CHAPTER 7

SOILS OF THE BASALT OF THE DRAKENSBERG FORMATION IN KWAZULU-NATAL

Location and Extent

Within KwaZulu-Natal the Drakensberg Formation occupies a relatively narrow and steep belt along the high Drakensberg escarpment with altitudes often exceeding 3 000 metres. Beginning in the north from about the provincial boundary with the Free State, and with the Lesotho border in the west, it runs south east to the Giants Castle buttress where it attains its maximum width. It then turns south to Sani Pass and south west to Bushmans Neck. South of Sani Pass it occupies only a narrow stretch of the high escarpment. However, south of the southern Lesotho border the formation occupies relatively large areas of the Barkly East District. The formation also occupies extensive areas of the mountain Kingdom of Lesotho (Figure 7.1).

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

The Drakensberg Formation lies as the upper most strata of the Karoo Sequence and comprises basaltic lava. The early recognition of these lavas placed them in the Stormberg Beds (SACS, 1980), while the name Drakensberg Beds later replaced the Volcanic Beds of the Stormberg Series (SACS, 1980). In the main Karoo Basin the name, basic concept and boundaries of the original "Drakensberg Beds" remain unchanged with the name Drakensberg Formation being applied (SACS, 1980). The formation comprises basaltic lava, with subordinate fine-grained sandstone and agglomerate (Geological Survey, 1981a, 1981b).

The basaltic lavas capping the Karoo succession in the Springbok Flats, and the succession of volcanics of the Lebombo Mountain Range were also recognised in early geological reports. In the 1970 edition of the geological map of South Africa the lavas of the Lebombo Range and of the Springbok Flats were correlated with the lavas of the Drakensberg Group (SACS, 1980). In view of uncertainties in the correlation of these basic and acidic lavas independent formation names have now been assigned to the main lithological units of the Lebombo Group. The lava extending from the Lebombo Range to the Soutpansberg and the Springbok Flats is now named as the Letaba Formation and forms part of the Lebombo Group (SACS, 1980).

Partridge and Maud (1987) describe the geomorphology of the greater part of the basalt zone of the Drakensberg Formation within KwaZulu-Natal and the Eastern Cape Province as escarpment separating the elevated interior from the coastal hinterland. Further to the interior within Lesotho the mountainous areas are considered to be above the African Surface (Partridge and Maud, 1987). Remnants of the old Gondwanaland landsurface are preserved on the flat-crested mountains of Lesotho, while remnants of subsequent surfaces are evident as spurs protruding from the high Drakensberg (King and King, 1963). A detailed explanation of the geomorphology of KwaZulu-Natal is given in van der Eyk, MacVicar and de Villiers (1969).

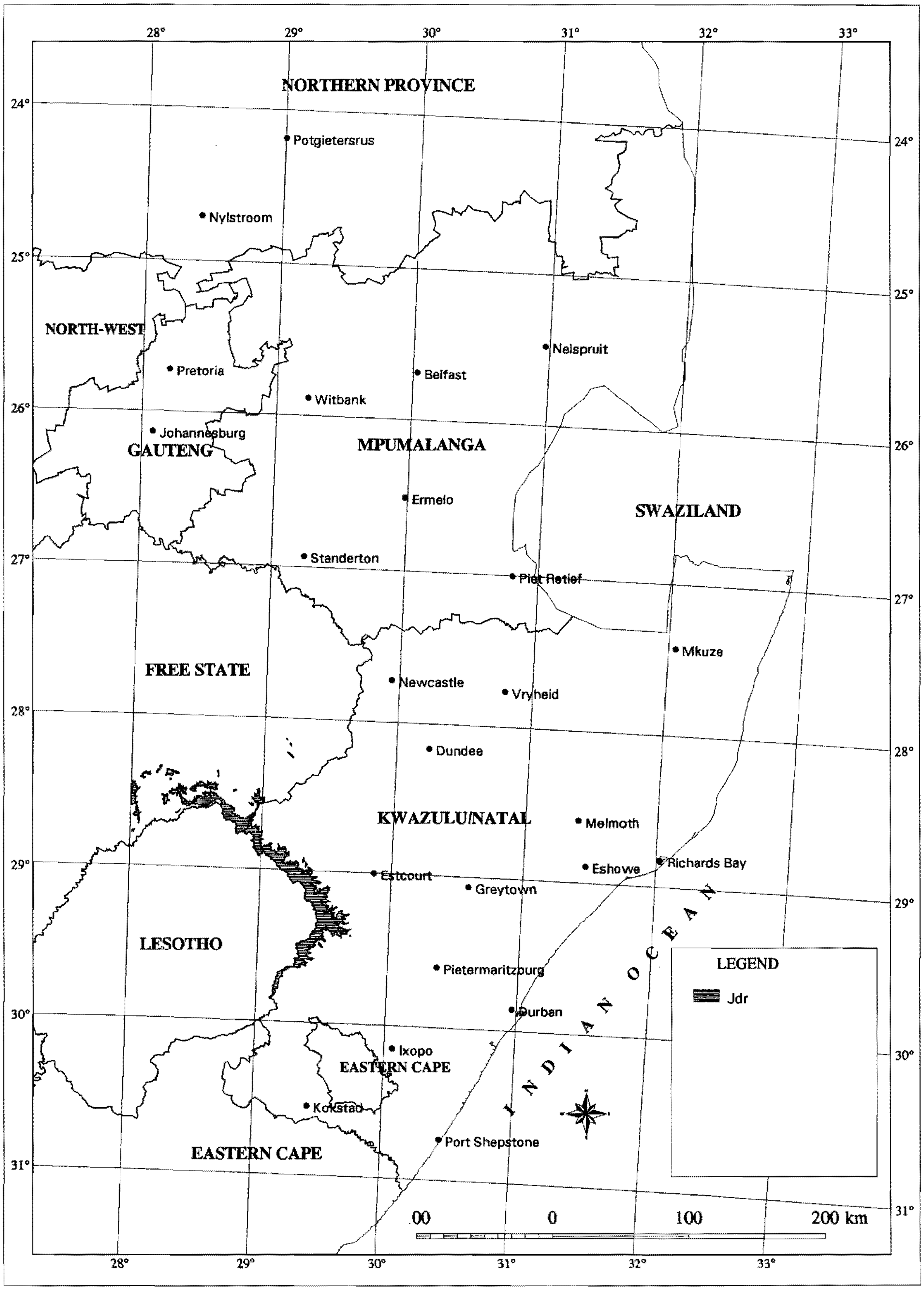

Figure 7.1. Location of the Drakensberg Formation in KwaZulu-Natal (after Geological Survey, 1984).

Physiography and Drainage Features

The basalt of the Drakensberg Formation occupies the narrow belt of steep land along the high escarpment. This area is described as comprising high mountains (Kruger, 1983) with high relief, and only very limited areas with slopes of less than 5 percent. Stream density is described as medium to high (Kruger, 1983) with drainage via the headwaters of streams and rivers feeding the Tugela, Mkomazi and Mzimvubu Rivers.

Vegetation

The vegetation is described at the high altitudes as Alti Mountain Grassland by Low and Rebelo (1996), while at the lower altitudes in the south of the zone it is described as Moist Upland Grassland, and in the north of the zone as Wet Cold Highveld Grassland.

Soils

Four major soil patterns are evident on the basalt of the Drakensberg Formation (Table 7.1). These are a yellow-brown and red apedal soil pattern with generally low base status, a red apedal pattern with high base status, black clays and lithosols.

The yellow-brown and red apedal soil pattern has a generally low base status, although intermediate to high base status soils are also present. These soils have developed from base rich basalt material in a cool to a cold climate, and with high rainfall. The weathering intensity is expected to be relatively high. However, in the incised and steep terrain of the high Drakensberg Mountains erosion from the soil mantle is relatively high. This erosion is reflected in the generally shallower soil depths of these yellow-brown and red apedal soils. However, interesting differences in the particle size distributions, base status variations and organic carbon values are evidence of the intense, but youthful weathering regimes. Furthermore, these soils differ from the highly weathered red and yellow-brown soils commonly encountered on the dolerite and other basic lavas. In the latter soils, depth can be much greater, clay contents greater and uniform throughout the profile, and low base statuses are properties reflected by a longer period of soil weathering. Mispah, Nomanci and Glenrosa soils, with rock is subdominant in this pattern.

Red apedal soils with high base status were recorded over a limited area (Table 7.1). In this pattern there is an absence of yellow-brown apedal soils, while Milkwood and Mayo soils are subdominant. Higher temperatures may be inferred form the absence of yellow soils, while the presence of melanic soils would indicate lower rainfall. This is confirmed from the climate information (Table 7.1). Regrettably heat units (a summation of temperatures) are not available for the yellow and red apedal soil pattern (Table 7.1). However, heat units for the red and yellow apedal soils of Karoo dolerite could be used as a reference value (Heat Unit = 2171 degree days for red and yellow apedal soil pattern). The heat unit values of the red apedal soils of high base status are then higher (Table 7.1). The location of this soil pattern in the upper reaches of the Mkomazi River Valley confirms the lower leaching status, lower rainfall and higher temperatures for this soil pattern.

Table 7.1 Dominant soils and selected climatic information for soil patterns occurring on Drakensberg Formation

Soil Patterns: Dominant Soils – Form	Series	Mean (%)	Sub-dominant Soils – Form	Series	Mean (%)	Climate Relationships (Annual Values): Statistic	Rainfall (mm)	Evaporation (mm)	Heat Unit (deg. day)	Aridity Index
Broad Soil Pattern: Yellow and Red Apedal Soils (generally low base status)										
Clovelly	Cv16 Cv17 Cv23	23	Mispah	Ms10	18	Ave	1074	-	-	-
			Nomanci	No10		Std	106	-	-	-
Hutton	Hu16 Hu17 Hu23	22	Glenrosa	Gs16	17	Max	1260	-	-	-
Kranskop	Kp10	2	Rock	Rock	11	Min	900	-	-	-
Total Area: 65 580 Ha			Means of 11 Land Types							
Broad Soil Pattern: Red Apedal Soils (high base status)										
Hutton	Hu27 Hu37	48.31	Mispah	Ms10	15	Ave	834	-	2471	-
			Glenrosa	Gs19	8	Std	30	-	-	-
			Milkwood	Mw11 My11	6	Max	865	-	-	-
			Mayo			Min	804	-	-	-
			Rock	Rock	7					
Total Area: 8 830 Ha			Means of 2 Land Types							
Broad Soil Pattern: Black Soils										
Milkwood	Mw10 My10	22	Rock	Rock	42	Ave	842	-	-	-
Mayo						Std	158	-	-	-
Bonheim	Bo10 Bo11 Bo30	19	Mispah	Ms10 Gs16	11	Max	1000	-	-	-
	Bo31					Min	684	-	-	-
Inhoek	Ik10	2								
Total Area: 112 660 Ha			Means of 6 Land Types							
Broad Soil Pattern: Lithosols										
Rock	Rock	34	Hutton	Hu26 Hu36	12	Ave	1139	1512	816	0.75
Glenrosa	Gs14 Gs16	13	Clovelly	Hu16		Std	243	142	758	0.09
Mispah	Ms10	11		Cv26 Cv36	8	Max	1650	1714	1872	0.98
Nomanci	No10	3		Cv16		Min	698	1412	96	0.49
Total Area: 146 640 Ha			Means of 16 Land Types							

Milkwood, Mayo and Bonheim soils are dominant in the Black Clay Soil Pattern on the basalt of the Barkly East tableland of the North Eastern Cape. Located south of the southern Lesotho border and beyond the boundary of KwaZulu-Natal, these soils have been included for comparison purposes. The reason for this extensive area of melanic black clay soils is somewhat unexpected to the author. Mean annual rainfall of 842 mm (Table 7.1) is not that much lower than encountered in the KwaZulu-Natal Midlands. The terrain morphological patterns described as mountains and lowlands (Kruger 1983), with between moderate slopes (20 to 50% slopes of less than 5%) is duplicated in much of the KwaZulu-Natal Midlands. Mean annual temperatures are expected to be low for this soil pattern. Regrettably, no temperature stations could be located for comparative purposes between the Yellow and Red Apedal Soil Pattern of the Drakensberg Formation basalt, or the dystrophic soil patterns of Karoo dolerite. It is possible that the genesis and properties of these soils resemble those of the mollic horizons of Europe.

The Lithosolic soil pattern covers most of the main high Drakensberg escarpment. The high proportion of rock in this soil pattern is to be expected. The Glenrosa and Mispah soils probably have higher levels of organic carbon, while the presence of the Nomanci soil (No10, Table 7.1) is indicative of a thick humic A1 horizon. Hutton and Clovelly soils also occur in this soil pattern. The variable base status is ascribed to youthful nature of these soils. Leaching is to the extent that removal of bases has not taken place in the eutrophic and mesotrophic soils. However, the soil genesis is sufficiently intense that freely drained red and yellow apedal soils may form.

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles for the Hutton, Clovelly, Mispah, Champagne and for the margalitic soils (Milkwood, Mayo and Bonheim) soils were extracted from the database. Two natural soil bodies are clearly evident for the Hutton and Clovelly soils (Table 7.2, Figure 7.2). This is supported by the range in texture properties (Table 7.2, Figures 7.3 and 7.4), their luvic properties (Figure 7.8), and in their base status values. These trends could be repeated in the Mispah and Champagne soils (Figure 7.6), but data is limited such that a clear picture does not emerge. It is probable that the genesis of the margalitic soils is so different that the textural properties of these two natural soils bodies are not necessarily repeated in data of the margalitic profiles (Figure 7.7).

The two natural soil bodies for the Hutton soils (labelled Hutton(1) and Hutton(2)) and Clovelly soils (labelled Clovelly(1) and Clovelly(2)) have been arbitrarily distinguished at a clay percentage value of 25% (Figure 7.2). The clay contents of the B1 horizons for soil profiles within the group Hutton(1) ranges from 11 to 14%, while those for Hutton(2) range from 35 to 41% (Table 7.2, Figure 7.4). Clay contents for the A1 horizons have a similar range clearly indicating two natural soil bodies. In the B1 horizon of the Clovelly soils this trend is repeated (Figure 7.3), while a plot of the A1 horizon textures shows the two soil bodies to merge about the 25% central value (Table 7.2, Figure 7.2, 7.3). The profiles within Hutton(1) and Clovelly(1) have higher silt, or higher silt plus fine sand values (Table 7.3), than those of Hutton(2) and Clovelly(2).

Exceptions, as measured by either the clay contents or the base status, in assigning profiles to either of the two groups is evident. This is a reflection that these soils (in this climate regime and in these terrain positions) must be undergoing rapid changes in mineral weathering and clay formation. One profile (data not shown) had a clay content for the A1 horizon of 27% (belonging to Hutton (2)) while that for the B1 horizon was 14% (belonging to Hutton (1)). The interpretation with respect to soil genesis, in these actively weathering soils, is that weathering of the A1 horizon has proceeded further than that of the B1 horizon. It may be postulated that weathering, leaching of bases, and clay formation could rapidly reach a near steady state position. If this were true, then the more common clay contents and base status, as commonly sampled for the dolerite derived soils should be attained.

Table 7.2 Textural properties of soils of the Drakensberg Formation derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton (Clay <25%)	A1 B1	Lm Lm-SiLm	12-19 11-14	38-49 18-57	24-31 23-35	4-9 3-12	3-7 2-5	fi fi	EL5 -
Hutton (Clay >25%)	A1 B1	SiClLm-ClLm SiClLm-ClLm	27-40 35-41	31-41 28-40	12-25 10-23	1-7 1-5	1-10 2-20	fi fi	NL2, L3 -
Clovelly (Clay <25%)	A1 B1	SiLm-Lm SiLm-Lm	14-31 5-20	28-50 13-51	12-31 11-66	3-6 4-9	2-10 2-11	fi, co fi, co	EL5 -
Clovelly (Clay >25%)	A1 B1	SiClLm-ClLm-Cl SiCl-ClLm	23-46 28-44	20-50 25-46	8-26 7-21	1-12 1-4	2-6 1-5	fi, co fi, co	NL2, L3 -
Mispah (All profiles)	A1	SiClLm-Lm	13-32	12-37	10-30	5-12	1-16	fi, co	-
Champagne (All profiles)	O1 G1	SiClLm-Lm SaClLm	25-30 23-23	18-42 15-15	16-24 43-43	2-10 14-14	2-7 5-5	fi	- -
Margalitic Soils (Milkwood, Mayo, Bonheim)	A1 B1	ClLm-Cl ClLm-Lm	29-44 38-62	29-42 23-31	17-21 10-19	2-6 1-4	3-4 3-7	fi	NL5 -

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).

The silt and fine sand fractions comprise the remaining dominant particle size classes (Table 7.2). While fine sand is the dominant sand grade (Figures 7.3, 7.4, 7.5) individual profiles do exhibit a dominance of coarse sand. This may be attributed to the remnants of physical weathering and colluviation.

The Hutton(1) and Clovelly(1) Group clearly shows a decrease in clay content between the A1 and B1 horizons(Figure 7.8), with a mean ratio Clay B1:Clay A1 of 0.59. These profiles are represented by the histogram bar 0.7 (Class interval 0.4 - 0.7, Figure 7.8). These profiles also have higher silt and fine sand fractions, and a higher base status in their B1 horizons. This is an indication of the youthful nature of these soils with more advanced weathering taking place in the A1 horizon. In contrast, the mean ratio of Clay B1:Clay A1 for the Hutton(2) and Clovelly is 1.14 (Figure 7.8) indicating clay illuviation or simply clay weathering and breakdown of some of the clay fraction of the A1 horizon has taken place. Clay values for the B2 horizon tend to be similar to those of the B1 horizon. These B1 horizons were originally not considered to qualify for the neocutanic B horizon on the basis of their morphology.

It is interesting that while weathering has proceeded to produce yellow and red soils, the B1 horizons do not qualify for the ferralic horizon of the World Reference Base System (ISSS, ISRIC, FAO, 1998). The higher CEC values should qualify for the cambic horizon. This implies that a wider range of profile weathering in the cambic horizon is permissible than would be recognised in the South African Soil Classification System.

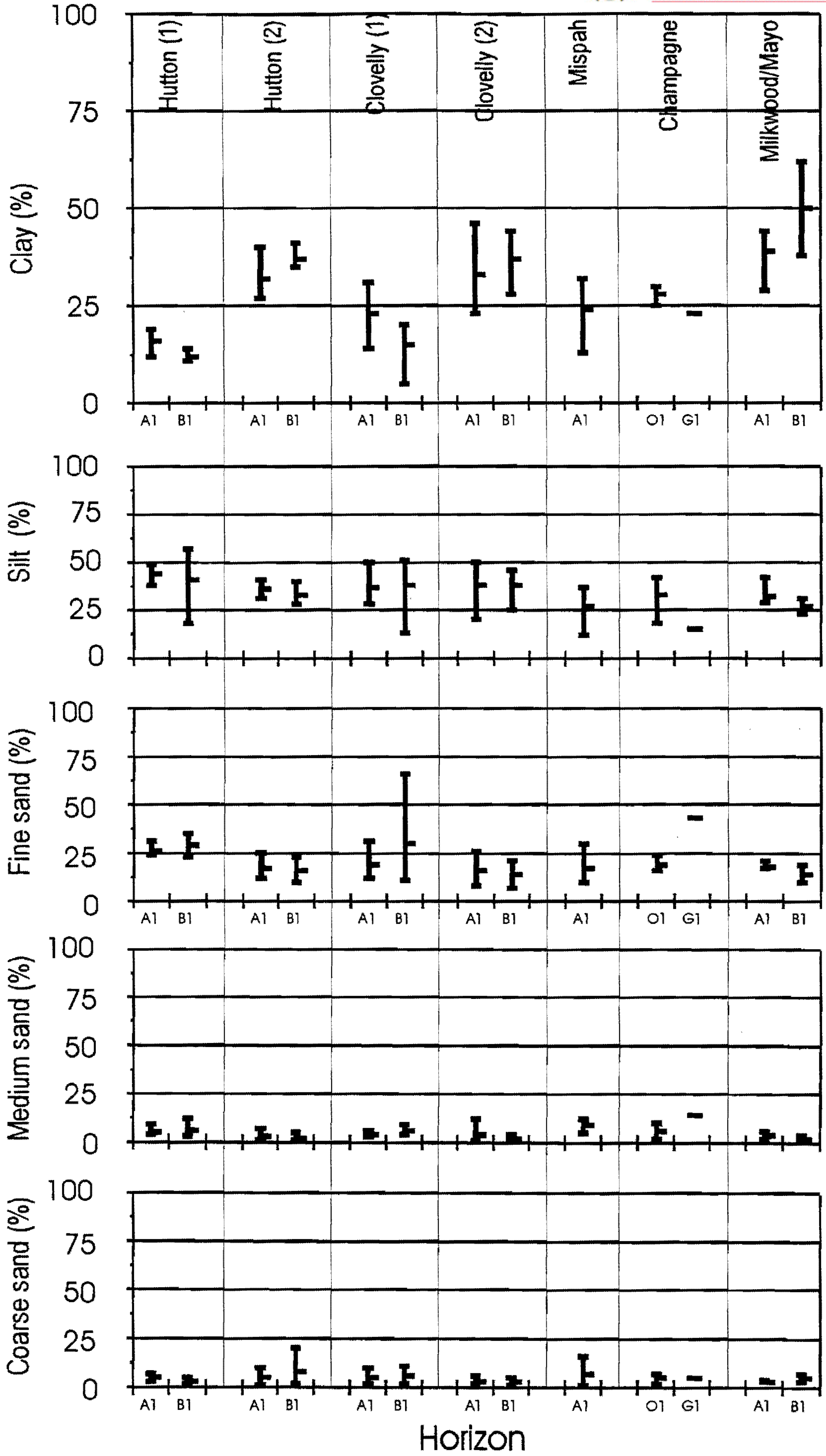

Figure 7.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Drakensberg Formation. Maximum, minimum and mean values are shown for each horizon.

The textural properties of the Mispah soils are similar to those of the Clovelly(1) soils (Table 7.2, Figure 7.2). The textures of the Champagne soils appear intermediate between those for the Hutton and Clovelly soils (Table 7.2, Figure 7.2). The existence of clay loam textures (30% clay) is confirmed for these organic horizon soils. There are a limited number of profiles for both soils in this group (Table 7.3).

The textures for the melanic soils are within the range determined for the Mayo soils of Jurassic dolerite and basalt of the Letaba Formation. There are a limited number of profiles in this group (Table 7.3).

Table 7.3 Means and standard deviations of five textural classes for soils of the Drakensberg 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 (Clay B1 horizon <25%)												
A1	303	16.3	3.1	44.3	4.6	26.7	3.1	5.7	2.4	5.0	1.6	3
B1	625	12.8	1.3	41.0	14.3	29.3	4.4	6.0	3.5	3.8	1.1	4
Form: Hutton (Clay B1 horizon >25%)												
A1	200	32.4	4.9	36.6	4.1	17.2	4.5	3.8	2.3	5.3	3.8	5
B1	437	37.8	2.4	33.5	5.5	16.3	5.8	2.5	1.5	8.0	8.5	4
Form: Clovelly (Clay B1 horizon <25%)												
A1	353	23.4	5.2	37.8	6.1	19.6	5.5	4.4	0.9	5.4	2.4	8
B1	746	15.5	4.9	38.9	11.8	30.3	17.0	6.4	1.5	6.0	2.7	8
Form: Clovelly (Clay B1 horizon >25%)												
A1	178	33.3	6.4	38.0	11.2	16.3	5.8	4.1	3.5	3.4	1.3	7
B1	566	37.0	6.0	38.4	8.1	14.8	4.8	2.4	1.0	3.2	1.3	5
Form: Mispah (All profiles)												
A1	157	24.5	7.2	27.0	9.5	17.3	7.7	9.0	2.7	7.8	6.1	4
Form: Champagne (All profiles)												
O1	633	28.3	2.4	33.7	11.1	19.7	3.3	6.0	3.3	5.0	2.2	3
G1	500	23.0	0.0	15.0	0.0	43.0	0.0	14.0	0.0	5.0	0.0	1
Form: Margalitic Soils (Milkwood, Mayo, Bonheim)												
A1	312	39.0	6.1	32.5	5.5	18.5	1.5	4.3	1.8	3.8	0.4	4
B1	750	50.0	12.0	27.0	4.0	14.5	4.5	2.5	1.5	5.0	2.0	2

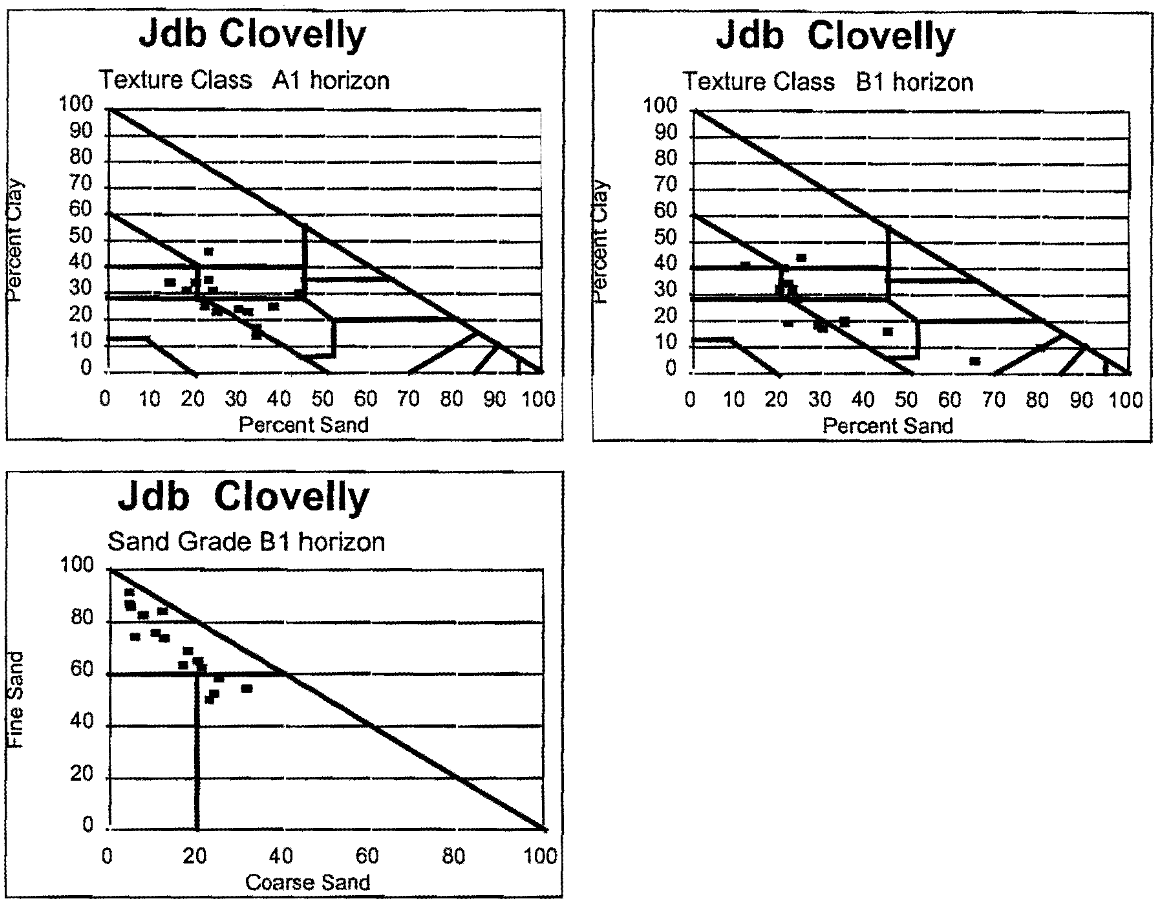

Figure 7.3. Distribution of soil textures, and dominant sand grade, within soils of the Clovelly Form.

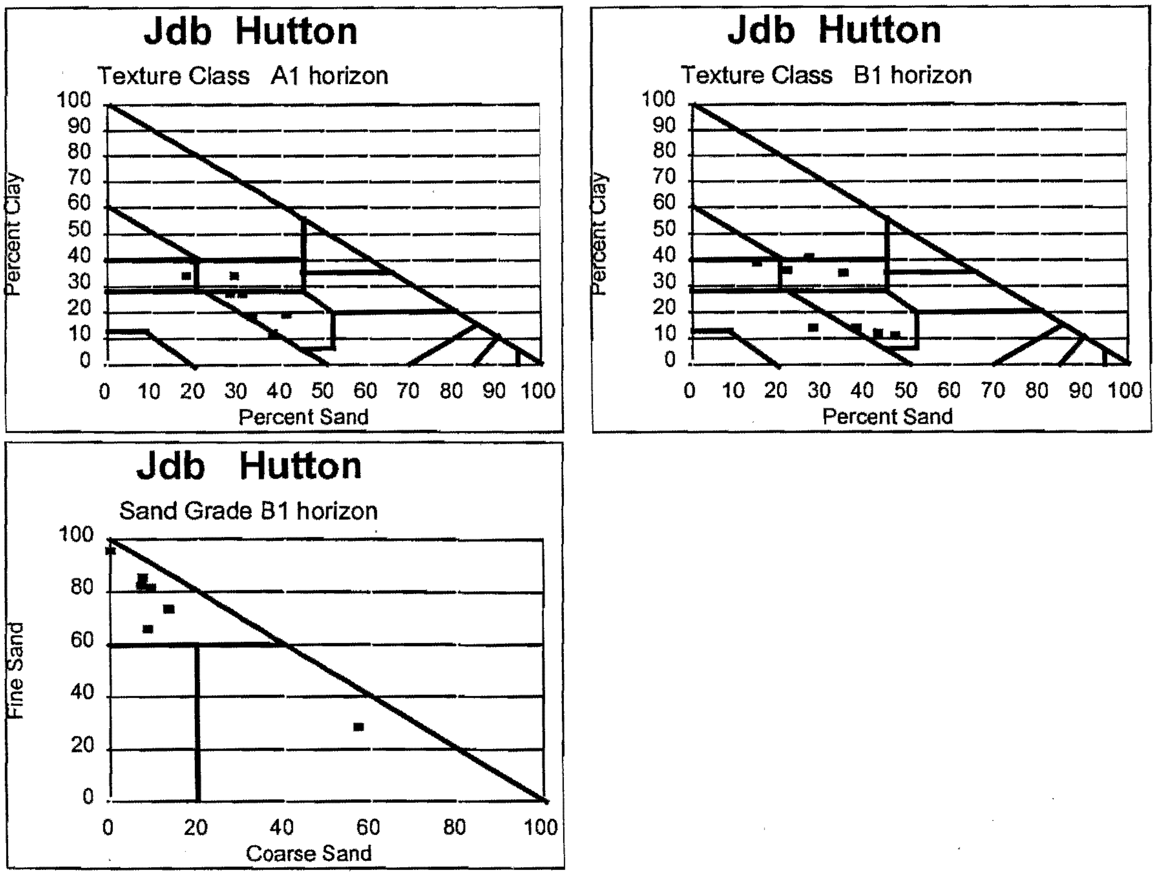

Figure 7.4. Distribution of soil textures, and dominant sand grade, within soils of the Hutton Form.

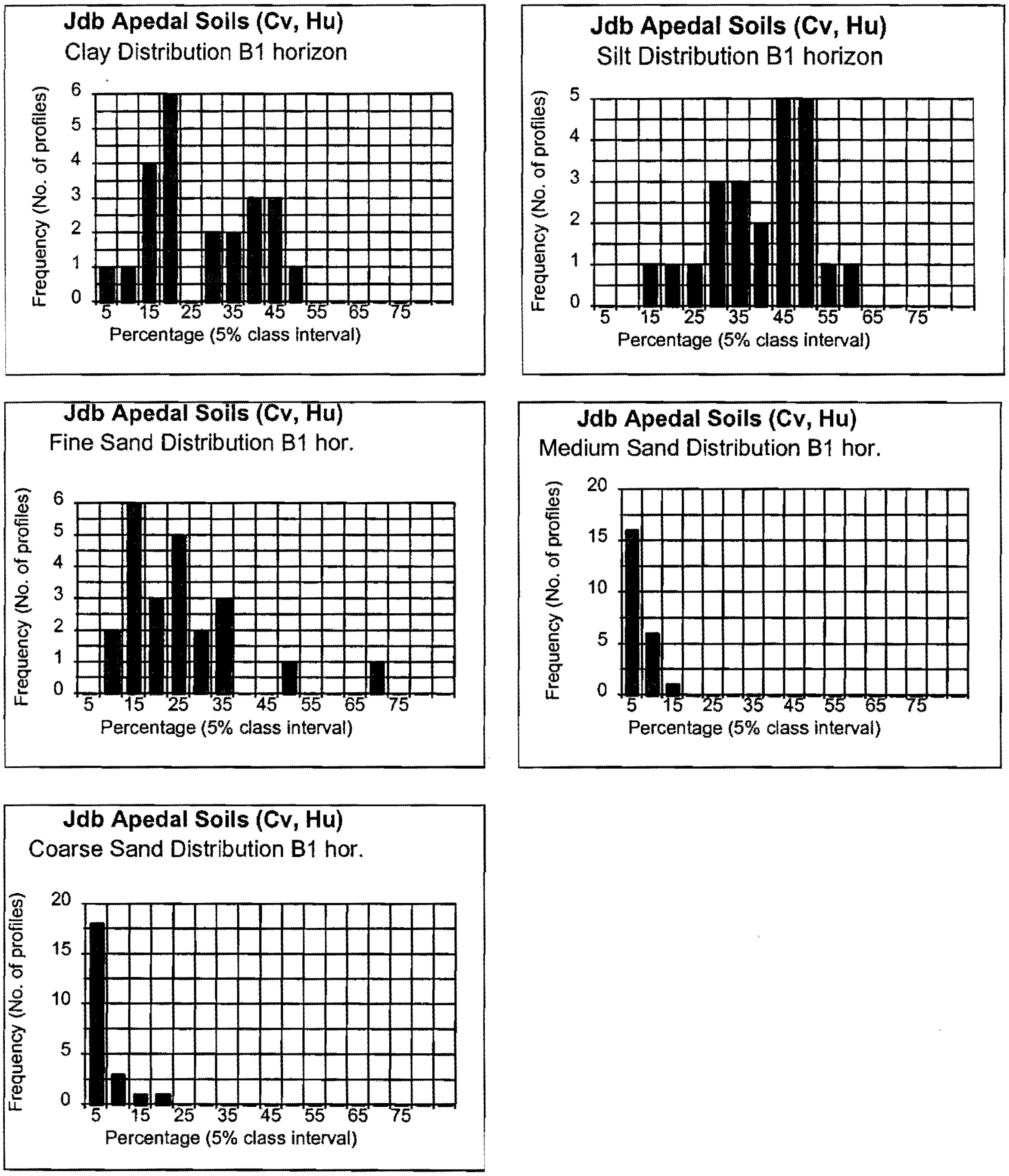

Figure 7.5 Distribution of clay, silt, fine sand, medium sand and coarse sand within soils of the Clovelly and Hutton Forms.

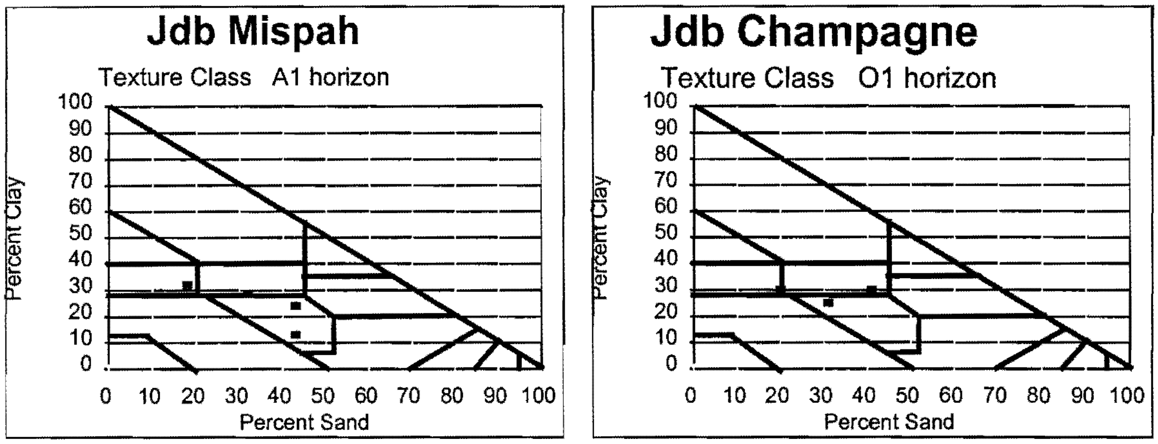

Figure 7.6 Distribution of soil textures within soils of the Mispah and Champagne Forms.

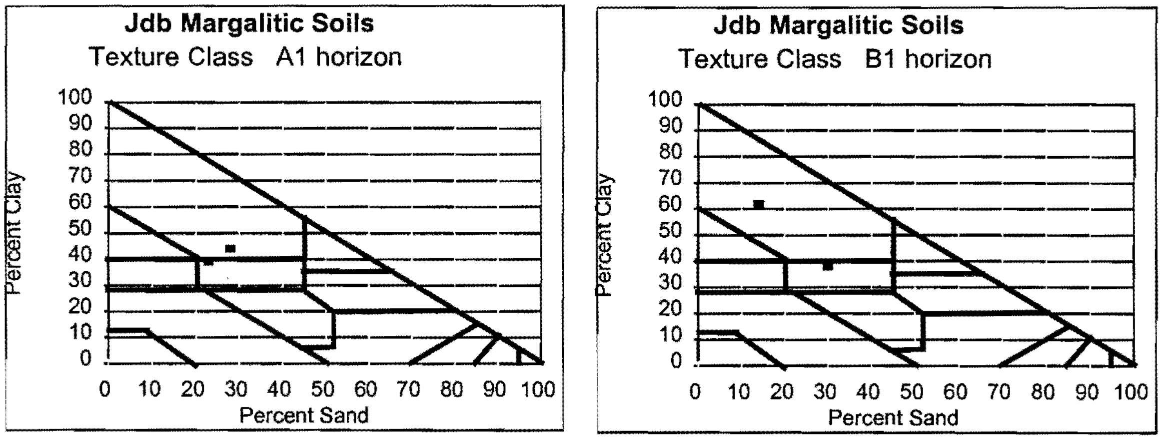

Figure 7.7 Distribution of soil textures within margalitic soils of the Milkwood, Mayo and Bonheim Forms.

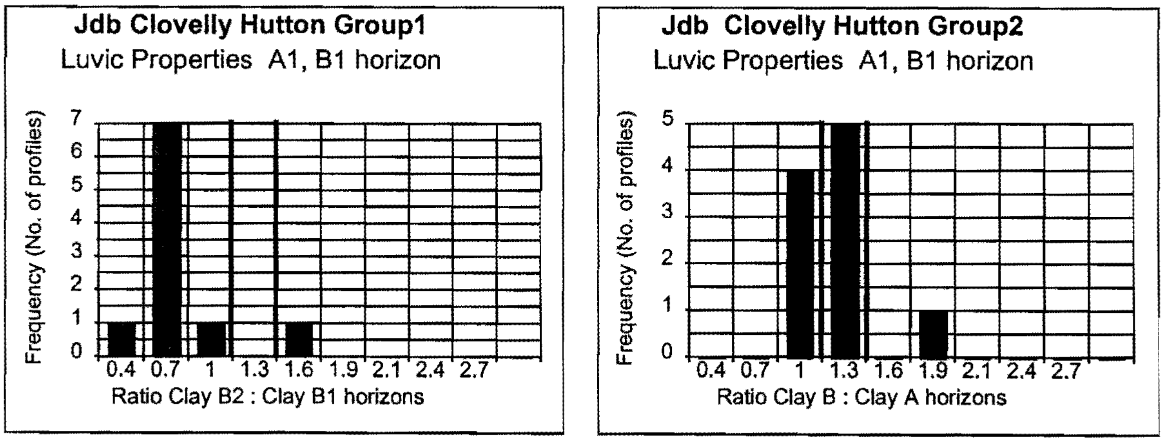

Figure 7.8 Luvic properties of two groups of soils within the Clovelly and Hutton Forms.

CHAPTER 8

SOILS OF THE BASALT OF THE LETABA FORMATION, LEBOMBO GROUP IN KWAZULU-NATAL AND MPUMALANGA

Location and Extent

The Letaba Formation runs in an extended belt from the Limpopo River in the north, stretching southwards through Mpumalanga and Swaziland. In KwaZulu-Natal it extends to form the common border with Swaziland southwards to the Mfolozi River. The formation is traceable well to the north of South Africa. The Letaba Formation, together with acid rhyolite volcanic member, forms the common border with Moçambique. The Letaba Formation also occupies extensive areas of the Springbok Flats in the Northern Province.

The formation covers an area of approximately 840 000 hectares, while within KwaZulu-Natal it covers an area of 197 600 hectares (Figure 8.1).

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

The Lebombo Group is a succession of basic and acidic lavas (SACS, 1980). The 1970 edition of the geological map of South Africa (Geological Survey, 1970) correlated these lavas with the Drakensberg Formation. However, uncertainties in their correlation have resulted in independent formation names being assigned for the three main lithological units of the Lebombo Group (SACS, 1980). The Letaba Formation comprises the lower basalt unit (SACS, 1980, Geological Survey, 1985a, Geological Survey, 1985b). The Jozini Formation is the name assigned to the rhyodacite acid unit (SACS, 1980; Geological Survey, 1985a; Geological Survey, 1985b). The third unit, the Movene Formation, is confined almost entirely to Moçambique. In this study soil profiles have only been sampled from the Letaba Formation. The remaining two units are hence not subsequently considered.

The basalt exposures of the Letaba Formation, east of the Lebombo Mountains is considered as of the Post African II surface which has become partly planed, and of Late Pliocene age (Partridge and Maud, 1987). The Lebombo Mountains themselves are descried as having exerted major structural control over this surface. The basalt exposures of the Springbok Flats are considered as part of a Post-African surface of Early Miocene age (Partridge and Maud, 1987).

