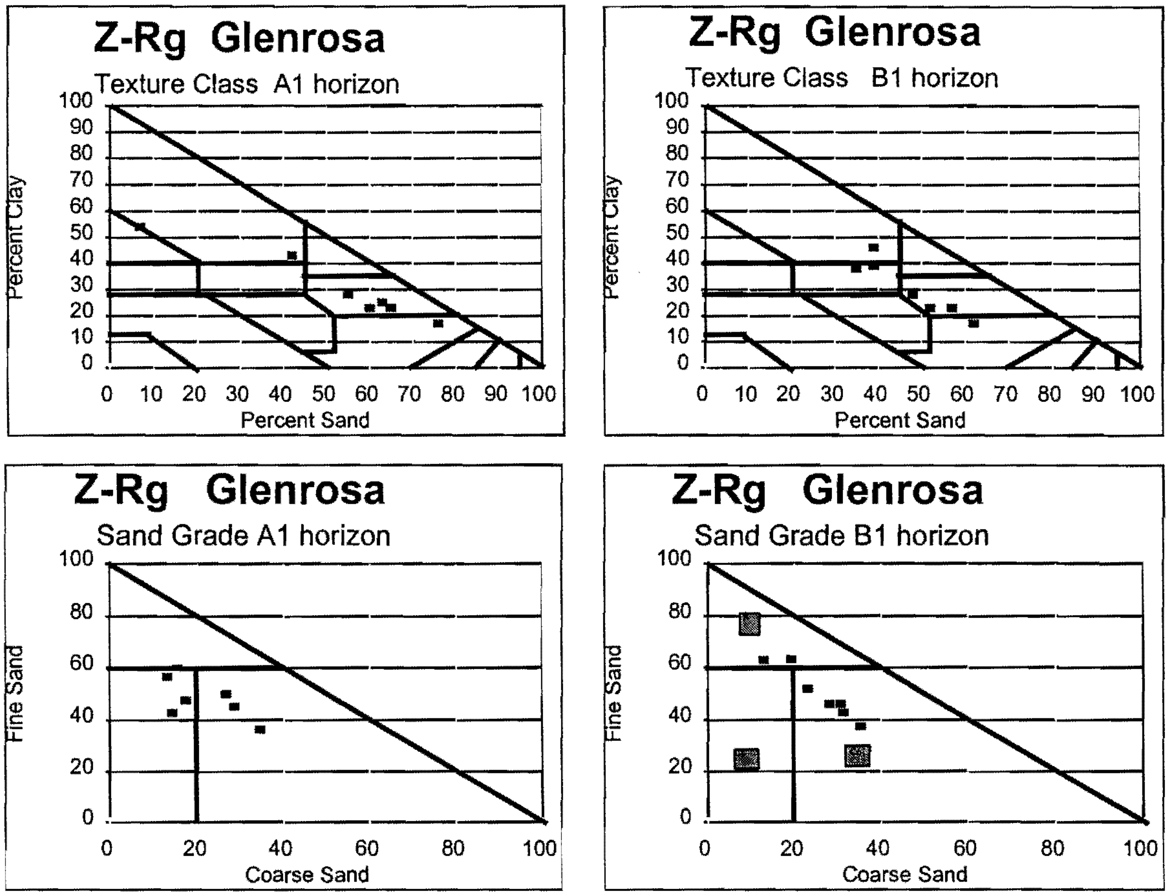

Figure 18.6 Distribution of soil textures, and dominant sand grade, within soils of the Glenrosa Form.

