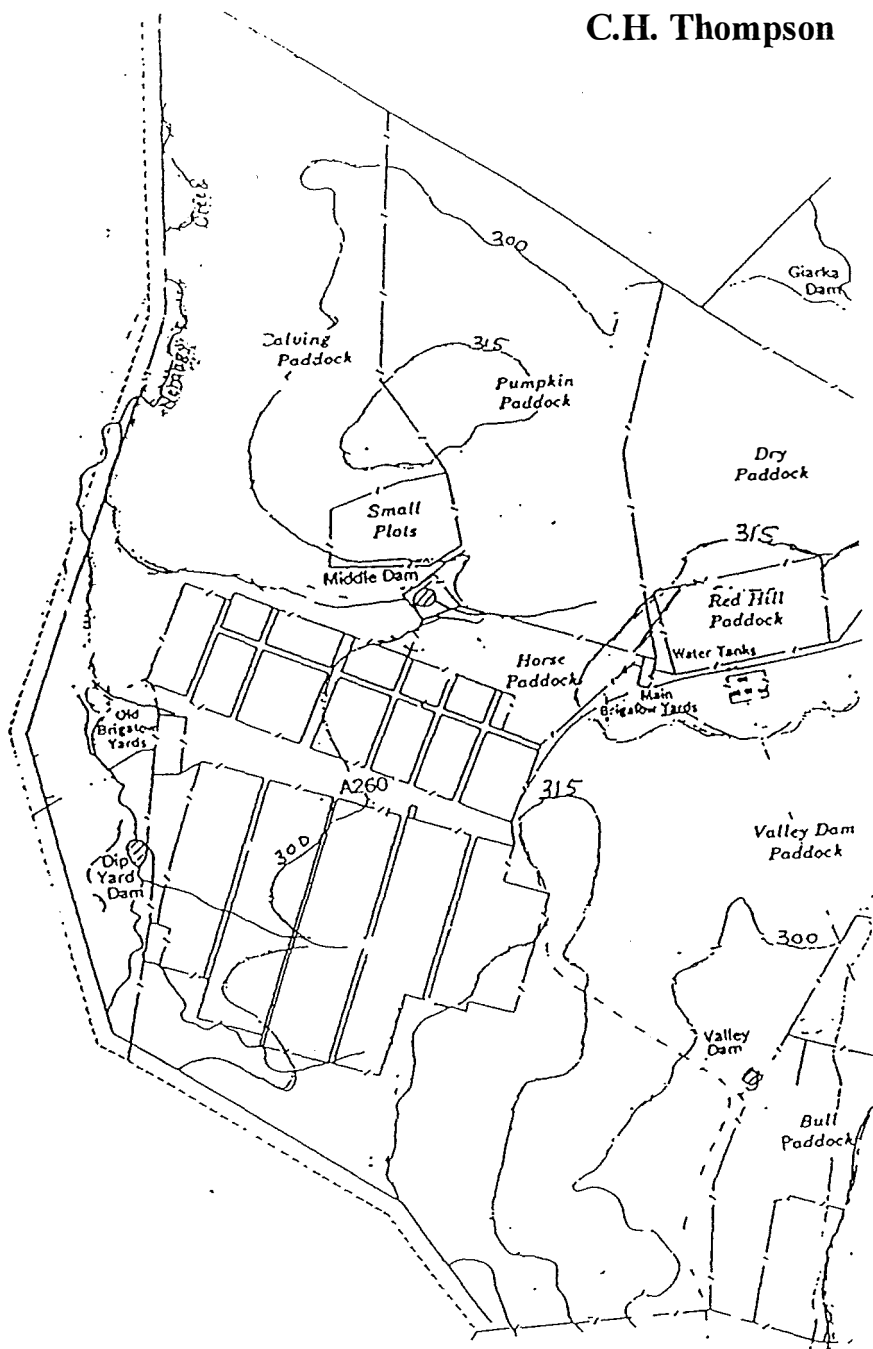


Soils of the crop rotation and grazing experiments  
in the brigalow area,  
CSIRO Narayen Research Station, Queensland

C.H. Thompson



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Thompson, C. H. (Clifford H)  
Soils of the crop rotation  
and grazing experiments in  
the brigalow area, CSIRO  
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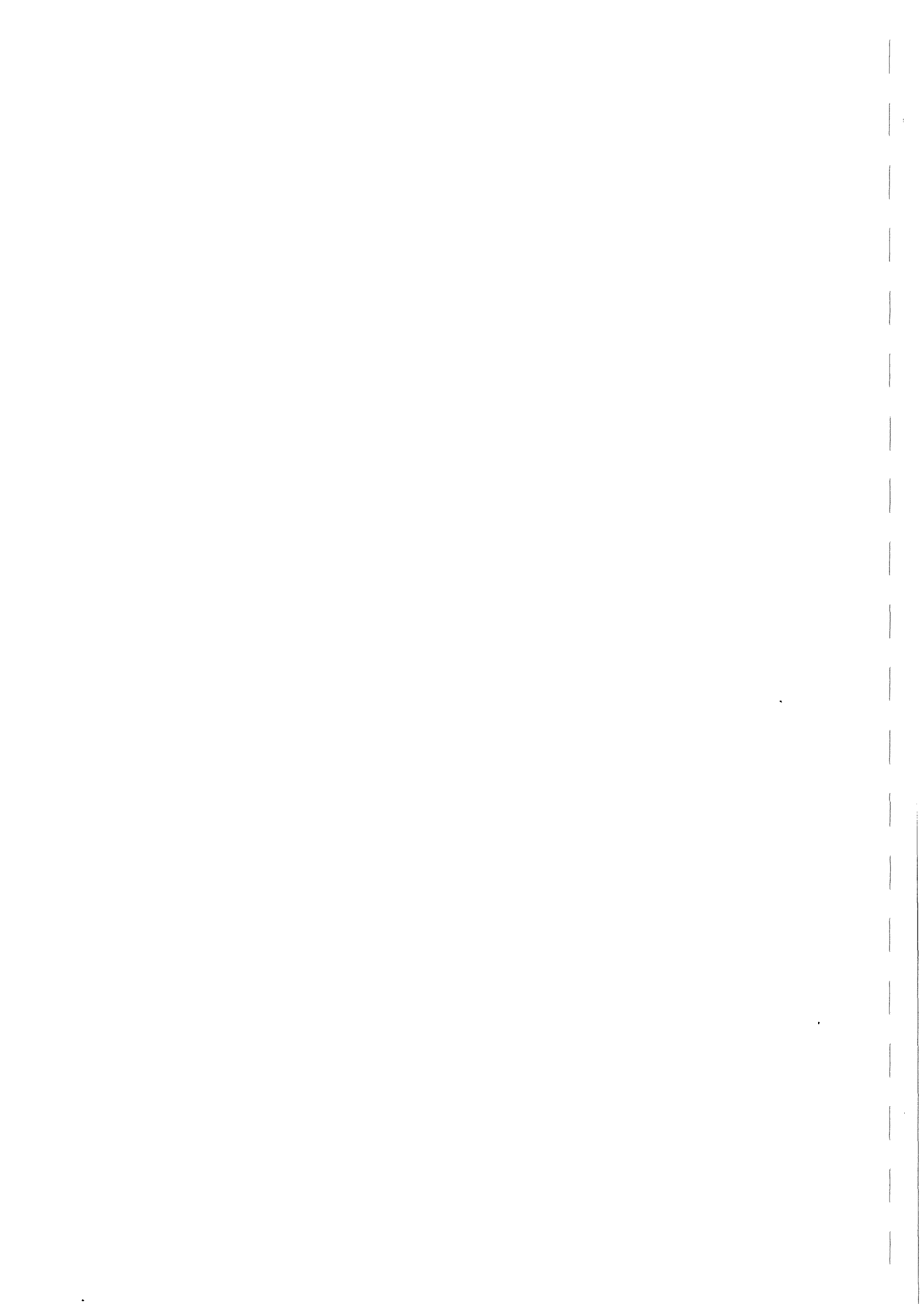
CSIRO Tropical Agriculture, Cunningham Laboratory, 306 Carmody Road, St Lucia, Brisbane,  
Queensland, 4067, Australia. (1998)

ISBN 0 643 06372 2

**Soils of the crop rotation and grazing experiments in the brigalow area, CSIRO Narayen  
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# Soils of the crop rotation and grazing experiments in the brigalow area, CSIRO Narayen Research Station Queensland

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## Summary

This report records the description, classification and distribution of soils in the 160ha of crop rotation and grazing experiments in the brigalow area of the CSIRO Narayen Research Station. The soils have been described and mapped at approximately soil type level and classified according to Australian Great Soil Groups, A Factual Key, the new Australian Soil Classification, USDA Soil Taxonomy and the revised legend of the World Soil Map. However, very few laboratory data are available for soil profiles in or adjacent to the area. Placements in the various classifications have been largely based on profile morphology and field pH and are therefore provisional.

The area has a complex soil pattern related to differences in soil parent materials and to stages in the development of the landscape. A brief interpretation of the local geomorphic history is given to assist in understanding soil distribution. Maps showing the distribution of the parent materials recognised, soil units, Principal Profile Forms, and Subgroups and Soil Depth Classes of the Australian Soil Classification are presented. The limited laboratory data available are tabulated as appendices.

## Keywords

Brigalow soils, profile description, classification, soil maps

## Introduction

This report records the descriptions, classification and distribution of soils in the crop-rotation (Coaldrake *et al.* 1970; Russell 1988) and grazing experiments (Silvey *et al.* 1978; Jones *et al.* 1995) (No A260) located in the brigalow area in the south-western part of Narayen Research Station (Map 1). In 1977 a small extension to the crop-rotation trial was used for an experiment comparing continuous, alternate and double cropping systems (Russell and Jones 1996). The overall objective is to provide a soils' framework to assist the interpretation of plant performance in the various experiments (Map 2). Although the area involved is only about 160ha, it has a complex soil pattern that is related to differences in soil parent materials and to stages in the development of the present landscape over the past several million years. A brief interpretation of the geomorphic history of the local landscape is therefore included to assist in understanding the soil pattern. The interpretation is based on local field data and on what is known of the regional geology and geomorphology (Whitaker *et al.* 1974, Wright 1968).

The experimental plots are located in an area of clayey soils that previously carried brigalow-belah shrubby open forest (Coaldrake *et al.* 1972). Published soil information for the area appears to be restricted to the Atlas of Australian Soils, Sheet 4 (Isbell *et al.* 1967). This placed the area in a broad unit dominated by alkaline friable earths with gradational texture profiles (Gn 3.43 soils) and dark cracking clays (Ug 5.15 soils). Several other soils, including alkaline gradational red soils (Gn 3.13) and brown soils with texture contrast (Db 1.13 soils), are listed as occurring in the unit. Coaldrake *et al.* (1972) included the area in their Narayen Land System occupying the Narayen Beds of dominantly andesitic rocks but gave no soil data other than that of Isbell *et al.* (1967). They saw some affinities between their Narayen unit and the Eurombah and Ramsay Land Systems described by Speck *et al.* (1968) in the adjacent upper Dawson River catchment. The area has recently been covered by 1:250000 scale mapping by QDPI and the Narayen Land System has been extended and redefined (Donnollan and Searle, in press). The major soils are now seen as moderately deep to deep, brown and black cracking clays with smaller areas of red and brown non-cracking clays and gradational and duplex soils.

## Methods

The soils were examined and described from material recovered by hand augering to a maximum depth of 1.2m, using a 75mm Jarret auger. Traverses were run up or downslope along plot fencelines and through the middle of wide plots to give a traverse interval of 50-60m. Soil examinations were made above and below changes in slope, surface colour and condition, and where there were obvious differences in the kind and amount of surface gravels or soil micro-relief. This led to descriptions of soils at 278 sites during the survey. A further 20 sites were described subsequently and some data were provided from another 22 sites examined for other purposes, giving an overall total of 320 sites or an approximate density of 2 examinations /ha. Soil colours were referenced to the Munsell Soil Color Charts and are for moist soil unless otherwise stated. Soil pH values were obtained in the field using a colorimetric method (Raupach and Tucker 1959)

The brigalow belah open forest had been cleared and sown to rhodes grass during 1937-38 (McDonald *et al.* 1995; Jones *et al.* 1995). The soils were ripped, cultivated and sown to pastures or crops before the soils were examined in late 1968. This disturbance caused some problems in assessing the pedality (structure), condition (hard-setting or otherwise when dry) and field textures of the surface horizon(s), particularly where thin loams and clay loams had been partly mixed with subsurface clays. Also, samples obtained with 75mm auger do not give a good representation of subsoil pedality. Where possible these features were also examined at undisturbed areas outside of the plots but for some soils the assessments must be regarded as provisional. Note that the cultivated surfaces as described, consist of a mixture of natural peds and broken fragments.

The soils are described and mapped at approximately soil type level (Soil Survey Staff 1951) but because of the small areas involved none has been named but each of the soil units has been given a number and referred to as Narayen Brigalow 1-30. Three depth phases, one subsoil colour phase and five gilgai complexes are included. Each of the soils has been classified according to the three classification schemes currently used in Australia, viz. Australian Great Soil Groups (Stace *et al.* 1968), A Factual Key (Northcote 1979) and the Australian Soil Classification (ASC) Isbell (1996). The soils have also been classed according to the USDA Soil Taxonomy (Soil Survey Staff 1992) and the revised legend of the World Soil Map (FAO 1988) but in the absence of laboratory data these placements should be viewed with caution.

## Geology and geomorphology

The plots lie across the western slopes of a dissected pediment below the long elevated ridge that extends northward from Mt Narayen to the high point in Red Hill Paddock and forms the interfluvium between the catchments of Nerangy and Narayen Creeks (Map 1). The experimental area is broken into three parallel lateral ridges by four small tributaries of Nerangy Creek which flows into Cheltenham Creek, a major tributary of the Auburn River. The experimental plots occupy most of the slopes of these lateral ridges from near their junction with the main ridge to the Nerangy Creek flats, a distance of about 1300m with a maximum local relief of 40m. Several features of the landscape, such as marked changes in the shape of slopes, distribution of gravels, and kind and depth of soil over short distances, indicate that it was formed over a long period of down-cutting by the streams during which both erosional and depositional processes have left their imprint.

Mildly metamorphosed volcanic rocks of the Narayen Beds (Whitaker *et al.* 1974), underlie most of the experimental area. The Narayen Beds are described as mainly intermediate to basic lavas and tuffs with minor beds of sandy tuff and conglomerates. Andesite is the most common lava and andesitic minerals and fragments of andesite dominate the pyroclastic rocks (agglomerates and tuffs) near Mt Narayen and are also prominent in some of the conglomerate beds elsewhere.

A small area of a coarse-grained intrusive rock occurs in the lower section of the crop rotation experiments. No outcrops were seen but from the weathering minerals in the subsoil it is presumed (by me) to be a granodiorite and probably a southern extension of the Upper Permian to Triassic intrusions mapped nearby (Whitaker *et al.* 1974). They give an example mineralogy of these rocks as dominantly plagioclase, K-feldspar, quartz and hornblende with some chlorite. Quartz and K-feldspar



together make up 35% of the minerals and because both are resistant to weathering they tend to persist through the soil profiles.

Two small remnants of an ancient drainage system and its alluvia occupy small gently sloping platforms on the crests of the northern and central lateral ridges of the experimental area and have small knolls of lateritized materials adjacent to them. Because of their position in the landscape and the evidence of lateritization on the knolls, both features are presumed to be of Late Tertiary age. The old alluvium in the crop rotation area is a very clayey deposit with ironstone gravels throughout at least the upper 1.2m. It appears to have been derived largely from sources outside of the experimental area. In the grazing experiments, the old alluvium consists of red-brown, strongly pedal (structured) medium to heavy clay which contains ironstone gravels, Mn segregations, and soft or concretionary  $\text{CaCO}_3$ . It is now buried by younger alluvia of varying thickness and appears to have been partly truncated before burial. Narrow belts of younger clayey alluvia (Quaternary deposits) flank the present drainage lines and have been largely derived through the erosion of the soil mantle within the experimental area. The Quaternary alluvia appears to overlie truncated remnants of Tertiary alluvia in the upper reaches of the drainage lines in the continuous pasture area.

In addition, attention is drawn to the crest of the hill in nearby Red Hill Paddock which overlooks the experimental area and is regarded as a remnant of a previously much more extensive lateritized surface of Early Tertiary age. The surficial red soil here grades with depth into strongly weathered lateritized sedimentary rocks (Late Cretaceous - Early Tertiary age, Whitaker *et al.* 1974) which in turn overlie the Narayen volcanic rocks. The deeply weathered profile contains variously coloured iron and (?) silica enriched materials and a band of dense, shiny, black to liver-coloured ironstone gravels. Both of these materials are very resistant to weathering and have been transported to lower parts of the landscape as the host rocks have been eroded. It is likely that the remnant alluvia of the ancient drainage system and of the adjacent lateritized knolls were partly derived from this source.