Physiography and Drainage Features

The rhyolite of the Jozini Formation together with the basalt of the Letaba Formation forms the Lebombo Mountain Range stretching through north eastern Mpumalanga and KwaZulu-Natal. In Mpumalanga this range of hills comprising largely rhyolite has moderate relief. In KwaZulu-Natal the altitude difference between the basaltic plains to the west and the Lebombo Range is pronounced, forming low mountains. To the west of the Lebombo Range lies the basaltic plains with gentle slopes, low relief and low drainage density (Kruger, 1983). South of the Hluhluwe River to the Mhlatuze River the basalt plains become dissected giving rise to undulating hills and valleys. These plains are drained by sections of the major rivers the Sabie, the Crocodile and Komati, the Pongola and Mkuze and the Mfolozi Rivers. The basalt exposed on the Springbok

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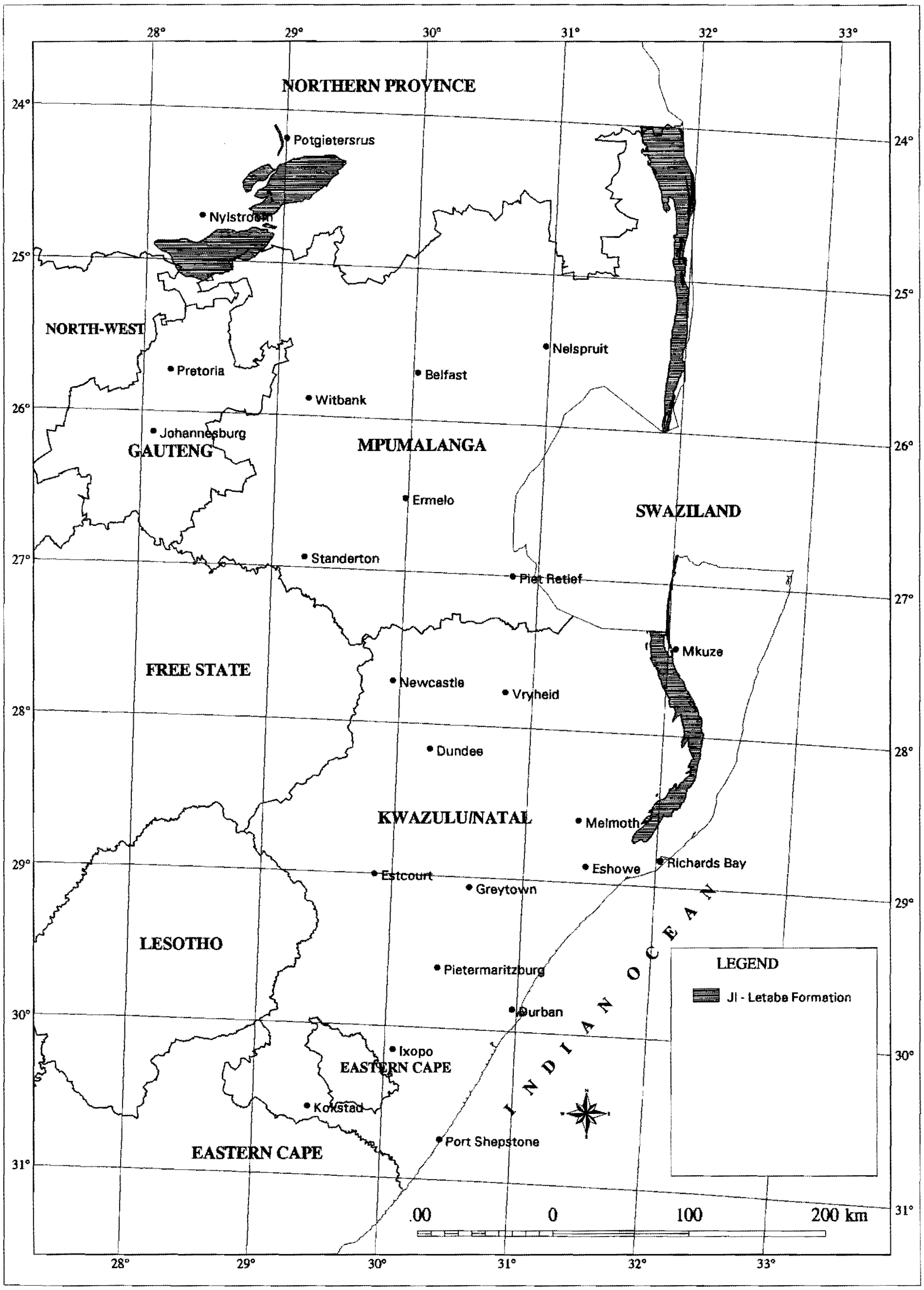

Figure 8.1. Location of the Letaba Formation, Lebombo Group in KwaZulu-Natal, Mpumalanga and Northern Province (after Geological Survey, 1984).

Flats forms an extensive plain of low relief and gentle slopes.

Vegetation

In Mpumalanga and stretching south to the Mkuze River the vegetation is described as Sweet Lowveld Bushveld (Low and Rebelo, 1996). South of the Mkuze River to the Mhlatuze river the vegetation is Natal Lowveld Bushveld (Low and Rebelo, 1996).

Soils

Two soil patterns are evident on the basalt of the Letaba Formation (Table 8.1). The first of these patterns is dominated by black clays of the Mayo, Milkwood, Bonheim and Arcadia soil forms. Other black clays may also be present. Red clays, Shortlands and Hutton soils, are also important components of this soil pattern. It is significant however, that the red soils of the Springbok Flats, which also overlie basalt of the Letaba Formation, have a significant component of red sandy loam to sandy clay loam soils (Land Type Survey Staff, 1987b). Judging by the sandy texture of these red soils, an external source of sand can be inferred. It is probable that this source of sand, in the red soils of the Springbok Flats, is from the sandstone of the Clarens Formation. A narrow band of the Clarens Formation is also present west of the Letaba Formation in KwaZulu-Natal and Mpumalanga. While sandier Hutton profiles are present in the sample set over basalt in KwaZulu-Natal and Mpumalanga, the extent of sandy material from the Clarens Formation east of the Lebombo Mountains appears much less.

The second soil pattern is a lithosolic one, associated with both basalt and rhyolite.

The pattern covering the largest area is that located on the plain west of the Lebombo Mountains. Mayo, Milkwood and Bonheim soils are dominant. Soils with both a non-calcareous and calcareous B horizons are indicated in the soil inventories (Land Type Survey Staff, 1986a; 1986b; 1987c; 1989a; 1989b). The calcareous soils are usually located in the lower midslope and valley bottom positions. Venter (1990) describes the presence of hardpan lime in bottomland sites in the Satara Land System, south of the Olifants River. Hardpan carbonate was also noticed south west of Komatipoort in Mayo soils on the Letaba Formation basalt. Similar occurrences of hardpan carbonates are not known to the author on basalt in KwaZulu-Natal. Arcadia soils are an integral component of this soil pattern. Rensburg soils were however estimated to cover only a limited area. The absence of Rensburg may be explained by the flat terrain with a few streambeds. There is only a limited area of bottomland soils, and in this relatively arid climate the extent of gleying is also limited. These observations seem to be confirmed in the descriptions given by Venter (1990).

Shortlands soils form an important component of this soil pattern, with both eutrophic and calcareous soils present (Table 8.1). The eutrophic Shortlands soils are present on the crest and midslope positions. Examples of the calcareous Shortlands were located on footslope positions.

Black clays, red and black clays, or lithosols are indicated to occur throughout this soil pattern (Table 8.1). There are zones within this soil pattern where the proportions of each of these components occurs to a greater or lesser extent (Land Type Survey Staff, 1986a; 1989b; Venter, 1990).

Table 8.1 Dominant soils and selected climatic information for soil patterns occurring on Letaba 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: Black and Red Clay soils (high base status)										
Mayo	My10 My11	12	Mispah	Ms10 Ms20	10	Ave	782	1707	4071	0.46
	My20 My21	2	Rock	Rock	5	Std	119	84	149	0.06
Milkwood	Mw10 Mw11	8				Max	918	1774	4078	0.52
	Mw20 Mw21	3				Min	608	1523	3842	0.36
Bonheim	Bo41	6								
	Bo31 Bo11 Bo21	6								
Arcadia	Ar40	9								
Shortlands	Sd21 Sd22	13								
	Sd31 Sd32	2								
Hutton	Hu37	4								
Total Area: 196 620 Ha			Means of 12 Land Types							
Broad Soil Pattern: Lithosolic soils										
Mispah	Ms10	50				Ave	600	1801	4150	0.33
Glenrosa	Gs16 Gs17	18				Std				
Rock		15				Max				
						Min				
Total Area: 900 Ha			Means of 1 Land Types							

The Lithosolic soil pattern is associated with basalt and rhyolite, the latter lithology giving rise to rockland with lithosolic soils. The area of this pattern is limited.

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles of the Hutton, Shortlands, Arcadia, Bonheim, Mayo, Glenrosa and Mispah Forms were extracted from the database. Their ranges in textural properties (maximum and minimum values) for five particle size classes, dominant sand grade and information on their luvic properties are presented in Table 8.2. These ranges are also represented graphically in Figure 8.2. The figure allows for an overview comparison between different soil forms and over particle size classes. The majority of the profiles fall into the sandy clay loam to clay textural class (Table 8.2).

The maximum values for the Hutton (Cl1 clay textural class), Shortlands, Arcadia, Bonheim and Mayo soils do not differ much (Figure 8.2). The Arcadia soils have the highest mean values, but they also have the narrowest range of clay contents. The Hutton (Cl1), Shortlands and Bonheim soils have very similar mean values for clay percentage (Figure 8.2), but show a much larger range of values than the Arcadia soils. The implication is that these soils may have clay

Table 8.2 Textural properties of soils of the Jl Jurassic Lava-basalt derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton(Cl1) (Lebombo)	A1 B1	SaCl-Cl ClLm-Cl	38-73 33-75	13-14 7-34	7-36 9-33	1-16 1-11	1-9 1-12	fi fi	- -
Hutton(Cl2) (Lebombo)	A1 B1	SaClLm Sa-LmSa-SaClLm	27 4-34	10 2-21	43 25-63	16 12-25	4-29 3-30	co co	- -
Hutton(Cl1) Nylstroom	A1 B1	ClLm-Cl ClLm-Cl	32-56 ??	7-29 ??	15-36 ??	4-14 ??	1-20 ??	fi fi	L3, N22 -
Hutton(Cl2) Nylstroom	A1	SaClLm-SaCl SaClLm-SaCl	18-38	3-20	25-43	13-27	3-23	fi, co fi, co	L3, NL2
Shortlands	A1 B1	SaClLm-ClLm-Cl SaClLm-ClLm-Cl	21-76 17-76	8-33 7-50	14-48 7-43	2-14 1-14	1-8 1-15	fi fi	NL4, L1 NL5
Arcadia	A1 A2 A3 C1	ClLm-Cl Cl Cl SaClLm-Cl	36-69 52-65 56-66 23-70	10-31 11-30 11-19 12-32	8-31 9-25 9-25 6-38	1-16 2-3 2-3 1-16	1-10 2-6 2-3 1-15	fi fi fi fi, co	NL5 NL5 NL3, EL2 -
Bonheim	A1 B1 B2	SaClLm-Cl SaClLm-Cl SaClLm-Cl	31-65 30-71 32-68	13-24 15-33 20-30	7-31 8-31 11-40	1-14 1-13 1-10	1-9 1-8 1-3	fi, co fi, co fi	NL5 NL2, EL3 EL5
Mayo	A1 B1	Lm-ClLm-Cl SaClFLm-SaCl-Cl	25-69 31-45	3-43 7-43	9-36 15-34	1-13 2-17	2-17 1-12	fi, co fi, co	EL -
Glenrosa	A1	SaLm-Lm-Cl	11-48	13-32	21-48	4-18	1-15	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).

percentages similar to, or lower than, those of the Arcadia soils. The mean clay percentages for the Mayo soils, and for the Glenrosa and Mispah soils respectively are lower than the others in this soil group (Figure 8.2).

The range of clay percentage values for the Shortlands are illustrated in Figures 8.2 and 8.5. It is common contention that the Shortlands soils should not have clay percentage values much below the sandy clay class (35 percent clay). In this sample set (Figure 8.5), and those from the dolerite soils (Chapter 6) there are profiles with these lower clay percentage values. Do Shortlands soils with loam textural classes really exist, and if so, should provision be made for them in any classification scheme? Alternatively, are these values simply the products of some form of error in either classification, analysis or data base construction? There is now only limited opportunity to detect such errors, and no opportunity to revisit these sites, or to re-analyse these soils. It seems probable that some form of provision for lower clay Shortlands soils will have to be made. However, these soils will probably be considered as exceptions, rather than part of the central concept of the Shortlands Form soils.

There is a small group of Hutton soils (labelled: Hutton (Cl2- Lebombo) which directly overlie the basalt of the Letaba Formation, but with sandy through loamy sand to sandy clay loam textures (Table 8.2). Coarse sand is dominant in these profiles. These profiles were sampled in the

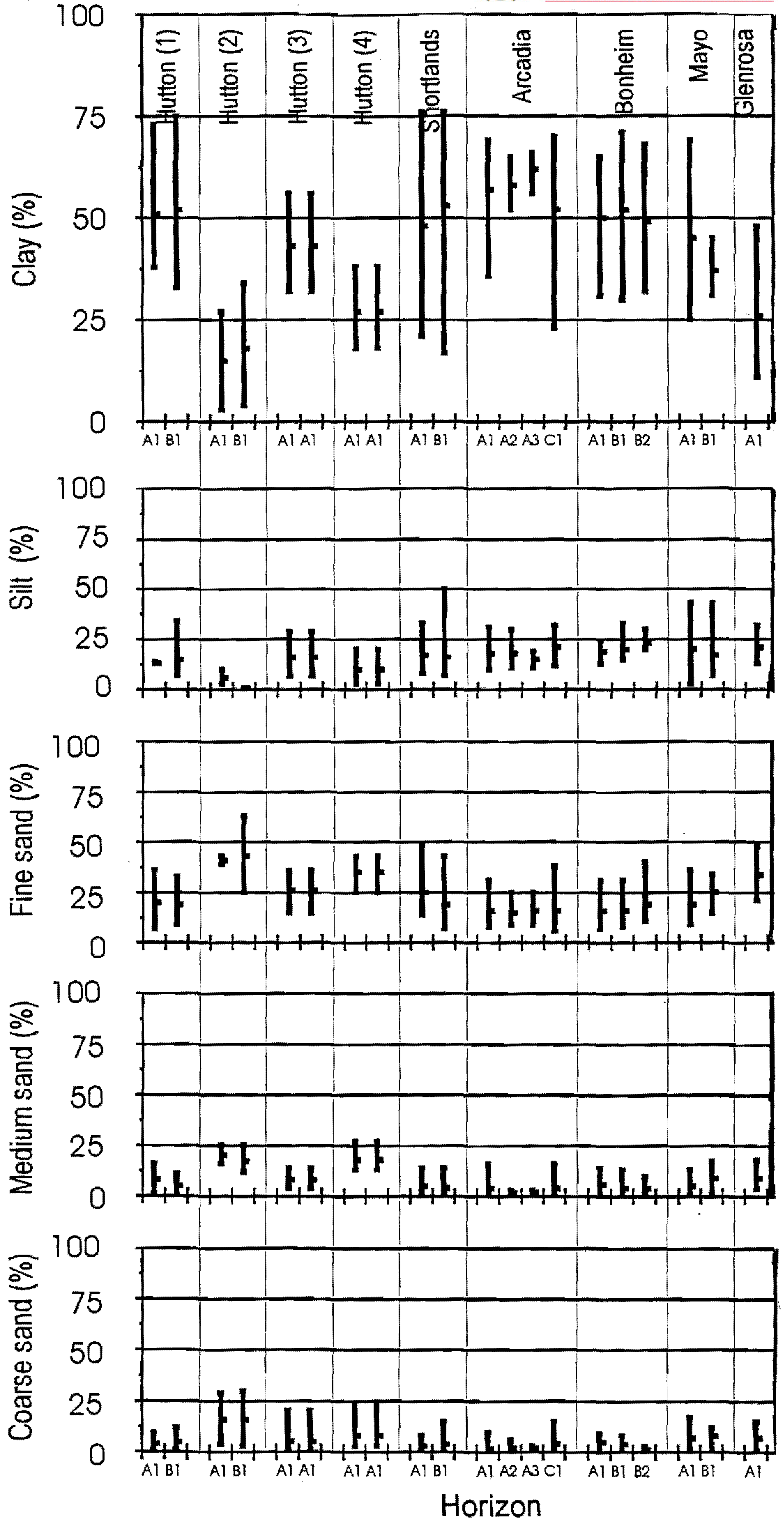

Figure 8.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Letaba Formation. Maximum, minimum and mean values are shown for each horizon.

Table 8.3 Means and standard deviations of five textural classes for soils of the Letaba 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 (Cl1) Lebombo: Profiles adjacent to Lebombo Mountain Range												
A1	216	51.3	15.5	13.7	0.5	20.0	12.0	8.0	6.2	4.3	3.4	3
B1	680	52.8	11.7	15.9	7.8	19.4	7.5	5.9	3.3	5.7	3.4	12
Form: Hutton (Cl2) Lebombo: Profiles adjacent to Lebombo Mountain Range												
A1	250	15.0	12.0	6.5	3.5	41.0	2.0	20.5	4.5	16.5	12.5	2
B1	530	18.2	11.4	7.2	7.1	43.6	12.7	17.4	6.2	16.8	9.8	5
Form: Hutton (Cl1) 2428 Nylstroom												
A1	-		-		-		-		-		-	
B1	725	43.4	6.4	16.0	7.7	26.4	7.0	8.6	2.6	5.5	6.3	14
Form: Hutton (Cl2) 2428 Nylstroom												
A1	-		-		-		-		-		-	
B1	583	27.1	6.1	10.3	4.0	35.3	5.3	18.8	3.7	8.2	5.2	18
Form: Shortlands												
A1	355	48.9	14.7	17.2	6.3	25.2	9.5	5.7	3.6	3.9	2.2	17
B1	679	53.2	16.0	16.3	8.6	19.8	8.6	4.7	3.1	4.4	3.5	38
Form: Arcadia												
A1	665	57.3	8.3	18.8	5.3	16.2	5.2	4.9	3.2	2.8	2.3	23
A2	665	58.3	5.7	18.8	6.3	15.3	5.5	2.5	0.5	2.8	1.5	6
A3	927	62.8	4.0	15.5	3.0	16.5	6.1	2.5	0.5	2.5	0.5	4
C1	1123	52.4	15.3	21.3	5.1	16.8	9.4	4.6	4.5	4.7	5.3	10
Form: Bonheim												
A1	393	50.1	10.0	19.7	3.4	16.0	6.5	6.2	3.8	5.6	2.5	10
B1	885	52.8	11.4	20.7	4.8	16.2	7.5	4.3	3.1	4.5	2.1	12
B2	1180	49.6	13.3	23.8	3.4	19.8	10.8	4.4	3.3	1.8	0.8	5
Form: Mayo												
A1	418	45.7	11.9	20.5	12.1	19.9	7.7	5.6	3.2	7.8	4.7	17
B1	638	37.3	5.1	17.3	12.8	25.0	7.6	9.6	6.0	8.0	4.3	6
Form: Glenrosa												
A1	253	26.1	13.7	21.8	7.3	34.0	9.8	9.0	5.0	7.8	4.4	8

Mpumalanga and Northern Provinces. No profiles with these texture classes were sampled from KwaZulu-Natal. To the west of the Letaba Formation basalt lies sandstone of the Clarens Formation. Colluvium or alluvium from this or other sources must be inferred as contributing to the sandy textures. Venter (1990) also notes the presence of these soils in the Vutome and Bulweni Land Systems within the Kruger National Park.

There is however, a similar group of sandy loam to sandy clay loam soils occurring in the Nylstroom District of the Springbok Flats (labelled: Cl2-Nylstroom). These soils have been more intensively sampled so that the textural properties (Table 8.3, Figure 8.4) can be described with greater confidence. In this district, two soil bodies overlying basalt of the Letaba Formation can be recognised on the basis of their clay content and sand grade. The first soil body is of Hutton profiles (labelled: Hutton Cl1-Nylstroom) with clay textures suggesting a genesis directly form the basalt of the Letaba Formation. Their textural properties (Tables 8.2 and 8.3) do not differ much from Hutton soils (labelled: Hutton Cl1-Lebombo) derived from basalt west of the Lebombo Mountains. The second group of Hutton profiles has clay percentages about half of those derived from the basalt, while silt and fine sand values are similar to those of Hutton and Clovelly soils over sandstone of the Clarens Formation. In listing all the Nylstroom profiles the distinction between the two groups was placed at 50 percent total sand (about 35 percent clay), though this value is somewhat arbitrary (Figure 8.3 and 8.4). The relatively large number of sandy loam Hutton profiles in this geographic location would indicate difference in their genesis. This is supported by Oberholtser (1969a, 1969b), Taylor (1972) and Bühmann, Kirsten, Paterson and Sobczyk, (1993), although some of their data sets were relatively smaller and from restricted localities.

The Mayo profiles (17) have textures located in the clay and clay loam classes (Figure 8.7). These textures do not differ appreciably from those of the Bonheim soils (Figure 8.8). Profiles (8) from the Glenrosa and Mispah soils are located with textures in the clay, in the loam, and in the sandy loam texture classes (Figure 8.9). The implication appears to be that although clay texture profiles are possible for Mispah soils, sandier textures including those with intermediate silt values should be expected (Table 8.2, Figure 8.9).

Half of the Hutton profiles show luvic properties (Figure 8.10). These profiles are mostly from the Nylstroom District. A much smaller proportion (25%) of Shortlands profiles have luvic properties.

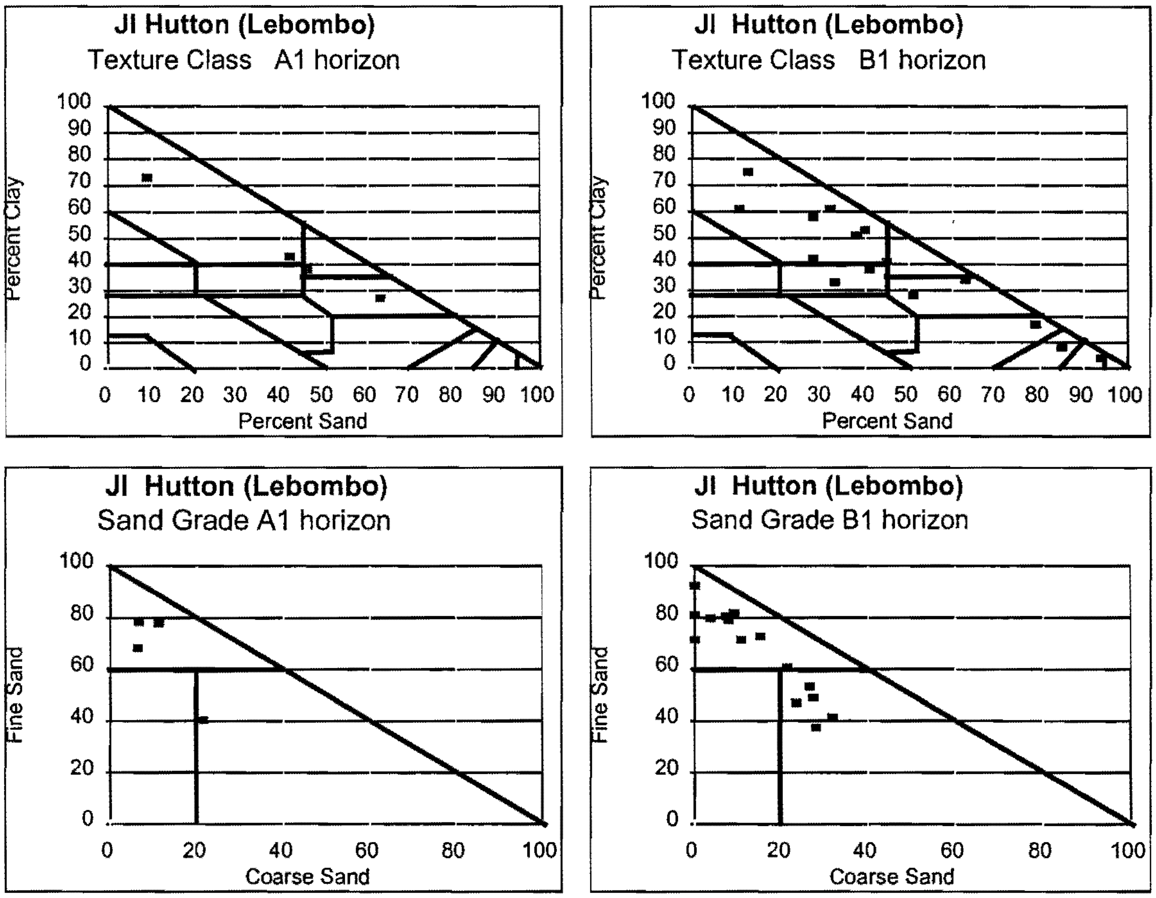

Figure 8.3 Distribution of soil textures, and dominant sand grade, within soils of the Hutton Form (Lebombo Districts).

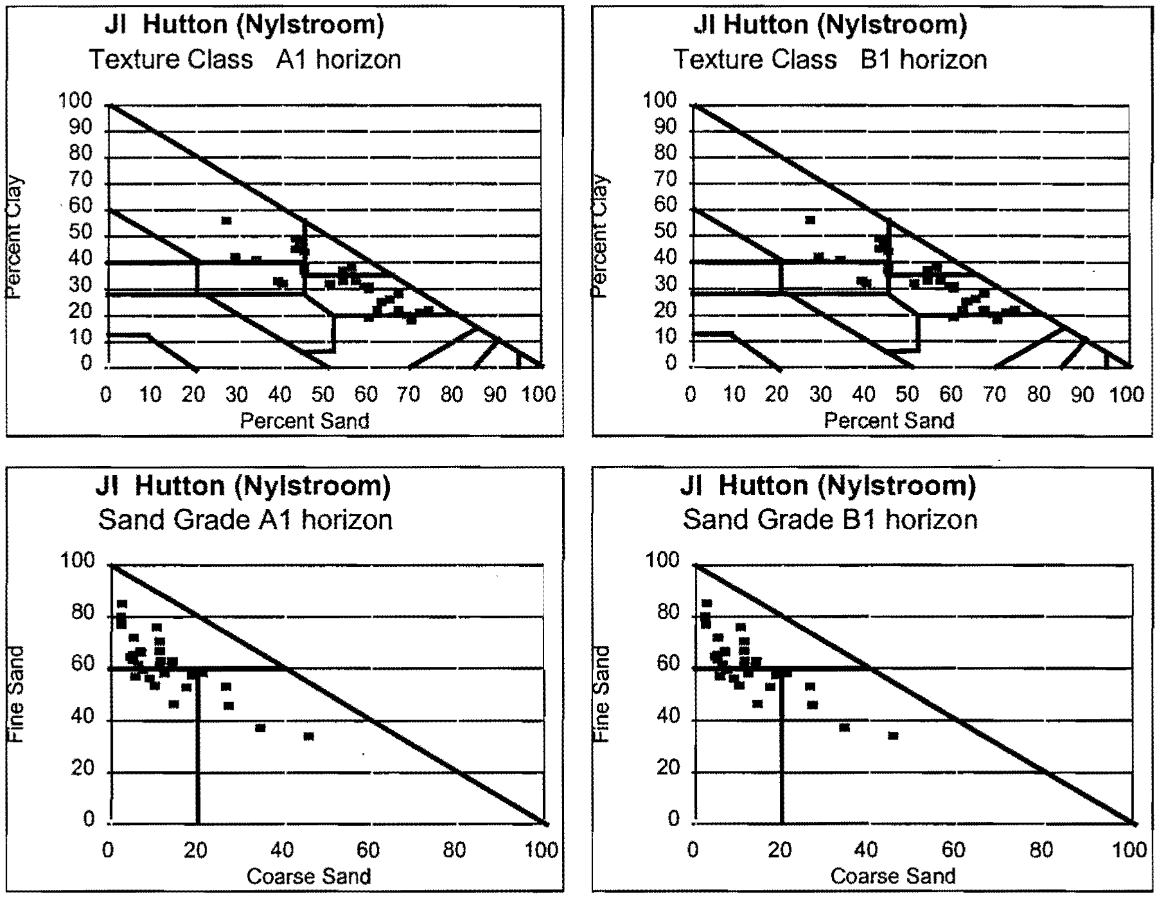

Figure 8.4 Distribution of soil textures, and dominant sand grade, within soils of the Hutton Form (Nylstroom District).

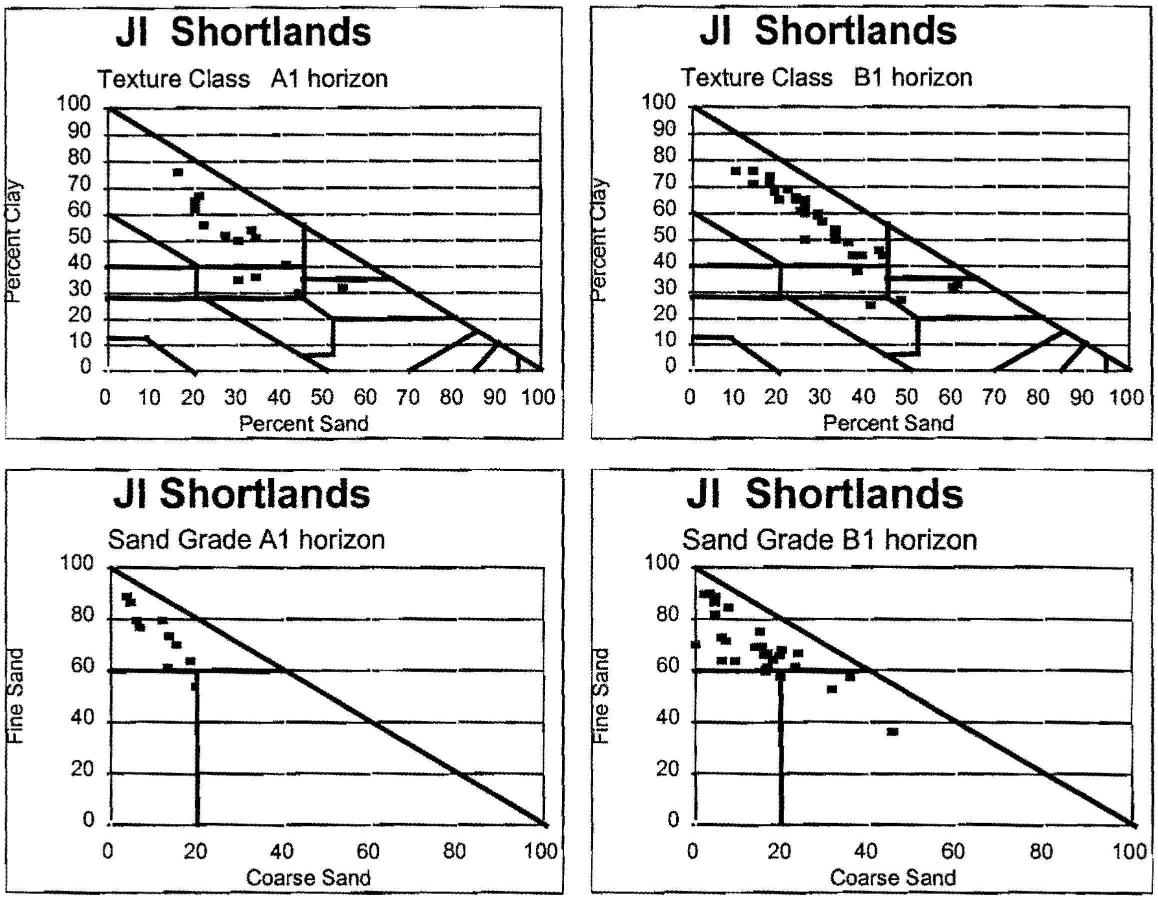

Figure 8.5 Distribution of soil textures, and dominant sand grade, within soils of the Shortlands Form.

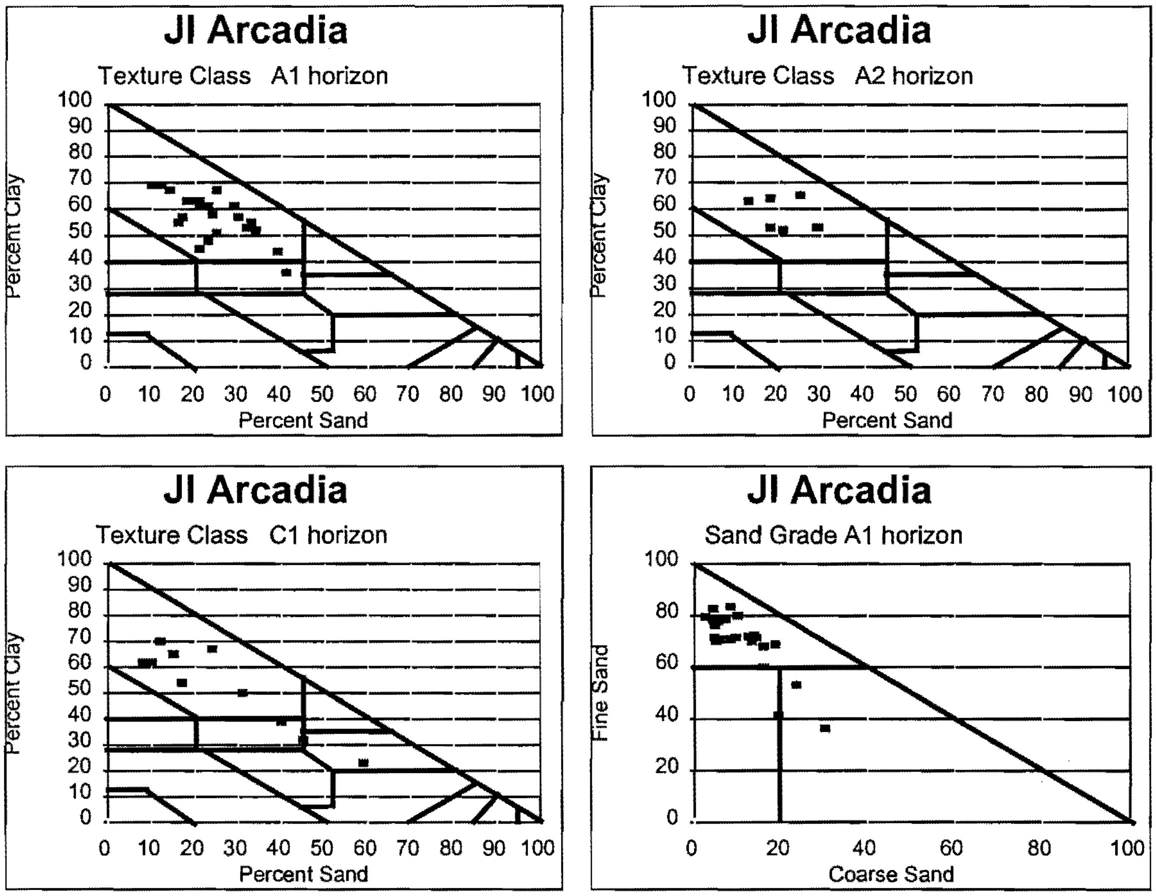

Figure 8.6 Distribution of soil textures, and dominant sand grade, within soils of the Arcadia Form.

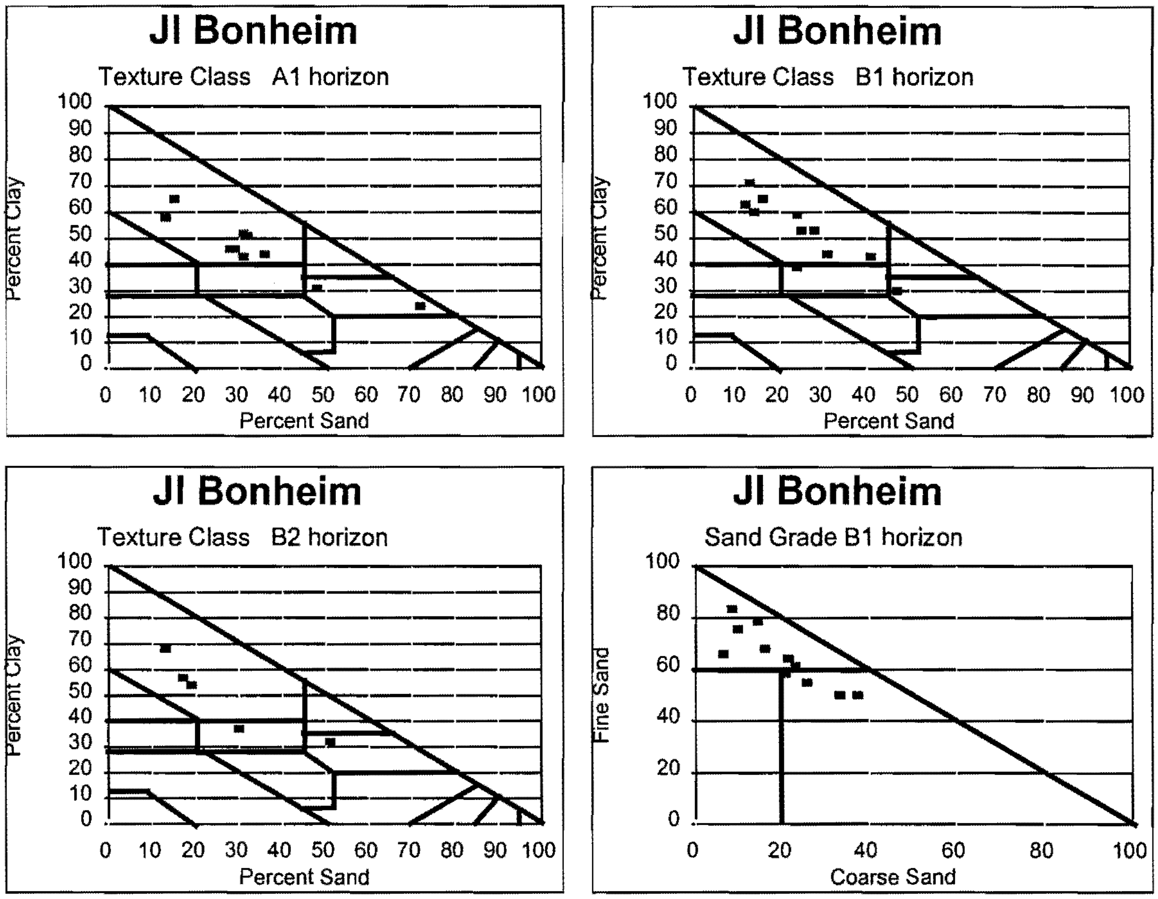

Figure 8.7 Distribution of soil textures, and dominant sand grade, within soils of the Bonheim Form.

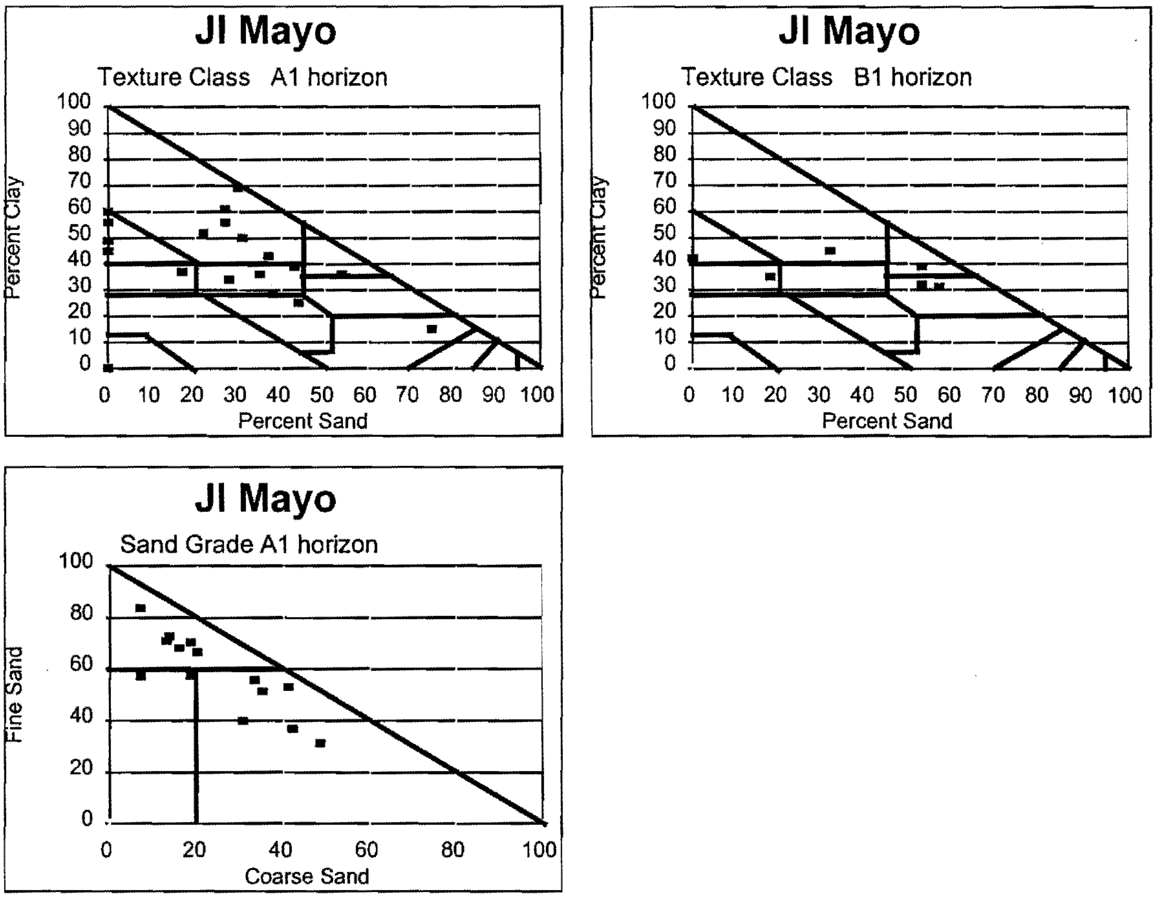

Figure 8.8 Distribution of soil textures, and dominant sand grade, within soils of the Mayo Form.

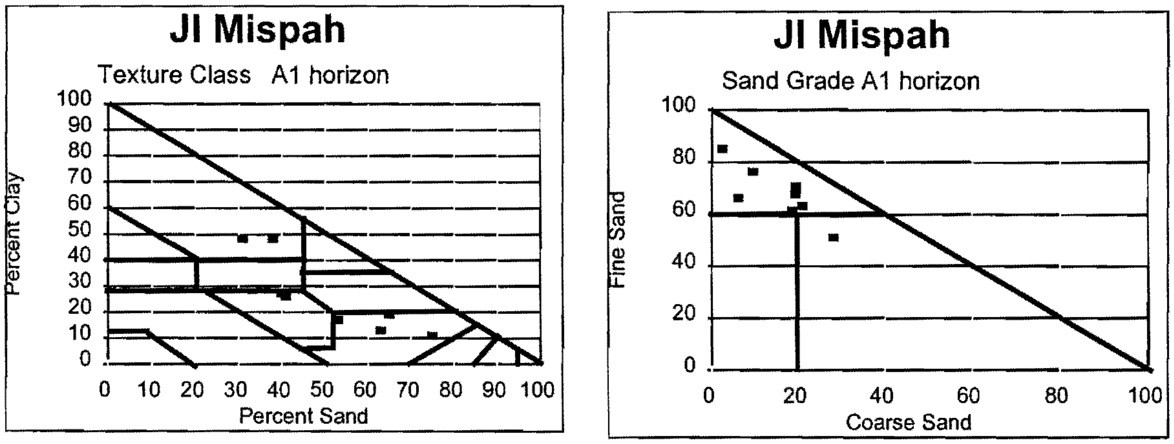

Figure 8.9 Distribution of soil textures within soils of the Mispah Form.

