4 SOILS

The general nature of the soils has been shown on small-scale maps (Skene 1952, Northcote 1960). Under the prevailing sub-humid climate, sodic duplex (solodic) soils are dominant. The drier flat plains in the north carry red calcareous sodic duplex soils (red-brown earths). In the humid south and on some old land surfaces, acidic duplex (podzolic) soils occur. Other soil groups occupy relatively small areas.

Within this general framework the detailed soils pattern is governed by geological-geomorphological changes, resulting in considerable diversity in soil depth, stoniness, texture and other features. Soils recognised as entities in the field on particular parent materials, corresponding to series in soil surveys, have been given descriptive names based largely on colour and profile form according to Northcote (1979). Table 8 lists the soils and their classification. Descriptions of the more common soils are given in Appendix IV.

Soils of uniform texture

1. Yellowish brown sand soils. Coarse sands with eluviation of iron oxide but not of clay occur among outcropping boulders on the crests and upper slopes in steep granitic areas. Soil depth usually ranges between 0.5and 1.5 m. The reaction is moderately acidic and the nutrient status is low despite the close proximity of relatively unweathered parent material. High permeability, allied with low water-holding capacity, leads to problems such as waterlogging at the base of slopes and, during drought, the death of shallow-rooted species Such as introduced clovers and grasses.

2. Sandy loam soils. Regularly flooded terraces beside the river and major creeks are composed of layered sandy deposits with little profile development other than accumulation of organic matter at the surface. The topsoil usually has a relatively high proportion of silt, is weakly structured and is noticeably powdery when dry.

3. Shallow stony brown soils. Shallow stony and gravelly loams occur on the upper slopes of the widespread metamorphic aureoles, often interspersed with outcropping beds of sandstone. Soil depth varies from almost nil to about 30 cm over short distances. In the deeper profiles the texture increases slightly to be clay loam at depth. The reaction is acidic, the water-holding capacity low and the surface structure weak. Few pasture species can survive this harsh environment, although deep-rooted perennials may persist in the higher-rainfall areas. On cleared land ground cover is sparse, leading to erosion *in situ* and to excessive runoff that causes problems downslope.

4. Grey calcareous sodic clay soils, coarsely structured (Plate 1). These soils have formed on deep clayey alluvium. Gilgai micro-relief is prominent, leading to a complex of soil features. Surface texture ranges from clay on the puffs to clay loam in the hollows, where some fine surface mottling is apparent. The structure is predominantly coarse angular blocky, becoming finer towards the surface of the puffs, and being fine subangular blocky in the hollows. Large clayskins are prominent in the subsoil, grooved by differential movement of the peds under the shrink-swell process. Visible lime occurs in subsoils, reaching the surface on the puffs. On seasonal wetting the subsoil cracks close up, leading to waterlogging and to the accumulation of soluble salts through lack of leaching. Poor moisture penetration, particularly on the puffs, accentuates the adverse moisture availability of the clays.

5. Grey, brown and red calcareous sodic clay soils (Plate 2). Gilgaied clay soils in which the colour varies with micro-relief have formed on calcareous aeolian dust overlying a variety of substrates in the north, mainly granitic rocks and alluvium. Relative to the grey clays (4, above) the structure is favourable, ranging from fine subangular blocky at the surface to medium angular blocky in subsoils. Thus moisture penetration and availability are more suitable for plant growth, and waterlogging serious only in the wettest seasons in low-lying areas. Fertility is also favourable.

Gradational soils

6. Red gradational soils (Plate 3). Shallow stony gradational soils are found on the upper slopes of gentle land on Ordovician bedrock. The A horizon stony loams are weakly structured and hard-setting, while the subsoil light clays are moderately pedal. The reaction is slightly acid to neutral at the surface, becoming more acid with depth. Shallowness and stone content make the water-holding capacity low. Fertility is moderate.

7. Yellowish brown gradational soils. are interspersed with 6 above, but developed on alluvium in drainage lines. These have similar texture and structure, but are yellower, deeper and less stony and thus have more favourable moisture characteristics. The subsoils are dispersible. This, allied with the drainage lines, leads to gully erosion following disturbance.

Duplex soils

8. Mottled duplex soils **(**Plate 4). Deeply weathered profiles are found on old land surfaces overlying gravelly Tertiary deposits. There is a strong texture contrast between the deep sandy A horizons and the well-structured mottled yellowish brown and red clay B horizons. Ironstone fragments occur in the A2 and B, horizons. The surfaces are slightly acidic, and the subsoils more acidic. The well-structured B horizons overlie coarsely mottled yellowish red and pale-grey weakly structured clay. At still greater depth there is a siliceous hardpan. Permeability and water-holding capacity are favourable, although quartz and ironstone gravel in the A horizons reduce water availability to shallow-rooted species. The fertility is low.