The lateritized knolls within the experimental area are regarded as remnants of a lower extensive surface that formed during the Tertiary but post-date the lateritization evident on the crest in Red Hill Paddock. The soils associated with these areas contain moderate to large amounts of lateritized rock fragments or lateritized rock fragments and dense ironstone gravels on the surface and through the profile, but are underlain by what appears to be lateritized or deeply weathered andesitic rocks. Because the ironstone gravels are distributed throughout the soil profiles it is unlikely that they have formed in place and their presence is taken as indicating a layer of ancient alluvia, probably derived in part from the erosion of the previously larger area of the high level laterite profile. Even so, the high total P values in the surface soil of these areas imply sizeable contributions of sediment from the andesitic rocks as well. Lateritization of these sediments and underlying andesitic rock on lateral ridges well below the hill crest in Red Hill Paddock implies either two periods of lateritization during the Tertiary, as has been suggested in adjacent areas (Wright 1968, Exon *et al.* 1970, Whitaker *et al.* 1974), or intermittent intervals of rapid and slow dissection during a long continuous period of lateritization.

Erosion of the lower lateritized surface has also released the dense ironstone gravels and fragments of lateritized rocks and distributed them downslope. These gravels persist in the upper part of the soil profiles on the middle and lower slopes of the central and northern lateral ridges and their presence has been used (by me) to indicate that the upper part of these soils has been derived from transported materials (i.e. they are hillslope deposits).

No fragments of lateritized rocks or dense ironstone gravels were recorded in the red soils on the strongly weathered andesite in the highest plots of the crop rotation experiment or upslope of them, or in the soils on less weathered andesite in the upper parts of the continuous pasture plots or upslope of these. This implies that this ridge has long been a locally high area that stood above the lateritized surface preserved on the crest in Red Hill Paddock or was affected to shallow depth only, all of which has been long since stripped. The lack of lateritic and ironstone gravels in the red soils on deeply weathered andesite or in the shallow soils on less weathered andesite of the western lateral ridge lends support to the former view.

## Soil parent materials

### *Parent Material Groupings*

Eight soil parent materials were recognised during the soil survey (Map 3). Three of these are associated with differences in the depth and degree of weathering or with evidence of lateritization of the andesitic rocks. The alluvia have been separated into ancient (Tertiary) and young (Quaternary) deposits and there is one unit for the coarse grained intrusive rock (granodiorite). Features used in the field to distinguish these parent materials include presence or absence of: andesite outcrop, andesite stone and gravel, soft weathered rock with a silty field texture, manganese concretions and segregations, fragments of lateritized rock, sub-angular to rounded dense ironstone gravel, primary quartz grains and K- feldspar and position in the landscape.

During the field work, an attempt was made to separately recognise the lavas and tuffs of the Narayan Beds but was abandoned because of doubts about consistent recognition of each from weathered materials. As a parent material, the tuffs and lavas are similar in that both are rich in silicate minerals and contain little or no primary quartz. On weathering both have the potential to release large amounts of Ca, Mg, Na, Fe, Al and Si and, under climates similar to the present, to form clays dominated by smectite clay minerals. Most of the soils on these rocks are calcareous but the presence or absence of  $\text{CaCO}_3$  does not appear to be associated with any particular lava flow or tuff bed.

Only a thin veneer of lateritized sediments remains as a surficial deposit in the remnants of the lower lateritized surface, judging from the distribution of dense black ironstone gravels through the surface and clay subsoil but not in the underlying lateritized or deeply weathered andesitic rock. Fragments of lateritized andesite were recorded throughout the soil and in the underlying weathered rock at some sites. It appears that the lateritizing processes have operated across the surficial deposits and the underlying andesitic rock eliminating many but not all the effects of parent material differences. The augered material showed no clear pedological break between the lower part of the clay subsoil and the underlying weathered rock which may in fact be a precursor of part of the lower subsoil.

The distribution of ironstone and lateritized andesitic gravels in soils downslope of the lateritic remnants imply that these soils have also developed in layered materials, viz. thin hillslope deposits overlying weathered andesitic rocks. Although there are trace to low amounts of ironstone and lateritized andesitic rock gravels through the surface soil and clay subsoils, the amounts appear to decrease downslope and there were no gravels and little evidence of lateritization in the underlying weathered andesitic rocks. No sharp contacts were observed in the augered material between the clay subsoils and underlying weathered andesitic rocks and it is likely that the latter is a precursor of at least the lower subsoil clays.

### *Total K, P, Cu and Zn Concentrations as Indicators of Local Soil Parent Materials*

While total amounts of elemental K and P in soils are not diagnostic for particular soil parent materials they can be useful indicators of local soil/parent material relationships, particularly where element data are available down the profile. While such profile data are not available for the soils of this area, a 0-10cm soil sample was collected from a selected site within each of 19 of the major soil types, and one deep phase for other aspects of research (Russell and Thompson 1974). These were submitted for a range of laboratory analyses including X-ray fluorescence (XRF) determinations of elemental K, P, S, Cu and Zn. Additional K and P values are also available from profile B813 sampled in NB10. These provide a limited basis for determining possible differences in local parent materials (Table 1).

Perusal of the K concentrations indicate three parent material groups: - high (granodiorite), intermediate (andesitic rocks) and low (lateritized materials and alluvia derived from them). The soils derived from andesitic rocks or alluvia from it tend to have the highest Cu and Zn concentrations, while those on lateritized rocks and alluvia from them tend to have lower values than the other soils. The generally high total P concentrations in soils derived from lateritized materials are taken to indicate that these materials had a strong contribution from the andesitic rocks prior to lateritization and that P has been immobilised by the iron and aluminium oxides during lateritization. The

variations for all four elements in soils on alluvia are probably due to variations in contributions from the different source materials.

**Table 1.** XRF element values for soils (0-10cm depth) on different parent materials

Parent Material	Soil	K %	P	Cu (ppm)	Zn
Andesitic rocks	weathered				
	NB1	0.7	1050	70	130
	NB5	0.8	810	100	75
	NB6	0.6	900	100	170
	NB9	0.5	860	100	140
	deeply weathered				
	NB10	0.7	1200	150	140
	NB10	0.8	1300	-	-
Lateritized sediments over laterized andesitic rocks	NB12	0.25	1100	55	45
	NB11	0.20	1250	85	50
	NB11d	0.21	1000	40	35
	NB15	0.21	1300	55	50
	NB13	0.23	1250	50	40
Hillslope deposits from lateritized sediments over weathered andesitic rocks	NB17	0.27	900	60	40
	NB19	0.40	910	50	45
	NB18	0.42	1400	90	100
Alluvia	Tertiary				
	NB20	0.18	830	55	45
	NB21	0.20	830	55	55
	Quaternary				
	NB25	0.40	1150	100	90
	NB24	0.85	1300	110	190
Granodiorite (weathered)	NB27	1.5	620	95	65
	NB29	1.5	1200	130	55
	NB28	2.2	1200	90	60

## The soils

In the following text, the soil units are described in groups according to my perception of the parent materials from which they have formed. Descriptions of soil morphology have been revised to essentially follow the recommendations of McDonald *et al.* (1984) except that horizon thicknesses are given in centimetres. Distribution of the soil units is indicated by Map 4.

### *Soils on weathered andesite (WA)*

These are shallow to moderately deep soils (40-110cm to weathered rock) with andesite boulder outcrop or surface stone in at least some part of the unit, and with weathered andesite stone or gravel through the profile or in the underlying C horizon. No lateritized fragments or dense black ironstone gravels are evident on the surface or in the soil but small black manganese concretions are usually present. Both cracking clay and texture contrast soils are recognised and two of the types lack visible CaCO<sub>3</sub>

#### *Soil unit: Narayen Brigalow I*

<b>Land form:</b>	Hill crests and upper slopes
<b>Micro-relief:</b>	Occasional low mounds in some areas
<b>Surface condition:</b>	Very cracked dry, trace to low amounts of surface stone
<b>Parent material:</b>	Andesite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.5 - 8.0	0-5	Very dark brown (10YR 2/2) light clay: moderate blocky 5-10mm; very hard dry, loose cultivated; few stones. Clear to:
B <sub>2</sub>	8.0 - 8.5	5-42/52	Dark grey-brown (10YR 3/2) or dark brown (7.5 YR 3/2) medium heavy clay; strong blocky 2-5cm; very hard dry; very few black Mn concretions 3-5mm. Diffuse to:
B <sub>3</sub>	8.0 - 8.5	42/52 - 55/75	Brown (7.5YR 4/3) or reddish brown (5YR 4/4) medium clay; moderate blocky 1-2cm; hard dry; few pockets of weathering minerals. Diffuse to:
C	8.0 - 8.5	55/75-	Light brown, reddish brown, yellowish brown, white etc. clay loam; weathered andesite.

### Classification

Great Soil Group:	Black earth (shallow)
A Factual Key:	Ug 5.13
Soil Taxonomy:	Aridic Haplustert
World Soil Map:	Eutric Vertisol
ASC:	Haplic Epipedal Black Vertosol (slightly gravelly, medium fine, medium fine, moderate)

*Soil unit: Narayen Brigalow 2*

<b>Land form:</b>	Broad gently sloping ridge crests and upper slopes of 1-2°
<b>Micro-relief:</b>	None evident
<b>Surface condition:</b>	Very many cracks dry, surface cracks 3-5cm wide and extending downwards at least 30-50cm; few stones
<b>Parent material:</b>	Andesite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.5 - 8.0	0-5	Dark grey-brown (10YR 3/2) light medium clay; probably moderate blocky 5-10mm; very hard dry; loose cultivated; few stones. Clear to:
B <sub>2</sub>	8.0 - 8.5	5-25/40	Dark grey-brown (10YR 3/2) heavy clay; moderate blocky 3-5cm; very hard dry. Diffuse to:
B <sub>3</sub>	8.5	25/40 - 60/80	Grey-brown (10YR 4/2) or yellowish brown (10 YR 5/3, 5/4) medium heavy clay; moderate blocky 2-4cm; hard dry; common soft CaCO <sub>3</sub> ; pockets of weathering minerals. Diffuse to:
C	8.0 - 8.5	60/80	Light brown, pale yellow, white etc. clay loam to light clay; weathered andesite.

### Classification

Great Soil Group: Black earth (shallow)  
A Factual Key: Ug 5.14  
Soil Taxonomy: Aridic Haplustert  
World Soil Map: Calcic Vertisol  
ASC: Endocalcareous Epipedal Black Vertisol (slightly gravelly, medium fine, medium fine, moderate)

*Soil unit: Narayen Brigalow 3*

**Land form:** Upper hillslopes of 2-3°  
**Micro-relief:** None evident  
**Surface condition:** Very many cracks dry, cracks 3-5cm; very few stones  
**Parent material:** Andesite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0	0-5	Dark grey-brown (10YR 3/2) light clay; cultivated, blocky 1-2cm, loose dry; very few stones Clear to:
B <sub>2</sub>	7.5	5-40	Grey-brown (10YR 4/2) heavy clay; strong blocky 3-5cm; very hard dry; few black Mn concretions 3-5mm. Diffuse to:
B <sub>3</sub>	8.0	40-60/80	Reddish brown (5YR 4/3) medium heavy clay; moderate blocky 2-5cm; hard dry; few pockets of weathering minerals. Diffuse to:
C	8.0 - 8.5	60/80-110	Light reddish brown (5YR 5/6) medium clay grading to light clay; weak blocky; firm moist; common nodular CaCO <sub>3</sub> ; many weathered rock inclusions. Grading to weathered andesite below 110cm.

### Classification

Great Soil Group: Grey clay (shallow)  
A Factual Key: Ug 5.23  
Soil Taxonomy: Aridic Haplustert  
World Soil Map: Calcic Vertisol  
ASC: Haplic Epipedal Grey Vertisol (non-gravelly, medium fine, medium fine, deep)

*Soil unit: Narayen Brigalow 4*

**Land form:** Hill crests and slopes with stone outcrop  
**Micro-relief:** None evident  
**Surface condition:** Variable few to many stones, andesite boulder outcrop in places; brown or yellowish brown dusty surface with weak platy structure, hard setting dry.  
**Parent material:** Andesite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5-7.0	0-8/15	Dark brown (7.5YR 3/2) or grey-brown (10YR 4/2) loam to clay loam; weak platy surface grading to weak blocky; hard dry; few to many andesite gravel and stones. Clear to:
B <sub>2</sub>	7.5-8.0	8/15-22/32	Brown (7.5YR 4/2) or dark brown (7.5YR 3/3) light medium clay; moderate blocky 1-2cm; hard dry; few to many gravel and stones. Gradual to:
B <sub>3</sub>	7.5-8.0	22/32-40/50	Brown (7.5YR 4/3) and yellowish brown (10YR 5/4) medium to heavy clay; very many andesite fragments and floaters, not penetratable by auger.

### Classification

Great Soil Group:	? Non-calcic brown soil
A Factual Key:	Dy 2.12
Soil Taxonomy:	Lithic Haplustalf
World Soil Map:	Haplic Luvisol
ASC:	Haplic Eutrophic Grey or Brown Chromosol (thin, gravelly to moderately gravelly, clay loamy, clayey, shallow)

**Soil unit:** *Narayen Brigalow 5*

<b>Land form:</b>	Upper slopes and crests of broad gently sloping lateral ridges
<b>Micro-relief:</b>	None evident
<b>Surface condition:</b>	Few fine cracks dry, few surface stones 5-10cm size, occasional andesite boulder outcrop and surface stone
<b>Parent material:</b>	Andesite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0-5/10	Very dark brown (7.5YR 2/2-3/2) clay loam; moderate crumb and subangular blocky 3-5mm, hard dry; occasional black Mn concretions 3-5mm.; few stones 5-10cm size. Clear to:
B <sub>21</sub>	7.0-8.0	5/10-20/30	Very dark brown (7.5YR 2/2-3/2) medium heavy clay; strong blocky 3-5cm; very hard dry; very few black Mn concretions 3-5mm. Gradual to:
B <sub>22</sub>	7.0-8.0	20/30-40/50	Dark brown (10YR 4/2-3/3) medium heavy clay; moderate blocky 3-5cm; very hard dry; very few black Mn concretions 3-5mm. Gradual to:
B <sub>3</sub>	7.5-8.0	40/50-55/70	Dark brown (7.5YR 4/2-5/2) medium clay, blocky 3-5cm, hard dry; common to very many white weathering minerals; very few weathered andesite kernels; occasional flecks of soft CaCO <sub>3</sub> . Diffuse to:
C	8.0-8.5	55/70-	Yellowish brown, pale yellow, white etc. mealy loam or clay loam of weathered andesite with very few patches of soft CaCO <sub>3</sub> . Continuing below 120cm.

### Classification

Great Soil Group: No suitable group  
A Factual Key: Dd 3.13  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Calcic Luvisol  
ASC: Haplic Hypocalcic Black Chromosol (thin, slightly gravelly, clay loamy, clayey, moderate)

*Soil unit: Narayen Brigalow 6*

**Land form:** Lower side-slopes of long gently sloping lateral ridges  
**Micro-relief:** Non evident  
**Surface condition:** Many surface cracks (1-5cm size) evident when dry, very few to common andesite stone and gravel  
**Parent material:** Andesite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.5-8.5	0-5/10	Very dark brown (7.5YR 2/2-3/2) clay loam; moderate crumb and subangular blocky 3-5mm, hard dry; very few black Mn concretions 3-5mm, very few to common andesite stone and gravel. Clear to:
B <sub>2</sub>	8.0-8.5	5/10-30/40	Very dark brown (10YR 2/2-3/2) heavy clay; strong blocky 3-5cm; very hard dry; common black Mn concretions 3-5mm. Gradual to:
B <sub>3</sub>	8.5-9.0	30/40-70/100	Reddish brown (5YR 4/4-3/4) or redder medium heavy clay, moderate blocky 3-5cm, hard dry; few to many soft patches and nodular CaCO <sub>3</sub> ; common black Mn segregations and/or concretions 3-5mm; variable amounts weathered rock, grit, and very few gravels. Gradual to:
C	8.5-9.0	70/100-	Light reddish brown (5YR 5/6-6/6), with various brown, yellow, olive and dark greenish mottling, clay loam to light clay; very weathered (?) andesite; variable, few to many soft patches and nodular CaCO <sub>3</sub> . Continuing below 120cm.

### Classification

Great Soil Group: No suitable group  
A Factual Key: Dd 3.13  
Soil Taxonomy: Calciorthidic Paleustalf  
World Soil Map: Calcic Luvisol  
ASC: Sodic Calcic Black Chromosol (thin, non-gravelly, clay loamy, clayey, moderate)

*Soil unit: Narayen Brigalow 7*

**Land form:** Hill slopes with variable surface stone and occasional outcrop.  
**Micro-relief:** None evident  
**Surface condition:** Variable, few to many stones (andesite) and very few boulders; dark reddish brown dusty surface with weak platy structure; few cracks dry.  
**Parent material:** Andesite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5-7.5	0-10/15	Dark reddish brown (5YR 3/2) or dark brown (7.5YR 3/2) loam to clay loam; weak platy surface grading to fine blocky; hard dry; few to many andesite gravel, very few stones. Clear to:
B <sub>2</sub>	6.5-7.5	10/15-20/25	Dark reddish brown (5YR 3/3) or redder medium to heavy clay; moderate blocky 1-3cm breaking to 5-8mm; hard dry; very few pockets of white weathering minerals; common andesite gravel and stone. Diffuse to:
B <sub>3</sub>	7.5-8.0	20/25-55/60	Reddish brown (5YR 4/6) with brown (7.5YR 4/3) medium clay, moderate blocky; hard dry; white weathering minerals; common to many andesite rock fragments. Diffuse to:
C	7.5-8.5	55-60	Light reddish brown (5YR 5/6) with brown, yellow, white etc., clay loam or light clay; weathered andesite.