CHAPTER 9

SOILS OF THE AMPHIBOLITE OF THE TUGELA GROUP AND MAPUMULO METAMORPHIC SUITE IN KWAZULU-NATAL AND MPUMALANGA

Location and Extent

Amphibolites, together with basic and andersitic lavas are located in the Piet Retief District of Mpumalanga. The main occurrences are south and west of the town. Amphibolites are also located between 40 and 80 kilometres from the coast, in an area north and east of the Tugela River described as the Natal Structural and Metamorphic Province (Geological Survey, 1988c). Extensive faulting in this area has resulted in a complex geological pattern with a variety of other rocks including granite, gneiss, schist and diorite and others together with the amphibolites. Amphibolites are also present in the coast belt in the Ngoye Range and the escarpment located between the towns of Eshowe and Gingindlovu. There are further isolated occurrences of amphibolite in the Mgeni River Valley north east of Durban, and south of Durban in the Umzinto District (Figure 9.1).

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

Crystalline rocks intruded by granitoids in northern KwaZulu-Natal were recognised prior to 1900, and initially placed with the Swaziland Series of rocks (SACS, 1980). The rocks known variously as Nkandla, Nondweni, Mfongosi and Tugela Series comprise quartzites, schists, chert, limestone, amphibolite, gneiss, banded ironstone and others. They have been collectively grouped within the Natal Structural and Metamorphic Province (Geological Survey, 1984). Of particular interest in this study are the soils derived from amphibolites. These amphibolites are classified within eight formations of the Tugela Group, one formation each of the Matigulu Group, the Mapumulo and Empangeni Metamorphic Suites and one independent formation in the Port Shepstone District (Geological Survey, 1888b; Geological Survey, 1988c; Geological Survey, 1988d). Amphibolites also occur south and west of Piet Retief as part of the Barberton Sequence (Geological Survey, 1988a).

The exposures of the amphibolite east of the Eshowe Plateau have been considered (Partridge and Maud, 1987) as part of a lowered African Surface of Early Cretaceous age. Remnants of the surface are usually preserved on the interfluves.

Physiography and Drainage Features

The area in the Piet Retief District where amphibolite is exposed comprises undulating hills and low mountains with moderate relief. To the south, some of these amphibolite zones west of Melmoth in the Tugela River Valley also comprise undulating hills and valleys. However, most of the Tugela River Valley, where amphibolite is present comprises hills with moderate relief and low mountains. The areas are drained by tributaries of the Pongola and Tugela Rivers respectively.

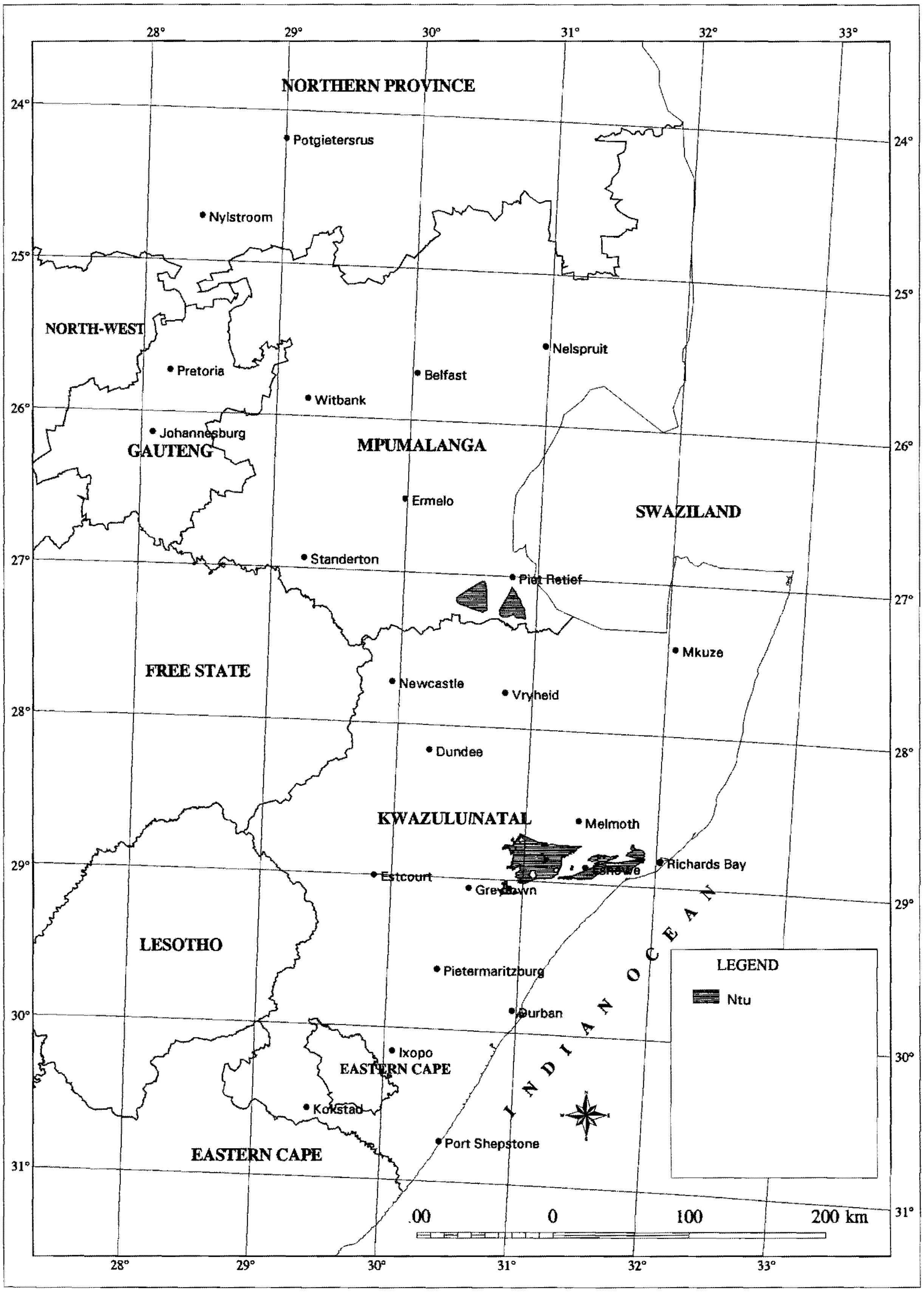

Figure 9.1. Location of the amphibolite rocks of the Tugela Group in KwaZulu-Natal (after Geological Survey, 1984).

Vegetation

The vegetation of these zones is North Eastern Mountain Grassland (Piet Retief District) and Coast Hinterland Bushveld (Tugela River Valley) (Low and Rebelo, 1996).

Soils

Four major soil patterns are evident on the amphibolites of the Tugela Group, Matigulu Group and Mapumulo Metamorphic Suite in KwaZulu-Natal. These are a red apedal pattern with dominantly mesotrophic base status, a pattern comprising of black and red clay soils, and lithosols with and without the presence of lime (Table 9.1). Information on the soils derived from amphibolite is somewhat limited. There are two reasons for this position. The amphibolite commonly occupies a limited surface extent. The separate recognition, at regional scales, of the soils derived from amphibolite, and those of other lithology has not been done. Furthermore, the amphibolite also occurs in steep and largely inaccessible land, such that accurate collection of soil information is not readily possible.

The red apedal soil pattern quoted (Table 9.1) is from the Tugela Valley where the base status and the proportions of Hutton and Shortlands soils have been recorded by field survey. Red soils, and probably of dystrophic base status, also occur in the Piet Retief District together with red soils derived from biotite granite. In this instance the soils derived from amphibolite have not been separated from those from granite. This information is not quoted in Table 9.1.

An area of dominantly Mayo, Bonheim and Shortlands soils is located in undulating land between Eshowe and Nkandla. The soils are moderately deep and have a sandy clay loam to clay texture.

The lithosolic soil patterns are located on steep land. Estimates of the soil distribution indicate the presence of Hutton, Shortlands, Mayo and Bonheim soils, in addition to those of Glenrosa and Mispah (Table 9.1).

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles of the Hutton, Shortlands and Mayo Forms were extracted from the database. Their ranges in textural properties (maximum and minimum values) for five particle size classes, dominant sand grade and information on their luvic properties are presented in Table 9.2. These ranges are also represented graphically in Figure 9.2. The figure allows for an overview comparison between different soil forms and over particle size classes.

The textures of the Mayo profiles derived from the amphibolite rocks of the Tugela Group are very similar to those from Karoo dolerite and the Letaba Formation basalt. Clay and sandy clay are the dominant texture classes with individual profiles extending to the sandy clay loam class (Figure 9.5). The B1 horizons too show these textures, indicating that weathering has proceeded in the case of these amphibolite rocks to at least 1 metre depth. Distinction between these Mayo soils derived from amphibolite, and those form dolerite and basalt, at series classification level

Table 9.1 Dominant soils and selected climatic information for soil patterns occurring on amphibolite.

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 (mesotrophic base status)										
Hutton	Hu27	52	Mispah	Ms10	10	Ave	850	1736	3514	0.48
Shortlands	Sd12 Sd21	30				Std				
						Max				
						Min				
Total Area: 1 640 Ha			Mean of 1 Land Type							
Broad Soil Pattern: Black and Red Clay Soils (high base status)										
Mayo	My11	36	Glenrosa	Gs16 Gs19	11	Ave	898	1549	3367	0.57
Bonheim	Bo31 Bo11	21				Std	71	38	143	0.03
Shortlands	Sd21 Sd22 Sd11 Sd12	18				Max	980	1593	3533	0.61
						Min	816	1505	3201	0.54
Total Area: 9 210 Ha			Means of 4 Land Types							
Broad Soil Pattern: Lithosols without the presence of lime										
Glenrosa	Gs16 Gs17	31	Cartref	Cf21 Cf31	3	Ave	953	1707	3386	0.56
Hutton	Hu26 Hu27	18	Bonheim	Bo31 Bo11	3	Std	109	110	573	0.09
Shortlands	Sd11 Sd12	14	Mispah	Ms10 Ms11	4	Max	839	1855	3874	0.68
Mayo	My10 My11	8	Rock	Rock	4	Min	1075	1546	2418	0.45
Total Area: 123 250 Ha			Means of 5 Land Types							
Broad Soil Pattern: Lithosols with the presence of lime										
Glenrosa	Gs16 Gs17 Gs26	32	Rock	Rock	5	Ave	720	1724	3523	0.41
Mispah	Ms10	16				Std	30	52	20	0.03
Hutton	Hu34 Hu36 Hu44 Hu46	14				Max	750	1776	3543	0.44
Shortlands	Sd21 Sd22	7				Min	690	1672	3503	0.38
Total Area: 117 920 Ha			Means of 4 Land Types							

is probably not required with respect to texture. However, it is interesting that a greater proportion of Mayo soils, together with Shortlands and Hutton soils, have developed on the amphibolite. Bonheim, Arcadia and Rensburg Form soils have not been sampled on amphibolite rocks, and appear to be sub-dominant in these landscapes. The resultant weathering in the Mayo soils is to kaolinite and 2:1 chlorite minerals in the clay fraction. Quartz, feldspar, 2:1 chlorite and even kaolinite minerals are present in the silt fraction. Only a minor amount of smectite was present in one horizon (Land Type Survey Staff, 1987c; 1994a). The clay fraction has no (or only limited) swelling capacity for the Mayo soils. The absence of smectite was unexpected in these Mayo soils. (How does this compare with the Mayo from dolerite and basalt). Mineralogy is available for only three Mayo profiles to support this trend. It remains uncertain whether smectite

Table 9.2 Textural properties of soils of amphibolite derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1 B1	ClLm-Cl SaLm-SaClLm-ClLm-Cl	30-69 15-65	15-26 4-27	13-29 13-44	2-11 4-28	2-4 3-17	fi fi,me,co	- -
Shortlands	A1 B1	SaClLm-Cl SaClLm-Cl	25-66 30-83	8-30 8-26	14-32 8-42	4-30 1-15	2-11 1-6	fi,me fi,me	L3,NL2 -
Mayo	A1 B1	SaClLm-SaCl-Cl SaLm-SaClLm-Cl	22-58 17-65	9-25 7-28	18-55 14-52	5-31 3-26	1-15 1-22	fi,me,co fi,me,co	NL2,EL2,L1 -

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).

would be present in other Mayo profiles. Cation Exchange Capacities (CEC, expressed in cmol(+)/kg clay) range from 20 to 100 cmol(+)/kg clay and present a varied picture. The CEC values for the profiles where the mineralogy was determined, were placed centrally within this CEC range. This could indicate that smectite may not be expected in these Mayo soils. In the Shortlands and Hutton soils it is assumed that kaolin minerals together with the iron minerals are dominant. Cation Exchange Capacities (CEC) for the Shortlands and Hutton soils ranges from 13 to 70 cmol(+)/kg clay. No mineralogical analyses for these soils were available.

Table 9.3 Means and standard deviations of five textural classes for soils derived from amphibolite.

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	0-290	49.5	19.5	20.5	5.5	21.0	8.0	6.5	4.5	3.0	1.0	2
B1	982	35.1	15.9	12.4	6.6	27.4	9.2	14.4	8.8	10.1	5.0	8
Form: Shortlands												
A1	488	39.2	15.4	18.7	8.1	23.8	6.7	12.7	8.5	5.3	2.8	6
B1	1011	55.7	14.7	16.3	6.9	18.1	11.1	7.1	4.0	3.8	1.7	7
Form: Mayo												
A1	524	40.1	10.2	14.9	4.6	28.0	10.1	12.7	6.3	6.3	4.5	15
B1	1025	42.5	14.8	17.2	5.7	25.9	12.5	10.9	7.6	6.8	6.0	10

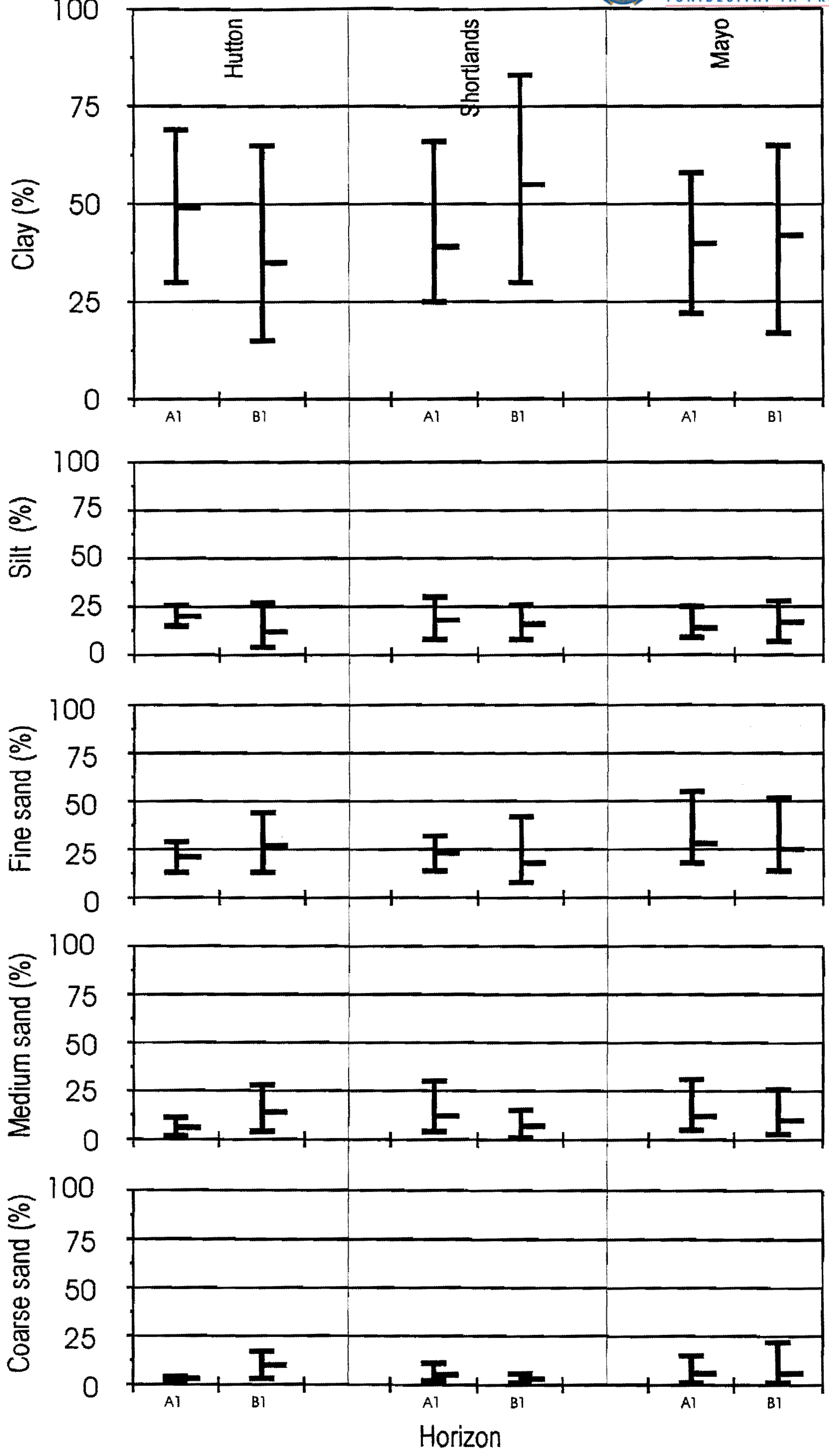

Figure 9.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the amphibolites of the Tugela Group. Maximum, minimum and mean values are shown for each horizon.

The texture of the A1 horizon of the Shortlands soils is dominantly sandy clay loam (Figure 9.4), while that for the B1 horizon rises to the clay class. This is clearly much lower than those soils derived from dolerite or basalt, which have clay texture classes throughout all horizons. This trend is more pronounced in the Hutton soils, where the textures of the B1 horizons range from sandy loam through to clay (Figure 9.3). Fine, medium and coarse sands are dominant within individual Mayo, Shortlands and Hutton profiles (Figures 9.3, 9.4, 9.5).

The Shortlands and Mayo soils have both luvic and non-luvic properties with respect to their A1 to B1 horizons.

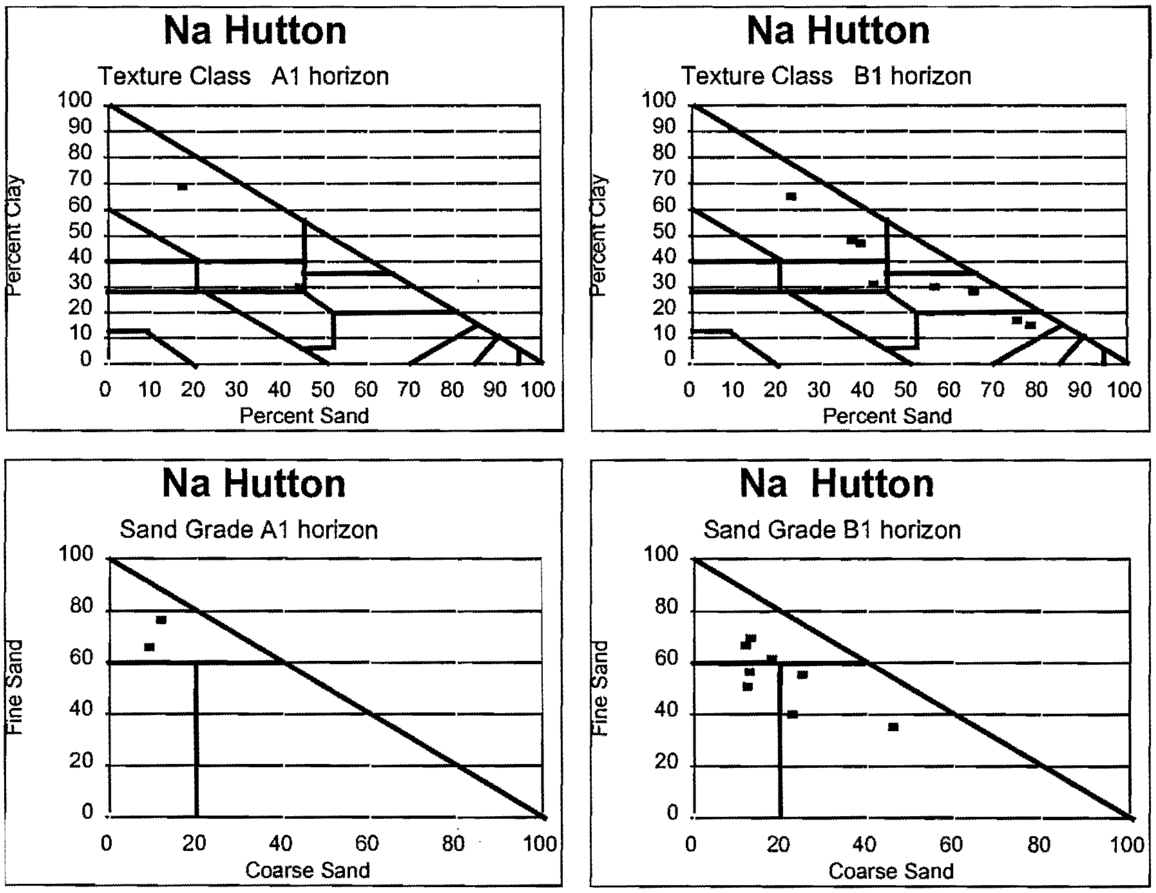

Figure 9.3. Distribution of soil textures, and dominant sand grade, within soils of the Hutton Form.

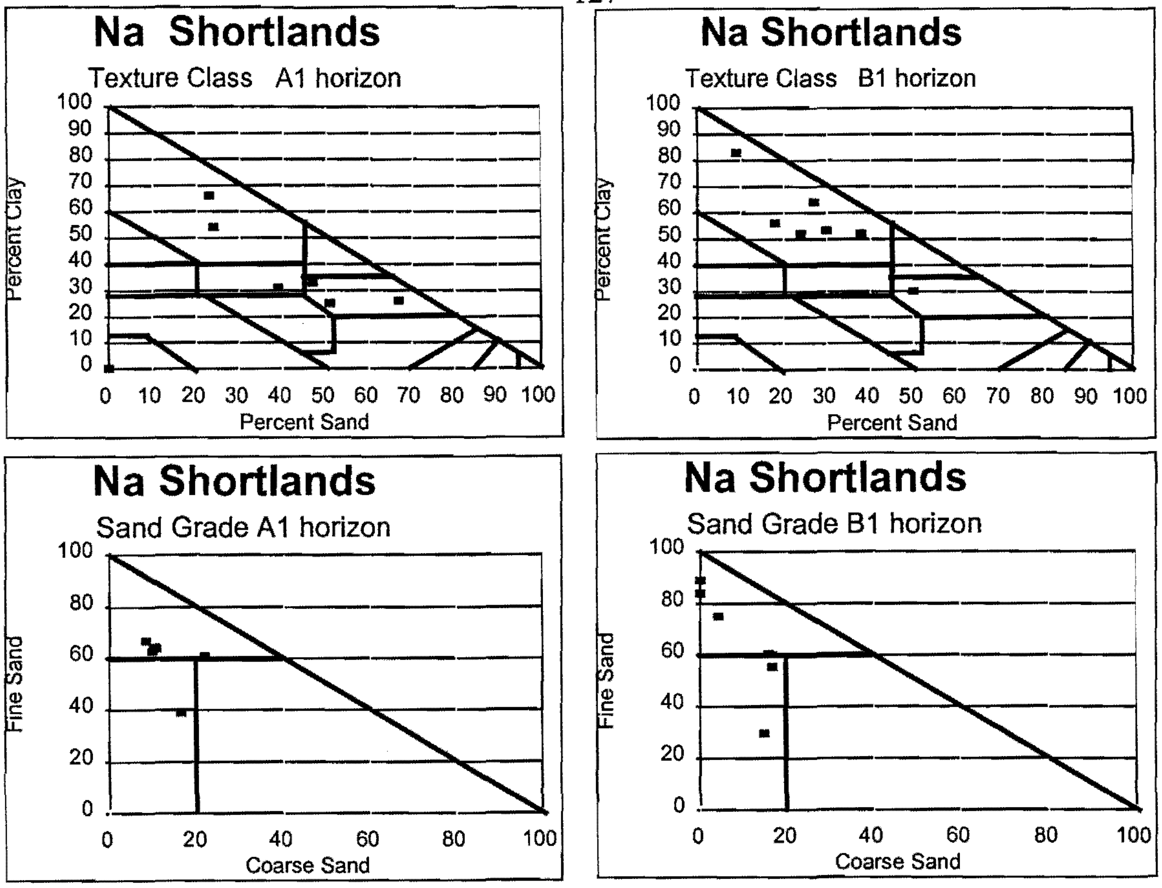

Figure 9.4. Distribution of soil textures, and dominant sand grade, within soils of the Shortlands Form.

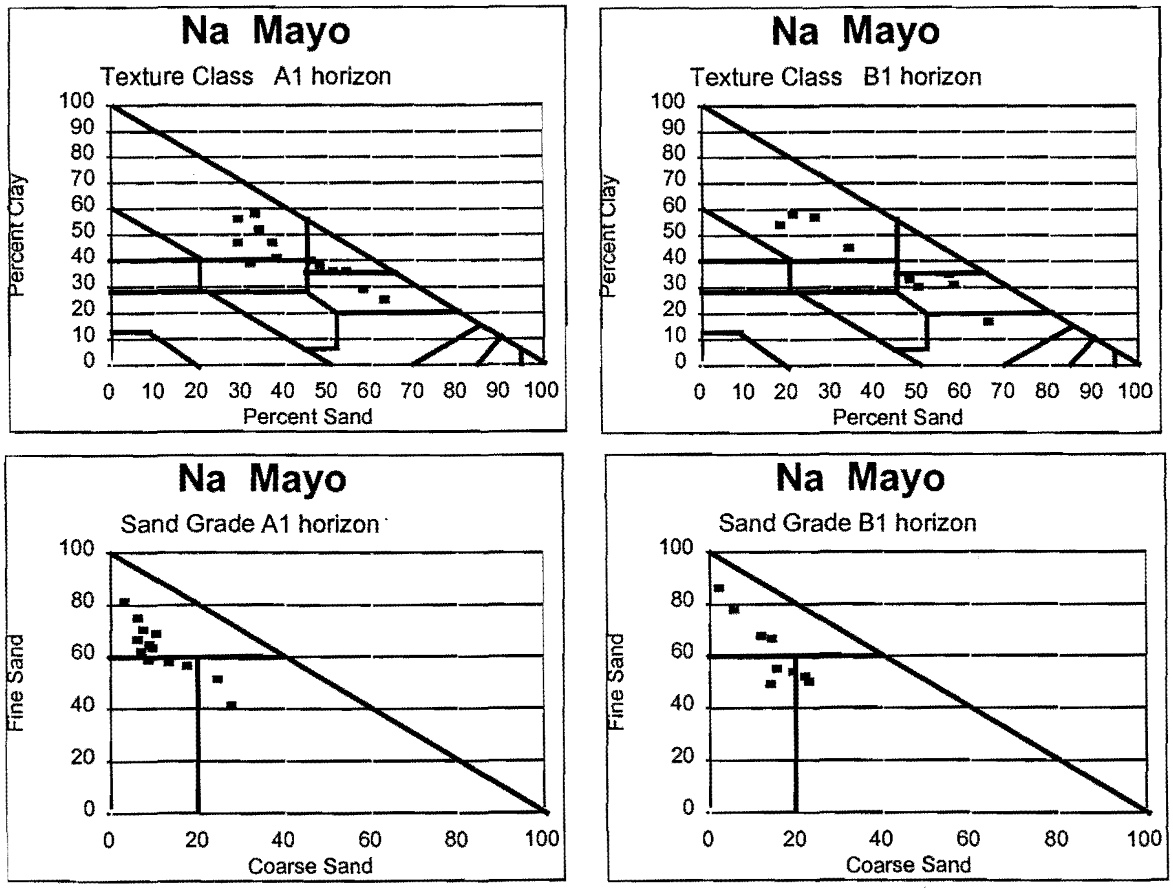

Figure 9.5. Distribution of soil textures, and dominant sand grade, within soils of the Mayo Form.

CHAPTER 10

SOILS OF THE SANDSTONE AND MUDSTONE OF THE TARKASTAD FORMATION, BEAUFORT GROUP IN KWAZULU-NATAL

Location and Extent

The Tarkastad Formation lies in a belt of between 15 and 30 kilometres wide, stretching from the source of the Klip River through southern KwaZulu-Natal. The formation is located in the foothills below the Drakensberg escarpment and the moist interior basins. In the west the formation is bounded by the Molteno and Elliot Formations. The eastern boundary is the Estcourt Formation in the north, while south of the Mkomazi River it bounded in the east by the Adelaide Formation (Figure 10.1). South of the Giants Castle buttress the area occupied by the Tarkastad Formation is intruded by extensive dolerite sheets.

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

The strata of the Beaufort Group can be readily subdivided into two geological mappable units, the upper Tarkastad Formation and the lower Adelaide Subgroup with the former possessing a greater proportion of sandstone and red mudstone (SACS, 1980). South of 31 degrees 30 minutes south (south of KwaZulu-Natal) two formations have been recognised, namely a lower arenaceous formation and an upper argillaceous formation. To the north it has not been possible to differentiate between the two formations and a single unit Tarkastad Formation is used. The Tarkastad Formation is described as comprising fine to medium grained yellow and grey sandstone and maroon (red) to green and blue mudstone (Geological Survey, 1981a; Geological Survey, 1981b).

Physiography and Drainage Features

The foothills of the Drakensberg Escarpment have undulating hills and low mountains with only limited land of flatter slopes. However, south of Giants Castle the proportion of land with slopes less than 5 percent increases significantly and lowlands and hills of moderate relief are encountered (Kruger, 1983). To the north drainage is via the Tugela, Bushmans and Mooi Rivers and their tributaries, while to the south drainage is via the Mkomazi, Mzimkulu and Mzimvubu Rivers.

Vegetation

The vegetation is largely North-eastern Mountain Grassland and Moist Upland Grassland (Low and Rebelo, 1996).

Soils

Four major soil patterns are evident on the sandstone and mudstone of the Tarkastad Formation (Table 10.1). The patterns include a red and yellow-brown apedal soil pattern where dystrophic sandy loam to sandy clay loam soils is dominant. The red clay soils (Hu18), while forming an integral part of this soil pattern, are probable derived from dolerite, and as such should be read in association with the sandier soils developed from the sandstones and mudstones of the

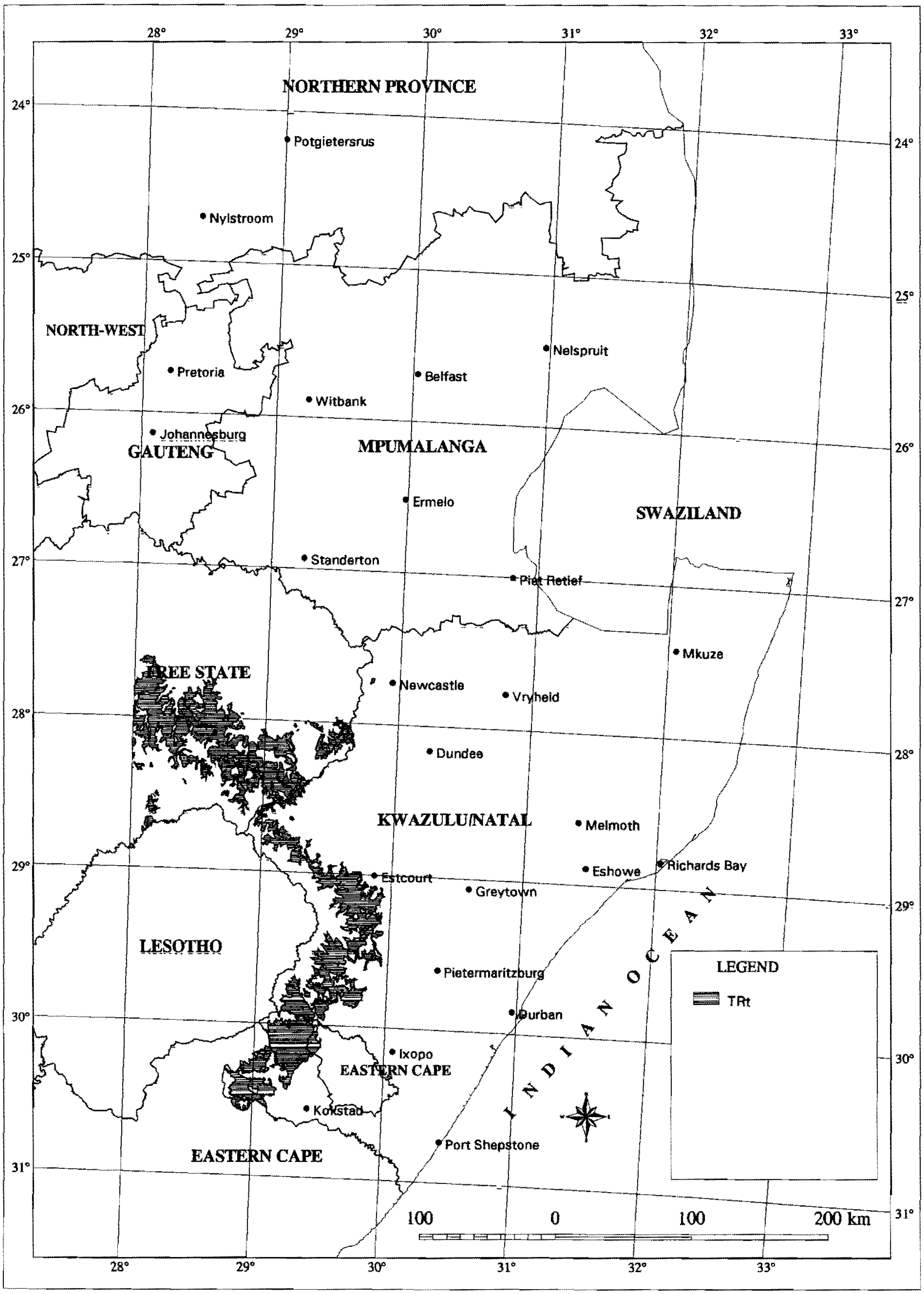

Figure 10.1. Location of the Tarkastad Formation, Beaufort Group in KwaZulu-Natal (after Geological Survey, 1984).

Table 10.1 Dominant soils and selected climatic information for soil patterns occurring on Tarkastad 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 Apedal Soils (dystrophic base status)										
Hutton	Hu16 Hu17 Hu26	20	Glenrosa	Gs16 Gs19	12	Ave	994	1716	1841	0.58
	(Hu18)	14	Mispah	Ms10	7	Std	151	286	361	0.11
Clovelly	Cv16 Cv17 Cv18	14				Max	1438	2951	3020	0.88
Griffin	Gf11 Gf12	8				Min	676	1230	1221	0.37
Oakleaf	Oa36	3								
Katspruit	Ka10	3								
Total Area: 324 370 Ha			Means of 99 Land Types							
Broad Soil Pattern: Plinthic Soils (mesotrophic base status) and Duplex Soils										
Avalon	Av23 Av24 Av26	33	Estcourt	Es13 Es16	8	Ave	753	1583	1459	0.48
Pinedene	Av16 Pn26 Pn16		Valsrivier	Va31 Va32	11	Std	47	28	82	0.03
Clovelly	Cv16 Cv26 Cv27	7		Va41 Va42		Max	800	1612	1541	0.50
Oakleaf	Oa36	3	Sterkspruit	Ss26	4	Min	706	1555	1377	0.45
			Swartland	Sw31 Sw32	2					
			Glenrosa	Gs16 Gs17	14					
			Mispah	Ms10						
			Rock	Rock	4					
Total Area: 162 680 Ha			Means of 5 Land Types							
Broad Soil Pattern: Duplex Soils										
Estcourt	Es33 Es34 Es36	17	Avalon	Av33 Av36	7	Ave	674	1718	2126	0.39
Valsrivier	Va31 Va41 Va21	27		Pn33		Std	25	50	632	-
Swartland	Sw31 Sw41 Sw11	11	Pinedene	Pn36		Max	710	1789	3008	0.40
	Sw21					Min	656	1682	1685	0.39
Sterkspruit	Ss23 Ss24 Ss26	12								
Glenrosa	Gs13 Gs16 Ms10	11								
Mispah										
Total Area: 32 350 Ha			Means of 5 Land Types							
Broad Soil Pattern: Lithosols without the presence of lime										
Glenrosa	Gs16 Gs17 Gs19	19	Hutton	Hu16 Hu26	15	Ave	881	1811	1647	0.48
Mispah	Ms10	11		Hu27		Std	169	427	383	0.11
Cartref	Cf11 Cf12	3	Estcourt	Es13 Es16	4	Max	1260	2766	2217	0.78
Rock	Rock	16	Swartland	Sw31 Va31	4	Min	622	1319	784	0.31
			Valsrivier							
Total Area: 250 060 Ha			Means of 67 Land Types							

Tarkastad Formation. The plinthic soil pattern comprises dominantly of mesotrophic Avalon soils (Table 10.1). Pinedene, Clovelly and Oakleaf soils are also present, with a proportion of dystrophic soils. Duplex soils are sub-dominant in this soil pattern, having a relatively high proportion of Estcourt soils. The presence of an E horizon in the Estcourt soils reflects a higher level of soil profile wetness, and a slowly permeable prismacutanic horizon at generally shallow depths. This contrasts with the plinthic soil patterns of the Vryheid Formation where Longlands, Wasbank, Westleigh and on occasions Cartref soils are present (Chapter 14), and with the Volksrust Formation where in addition to plinthic soils, deeper Kroonstad soils are dominant (Chapter 13).

The duplex soil pattern is dominated by Valsrivier soils (Table 10.1). This soil form has unconsolidated material below the diagnostic pedocutanic horizon, and together with the Sterkspruit soils, could be evidence of transported material in the lower positions in these landscapes. Swartland, Sterkspruit and Estcourt soils, and the lithosolic soils Glenrosa and Mispah, also comprise significant proportions of the soil pattern. Avalon and Pinedene soils are sub-dominant in this pattern (Table 10.1). The presence again of a relatively larger proportion of Estcourt soils must be interpreted as giving an indication of the higher seasonal levels of profile wetness in bottomland positions. Two Estcourt profiles are included in the dataset (Tables 10.2, 10.3). Regrettably there are no Valsrivier, Swartland or Sterkspruit profiles sampled directly over the sandstone and mudstone of the Tarkastad Formation. Profiles of the Valsrivier, Sterkspruit and Estcourt Forms were noted overlying the Masotcheni Formation, the name given to the Quaternary lithology in the interior of KwaZulu-Natal. In this area the bottomland soils could be dominated by materials which comprise the Masotcheni Formation. An overview of the distribution and extent of the Masotcheni Formation is given by Botha, Scott, Vogel and Von Brunn (1992). The sediments are commonly located in the footslope and valley bottoms within the Ecca and Beaufort Group lithologies (Geological Survey, 1981a; 1981b; 1988a; 1988b; 1988c). Dramatic examples of deep gully erosion can be seen in many of the KwaZulu-Natal interior valley basins. The geomorphology and soil formation can be studied from the hillslope profiles and form the sediments within the gullies. Exposures in these gullies, which now commonly have Valsrivier and other duplex soils at their surface, often show a number of cycles of soil formation. Pictorial evidence of cycles of soil formation in these gullies and of the erosional landsurfaces is illustrated by photographs in Soils of the Tugela Basin (van der Eyk, MacVicar and de Villiers, 1969). The evidence of cyclic phases of soil formation within transported materials has been described by de Villiers (1962). Botha, *et al.* (1992) have dated examples of these soil erosional events.

A description of the erosional history and geomorphology of the KwaZulu-Natal Interior is given in Van der Eyk, *et al.* (1969). A review of the erosional history of the subcontinent is given by Partridge and Maud (1987).

The final lithosolic soil pattern has Glenrosa and Mispah soils dominant (Table 10.1). It is interesting that the clay and clay loam textural classes within the Glenrosa soils are recorded within this pattern. The sandy clay loam and sandier textural classes are those usually encountered. Hutton soils are subdominant in the high rainfall areas, while Estcourt, Swartland and Valsrivier soils are subdominant in the drier parts.

The summary information contained in Table 10.2 has been derived for the Land Type Survey (Land Type Survey Staff, 1994a; 1996; 1997a; 1997b).This survey focused on obtaining the soil distribution information by establishing the presence and estimated proportions of soils in any given area. Soil properties were estimated by the modal profile sampling program. Little attention could be directed at soil genesis and landscape evolution.

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles of the Hutton, Clovelly, Oakleaf, Estcourt, Mispah and Katspruit Forms were extracted from the database. Their ranges in textural properties (maximum and minimum values) for five particle size classes, dominant sand grade and information on their luvic properties are presented in Table 10.2. These ranges are also represented graphically in Figure 10.2. The figure allows for an overview comparison between different soil forms and over particle size classes.

Table 10.2 Textural properties of soils of the Tarkastad Formation derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1 B1 B2	SaClLm-Lm-Cllm SaClLm-SaCl-ClLm-Cl Lm-SaClLm	4-47 4-54 17-40	2-42 3-39 4-30	19-73 6-61 30-55	1-15 1-15 2-6	1-4 1-12 1-2	fi fi fi	NL1,L1,EL3 NL1,L1,EL3 -
Clovelly	A1 B1 B2	SaClLm-SaCl-ClLm-Cl SaClLm-SaCl-ClLm-Cl SaClLm-ClLm-SiClLm	19-52 16-52 16-47	8-37 10-41 12-50	4-53 6-58 10-54	1-15 1-18 1-24	1-9 1-7 1-13	fi fi fi	NL1,L1,EL3 NL5 -
Oakleaf	B1	SaLm-SaClLm	12-24	10-25	43-58	2-18	1-2	fi	-
Eluvic Horizon Soils	A1	SaClLm-SaLm	4-50	6-38	8-54	1-14	1-8	fi	-
Estcourt	A1 E1 B1	SaLm SaLm SaLm	8-17 9-17 53-56	10-21 12-20 3-10	52-52 51-51 23-23	13-13 14-14 7-7	4-4 4-4 2-2	fi fi fi	NL L -
Mispah	A1	Lm-ClLm-Cl	4-50	30-32	13-33	1-4	1-5	fi	-
Katspruit	A1	Cl-SaLm	12-50	20-38	13-53	2-11	3-4	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).