9. Mottled sodic duplex soils (Plate 5). Deeply weathered profiles similar to those in 8 above occur on gentle granitic lands towards the south. However, the fertility is not as low, as indicated by analyses for nutrients, the subsoils are sodic and the A horizons have higher water-holding capacities because they contain less stones and gravel.

10. Stony red duplex soils (Plate 6). In the humid southern areas such as the steep slopes of the Pyrenee Range and the footslopes to steep country on Ordovician sediments, the soils have weakly structured stony loam surfaces, bleached A2 horizons and an abrupt change to moderately pedal, non-sodic clay subsoils. They have an acidic reaction throughout and moderate fertility. Water-holding capacity is low in the A horizons because of stone content. The soils are interspersed with rock outcrop, and soil depth is particularly variable.

11. Red calcareous sodic duplex soils (Plates 7 and 8) occur mainly in the north where calcareous aeolian dust overlies various rocks and sediments, and also on broad alluvial plains in the Natte Yallock-Avoca area. Surface textures range from loamy sand to clay loam, but the topsoil is invariably weakly structured and hard-setting. The A horizons are frequently thin. Permeability ranges from low to moderate, while fertility and water-holding capacity are moderate.

12. Brown calcareous sodic duplex soils (Plate 9). In poorly drained depressions on the alluvial plains, notably the broad plains near Natte Yallock, the soils are similar to those in 11 above, but are brown and have heavier subsoils.

Table 8 - Soils of the Avoca River catchment

Number	Description	Parent material	Sample profile no.	Classification	
				Northcote (1979)	Stace *et al* (1968)
Soils of uniform texture					
1 .	Yellowish brown sand soils	Devonian granitic rocks		Uc 5.11	Lithosols
2.	Sandy loam soils	Recent alluvium		Uc 4.31	Alluvial soils
3.	Shallow stony brown soils	Ordovician sediments		Urn 5.21	Lithosols
4.	Grey calcareous sodic clay soils, coarsely structured	Quaternary alluvium	915*, 916*	Ug 5.21 Ug 5.21	Grey, brown and red clays
5.	Grey, brown and red calcareous sodic clay soils	Quaternary parna	929	Ug 6.10	Grey, brown and red clays
Gradational soils					
6.	Red gradational soils	Ordovician sediments	910, 931	Gn 4.11 Gn 4.11	Lithosols Lithosols
7.	Yellowish brown gradational soils	Quaternary alluvium	-	Gn 2.24	Brown earths
Duplex soils					
8.	Mottled duplex soils	Tertiary deposits	907, 920	Dr 5.41 Dr 5.21	Lateritic podzolic soils
9.	Mottled sodic duplex soils	Devonian granitic rocks	924	Dy 3.41	Solodic soils
10.	Stony red duplex soils	Ordovician sediments	901, 904	Dr 2.41 Dr 3.41	Red podzolic soils
11.	Red calcareous sodic duplex soils	Quaternary alluvium	917	Dr 3.33	Red-brown earths
12.	Red calcareous sodic duplex soils	Parna on Tertiary deposits	927	Dr 2.43	Red-brown earths
		Parna on Devonian	928	Dr 2.23	Red-brown

Number	Description	Parent material	Sample profile no.	Classification Northcote (1979)	Stace *et al* (1968)
		granitic rocks			earths
		Quaternary parna	930	Dr 2.13	Red-brown earths
13.	Brown calcareous sodic duplex soils	Quaternary alluvium	918	Db 2.43	Solodic soils
14.	Yellow sodic duplex soils	Tertiary deposits	902,	Dy 3.32	Solodic soils
			908	Dy 3.42	Solodic soils
		Devonian granitic rocks	903,	Dy 3.42	Solodic soils
			905,	Dy 3.42	Solodic soils
			914,	Dy 3.42	Solodic soils
			926	Dy 2.41	Solodic soils
		Ordovician sediments	912	Dy 3.41	Solodic soils
		Recent alluvium	923	Dy 3.42	Solodic soils
15.	Red sodic duplex soils	Quaternary alluvium	909,	Dr 3.42	Solodic soils
			919	Dr 2.42	Solodic soils
		Tertiary deposits	906,	Dr 3.41	Solodic soils
			921,	Dr 3.42	Solodic soils
			922	Dr 2.31	Solodic soils
		Ordovician sediments	911	Dr 2.42	Solodic soils
		Devonian granitic rocks	913	Dr 3.42	Solodic soils
16.	Brown sodic duplex soils	Devonian granitic rocks	925	Db 1.43	Solodic soils