#### Classification

Great Soil Group:	? Non-calcic brown soil
A Factual Key:	Dr 2.12
Soil Taxonomy:	Aridic Paleustalf
World Soil Map:	Chromic Luvisol
ASC:	Haplic Eutrophic Red Chromosol (medium, gravelly, clay loamy, clayey, moderate)

*Soil unit: Narayen Brigalow 8*

<b>Land form:</b>	Gentle lower sideslopes of stony ridges adjacent to drainage heads
<b>Micro-relief:</b>	May have an occasional red mound in lower positions.
<b>Surface condition:</b>	Dark reddish brown dusty surface; common to many cracks when dry; very few andesite floaters 15-50cm size.
<b>Parent material:</b>	Andesite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0-7/12	Dark reddish brown (5YR 3/2) loam to clay loam; weak to moderate subangular blocky 2-8mm; hard dry; very few gravels. Clear to:
B <sub>2</sub>	7.0-8.0	7/12-30/50	Dark reddish brown (5YR 3/3, 3/4) medium heavy clay; moderate blocky 2-5cm; very hard dry; very few black Mn concretions 2-5mm. Diffuse to:
B <sub>3</sub>	7.5-8.5	30/50-60/90	Light reddish brown (5YR 5/6,4/6) medium clay, moderate blocky 1-3cm; hard dry; very few black Mn concretions; may have trace soft CaCO <sub>3</sub> . Diffuse to:
C	8.0-8.5	60/90-	Yellowish brown, reddish brown, yellow, white etc. mealy loam to clay loam of weathered andesite; few black Mn segregations and very few soft CaCO <sub>3</sub> patches.



### Classification

Great Soil Group: ? No suitable group (affinity with red-brown earths)  
A Factual Key: Dr 4.13  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Chromic Luvisol  
ASC: Haplic Hypocalic Red Chromosol (thin, non-gravelly, clay loamy, clayey, moderate).

*Soil unit: Narayen Brigalow 9 gilgai complex*

**Land form:** Broad convex crest of gently sloping lateral ridge  
**Micro-relief:** General level (shelf) with scattered large reddish brown mounds 12-15m across, 40-60m apart and 50-60cm above general level.  
**Surface condition:** Cultivated reddish brown, many cracks when dry.  
**Parent material:** Andesite

### Shelf Profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.0-8.5	0-6/10	Dark reddish brown (5YR 3/2, 2/2) clay loam; cultivated, crumb and subangular blocky 2-5mm; hard dry. Gradual to:
B <sub>21</sub>	8.5	6/10-10/20	Dark reddish brown (5YR 3/3, 3/2) light medium clay increasing to medium clay; strong blocky 1-2cm; hard dry; very few black Mn concretions 3-5mm. Gradual to:
B <sub>22</sub>	8.5	10/20-30/40	Dark reddish brown (5YR 3/3,4/3) medium heavy clay, strong blocky 1-2cm; hard dry; very few soft CaCO <sub>3</sub> patches; very few black Mn concretions 2-3mm; few flecks of weathering minerals. Diffuse to:
B <sub>3</sub>	8.5-9.0	30/40-50/75	Light reddish brown (5YR 5/6,4/6) light medium clay; weak blocky 1-2cm; slight to moderate soft CaCO <sub>3</sub> patches; speckled with weathering rock minerals. Diffuse to:
C	8.5-9.0	75-	Light brown, off-white, pale yellow, reddish brown etc. clay loam of weathered andesite; may have few soft CaCO <sub>3</sub> patches; continuing below 120cm.

### Classification

Great Soil Group: No suitable group (affinity with red-brown earths).  
A Factual Key: Gn 3.13 (may include some Dr 4.13)  
Soil Taxonomy: Aridic Haplustalf  
World Soil Map: Calcic Luvisol  
ASC: Vertic Hypercalcic Red Dermosol (thin, non-gravelly, clay loamy, clayey, moderate).

## Mound Profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.5	0-6/8	Dark reddish brown (5YR 2/2, 3/2) loam; cultivated, crumb and subangular blocky 2-8mm; loose dusty dry. Gradual to:
A <sub>3</sub>	8.5	6/8-25/30	Dark reddish brown (5YR 3/3, 3/2) clay loam increasing to light clay; moderate blocky 1-3cm; hard dry; white fungal mycelium. Gradual to:
B <sub>2</sub>	8.5	25/30-60/80	Reddish brown (5YR 4/4, 3/4) and dark reddish brown (5YR 3/2) medium clay; moderate blocky 1-3cm; hard dry; few patches soft CaCO <sub>3</sub> . Gradual to:
C	8.5	60/80	Light brown, off-white, pale yellow, reddish brown etc. clay loam of weathered andesite; few patches soft and nodular CaCO <sub>3</sub> ; continuing below 120cm.

## Classification

Great Soil Group:	No suitable group
A Factual Key:	Gn 3.13
Soil Taxonomy:	Aridic Haplustalf
World Soil Map:	Calcic Luvisol
ASC:	Vertic Calcic Red Dermosol (medium, non-gravelly, loamy, clayey, moderate).

## *Soils on deeply weathered andesitic rocks (DWA)*

These are red moderately deep soils, 60-90cm to soft, deeply weathered andesitic rock which has smooth silty field textures. The thickness of weathered rock is likely to be very uneven; it is known to exceed 4.5m at one site (upslope of the crop rotation experiments) but there is also surface stone and an outcrop of weathered andesite nearby.

No fragments of lateritized rock or dense ironstone gravels were recorded on the surface or in the profiles examined. Small black manganese concretions are common and the subsoils and weathered rock usually contain some soft and concretionary CaCO<sub>3</sub>. Andesite gravel may occur in profiles adjacent to the outcrops. Only one soil type, Narayen Brigalow 10, has been recognised within the experimental area.

## *Soil unit: Narayen Brigalow 10*

<b>Land form:</b>	Upper to middle hillslopes of 2-3°
<b>Micro-relief:</b>	None evident
<b>Surface condition:</b>	Under brigalow/softwood scrub, loose moderate crumb and subangular blocky dry, dark reddish brown surface.
<b>Parent material:</b>	Andesite, deeply weathered or altered to depths of 4m or more.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5-7.5	0-5/7	Dark reddish brown (5YR 2/2, 3/2) loam; cultivated, crumb and subangular blocky 2-8mm; loose dusty dry. Gradual to:

A <sub>3</sub>	6.5-7.5	5/7-15/20	Dark reddish brown (5YR 3/2, 3/3) clay loam increasing to light clay; moderate blocky 1-3cm; hard dry; white fungal mycelium. Gradual to:
B <sub>2</sub>	6.5-7.5	15/20-40/50	Reddish brown (5YR 4/4, 3/4) and dark reddish brown (5YR 3/2) medium clay; moderate blocky 1-3cm; hard dry; very few to few soft patches CaCO <sub>3</sub> ; few black Mn concretions 1mm. Gradual to:
B <sub>3</sub>	8.0-8.5	40/50-60/90	Light reddish brown (5YR 5/6, 4/6) light medium clay; weak blocky 5-10mm; may have very few CaCO <sub>3</sub> concretions. Diffuse to:
C	8.5	60/90-	Light brown, pale yellow, off-white, reddish brown etc, silty clay loam or silty clay of deeply weathered andesite; may have very few to few patches of soft and concretionary CaCO <sub>3</sub> ; continuing below 120cm. Deeply weathered andesite has been found to continue to >4.5m at one site.

### Classification

Great Soil Group:	No suitable group (affinity with euzozems)
A Factual Key:	Gn 3.13
Soil Taxonomy:	Aridic Haplustalf
World Soil Map:	Calcic Luvisol
ASC:	Haplic Calcareous Red Ferrosol (medium, non-gravelly, loamy, clayey, moderate).

### *Soils on lateritized andesitic rocks. (LAR)*

These are shallow to moderately deep soils (50-70cm), to lateritized andesitic rocks which have silty field textures. Numerous fragments of lateritized rock occur as gravel on the surface and through the profile. No dense black ironstone gravels were observed on the surface or in the soils in the six profiles examined. Only one soil Narayen Brigalow 11 has been recognised on this material. The most closely related soil is Narayen 10, distinguished by its lack of lateritic gravel.

### *Soil unit: Narayen Brigalow 11*

<b>Land form:</b>	Crest and upper slopes of convex spur of lateral ridge.
<b>Micro-relief:</b>	None
<b>Surface condition:</b>	Loose, dusty dry, very few to common lateritized rock gravel.
<b>Parent material:</b>	Lateritized andesitic rock.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0-5/10	Dark reddish brown (5YR 3/2, 3/3), mixed with some very dark brown (7.5YR 4/2), clay loam; moderate crumb and subangular blocky; brittle dusty dry; very few to common lateritized rock gravels. Gradual to:
B <sub>1</sub>	7.0-8.0	5/10-12/25	Dark reddish brown (5YR 3/3, 3/4) light clay; moderate blocky 5-10mm; hard dry; few to common lateritized rock gravel. Gradual to:

B <sub>2</sub>	7.0-8.0	12/25-45/50	Reddish brown (5YR 4/4) or red-brown (2.5YR 4/4) medium clay; strong blocky 5-10mm; hard dry; few to common lateritized rock gravel 1-3cm size. Diffuse to:
B <sub>3</sub>	8.5	45/50-50/65	Reddish brown (5YR 4/4), with fine brown (7.5YR 5/6) and yellowish brown (10YR 5/4) mottled, light medium clay; moderate fine blocky; hard dry; may have very few soft patches and nodular CaCO <sub>3</sub> ; common to many lateritized rock gravel. Diffuse to:
C	9.0	50/65-	Light grey (2.5Y 7/1), yellow (10YR 7/6), brown (7.5YR 5/6) and white, weathered lateritized andesitic rock with silty clay or silty clay loam field texture.

### Classification

Great Soil Group:	No Suitable Group (affinity with euchrozems)
A Factual Key:	Gn 3.13
Soil Taxonomy:	Aridic Haplustalf
World Soil Map:	Calcic Luvisol
ASC:	Haplic Calcareous Red Ferrosol (thin, slightly gravelly, clay loamy, clayey, moderate).

### Deep Phase Profile

A deep phase has been mapped on the crest and gentle upper slopes of the lateral ridge downslope of the main unit in the crop rotation area. The phase is distinguished by its greater depth (70-95cm) to soft, weathered lateritized andesitic rock and slightly higher field pH in the deep subsoil.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0-3/5	Mixed dark reddish brown (5YR 3/2) and reddish brown (5YR 4/3) loam to clay loam; cultivated, crumb and subangular blocky; few to common lateritic gravel. Clear to:
A <sub>3</sub>	7.0-8.0	3/5-10/20	Reddish brown (5YR 4/4, 4/3) clay loam to light clay; moderate blocky 5-10mm; few to common lateritic gravel. Gradual to:
B <sub>21</sub>	7.5-8.5	10/20-40/55	Red-brown (4YR 3/6, 4/6) medium clay; strong blocky 1-2cm; hard dry; very few to few lateritic gravel. Diffuse to:
B <sub>22</sub>	8.0-8.5	40/55-60/70	Light reddish brown (5YR 5/6 or brown (7.5YR 5/6) light medium clay; few to very few lateritic gravel coated with CaCO <sub>3</sub> . Diffuse to:
B <sub>3</sub>	8.5-9.0	60/70-75/90	Light reddish brown (5YR 5/6), light brown (10YR 6/3), yellowish brown (10YR 5/6) light medium clay or light clay; few to common CaCO <sub>3</sub> coated lateritic gravel. Diffuse to:
C	9.0	75/90-	Yellowish brown, light brown, white etc. soft light clay or clay loam; weathered lateritized andesitic rock with CaCO <sub>3</sub> coatings on some gravels continuing below 100cm.

**Classification:**

Great Soil Group: No suitable group (affinity with euchrozems)  
 A Factual Key: Gn 3.13  
 Soil Taxonomy: Aridic Haplustalf  
 World Soil Map: Calcic Luvisol  
 ASC: Sodic Calcareous Red Ferrosol (medium, slightly gravelly, clay loamy, clayey, moderate).

*Soils on lateritized sediments overlying lateritized or deeply weathered andesitic rocks. (LSLAR)*

These are moderately deep to deep soils with reddish brown loam or clay loam surfaces and reddish brown or brown clay subsoils which grade into lateritized or deeply weathered andesitic rocks below depths of 50-100cms. They have common to many gravels, both lateritized andesitic rock fragments and dense black ironstone gravels on the surface. Both gravels are evident through the surface soil and subsoil clays but only lateritized rock has been recorded in the underlying C horizons. Because of their distribution through the soil, it is unlikely that the ironstone gravels have formed *in situ*, or that they represent lag gravels left behind from the erosion of an ironstone gravel band that had formed higher in the soil profile. They are therefore taken as evidence that the upper part of the profile is of mixed sedimentary origin transported from the older lateritic profiles, such as that exposed at Red Hill Paddock, with some input from andesitic rocks as well, judging from the high total P values recorded for the surface soil (Table 1).

*Soil unit: Narayen Brigalow 12*

**Land form:** Crests and upper slopes of gently sloping convex knolls on the long lateral ridges.  
**Micro-relief:** None evident.  
**Surface condition:** Dusty surface dry; probably hard-setting; common to many surface gravels, mainly lateritized andesitic rock 7-15cm size but including black ironstone gravels.  
**Parent material:** Lateritized sediments overlying lateritized or deeply weathered andesitic rocks.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5-8.0	0-12/15	Dark reddish brown (5YR 3/2, 3/3), or dark brown (7.5YR 3/2) loam; cultivated, loose and dusty dry; common to very many gravels, (fragments of lateritized rock 1-15cm, very few to few ironstone gravels 4-10mm). Clear boundary to:
B <sub>2</sub>	6.0-8.0	12/15-30/35	Reddish brown (5YR 4/4, 3/4) medium clay; moderate blocky 2-5cm; hard dry; many gravels, (fragments of lateritized rock and black ironstone gravel). Diffuse to:
B <sub>3</sub>	6.0-8.0	30/35-50/60	Reddish brown (5YR 4/6) or yellow-brown (10YR 6/6) light medium or medium clay; very many lateritized andesitic rock fragments, may have few ironstone gravels, may have very few CaCO <sub>3</sub> nodules. Diffuse to:
C	6.0-8.0	50/60-	Yellow-brown, reddish yellow, light grey, dark purplish red, etc lateritized andesitic rock with light reddish brown clay veins along fractures; may have very few CaCO <sub>3</sub> nodules; continuing below 60cm.

### Classification

Great Soil Group: No suitable group (affinity with red-brown earths)  
A Factual Key: Dr 2.13  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Chromic Luvisol  
ASC: Haplic Hypocalcic Red Chromosol (medium, gravelly, loamy, clayey, moderate).

### Soil unit: *Narayen Brigalow 13*

**Land form:** Gently sloping platform on long lateral ridge in continuous pasture area.  
**Micro-relief:** None evident.  
**Surface condition:** Cultivated surface loose and dusty dry; very few to common surface gravels (black ironstone 5-10mm and 1-5cm fragments of lateritized andesitic rocks).  
**Parent material:** Lateritized sediments overlying lateritized andesitic rocks.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0- 8/15	Dark reddish brown (5YR 3/2, 3/3) loam to clay loam; ? crumb and subangular blocky; hard dry; very few to common gravels, (black ironstone 5-10mm and lateritized rock 1-5cm). Clear to:
B <sub>2</sub>	7.5-8.0	8/15-35/45	Reddish brown (5YR 4/4, 3/4) medium heavy clay; moderate blocky 2-5cm; hard dry; very few to common gravels (black ironstone 5-10mm and lateritized rock 1-5cm). Diffuse to:
B <sub>3</sub>	7.5-8.5	35/45-60/70	Light reddish brown (5YR 5/4, 5/6, 4/6) light medium clay; moderate blocky 1-2cm; hard dry; common to many gravels (weathered lateritized rock and hard ironstone). Diffuse to:
C	8.5	60/70-	Light reddish brown, yellowish brown, light grey, white etc. weathered lateritized andesitic rock, continuing below 100cm.

### Classification

Great Soil Group: No suitable group (affinity with red-brown earths)  
A Factual Key: Dr 4.13  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Chromic Luvisol  
ASC: Haplic Eutrophic Red Chromosol (thin to medium, slightly gravelly, clay loamy, clayey, moderate).