The Hutton profiles are located in a single natural soil body clustered about the loam to sandy clay loam textural classes (Figure 10.3). Profiles with high clay contents extend into the clay loam and clay classes, while textures extending into the sandy loam class were also sampled. Within the Clovelly Form the spread of profile textures about the loam and sandy clay loam classes is similar to those of the Hutton Form. The clay profiles however are displaced with small increases in the silt and small decreases in the fine sand values. Two natural bodies with respect to texture can be recognised in the Clovelly profiles. This trend is extended into the A1 horizons of the remaining profiles (Oakleaf, Estcourt, Mispah, and Katspruit Forms) with orthic topsoils (Figure 10.6).

To retain a consistent pattern within the sediments of the Tarkastad Formation, two natural bodies have been selected. The threshold value for separation has been set at above and below 30 percent total sand. The means and standard deviations for five particle size classes centred around the sandy clay loam and clay loam respectively are given (Tables 10.3, 10.4). Fine sand is the dominant sand grade (Figures 10.3, 10.4, 10.6), silt values lie within a narrow range with means around 20 percent giving rise to the loam textural classes.

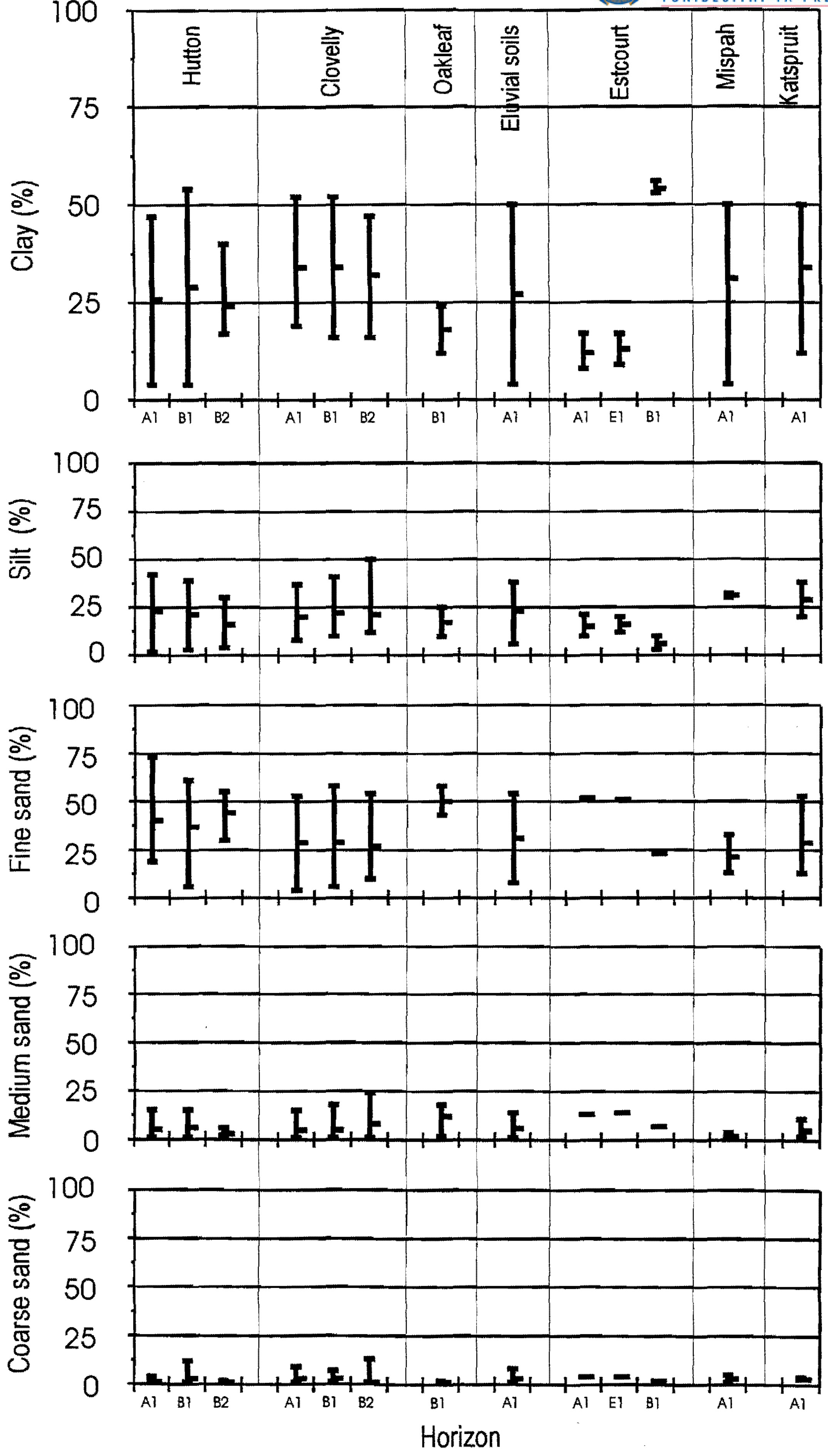

Figure 10.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Tarkastad Formation. Maximum, minimum and mean values are shown for each horizon.

Dominantly non-luvic profiles were measured for both the Hutton and Clovelly soils (Figure 10.7).

Duplex soils though widespread on the Tarkastad Formation cover only a limited area in KwaZulu-Natal (Table 10.1). No profiles of duplex soils were available in this sample set.

Table 10.3 Means and standard deviations of five textural classes for soils of the Tarkastad Formation.

Hori zon	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	288	26.6	9.6	23.3	12.4	40.0	11.2	5.8	3.5	1.6	1.0	43
B1	741	29.6	11.5	21.2	8.3	37.1	12.7	6.0	8.0	3.3	6.3	46
B2	1097	24.5	7.2	16.8	8.3	44.2	10.5	3.8	1.5	1.7	0.5	9
Form: Clovelly												
A1	275	34.3	8.9	20.9	8.1	29.3	12.4	5.9	4.1	3.3	2.5	24
B1	706	34.7	9.9	22.9	8.5	29.0	13.4	5.1	4.0	3.1	2.0	30
B2	1011	32.2	8.0	21.7	10.4	27.9	12.9	8.0	6.9	4.1	4.1	11
Form: Oakleaf												
B1	620	18.4	5.0	17.0	5.9	50.4	5.6	12.0	5.5	1.5	0.5	5
Form: Eluvic												
A1	341	27.5	16.1	23.9	10.5	31.6	17.1	6.5	5.1	3.1	2.1	13
Form: Estcourt												
A1	225	12.5	4.5	15.5	5.5	52.0	0.0	13.0	0.0	4.0	0.0	2
E1	340	13.0	4.0	16.0	4.0	51.0	0.0	14.0	0.0	4.0	0.0	2
B1	650	54.5	1.5	6.5	3.5	23.0	0.0	7.0	0.0	2.0	0.0	2
Form: Mispah												
A1	310	31.0	19.6	31.3	0.9	21.0	8.6	2.7	1.3	3.0	1.6	3
Form: Katspruit												
A1	522	34.5	14.5	29.5	8.1	29.3	17.1	5.3	4.0	3.3	0.5	4

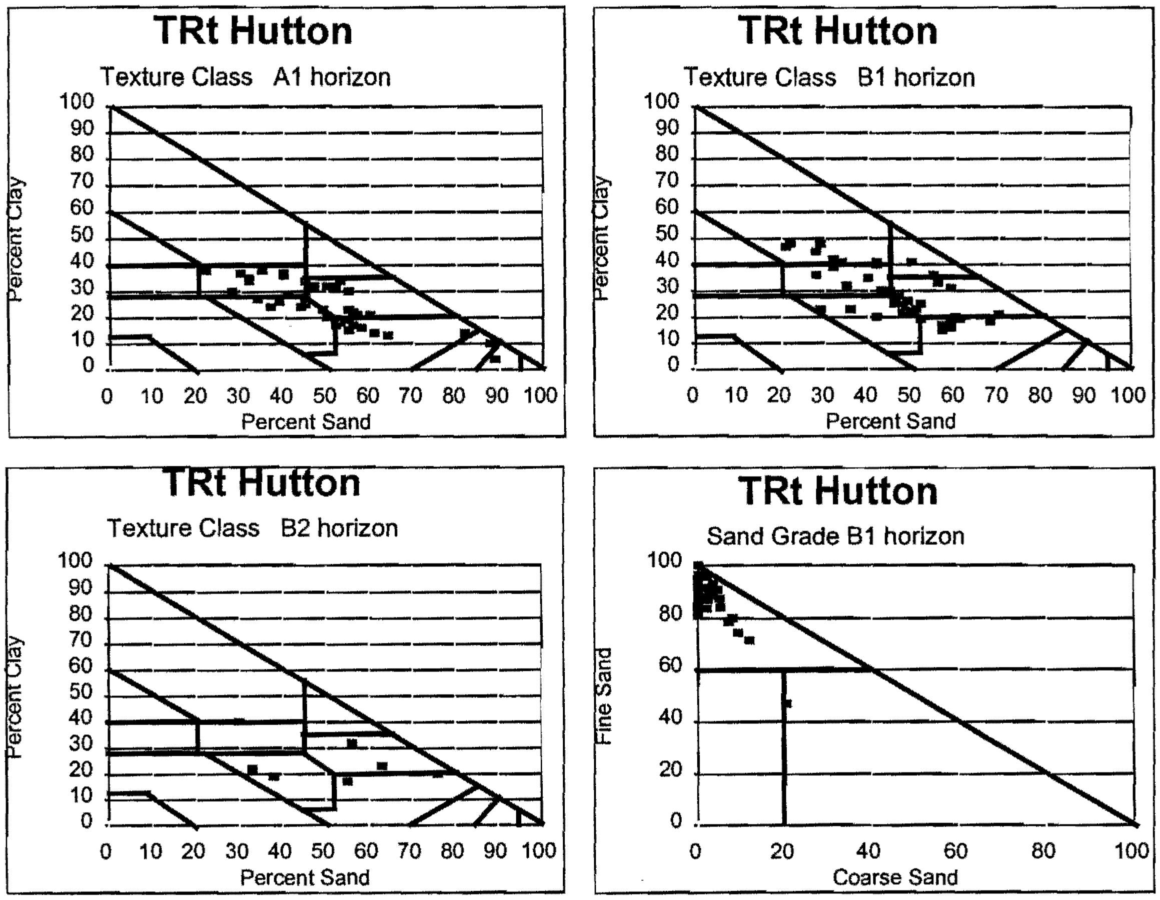

Figure 10.3. Distribution of soil textures, and dominant sand grade, within soils of the Hutton Form.

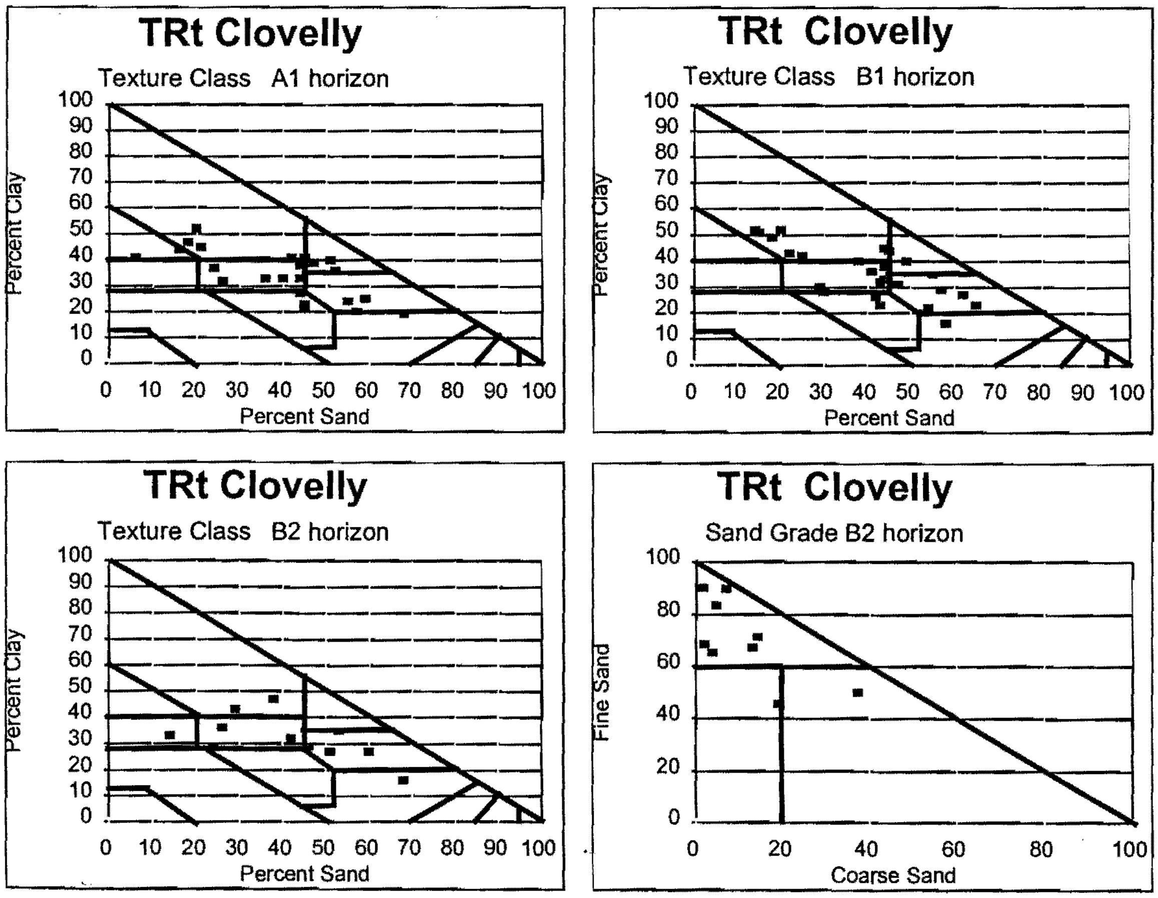

Figure 10.4. Distribution of soil textures, and dominant sand grade, within soils of the Clovelly Form.

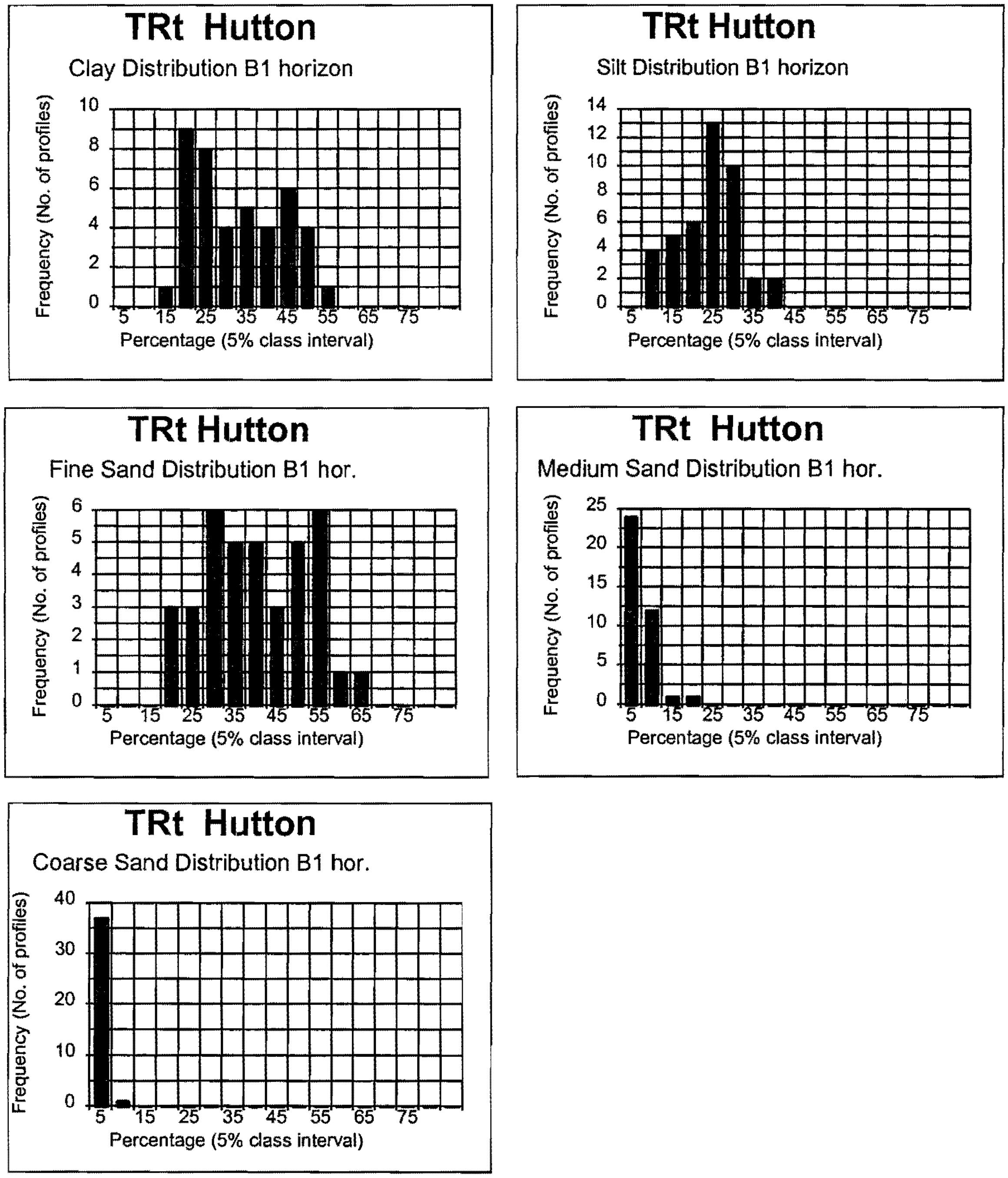

Figure 10.5 Distribution of clay, silt, fine sand, medium sand and coarse sand within soils of the Hutton Form.

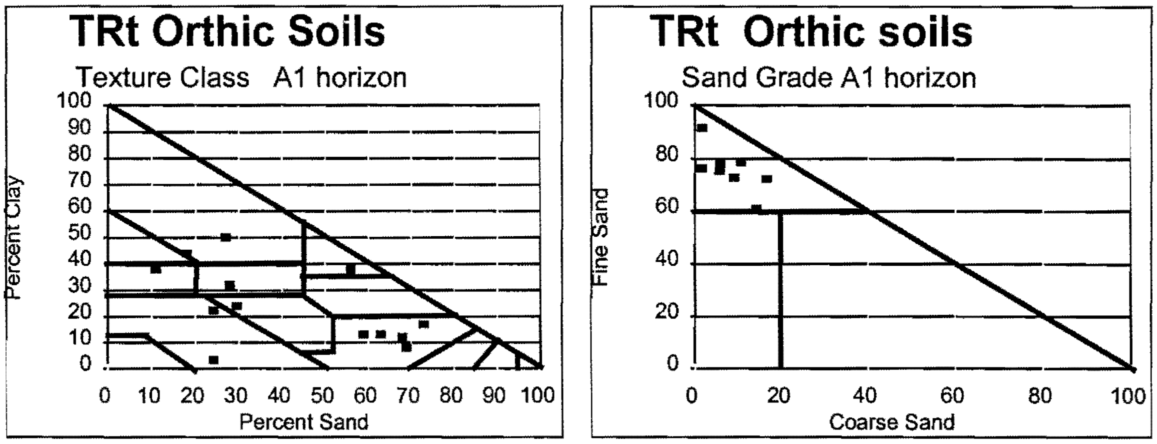

Figure 10.6 Distribution of soil textures, and dominant sand grade, within soils with an orthic horizon. Soils include profiles from the Estcourt, Longlands, Mispah and Katspruit Forms.

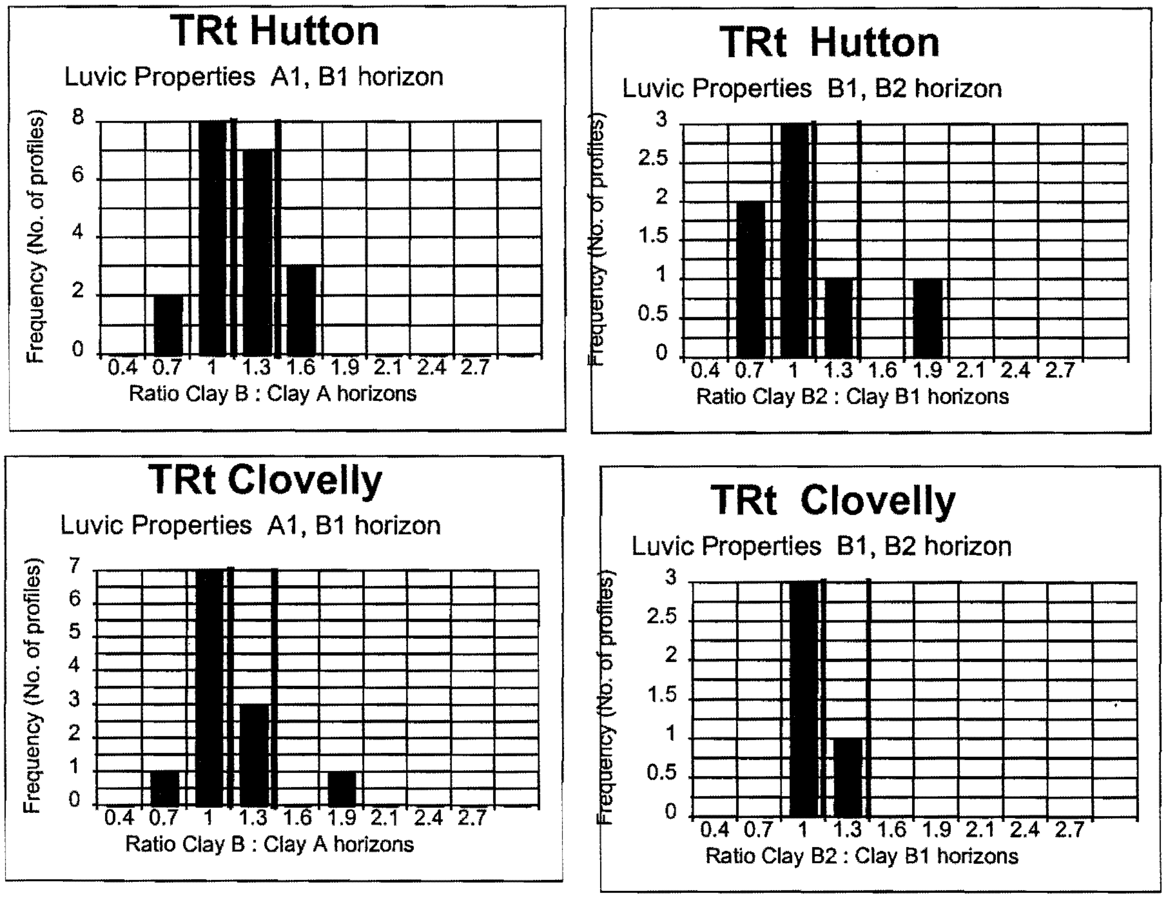

Figure 10.7 Luvic properties of soils of the Hutton and Clovelly Forms.

CHAPTER 11

SOILS OF THE MUDSTONE AND SANDSTONE OF THE ADELAIDE SUBGROUP, BEAUFORT GROUP IN KWAZULU-NATAL

Location and Extent

The Adelaide Subgroup stretches in a relatively broad belt of between 12 and 50 kilometres wide in the southern KwaZulu-Natal Interior Basins. It is located south of the Mkomazi River Valley between the Tarkastad Formation in the west and the shales and sandstones of the Ecca Group in the east. As with the Tarkastad Formation, the Adelaide Subgroup is locally intruded by relatively extensive dolerite intrusions (Geological Survey, 1981a; Geological Survey, 1981b). The Subgroup occupies approximately 356 110 hectares in extent (Figure 11.1). The equivalent parts of the Beaufort Group rocks in the northern KwaZulu-Natal basins are now recognised as the Estcourt Formation.

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

The strata of the Beaufort Group can be readily subdivided into two geological mappable units, the upper Tarkastad Formation and the lower Adelaide Subgroup. The Adelaide Subgroup consists of essentially greenish (or bluish) grey, and greyish-red mudstones and sandstones (SACS, 1980). The Adelaide Subgroup is described as comprising grey and reddish-brown mudstone and yellow and grey fine grained sandstone (Geological Survey, 1981a; Geological Survey, 1981b).

Physiography and Drainage Features

The area where the Adelaide Subgroup is exposed comprises undulating to strongly undulating lowlands and hills (Kruger, 1983). Moderate slopes are encountered on much of the land drained by the Mzintlava River. To the south east and south west of the town of Kokstad lies the Ngele and Ngintsizwa Mountain Highlands with extensive dolerite intrusions.

Vegetation

The vegetation is Moist Upland Grassland with small occurrences of Mountain Forest (Low and Rebelo, 1996).

Soils

Five major soil patterns are evident for the soils derived from the mudstones and sandstones of the Adelaide Formation (Table 11.1). The first is a red and yellow-brown apedal soil pattern with Hutton, Clovelly and Griffin soils dominant. Glenrosa, Mispah and Katspruit soils are subdominant. A wide textural range has been measured for these soils. The plinthic soil pattern has Avalon, Glencoe, Longlands, Wasbank and Westleigh soil together with Clovelly, Pinedene and Hutton soils (Table 11.1). These dominantly mesotrophic soils are of the loamy sand to sandy clay loam textural classes, lacking the clay textural classes encountered in the red and yellow-brown apedal soils. Soils with an E horizon comprise one third of the soils within the

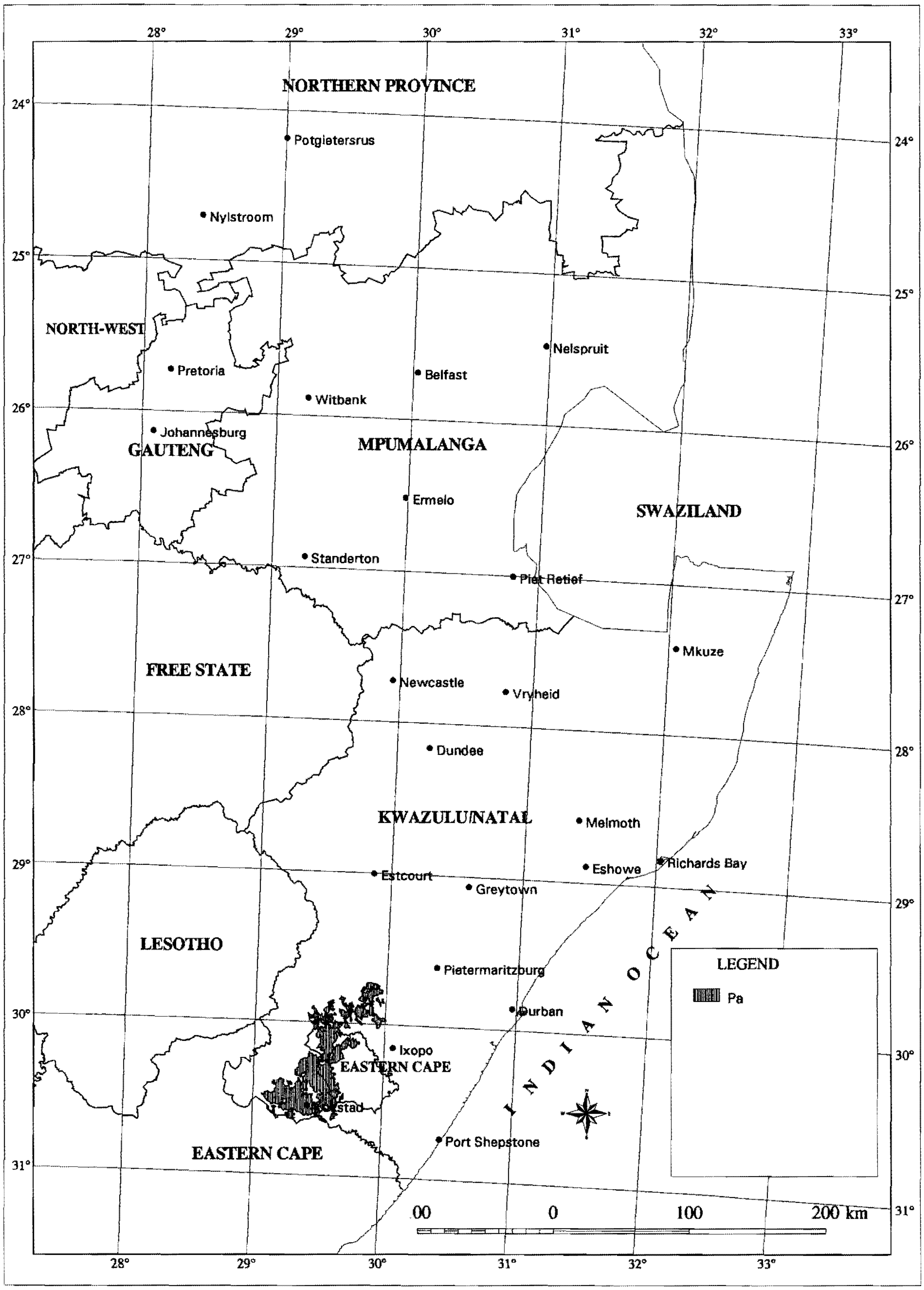

Figure 11.1. Location of the Adelaide Subgroup, Beaufort Group in KwaZulu-Natal and Mpumalanga (after Geological Survey, 1984).

Table 11.1 Dominant soils and selected climatic information for soil patterns occurring on Adelaide Subgroup.

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 Apedal Soils (dystrophic and mesotrophic base status)										
Hutton	Hu17 Hu18	15	Glenrosa	Gs16 Gs19 Ms10	18	Ave	922	1350	1586	0.68
	Hu16	12	Mispah			Std	132	266	484	0.20
	Hu26 Hu27	5	Katspruit	Ka10	3	Max	1280	1737	2608	-
Clovelly	Cv16	10				Min	706	862	822	0.43
	Cv17	4								
Griffin	Gf11 Gf12	10								
Total Area: 186 166 Ha			Means of 54 Land Types							
Broad Soil Pattern: Plinthic and Apedal Soils (mesotrophic base status)										
Avalon	Av26 Av27 Gc26	6	Cartref	Cf11 Cf12	10	Ave	740	1321	843	0.56
Glencoe			Estcourt	Es13 Es16	4	Std				
Longlands	Lo11 Lo12 Wa11	10	Swartland	Sw31 Va31	5	Max				
Wasbank	Wa12		Valsrivier			Min				
Westleigh	We11 We12	7	Mispah	Ms10 Gs16	10					
Clovelly	Cv26 Cv27 Pn26	16	Glenrosa							
Pinedene										
Hutton	Hu26 Hu27	11								
Total Area: 11 720 Ha			Means of 3 Land Types							
Broad Soil Pattern: Duplex Soils										
Estcourt	Es33 Es36 Es16	9	Longlands	Lo11 Lo12 We11	4	Ave	709	1852	2472	0.38
Kroonstad	Kd16		Westleigh	We12		Std	54	114	604	0.05
Sterkspruit	Ss23 Ss26	4	Glenrosa	Gs16 Gs19 Ms10	10	Max	776	1967	3076	0.43
Valsrivier	Va31 Va32 Va41	13	Mispah			Min	654	1737	1868	0.33
	Va42									
Swartland	Sw31 Sw32	6								
	Sw41 Sw42									
Oakleaf	Oa16 Oa36 Oa46	14								
Total Area: 18 000 Ha			Means of 5 Land Types							
Broad Soil Pattern: Lithosols without the presence of lime										
Glenrosa	Gs16 Gs19	14	Hutton	Hu17 Hu16 Hu27	20	Ave	799	1474	1573	0.54
Mispah	Ms10	10		Hu26		Std	99	179	258	0.11
Cartref	Cf12 Cf11 Cf21	5	Clovelly	Cv16 Cv17 Cv26	8	Max	999	1737	1868	0.77
	Cf22			Cv27		Min	649	1230	1040	0.43
Rock	Rock	16								
Total Area: 107 360 Ha			Means of 18 Land Types							
Broad Soil Pattern: Lithosols with the presence of lime										
Glenrosa	Gs16 Gs19	17	Swartland	Sw30 Sw31	4	Ave	839	1700	2197	0.49
Mispah	Ms10	10	Valsrivier	Va30 Va31 Va41	5	Std	103	149	299	0.09
Cartref	Cf12 Cf11	3	Estcourt	Es16 Ss26	9	Max	1033	1976	2566	0.62
Rock	Rock	7	Sterkspruit			Min	668	1455	1566	0.37
			Hutton	Hu27 Hu28	14					
Total Area: 32 870 Ha			Means of 15 Land Types							

plinthic soil pattern. The duplex soil pattern has a range of soil forms and textures. Calcareous and non-calcareous soils are present (Table 11.1). Lithosols with and without the presence of lime comprise the remaining two soil patterns (Table 11.1). Dystrophic and mesotrophic Hutton and Clovelly soils are subdominant where lime is absent, while duplex soils are subdominant contributing to the soil pattern where lime is present (Table 11.1).

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles of the Hutton, Griffin, Clovelly, Avalon, Longlands, Estcourt, Swartland and Glenrosa Forms were extracted from the database. Two natural bodies based on textural properties are evident (Figures 11.4 to 11.10) with a threshold for their separation set at 60 percent total sand. The ranges in textural properties (maximum and minimum values) for five particle size classes, dominant sand grade and information on their luvic properties are presented (Tables 11.2 and 11.3). These ranges are also represented graphically (Figures 11.2 and 11.3). Each figure allows for overview comparisons between different soil forms and over particle size classes. In the Estcourt soils only one natural body has been used as profile textures lie on either side of the 60 percent total sand value (Table 11.3).

Table 11.2 Textural properties of the clay loam to clay soils of the Adelaide Subgroup derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1	ClLm-SiCl-Cl	27-73	13-51	1-29	1-6	1-28	fi	NL2,EL2,L1
	B1	ClLm-SiCl-Cl	20-74	5-53	1-41	1-7	1- 4	fi	-
Griffin	A1	Cl	57-60	13-33	3-24	1-2	1-2	fi	NL3, L1,EL1
	B1	Cl	49-68	13-34	4-24	1-2	1-2	fi	-
Clovelly	A1	SaCl-ClLm-SiClLm-Cl	30-53	13-50	9-42	1-6	1-6	fi	NL4,EL1
	B1	ClLm-SiClLm-Cl	25-58	10-53	6-40	1-13	1-9	fi	NL5
	B2	Cl	51-60	12-29	7-7	1-1	5-5	fi	-
Swartland	A1	SiCl-Cl	32-60	11-40	8-12	1-3	1-3	fi	L5
	B1	SiCl-Cl	32-67	11-44	8-17	1-4	2-4	fi	-
Mispah	A1	Cl	41-50	18-33	11-20	1-4	2-2	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).

A striking feature of the soils is the wide range of textural classes determined from the database (Figures 11.4 to 11.10). All the textural classes, with the exception of the siltiest classes; silt and silt loam, and pure sand are represented in the Hutton, Clovelly and Griffin soils. Histogram distributions confirm the wide clay range of the Clovelly soils, two silt distribution peaks, and the dominance of fine sand (Figure 11.6). The Swartland soils too have clay and silty clay classes on the one hand, and with a second grouping around sandy clay loam (Figure 11.9). The Mispah soils show a similar trend (Figure 11.10). The Avalon soils (A1 and B1 horizons)(Figure 11.7), and the Longlands (Tables 11.3 and 11.5) and Estcourt soils (A1 and E1 horizons)(Figure 11.8) are dominantly sandy loam. Small increases in clay percentage for the soft plinthite horizon of the Avalon (Figure 11.7) and Longlands (Table 11.5) soils were determined. Much larger clay increases for the prismacutanic horizon of the Estcourt soils were determined (Figure 11.8). Means and standard deviations for five particle size classes for the two natural soil bodies are given (Tables 11.4, 11.5).

A small proportion of profiles showed luvic properties (Table 11.3), while clay decreases in the B1 horizon relative to the A1 are dominant in the Griffin and Clovelly soils. The mean clay increase ratios for the Swartland (A1 and B1 horizons) and Estcourt (E1 and B1 horizons) soils were 2.2 and 4.4 respectively (Reflected in Table 11.3).

Table 11.3 Textural properties of the loamy sand to sandy clay loam soils of the Adelaide Subgroup derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1 B1	LmSa-SaClLm LmSa-SaClLm	12-26 9-16	4-13 4-10	37-53 53-73	13-25 5-20	1-12 1-4	fi fi	NL2, L1, EL2 -
Clovelly	A1 B1 B2	Sa-SaClLm LmSa-SaLm SaClLm	6-24 7-18 24-24	2-21 2-8 6-6	37-73 38-77 36-36	2-25 8-32 28-28	1-10 5-7 6-6	fi,co fi,co fi,co	NL3, EL2 - -
Avalon	A1 B1 B2	LmSa-SaClLm LmSa-SaLm LmSa-SaLm	8-23 8-36 7-18	3-10 2-11 3-12	48-70 32-73 43-71	15-17 14-19 16-20	1-4 1-8 1-5	fi, fi,me fi	NL2,L3 - -
Longlands	A1 E1 B1	SaLm SaLm-SaClLm SaLm-SaClLm	13-18 11-25 15-29	5-23 22-25 6-28	49-73 14-54 40-58	7-15 1-54 4-12	1-3 1-32 1-11	fi fi,me fi	EL L -
Estcourt	A1 E1 B1	SaLm-SaClLm PuSa-SaClLm SaCl-Cl	9-34 4-30 36-50	8-42 1-47 5-34	28-43 7-43 19-29	1-23 21-43 7-14	1-14 8-60 3-16	fi fi,me fi	EL4,NL1 L5 -
Swartland	A1 B1	SaLm-SaClLm Lm-SaClLm	19-33 12-24	8-13 6-38	39-49 48-56	8-18 15-15	1-2	fi fi	L -
Mispah	A1	SaLm	8-8	14-14	44-44	24-24	8-8	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).

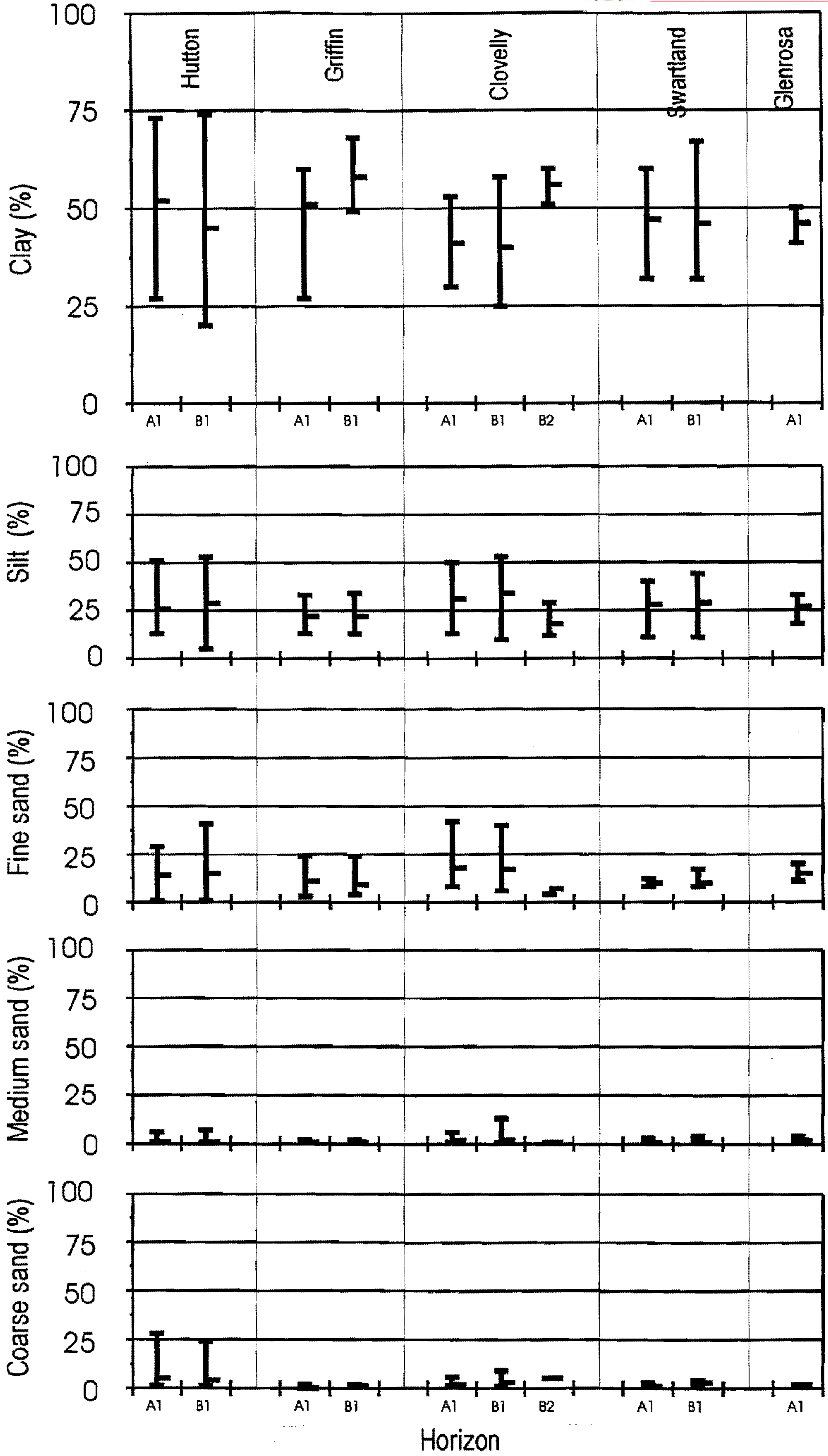

Figure 11.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Adelaide Subgroup with a clay loam to clay texture. Maximum, minimum and mean values are shown for each horizon.