**Gilgaied, with more organic matter in topsoil of depressions*

13. Yellow sodic duplex soils (Plate 10) occur in the south on a wide variety of parent materials - Ordovician sediments, granite, gravelly Tertiary deposits and alluvium. On hilly lands they occupy the lower slopes. Their common features are a strong texture contrast, a sharp boundary between A and B horizons, a prominent bleached A2 horizon and coarse blocky subsoils. The structure tends to be columnar in places. The reaction is acidic except in the deeper subsoil. The A horizons are weakly structured, hard-setting and may contain ferromanganiferous nodules in the lower parts. The B horizons are usually mottled, relatively saline and at depth are strongly sodic, sodium constituting 10-20% of the cation exchange capacity. Fertility and moisture characteristics are moderate, but seasonal waterlogging is a problem because of the slowly permeable subsoils.

14. Red sodic duplex soils (Plate 11). On the extensive older terraces near Avoca and on nearby gentle slopes overlying Ordovician sediments the soils are similar to those of 13 above, but are better-drained and less sodic. Being stone-free and developed on alluvium, the soils of the terraces have better fertility and water-holding capacity.

15. Brown sodic duplex soils (Plate 12) occur in drainage lines on alluvium derived from granitic rocks. They have features similar to those in 13 above, but the B horizons are darker and seasonal waterlogging is more pronounced. These soils occupy only small areas.

Physical and chemical characteristics

The more widespread soils were sampled on road casements or Crown land reserves at sites retaining the native vegetation and having minimal soil disturbance. Thus the analyses should represent the original physical and chemical conditions, which can be used as benchmarks against which to measure changes since European settlement.

The results of analyses are given in Appendices 1 and II and the laboratory methods in Appendix III.

Particle-size analysis

The particle-size analyses reflect the classification of the soils into uniform, gradational and duplex classes according to textural change down the profile (see Figure 9). Other noticeable features are the high values for coarse sand in the upper horizons of soils on granitic rocks and the high clay contents in subsoils of the old, strongly leached mottled duplex soils. As has been noted in several earlier publications, the soils developed on parna have particularly low silt contents.

Reaction (pH)

As shown in Figure 10, reaction varies from alkaline throughout the profile in the calcareous clay soils to acidic throughout, notably in the highly leached mottled duplex soil on Tertiary gravels. This soil has a low pH at the surface, reflecting its poor agronomic performance and indicating the need for application of lime for pasture establishment. The stony red duplex soils and the red gradational soils are also acidic throughout. Both soils occur in the south, and the low pH values reflect the more humid climate and possibly less accession of parna. The sodic duplex soils show the usual alkaline reaction trend, from acidic at the surface to alkaline in the lower B horizons.

Electrical conductivity and chloride

Values for electrical conductivity and chloride (see Figure 11) tend to be proportional, indicating that chlorides comprise the bulk of the soluble salts, at least when values are high.

A general trend towards increasing salinity from south to north reflects increasing acidity. Values are particularly low in the old mottled duplex soils on Tertiary gravels, and particularly high in the calcareous

clay soils and the red calcareous sodic duplex soils on alluvium and parna where salinity of subsoils is likely to limit crop yields.

Organic carbon and nitrogen

The rather low carbon and nitrogen values of the A, horizons are characteristic of soils in sub-humid parts of Victoria. Also characteristic are the high carbon: nitrogen ratios, which indicate low inherent fertility. By far the highest ratio occurs in the highly leached soil on Tertiary gravels. The lowest ratio is found in the clay soils.

Free ferric oxide

Variations in free ferric oxide (see Figure 12) with depth can indicate the amount of leaching the soil has undergone and so may provide a guide to soil age. The strongest increase is in the old mottled duplex soil on Tertiary gravels. The weakest trends occur in the slowly permeable clay soils and in the duplex soils developed on parna. The low values at or near the surface indicate that none of the soils sampled presents a serious hazard of fixation of applied phosphate.

Total and available phosphorus and potassium

Although variable, total phosphorus is low in all soils. The highest values occur on granitic rocks. All soils are deficient in available phosphorus except for the surface of the brown duplex soil on alluvium: this may be related to the vegetation at the sampling site *(Eucalyptus camaldulensis).* Murray and Mitchell (1962) noted concentration of nutrients at the surface beneath this species.