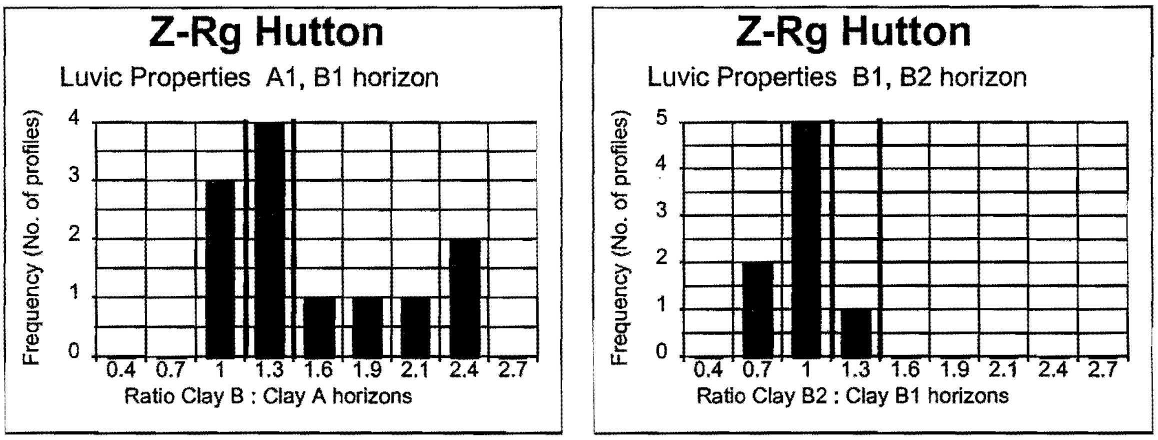

Figure 18.7 Luvic properties of soils of the Hutton, Griffin and Glenrosa Forms.

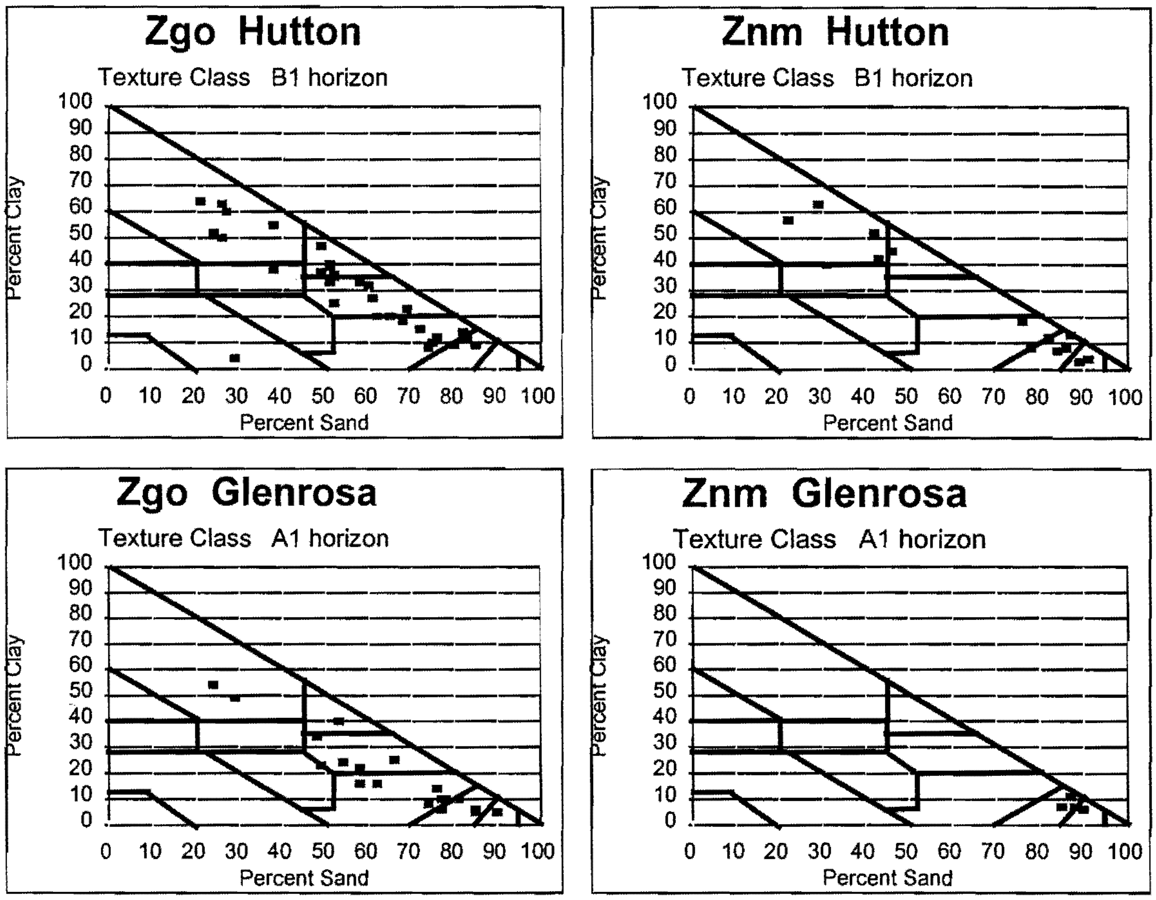

Figure 18.8 Distribution of soil textures within soils of the Hutton and Glenrosa Forms derived from Goudplaats Granite and from a omponent of the Nelspruit Suite.