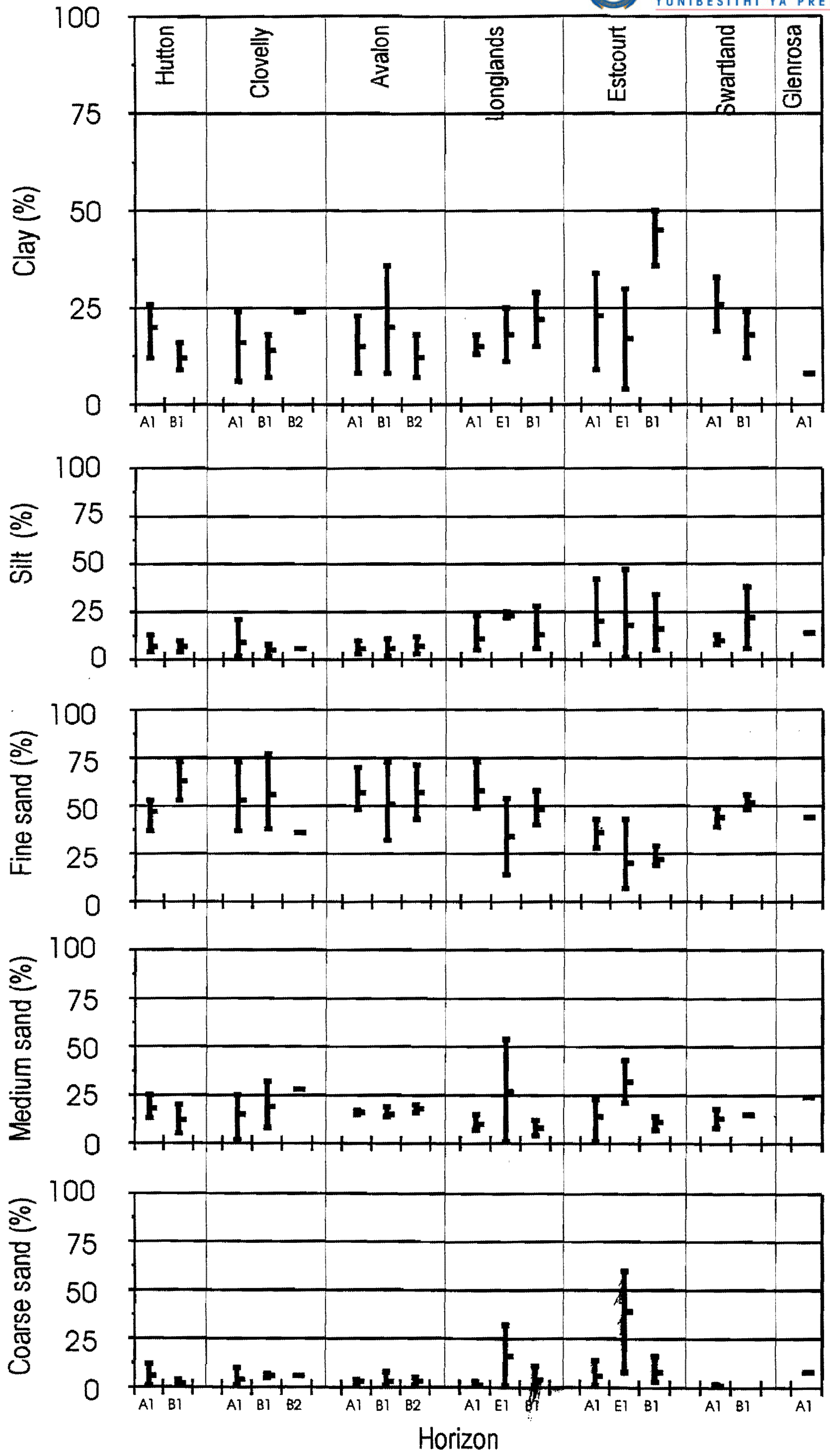

Figure 11.3 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Adelaide Subgroup with aloamy sand to sand clay loam texture. Maximum, minimum and mean values are shown for each horizon.

Table 11.4 Means and standard deviations of five textural classes of the clay loam to clay soils of the Adelaide Subgroup.

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	323	52.0	14.5	26.4	12.3	14.3	8.1	1.6	1.4	5.0	7.4	13
B1	689	45.4	15.0	29.0	12.6	15.9	9.2	1.8	1.5	4.2	5.1	23
Form: Griffin												
A1	280	51.5	14.2	22.3	9.3	11.0	9.3	1.3	0.5	0.7	1.3	4
B1	680	58.8	6.1	22.8	8.0	9.8	8.3	1.3	0.5	1.7	0.5	5
Form: Clovelly												
A1	320	41.2	6.3	31.3	10.9	18.8	10.3	2.1	1.4	2.5	1.8	15
B1	695	40.4	8.7	34.0	10.9	17.4	8.3	2.6	3.2	3.2	2.3	24
B2	970	56.3	3.9	18.0	7.8	7.0	0.0	1.0	0.0	5.0	0.0	3
Form: Swartland												
A1	376	47.2	8.9	28.4	10.3	10.5	1.5	1.8	0.8	1.8	0.8	5
B1	606	46.8	11.6	29.8	11.4	10.6	3.4	1.8	1.2	3.0	0.9	6
Form: Mispah												
A1	320	46.0	3.7	27.7	6.8	15.5	4.5	2.5	1.5	2.0	0.0	3

Table 11.5 Means and standard deviations of five textural classes loamy sand to sandy clay loam soils of the Adelaide Subgroup.

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	410	20.0	5.9	7.7	3.9	47.0	7.1	18.0	5.1	6.0	4.5	3
B1	1050	12.5	3.5	7.0	3.0	63.0	10.0	12.5	7.5	2.5	1.5	2
Form: Clovelly												
A1	346	16.0	5.9	9.2	6.6	53.6	12.5	15.2	7.9	4.0	3.4	5
B1	683	14.0	5.0	5.3	2.5	56.3	16.0	19.7	9.8	6.0	1.0	3
B2	920	24.0	0.0	6.0	0.0	36.0	0.0	28.0	0.0	6.0	0.0	1
Form: Avalon												
A1	450	15.3	5.5	6.0	2.5	57.0	8.5	16.3	0.8	3.0	1.4	4
B1	897	20.3	10.1	6.3	3.3	51.8	15.1	15.8	1.9	3.8	2.6	4
B2	1325	12.5	5.5	7.5	4.5	57.0	14.0	18.0	2.0	3.0	2.0	2
Form: Longlands												
A1	277	15.0	2.1	11.8	6.8	58.0	10.7	10.7	3.3	1.7	0.9	4
E1	450	18.0	7.0	23.5	1.5	34.0	20.0	27.5	26.5	16.5	15.5	2
B1	687	22.5	5.0	13.3	8.8	48.3	7.4	8.3	3.3	4.7	4.5	4
Form: Estcourt												
A1	285	23.3	9.0	20.3	10.7	36.0	5.6	14.5	8.7	6.5	4.8	6
E1	577	17.3	11.8	18.3	17.5	20.0	14.8	32.3	9.0	39.3	22.5	4
B1	738	45.0	4.8	16.6	9.9	22.5	3.8	11.0	2.9	8.0	5.7	5
Form: Swartland												
A1	340	26.0	7.0	10.5	2.5	44.0	5.0	13.0	5.0	1.5	0.5	2
B1	940	18.0	6.0	22.0	16.0	52.0	4.0	15.0	0.0			2
Form: Mispah												
A1	400	8.0	0.0	14.0	0.0	44.0	0.0	24.0	0.0	8.0	0.0	1

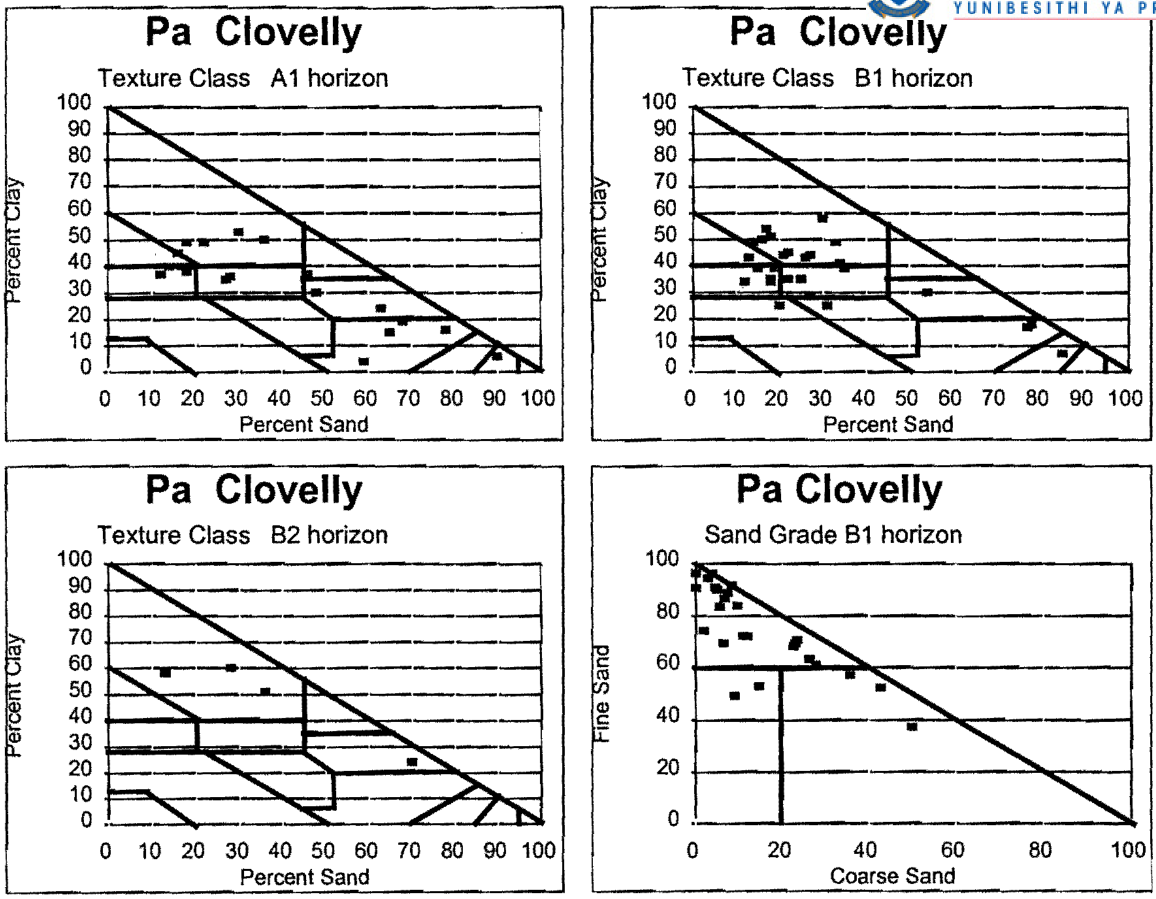

Figure 11.4. Distribution of soil textures, and dominant sand grade, within soils of the Clovelly Form.

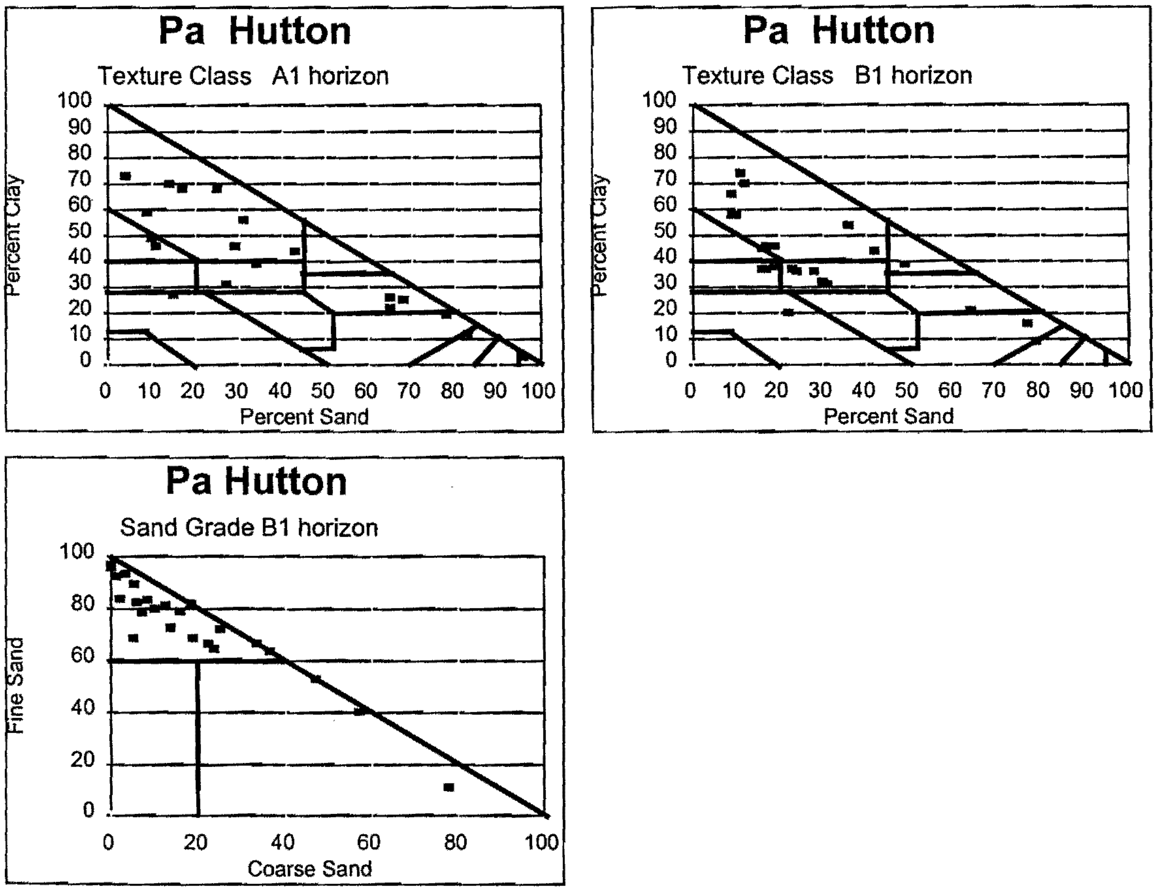

Figure 11.5 Distribution of soil textures, and dominant sand grade, within soils of the Hutton Form.

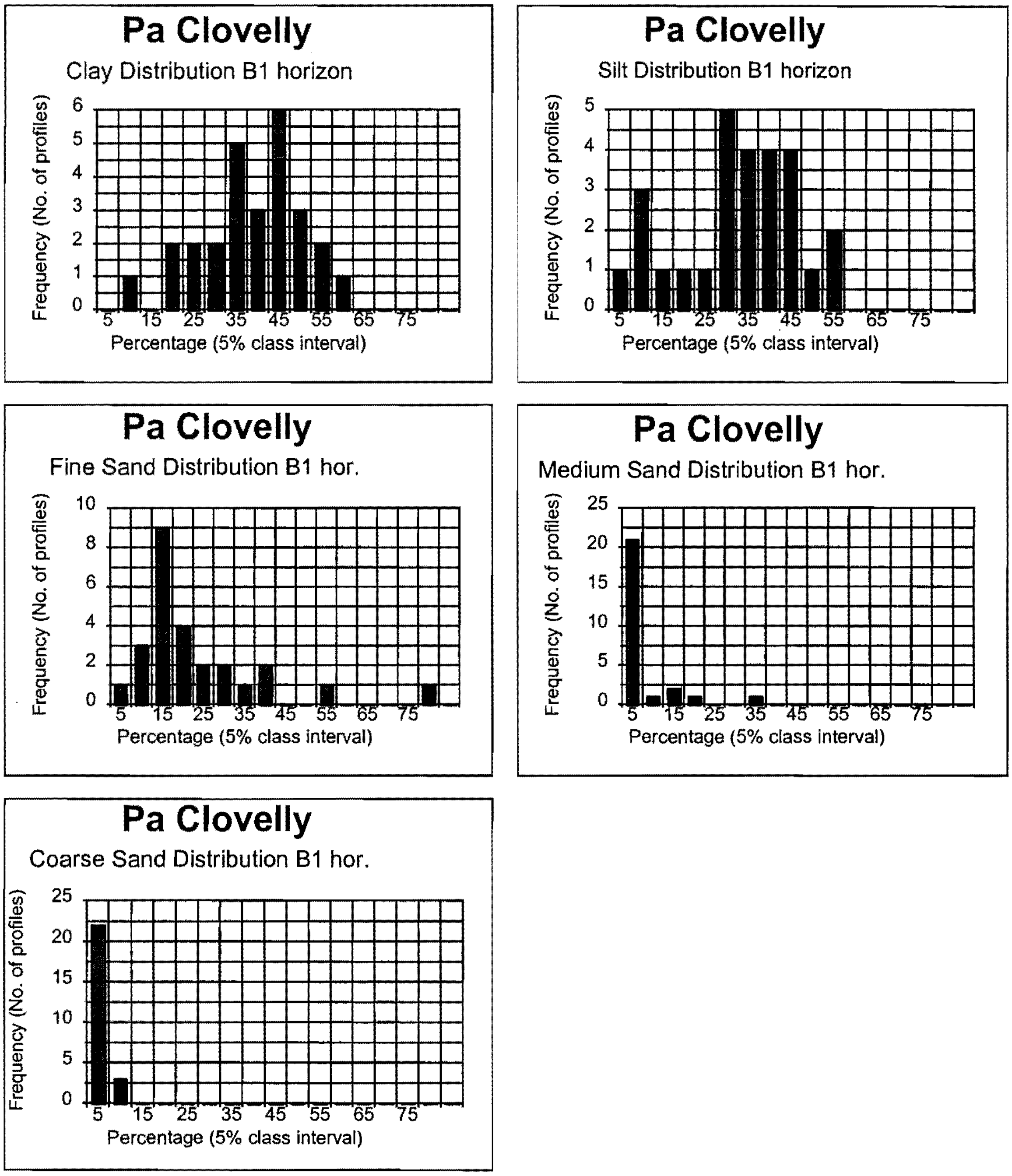

Figure 11.6 Distribution of clay, silt, fine sand, medium sand and coarse sand within soils of the Clovelly Form.

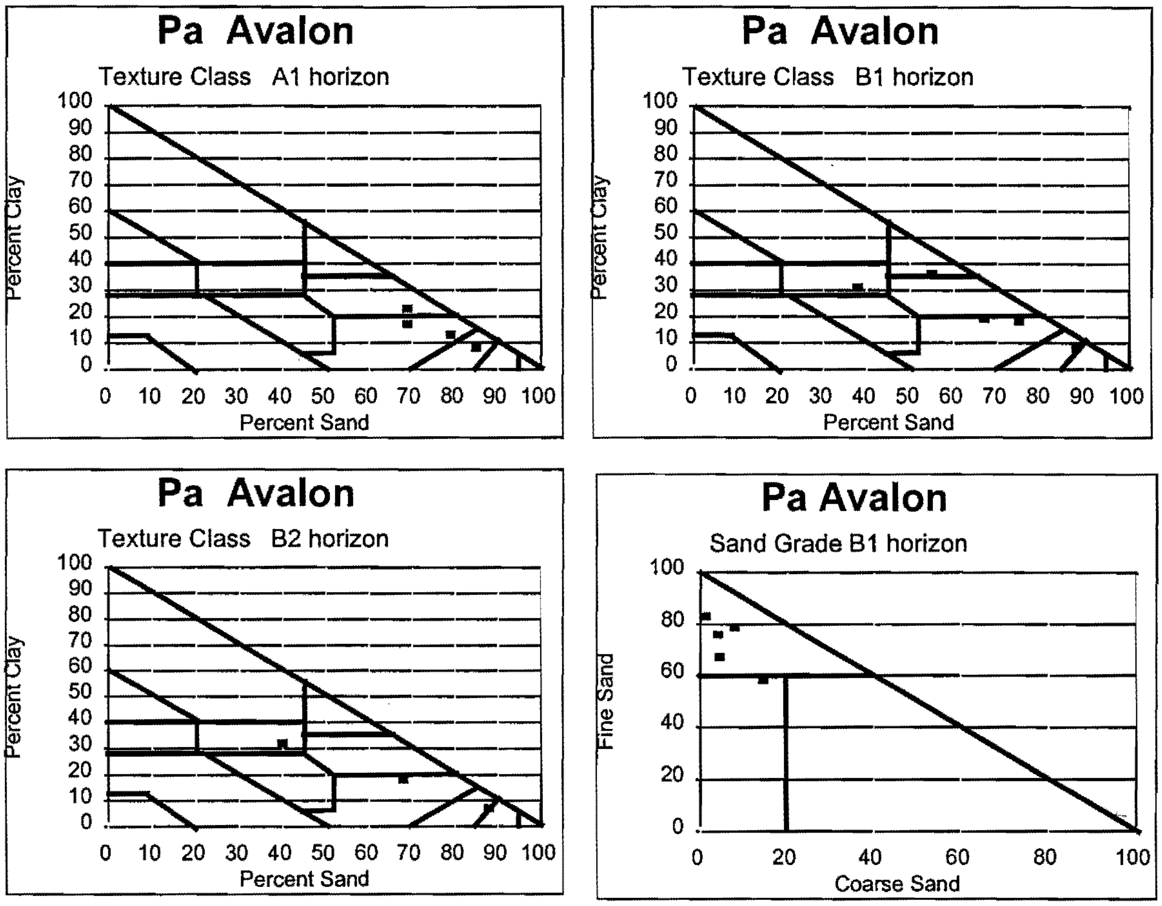

Figure 11.7. Distribution of soil textures, and dominant sand grade, within soils of the Avalon Form.

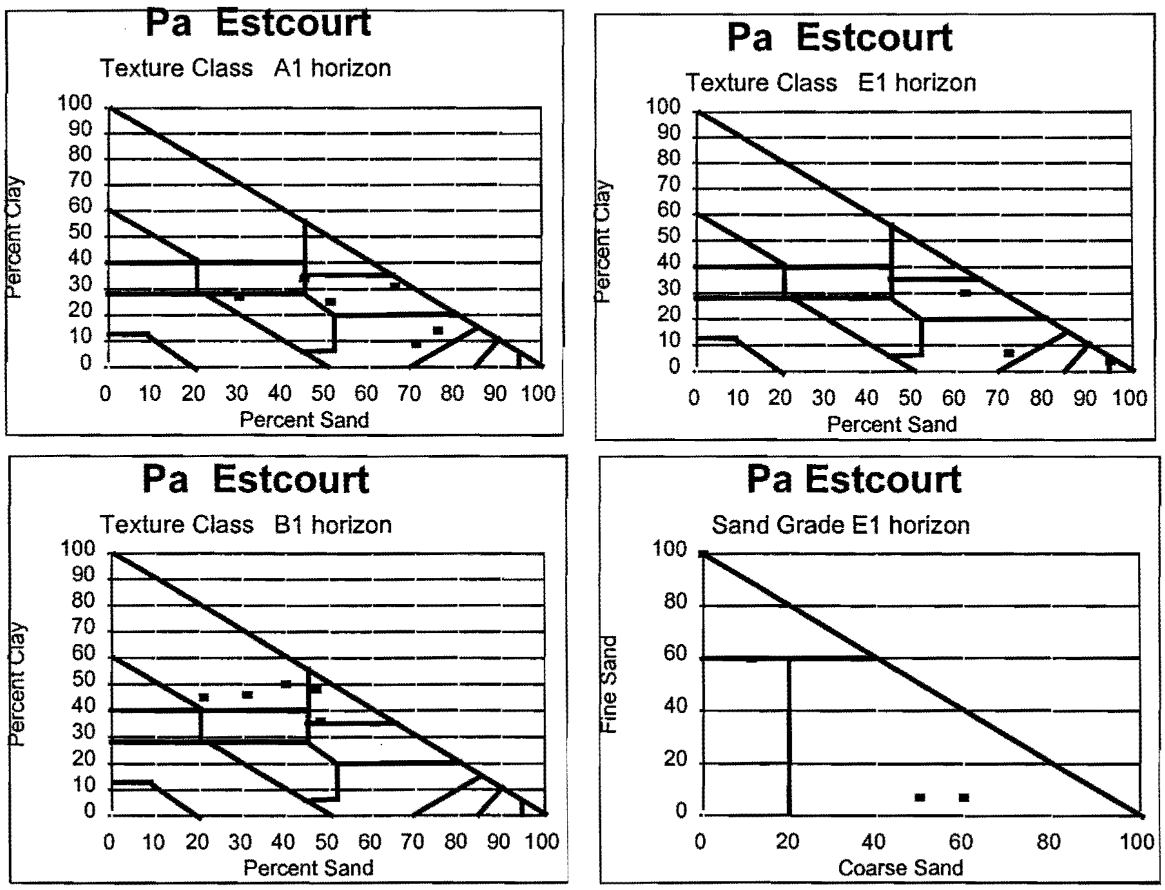

Figure 11.8. Distribution of soil textures, and dominant sand grade, within soils of the Estcourt Form.

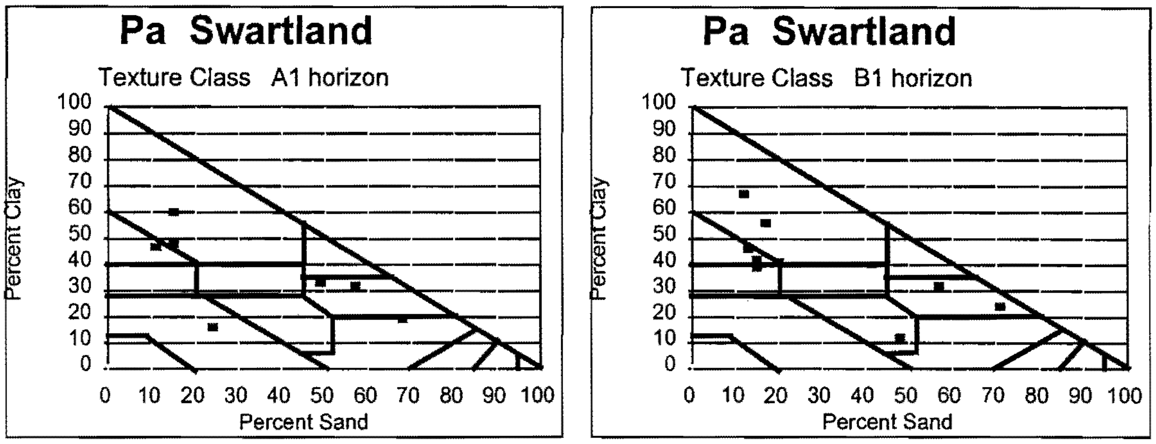

Figure 11.9 Distribution of soil textures within soils of the Swartland Form.

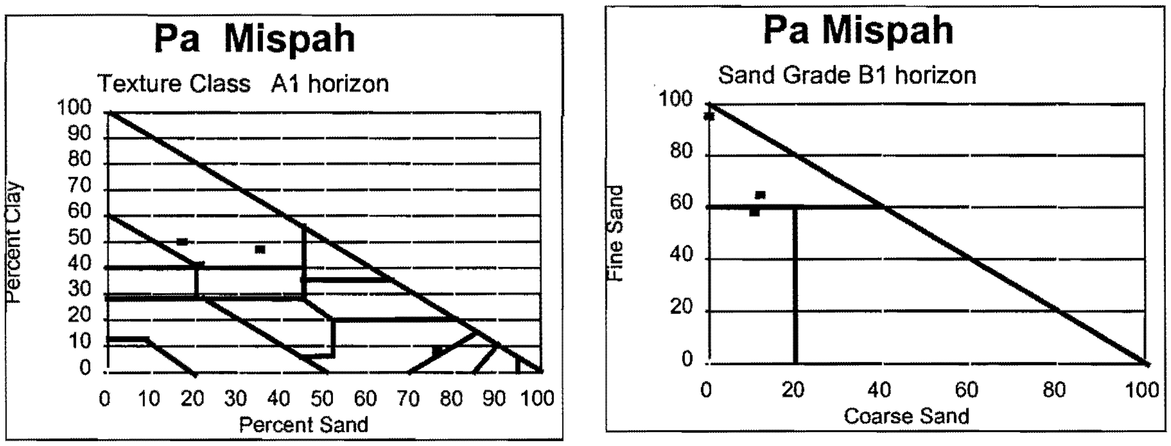

Figure 11.10 Distribution of soil textures, and dominant sand grade, within soils of the Mispah Form.

CHAPTER 12

SOILS OF THE SHALE AND SANDSTONE OF THE ESTCOURT FORMATION, BEAUFORT GROUP IN KWAZULU-NATAL

Location and Extent

The Estcourt Formation occurs at isolated locations on the Mpumalanga Highveld and in northern KwaZulu-Natal. The largest of these exposures forms the crest lands of the Ballesberg Highlands. To the south and west it occupies a narrow belt of between three and ten kilometres wide stretching along the KwaZulu-Natal and Free State boundary (Geological Survey, 1984, 1992) located between the Volksrust Formation of the Ecca Group, and the Tarkastad Formation of the Beaufort Group (Figure 12.1). The formation covers extensive areas of the north eastern Free State Province. South of the Klip River the formation widens to cover extensive areas in the KwaZulu-Natal Interior Basin and of the Highland Sourveld (Geological Survey, 1981a). The extent of the dark grey shale, siltstone and sandstone of the formation is recognised southwards to the Mkomazi River. South of this locality the mudstones and sandstones are considered as forming part of the Adelaide Subgroup, Beaufort Group.

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

Overlying the Volksrust Formation in the Estcourt and Mooi River area is a mappable unit consisting of laminated carbonaceous shale and an often coarse grained sandstone with a few thin coal seams (SACS, 1980). The South African Committee for Stratigraphy (SACS, 1980) noted that because of the similarities in the lithology of the Ecca and Beaufort Groups in this area it proved difficult in assigning the formation to either group. However, since the formation is laterally equivalent to the Adelaide Subgroup in the south, it may be more convenient to include it with the Beaufort Group. The Estcourt Formation is described as comprising dark-grey shale (often carbonaceous), siltstone and fine and medium to coarse grained sandstone (Geological Survey, 1981a; Geological Survey, 1988b; Geological Survey, 1988c).

Physiography and Drainage Features

The physiography of the northern and central zones where the Estcourt Formation is exposed range from strongly undulating land to low mountains (Kruger, 1983), with only limited areas of gentle slopes. In the KwaZulu-Natal Interior Basin irregular undulating lowlands and hills are encountered with slopes commonly less than five percent. To the south the proportion of steeper slopes increase. Undulating hills and lowlands and in places low mountains are encountered (Kruger, 1983).

Vegetation

In the north the vegetation is described as Moist Cool Highland Grassland, or as Wet Cold Highland Grassland (Low and Rebelo, 1996). The central zone of the KwaZulu-Natal Interior Basin has a drier climate where the dominant vegetation covering the rocks of the Estcourt Formation is described as Natal Central Bushveld. In the south the vegetation is recorded as dominantly Moist Upland Grassland (Low and Rebelo, 1996).

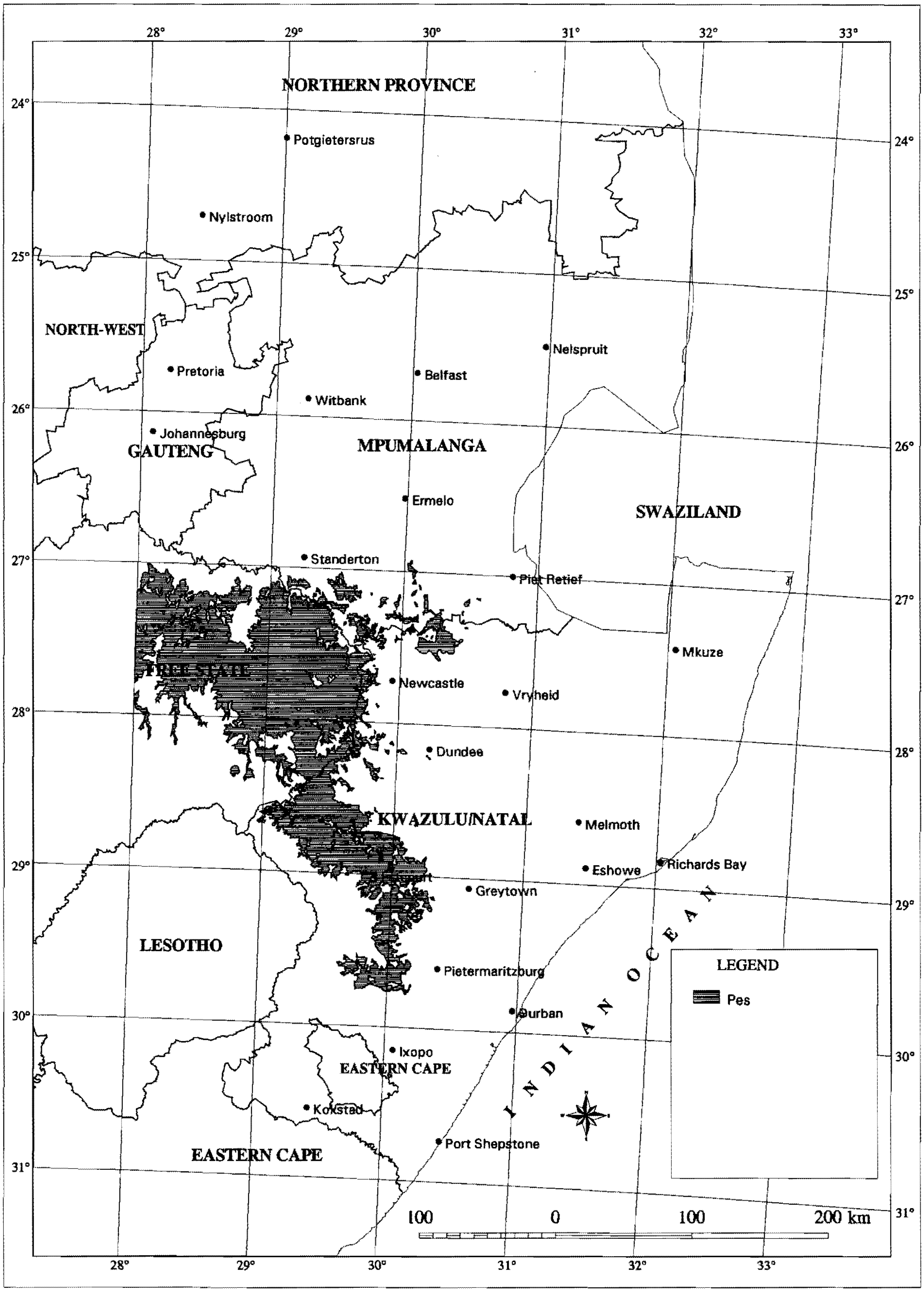

Figure 12.1. Location of the Estcourt Formation, Beaufort Group in KwaZulu-Natal and Mpumalanga (after Geological Survey, 1984).

Soils

Seven major soil patterns are evident in the soils derived from the dark grey shale, silt stone and sandstone of the Estcourt Formation (Table 12.1). The first is a red and yellow apedal soil pattern with Hutton, Griffin and Clovelly soils dominant. Katspruit, Mispah and Glenrosa soils are subdominant. A variant of this soil pattern has sandy to sandy loam and sandy clay loam, dystrophic yellow apedal soils occurring in the soil pattern (Table 12.1). Cartref soils with an E horizon are also present in the moist, yet younger landsurfaces than where the apedal soils are dominant. In the plinthic soil pattern Avalon, Glencoe, Longlands, Wasbank and Westleigh soils are present together with Mispah, Glenrosa, Cartref soils and rock land. Rainfall decreases in this soil pattern to that encountered in the apedal soil patterns (Table 12.1). The plinthic and duplex soil pattern has Longlands, Wasbank and Westleigh soils together with the duplex soils of the Swartland, Valsrivier and Estcourt Forms as dominant soils. Here the recorded rainfall is again lower and aridity indexes higher than where duplex soils are absent. The proportion of Avalon and Glencoe soils are also lower than where duplex soils are absent (Table 12.1). Duplex soils occur over extensive areas of the KwaZulu-Natal Interior Basin. Lithosolic soil patterns with and without the presence of lime are located throughout the zone. While Mispah and Glenrosa soils may contain lime, free calcium carbonate is generally located in the lower horizons of the duplex soils (Table 12.1).

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles of the Hutton, Griffin, Clovelly, Avalon, Longlands, Estcourt, Swartland and Glenrosa forms were extracted from the database. Two natural soil bodies are evident (Figures 12.4 to 12.8) with the threshold for their separation set at 60 percent total sand. The subdivision reflects a group of soils with the dominant textural classes in the clay, clay loam and loam classes, and despite a relatively wide spread these profiles are retained within one group. The other, more sandy group, has textures clustering in the sandy clay loam and sandy loam classes. Within the more extensively sampled clay grouping additional subdivision could be envisaged, particularly of those profiles falling towards the loam class with higher silt proportions. The ranges in textural properties (maximum and minimum values) for five particle size classes, dominant sand grade and information on their luvic properties are presented (Tables 12.2 and 12.3). These ranges are represented graphically (Figures 12.2 and 12.3). Each figure allows for overview comparisons between different soil forms and over particle size classes.

Within the clay group of soils the Clovelly soils (B1 horizons) have ranges in clay and silt of between 19 and 55% clay and 12 and 52% silt respectively. These values are representative of the red and yellow apedal soils and Avalon soils (Table 12.2, Figures 12.3, 12.5, 12.6). There does appear a tendency for the yellow soils (Cv, Gf, Av) to have higher silt values than the Hutton soils although the reason for this observation is not apparent. These ranges in textural classes show similarities to the soils derived from the Adelaide Subgroup (Pa), Beaufort Group, and the Volksrust Formation (Pvo), Ecca Group. However, the equivalent clay textural class for the Pa and Pvo soils appear to have slightly higher clay and silt values than those of the soils from the Estcourt Formation. The apedal soils derived from the Estcourt Formation show relatively clear differences from the soils derived from the Tarkastad Formation (TRt, dominantly clay loam to sandy clay loam), and clear differences from the sandier soils derived from the Vryheid Formation (Pv), Ecca Group, and the Natal Group (O-Sn).

Table 12.1 Dominant soils and selected climatic information for soil patterns occurring on Estcourt Formation.

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rain fall mm	Evapor ation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Red and Yellow-brown Apedal Soils (dystrophic base status)										
Hutton	Hu17 Hu16	39	Katspruit	Ka10	3	Ave	877	1388	1856	0.63
Griffin	Gf12 Gf13	17	Mispah	Ms10 Gs17	10	Std	65	80	124	0.06
Clovelly	Cv17	17	Glenrosa	Gs19		Max	973	1568	1991	0.74
						Min	789	1321	1574	0.55
Total Area: 50 036 Ha			Means of 8 Land Types							
Broad Soil Pattern: Yellow-brown Apedal Soils (dystrophic base status)										
Clovelly	Cv16 Cv17	17	Cartref	Cf10 Cf11	18	Ave				
	Cv13 Cv14 Cv10	17	Mispah	Ms10	14	Std				
	Cv11					Max				
						Min				
Total Area: 16 290 Ha			Means of 2 Land Types							
Broad Soil Pattern: Plinthic Soils (mesotrophic and dystrophic base status)										
Avalon	Av26 Av27 Av16	4	Hutton	Hu26 Hu27	17	Ave	732	1428	2050	0.52
	Av27		Clovelly	Cv26 Cv27	8	Std	55	87	132	0.06
Glencoe	Gc16 Gc17	2				Max	825	1561	2207	0.62
						Min	676	1321	1843	0.46
Longlands	Lo11 Lo12 Lo22	7								
Wasbank	Wa12									
Westleigh	We12 We22	7								
Mispah	Ms10 Ms11	13								
Glenrosa	Gs16 Gs17	12								
Cartref	Cf12	10								
Rock	Rock	4								
Total Area: 15 093 Ha			Means of 4 Land Types							
Broad Soil Pattern: Plinthic and Duplex Soils										
Longlands	Lo11 Lo12	12	Hutton	Hu36 Hu37	11	Ave	673	1427	2154	0.47
Wasbank	Wa11 Wa12	4		Hu26		Std	4	17	74	-
Westleigh	We11 We12	10	Clovelly	Cv36 Cv37	5	Max	676	1439	2207	0.48
	We13			Cv26		Min	667	1403	2049	0.47
Avalon	Av26 Av27 Gc26	5								
Glencoe	Gc27									
Swartland	Sw30 Sw31	9								
Valsrivier	Va41	3								
Estcourt	Es33 Es36	5								
Mispah	Ms10 Ms11	6								
Glenrosa	Gs16 Cf12	12								
Cartref										
Total Area: 11 560 Ha			Means of 3 Land Types							

Table 12.1 continued. Dominant soils and selected climatic information for soil patterns occurring on Estcourt Formation.

Soil Patterns						Climate Relationships (Annual Values)				
Dominant Soils			Sub-dominant Soils							
Form	Series	Mean %	Form	Series	Mean %	Statistic	Rain fall mm	Evapor ation mm	Heat Unit deg. day	Aridity Index
Broad Soil Pattern: Duplex Soils										
Valsrivier	Va41 Va42	15	Glenrosa	Gs14 Gs16	10	Ave	676	1544	2336	0.44
	Va31 Va32			Gs17		Std	62	214	401	0.08
Swartland	Sw41 Sw42	15	Mispah	Ms1 Ms20	7	Max	765	1967	3076	0.55
	Sw31 Sw32		Rock	Rock	4	Min	596	1385	1966	0.33
Sterkspruit	Ss26 Ss27	4								
Estcourt	Es33 Es36	8								
Total Area: 19 980 Ha			Means of 5 Land Types							
Broad Soil Pattern: Lithosols without the presence of lime										
Mispah	Ms10	13	Clovelly	Cv16 Cv17	13	Ave	838	1354	1863	0.62
Glenrosa	Gs16 Gs19	14	Hutton	Hu27	12	Std	99	69	327	0.11
Cartref	Cf12	14				Max	989	1455	2316	0.79
Rock	Rock	15				Min	720	1251	1441	0.51
Total Area: 42 410 Ha			Means of 7 Land Types							
Broad Soil Pattern: Lithosols with the presence of lime										
Mispah	Ms10 Ms20	38	Swartland	Sw31 Sw32	7	Ave	704	1729	2823	0.41
Glenrosa	Gs16 Gs17	11		Sw41 Sw42		Std	97	278	680	0.11
	Gs26		Valsrivier	Va41 Va42	5	Max	1052	2274	4822	0.71
Rock	Rock	12	Estcourt	Es34 Es36	2	Min	635	1403	1966	0.31
Total Area: 59 770 Ha			Means of 15 Land Types							

There are also differences in the dominant textures of profiles from the Griffin, Clovelly and Avalon soils. The Griffin soils have textures dominantly in the clay class (Figure 12.4), the Clovelly soils in a portion of the clay and clay loam classes (Figure 12.3), and the Avalon soils in the loam class (Figure 12.6).