### Soil unit: *Narayen Brigalow 14*

**Land form:** Gently sloping crest and upper slopes of small platform on the long lateral ridge in the crop rotation area.  
**Micro-relief:** None evident.  
**Surface condition:** Cultivated dark reddish brown or reddish brown dusty surface, very few to few ironstone and lateritized andesitic rock gravels.  
**Parent material:** Lateritized sediments overlying lateritized andesitic rocks.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.0-6.5	0-5/8	Dark reddish brown (5YR 3/3, 3/2), loam to clay loam; cultivated, crumb and subangular blocky; dusty dry; very few to few ironstone and lateritized andesitic rock gravels. Clear to:
A <sub>13</sub>	6.5-7.0	5/8-14/20	Reddish brown (5YR 3/4, 4/4) clay loam to light clay; weak blocky 1-3cm; brittle dry; very few to few ironstone 5-10mm and lateritized andesitic rock gravels 3-5cm. Clear to:
B <sub>21</sub>	7.5-8.0	14/20-30/45	Dark reddish brown (5YR 3/3, 3/2) or reddish brown (5YR 4/4) medium or medium heavy clay; strong blocky 1-3cm; hard dry; very few to few ironstone and lateritized andesitic rock gravels. Gradual to:
B <sub>3</sub>	8.0-8.5	30/45-90/100	Yellowish brown (10YR 5/6, 5/4) with some brown (7.5YR 5/6) patches, medium heavy grading to medium clay; moderate blocky 2-5cm; few to common lateritized andesitic rock gravels, may have very few ironstone gravels. Gradual to:
C	9.0	90/100-	Yellowish brown, pale yellow, very light grey etc. silty light medium clay grading into deeply weathered andesitic rock.

#### Classification

Great Soil Group:	? No suitable group (affinity with euchrozem)
A Factual Key:	Dr 4.13 (may include some Gn 3.13)
Soil Taxonomy:	Aridic Haplustalf
World Soil Map:	Chromic Luvisol
ASC:	Haplic Eutrophic Red Chromosol (medium, slightly gravelly, clay loamy, clayey, deep).

**Soil unit:** *Narayan Brigalow 15*

<b>Land form:</b>	Gentle slopes (c.1°) below small platform on long lateral ridge in the crop rotation area.
<b>Micro-relief:</b>	None evident.
<b>Surface condition:</b>	Dark brown or dark reddish brown dusty surface, very few to common black ironstone and dark red lateritized rock gravels.
<b>Parent material:</b>	Lateritized sediments overlying lateritized andesitic rocks.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0-5/10	Dark brown (7.5YR 3/2) and dark reddish brown (5YR 3/2) loam or clay loam; cultivated, crumb and subangular blocky; very few to common black ironstone and lateritized rock gravels. Clear to:
A <sub>3</sub>	7.0-8.0	5/10-10/25	Reddish brown (5YR 4/3, 4/4) clay loam to light clay; weak blocky 1-2cm; brittle dry; few to many lateritized rock gravels, very few to few ironstone gravels. Abrupt to:

B <sub>21</sub>	7.5-8.5	10/25-30/45	Dark brown (7.5YR 4/2, 3/2) medium heavy clay; moderate blocky 2-5cm; hard dry; very few to few gravels (ironstone and lateritized rock gravels). Diffuse to:
B <sub>22</sub>	8.5-9.0	30/45-90/100	Brown (7YR 5/4, 5/6) grading to yellowish brown (10YR 5/4, 5/6) medium heavy grading to medium clay; very few to few gravels (ironstone and lateritized rock gravels); may have very few soft patches and nodular CaCO <sub>3</sub> . Diffuse to:
B <sub>3</sub>	9.0	90/100-	Yellowish brown, light brown, very light grey etc. silty medium clay or light clay; continuing below 120cm into deeply weathered andesitic rocks.

### Classification

Great Soil Group:	No suitable group
A Factual Key:	Dy 4.23 or Dd 3.23
Soil Taxonomy:	Aridic Paleustalf
World Soil Map:	Calcic Luvisol
ASC:	Sodic Hypocalcic Grey Chromosol (medium, slightly gravelly, clay loamy, clayey, deep).

### Brown Subsoil Phase Profile

A brown subsoil phase of Narayen Brigalow 15 has been recognised on the gentle side slopes adjacent to a small remnant of lateritized materials, slightly downslope of the main unit. It is distinguished by its brown (rather than dark brown) clay subsoil and its light reddish brown clay deep subsoil.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0-3/8	Very dark brown (7.5YR 2/2, 3/2) clay loam; weak crumb and subangular 3-5mm; hard dry; very few to common gravels (black ironstone and lateritized rock gravel, 5-10mm). Clear to:
A <sub>13</sub>	7.0-7.5	3/8-10/25	Reddish brown (5YR 3/2, 4/2) clay loam to light clay; weak blocky 1-2cm; brittle dry; very few to few gravels (black ironstone and lateritized rock gravels 5-10mm). Abrupt to:
B <sub>21</sub>	8.0-8.5	10/25-30/40	Brown (7.5YR 4/3) may have fine reddish (5YR 4/3) and greyish (10YR 4/2) mottles, medium heavy clay; moderate blocky 1-5cm; very hard dry; very few to few ironstone gravels, may have very few silcrete gravels. Diffuse to:
B <sub>22</sub>	8.5-9.0	30/40-85/100	Light reddish brown (5YR 5/6, 4/6) medium or medium heavy clay; moderate blocky 1-3cm; hard dry; very few to few gravels (ironstone and lateritized rock gravels); CaCO <sub>3</sub> coating on some gravels below 70cm. Diffuse to:



B <sub>3</sub>	9.0	85/100-	Brown (7.5YR 5/6) and yellowish brown (10YR 5/4) medium or light medium clay; few to common lateritized rock gravels; some coated with CaCO <sub>3</sub> ; few white weathered minerals; continuing below 120cm.
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Great Soil Group:	No suitable group
A Factual Key:	Db 3.23
Soil Taxonomy:	Aridic Paleustalf
World Soil Map:	Haplic Luvisol
ASC:	Sodic Hypocalcic Brown Chromosol (medium, slightly gravelly, clay loamy, clayey, deep).

*Soils on hillslope deposits overlying weathered andesitic rocks. (HDWA)*

These are moderately deep to deep soils with dark reddish brown loam or clay loam surfaces overlying reddish brown, strongly-structured medium clays which grade into lateritized or weathered andesite at depths of more than 70cm; both gradational and duplex textural profiles with calcareous deep subsoils have been recorded. Ironstone gravels and fragments of lateritized andesitic rock are evident in the surface and upper subsoils and decrease in amount downslope. These are taken as indicating that the upper part of the profile is hillslope deposition derived from the soils on lateritized sediments and andesitic rocks upslope (Narayan Brigalow 11, 12, 13, 14, 15). Also, there is less evidence of lateritization of the underlying weathered andesite as one proceeds downslope and the latter's contribution to the soil profile appears to increase.

*Soil unit: Narayan Brigalow 16* (closely related to Narayan Brigalow 13 but thicker solum)

<b>Land form:</b>	Gentle sideslopes off long sloping lateral ridge
<b>Micro-relief:</b>	Occasional very low reddish mounds 1-2m x 2-4m.
<b>Surface condition:</b>	Dark reddish brown with few scattered reddish patches trace to slight black ironstone gravel 5-10mm and lateritized rock 1-5cm.
<b>Parent material:</b>	Hillslope deposits, from lateritized sediments and andesitic rocks, overlying weathered andesitic rock.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5-7.5	0-10/20	Dark reddish brown (5YR 3/2, 3/3) loam to clay loam; cultivated crumb and subangular blocky; hard dry; very few to few gravels (black ironstone and lateritized rock). Clear to:
B <sub>2</sub>	6.5-7.0	10/20-60/75	Reddish brown (5YR 4/4, 4/6) medium heavy clay; moderate blocky 2-5cm; hard dry; very few to few gravels (black ironstone and lateritized rock). Diffuse to:
B <sub>3</sub>	8.0-8.5	60/75-90/100	Light reddish brown (5YR 5/6) medium clay; blocky 1-2cm; hard dry; very few to few gravels (black ironstone and lateritized rock). Diffuse to:
B <sub>3</sub>	8.5	90/100-	Light reddish brown (5YR 5/6) brown (7.5YR 5/6), yellow-brown (10YR 6/6) medium clay; blocky 1-2cm; very few to few gravels (ironstone and lateritized rock); very few to few patches of soft CaCO <sub>3</sub> ; continuing below 120cm.

### Classification

Great Soil Group: No suitable group (affinity with red-brown earths)  
A Factual Key: Dr 4.13  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Calcic Luvisol  
ASC: Haplic Hypocalcic Red Chromosol (medium, slightly gravelly, clay loamy, clayey, deep).

*Soil unit: Narayen Brigalow 17*

**Land form:** Crests and side-slopes of long, gently-sloping lateral ridge  
**Micro-relief:** None evident  
**Surface condition:** Dark reddish brown surface with very few gravels (black ironstone gravel 5-10mm and lateritized rock fragments)  
**Parent material:** Hillslope deposits, from lateritized sediments and andesitic rocks, over-lying mealy weathered andesitic rock.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0-6/12	Dark reddish brown (5YR 3/2, 4/2) clay loam; cultivated, crumb and subangular blocky 5-10mm; hard dry; very few black ironstone gravels 5-10mm. Clear to:
B <sub>2</sub>	7.5-8.0	6/12-15/25	Dark reddish brown (5YR 4/2, 4/3) medium clay or medium heavy clay; strong blocky 2-5cm; hard dry; very few black ironstone gravels, very few black Mn concretions 2-5mm. Gradual to:
B <sub>22</sub>	8.5-9.0	15/25-40/60	Reddish brown (5YR 4/4, 3/4) medium heavy clay; strong blocky 2-5cm; very hard dry; very few to few black ironstone gravels; very few black Mn concretions 2-5mm; may have very few lateritized rock fragments and very few soft CaCO <sub>3</sub> patches. Diffuse to:
B <sub>3</sub>	8.5-9.0	40/60-70/90	Light reddish brown (5YR 5/6, 4/6) medium clay; blocky 1-3cm; hard dry; very few black ironstone gravels; very few soft CaCO <sub>3</sub> patches. Diffuse to:
C	8.5-9.0	70/90-	Light reddish brown, yellowish brown, light grey, white etc. mealy weathered andesitic rock may contain soft CaCO <sub>3</sub> , continuing below 120cm.

### Classification

Great Soil Group: No suitable group (affinity with red-brown earths)  
A Factual Key: Dr 4.13  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Calcic Luvisol  
ASC: Sodic Hypocalcic Red Chromosol (thin, non-gravelly, clay loamy, clayey, moderate).

*Soil unit: Narayen Brigalow 18*

**Land form:** Gently sloping crest (<1°) and side-slopes (1-2°) of small tread on long lateral ridge.  
**Micro-relief:** None evident  
**Surface condition:** Loose dark brown or dark reddish brown dusty surface cultivated, not hardsetting dry.  
**Parent material:** Hillslope deposits, derived from lateritized sediments and andesitic rocks, overlying weathered andesitic rock.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-8.0	0-2/5	Dark reddish brown (5YR 3/2, 4/2) clay loam; cultivated, crumb and subangular blocky 5-10mm; hard dry; very few black ironstone gravels 5-10mm. Clear to:
B <sub>21</sub>	7.5-8.5	2/5-10/18	Dark reddish brown (5YR 4/2, 4/3) medium clay or medium heavy clay; strong blocky 2-5cm; hard dry; very few black ironstone gravels, very few black Mn concretions 2-5mm. Gradual to:
B <sub>22</sub>	8.0-8.5	10/18-20/30	Reddish brown (5YR 4/4, 3/4) medium heavy clay; strong blocky 2-5cm; very hard dry; very few to few black ironstone gravels; very few black Mn concretions 2-5mm, may have very few lateritized rock fragments and very few soft CaCO <sub>3</sub> patches. Diffuse to:
B <sub>22</sub>	8.0-8.5	20/30-50/60	Reddish brown (5YR 4/4, 4/6) medium clay; blocky 1-3cm; hard dry; very few black ironstone gravels; very few soft CaCO <sub>3</sub> patches. Diffuse to:
B <sub>3</sub>	8.5-9.0	50/60-70/90	Light reddish brown (5 YR 5/6, 4/6) silty light medium clay; few weathered andesitic rock fragments; very few soft CaCO <sub>3</sub> patches. Diffuse to:
C	9.0	70/90-	Light brown, yellowish brown, and reddish brown silty clay or silty clay loam, deeply weathered andesitic materials; some CaCO <sub>3</sub> coating gravels; continuing below 120cm.

**Classification**

Great Soil Group: No suitable group (affinity with red-brown earths)  
A Factual Key: Dr 4.13  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Calcic Luvisol  
ASC: Sodic Hypocalcic Red Chromosol (thin, non-gravelly, clay loamy, clayey, moderate).

*Soil unit: Narayen Brigalow 19*

**Land form:** Gentle lower slopes of long sloping lateral ridge  
**Micro-relief:** None evident  
**Surface condition:** Dark brown to dark reddish brown dusty clay loams; very few to few gravels (black ironstone and lateritized rock)

**Parent material:** Lower hillslope deposit or local alluvium, derived from lateritized sediments and andesitic rocks, overlying weathered andesitic rocks.

Horizon	Field pH	Depth cm	Morphology
A <sub>1</sub>	8.0-8.5	0-5/10	Dark brown (7.5YR 3/2, 2/2) or dark reddish brown (5YR 3/2) clay loam; cultivated, crumb and subangular 2-10mm; hard dry; very few to few gravels, (black ironstone 5-10mm and lateritized rock 1-2cm). Abrupt to:
B <sub>21</sub>	8.5	5/10-20/30	Dark brown (7.5YR 3/2, 2/2) medium heavy clay; moderate blocky 3-5cm; very hard dry; very few to few black ironstone gravels, very few black Mn concretions 2-5mm; may have very few lateritized rock gravels. Diffuse to:
B <sub>22</sub>	8.5-9.0	20/30-40/50	Brown (7.5YR 4/3, 4/4) or reddish brown (5YR 3/4) medium heavy clay; moderate blocky 3-5cm; very hard dry; very few black ironstone gravels; very few to few soft patches and nodular CaCO <sub>3</sub> . Diffuse to:
B <sub>3</sub>	8.5-9.0	40/50-70/90	Yellow-brown (10YR 6/4), brown (7.5YR 4/4) and yellow (2.5YR 8/6) medium or light medium clay; pockets of weathered andesitic rock and many soft patches and nodular CaCO <sub>3</sub> .
C	8.5-9.0	70/90-	Yellow-brown, pale brown, yellow, etc. mealy weathered andesitic rock, many soft patches and nodular CaCO <sub>3</sub> , continuing below 120cm.

#### Classification

Great Soil Group: No suitable group  
 A Factual Key: Dd 3.13  
 Soil Taxonomy: Calcorthidic Paleustalf  
 World Soil Map: Calcic Luvisol  
 ASC: Sodic Calcic Black Chromosol (thin, slightly gravelly, clay loamy, clayey, moderate).

#### *Soils on Tertiary alluvia (TA)*

These are cracking clays formed on ancient clayey deposits containing both ironstone and lateritized rock gravels throughout at least the upper 1.2m. The higher deposit in the crop rotation area is interpreted as representing the little modified surface of an old drainage line deposit while the lower area appears to be a truncated remnant of the same material.

The higher area has moderately developed gilgai of mound, shelf and depression components throughout which there are a few large melon-holes. A different soil is associated with each of these components forming a gilgai complex. All of the lower area had been cultivated and no gilgai was evident, although there were some slight differences in level. The soil on this area had a very harsh cloddy surface when cultivated.

**Soil unit:** *Narayan Brigalow 20 gilgai complex*

**Land form:** Crest and gentle side-slopes of old alluvial landform left as an elevated platform on the lateral ridge in the crop rotation area..

**Micro-relief:** Moderate gilgai, complex of irregular brown or reddish mounds 7-15m across, depressions 5-8m across and 30cm deep, and scattered large melon-holes 11-20m across 60-80cm deep; small self-mulching patches 1-2m across occur on some mounds; black ironstone gravel and water-worn lateritized rock gravels are evident in places.

**Parent material:** Ancient (Tertiary) alluvium derived mainly from lateritized early Tertiary sediments.

**Mound Profile:**

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.0-8.5	0-2/5	Dark brown (7.5YR 3/2) or dark reddish brown (5YR 3/2) light clay; cultivated, crumb and subangular blocky 3-5mm; hard dry; very few to few black ironstone gravels 5-15mm. Clear to:
B <sub>21</sub>	8.0-8.5	2/5-25/60	Brown (7.5YR 4/4, 4/3) or reddish brown (5YR 4/3) heavy clay; moderate blocky 3-5cm; puggy wet, very hard dry; very few to few black ironstone gravels. Gradual to:
B <sub>22</sub>	8.5-9.0	25/60-75/100	Yellowish brown (10YR 5/4, 4/4) or reddish brown (5YR 4/4) medium to heavy clay; very few to few black ironstone gravels; very few to few soft patches and nodular CaCO <sub>3</sub> ; may have very few black Mn concretions. Gradual to:
B <sub>3</sub>	9.0	75/100-	Yellowish brown (10YR 5/6) or light reddish brown (5YR 5/6) mottled with brown (7.5YR 4/4, 10YR 4/3), medium to heavy clay; very few to few ironstone gravels; very few soft patches or nodular CaCO <sub>3</sub> ; continuing below 120cm.