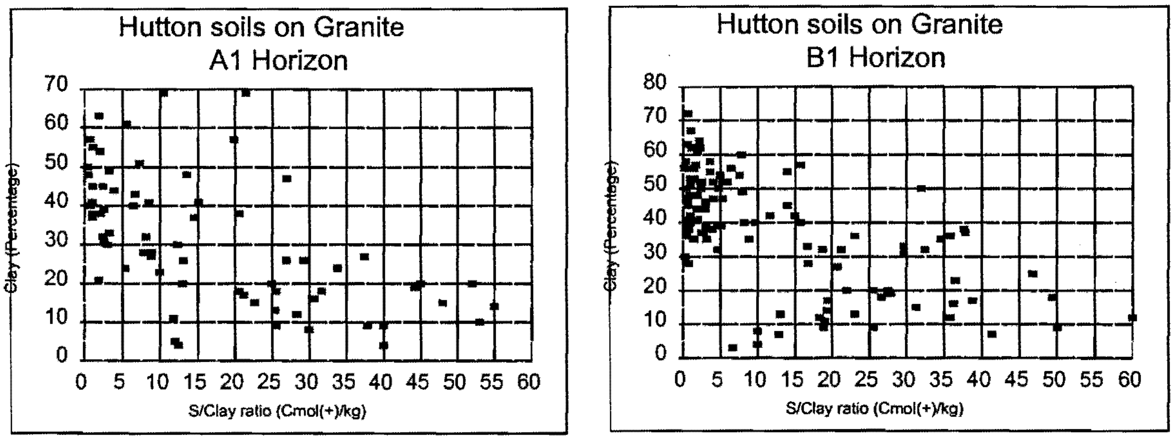

Figure 18.9 Distribution of clay percentages relative to S/clay ratios of Hutton soils derived from granitic rocks in KwaZulu-Natal, Mpumalanga and Northern Province.

CHAPTER 19

APPROACHES FOR THE RECOGNITION OF NATURAL SOIL BODIES

Recognition of natural soil bodies within the soil form classification class

A natural body could be defined as a collection of soil individuals that are more similar to each other than to the soils that border them. This is also the basis of soil classification. The debate concerning natural soil bodies would seem to centre around creating close fitting soil groupings that generally reflect sharp changes in soil landscapes. These groupings should be perceived as representing useful groups of like soil individuals by those who study and use soils.

Soil profiles currently classified to soil form, family or series represent groupings within a classification class. They should also become recognised as natural soil bodies reflecting the influences of natural factors on their formation, properties and position in the landscape. Finally they should also be recognised for their interpretative and administrative value. They often have an acceptably narrow range of variation and demonstrate similar measurable properties. The soil form classification class provides a common basis upon which interpretations for land use decisions can be made. They also reflect strong similarities in our understanding of the processes that have given rise to their genesis.

There is a need to recognise soil forms as natural soil bodies in addition to their taking on the general properties of the soil form. This recognition as natural soil bodies implies beginning to associate the soil forms with defined locations, geology formations, geomorphological positions and climate properties. In addition this will imply that the range of variation of soils classified to a single soil form and falling within a given natural soil body will be more limited than all soils classified to that soil form. Glenrosa soils derived from coarse grained granite have strong similarities with one another but differ from Glenrosa soils derived from tillite of the Dwyka Formation. Each should become recognised as a natural soil body by virtue of the identifiable changes in boundary conditions at the soil form and at the subordinate soil classification classes. It could also imply using soil forms and appropriate family or series classification levels in administrative functions. The characteristic relationship between soil forms and geology formations is documented in this thesis. Detailed information is presented in Chapters 4 to 18 with summary information collected in Chapter 3.