There are textural differences too between the apedal soils (Hu, Gf, Cv, Av) and those of the Longlands and Estcourt soils derived from shale and siltstone of the Estcourt Formation. The lower clay contents of the Longlands and Estcourt soils can be explained by clay eluviation from the E horizons. The A1 horizons too show various degrees of bleaching, and eluviation for these horizons could also be expected. Texture similarities exist within the A1 and E1 horizons of the Longlands and Estcourt soils (Table 12.2, Figures 12.7, 12.8). A feature of the textures of these soils (Lo, Es) is the relatively high silt values present in many of the soils derived from the Estcourt Formation. Whilst there are commonly increases in the clay content of the B1 horizons of the Longlands soils, there are markedly large clay percentage increases for the B1 horizons of the Estcourt soils (Table 12.4, Figure 12.7, 12.8). Fine sand is dominant in all soils developed from the Estcourt Formation (Tables 12.2 and 12.3).

Table 12.2 Textural properties of the clay loam to clay soils of the Estcourt Formation derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1 B1	SaClLm-Cl SaClLm-Cl	39-49 29-59	6-16 8-38	20-41 16-42	9-10 1-9	1-3 1-5	fi fi	NL5 -
Griffin	A1 B1 B2	ClLm-Cl ClLm-Cl Cl	34-48 30-67 39-63	14-38 11-43 12-34	7-30 4-40 3-28	1-3 1-5 1-1	3-5 1-5 1-6	fi fi fi	NL3,L2 NL3,EL2 -
Clovelly	A1 B1	Lm-SaClLm-Cl SaClLm-ClLm-Cl	18-50 19-55	12-39 12-52	5-39 4-51	1-11 1-11	1-4 1-6	fi fi	NL3,EL2 -
Avalon	A1 B1 B2	Lm -ClLm-Cl Lm-ClLm-Cl Lm-ClLm-Cl	17-49 18-51 20-54	8-35 7-34 10-27	21-45 17-44 22-39	1-7 1-6 2-5	1-4 1-6 1-7	fi fi fi	- - -
Longlands	A1 E1 B1	SaClLm SaClLm ClLm-Cl	18-33 19-41 16-48	12-38 8-31 5-32	30-58 32-53 19-35	2-5 2-11 4-4	1-9 1-11 3-12	fi fi fi	NL5 NL3,L2 -
Estcourt	B1	Lm-ClLm Lm-ClLm Cl	17-32 14-38 48-71	3-32 28-45 8-23	2-48 33-42 13-20	1-24 1- 4 1- 5	4-29 6-6 4-10	fi, co	-
Swartland	B1	SaCl-Cl	44-58	3-19	25-28	1-19	3-8	fi, me	-
Mispah	A1	ClLm-Cl	13-47	4-31	7-30	2-35	1-18	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).

Table 12.3 Textural properties of the sandy loam to sandy clay loam soils of the Estcourt Formation derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	B1	SaClLm	20-31	8-14	27-47	13-22	2-12	fi	-
Avalon	A1 B1	Lm-ClLm Lm-ClLm	14-20 10-26	4-10 4-12	57-82 48-73	7- 7 2-11	6-6 1-13	fi fi	- -
Longlands	A1 E1 B1	LmSa-SaClLm LmSa-SaClLm SaClLm	9-28 9-9 10-29	5-18 4-4 4-18	40-79 74-74 54-74	7-10 10-10 6-9	2-13 2-2 1-6	fi fi fi	- -
Estcourt	A1 E1	SaLm SaClLm	16-25 11-39	10-15 8-16	41-64 7-52	5-16 3-14	3-7 4-7	fi 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).

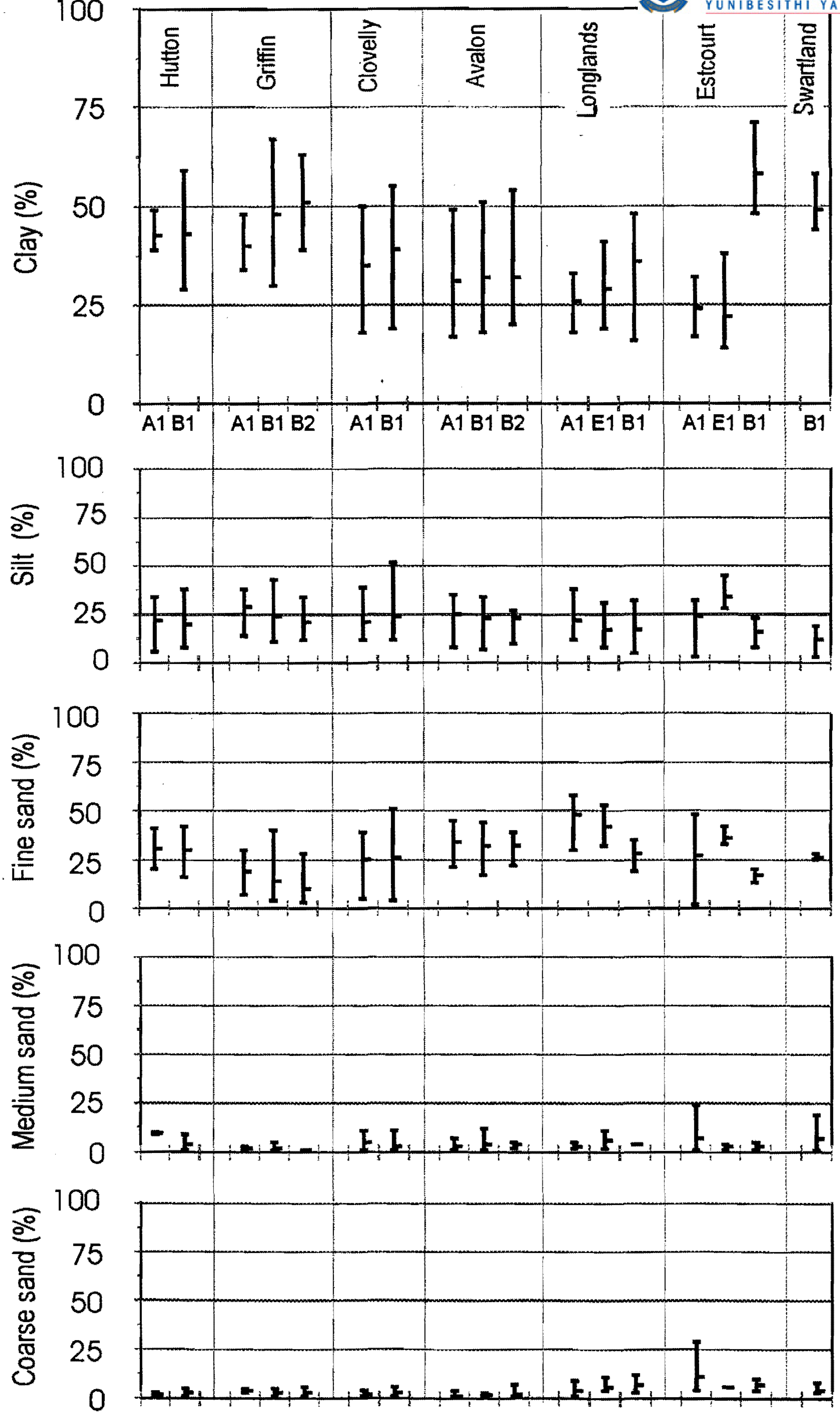

Figure 12.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Estcourt Formation with a clay loam to clay texture. Maximum, minimum and mean values are shown for each horizon.

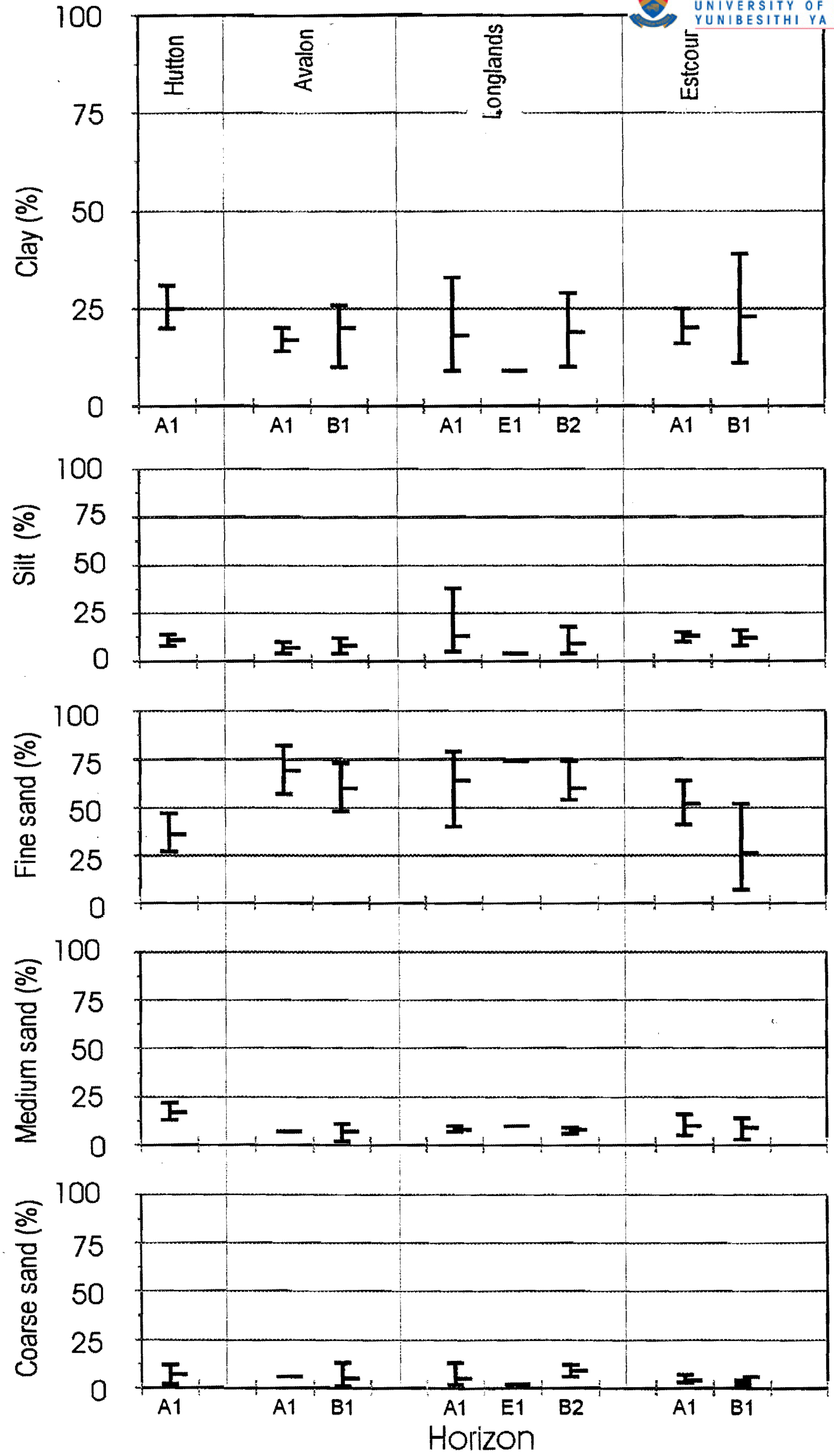

Figure 12.3 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of the Estcourt Formation with a sandy loam to sandy clay loam texture. Maximum, minimum and mean values are shown for each horizon.

Table 12.4 Means and standard deviations of five textural classes for the clay loam to clay soils of the Estcourt 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	276	42.7	4.5	21.7	11.7	30.5	10.5	9.5	0.5	2.0	1.0	3
B1	765	43.0	8.5	19.8	7.3	29.9	8.4	3.8	2.9	2.7	1.3	12
Form: Griffin												
A1	298	40.4	6.0	28.6	8.7	19.0	9.4	1.7	0.9	3.7	0.9	5
B1	568	47.2	9.3	24.0	11.6	14.4	11.1	2.0	1.3	3.4	1.5	11
B2	1157	50.6	8.1	21.3	8.0	10.0	9.1	1.0	0.0	3.2	1.6	7
Form: Clovelly												
A1	324	34.8	10.0	20.9	7.8	25.1	11.6	4.9	3.5	2.4	1.3	11
B1	646	38.9	9.1	24.1	8.9	25.9	10.5	3.3	2.8	2.5	1.5	29
Form: Avalon												
A1	309	31.2	9.8	25.0	7.8	34.1	7.5	3.1	2.0	1.4	1.0	10
B1	506	32.7	8.6	23.3	7.8	32.1	6.1	4.0	3.0	2.8	1.7	23
B2	685	51.5	2.5	23.0	4.0	22.5	0.5	3.0	0.0	1.5	0.5	2
Form: Longlands												
A1	314	26.0	4.5	21.9	7.5	48.2	9.1	3.3	1.3	4.5	3.0	9
E1	576	28.8	7.1	17.9	7.2	42.0	9.1	6.5	3.2	6.3	2.9	8
B1	841	36.3	10.5	17.7	10.4	28.0	6.7	4.0	0.0	7.3	3.7	7
Form: Estcourt												
A1	312	23.6	5.2	24.0	11.0	27.6	15.8	7.4	8.5	11.5	10.2	5
E1	470	22.3	11.1	34.7	7.4	36.7	3.9	2.7	1.3	6.0	0.0	3
B1	628	58.2	8.4	16.0	5.6	17.2	2.6	3.0	1.4	7.3	2.4	5
Form: Swartland												
B1	503	49.0	6.4	12.0	6.7	26.7	1.3	7.0	8.5	4.7	2.4	3
Form: Mispah												
A1	221	32.3	12.8	21.3	8.4	20.2	7.5	10.2	12.8	6.0	6.2	6

Table 12.5 Means and standard deviations of five textural classes for sand loam to sandy clay loam soils of the Estcourt 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	766	25.0	4.5	11.0	2.5	36.7	8.2	17.7	3.7	7.3	4.1	3
Form: Avalon												
A1	250	17.0	3.0	7.0	3.0	69.5	12.5	7.0	0.0	6.0	0.0	2
B1	600	19.5	6.5	8.3	2.9	60.0	8.9	7.5	3.8	5.0	4.7	4
Form: Longlands												
A1	307	18.4	7.5	13.3	10.3	64.7	10.3	8.2	1.2	5.4	4.2	9
E1	500	9.0	0.0	4.0	0.0	74.0	0.0	10.0	0.0	2.0	0.0	1
B1	687	18.8	6.8	9.5	5.6	60.3	8.1	7.8	1.3	3.5	1.8	4
Form: Estcourt (no data available for E horizons)												
A1	226	20.0	3.7	12.7	2.0	52.7	9.4	10.0	4.5	4.3	1.9	3
B1	722	23.0	11.9	11.5	3.0	26.5	18.4	8.8	5.3	26.0	21.5	2

There are relatively few samples of Swartland soils. Textures of the B1 horizons are of the sandy clay to clay class (Table 12.2). The textures of the Mispah soils (Figure 12.3) are in the same range (loam through clay loam to clay) as those measured for other soils of the Estcourt Formation. A common perception that the Mispah soils will exhibit lower clay percentages, is inaccurate.

The sandy loam group contained profiles from the Hutton, Avalon, Longlands and Estcourt Form (Table 12.3, 12.5), although data is limited. It must be assumed that these profiles are derived from the sandstone source of the Estcourt Formation. Sand grades are fine (Table 12.3). A feature to distinguish this group from the clay group is the sandier textures and the lower silt values (Figures 12.4, 12.6, 12.7, 12.8). Clay contents range from about 10 to 30 percent and silt values from 4 to 20% (Table 12.3).

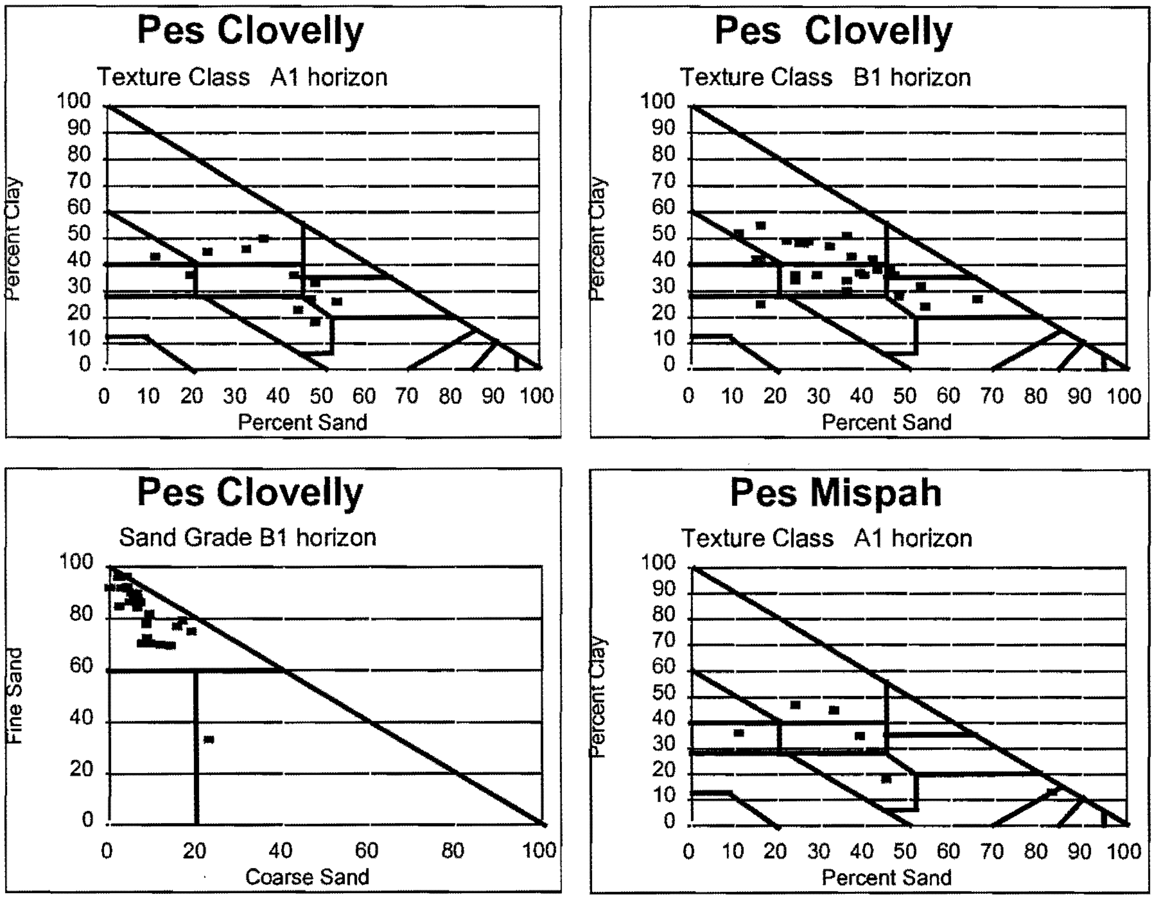

Figure 12.4 Distribution of soil textures, and dominant sand grade, within soils of the Clovelly and Mispah Forms.

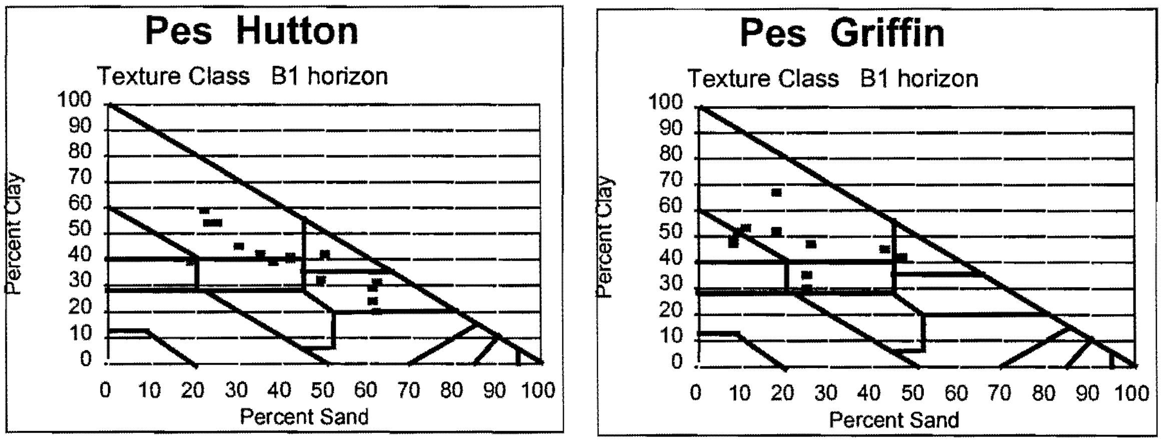

Figure 12.5 Distribution of soil textures within soils of the Hutton and Griffin Forms.

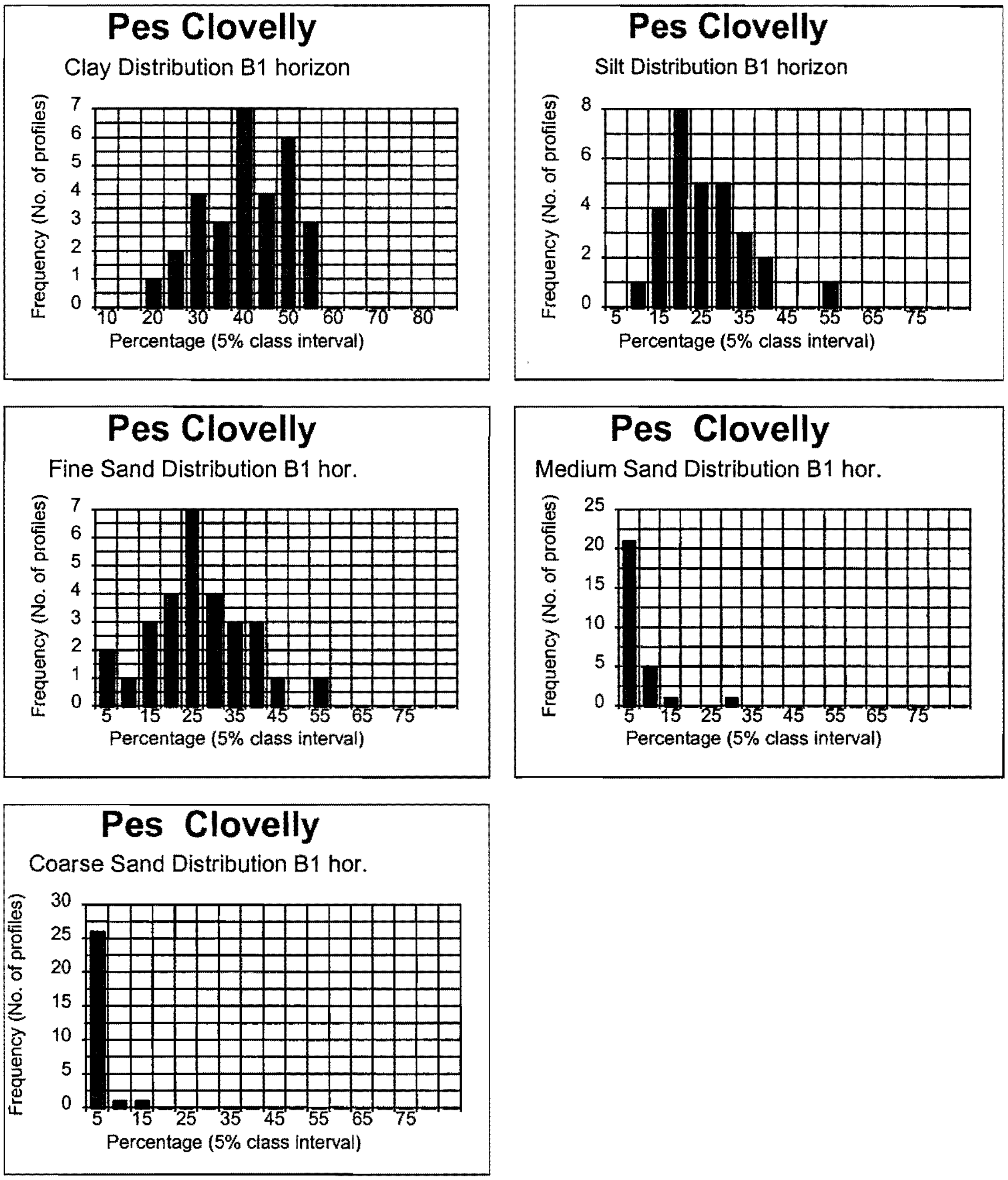

Figure 12.6 Distribution of clay, silt, fine sand, medium sand and coarse sand within soils of the Clovelly Form.

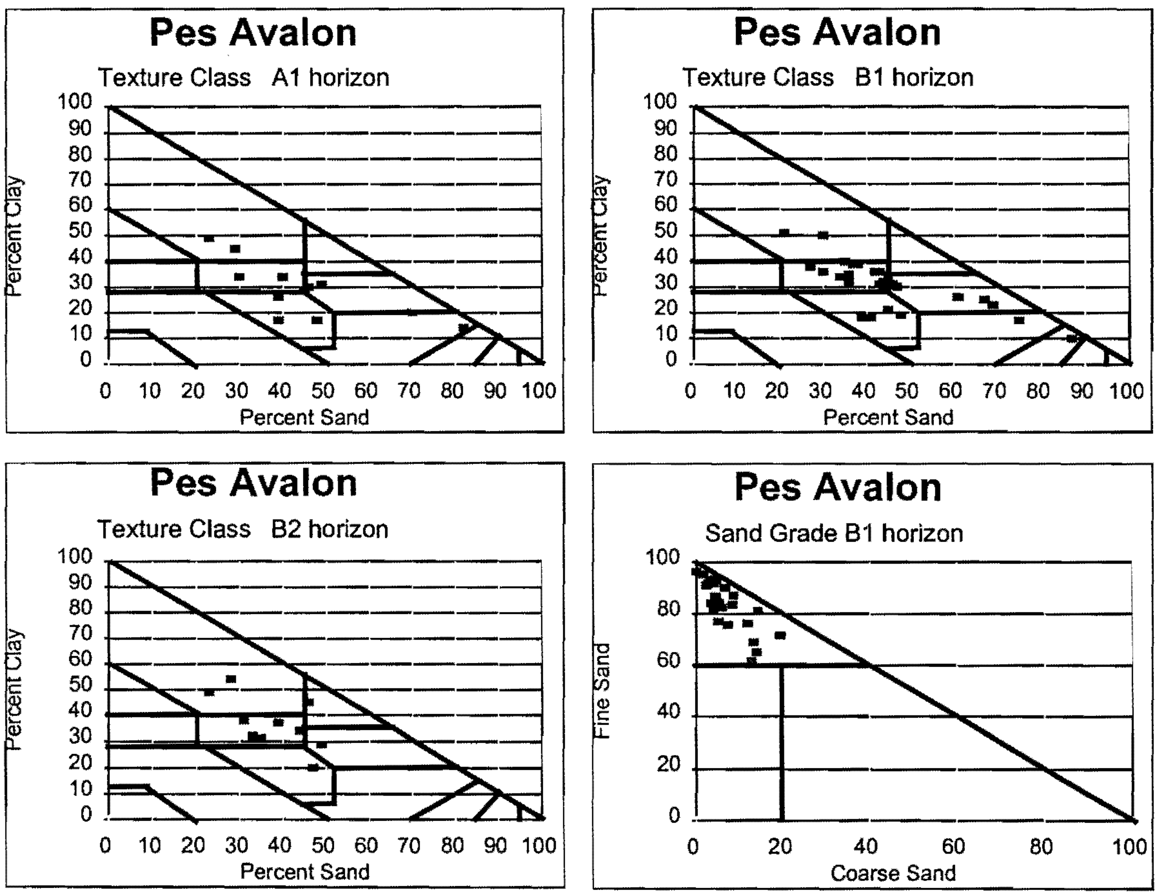

Figure 12.7 Distribution of soil textures within soils of the Avalon Form.

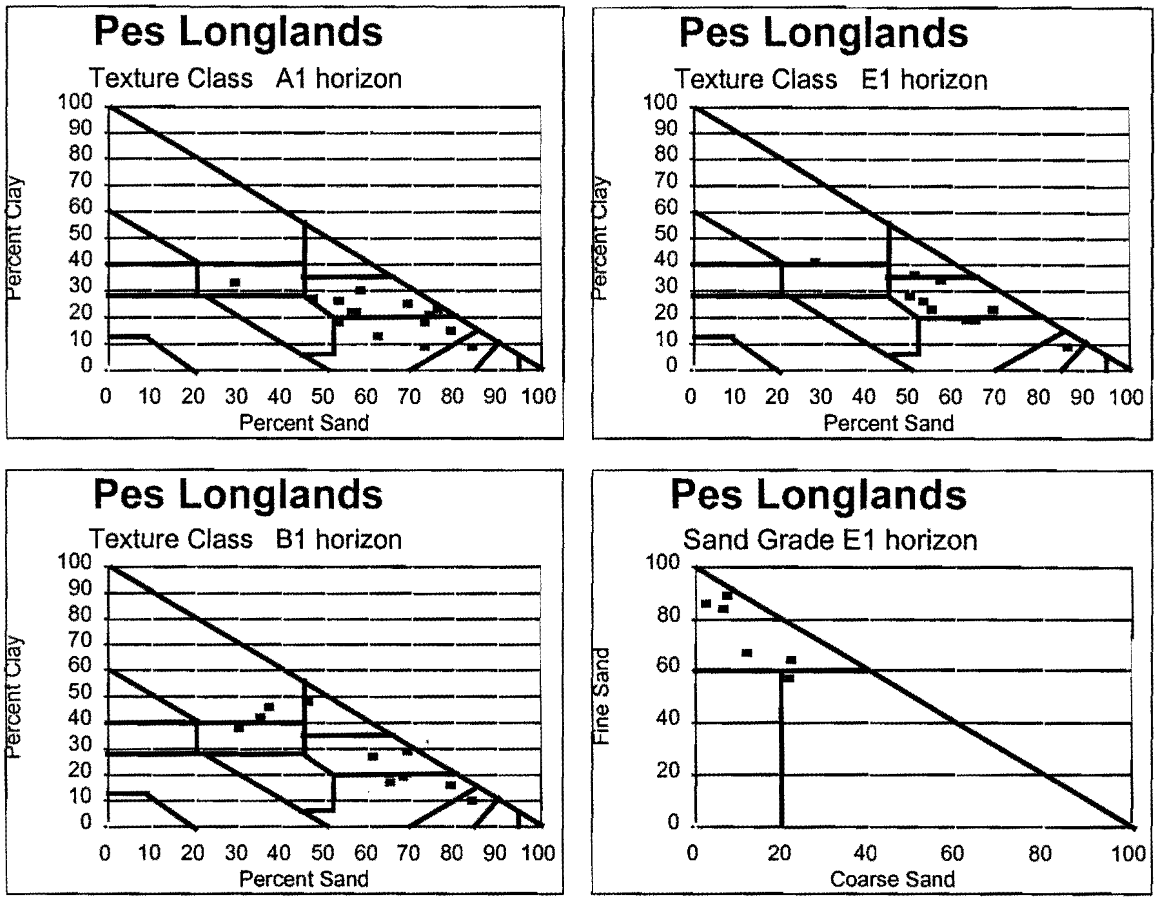

Figure 12.7. Distribution of soil textures, and dominant sand grade, within soils of the Longlands Form.

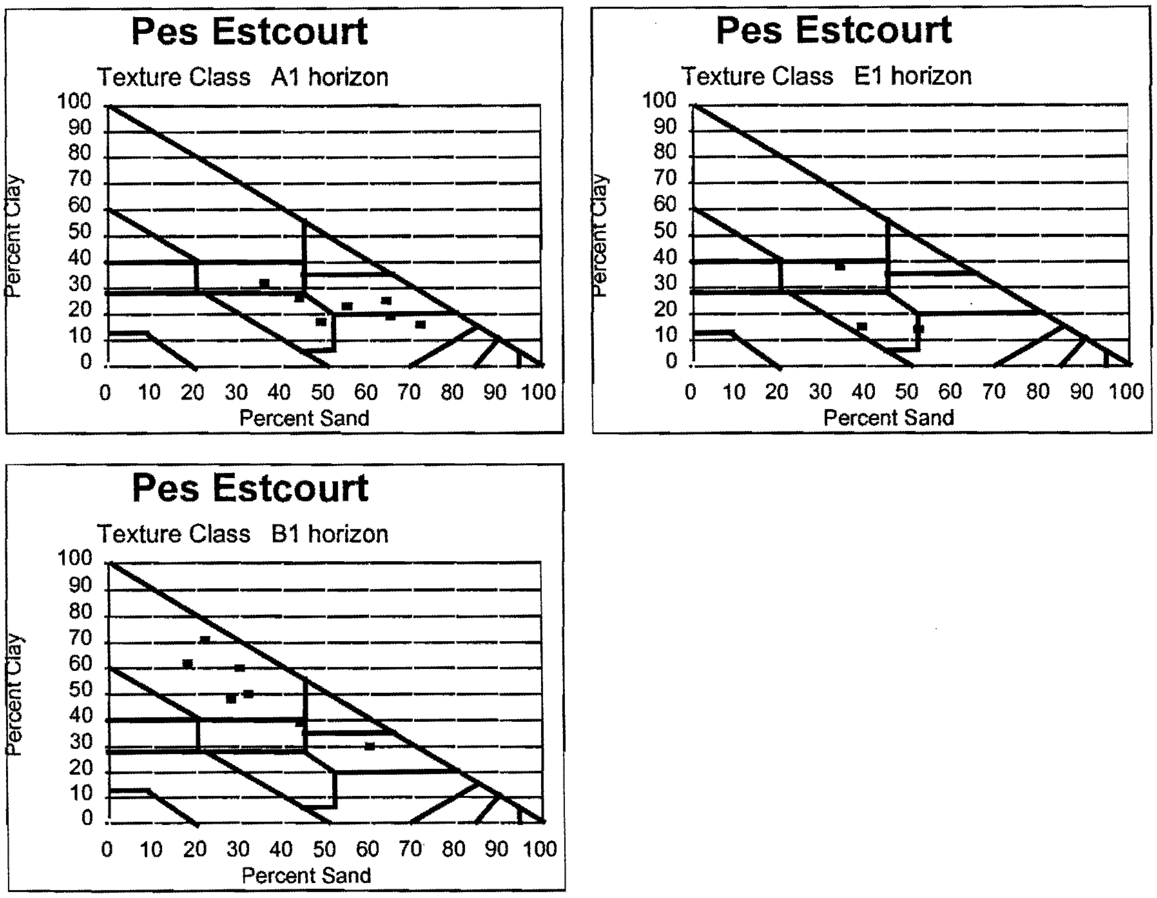

Figure 12.8. Distribution of soil textures, and dominant sand grade, within soils of the Estcourt Form.

CHAPTER 13

SOILS OF THE MUDSTONE AND SHALE OF THE VOLKSRUST FORMATION, ECCA GROUP IN KWAZULU-NATAL AND MPUMALANGA

Location and Extent

The Volksrust Formation covers extensive areas of the Highveld Plain south of the Vaal River extending eastwards to the town of Volksrust from which the formation derives its name. Southwards the formation occupies a narrow belt east of the main Drakensberg Escarpment, on the western parts of the KwaZulu-Natal Interior Basin. South of the Klip and Tugela Rivers the formation is more extensive, being located between the Vryheid Formation in the east and the Estcourt Formation, Beaufort Group in the west. The southern extent of the formation is near the southern KwaZulu-Natal boundary (Figure 13.1). The formation covers some 690 000 hectares in the study area.

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

The Volksrust Formation is the name applied to the old Upper Ecca beds, comprising 150 to 250 m of shale which overlies the Vryheid Formation (SACS, 1980). The formation is described as bluish-grey or dark grey mudstone and shale with subordinate siltstone (Geological Survey, 1992) and as shale and siltstone (Geological Survey, 1988a, 1988b). As with the Pietermaritzburg Formation, the Volksrust formation is limited by a lateral cutoff coinciding with the pinch-out of the Vryheid Formation. In southern KwaZulu-Natal this occurs just south of the Mzimkulu River.

Physiography and Drainage Features

The physiography of the zones where the Volksrust Formation is exposed range from slightly undulating plains (slopes 2 - 5%) to irregular undulating land (slopes 2 - 8%) (Kruger, 1980). It is in these zones that plinthic and duplex soil patterns are present. The Highveld Plain is drained by the Vaal River and its tributaries. The portions where the Volksrust Formation is exposed on the northern Drakensberg Escarpment is largely low mountains. In the central and southern KwaZulu-Natal areas the terrain varies between undulating lowland with hills (slopes 2-8%), undulating hills (slopes 5-15%) to low mountains (slopes 8-30%) (Kruger, 1980). The drainage is via the Tugela River and its southern tributaries and the Mgeni, Mkomazi and Mzimkulu Rivers.

Vegetation

On the Highveld the vegetation is largely the Moist Clay Highveld Grassland and Wet Cold Highveld Grassland (Low and Rebelo, 1986). In central and southern KwaZulu-Natal the vegetation comprises the Moist Upland and Short Mistbelt Grasslands. There are areas covered by Valley Thicket.

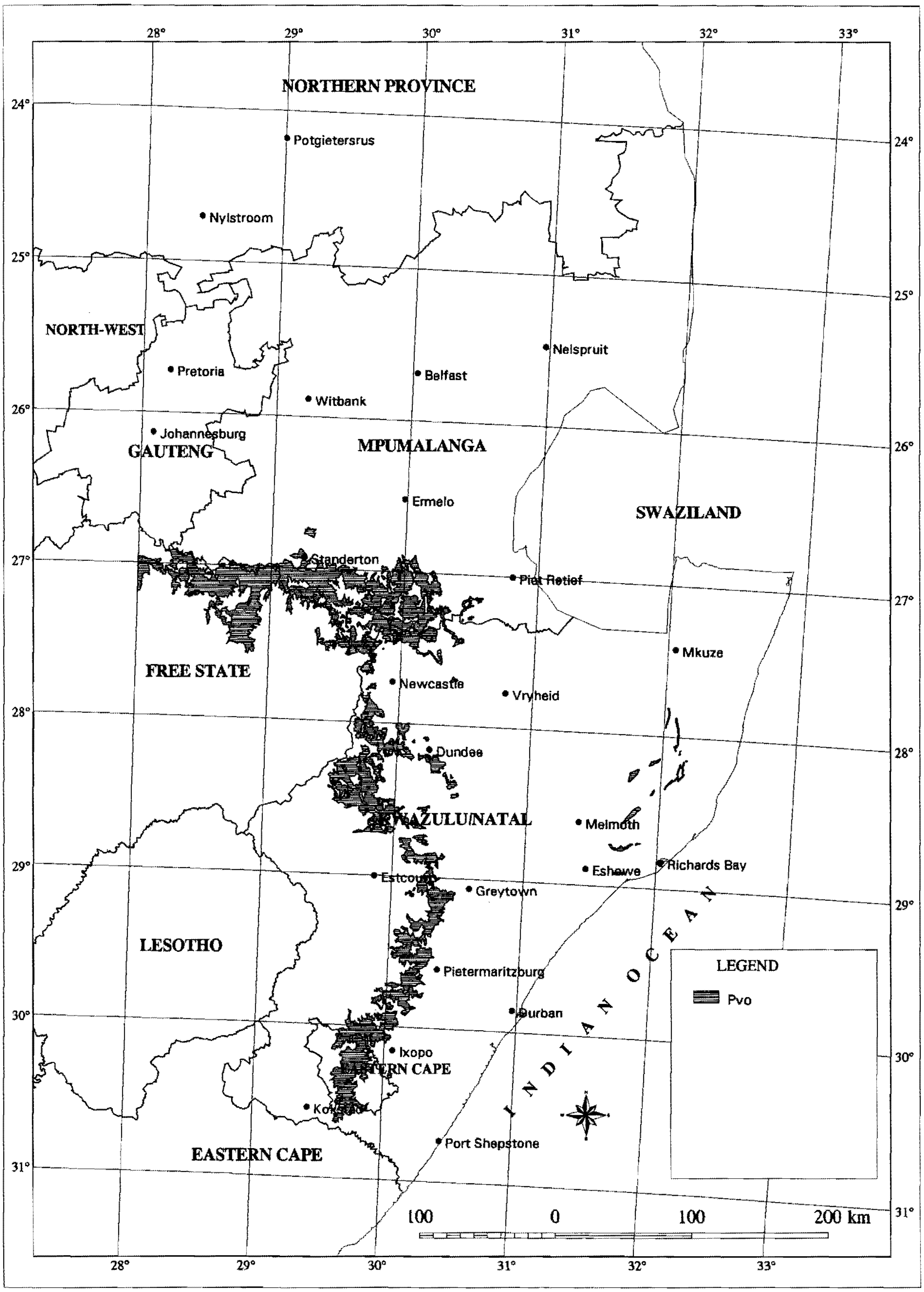

Figure 13.1. Location of the Volksrust Formation, Ecca Group in KwaZulu-Natal and Mpumalanga (after Geological Survey, 1984).

Soils

Six major soil patterns are evident on the materials of the Volksrust Formation (Table 13.1). These include a red and yellow apedal soil pattern where dystrophic soils are dominant and a plinthic pattern which has together with the plinthic soils, red and yellow apedal soils of dominantly mesotrophic base status. There is also a plinthic pattern where plinthic soils, soils with E horizons and duplex soils dominate. In the duplex soil pattern soils of the Swartland Form are dominant. Lithosols, with and without the presence of lime makes up the remaining two patterns. Here Mispah and Glenrosa soils are dominant, while respectively Hutton and Swartland soils are sub-dominant (Table 13.1).

The red and yellow apedal soil patterns on rocks of the Volksrust Formation are only present in southern KwaZulu-Natal. Hutton, Griffin and Clovelly soils occur over a range of slopes and terrain positions. These range from gently undulating (2 - 5%) and undulating slopes (5 - 8%) through to moderately steep land (15 - 30% slopes). Dystrophic soils are dominant over the mesotrophic soils. Glenrosa, Mispah and Katspruit soils are also present in smaller proportions. While dystrophic soils are dominant in the red and yellow apedal soil patterns, they may also be present in other soil patterns, notably in the plinthic soil pattern.

Sandy loam to sandy clay loam Avalon and Glencoe soils form an important component of the plinthic soil pattern with red and yellow apedal soils. Other soils include the Clovelly, Hutton and Griffin Forms with mesotrophic and dystrophic base status (Table 13.1). The profile analyses indicate that the clay contents of these soils can be higher than those quoted in the source data used to compile Table 13.1. Longlands, Wasbank and Westleigh soils are also important in this soil pattern. These soils are commonly located on gently undulating slopes (2 - 5% slope).