**Classification**

Great Soil Group: Brown or red clay  
 A Factual Key: Ug 5.34 or Ug 5.38  
 Soil Taxonomy: Aridic Haplustert  
 World Soil Map: Calcic Vertisol  
 ASC: Endocalcareous Epipedal Brown or Red Vertisol (slightly gravelly, fine, medium fine, very deep).

**Shelf Profile**

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5	0-3	Very dark brownish grey (10YR 3/1) and olive brown (2.5YR 5/3) light medium clay; cultivated, granular; very hard dry; very few black ironstone gravels 5-15mm. Abrupt to:
B <sub>21</sub>	7.5	3-40	Olive-brown (2.5Y 5/3) or brown (7.5YR 4/4) heavy clay; moderate blocky 5-7cm; very hard dry; very few ironstone gravels; very few black Mn segregations. Diffuse to:

B <sub>22</sub>	8.5	40-65	Yellowish brown (10YR 5/4) heavy clay; moderate blocky 5cm; very hard dry; very few CaCO <sub>3</sub> concretions 3-5mm. Diffuse to:
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B <sub>23</sub>	7.0	65-	Yellowish brown (10YR 5/4) with fine reddish brown (5YR 4/4) mottles, heavy clay; blocky; very firm moist; no CaCO <sub>3</sub> evident; continuing below 120cm.
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Great Soil Group:	Grey or brown clay
A Factual Key:	Ug 5.24 or Ug 5.34
Soil Taxonomy:	Aridic Haplustert
World Soil Map:	Eutric Vertisol
ASC:	Haplic Epipedal Grey or Brown Vertosol (non-gravelly, medium fine, medium fine, very deep).

#### Depression profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.0-7.5	0-5/10	Very dark brownish grey (10YR 3/1) and dark brown (7.5YR 3/2), clay loam; cultivated, crumb and subangular blocky; hard dry; few black ironstone gravels. Abrupt to:
B <sub>21</sub>	7.0-7.5	5/10-20/25	Dark brown (7.5YR 3/2) or brown (7.5YR 4/4) heavy clay; strong blocky 2-6cm very hard dry; very few to few ironstone gravels. Diffuse to:
B <sub>22</sub>	8.0-8.5	20/25-75/90	Dark brown (7.5YR 4/2) or brown (7.5YR 4/4) heavy clay; strong blocky 2-6cm; very hard dry; very few to few ironstone gravels 5-15cm. Diffuse to:
B <sub>23</sub>	8.5-9.0	75/90-	Brown (7.5YR 5/4) or yellowish brown (10YR 5/4) or reddish brown (5YR 4/4) medium heavy clay; blocky 2-5cm; continuing below 120cm.

Great Soil Group:	No suitable group
A Factual Key:	Dd 3.13 or Db 3.13
Soil Taxonomy:	Vertic Paleustalf
World Soil Map:	Vertic Luvisol
ASC:	Vertic Eutrophic Black or Brown Chromosol (thin, slightly gravelly, clay loamy, clayey, very deep).

#### Melon-hole profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5	0-2/3	Dark brownish grey (10YR 4/1) medium clay; moderate granular 5mm; very hard dry . Abrupt to:
B <sub>21</sub>	6.0	2/3-25	Dark brownish grey (10YR 4/1) heavy clay; moderate blocky 5-10cm; very firm moist; prominent brown (7.5YR 4/4) rootlines and flecks. Diffuse to:

B <sub>22</sub>	5.5	25-75	Brownish grey (10YR 5/1) heavy clay; coarse blocky; puggy wet; prominent brown (7.5YR 4/4) and reddish brown (5YR 4/4) rootlines and flecks. Diffuse to:
B <sub>23</sub>	5.0	75-120	Yellowish brown (10YR 5/3, 5/4) mottled with grey-brown (10YR 4/2) and brown (7.5YR 5/6), heavy clay; puggy wet; continuing below 120cm.
Great Soil Group:	Grey clay		
A Factual Key:	Ug 5.25		
Soil Taxonomy:	Ustic Endoaquert		
World Soil Map:	Eutric Vertisol		
ASC:	Endoacidic-mottled Epipedal Aquic Vertosol (non-gravelly, medium fine, medium fine, very deep).		

**Soil unit: Narayan Brigalow 21**

<b>Land form:</b>	Gently sloping flat adjoining and below old alluvial platform with melon-hole gilgai.
<b>Micro-relief:</b>	Not obvious but there are some indications of broad low mound and depression gilgai before cultivation.
<b>Surface condition:</b>	Cultivated, harsh cloddy surface, very few gravels (quartz and silicified mottle zone gravels 1-8cm).
<b>Parent material:</b>	Ancient alluvium derived mainly from lateritized Tertiary sediments; this soil appears to have formed on the truncated alluvia that gave rise to the adjacent Unit 20 gilgai complex.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.0-8.5	0-5/8	Black (10YR 2/1) and dark brownish grey (10YR 4/1) light medium clay; cultivated, blocky 5-20mm; very hard dry; may have very few black ironstone (5mm), quartz or silcrete gravels 1-8cm. Clear to:
B <sub>21</sub>	8.0-8.5	5/8-50/75	Dark brownish grey (10YR 4/1, 2.5YR 4/1) heavy clay; moderate blocky 5-10cm; stiff and puggy wet; very few black Mn concretions 2-3mm; may have very few silcrete or black ironstone gravels 5-15mm. Diffuse to:
B <sub>22</sub>	8.5	50/75-95/120	Grey-brown (10YR 4/2) or brown (7.5YR 4/3) heavy clay: coarse blocky; puggy wet; very few to few soft CaCO <sub>3</sub> patches; very few black Mn concretions and ironstone gravels; may have occasional silcrete gravel. Diffuse to:
D	6.0-6.5	95/120-	Light grey-brown (10YR 6/2, 5/2) with fine brown (7.5YR 4/3) mottles, heavy clay; blocky; puggy heavy clay; very few ironstone gravels; continuing below 120cm.

## Classification

Great Soil Group:	Grey clay
A Factual Key:	Ug 5.24
Soil Taxonomy:	Aridic Haplustert
World Soil Map:	Eutric Vertisol
ASC:	Endocalcareous Epipedal Grey Vertosol (non-gravelly, fine, medium fine, very deep).

### *Soils on Quaternary alluvia (QAabc)*

The Quaternary alluvia comprise that along the present drainage lines and a thin deposit of Nerangy Creek alluvia that has persisted on the lower slopes in the north-western section of the continuous pasture area. The alluvia may overlie truncated Tertiary deposits or weathered andesitic rocks within 1.2m depth or continue to greater depths without obvious stratigraphic breaks. Each of these has been separated in the soil mapping because of possible influence on plant growth. Colour, pedality and texture of the soils also vary with differences in the source of the parent alluvium.

(a) Nerangy Creek alluvium overlying weathered andesitic rocks.

These are dark clays formed in alluvium overlying reddish brown clay subsoils apparently derived from the underlying weathered andesitic rock. A single unit, Narayen Brigalow 22 has been mapped as a gilgai complex.

### *Soil unit: Narayen Brigalow 22 gilgai complex*

<b>Land form:</b>	Very gently sloping to flat platform across the lower slope of the long sloping lateral ridge, in the continuous pasture area.
<b>Micro-relief:</b>	Scattered shallow melon holes 2-8m across, 20-50cm deep and occasional low mounds 2-3m across 20cm above general level.
<b>Surface condition:</b>	Very dark grey-brown surface; cracked when dry; very few to few black ironstone gravels in places.
<b>Parent material:</b>	Thin clay alluvium of Nerangy Creek overlying weathered andesitic rocks within 1-2m.

### Shelf Profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.5	0-2/5	Dark grey-brown (10YR 3/2, 4/2) light clay; cultivated, granular 3-6mm; very hard dry; may have very few black ironstone gravels 5-10mm. Clear to:
B <sub>21</sub>	8.5	2/5-25/35	Dark grey-brown (10YR 3/2, 4/2) heavy clay; moderate blocky 5-8cm; very hard dry; very few black Mn concretions 2-5mm; may have very few CaCO <sub>3</sub> patches. Gradual to:
B <sub>22</sub>	8.5	25/35-60/70	Reddish brown (5YR 4/4) medium heavy clay; moderate blocky 1-5cm; hard dry; very few to few soft patches and nodular CaCO <sub>3</sub> . Diffuse to:
B <sub>3</sub>	8.5	60/70-80/120	Light reddish brown (5YR 5/4, 5/6) and brown (7.5YR 4/4) medium heavy clay; blocky; hard dry; very few to few soft patches and nodular CaCO <sub>3</sub> ; pockets of weathering minerals.



C            8.5            80/120-            Light reddish brown, yellow, white, etc. mealy weathered andesitic rock, very few to few soft patches and nodular CaCO<sub>3</sub>.

Great Soil Group: Black earth or grey clay  
 Factual Key: Ug5.13, Ug5.23  
 Soil Taxonomy: Aridic Haplustert  
 World Soil Map: Calcic Vertisol  
 ASC: Endocalcareous Epipedal Black or Grey Vertosol (non-gravelly, fine, medium fine, moderate to deep)

**Mound Profile**

Horizon	Field pH	Depth cm	Morphology
A <sub>1</sub>	8.5	0-2	Dark reddish brown (10YR 3/1) light clay; moderate granular grading to blocky; hard dry; Clear to:
B <sub>21</sub>	8.5	2-32	Yellowish brown (10YR 5/4) with dark brownish grey (10YR 3/1) patches, heavy clay; moderate coarse blocky; very hard dry; few soft CaCO <sub>3</sub> patches. Diffuse to:
B <sub>22</sub>	9.0	32-120	Yellowish brown (10YR 5/4) heavy clay; coarse blocky; very hard dry; few soft CaCO <sub>3</sub> patches; continuing below 120cm, but note that nearby shelf profile is underlain by weathered volcanic rock below 80cm.

Great Soil Group: Brown clay  
 A Factual Key: Ug 5.22  
 Soil Taxonomy: Aridic Haplustert  
 World Soil Map: Calcic Vertisol  
 ASC: Epicalcareous-Endohypersodic Self-mulching Brown Vertosol (non-gravelly, fine, medium fine, deep).

(b) Local alluvium overlying truncated soils on Tertiary alluvia

These are duplex soils with loam to clay loam surface horizons overlying reddish brown or dark brown medium clay subsoils which are frequently underlain by red-brown, strongly pedal medium heavy clays within 1-2m depth. Black ironstone gravels may occur throughout the soil or only on top of and through the underlying red-brown clays. Because of their position in the landscape, variation in depth below the present surface and presence of ironstone gravels, the red-brown clays are interpreted as truncated remnants of ancient soils formed on Tertiary alluvia. The reddish brown and dark brown subsoils are thought to reflect differences in the source of local alluvium.

*Soil Unit: Narayen Brigalow 23*

**Land Form:** Gently sloping semi-circular head, upper reaches and almost flat interfluvium of present drainage lines in continuous pasture area.  
**Micro-relief:** Occasional low reddish brown mounds (? remnants of scrub turkey nests)  
**Surface condition:** Cultivated, fine crumb very dusty, little evidence of cracking.  
**Parent material:** Local alluvium (mainly red-brown clays) on truncated Tertiary alluvia.

### General level profile:

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.0	0-5/8	Dark reddish brown (5YR 3/2) or dark brown (7.5YR 3/2) loam or clay loam; cultivated, crumb and subangular blocky 2-8mm; loose dry; very few Mn concretions. Clear to:
B <sub>2</sub>	8.0	5/8-35/55	Reddish brown (5YR 3/4, 4/4) medium or medium heavy clay; moderate blocky 2-3cm; hard dry; few black Mn segregations or concretions. Diffuse to:
B <sub>3</sub>	8.5	35/55-60/80	Light reddish brown (5YR 5/6, 4/6) light medium or light clay; strong blocky 1-2cm; auger friable; very few soft patches and nodular CaCO <sub>3</sub> ; very few Mn concretions; may have very few black ironstone gravels. Abrupt to:
B <sub>3b</sub>	8.5-9.0	60/80-	Red-brown (4YR 3/6, 4/6) medium heavy clay; strong blocky 2-5cm; very hard dry; strong pedological organisation; few to many black Mn segregations; few to common soft patches and nodular CaCO <sub>3</sub> ; very few to few black ironstone gravels; continuing below 120cm. Note this layer, interpreted as Tertiary alluvia, may not occur along drainage line margins where B <sub>3</sub> horizon may grade into weathered andesitic rock.

Great Soil Group: No suitable group (affinity with red-brown earths)  
A Factual Key: Dr 4.13 (Dr 2.13)  
Soil Taxonomy: Aridic Paleustaff  
World Soil Map: Calcic Luvisol  
ASC: Sodic Hypocalcic Red Chromosol (thin, non-gravelly, clay loamy, clayey, moderate)

### Mound profile

Horizon	Field pH	Depth cm	Morphology
A <sub>11</sub>	8.5	0-10/12	Dark reddish brown (5YR 3/2) loam to clay loam; crumb grading to subangular blocky; dry; few gravels 5mm. Clear to:
A <sub>12</sub>	8.5	10/12-35	Reddish brown (5YR 3/4) loam to clay loam; slight grit; weak polyhedral 1-2cm; brittle dry; few gravels 5mm. Clear to:
B <sub>2</sub>	8.5	35-60	Red-brown (5YR 4/4) medium clay; moderate polyhedral 2-3cm; hard dry. Diffuse to:
B <sub>3</sub>	8.5	60-75	Reddish-yellow (5YR 5/6) light clay; weak polyhedral 2-3cm; brittle dry. Clear to:
B <sub>2b</sub>	8.5	75-	Red-brown (2.5YR 4/4) medium heavy clay; strong polyhedral 2-5cm; very hard dry; few soft CaCO <sub>3</sub> patches and continuing below 120cm.

Great Soil Group: No suitable group (affinity with red-brown earths)  
 Factual Key: Dr 4.13  
 Soil Taxonomy: Aridic Paleustalf  
 World Soil Map: Calcic Luvisol  
 ASC: Haplic Hypocalcic Red Chromosol (thick, slightly gravelly, loamy, clayey, moderate)

**Soil Unit: Narayen Brigalow 24**

**Land Form:** Gently sloping semi-circular head and upper reaches of present drainage lines in continuous pasture areas.  
**Micro-relief:** Scattered low reddish brown mounds in some parts (? remnants of scrub turkey nests).  
**Surface condition:** Cultivated fine crumb, dusty and much surface cracking dry.  
**Parent material:** Local alluvium (mainly from soils on andesitic rocks) in places overlying truncated strongly pedal clays on Tertiary alluvia.

**General level profile**

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.5-8.0	0-5/10	Very dark brown (10YR 2/2, 7.5YR 2/2) and dark brown (7.5YR 3/2, 4/2) clay loam; crumb and subangular blocky 2-5mm; loose dry; very few to few black Mn concretions 1-3mm and black ironstone gravel. Clear to:
B <sub>21</sub>	8.0-8.5	5/10-25/35	Very dark brown (7.5YR 2/2, 3/2) medium heavy clay; moderate blocky 2-5cm; very hard dry; few to common Mn concretions; very few ironstone gravels. Gradual to:
B <sub>22</sub>	8.5	25/35-40/50	Dark brown (7.5YR 3/2) and brown (7.5YR 4/4) medium heavy or medium clay; strong blocky 1-3cm; few to common Mn concretions; very few water-worn and ironstone gravels. Gradual to:
B <sub>3</sub>	8.5	40/50-75/90	Reddish brown (5YR 4/4, 4/6) light medium or light clay; blocky 5-10mm; auger friable dry; very few to few CaCO <sub>3</sub> nodules, ironstone gravels and black Mn segregations. Clear or abrupt:
bB <sub>2</sub>	8.5	75/90-	Red-brown (4YR 4/4) medium heavy clay; strong blocky highly organised pedality; few to common soft CaCO <sub>3</sub> patches, very many Mn segregations; very few black ironstone gravel; continuing below 120cm.