Total potassium levels are more satisfactory in the north, reflecting the lower leaching rate in the drier climate. Values are high in clay soils. Using 200 parts per million(p.p.m.) in the A horizons as a yardstick for ample supplies, available potassium levels are satisfactory in the north but marginal in the south. The mottled duplex soils on Tertiary gravels have particularly low values.

Exchange cations

Cation exchange capacities (see Figure 13) in the catchment are governed largely by clay content, and by organic matter content at the surface. Surface values range from particularly low in the sandy materials on granitic rocks and on Tertiary gravels to high in the clay soils. There is also a trend towards higher values in the drier north. In subsoils the values show close correlation with clay content and the presence of visible carbonates, which gives high values for calcium and magnesium.

Figure 9 - Particle-size distribution in selected soils

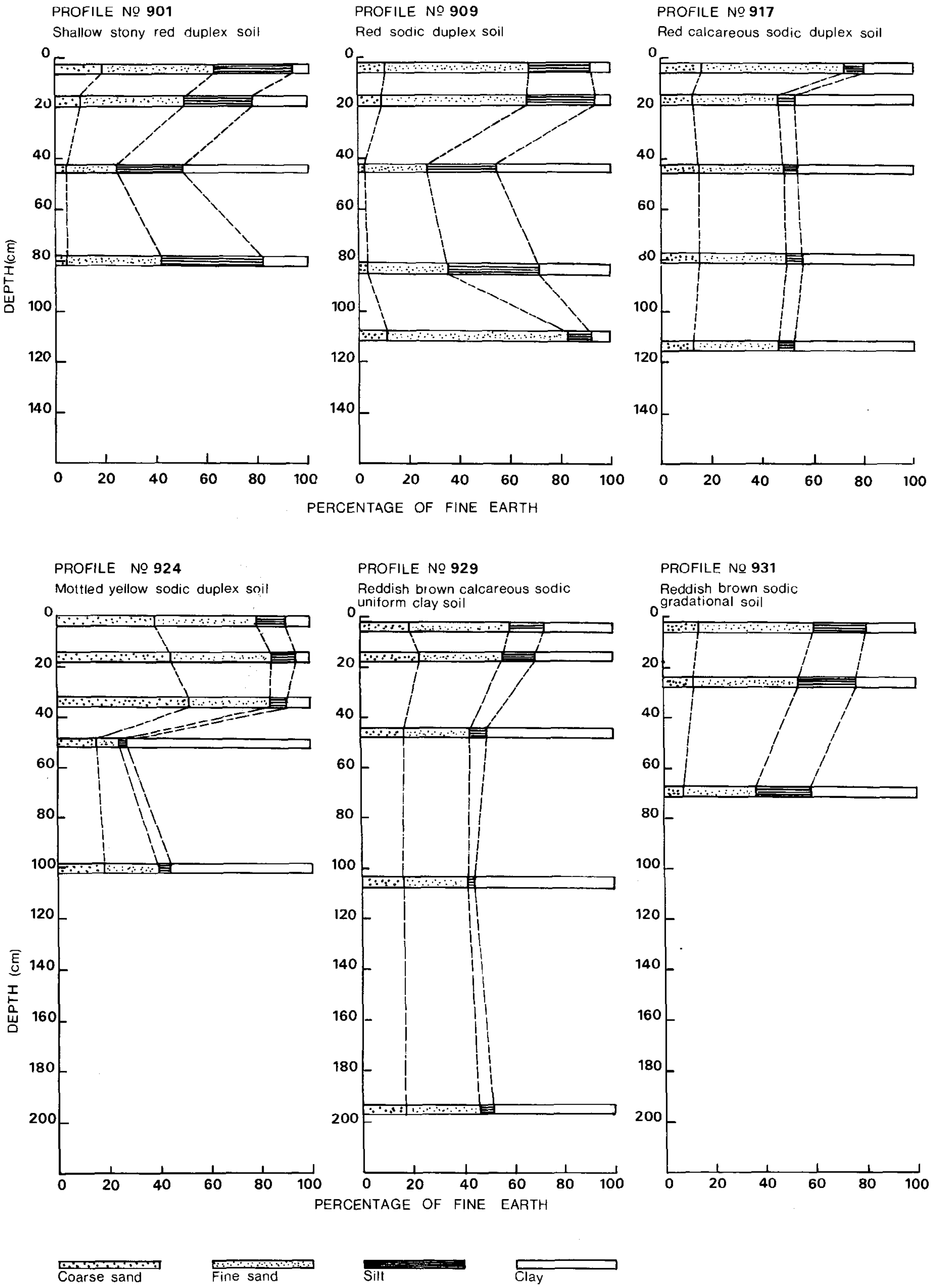