Plinthic soils with E horizons and duplex soils occur regularly together in the same landscape. On the shales and mudstones of the Volksrust Formation fine sandy loam to sandy clay Kroonstad and Cartref soils are dominant (Table 13.1). Other duplex and plinthic soils are present (Table 13.1). However, mesotrophic and dystrophic Clovelly soils are also present (Table 13.1). In these shales and mudstones which occur at generally high altitudes, and in cool climates, weathering to kaolinitic apedal soils could be expected. Their presence together with duplex soils is unusual, and is associated with the parent material and the cooler climate.

In the duplex pattern Swartland soils with sandy clay to clay subsoils are dominant (Land Type Survey Staff, 1985 -1997). Valsrivier, Estcourt, Mispah and Glenrosa are also present (Table 13.1).

In the more youthful landscapes, where either the slopes are greater or effective rainfall is less, lithosols are dominant. Time for soil formation must be assumed to be short. In those zones where effective rainfall is lower the proportion is in favour of Mispah, Glenrosa and Swartland soils (Table 13.1), while where effective rainfall is higher the proportion is in favour of Glenrosa, Mispah and Hutton soils (Table 13.1). Leaching to the extent that loss of calcium carbonates has taken place.

Table 13.1 Dominant soils and selected climatic information for soil patterns occurring on shale and siltstone of the Volksrust Formation, Ecca Group. Subdominant occurrences of soils derived from other geology rock types, notably those of the Karoo Sediments are included.

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 Apedal Soils (Dominantly dystrophic)										
Hutton	Hu17 Hu18	25	Glenrosa	Gs16 Gs19	10	Ave	977	1479	2243	0.66
	Hu16	3	Mispah	Ms10	8	Std	149	300	299	0.15
	Hu27 Hu28	5	Katspriut	Ka10	3	Max	1408	2980	2948	-
Clovelly	Cv16	7				Min	760	1117	1599	0.41
	Cv17	4								
Griffin	Gf11 Gf12	9								
Total Area: 192 410 Ha			Means of 44 Land Types							
Broad Soil Pattern: Plinthic Soils with Red and Yellow Apedal Soils (Mesotrophic and Dystrophic Base Status)										
Avalon	Av16 Av17	14	Mispah	Ms10	6	Ave	826	1469	2239	0.56
Glencoe	Gc16 Gc17	2				Std	48	319	305	0.11
						Max	886	1988	2657	0.77
Clovelly	Cv16 Cv17	5				Min	706	1026	1755	0.43
	Cv26 Cv27	4								
Hutton	Hu27 Hu28	6								
	Hu17 Hu18	5								
Griffin	Gf12	5								
Longlands	Lo22 Lo13	8								
Wasbank	Wa22 Wa21	3								
Westleigh	We12 We13 We22	4								
Total Area: 85 080 Ha			Means of 13 Land Types							
Broad Soil Pattern: Plinthic (with E horizons) and Duplex Soils										
Kroonstad	Kd13 Kd16	25	Clovelly	Cv26 Cv16	20	Ave	791	1884	2588	0.42
Estcourt	Es16 Es36	4				Std	86	389	1349	0.17
Other	Va41 Sw31	4				Max	964	2274	4822	0.65
Duplex						Min	710	1494	1518	0.31
Wasbank	Wa12 Wa13	4								
Westleigh	We13	4								
Cartref	Cf12 Cf13	10								
Total Area: 224 510 Ha			Means of 10 Land Types							
Broad Soil Pattern: Duplex Soils										
Swartland	Sw31 Sw32	19				Ave	809	1674	2661	0.48
Valsrivier	Va31 Va32	7				Std	78	262	322	0.12
Estcourt	Es36 Es37	6				Max	929	1881	3188	0.77
						Min	694	1026	2316	0.37
Mispah	Ms10	11								
Glenrosa	Gs16 Gs19	7								
Total Area: 49 260 Ha			Mean s of 17 Land Types							

Table 13.1 continued. Dominant soils and selected climatic information for soil patterns occurring on shale and siltstone of the Volksrust Formation, Ecca Group. Subdominant occurrences of soils derived from other geology rock types, notably those of the Karoo Sediments are included.

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 Rockland	Gs16 Gs17 Ms10 R	12 9 18	Hutton	Hu17 Hu27	15	Ave Std Max Min	852 100 1045 649	1590 205 1887 1212	2186 396 2918 1122	0.54 0.09 0.69 0.37
Total Area: 84 060 Ha			Means of 29 Land Types							
Broad Soil Pattern: Lithosols (with the presence of lime)										
Mispah Glenrosa Rockland	Ms20 Ms10 Gs16 Gs17 Gs26 Gs27 R	19 17 10	Swartland	Sw31 Sw32 Sw41 Sw42	10	Ave Std Max Min	693 53 840 635	1701 216 1967 1361	2781 432 3965 2071	0.41 0.07 0.52 0.33
Total Area: 55 900 Ha			Means of 16 Land Types							

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles for Hutton, Griffin, Clovelly, Avalon, Longlands, Estcourt, Swartland, Katspruit, Mispah, Arcadia and Mayo Forms were extracted form 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 in Table 13.2.

These ranges are presented graphically in Figure 13.2. The figure allows for an overview comparison between different soil forms and over particle size classes. It shows the clayey and silty nature of many of these soils derived from shale and mudstone of the Volksrust Formation (Table 13.2). The clay contents of the Clovelly soils (B1 horizons) range between 21 and 67 percent. The silt contents for these soils range between 9 and 46 percent. These values are representative of the red and yellow-brown apedal soils. Similarly, the soils with E horizons have large ranges in clay and silt contents. Examples are in the E horizons of soils of the Estcourt Form. Ranges in clay content are between 8 and 39 percent, while ranges in silt content are between 6 and 53 percent (Table 13.2). Fine sand is the dominant sand grade, while medium and coarse sand values are low.

These textural values contrast sharply with the soils derived from the Vryheid and Dwyka Formations, and the Natal Group sandstone. However they do show similarities and differences

Table 13.2 Textural properties of soils of the Volksrust Formation derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1 B1	ClLm-SaClLm Cl-ClLm	21-61 31-75	6-34 5-35	4-38 3-34	1-21 1-10	1-11 1-8	fi,co fi,co	EL2,NL2,L1 -
Griffin	A1 B1 B2	Cl-SaClLm Cl-SaCl Cl-SiCl-SaCl	34-68 27-70 31-58	11-46 8-51 7-39	4-37 5-38 18-44	1-9 1-14 2-10	1-7 1-12 1-7	fi fi fi	EL3,NL2,L1 EL4,NL1 -
Clovelly	A1 B1	Cl-SaClLm Cl-SaClLm	26-58 21-67	10-35 9-46	6-50 3-54	1-13 1-13	1-8 1-10	fi fi,co	EL3,NL2 -
Avalon	A1 B1 B2	Cl-SaLm Cl-SaLm Cl-SaClLm	16-57 22-57 26-63	6-40 6-41 9-33	15-55 11-51 11-47	1-22 1-17 1-17	1-12 1-20 2-23	fi fi,co fi,co	NL5 El2 -
Longlands	A1 E1 B1	Lm-SaLm Lm-SaClLm Lm-SaCl	18-27 22-41 24-42	15-44 16-41 14-44	12-48 7-50 11-32	2-16 2-10 1-12	1-21 2-19 4-30	fi,co fi,co	EL3,NL2 - -
Estcourt	A1 E1 B1	ClLm-SaLm SiClLm- SaClLm SiCl-Cl	8-37 8-39 20-50	8-56 6-53 9-46	3-55 6-57 2-48	2-18 1-17 1-12	1-15 2-17 2-11	fi fi,co fi	EL4,NL1 L5 -
Swartland	A1 B1	SiClLm-ClLm Cl-Lm-SaClLm	27-43 22-80	15-43 9-38	9-36 7-27	3-13 1-6	1-23 1-43	fi,co fi,co	NL3,L2 -
Katspruit	A1	Cl-SiCl-Lm	20-64	23-45	3-37	1-9	1-4	fi	-
Mispah	A1	Cl-SiCl- SaClLm	20-47	14-34	7-48	2-11	2-13	fi	-
Arcadia Mayo	A1	Cl-ClLm	35-47	26-33	5-24	5-9	2-8	fi,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).

to soils derived from the sedimentary rocks of the Beaufort Group.

The range in texture values is relatively large and subdivision of this range could have advantages towards understanding the soil properties and in land use applications. The A1, E1 and B1 horizons of all the soil forms were extracted from the database and plotted onto texture diagram graphs. A selection of these graphs is shown in Figures 13.3 to 13.9. Examination of these texture graphs allows the postulation of a number of natural clusters for soils of the Volksrust Formation. A number of possibilities were examined. Limiting the number of clusters to three, appears to be useful. Each of these clusters, with regard to texture class, could be considered as a natural soil body. The threshold values are given in Table 13.3. The values are somewhat arbitrary, but appear to apply over all soils sampled from within the Volksrust Formation. The original composite file was subdivided to prepare three files using these threshold values, and means and standard deviations determined from these files for each natural soil body. These data for texture are reported in Tables 13.4 to 13.6 respectively.

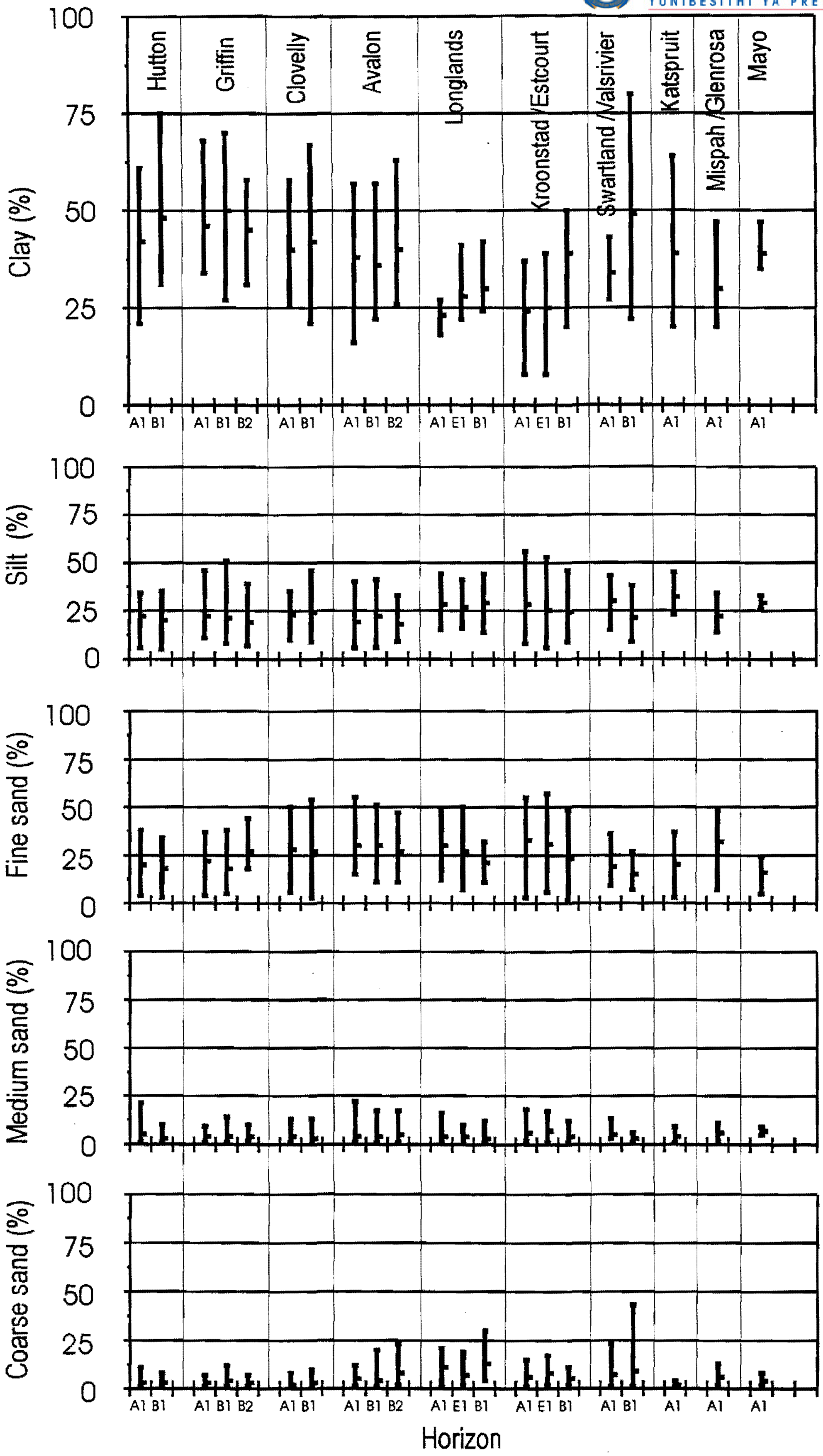

Figure 13.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of Volksrust Formation. Maximum, minimum and mean values are shown for each horizon.

Table 13.3 Threshold values for three natural soil bodies within the Volksrust Formation.

Natural body based on texture	Threshold Value	Natural Body present in samples of the following soils:	Dominant Texture Class	Data referenced in:
1	>40% clay	Hutton A1, B1 Clovelly A1, B1 Griffin B1 Katspruit A1 Avalon B1 Swartland B1 Kroonstad B1	Clay	Table 13.4
2	<40%clay and >30% total sand	Clovelly A1, B1 Katspruit A1 Avalon B1 Kroonstad A1, B1 Swartland A1, B1	Clay Loam, Sandy Clay, Sandy Clay Loam	Table 13.5
3	<40% clay and <30% total sand	Griffin B1 Avalon A1, B1 Kroonstad A1, E1, B1 Swartland A1	Clay Loam, Silty Clay Loam, Silty Loam	Table 13.6

There is surprising little difference between the means within each natural body. In considering Table 13.4 there is little difference between the corresponding A1 and B1 horizons for the apedal soils, with similarities extending to the duplex and gleyed soils. It should be noted that while the clay values are higher the silt values and their standard deviations are also higher (Table 13.4) than the corresponding apedal soils (Hutton, Griffin, Clovelly and Avalon) within the (second) sandy to sandy loam natural body (Table 13.5).

In the sandy to sandy loam natural body similarities exist within the apedal soils (Hutton, Griffin, Clovelly and Avalon) (Table 13.5). There are similarities within the corresponding horizons of the Longlands and Kroonstad soils, although their clay values are lower and silt values higher than the apedal soils (Table 13.5). The classical concept of reduction (verified by the E horizon colours) and loss of CBD iron applies (Table 13.7). However, there is an increase in clay from the A1 to the E1 and to the B1 horizons (Table 13.5). This appears to be a feature of the soils of this geology formation. It is unusual and will require additional sampling for confirmation. However, it may be partly explained by the higher silt contents commonly encountered on this geology formation. In the presence of these silt values incomplete reduction of iron and loss of clay during pedogenesis could provide some explanation for their properties. Profile descriptions give grey matrix colours and an E horizon classification.

There are relatively few soils with the unusually high silt values (Table 13.6) and relatively low clay values. These soils with rather high silt values are somewhat unusual in South Africa. There are sufficient profile analyses to recognise that soils with these properties do exist and should be accommodated at the soil series level of classification.

Table 13.4 Means and standard deviations of five particle classes from the clay natural soil body for soils of the Volksrust Formation.

Horizon	Depth mm	Clay %		Silt %		Fine Sand %		Medium Sand %		Coarse Sand %		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Form: Hutton												
A1	310	48.6	11.6	24.3	9.2	10.3	5.8	2.3	1.8	2.7	1.1	8
B1	896	55.9	9.7	22.5	7.3	12.5	7.0	1.8	1.1	2.6	1.6	12
Form: Griffin												
A1	291	51.5	9.3	19.7	7.0	20.6	9.3	4.6	2.9	2.8	1.6	6
B1	718	56.8	6.7	19.0	5.9	16.6	7.2	3.4	2.6	2.8	1.6	12
B2	1118	52.6	3.8	15.6	5.0	24.8	3.1	4.5	3.3	3.0	2.4	5
Form: Clovelly												
A1	233	50.7	4.9	29.3	3.7	14.8	5.8	2.3	1.3	1.8	0.8	6
B1	619	52.0	6.8	28.5	7.8	13.3	8.3	1.8	1.7	3.6	2.8	24
Form: Avalon and Glencoe												
A1	304	51.0	3.3	16.4	3.5	25.5	6.0	2.3	2.2	3.0	2.1	5
B1	776	51.2	4.0	18.2	5.3	22.2	5.7	2.5	1.7	4.3	3.0	6
Form: Swartland and Valsrivier												
A1	164	34.1	5.8	30.0	9.7	19.6	8.8	5.4	3.3	7.3	7.2	7
B1	632	55.6	10.2	20.2	8.6	15.8	6.2	2.7	1.5	4.5	3.3	10
Form: Katspruit												
A1	346	55.0	7.3	36.3	6.2	5.5	2.5	1.0	0.0	1.0	0.0	3

Table 13.5 Means and standard deviations of five particle classes from the sandy to sandy loam natural soil body for soils of the Volksrust 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: Hutton												
A1	250	30.8	6.8	17.5	2.6	35.3	3.3	10.3	6.6	5.3	3.5	4
B1	670	38.0	3.0	20.8	4.9	30.4	5.3	6.2	2.7	4.0	2.6	5
Form: Griffin												
A1	370	36.0	2.0	17.5	0.5	36.5	0.5	7.0	2.0	3.0	1.0	2
B1	720	35.0	4.2	14.7	6.2	32.3	4.5	10.0	3.3	7.3	1.9	3
B2	1275	32.5	1.5	19.5	9.5	38.0	6.0	6.5	1.5	3.5	0.5	2
Form: Clovelly												
A1	260	32.9	4.0	18.6	7.8	35.1	8.6	6.1	3.5	3.1	2.4	8
B1	704	32.4	4.6	18.7	7.3	40.6	7.7	5.0	3.8	2.7	1.7	21
Form: Avalon												
A1	370	27.5	6.7	18.3	8.7	36.5	9.6	7.2	7.1	6.7	3.2	6
B1	696	32.1	5.3	19.6	8.3	36.3	7.5	5.5	4.7	4.8	4.1	20
B2	1028	31.9	3.4	19.6	9.2	31.1	9.8	7.0	5.2	9.9	6.7	7
Form: Longlands												
A1	369	23.6	3.1	28.0	10.7	30.7	12.2	4.8	4.2	11.0	6.2	10
E1	546	28.3	5.5	27.5	9.6	27.6	13.2	4.9	2.4	7.6	5.1	8
B1	732	30.9	7.0	29.2	9.2	21.6	8.2	3.8	3.3	13.3	8.3	9
Form: Kroonstad and Estcourt												
A1	256	16.8	7.7	21.8	10.6	44.6	9.2	8.6	4.8	7.0	5.4	5
E1	410	23.0	7.3	18.2	7.0	39.5	11.3	8.8	3.8	8.2	5.0	6
B1	718	44.3	3.8	20.7	3.7	22.8	4.1	4.7	1.7	4.8	2.3	6
Form: Swartland												
B1	603	28.3	7.6	25.0	8.3	13.3	4.5	5.0	0.8	24.0	13.7	3
Form: Katspruit												
A1	422	30.0	6.1	31.8	6.4	28.3	5.6	5.3	3.3	3.0	0.7	5
Form: Mispah/Glenrosa												
A1	112	26.5	4.7	19.0	7.0	38.5	7.3	7.5	2.1	8.0	4.1	4
Form: Mayo												
A1	366	36.3	1.9	28.7	2.0	20.7	4.7	6.7	1.7	4.7	2.5	3

Table 13.6 Means and standard deviations of five particle classes from the clay loam to loam natural soil body for soils of the Volksrust 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: Avalon and Griffin												
A1	300	36.0	0.0	43.0	3.0	10.5	4.5	2.0	0.0	6.0	1.0	2
B1	758	35.2	4.0	40.3	5.9	14.8	5.6	1.6	0.5	7.2	4.1	6
Form: Kroonstad and Estcourt												
A1	205	33.0	4.2	36.8	13.2	15.0	8.6	2.7	0.9	4.7	4.5	4
E1	300	31.0	8.0	46.5	6.5	8.0	2.0	3.0	2.0	9.0	1.0	2

Table 13.7 Means of CBD-Iron values for soils of the Volksrust Formation. Horizon notation is given.

Hutton		Clovelly		Griffin		Avalon		Kroonstad Estcourt		Swartland	
Horizon	%	Horizon	%	Horizon	%	Horizon	%	Horizon	%	Horizon	%
A1	2.8	A1	2.4	A1	5.4	A1	3.5	A1	0.9	A1	2.3
B1	2.8	B1	3.0	B1	5.4	B1	3.1	E1	1.1	B1	2.4
B2		B2		B2		B2		B1	1.4	B2	

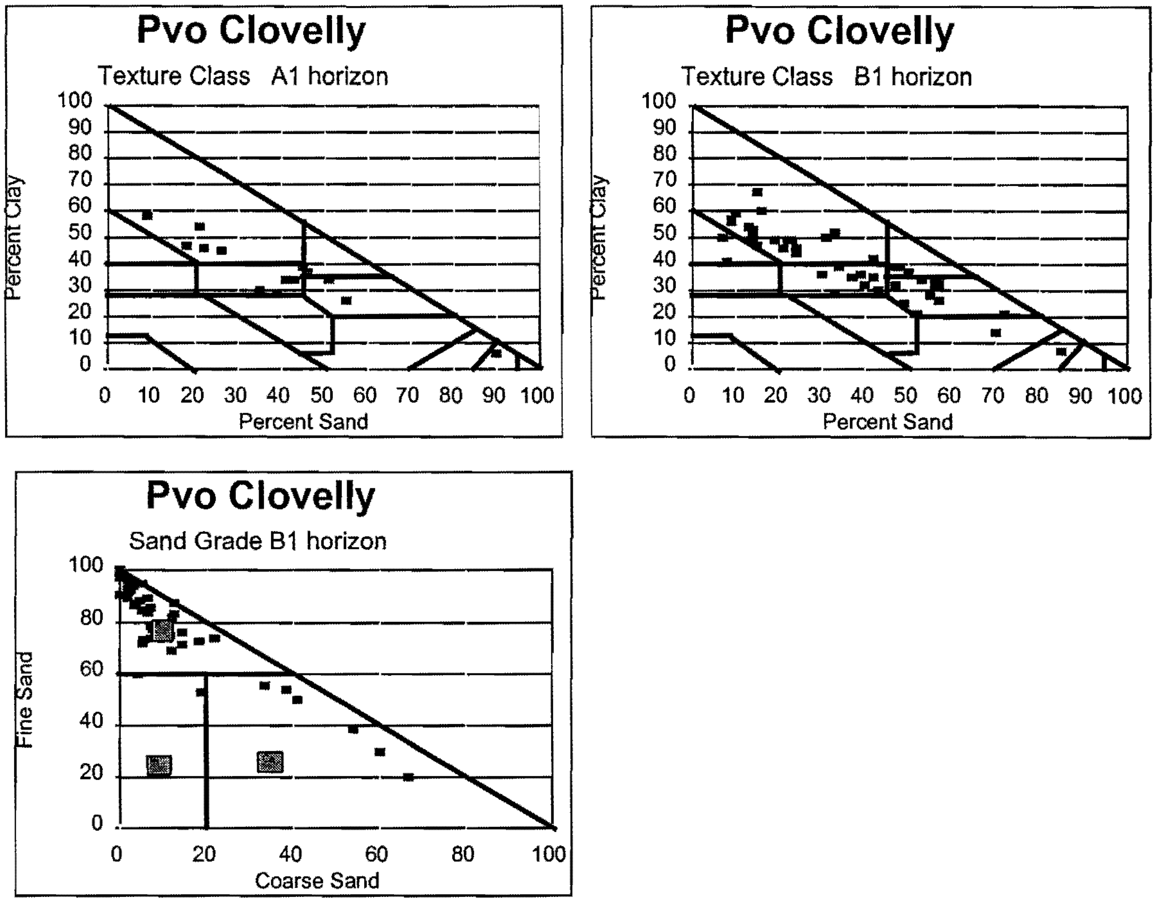

Figure 13.3 Distribution of textures, and dominant sand grades, within soils of the Clovelly Form.

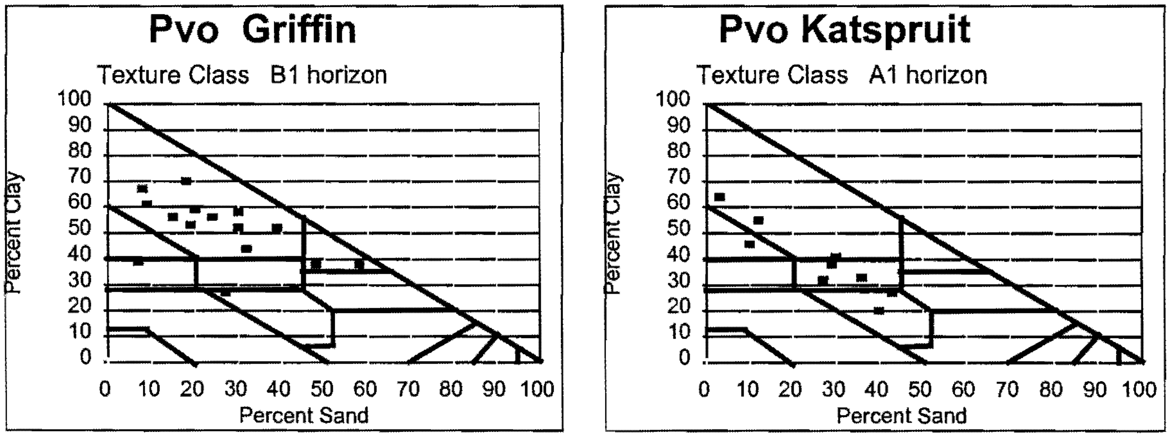

Figure 13.4 Distribution of soil textures within soils of the Griffin and Katspruit Forms.

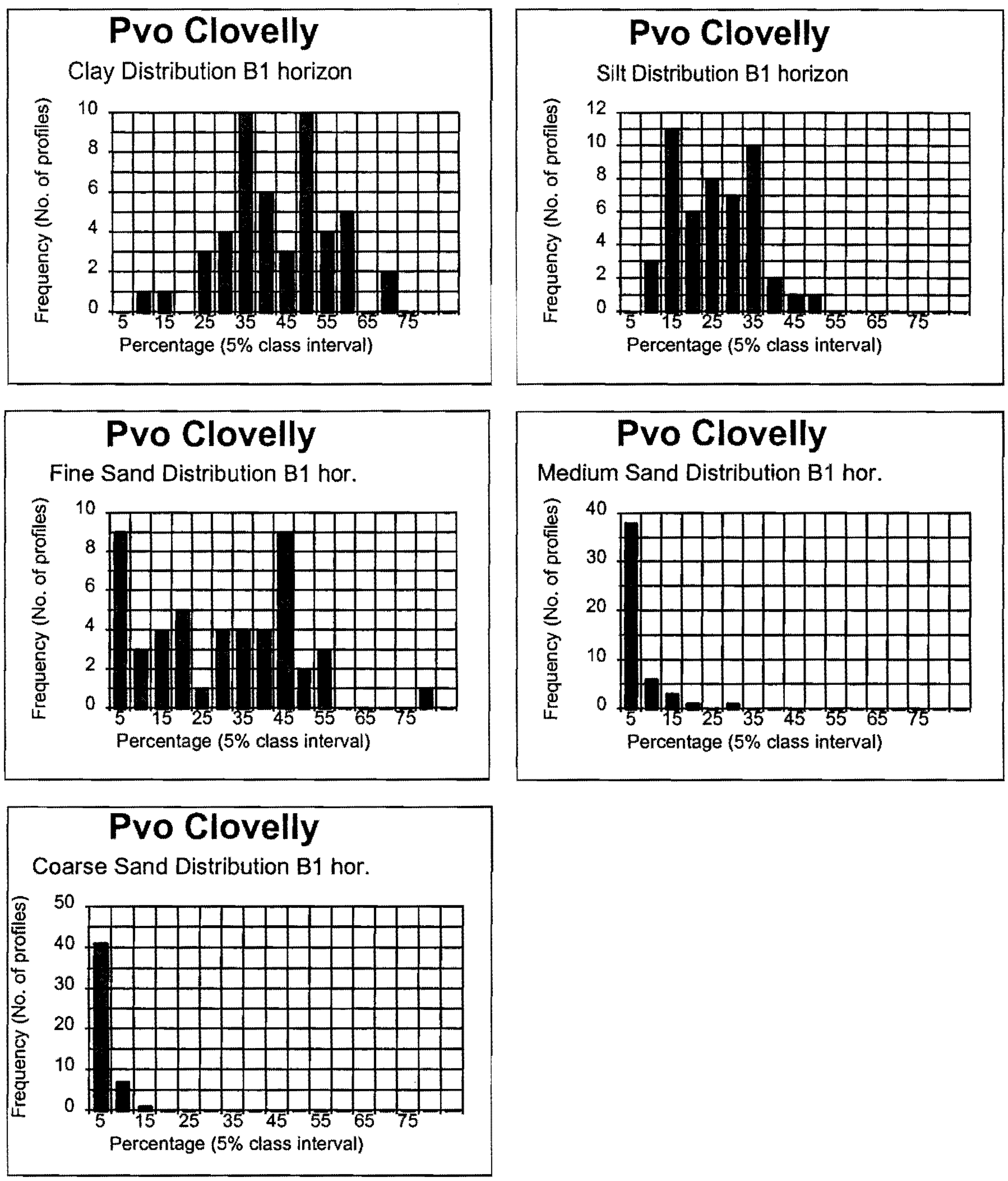

Figure 13.5 Distribution of clay, silt, fine sand, medium sand and coarse sand within soils of the Clovelly Form.

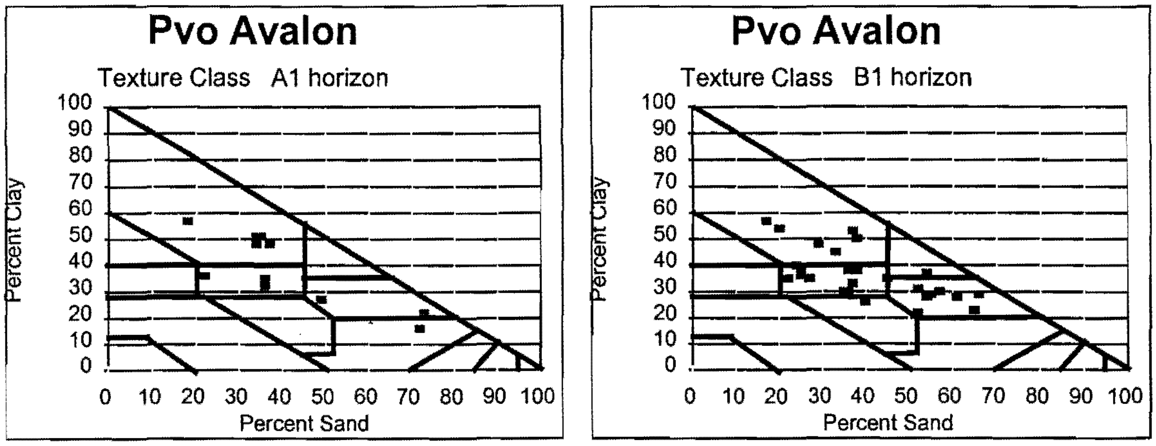

Figure 13.6 Distribution of soil textures within soils of the Avalon Form.

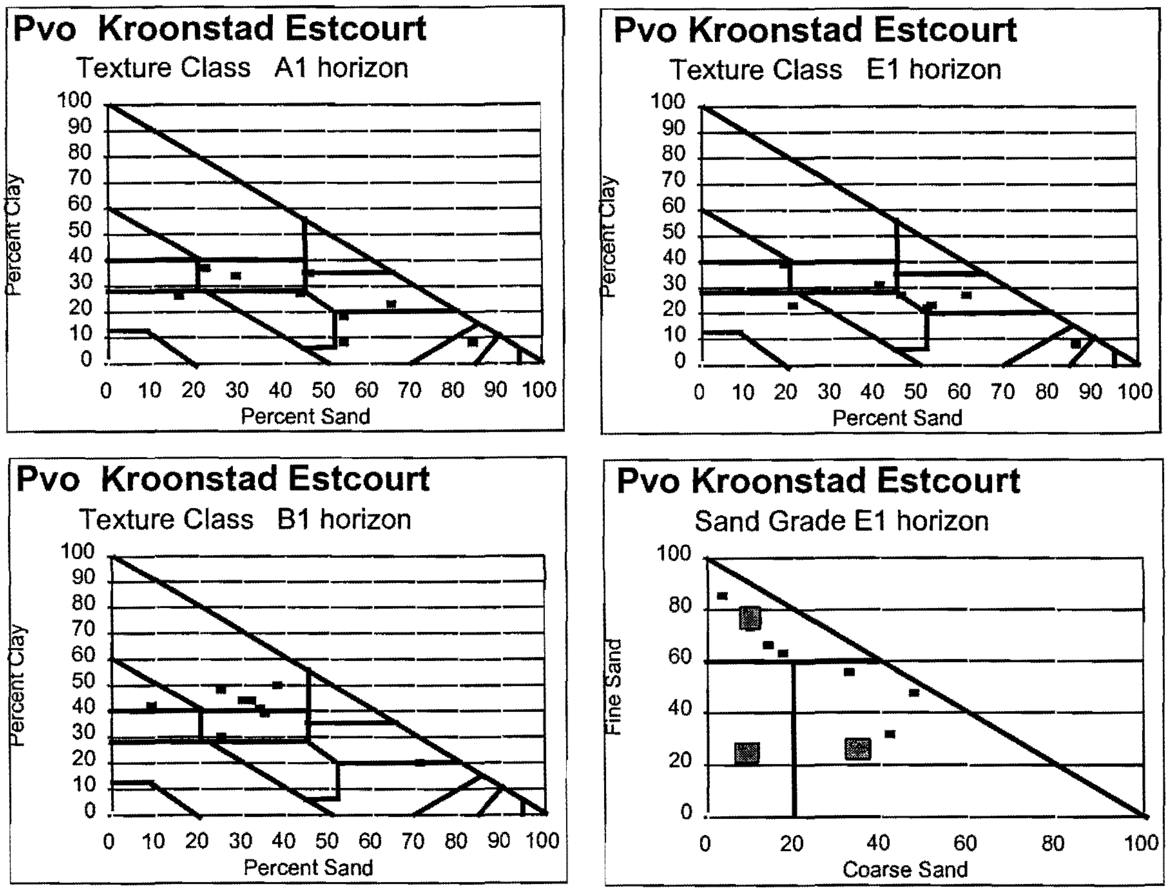

Figure 13.7 Distribution of soil textures, and dominant sand grade, within soils of the Kroonstad and Estcourt Forms.

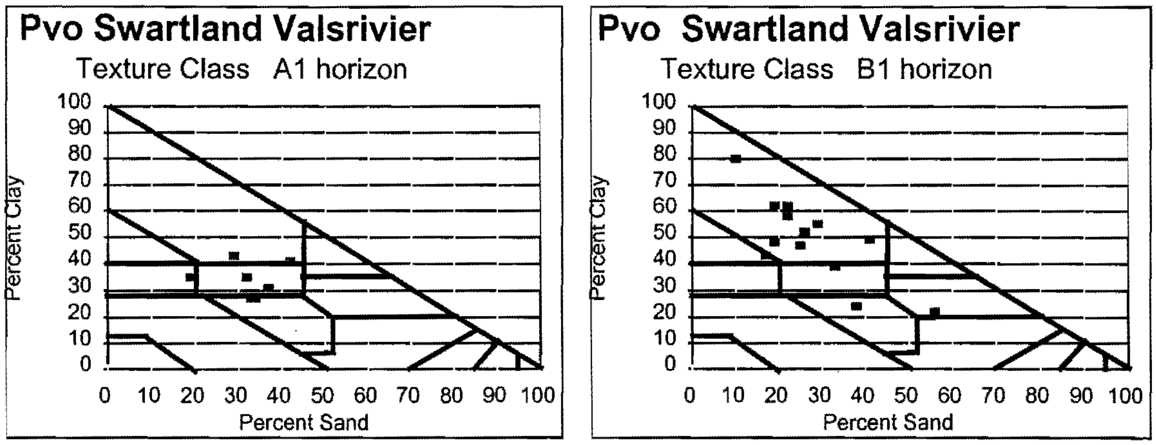

Figure 13.8 Distribution of soil textures within soils of the Swartland and Valsrivier Forms.

CHAPTER 14

SOILS OF THE SANDSTONE AND SHALE OF THE VRYHEID FORMATION, ECCA GROUP KWAZULU-NATAL AND MPUMALANGA

Location and Extent

The Vryheid Formation covers extensive areas of the Highveld Plain and the Interior Basins of KwaZulu-Natal. Within the study area it is located from Benoni on the East Rand stretching north east to the edge of the Highveld Plain at the towns of Witbank and Middelburg in the Mpumalanga Province (Geological Survey, 1984). To the north are rocks of the Transvaal Sequence and the Bushveld Igneous Complex. Further to the east exposures of the Vryheid Formation are bounded by the Archaean Granites. The southern boundary is located near the Vaal River at the contact with the Volksrust Formation. Interspersed over much of the area covered by the formation are intrusions of dolerite. One such extensive intrusion is located in the south western Highveld zone around the town of Standerton. Stretching southwards into KwaZulu-Natal the Vryheid Formation covers large areas of the KwaZulu-Natal Interior Basin. It is bounded in the west by the Volksrust Formation and in the east by the Dwyka Formation (Geological Survey 1984). Further to the east the formation is extensively exposed in the Mfolozi River Basin bounded in the west by various geological formations, including tillite of the Dwyka Formation, and in the east by basalt of the Letaba Formation. South of the Tugela River the extent of the formation is limited to a narrow strip of the KwaZulu-NatalMidland Escarpment. The formation pinches out south of the Mzimkulu River near the southern KwaZulu-Natal boundary (Figure 14.1). The formation covers some 3.964 million hectares in the study area.

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

The distinguishing features and boundaries of this formation are those of the Middle Ecca. It consists of sandstone, shale and subordinate coal beds, and has a maximum thickness of 500m (SACS, 1980). The formation is described as medium to coarse grained sandstone, grey micaceous shale, with subordinate grit and coal beds (Geological Survey, 1988a, 1988b; Geological Survey, 1992)

Physiography and Drainage Features

The physiography of the zones where the Vryheid Formation is exposed on the Highveld Plain range from slightly undulating plains (slopes 2 - 5%) to strongly undulating land (slopes 2 - 8%) (Kruger, 1980). It is in these zones that red and yellow-brown apedal and plinthic soil patterns are common. The Highveld Plain is drained by in the north by the Wilge, Olifants and Klein Olifants Rivers and their tributaries. To the south the exposures of the Vryheid formation are drained by the Vaal River and its tributaries. In the KwaZulu-Natal Interior Basin the terrain varies between undulating lowland plains with hills (slopes 2-8%) to undulating hills (slopes 5-15%). It is from these chains of hills in the District of Vryheid that the formation takes its name. Soils range from red and yellow apedal, through plinthic to duplex soil patterns (Land Type Survey Staff, 1984-1997). Here the drainage is via the Buffalo, Tugela and Mooi Rivers and their tributaries. In the Tugela River valley the slopes are steeper with the presence of low mountains (slopes 8-30%) (Kruger, 1980). Duplex and lithosolic soil patterns are present.

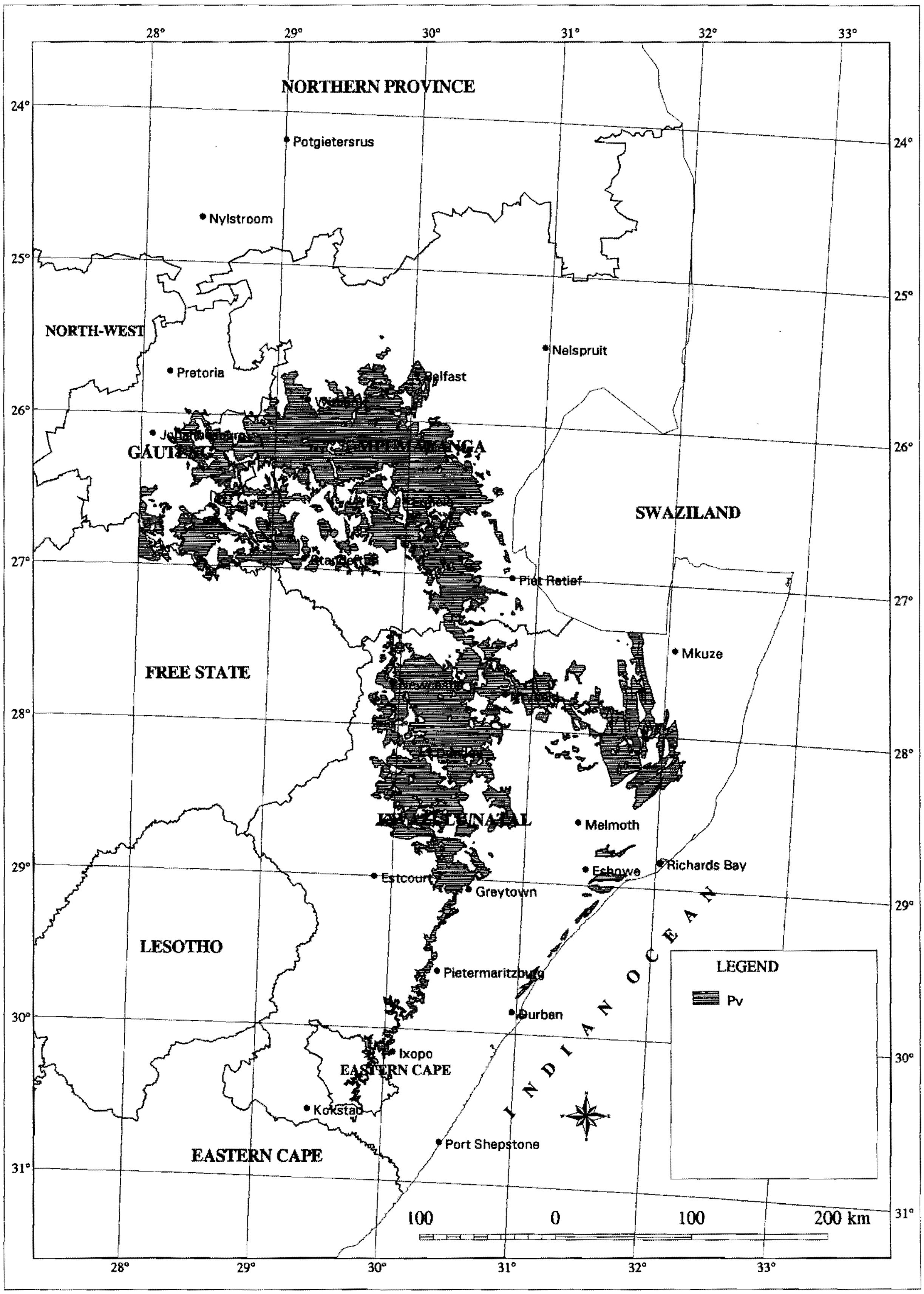

Figure 14.1. Location of the Vryheid Formation, Ecca Group in KwaZulu-Natal and Mpumalanga (after Geological Survey, 1984).