Natural soil bodies and point soil information sources

The approaches to recognising natural soil groupings, particularly with regard to soil texture has followed two courses. The first has been to group soils about a central concept or range of properties. This grouping could be described as a grouping from within. The extremities of the range of a property were commonly defined by a sharp change in that property or from the extent of sampling. Conceivably the boundary could progressively change as additional information is gained. The boundary values appear to be strongly influenced by location and extent of sampling. Examples are probably the early soil series of the United States of America. The early soil series of the KwaZulu-Natal Coastal Belt did not have boundaries defined as much by property values, but by the extent of the underlying geology formation. This approach has undoubtedly conveyed much valuable information and facilitated soil and land management practices. Traditionally these valuable classification tools have been structured and interpreted by a relatively small group of specialist researchers. The major limitations in this approach are that the information may not be specific enough to meet all the current information needs. The range of property values may be large or the boundary values may lack clear or reproducible values. Classes that are established must be clearly defined to promote their consistent application by all soil users.

Alternatively, when viewed from a broader national perspective the approach to soil classification has been to determine acceptable threshold limits to a soil property. Classes at the family and series levels may cut across natural soil bodies, but would provide classes that can be consistently applied by a wide range of persons. It must be assumed that these limits are set with a specific purpose in mind.

The future strategy would seem to lie in a progressively improved understanding the range of variation of soil properties. Classification forms an integral part of this understanding. Soil scientists should however recognise that procedures to account for ranges in property values, or alternatively for point data sources, will also become necessary to meet future information needs. The understanding of the range in variation of soil properties is central to the future definition of natural soil bodies. Consideration should be given to all soil properties, not necessarily only those chosen to represent threshold values in soil classification classes. In this way the range of properties within a natural soil body (or even within arbitrary defined classes where these are retained) will become known. Programs aimed at establishing natural soil bodies will be beneficial. They should be supported by a full spectrum of persons who could supply expertise and information. The programs should also focus on progressively documenting point soil profile information. Efficient storage and retrieval of this point information are also essential if a program to define natural soil bodies were to be effective. It would seem that natural bodies must be stratified according to some criteria restricting locations. The geology formation has been shown to be one criterion that is effective. Other criteria may also be used. A defined range in variation in individual soil properties would then represent the further subdivisions giving rise to natural soil bodies.

The natural body concept, or soil taxonomy classes with defined though arbitrary limits, represent effective ways of transferring soil information in a qualitative and semi-quantitative manner. Where the need for more precise information is indicated, qualitative assessment followed by quantitative modelling approaches will be required. However, detailed distributions of point data and precise models capable of handling quantitative soil response functions will be required. The soil information needs will range from those requiring useful descriptive classes through to precise soil response functions. The information on soil property values of natural soil bodies will provide an integral part of these information needs.

The interpretation of soil attribute values in natural soil bodies

Well-defined natural soil bodies could be identified and the range of textural properties determined. Means and standard deviation values can be estimated. These estimates provide a measure of the precision when using attribute values for interpretations or when used in models. Similarly the maximum and minimum values of those attribute values can be determined which will give broad overview perspectives. The use of natural soil bodies in this way could have considerable advantages. It introduces the concept of variation within a soil classification unit and within the chosen stratification criteria. As soil databases become more accessible, this provides a real option to understanding and managing soil variability. It should provide a measure of soil variability where access to large volumes of point values is not available.

Two problems should be noted in a quest to use these natural soil bodies for interpretation of soil attribute values in the same way those arbitrary soil series boundaries were previously used. Firstly, in many instances the textural ranges are much wider than has been traditionally accepted in soil series class. This places limitations on the practical usefulness of natural soil bodies when interpretations using a class interval approach is preferable. This class interval approach has been favoured in many of the qualitative land evaluation systems. The quantitative approaches are expected to be increasingly used in future land assessments. Indeed, a qualitative screening followed by quantitative approaches seems to have much promise in soil and land assessment. Where the ranges in soil attribute values are large, arbitrary chosen threshold values, used in combination with the natural boundaries, could improve this situation when defining soil series.