Great Soil Group: No suitable group  
 Factual Key: Dd 3.13 (small patches of Gn 3.13 soils are included in the mapped unit)  
 Soil Taxonomy: Aridic Paleustalf  
 World Soil Map: Calcic Luvisol  
 ASC: Haplic Hypocalcic Black Chromosol (thin, non-gravelly, clay loamy, clayey, deep)

**Mound profile:**

<b>Horizon</b>	<b>Field pH</b>	<b>Depth cm</b>	<b>Morphology</b>
A <sub>1p</sub>	8.0	0-10/20	Dark reddish brown (5YR 3/2) or dark brown (7.5YR 3/2) loam or clay loam increasing to light clay with depth; cultivated, crumb and subangular blocky 2-10mm, loose dusty dry; may have very few gravels. Gradual to:
B <sub>21</sub>	8.5	10/20-70/80	Reddish brown (5YR 3/4, 3/3) or brown (7.5YR 4/3) medium or medium heavy clay; strong blocky 5-10mm; hard dry; few to common rock and ironstone gravels; may have very few black Mn concretions and soft CaCO <sub>3</sub> patches. Gradual to:
B <sub>22</sub>	8.5	70/80-	Reddish brown (5YR 4/4) medium heavy clay; moderate blocky 10-15mm; hard dry; few to common soft patches and concretionary CaCO <sub>3</sub> ; common ironstone and water-worn rock gravels; may have black Mn concretions; continuing below 120cm.

Great Soil Group: No suitable group (affinity with euchrozems)  
Factual Key: Gn 3.13, Gn 3.23  
Soil Taxonomy: Calciorthidic Paleustalf  
World Soil Map: Calcic Luvisol  
ASC: Haplic Calcareous Red Ferrosol (medium, slightly gravelly, clay loamy, clayey, deep)

(c) Local alluvium

Two gilgai complexes have been recognised on what appears to be local alluvium, judging from its position in the landscape and a lack of clear to sharp stratigraphic breaks in the upper 1.2m. However, some areas may be underlain by truncated remnants of soils on Tertiary clays similar to that below Narayen Brigalow 23 and 24. One of the units has low to moderate gilgai and soils with dominantly reddish brown profiles while the other has dark grey-brown clays and weak gilgai development.

**Soil Unit:** *Narayen Brigalow 25 gilgai complex*

**Land form:** Broad gently sloping alluvial flat.  
**Micro-relief:** Low to moderate gilgai development, small depressions 2-6m across set in general level (shelf) which in places has low mounds which are 5-10cm higher.  
**Surface condition:** Shelf has dark reddish brown or dark brown loose surface with few ironstone gravels.  
**Parent material:** Local alluvium from andesite rocks and lateritized sedimentary and andesitic rocks.

**Shelf profile:**

<b>Horizon</b>	<b>Field pH</b>	<b>Depth cm</b>	<b>Morphology</b>
A <sub>1p</sub>	7.5	0-8/15	Dark reddish brown (5YR 3/2, 3/3) clay loam; loose cultivated, crumb and subangular blocky 3-6mm; hard dry; very few to common black ironstone gravels 5-10mm. Clear to:

B <sub>21</sub>	7.5	8/15-35/45	Reddish brown (5YR 4/3, 4/4) medium heavy clay; moderate blocky 1-4cm; very hard dry; common black ironstone and lateritized rock gravels 5-25mm. Gradual to:
B <sub>22</sub>	8.0	35/45-90	Reddish brown (5YR 4/4, 4/6) medium heavy clay; moderate blocky 1-4cm; very hard dry; common black ironstone and lateritized rock gravels 5-30mm; may have very few soft CaCO <sub>3</sub> patches. Diffuse to:
B <sub>3</sub>	8.5	90-	Reddish brown (5YR 4/4) and brown (2.5YR 4/4) medium heavy clay; moderate blocky; hard dry; common ironstone gravels; few soft CaCO <sub>3</sub> patches; few black Mn segregations; continuing below 120cm.

### Classification

Great Soil Group:	No suitable group (affinity red brown earth)
A Factual Key:	Dr 4.13
Soil Taxonomy:	Aridic Paleustalf
World Soil Map:	Calcic Luvisol
ASC:	Haplic Hypocalcic Red Chromosol (thin to medium, slightly gravelly, clay loamy, clayey, very deep)

### Mound profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.0	0-5/8	Dark reddish brown (5YR 3/3, 3/2) light clay; cultivated, crumb and subangular blocky 3-6mm; loose dry; few black ironstone gravels 5-15mm. Gradual to:
B <sub>1</sub>	8.5	5/8-15/20	Reddish brown (5YR 4/3) medium clay; strong blocky 5-10cm breaking to 5-15mm; hard dry; few black ironstone gravels 5-15mm. Gradual to:
B <sub>21</sub>	8.5	15/20-75/90	Reddish brown (5YR 4/3, 4/4) medium heavy clay; strong blocky 2-5cm; very hard dry; common black ironstone gravels 5-15mm; may have very few soft CaCO <sub>3</sub> patches. Diffuse to:
B <sub>22</sub>	8.5	75/90-	Reddish brown (5YR 4/4, 4/6) and brown (7.5YR 4/6, 5/6) medium heavy clay; strong blocky 1-2cm; common black ironstone gravels 5-15mm; very few to few soft CaCO <sub>3</sub> patches; continuing below 120cm.

Great Soil Group:	Red clay
A Factual Key:	Ug 5.38
Soil Taxonomy:	Typic Chromustert
World Soil Map:	Calcic Vertisol
ASC:	Endocalcareous Self-mulching Red Vertosol, (slightly gravelly, fine, medium fine, very deep)

### Depression profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.5	0-5	Dark reddish brown (5YR 3/2) or dark brown (7.5YR 3/2) light clay; cultivated, crumb and subangular blocky; loose dry; very few to few black ironstone gravels; very few to few black Mn concretions 3-5mm. Gradual to:
B <sub>2</sub>	8.5	5-40/60	Dark brown (7.5YR 4/2) medium heavy clay; strong blocky 2-5cm; very hard dry; few black ironstone gravels 5-15mm; few black Mn concretions 3-5mm. Diffuse to:
B <sub>2</sub>	8.5	40/60-90/110	Reddish brown (5YR 4/4) medium heavy clay; moderate blocky 1-3cm; hard dry; few soft patches and concretionary CaCO <sub>3</sub> ; few black ironstone gravels; very few to few black Mn concretions. Diffuse to:
B <sub>3</sub>	8.5	90/110-	Variously mottled light grey (2.5YR 7/1), pale yellow (2.5YR 6/3), light reddish brown (5YR 5/6) medium heavy clay; may contain gritty bands; soft and concretionary CaCO <sub>3</sub> and black ironstone gravels; continuing below 120cm.

Great Soil Group: Brown clay  
A Factual Key: Ug 5.25  
Soil Taxonomy: Aridic Haplustert  
World Soil Map: Calcic Vertisol  
ASC: Endocalcareous Epipedal Grey Vertosol (slightly gravelly, fine, medium fine, very deep)

### Soil Unit: *Narayan Brigalow 26 gilgai complex*

**Land form:** Gently sloping alluvial plain.  
**Micro-relief:** Weak to slight gilgai - very low broad mounds or general level with small depressions 2-4m across 6-8m apart.  
**Surface condition:** Very dark brown, cultivated loose surface with very few black ironstone gravels and CaCO<sub>3</sub> concretions.  
**Parent material:** Clayey alluvium

### Shelf profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.5	0-5/10	Very dark brown (7.5YR 2/2) light clay; cultivated, granular and subangular blocky 2-10mm; loose dry; very few black Mn concretions 2-5mm, very few CaCO <sub>3</sub> nodules 3-5mm; very few water-worn and black ironstone gravels 5-10mm. Gradual to:
B <sub>2</sub>	8.5	5/10-40/50	Dark grey-brown (10YR 4/2) heavy clay; moderate blocky 2-5cm; very hard dry; very few Mn concretions, few soft patches and nodular CaCO <sub>3</sub> , few water-worn gravels. Gradual to:

B <sub>3</sub>	8.5	40/50-	Reddish brown (5YR 4/3, 4/4) medium heavy clay; strong blocky 1-2cm; hard dry; few to common soft patches and nodular CaCO <sub>3</sub> ; very few Mn concretions, water-worn and black ironstone gravels; continuing below 120cm.
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Great Soil Group:	Grey clay
Factual Key:	Ug 5.25
Soil Taxonomy:	Aridic Calcicustert
World Soil Map:	Calcic Vertisol
ASC:	Epicalcareous Epipedal Grey Vertisol (non-gravelly, fine, medium fine, very deep)

#### Depression profile

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.5	0-5/8	Very dark brown (7.5YR 2/2, 3/2) light clay; cultivated, granular and subangular blocky 2-10mm; very few black ironstone gravels. Gradual to:
B <sub>2</sub>	8.0	5/8-40/60	Dark grey-brown (10YR 3/2) or dark brown (7.5YR 3/2) heavy clay; moderate blocky 2-5cm; very hard dry; few black Mn concretions 2-5mm, black ironstone and water-worn gravels 5-10mm. Clear to:
B <sub>3</sub>	8.5	40/60-	Reddish brown (5YR 4/3, 4/4) medium heavy clay; moderate blocky 1-2cm; hard dry; few soft patches and nodular CaCO <sub>3</sub> , black Mn concretions, ironstone and water-worn gravels; thin gritty bands occur below 90cm in some profiles, otherwise continuing without change below 120cm.

Great Soil Group:	Black earth
Factual Key:	Ug 5.15
Soil Taxonomy:	Aridic Haplustert
World Soil Map:	Calcic Vertisol
ASC:	Endocalcareous Epipedal Black Vertisol (non-gravelly, fine, medium, very deep)

#### *Soils on granodiorite (GD)*

These soils occupy the crest and gentle side-slopes of the lower part of the central ridge in the crop rotation area between two lateral tributaries of Nerangy Creek. The soils have dark sandy loam, loam or clay loam surface horizons which are massive and hard setting when dry and which abruptly overlie sandy clays with coarse prismatic structure. Depth of soil to weathered granodiorite varies from 30 to >120cm. In some areas, the surface horizons have received some alluvium of mixed origin from soils upslope.

#### *Soil Unit: Narayen Brigalow 27*

<b>Land form:</b>	Gentle (<1°) slope at base of long stepped ridge forming the interfluvium between two tributaries of Nerangy Creek.
<b>Micro-relief:</b>	None evident.
<b>Surface condition:</b>	Dark grey-brown to black surface, hardsetting dry.
<b>Parent material:</b>	Granodiorite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.0-8.5	0-4/10	Dark grey-brown (10YR 3/2) to black (10YR 2/1) sandy clay loam; weak platy 1cm to massive, hardsetting dry; very few to few white mineral flecks. Very abrupt to:
B <sub>21</sub>	8.5	4/10-20/32	Dark grey-brown (10YR 3/2, 4/2) sandy medium clay; moderate to strong prismatic 10x10x15cm breaking to blocky 5cm; very hard dry; few white mineral flecks. Gradual to:
B <sub>22</sub>	8.5	20/32-40/50	Grey-brown (10YR 4/2) or brown (7.5YR 4/2) sandy light medium clay; moderate blocky 5cm; very hard dry; few to common white mineral flecks. Diffuse to:
B <sub>3</sub>	8.5	40/50-55/65	Brown (7.5YR 5/4, 5/6) and yellowish brown (10YR 5/4) sandy clay; massive; many white weathering minerals; very few soft patches or nodular CaCO <sub>3</sub> . Diffuse to:
C	9.0	55/65-	Yellow-brown, brown, white, etc. gritty sandy clay loam of weathered granodiorite; very few to few soft patches and nodular CaCO <sub>3</sub> ; continuing below 120cm.

A shallow phase <30cm to C horizon has been mapped in one small area.

Great Soil Group: Solodized solonetz  
Factual Key: Dd 1.13  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Calcic Luvisol  
ASC: Hypocalcic Subnatric Black Sodosol (thin, non-gravelly, clay loamy, clayey, moderate)

*Soil Unit: Narayen Brigalow 28*

**Land form:** Lower slopes around the base of a long stepped ridge forming the interfluvium between two tributaries of Nerangy Creek.  
**Micro-relief:** Occasional small roughly circular areas with clay <5cm below surface imply incipient gilgai.  
**Surface condition:** Very dark grey-brown or dark brown platy hardsetting dry; may have a very few black ironstone gravels.  
**Parent material:** Thin veneer of mixed alluvium from soils on hillslope deposits over sub soils formed in granodiorite.



Horizon	Field pH	Depth cm	Morphology
A <sub>1p1</sub>	6.5-7.0	0-2/5	Very dark brownish grey (10YR 3/1) loam; weak platy to massive; hardsetting dry; may have very few black ironstone gravels 5-15mm. Clear to:
A <sub>1p2</sub>	6.5-7.5	2/5-10/15	Dark brown (7.5YR 4/2) clay loam; weak blocky to massive hard brittle dry; may have very few ironstone gravels. Very abrupt to:
B <sub>21</sub>	7.5-8.0	10/15-20/30	Dark grey-brown (10YR 3/2) or dark brown (7.5YR 4/2) medium heavy clay; moderate prismatic 5x8x10cm breaking to blocky 3-5cm; very hard dry; very few to few white mineral flecks through peds; may have a few black Mn concretions. Gradual to:
B <sub>22</sub>	8.5-9.0	20/30-40/60	Brown (7.5YR 4/2, 4/3) or reddish brown (5YR 4/3, 4/4) medium clay; moderate blocky 1-2cm; very few to few soft patches and nodular CaCO <sub>3</sub> ; few white mineral flecks. Diffuse to:
B <sub>31</sub>	8.5-9.0	40/60-90/120	Light reddish brown (5YR 5/6) and brown (5YR 5/4) medium clay; few soft patches and nodular CaCO <sub>3</sub> ; few white minerals.
B <sub>32</sub>	8.5-9.0	90/120-	Brown (7.5YR 5/6) and yellowish brown (10YR 5/4, 5/6) light medium clay with few soft patches and concretionary CaCO <sub>3</sub> ; white minerals and pockets of weathered rock; grading into weathered granodiorite below 120cm.

Great Soil Group: Solodized solonetz  
Factual Key: Dd 1.23 (Dd 2.23)  
Soil Taxonomy: Aridic Paleustalf  
World Soil Map: Calcic Luvisol  
ASC: Hypocalcic Subnatric Black Sodosol (medium, non-gravelly, loamy, clayey, deep)

**Soil Unit:** *Narayan Brigalow 29*

**Land form:** Very gentle sideslopes and crest of a long stepped ridge forming the interfluvium between two tributaries of Nerangy Creek.  
**Micro-relief:** None evident  
**Surface condition:** Thin very dark brown platy hardsetting surface becoming brown below 1-5cm.  
**Parent material:** Mostly granodiorite but may have minor contributions to the surface from soils upslope.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p1</sub>	6.5-7.5	0-1/5	Very dark brown (7.5YR 2/2, 3/2) loam; weak platy 1cm to massive; hardsetting dry. Clear to:
A <sub>1p2</sub>	6.5-7.5	1/5-10/18	Dark brown (7.5YR 4/2, 3/2) clay loam sandy; weak blocky to massive; hard and brittle dry. Very abrupt to:

B <sub>21</sub>	7.0-8.0	10/18-20/35	Dark brown (7.5YR 3/2, 4/2) sandy medium to medium heavy clay; strong prismatic 5x8x12cm breaking to blocky 5cm; very hard dry; white mineral flecks through peds, very dark brown cutans along cleavages. Gradual to:
B <sub>22</sub>	8.0-8.5	20/35-40/60	Brown (7.5YR 4/2, 4/4) sandy medium clay; moderate blocky 5cms; very hard dry; common to many white mineral flecks. Diffuse to:
B <sub>3</sub>	8.5-9.0	40/60-60/80	Reddish brown (5YR 4/4, 4/6) sandy light medium clay; massive; many white mineral flecks few nodular CaCO <sub>3</sub> . Diffuse to:
C	9.0	60/80-	Yellow-brown, brown, white etc. gritty clay loam of weathered granodiorite; many white speckles of weathering mineral; few nodular CaCO <sub>3</sub> ; continuing below 120cm.

A shallow phase <50cm to C horizon is recognised in one area.

Great Soil Group: Solodized Solonetz  
 Factual Key: Dd 1.23 (Dd 2.23)  
 Soil Taxonomy: Aridic Paleustalf  
 World Soil Map: Calcic Luvisol  
 ASC: Hypocalcic Subnatric Black Sodosol (medium, non-gravelly, clay loamy, clayey, moderate)

*Soil Unit: Narayen Brigalow 30*

**Land form:** Small semi-circular drainage head and narrow drainage line on gently sloping side-slope off lower section of interfluvium.  
**Micro-relief:** None evident  
**Surface condition:** Dark grey-brown hardsetting surface with few to common black Mn concretions in cultivated land.  
**Parent material:** Granodiorite and alluvium from soils on granodiorite.