Vegetation

On the Highveld the vegetation on the soils of the Vryheid Formation is dominated by the Moist Sandy Highveld Grasslands (Low and Rebelo, 1996). The vegetation where dolerite intrusions are common into the sandstones and shales is described as Moist Clay Highveld Grassveld. To the east the vegetation is North Eastern Mountain Grassveld. Vegetation covering much of the KwaZulu-Natal Interior Basin is described as the Natal Central Bushveld of the Savanna Biome (Low and Rebelo, 1996).

Soils

Six major soil patterns are evident on the sandstones and shales of the Vryheid Formation (Table 14.1). These include a red and yellow apedal soil pattern where dystrophic soils are dominant and a plinthic soil pattern which has together with the plinthic soils, red and yellow apedal soils of dystrophic and mesotrophic base status. There is also a plinthic pattern where plinthic soils, soils with E horizons and duplex soils dominate. In the duplex soil pattern soils of the Swartland, Valsrivier and Sterkspruit Forms are dominant. Lithosols with, and without the presence of lime make up the remaining two patterns. Here Mispah and Glenrosa soils are dominant, while respectively Cartref and Swartland soils are sub-dominant (Table 14.1).

The red and yellow apedal freely drained soil patterns on sandstones and shales of the Vryheid Formation occur on the moist eastern regions of the Highveld Plain and the highlands of north eastern KwaZulu-Natal. Located at the foot of the Skurweberg and at Nkambula are undulating (slopes 5 - 8%) to rolling (slopes 8 - 15%) areas of dystrophic red and yellow apedal soils. The soils of the Vryheid Formation characteristically have a sandy to sandy clay loam texture. Occasionally soils of a clay texture have been sampled and are associated with the shales present within the formation. The dystrophic and mesotrophic Clovelly, Griffin soils, and the sandy loam Hutton (Hu16) soils (Table 14.1) are derived from sedimentary rocks of the Vryheid Formation. The clay Hutton soils (Hu17, Hu18, Hu27, Hu28 of Table 14.1) are likely derived from the numerous dolerite intrusions into the Vryheid Formation. Glenrosa, Mispah and Katspruit soils are also present in smaller proportions.

The plinthic soil pattern covers extensive areas of the Highveld Plain and Interior Basins of KwaZulu-Natal (Table 14.1). With the gently undulating (slopes 2 - 5%) to undulating (slopes 5 - 8%) and favourable climate they form important areas for crop production. There are characteristic zones of dystrophic and of mesotrophic soils. Eutrophic soils are also present together with mesotrophic soils where there is decreasing effective rainfall. As the rainfall decreases further Longlands and Wasbank soils become dominant to the exclusion of the freely drained apedal soils.

Plinthic soils with E horizons and duplex soils occur regularly together in the same landscape. On the sandstones and shales of the Vryheid Formation a variety of soils may occur (Table 14.1). Plinthic soils and those with an E horizon (Longlands, Wasbank, Westleigh and Cartref) are common. A range of duplex soils are commonly present, while Avalon, Glencoe, Clovelly and Hutton soils may be present to varying proportions (Table 14.1). Each of these soils have a characteristic range of textures. The soils are present on younger land surfaces and within zones where there is diminishing effective rainfall (Table 14.1).

Table 14.1 Dominant soils and selected climatic information for soil patterns occurring on sandstone and shale of the Vryheid Formation, Ecca Group. Subdominant occurrences of soils derived from other geology formations, notably Jurassic dolerite are included.

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 Freely Drained Soils										
Clovelly	Cv16 Cv14	10	Mispah	Ms10	7	Ave	964	1492	2401	0.65
	Cv17	7	Glenrosa	Gs16	5	Std	166	378	437	0.17
Griffin	Gf12	8				Max	1514	3210	3683	-
Hutton	Hu16	11				Min	620	1038	1327	-
	Hu17 Hu18	21								
	Hu27 Hu28									
Total Area: 355 190 Ha			Means of 53 Land Types							
Broad Soil Pattern: Plinthic Soils										
Avalon	Av16 Av14	12	Mispah	Ms10	9	Ave	740	1759	2192	0.42
	Av26 Av24	6				Std	79	260	479	0.09
	Av36 Av34	1				Max	882	2186	3020	0.68
Glencoe	Gc16 Gc14 Gc26	8				Min	580	1306	1350	0.29
Hutton	Hu16 Hu26	17								
	Hu27	4								
Clovelly	Cv16 Cv14 Cv26	6								
Longlands	Lo21 Lo20	6								
Wasbank	Wa21 Wa20	3								
Westleigh	We22 We13	3								
Total Area: 2 161 260 Ha			Mean of 53 Land Types							
Broad Soil Pattern: Plinthic (with E horizons) and Duplex Soils										
Longlands	Lo21 Lo20	10	Avalon	Av36 Av26	8	Ave	735	1673	2683	0.44
Wasbank	Wa21	3	Glencoe	Gc26	3	Std	63	217	303	0.08
Westleigh	We13 We22	2				Max	909	2186	3002	0.58
Cartref	Cf20 Cf21	5	Hutton	Hu36 Hu26	6	Min	620	1385	2063	0.29
			Clovelly	Cv26	6					
Kroonstad	Kd14 Kd13 Kd21	6								
Estcourt	Es34	6	Mispah	Ms10	5					
Valsrivier	Va31 Va41	7	Glenrosa	Gs14 Gs16	5					
Swartland	Sw31	4								
Sterkspruit	Ss24	3								
Total Area: 389 560 Ha			Means of 25 Land Types							
Broad Soil Pattern: Duplex Soils										
Swartland	Sw30 Sw31 Sw41	17	Mispah	Ms10	4	Ave	755	1730	3242	0.44
Valsrivier	Va40 Va41 Va42	13	Glenrosa	Gs16 Gs17	4	Std	131	136	659	0.08
Sterkspruit	Ss24 Ss26 Ss21	14				Max	900	1924	4255	0.63
Estcourt	Es34 Es36	9	Bonheim	Bo41	3	Min	580	1346	1772	0.34
Kroonstad	Kd14	4	Mayo	My21	3					
Total Area: 201 350 Ha			Means of 27 Land Types							

Table 14.1 continued. Dominant soils and selected climatic information for soil patterns occurring on sandstone and shale of the Vryheid Formation, Ecca Group. Subdominant occurrences of soils derived from other geology formations, notably Jurassic dolerite are included.

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	Gs16 Gs17 Gs14	22	Cartref	Cf21	4	Ave	858	1504	2599	0.57
Mispah	Ms10	18				Std	179	204	719	0.17
						Max	1495	2274	4822	-
Rockland	Rock	20				Min	638	1194		0.29
Total Area: 278 160 Ha			Means of 48 Land Types							
Broad Soil Pattern: Lithosols (With the presence of lime)										
Glenrosa	Gs16 Gs17 Gs26	25	Swartland	Swf31 Sw41	7	Ave	692	1708	3296	0.41
Mispah	Ms10 Ms20	17				Std	93	201	661	0.09
						Max	991	2274	4822	0.59
Rockland	Rock	10				Min	557	1394	1889	0.26
Total Area: 579 470 Ha			Means of 60 Land Types							

In the duplex pattern Swartland, Valsrivier, Sterkspruit, Estcourt, and Kroonstad soils with characteristic sandy topsoil textures are present (Land Type Survey Staff, 1985 -1997). Mispah and Glenrosa are also present (Table 14.1). The Bonheim soils, commonly in bottomland and eroded positions is associated with dolerite.

In the more youthful landscapes, where either the slopes are greater or effective rainfall is less, lithosols are dominant. Time for soil formation must be assumed to be shorter. In those zones where effective rainfall is higher Cartref soils are dominant (Table 14.1). Higher rainfalls result in the formation of soils with an E horizon. Where rainfall is lower calcareous and non-calcareous Swartland soils dominate (Table 14.1).

Physical Properties of Natural Soil Bodies: Textural Properties

Soil profiles for Hutton, Griffin, Clovelly, Avalon, Longlands, Cartref, Estcourt, Swartland, Sterkspruit, Mispah and Katspruit were extracted form the database. It is apparent that the soils derived from the sandstone of the Vryheid Formation have a characteristic loamy sand to sandy clay loam texture. Silt contents are low and have fairly constant values. On plotting the range of textures in histograms and in textural triangle graphs there is a strong dominance in these textural classes. However, there is also a smaller group of soils with sandy clay to clay textures that could be clearly distinguished from the more sandy group. These soils are likely to be derived from the shales of the Vryheid Formation. The ranges in textural properties are reported separately (Table

Table 14.2 Textural properties of soils from the loamy sand to sandy loam natural soil body of the Vryheid Formation, Ecca Group derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades	Luvic Properties
Hutton	A1	me-fiSa-SaCl	5-42	1-19	16-56	6-35	3-41		L3,NL2
	B1	me-fiSa-SaCl	3-49	1-30	18-63	3-38	1-41	fi,me,co	NL4,EL1
	B2	meSa-SaCl	4-42	2-15	17-42	9-29	4-40	fi,me	-
Griffin	A1	SaLm-SaCl	13-41	4-22	23-48	12-37	2-14	fi,me	NL4,EL1
	B1	SaLm-SaCl	4-44	2-22	12-75	6-38	3-43	fi,me	NL4,EL1
	B2	SaClLm-SaCl	26-44	1-20	21-36	5-24	3-16	fi,me,co	-
Clovelly	A1	me-fiSa-SaCl	5-39	2-53	4-59	1-39	1-20	fi,me,co	NL3,L2,E1
	B1	me-fiSa-SaCl	4-44	1-23	1-63	5-40	2-39	fi,me	NL4,L1
	B2	me-fiSa-SaClLm	4-44	1-36	1-63	1-40	2-39	fi,me	-
Avalon	A1	LmSa-SaClLm	2-30	1-27	5-64	7-44	2-47	fi,me,co	L3,NL1,EL1
	B1	LmSa-SaCl	1-41	1-34	8-65	1-45	1-39	fi,me,co	NL2,L2,EL1
	B2	SaLm-SaCl	13-39	1-30	6-61	6-31	2-40	fi,me,co	-
Longlands	A1	me-fiSa-SaClLm	5-23	2-25	26-57	6-48	2-30	fi,me,co	EL3,L2
	E1	me-fiSa-SaClLm	2-34	1-25	14-60	5-44	1-45	fi,me,co	L4,NL1
	B1	SaClLm-SaCl	24-42	14-44	11-32	1-12	4-30	fi,me,co	-
Cartref	A1	me-fiSa-SaClLm	6-21	2-3	54-58	14-36	2-3	fi,me	-
	E1	me-fiSa-SaClLm	2-28	2-9	27-58	11-43	2-26	fi,me,co	-
Estcourt	A1	me-fiSa-SaLm	4-35	1-32	10-62	3-39	2-40	fi,me,co	EL3,NL2
	E1	me-fiSa-SaClLm	3-34	2-37	9-67	3-50	1-44	fi,me,co	L5
	B1	LmSa-SaCl	5-46	1-20	15-51	8-33	2-46	fi,me,co	-
Swartland	A1	me-fiLmSa-SaCl	11-43	3-30	5-61	3-35	3-24	fi,me,co	L4,NL1
	B1	SaLm-SaCl	16-42	3-21	9-54	7-30	1-30	fi,me,co	L3,NL2
	B2	SaClLm-SaCl	27-58	3-18	12-70	10-30	4-21	fi,me,co	-
Sterkspruit	A1	me-fiSa-SaClLm	6-29	2-18	20-67	4-41	2-20	fi,me,co	L5
	B1	SaClLm-SaCl	24-39	4-18	20-45	3-25	1-17	fi,me	-
	B2	SaClLm	33	8	20	19	19	fi,me	-
Mispah	A1	me-fiSa-SaCl	10-41	2-37	10-61	4-29	2-30	fi,me,co	-
Katspruit	A1	me-fiSa-SaCl	10-32	14-31	15-42	4-8	2-6	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).

14.2 and Table 14.3) for these two groups of soils. 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 in Tables 14.2 and 14.3.

Table 14.3 Textural properties of soils from the clay natural soil body of the Vryheid Formation, Ecca Group derived from profile values.

Form	Horizon	Texture Class	Clay %	Silt %	Fine Sand %	Medium Sand %	Coarse Sand %	Sand Grades
Griffin	A1	Cl-SiCl	47-56	5-32	5-33	1-5	5-5	fi,me
	B1	Cl	58-67	14-25	3-13	1-1	1-11	fi,me
	B2	Cl	54-54	28-28	6-6	1-1	11-11	fi,me
Clovelly	A1	Cl-SiCl	46-69	16-32	7-20	1-4	1-7	fi,me
	B1	Cl-SiCl	50-65	8-45	3-20	1-10	1-7	fi,me
Avalon	A1	Cl	46-48	19-20	21-25	2-3	3-3	fi,me
	B1	Cl	45-53	11-21	23-29	2-6	1-4	fi,me
	B2	Cl	46-51	6-16	27-36	3-13	2-4	fi,me
Estcourt	B1	Cl	52-65	1-25	11-23	1-15	2-16	fi,me
Swartland	A1	Cl	48-56	10-10	25-26	3-12	2-3	fi,me
	B1	Cl	46-60	6-26	10-30	1-10	2-5	fi,me

These ranges are presented graphically in Figure 14.2 and 14.3. The figures allow for overview comparisons between different soil forms and over particle size classes. Figure 14.2 shows the range in clay contents for the red and yellow-brown apedal soils (Hutton, Griffin, Clovelly and Avalon) from 2% to about 45% clay. Silt values are low, commonly less than 20% and seldom exceed 30% (Table 14.2). Fine, medium and coarse sand grades are present in varying proportions. There are similarities between the soils with E horizons (Longlands, Cartref, Estcourt Forms) and those of the red and yellow-brown apedal soils, although clay contents are slightly lower in the A1 and E1 horizons (Table 14.2). The duplex soils (Swartland and Sterkspruit Forms) have properties between these two soil groups.

The textural properties of the soils of the Vryheid Formation (formerly known as Middle Ecca) show some similarities to those of the tillites of the Dwyka Formation and sandstone of the Natal Group. With erosion and faulting these geological formations are often located near to the Vryheid Formation. However, soils derived from the Vryheid Formation show striking textural differences to the soils derived from the Pietermaritzburg and Volksrust Formations (formerly known as Lower and Upper Ecca respectively) and to the soils derived from dolerite.

Figure 14.3 shows the clay nature of the group of soils assumed to be derived from shale within the Vryheid Formation. Silt values are somewhat higher(Tables 14.3 and 14.5) than the sandy group (Tables 14.2 and 14.4), but generally lower than those soils derived from the Volksrust Formation (Chapter 13) where mean silt values of between 20 and 30% were commonly measured. Fine sand is the dominant sand grade with low values for medium and coarse sand respectively (Table 14.3).

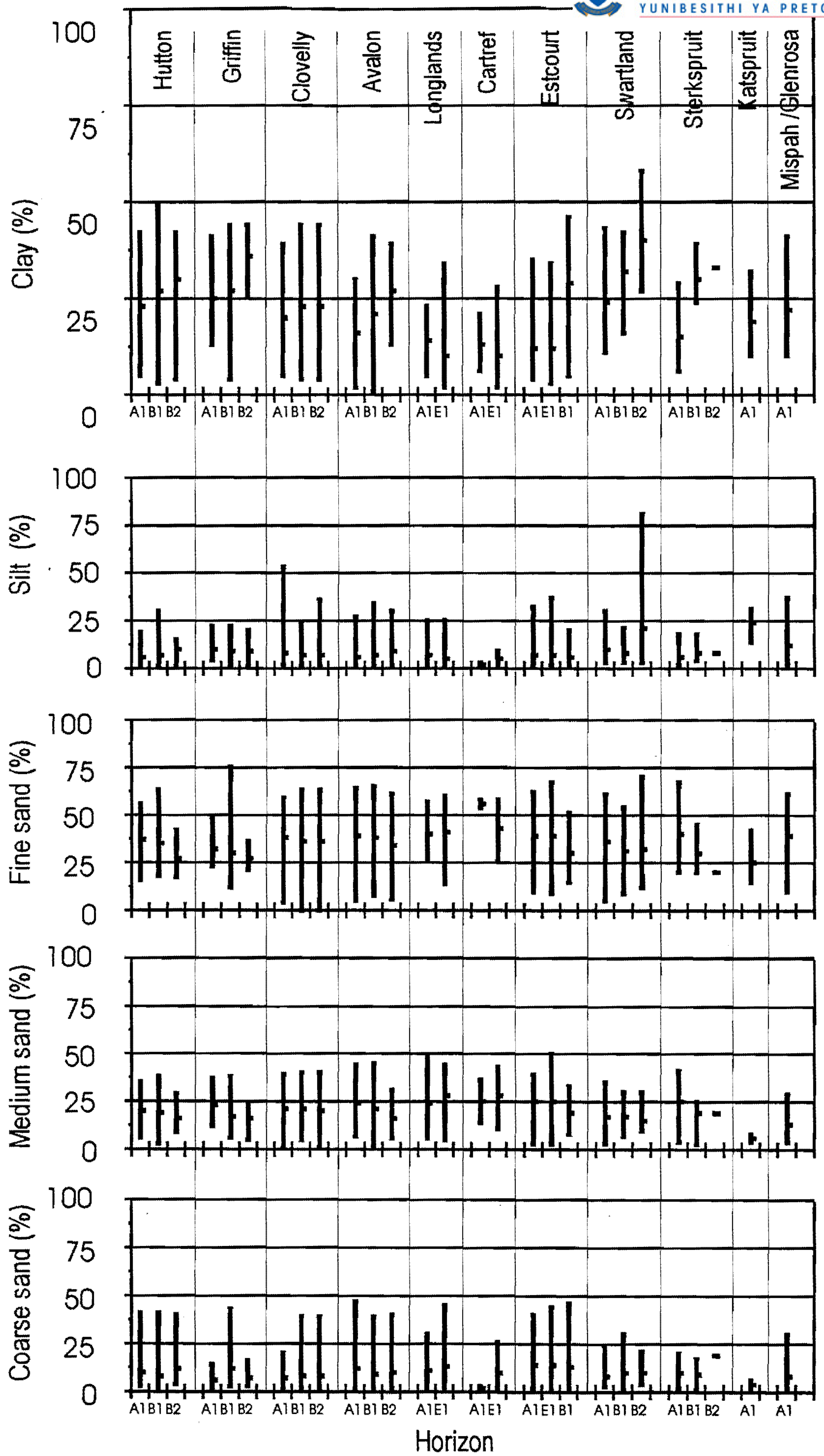

Figure 14.2 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of Vryheid Formation with a sand to sandy loam texture. Maximum, minimum and mean values are shown for each horizon.

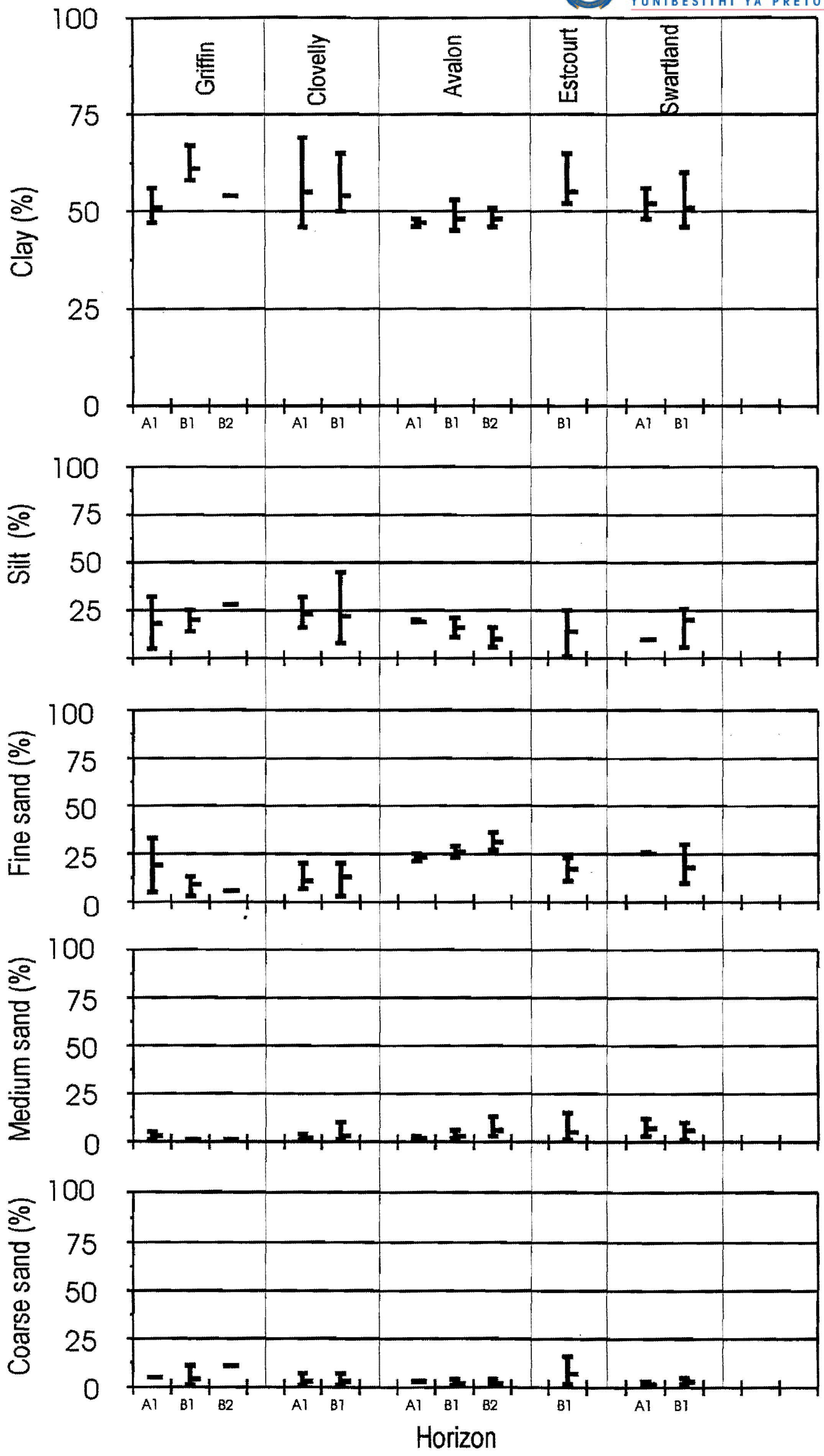

Figure 14.3 Ranges in clay, silt, fine sand, medium sand and coarse sand for soils of Vryheid Formation with a sandy clay to clay texture. Maximum, minimum and mean values are shown for each horizon.

Table 14.4 Means and standard deviations of five textural classes for soils of the Vryheid Formation from the sand to sandy clay loam natural soil body.

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												
A1	304	23.1	8.9	6.8	4.7	37.9	10.0	20.3	7.3	10.3	7.5	35
B1	757	27.1	10.0	7.4	5.4	35.2	8.4	19.2	6.7	8.7	6.3	80
B2	1333	30.8	12.7	10.0	5.4	27.8	8.3	16.5	6.2	12.7	12.4	6
Form: Griffin												
A1	360	25.1	8.0	10.7	5.8	32.0	7.2	23.0	8.7	6.7	4.0	10
B1	719	27.9	11.3	14.9	2.4	30.5	12.9	17.8	8.6	12.5	11.3	19
B2	1114	36.8	6.1	17.3	2.5	27.8	4.8	16.3	6.4	7.4	4.1	9
Form: Clovelly												
A1	334	20.1	8.2	8.8	9.3	38.1	12.4	21.7	8.5	7.3	4.5	32
B1	761	23.7	8.9	7.3	4.2	36.8	10.1	21.2	7.6	8.8	6.3	82
B2	763	23.8	8.9	7.7	5.2	36.6	10.2	20.9	7.9	8.8	6.3	83
Form: Avalon												
A1	314	16.0	6.2	6.0	4.1	39.4	11.3	24.6	8.0	12.0	8.6	60
B1	746	21.5	9.4	7.5	5.9	38.9	10.2	21.4	8.7	9.2	5.9	148
B2	1014	27.1	7.4	9.5	6.4	34.6	10.0	16.9	7.1	10.7	7.8	32
Form: Longlands												
A1	314	14.7	4.8	7.4	5.5	40.6	8.3	24.5	9.8	11.7	6.4	21
E1	675	10.1	6.8	5.1	4.8	41.5	11.1	28.8	9.1	13.6	10.3	32
B1	732	30.9	7.0	29.2	9.2	21.6	8.2	3.8	3.3	13.3	8.3	9
Form: Cartref												
A1	300	13.5	7.5	2.5	0.5	56.0	2.0	25.0	11.0	2.5	0.5	2
E1	650	10.7	8.3	5.0	2.2	43.0	10.8	28.9	10.0	10.7	8.2	10

Table 14.4 continued. Means and standard deviations of five textural classes for soils of the Vryheid Formation from the sand to sandy clay loam natural soil body.

Horizon	Depth mm	Clay %		Silt %		Fine Sand %		Medium Sand %		Coarse Sand %		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Form: Estcourt												
A1	264	12.3	6.8	7.4	7.9	39.0	11.1	25.2	9.5	14.6	8.9	23
E1	589	12.9	9.2	7.4	6.5	39.8	14.2	25.5	10.4	14.2	10.1	36
B1	850	29.9	12.5	6.6	4.6	30.4	10.1	19.2	7.3	13.9	10.8	23
Form: Swartland												
A1	302	24.5	9.2	10.9	8.5	36.5	12.8	17.7	8.3	8.8	5.7	24
B1	641	23.8	2.7	32.1	7.8	31.1	11.1	17.1	6.5	10.8	7.1	18
B2	993	28.9	2.7	40.5	10.9	32.8	20.1	15.2	7.2	10.8	6.0	6
Form: Sterkspruit												
A1	249	15.9	8.1	6.3	4.4	40.3	10.6	25.4	10.6	10.1	5.7	12
B1	687	30.9	5.1	8.8	4.7	30.7	6.5	19.3	6.2	9.1	4.2	9
B2	700	33.0	0.0	8.0	0.0	20.0	0.0	19.0	0.0	19.0	0.0	1
Form: Katspruit												
A1	313	19.7	9.2	24.7	7.6	25.7	11.7	6.0	1.6	4.0	1.6	3
Form: Glenrosa												
A1	264	22.3	7.9	12.2	8.6	39.7	13.5	13.7	7.9	8.3	7.4	20

Table 14.5 Means and standard deviations of five textural classes for soils of the Vryheid Formation from the sand clay to clay natural soil body.

Horizon	Depth mm	Clay %		Silt %		Fine Sand %		Medium Sand %		Coarse Sand %		Sample Size
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Form: Griffin												
A1	225	51.5	4.5	18.5	13.5	19.0	14.0	3.0	2.0	5.0	0.0	2
B1	633	61.3	4.0	20.3	4.6	9.3	4.5	1.0	0.0	4.3	4.7	3
B2	1500	54.0	0.0	28.0	0.0	6.0	0.0	1.0	0.0	11.0	0.0	1
Form: Clovelly												
A1	312	55.3	8.6	23.8	6.9	11.8	5.1	2.8	1.3	3.5	2.2	4
B1	733	54.7	4.3	22.9	11.1	13.0	5.8	3.7	3.3	3.2	2.0	9
Form: Avalon												
A1	225	47.0	1.0	19.5	0.5	23.0	2.0	2.5	0.5	3.0	0.0	2
B1	791	48.2	2.6	16.5	3.3	26.6	2.6	3.2	1.5	2.4	1.0	6
B2	1100	25.1	0.9	48.7	2.0	31.3	3.7	6.3	4.7	2.7	0.9	3
Form: Estcourt												
B1	766	55.8	4.7	14.0	8.4	17.8	4.1	5.3	5.1	7.0	5.1	6
Form: Swartland												
A1	445	52.0	4.0	10.0	0.0	25.5	0.5	7.5	4.5	2.5	0.5	2
B1	655	51.0	4.4	20.3	7.2	18.8	6.9	6.0	3.1	3.5	1.0	6

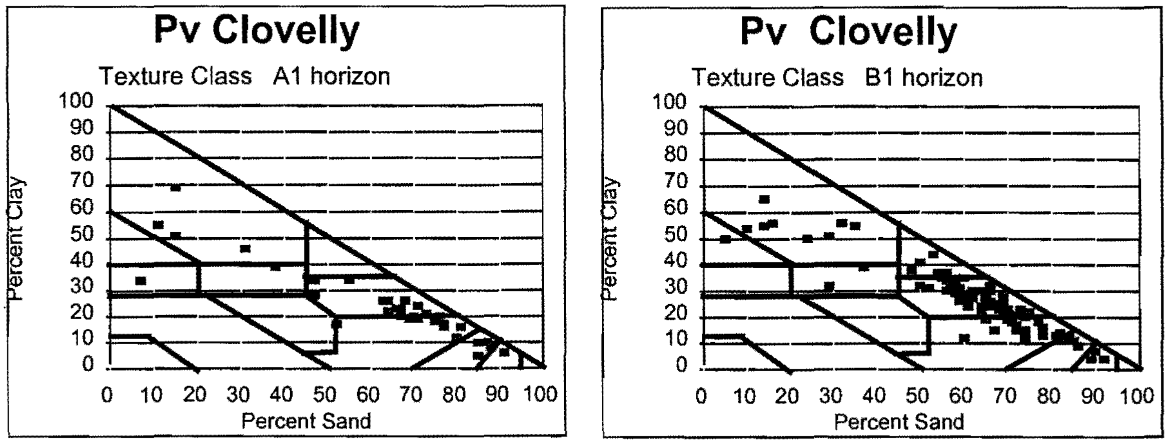

Figure 14.4 Distribution of soil texture within soils of the Clovelly Form.

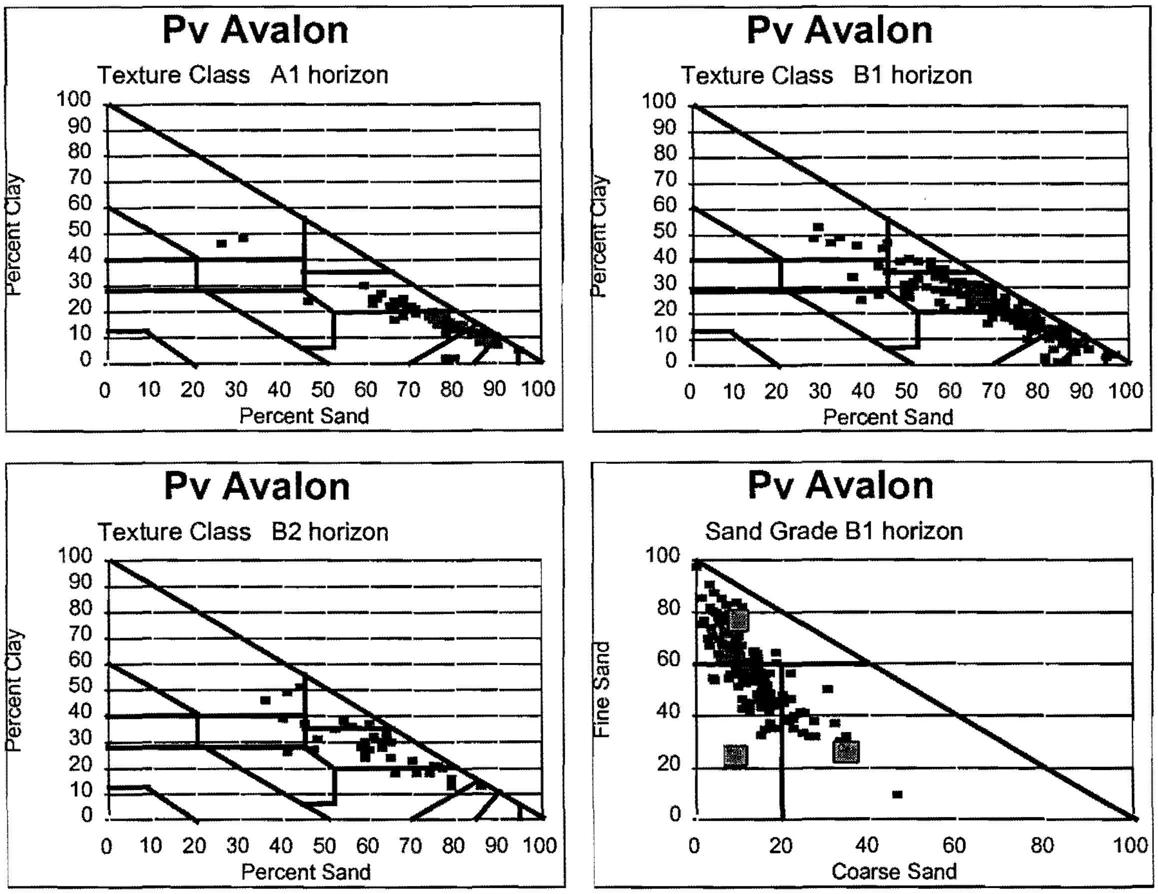

Figure 14.5 Distribution of soil texture, and dominant sand grade, within soils of the Avalon Form.

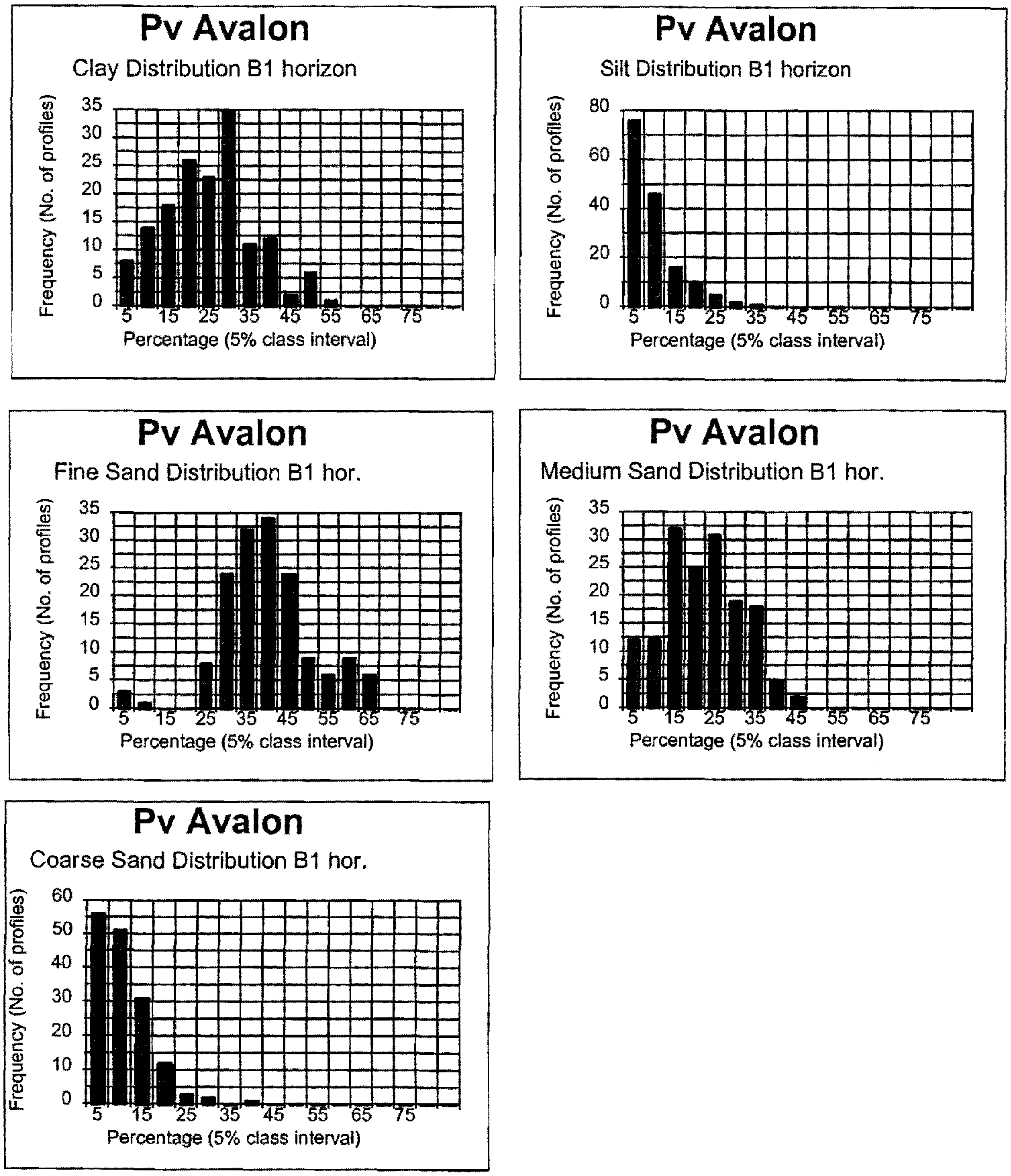

Figure 14.6 Distribution of clay and silt, fine sand, medium sand and coarse sand within soils of the Avalon Form.

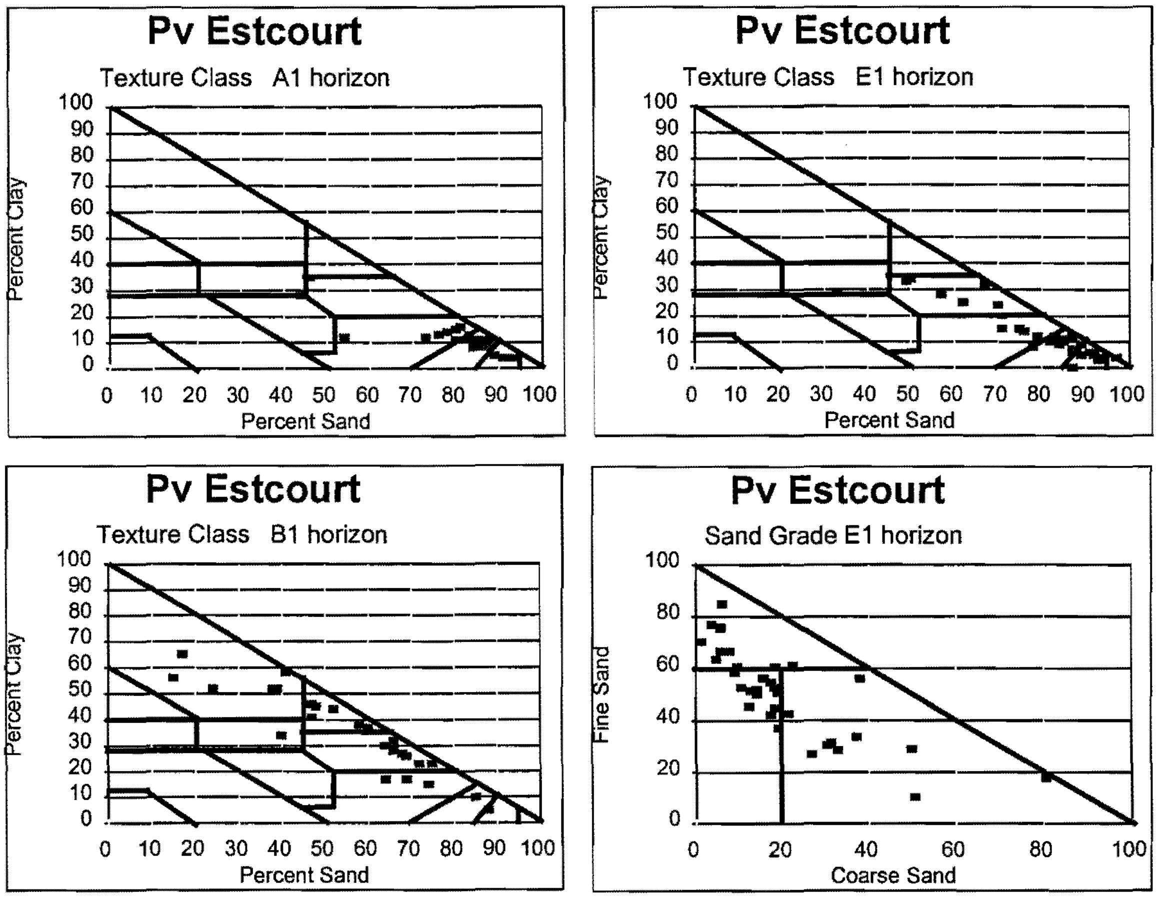

Figure 14.7 Distribution of soil textures, and dominant sand grade, within soils of the Estcourt Form.

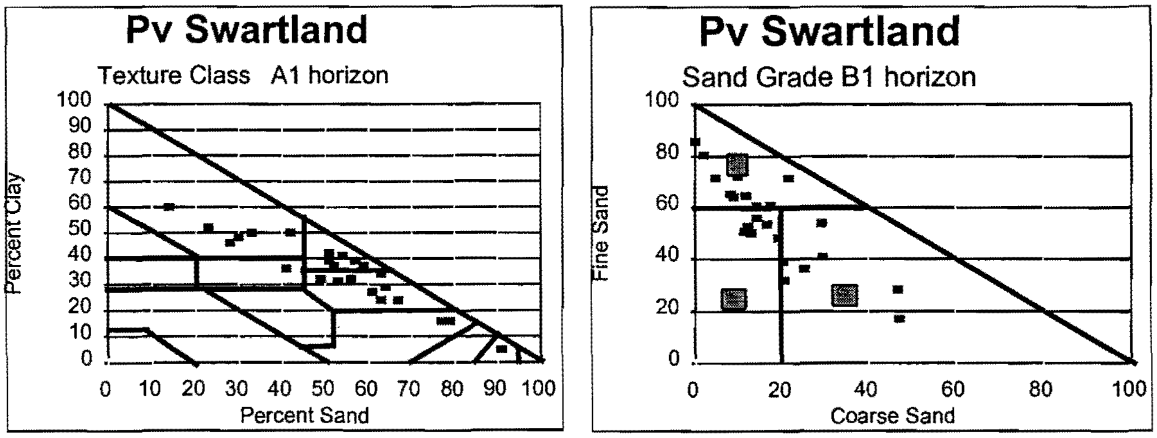

Figure 14.8 Distribution of soil textures, and dominant sand grade within soils of the Swartland Form.