The second problem is that definite, often large overlaps in attribute values occur between different natural soil bodies. A given combination of sand, silt and clay will seldom belong to a single, mutually exclusive natural soil body. Alternatively, if the starting point were a given combination of sand, silt and clay, then it could conceivably be assigned to more than one natural soil body. Guideline procedures based on preferred factors would be required in assigning the soil to a given natural soil body. These factors could be geology (as used in this study), climate, location or some similar criteria. Finally, if the path of natural soil bodies, as opposed to arbitrary chosen threshold values is preferred, then the concept of single mutually exclusive entities should be dispensed with.

Threshold values for soil properties

Objections to the arbitrary, but practically useful, textural limits adopted in Soil Classification: A Binomial System for South Africa (MacVicar *et al.*, 1977) became an important consideration in not formally defining soil series in the revised soil classification system (Soil Classification Working Group, 1991). The notion that a limited range in soil variability, in this case soil textural variability, existed in natural soil bodies was a further consideration. The concept that a soil property value should not extend beyond the defined class limit implied that soil series as previously defined (MacVicar *et al.*, 1977) often divided natural soil bodies. This type of artificial subdivision was much less evident at the soil form level. The class limits set for the soil form level generally exhibited sharp changes in property values that are accepted as separating different soils. The concept of a soil property value extending beyond the class limits has been addressed only informally in South Africa. Strictly the definition of any class should apply. However, the classification has recognised morphological properties (which do not always lend to precise measurement) to be important in the classification process and placed emphasis on infield decision making to determine classes. This is one of the strengths of the South African soil classification system and it should be retained as far as possible. This does not imply that laboratory analyses should not be used. They should rather fulfill a supporting role. Furthermore, persons classifying soils should be urged to use their judgement in placing soils in classes, particularly where intergrades are apparent. The classification class that is chosen should reflect the best information message that can be conveyed to land users. This should best reflect the dominant features that are exhibited in the profile morphology and any soil analysis. The need for these persons to classify soils to the appropriate classes is indeed important where only limited soil correlation is possible.

In defining natural soil bodies the concept of the control horizon would need review. This concept is extensively used in Soil Taxonomy for recognition of the family and series classification classes (Soil Survey Staff, 1999). It is specified for the soil properties under review as being the depth below the mineral soil surface, or the depth to the upper boundary of a root-limiting layer. Keys define the control section classes for family and series differentiae routinely used in Soil Taxonomy (Soil Survey Staff, 1999). Particle size and mineralogy classes are listed first and second respectively, indicating their relative importance in defining soils to these taxa. The concept of a control section has precedent in Soil Classification: A Binomial System for South Africa (MacVicar *et al.*, 1977). The control horizon gives prominence to the properties of a defined horizon. It would seem important in evaluating which properties should be considered diagnostic. Where numerical differences between properties of horizons indicate that the soil may be placed in more than one classification class, preference should be assigned to the defined horizon. In defining natural soil bodies attention should be directed at whether the properties are measured in the A, E or B horizons. The Soil Classification Working Group (1991) has defined the surface horizon to be important in describing soil texture. In this study prominence has been assigned to the B and the E horizons. They are recommended to retain significance as control horizons. However, the decision to use these horizons in this study has largely been a pragmatic one. There was simply more data available for B and E horizons, than their corresponding A horizons.

The problem of soils having measured soil property values beyond the defined limits will increase as natural soil bodies are defined. There are many examples of soils within a restricted geographical area having dominantly fine and medium sands without there being clear distinctions between soils exhibiting these sand grades. Similarly, soils within a natural entity having base status values extending on either side of base status class limits have been reported. In these cases the class limits (dominant sand grade, base status) has shown their practical usefulness and do not necessarily require alteration. Clearly, guidelines to accommodate these situations should be established. The concepts of limiting the number of natural soil bodies to those which can be clearly defined and which are dominant in the South African soil mantle seems to hold promise.