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5	0-10	Dark grey-brown (10YR 3/2) sandy loam (heavy); massive; hardsetting dry; few to common black Mn concretions 2-5mm. Clear to:
A <sub>2</sub>	6.5	10-20	Grey-brown (10YR 4/2) with paler patches (10YR 5/2, 6/2 and 7/2), sandy clay loam; massive; hardsetting dry; common black Mn concretions 2-5mm. Abrupt to:
B <sub>2</sub>	6.5	20-50	Brown (7.5YR 5/2), with fine light grey-brown (10YR 5/2, 6/2) patches along ped margins, sandy medium clay; weak coarse prismatic; very hard dry; common to many black Mn concretions and segregations. Gradual to:
B <sub>3</sub>	7.0	50-65	Light grey-brown (2.5YR 5/2), with coarse grey-brown (10YR 4/2) mottles, sandy clay; massive; hard dry; very many black Mn segregations. Diffuse to:

C	7.5	65-120	Light grey-brown (2.5YR 5/2) sandy clay loam; with white weathering minerals; grading into weathered granodiorite below 120cm.
Great Soil Group:		Solodic soil	
Factual Key:		Dy 2.52	
Soil Taxonomy:		Aquic Paleustalf	
World Soil Map:		Dystric Planosol	
ASC:		Manganic Subnatric Grey Sodosol; (medium, slightly gravelly, loamy, clayey, deep)	

## Discussion

### *Soil Classification*

Each of the soil units has been classified into larger groupings (higher categories) according to my perception of how they meet the criteria of two local and two international schemes in common use in Australia (Stace *et al* 1968, Northcote 1979, FAO 1988, Soil Survey Staff 1992) and according to the recently developed Australian Soil Classification (Isbell 1996). Placement of the soils in the various classifications rests largely on profile morphology and field pH (Raupach and Tucker 1959) because no profiles within the area have been analysed in the laboratory for classification purposes. Most placements must therefore be regarded as provisional.

Six hierarchical categories - order, suborder, great group, subgroup, family and soil series or the approximate equivalent of these categories - are commonly recognised in soil classification schemes, although some schemes may be developed at one or two levels only, (eg. Stace *et al* 1968, FAO 1988). In the text, the soil units have been classified to family level of the Australian Soil Classification, Principal Profile Form (approximate family level) of A Factual Key, subgroups of Soil Taxonomy, great groups of A Handbook of Australian Soils and suborders of Soil Map of the World. These are unchanged in Table 2 except that placement in the Australian Classification is to suborder only. The distribution of Principal Profile Forms within the experimental area is shown on Map 5.

In Table 3, the soil units are classified down to the subgroup level of the Australian Classification, the eight letter computer code used for these groupings is given and one of the family criteria - soil depth class - is also presented. Distribution of these subgroups within the experimental area is shown on Map 6 using the published computer code as unit symbols.

### *Soil depth*

The soil depth classes (Table 3) are based on the combined thickness of the A + B horizons, i.e. depth of sola or pedological development. This does not necessarily represent effective root depth because some roots of many plants may access both moisture and nutrients from the weathered C horizon where they are able to penetrate it. None-the-less, thickness of sola is a useful indicator of the major soil zone available for water storage and nutrient supply in most soils.

The distribution of soil depth classes is indicated on Map 7. This shows that most of the soils on the hillslopes are moderately deep (0.5 - 1.0m) while those formed in alluvia are usually very deep (>1.5m though probably <5m). Small areas of very shallow (<0.25m) and shallow (0.25 - 0.5m) soils are restricted to the stony andesite hillslopes and small patches of the granodiorite area.

### *Field pH*

The ranges in field pH values recorded for the main soil horizons of the soil units are listed in Table 4. This shows that the soil surface values are commonly neutral to mildly alkaline (7.0 - 7.5) but range 6.0 - 8.5. Most of the clay subsoils are alkaline throughout with pH increasing with depth to 8.5 - 9.0 and many also contain soft and concretionary CaCO<sub>3</sub> in the lower part or underlying weathered rock. One exception is the NB20 gilgai complex in which the melonhole profile is mildly acid in the surface

soil and strongly acid (pH 5.0) at depth. It is likely that the entire complex (and NB21 as well) is underlain by acid substrate clays, similar to those reported elsewhere in southern Queensland (Hubble and Isbell 1958).

Field pH values are estimated to the nearest 0.5 of a unit and while they may not coincide with values determined in the laboratory, they do provide a rapid guide to those soils both within and outside of the range considered as satisfactory for agriculture. Also, pH values above 8.5 are used to indicate significant amounts of exchangeable sodium on the exchange complex of alkaline soils (Northcote and Skene 1972). Values of 9.0 have been used in this report to indicate sodic subsoils. However, laboratory data for the two profiles sampled imply that sodicity at depth may be more wide-spread in the area than indicated by field pH to 120cm depth.

#### *Computer map of field pH*

An *historic* computer-produced map showing calculated isopleths for field pH of the surface soil (within 0-2cm depth) in the crop rotation experiment is presented in Map 8. The map was produced 1971 from a program by A. W. Moore, formally Division of Soils, Brisbane. It is based on data from 134 points (where the soils were described during soil survey) as an example of single attribute maps that might be produced by computer. The initial output was as a mirror image of the plot area.

In interpreting a map of this kind, it needs to be remembered that its construction views the soils as a continuum in which there is a *gradual* change from one field pH class to the next. Also, the data are from 134 points only and the computer will produce equally spaced isopleths between points of more than two class units. It seems more likely that major changes in field pH will be more closely related to differences in soil parent materials in this area.

The bulked 0-10cm samples from each plot (Appendix 3) show a range in laboratory pH of 6.0 - 7.5 whereas the field pH values recorded for (0-2cm depth) at 320 sites ranged 6.0 - 8.5. The higher values for field pH are partly due to inclusions of mound profiles in the gilgai complexes but field pH levels of 8.0 - 8.5 were also recorded at several sites lacking gilgai development.

#### *Laboratory data*

Laboratory data for two soil profiles described and sampled by G. D. Hubble adjacent to the experimental plots are presented in Appendix 1. A feature of both profiles is the high sodicity and high pH values at depth; exchangeable sodium comprises 15-25% of the exchange complex below 60cm in B805 and 18% of the exchange complex below 105cm in B813. A comparison of B805 with an adjacent virgin area under brigalow shows an apparent effect of cultivation to the surface soil through presumed mixing, erosion loss and increased rates of mineralisation of organic matter; both G. D. Hubble and the author have independently recorded clay loam surface textures under brigalow nearby and have classified these soils as Gn 3.43 and in the experimental plots as Ug 5.13. Similar changes are to be expected in soil unit NB10 judging from the clay content and high organic matter versus field textures recorded for 0-10 cm depth in profile B813.

Data from single bulk density cores (6 cm diameter x 0-10cm), representing 19 of the soil units and 1 phase, are tabulated in Appendix 1. These were collected by J.S. Russell and the author in 1971, to provide bulk density values, field pH and 5 x XRF element concentrations at sites sampled for a comparative study of morphological and chemical features of the soils with the nutritive response of different plant species in the glasshouse (Russell and Thompson 1974).

Field descriptions and laboratory data for three soil profiles sampled within the grazing experiments by Sue McCarrall (QDPI) are presented in Appendix 2. These profiles provide considerable data for the 0-10cm depths but only pH, electrical conductivity and extractable chloride for three subsoil depths within a metre. The pH values imply that the subsoils at two of the sites are strongly sodic.

#### *Total element data for bulked 0-10cm depths from each plot*

Semiquantitative total values determined by emission spectrograph for a range of elements in bulked samples (15 x 0-10cm depth) from each plot are tabulated in Appendix III. The samples were taken in 1968, at random in each plot so as to give a mean value for the plot, by J.S. Russell (Division of Tropical Crops and Pastures) and analysed by the Australian Mineral Development Laboratories (AMDEL), Adelaide. Although the values obtained by emission spectrograph are said to be semiquantitative, there is quite good agreement between these values for P, Cu and Zn and the point values for these elements determined by x-ray fluorescence (XRF) in Brisbane and tabulated in Appendix I, thereby increasing the confidence in the spectrographic data.

A considerable range in values has been recorded for each element within the experimental area (Appendix III tables). However, when the geographic distribution of selected elements is recorded on a plot basis, it is evident that the concentrations are not randomly distributed but occur as populations within specified areas. An attempt has been made to graphically demonstrate this by showing the distribution of selected classes on a plot basis for three elements, P, Cu and Zn. It needs to be stated that, as far as the author is aware, the class boundaries used have no geochemical or agricultural significance but have been chosen purely to illustrate locally low, moderate, high (and for Zn, very high) concentrations. In fact, no clear relationship was found between soil boundaries and the occurrence of unsown species within the grazing experiment (McDonald *et al.* 1996)

The elemental values in Table 3 could be compared with those of the same elements in the surface horizons of 118 Queensland soils by Oertel and Giles (1959) and Giles (1959).

#### *Extension to the Crop Rotation Experiment*

In 1977, an extension of about 5 ha was made to the crop rotation experiment, immediately downslope of and adjoining its replicate 4 plots (Russell and Jones 1996). The extension occupies a gently sloping platform across the lower part of the long lateral ridge of the crop rotation area and lies along the eastern side of Nerangy Creek.

In May 1998, five x 5 cm cores to depths of 90-160 cm were collected, one from each of replicates 1, 2 and 4, and two from replicate 3 (Map 12). These are described in Appendix 4. They show that the soils have formed in clayey alluvium from local sources, but overlie weathered granodiorite or andesitic volcanics at relatively shallow depths. Variations in depth to the brown calcareous subsoil imply a gilgai complex of mound and depression before cultivation. The soils to 60 cm (and >90 cms in the deeper profiles) are very similar to Narayen Brigalow 22 gilgai complex (which occupies a similar landform position in the grazing experiment) and could probably be included in this unit.

#### **Acknowledgments**

The author gratefully acknowledges assistance received from CSIRO Division of Soils staff at the time of survey, in particular A. L. Chandica and K. J. Smith during field work and G. D. Hubble for providing profile data. I am also indebted to Sue McCarrall, Division of Land Utilisation, QDPI for field and laboratory data from three sites within the experimental area. I thank Dick Jones for editorial assistance, Leesa Austin and Kathy Mitchell of CSIRO Division of Tropical Crops and Pastures, for typing the manuscript and Dr J. S. Russell (CSIRO Division of Tropical Crops and Pastures) for provision of total element data for the surface soil of each plot.

**Table 2.** Classification of the soils according to five schemes

Soil Unit	AGSG <sup>1</sup>	F. Key <sup>2</sup>	ASC <sup>3</sup>	Soil Taxonomy <sup>4</sup>	WSM <sup>5</sup>
NB1	Black earth	Ug 5.13	Black Vertosol	Aridic Haplustert	Eutric Vertisol
NB2	Black earth	Ug 5.14	Black Vertosol	Aridic Haplustert	Calcic Vertisol
NB3	Grey clay	Ug 5.23	Grey Vertosol	Aridic Haplustalf	Calcic Vertisol
NB4	?Non-calcic brown	Dy 2.12	Grey Chromosol	Lithic Haplustalf	Haplic Luvisol
NB5	NSG <sup>6</sup>	Dd 3.13	Black Chromosol	Aridic Paleustalf	Calcic Luvisol
NB6	NSG	Dd 3.13	Black Chromosol	Calciorthidic Paleustalf	Calcic Luvisol
NB7	Non-calcic brown	Dr 2.12	Red Chromosol	Aridic Paleustalf	Chromic Luvisol
NB8	NSG aff RBE <sup>7</sup>	Dr 4.13	Red Chromosol	Aridic Paleustalf	Chromic Luvisol
NB9 shelf mound	NSG aff RBE	Gn 3.13	Red Dermosol	Aridic Haplustalf	Calcic Luvisol
	NSG aff RBE	Gn 3.13	Red Dermosol	Aridic Haplustalf	Calcic Luvisol
NB10	NSG aff Eu <sup>8</sup>	Gn 3.13	Red Ferrosol	Aridic Haplustalf	Calcic Luvisol
NB11 deep	NSG aff Eu	Gn 3.13	Red Ferrosol	Aridic Haplustalf	Calcic Luvisol
	NSG aff Eu	Gn 3.13	Red Ferrosol	Aridic Haplustalf	Calcic Luvisol
NB12	NSG aff RBE	Dr 2.13	Red Chromosol	Aridic Paleustalf	Chromic Luvisol
NB13	NSG aff RBE	Dr 4.13	Red Chromosol	Aridic Paleustalf	Chromic Luvisol
NB14	NSG aff Eu	Dr 4.13	Red Chromosol	Aridic Haplustalf	Chromic Luvisol
NB15 brown	NSG	Dy 4.23	Grey Chromosol	Aridic Paleustalf	Calcic Luvisol
	NSG	Db 3.23	Brown Chromosol	Aridic Paleustalf	Haplic Luvisol
NB16	NSG aff RBE	Dr 4.13	Red Chromosol	Aridic Paleustalf	Calcic Luvisol
NB17	NSG aff RBE	Dr 4.13	Red Chromosol	Aridic Paleustalf	Calcic Luvisol
NB18	NSG aff RBE	Dr 4.13	Red Chromosol	Aridic Paleustalf	Calcic Luvisol
NB19	NSG	Dd 3.13	Black Chromosol	Calciorthidic Paleustalf	Calcic Luvisol
NB20 mound shelf	Brown clay	Ug 5.34	Brown Vertosol	Aridic Haplustert	Calcic Vertisol
	Grey clay	Ug 5.24	Grey Vertosol	Aridic Haplustert	Eutric Vertisol
NB20 dpn melonhole	NSG	Dd 3.13	Black Chromosol	Vertic Paleustalf	Vertic Luvisol
	Grey clay	Ug 5.15	Aquic Vertosol	Ustic Endoaquert	Eutric Vertisol
NB21	Grey clay	Ug 5.24	Grey Vertosol	Aridic Haplustert	Eutric Vertisol
NB22 shelf mound	Black earth	Ug 5.13	Black Vertosol	Aridic Haplustert	Calcic Vertisol
	Brown clay	Ug 5.22	Brown Vertosol	Aridic Haplustert	Calcic Vertisol
NB23 mound	NSG aff RBE	Dr 4.13	Red Chromosol	Aridic Paleustalf	Calcic Luvisol
	NSG aff RBE	Dr 4.13	Red Chromosol	Aridic Paleustalf	Calcic Luvisol
NB24 mound	NSG	Dd 3.13	Black Chromosol	Aridic Paleustalf	Calcic Luvisol
	NSG aff Eu	Gn 3.13	Red Ferrosol	Calciorthidic Paleustalf	Calcic Luvisol
NB25 shelf mound	NSG aff RBE	Dr 4.13	Red Chromosol	Aridic Paleustalf	Calcic Luvisol
	Red clay	Ug 5.38	Red Vertosol	Typic Chromustert	Calcic Vertisol
NB25 dpn	Brown clay	Ug 5.25	Grey Vertosol	Aridic Haplustert	Calcic Vertisol
	Grey clay	Ug 5.25	Grey Vertosol	Aridic Calcicustert	Calcic Vertisol
NB26 shelf dpn	Black earth	Ug 5.15	Black Vertosol	Aridic Haplustert	Calcic Vertisol
	Black earth	Ug 5.15	Black Vertosol	Aridic Haplustert	Calcic Vertisol
NB27	Solodized solonetz	Dd 1.13	Black Sodosol	Aridic Paleustalf	Calcic Luvisol
NB28	Solodized solonetz	Dd 1.23	Black Sodosol	Aridic Paleustalf	Calcic Luvisol
NB29	Solodized solonetz	Dd 1.23	Black Sodosol	Aridic Paleustalf	Calcic Luvisol
NB30	Solodic soil	Dy 2.52	Grey Sodosol	Aquic Paleustalf	Dystric Planosol

<sup>1</sup> Australian great soil groups (Stace *et al.* 1968)

<sup>2</sup> A Factual Key (Northcote 1979)

<sup>3</sup> Australian Soil Classification (Isbell 1996)

<sup>4</sup> Soil Taxonomy (Soil Survey Staff 1992)

<sup>5</sup> Soil Map of the World Revised Legend (FAO 1988)