Figure 10 - Reaction (pH) trends in selected soils

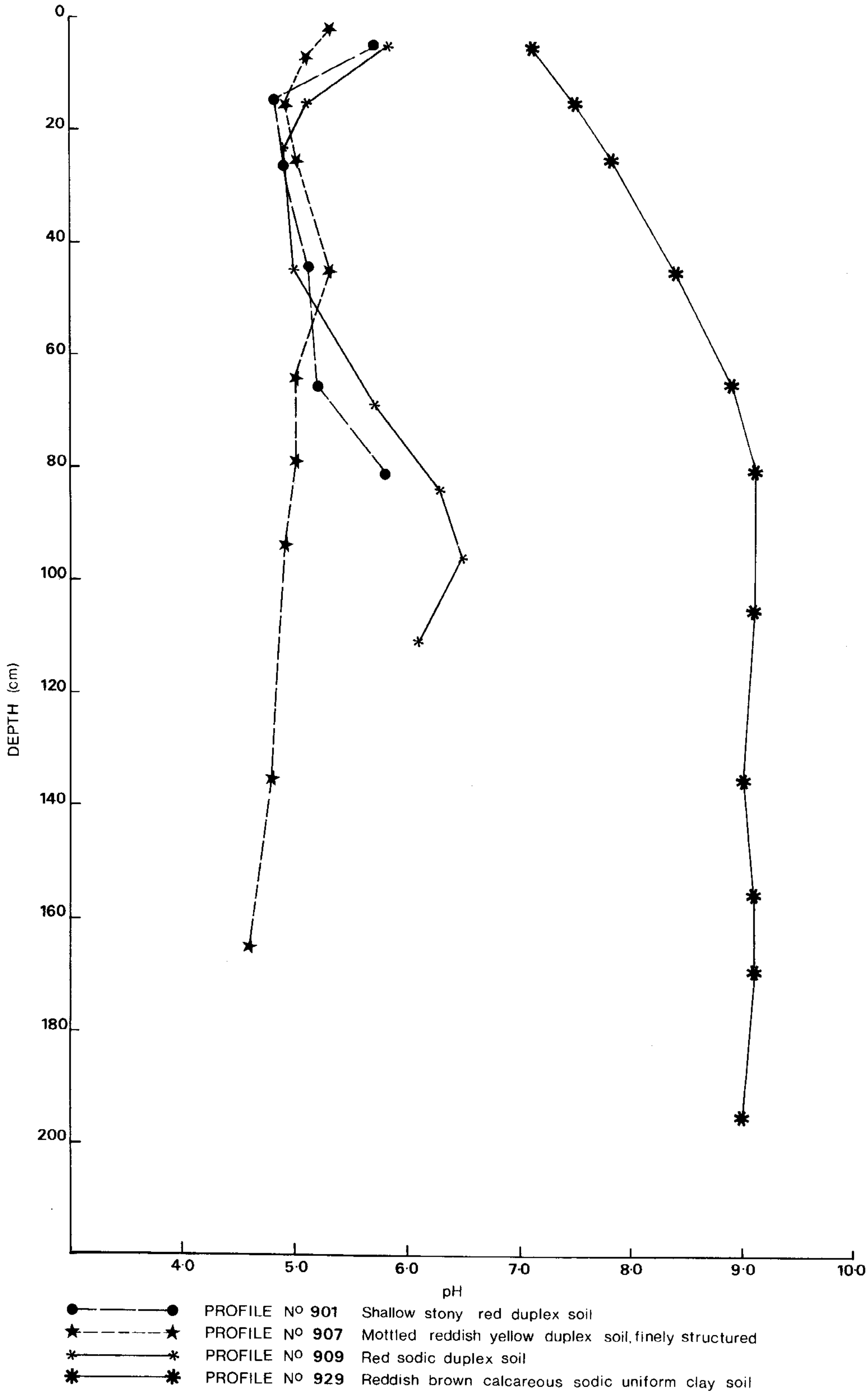


Figure 11 - Chloride in selected soils

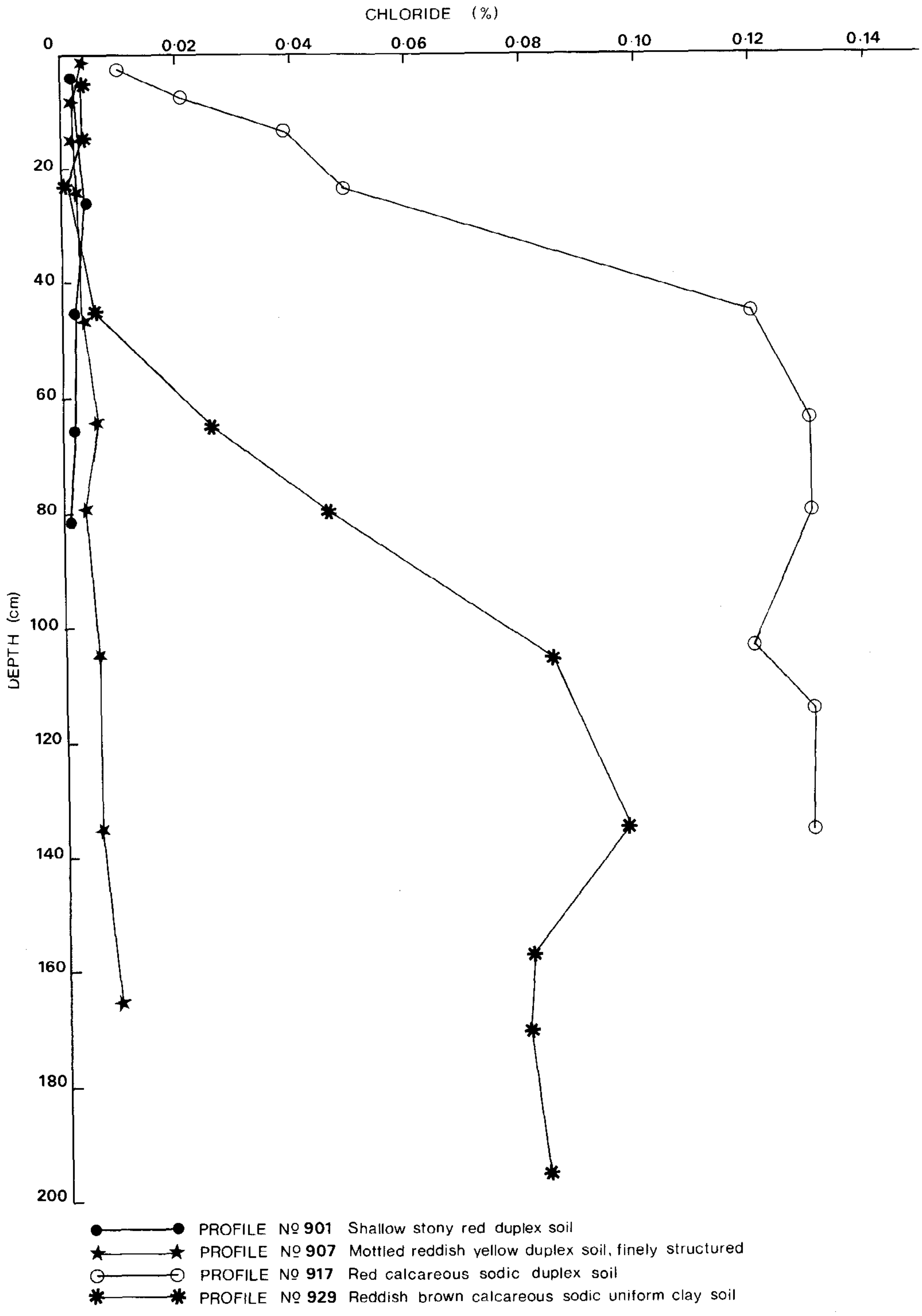


Figure 12 - Free ferric oxide in selected soils

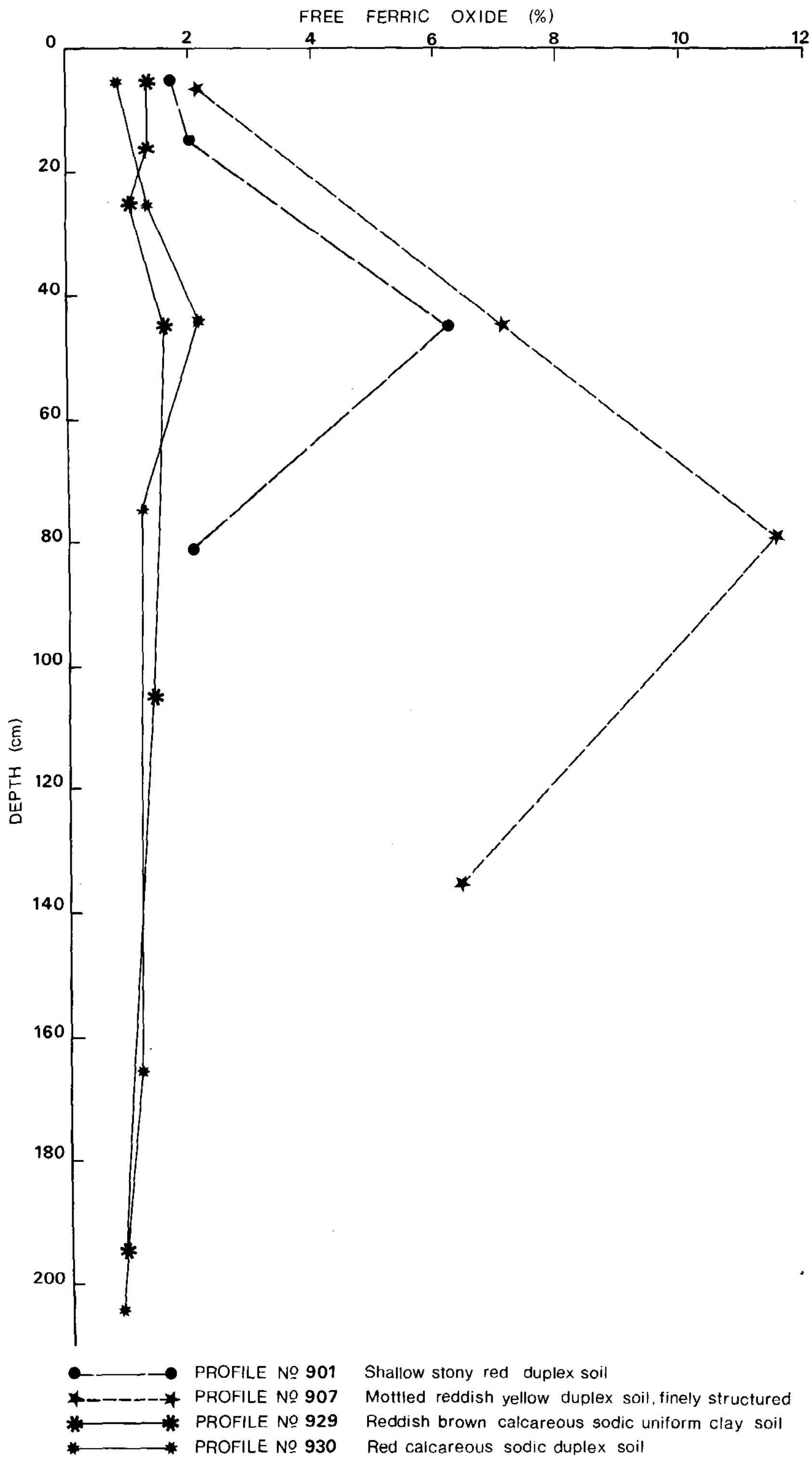
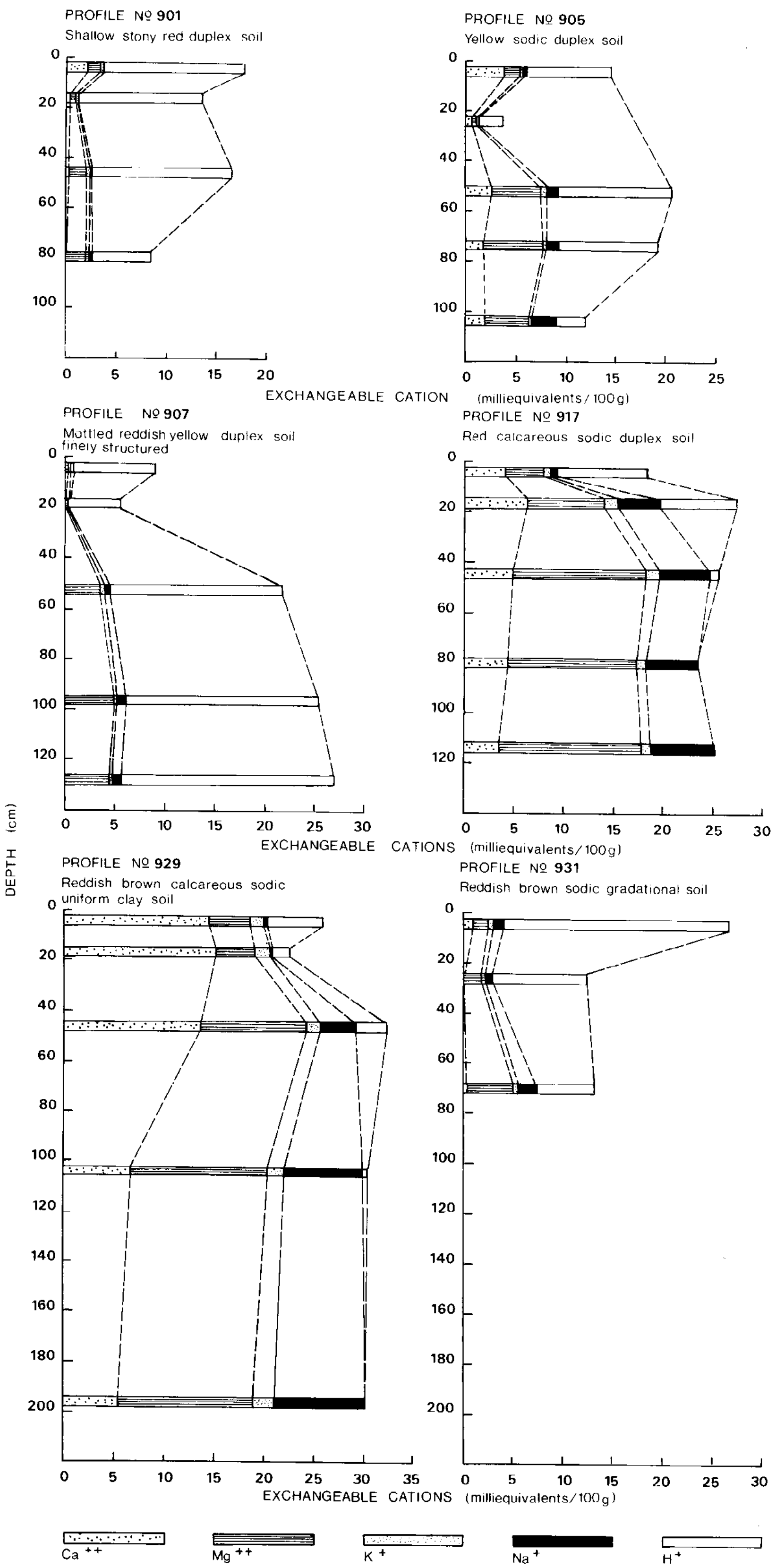