Accommodation of silt in natural soil bodies

The distribution of silt (0.02 to 0.002 mm) for the soils of each geological formation of KwaZulu-Natal and Mpumalanga has been summarized in Chapter 3. Silt values have generally been recognised as low, with values of between approximately 2 and 45 percent being measured. The silt values for the soils derived from the sediments of the Vryheid Formation, Ecca Group; the Natal Group (formerly Table Mountain Sandstone) and the Quaternary and Cretaceous Sediments are generally low. The silt values for soils derived from granite are similarly low. The values range from less than 10 percent in the sand texture class to about 15 to 20 percent in the sandy clay loam class. Soils in the sand to loamy sand texture class seldom contain more than approximately 10 percent silt. The portion of the texture triangle with silt values greater than 10 percent silt is not representative of the soils of KwaZulu-Natal and Mpumalanga. The description sand or loamy sand is misleading as it also includes silt values considerably higher than were regularly determined. In the sandy loam texture class silt values of commonly less than 15 percent, and in the sandy clay loam texture class less than about 20 percent were determined. Profile textures are consistently located in only a small portion of the sandy loam class making the use of these texture descriptions misleading as well.

Soils derived from sediments of the Beaufort Group had textures located through the sandy clay loam, loam, clay loam and clay texture classes. Soils derived from these sediments are represented by intermediate clay contents (20 to 75 percent) and by higher silt contents (15 to 45 percent). Clay contents of red and yellow-brown apedal soils ranged from 20 to 45 percent in the Tarkastad Formation and from 30 to 75 percent in the Estcourt Formation and Adelaide Subgroup respectively. The clay contents for soils with an E horizon were lower.

Soils derived from Jurassic dolerite and basalt fills the clay texture class. Ranges in clay content are from about 30 to 80 percent were recorded. Silt values range up to about 40 percent making this boundary (40 percent silt) between the clay and silty clay classes relevant. The 40 percent silt value could however, be extended into the clay loam class. Soil textures in the sandy clay class were recorded, but tend to be better associated with the textures of natural soil bodies from the clay or from the sandy clay loam classes. The sandy clay texture description appears of limited significance for these soils.

A modified textural triangle (Figure 19.1) is proposed that may provide useful textural descriptions for the soils of KwaZulu-Natal and Mpumalanga. Subdivisions of clay percentage

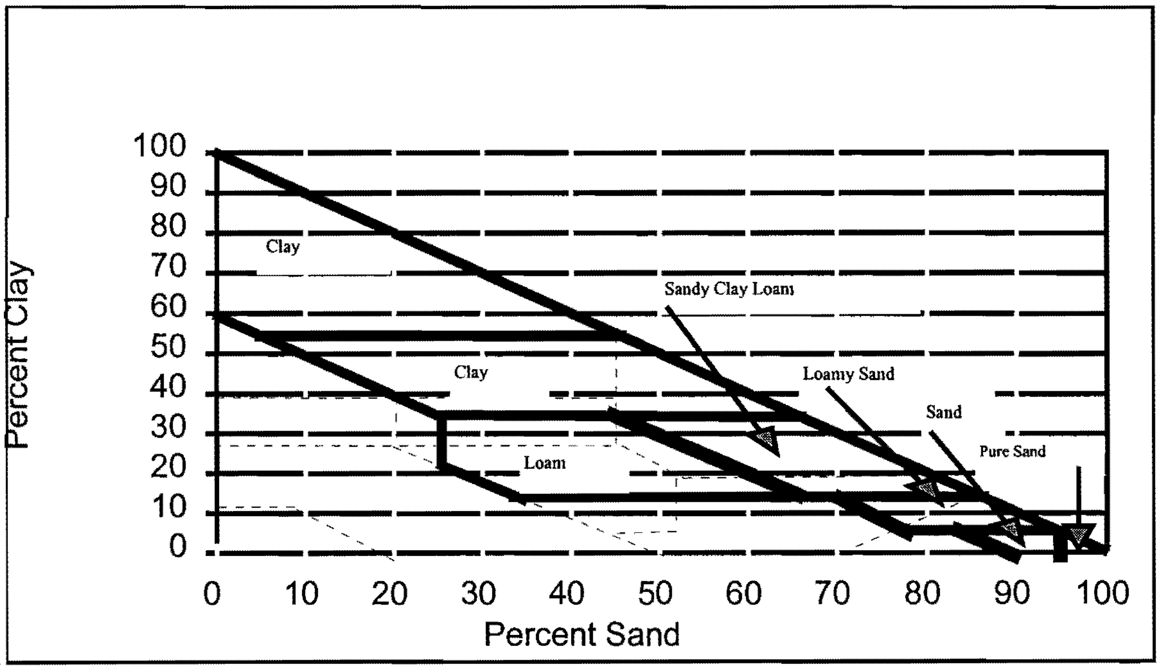

Figure 19.1 A practical textural diagram to describe the soils of KwaZulu-Natal and Mpumalanga.

have been widely used (MacVicar *et al.*, 1977) in soil survey reports in South Africa. These arbitrary subdivisions have been retained in view of their regular use and familiarity to soil surveyors. Silt boundaries are set to accommodate the soil textural analyses determined for these provinces. The classes accurately reflect particle size compositions from soil analyses. They may also bring a level of simplicity to practical soil surveys by combining silt threshold values with the widely used clay percentage subdivisions. Textures outside these classes were rarely encountered and could largely be ignored.

Summary statements concerning natural soil bodies

* Natural soil bodies at the soil form level of classification can be regularly identified for defined geological formations.

* Natural soil bodies according to soil texture could be identified using geology and soil form as selection criteria. Such natural soil bodies appear reasonably unique and consistent for a given geological formation.

* Stratification of some kind would appear necessary if the natural body concept is to have practical significance. This stratification would be to limit the extent of the locations from which soil profiles may be drawn in order to qualify for inclusion in that natural soil body.

* Boundary values for natural soil bodies expressed on a textural basis are not mutually exclusive. The boundaries regularly overlap when considered over different geology formations. This overlap in textural boundaries is less apparent when considered over different soil forms but still within the same geological formation.

* These boundaries tend not to coincide with the arbitrary, but convenient to use clay only boundaries applied in the 1977 definition of soil series.

* Ranges in maximum and minimum values for texture have been identified. They provide a basis for recognition of natural soil bodies at this level of soil classification.

* The classical boundaries for soil textural classes as traditionally established in the literature appear to hold only limited significance for the actual boundaries determined from soil analyses for this study area. This is particularly apparent for the sand to sandy loam textural classes. Modifications to these classes could be useful for South African soils.

* An administrative procedure should be established to recognise natural soil bodies. The procedure should be fully supported by all persons who could supply expertise and information. The procedure should also focus on progressively documenting point soil profile information in electronic and standard formats.

* The nature of the underlying materials of soils has traditionally been considered important in agriculture, forestry and engineering. Presently there is no formal treatment of underlying materials by the classification, although an indication of underlying materials is given in certain soil forms. The nature of the underlying materials may be incorporated into the classification via their influence on soil texture within the natural body concept.

Procedures for the collection of information on natural soil bodies

The concept would be to promote the description in scientific terms of natural soil bodies making up the South African soil mantle. Description would be at roughly the series level of abstraction. The defined natural soil bodies should also lend themselves to a large number of land use interpretations. They may be derived from existing data or new data. The examples quoted in this document are strongly associated with geological formations or place defined localities. The essential information and procedures should include:

* Profile descriptions including site information (usual position in the landscape, probable parent material) and horizon information.
* An indication of the spatial extent of the natural soil body and geographic location of type sites.
* A classification of the natural soil body within the South African Soil Classification Systems (MacVicar *et al.*, 1977; Soil Classification Working Group, 1991), the USDA Soil Taxonomy (Soil Survey Staff, 1999) and the World Reference Base for Soil Resources (ISSS, ISRIC, FAO, 1998). Classification to other international systems may also be useful.
* Comprehensive soil analyses using recognised standard analytical methods should be applied (Non-Affiliated Soil Analysis Work Group, 1990; Soil Survey Staff (USDA), 1996c; Brunt and Van Reeuwijk, 1995).
* Data storage in electronic or paper formats is recommended.
* Publication and distribution of material are recommended. Contribution of information on natural soil bodies should add to our public information sources.
* Central and Regional Administering Authorities is recommended.

While textural considerations have received most attention in recognising natural soil bodies, other criteria could also be considered. These criteria could include the following:

* Nature of the underlying geological formation,
* Coarse fragments,
* Duration of soil water saturation,
* Signs of wetness,
* A narrower range of those soil properties used at higher levels of classification. These properties could include thickness of horizons, organic carbon content, base status, plasticity index, colour and others. The classes would be chosen to give improved interpretative properties.
* Mineralogy properties,
* Measured values of certain chemical elements that differ appreciably from a standard value or ranges and beneficially of adversely affect plant growth or human and animal health.