Figure 13 - Exchangeable cations in selected soils



Exchangeable calcium ranges from high in the calcareous soils to particularly low in the highly weathered soils on Tertiary gravels. Values follow the higher trend in the north. Magnesium shows similar trends as to the total amount in profiles, but increases instead of decreases with depth. Except in clay soils and in the subsoils of the drier north, potassium levels are sub-optimal throughout the profile. Exchangeable sodium increases markedly with depth in the widespread sodic profiles.

In terms of proportions, calcium is the dominant metal ion at the surface and comprises more than half the metal ions in the calcareous clay soils. Magnesium dominates in subsoils, frequently with values of more than 50% in the drier north, even in calcareous soils. Values for potassium are low except in northern subsoils. Where sodium comprises more than 6% of the cation exchange capacity the soils are regarded as sodic (Northcote and Skene 1972). Most soils of the catchment are sodic, and calcareous soils in the north are particularly so.

Moisture characteristics

Moisture characteristics determined on relatively undisturbed core samples (Appendix 11) show that, except for the clay soil on parna, topsoils have the desirable combination of reasonably high macroporosities and available water capacities.

The lowest value for macroporosity in the profile indicates the horizon limiting the infiltration rate of water. B horizons of sodic duplex soils generally have low values, with an extremely low value in the yellow sodic duplex soils. The non-sodic stony red duplex soils in the south and the clay soils on parna have relatively high subsoil macroporosities.

The available water capacities are relatively low in all clay subsoils, and low throughout the clay profile.

Bulk densities tend to be highest in the A2 horizons of the sodic duplex soils, indicating poor root penetration close to the soil surface.

Engineering characteristics

The main influences on engineering characteristics of the soils (Appendix V) appear to be parent material and topographic position. The more common soils on sandstone-shale or granite bedrock usually have high liquid limits and high linear shrinkage values, resulting in soil movements and potential problems with foundations for buildings and roads. The shallower soils on sedimentary rock and the calcareous soils in the central and northern areas of the catchment have moderate liquid limits and linear shrinkage values.

The gilgaied soils on basalt and alluvium have very high linear shrinkage values. These soils have a high plasticity index and in the Unified Classification rank as CH soils, indicating that they require greater management to overcome their physical limitations for construction purposes.

Soils with low liquid limits also have low linear shrinkage values. They are usually the old soil profiles on Tertiary gravelly deposits and are classified as CL soils, which are regarded as suitable foundations for constructional purposes.