<sup>6</sup> No suitable group

<sup>7</sup> Affinity with red-brown earths

<sup>8</sup> Affinity with euzozems

**Table 3.** Australian Soil Classification to subgroup level, computer code and depth classes (Isbell 1996)

Soil Unit	Order	Suborder	Great Group	Subgroup	Code	Depth Class
NB1	Vertosol	Black	Epipedal	Haplic	VEAEGSCD	moderate
NB2	Vertosol	Black	Epipedal	Endocalcareous	VEAEGSFZ	moderate
NB3	Vertosol	Grey	Epipedal	Haplic	VEADGSCD	deep
NB4	Chromosol	Grey	Eutrophic	Haplic	CHADAHCD	shallow
NB5	Chromosol	Black	Hypocalcic	Haplic	CHAECVCD	moderate
NB6	Chromosol	Black	Calcic	Sodic	CHAEBDEO	moderate
NB7	Chromosol	Red	Eutrophic	Haplic	CHAAAHCD	moderate
NB8	Chromosol	Red	Hypocalcic	Haplic	CHAAVCVD	moderate
NB9 shelf mound	Dermosol	Red	Hypercalcic	Vertic	DEAACQEX	moderate
	Dermosol	Red	Calcic	Vertic	DEAABDEX	moderate
NB10	Ferrosol	Red	Calcareous	Haplic	FEAABCCD	moderate
NB11 deep	Ferrosol	Red	Calcareous	Haplic	FEAABCCD	moderate
	Ferrosol	Red	Calcareous	Sodic	FEAABCEO	moderate
NB12	Chromosol	Red	Hypocalcic	Haplic	CHAAVCVD	moderate
NB13	Chromosol	Red	Eutrophic	Haplic	CHAAAHCD	deep
NB14	Chromosol	Red	Eutrophic	Haplic	CHAAAHCD	deep
NB15 brown	Chromosol	Grey	Hypocalcic	Sodic	CHADCVEO	deep
	Chromosol	Brown	Hypocalcic	Sodic	CHABCVEO	deep
NB16	Chromosol	Red	Hypocalcic	Haplic	CHAAVCVD	moderate
NB17	Chromosol	Red	Hypocalcic	Sodic	CHAAVCVEO	moderate
NB18	Chromosol	Red	Hypocalcic	Sodic	CHAAVCVEO	moderate
NB19	Chromosol	Black	Calcic	Sodic	CHAEBDEO	moderate
NB20 mound shelf depn m-hole	Vertosol	Brown	Epipedal	Endocalcareous	VEABGSFZ	very deep
	Vertosol	Grey	Epipedal	Haplic	VEADGSCD	very deep
	Chromosol	Black	Eutrophic	Vertic	CHAEAHEX	very deep
	Vertosol	Aquic	Epipedal	Endo-acidic mottled	VEAMGSGSGL	very deep
NB21	Vertosol	Grey	Epipedal	Endocalcareous	VEADGSFZ	very deep
NB22 shelf mound	Vertosol	Black	Epipedal	Endocalcareous	VEAEGSFZ	mod deep
	Vertosol	Brown	Self-mulching	Epicalcareous-Endohypersodic	VEABEIGM	deep
NB23 mound	Chromosol	Red	Hypocalcic	Sodic	CHAAVCVEO	moderate
	Chromosol	Red	Hypocalcic	Haplic	CHAAVCVD	moderate
NB24 mound	Chromosol	Black	Hypocalcic	Haplic	CHAECVCD	deep
	Ferrosol	Red	Calcareous	Haplic	FEAABCCD	deep
NB25 shelf mound depn	Chromosol	Red	Hypocalcic	Haplic	CHAAVCVD	very deep
	Vertosol	Red	Self-mulching	Endocalcareous	VEAAEIFZ	very deep
NB26 shelf depn	Vertosol	Grey	Epipedal	Endocalcareous	VEADGSFZ	very deep
	Vertosol	Black	Epipedal	Epicalcareous	VEAEGSFY	very deep
NB27	Vertosol	Black	Epipedal	Endocalcareous	VEAEGSFZ	very deep
	Sodosol	Black	Subnatric	Hypocalcic	SOAEESCV	moderate
NB28	Sodosol	Black	Subnatric	Hypocalcic	SOAEESCV	deep
NB29	Sodosol	Black	Subnatric	Hypocalcic	SOAEESCV	moderate
NB30	Sodosol	Grey	Subnatric	Manganic	SOADESDC	deep

**Table 4.** Ranges in field pH recorded for the main soil horizons

Soil Unit	A <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	C
NB1	7.5 - 8.0	8.0 - 8.5	8.0 - 8.5	8.0 - 8.5
NB2	7.5 - 8.0	8.0 - 8.5	8.0 - 8.5	8.0 - 8.5
NB3	7.0	7.5	8.0	8.0 - 8.5
NB4	6.5 - 7.0	7.5 - 8.0	7.5 - 8.0	-
NB5	7.0 - 8.0	7.0 - 8.0	7.5 - 8.0	8.0 - 8.5
NB6	7.5 - 8.5	8.0 - 8.5	8.5 - 9.0	8.5 - 9.0
NB7	6.5 - 7.5	6.5 - 7.5	7.5 - 8.0	7.5 - 8.5
NB8	7.0 - 8.0	7.0 - 8.0	7.5 - 8.5	8.0 - 8.5
NB9 shelf	8.0 - 8.5	8.5	8.5 - 9.0	8.5 - 9.0
mound	8.5	8.5	8.5	8.5 - 9.0
NB10	6.5 - 7.5	6.5 - 7.5	8.0 - 8.5	8.5
NB11	7.0 - 8.0	7.0 - 8.0	8.5	9.0
deep	7.0 - 8.0	7.5 - 8.5	8.5 - 9.0	9.0
NB12	6.5 - 8.0	6.0 - 8.0	6.0 - 8.0	6.0 - 8.0
NB13	7.0 - 8.0	7.5 - 8.0	7.5 - 8.5	8.5
NB14	6.0 - 6.5	7.5 - 8.0	8.0 - 8.5	9.0
NB15	7.0 - 8.0	7.5 - 8.5	9.0	9.0
brown	7.0 - 8.0	8.0 - 8.5	9.0	-
NB16	6.5 - 7.5	6.5 - 7.5	8.0 - 8.5	-
NB17	7.0 - 8.0	7.5 - 8.0	8.5 - 9.0	8.5 - 9.0
NB18	7.0 - 8.0	7.5 - 8.5	8.5 - 9.0	9.0
NB19	8.0 - 8.5	8.5	8.5 - 9.0	8.5 - 9.0
NB20 mound	8.0 - 8.5	8.0 - 8.5	9.0	-
shelf	6.5	7.5 - 8.5	7.0	-
depn	7.0 - 7.5	7.0 - 7.5	8.5 - 9.0	-
m-hole	6.5	5.5 - 6.0	5.0	-
NB21	8.0 - 8.5	8.0 - 8.5	-	6.0 - 6.5*
NB22 shelf	8.5	8.5	8.5	8.5
mound	8.5	8.5	9.0	-
NB23	8.0	8.0	8.5	8.5 - 9.0*
mound	8.5	8.5	8.5	8.5*
NB24	7.5 - 8.0	8.0 - 8.5	8.5	8.5*
mound	8.0	8.5	8.5	-
NB25 shelf	7.5	7.5	8.5	-
mound	8.0	8.5	8.5	-
depn	8.5	8.5	8.5	-
NB26 shelf	8.5	8.5	8.5	-
mound	8.5	8.0	8.5	-
NB27	8.0 - 8.5	8.5	8.5	9.0
NB28	6.5 - 7.0	7.5 - 8.0	8.5 - 9.0	9.0
NB29	6.5 - 7.5	7.0 - 8.0	8.5 - 9.0	9.0
NB30	6.5	6.5	7.0	7.5

\* Indicates buried B or D horizons



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**Appendix 1. CSIRO profile descriptions and laboratory data**

**Laboratory Methods**

Method #	Analysis	Method
4A1	pH (H <sub>2</sub> O)	20:100 Soil:H <sub>2</sub> O
3A1	Electrical Conductivity	20:100 Soil:H <sub>2</sub> O
5A2	Chloride (Cl) extractable	20:100 Soil:H <sub>2</sub> O
9G2	Phosphorus (P) acid ext.	1:200 Soil:0.005M H <sub>2</sub> SO <sub>4</sub> (BSES)
15C	Calcium (Ca)	2.5:100 Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
15C	Magnesium (Mg)	2.5:100 Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
15C	Sodium (Na)	2.5:100 Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
15C	Potassium (K)	2.5:100 Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
15I	CBC (pH 8.5)	2.5:100 Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
17A1	Total Potassium	X-ray fluorescence
10A1	Total Sulphur	X-ray fluorescence
9A1	Total Phosphorus	X-ray fluorescence
6A1	Organic Carbon (OC)	Walkley & Black
7A2	Total Nitrogen (N)	Kjeldahl digest
-	Total Zinc	X-ray fluorescence
-	Total Copper	X-ray fluorescence
-	Particle Size	Plummet balance (Hutton 1955)

# Australian Laboratory Handbook of Soil and Water Chemical Methods (Rayment and Higginson 1992)

**Appendix 1. (continued) Field pH, XRF element concentrations and bulk density 0-10cm depth**

Sample	Soil	Field	XRF (total) ppm					Moisture	Bulk Density
No	Unit	pH	P	K	S	Cu	Zn	as Sampled %	Mg/m <sup>3</sup>
1	NB10	6.5	1200	7000	500	150	140	15.3	1.3
2	NB18	8.0	1400	4200	520	90	100	13.3	1.2
3	NB29	8.5	1200	22000	380	130	55	9.3	1.4
4	NB27	7.0	620	15000	200	95	65	12.2	1.7
5	NB21	8.0	830	2000	410	55	55	17.1	1.0
6	NB20	7.0	830	1800	420	55	45	14.8	1.3
7	NB11	7.0	1250	2000	690	85	50	14.3	1.1
8	NB15	8.0	1300	2100	610	55	50	13.3	1.0
9	NB11d	7.0	1000	2100	580	40	35	12.6	1.1
10	NB28	6.5	1100	14500	320	90	60	9.0	1.4
11	NB25	6.5	1150	3900	460	100	90	16.8	1.2
12	NB17	6.5	900	2700	500	60	40	17.1	1.2
13	NB5	8.0	810	8100	400	100	75	19.9	1.2
14	NB13	7.5	1250	2300	590	50	40	10.9	1.2
15	NB9	8.5	860	5200	420	110	140	18.5	1.3
16	NB24	7.5	1300	8500	570	110	190	17.8	1.2
17	NB1	8.5	1050	7000	530	70	130	21.1	1.1
18	NB19	8.0	910	4000	440	50	45	14.7	1.2
19	NB12	7.0	1100	2500	530	55	45	11.5	1.3
20	NB6	8.5	900	5700	570	100	170	17.4	1.2

Appendix 1. (continued)

Soil Unit: Parent Material: Weathered andesitic rock  
 Aust. Great Soil Group: Black earth Factual Key: Ug 5.13  
 Aust. Classification: Epicalcareous - Endohypersodic Self-mulching Black Vertosol

Location: Auburn 100 000 grid ref. 771553  
 Soil Taxonomy: Sodic Calcicustert

World Soil Map: Calcic Vertisol  
 Pedologist: G D Hubble (June 1972)

Sample No.	Horizon	Depth cm	Morphology					
			Color	Texture	Structure	Moisture	Gravel	Other
B805.1	A <sub>1p</sub>	0-5	Black (5YR 2/1)	light medium clay;	moderate fine granular;	friable moist;	very few andesite gravels	Gradual to:
B805.2	A <sub>1</sub>	5-10	Black (5YR 2/1)	medium clay;	moderate fine blocky;	friable moist;	very few andesite gravels	Gradual to:
B805.3 B805.4	B <sub>21</sub>	10-20 20-30	Very dark brownish grey (5YR 3/1)	medium heavy clay;	strong blocky 20mm breaking to 5-10mm	firm moist;	very few andesite gravels few soft CaCO <sub>3</sub>	Gradual to:
B805.5	B <sub>22</sub>	30-45	Very dark brownish grey (5YR 3/1) with dark reddish brown (5YR 3/2) patches	heavy clay;	strong lenticular 50mm breaking to 15mm;	firm moist;	very few andesite gravels few soft CaCO <sub>3</sub>	Gradual to:
B805.6 B805.7	B <sub>23</sub>	45-60 60-80	Dark reddish brown (5YR 3/2) and reddish brown (5YR 4/4)	heavy clay;	strong lenticular 50mm breaking to 15mm;	firm moist;	very few andesite gravels few soft and concretionary CaCO <sub>3</sub>	Diffuse to:
B805.8	B <sub>3</sub>	80-90	Reddish brown (5YR 4/4) with yellow (10YR 7/6) speckling	medium clay;	weak blocky 20mm	very firm moist	very few andesite gravels common soft and concretionary CaCO <sub>3</sub>	Diffuse to:
B805.9	C	90-120 120-15	Yellow (10YR 7/6) with reddish brown (5YR 4/4) and yellowish brown (10YR 5/4) mottles	clayey weathered andesitic rock	-	very firm moist	Common weathered andesite few soft CaCO <sub>3</sub> diffused through soil	Continuing below 150 cm

Sample No	pH	TSS %	NaCl %	Particle Size %				CEC m.e./100g	Exchangeable Cations m.e./100g				Base Sat %	Org C %	N %	XRF ppm			BSES (ppm) P
				CS	FS	Si	C		Ca	Mg	K	Na				K	S	P	
1	7.8	0.10	0.06	5	15	23	45	52.5	21.6	5.2	2.5	0.58	57	5.3	0.58				32
2	7.7	0.01	0.01	6	14	23	50	48.7	17.2	5.9	1.5	0.60	52	3.0	0.36				14
3	8.2	0.03	0.02	7	14	22	52	40.4	14.2	7.0	0.3	1.2	56	1.3	0.17				7
4	8.8	0.06	0.02	4	13	19	61	-	-	-	-	-	-	0.9	0.12				8
5	9.0	0.14	0.05	4	12	19	64	45.4	12.2	12.2	0.24	3.8	63	0.8	0.10				-
6	9.1	0.23	0.12	3	11	38	42*	-	-	-	-	-	-	0.6	0.09				-
7	9.1	0.36	0.23	4	10	34	42*	39.8	12.0	12.3	0.17	6.1	67	0.6	0.08				-
8	9.2	0.37	0.24	2	13	28	47*	-	-	-	-	-	-	0.3	0.04				-
9	9.4	0.52	0.29	6	14	33	37*	33.8	10.4	10.4	0.06	8.2	75	0.2	0.03				-

\*Low particle size summation, dispersion probably incomplete

Appendix 1. (continued)

Soil Unit: NB10

Aust. Great Soil Group: No suitable group

Aust. Classification: Haplic Calcareous Red Ferrosol

Parent Material: Deeply weathered andesitic rock

Factual Key: Gn 3.13

Location: Auburn 1:100 000 grid ref. 782562

Soil Taxonomy: Typic Rhodustalf

World Soil Map: Rhodic Nitosol/Calcic Luvisol

Pedologist: G D Hubble (June 1973)

Sample No.	Horizon	Depth cm	Morphology																	
B813.1	A <sub>1</sub>	0-5	Dark reddish brown (5YR 3/3)	clay loam;	moderate polyhedral 5-20mm	friable moist;		Clear to:												
B813.2	B <sub>1</sub>	5-10	Red (2.5YR 3/6)	light clay;	moderate polyhedral 5-25mm	friable moist;	few fine Mn concretions	Gradual to:												
B813.3 B813.4 B813.5 B813.6	B <sub>2</sub>	10-20 20-30 30-50 50-60	Red (2.5YR 3/6)	medium heavy clay;	strong blocky breaking to polyhedral 5mm;	friable moist;	common fine Mn concretions 1mm	Clear to:												
B813.7	B <sub>2ca1</sub>	60-75	Red (2.5YR 3/6)	medium heavy clay;	strong polyhedral 5mm	firm moist;	common soft CaCO <sub>3</sub> common Mn concretions	Clear to:												
B813.8 B813.9	B <sub>2ca2</sub>	75-90 90-105	Yellowish red (5YR 4/6) with yellow (10YR 7/6) mottle	medium clay;	strong polyhedral 5mm	firm moist	many soft CaCO <sub>3</sub> common Mn concretions	Gradual to:												
B813.10 B813.11	B <sub>3</sub>	105-120 120-150	Brown (7.5YR 5/6) with yellow (10YR 7/6) mottle	medium clay;	fine blocky;	hard dry	few soft CaCO <sub>3</sub> few Mn segregations	Diffuse to:												
B813.12	C	150-180	Yellow (10YR 5/6) mottled with brown (7.5YR 5/6), red (2.5YR 4/6) and white	clayey weathered andesitic rock			brittle weathered rock fragments	Continuing below 180cm												
Sample No	pH	TSS %	NaCl %	Particle Size %				CEC m.e./100g	Exchangeable Cations m.e./100g				Base Sat %	Org C %	N %	XRF ppm			BSES ppm	Bulk Density
				CS	FS	Si	C		Ca	Mg	K	Na				K	S	P	P	
1	6.6	0.13	0.01	4	14	44	35	36.5	13.7	3.2	5.7	0.17	62	4.6	0.48	8900	780	1400	104	1.05
2	5.9	0.07	0.01	4	14	25	55	29.6	9.8	1.0	2.9	0.06	47	2.25	0.29	7100	560	1200	32	1.09
3	5.6	0.04	0.02	3	14	26	57	-	-	-	-	-	-	1.43	0.20	6000	380	990	34	1.01
5	5.7	0.03	0.01	3	10	25	64	33.9	12.3	10.0	0.8	0.9	71	0.95	0.06	4500	320	300	5	1.29
7	8.8	0.03	0.06	1	6	19	51	24.1	12.6	10.3	0.8	1.0	100	0.20	0.03				4	1.50
9	9.1	0.26	0.20	0	3	21	63	17.6	4.5	10.7	0.2	3.3	100						1	1.27
10	9.1	0.36	0.44	0	2	27	68													
12	8.4	0.50		0	2	38	63													

## Appendix 2. QDPI Profile descriptions and laboratory data

### Laboratory Methods

Method #	Analysis	Method
4A1	pH (H <sub>2</sub> O)	20:100,Soil:H <sub>2</sub> O
3A1	Electrical conductivity	20:100,Soil: H <sub>2</sub> O
5A2	Chloride (Cl) extractable	20:100,Soil: H <sub>2</sub> O
9B2	Phosphorus (P) bicarb.ext.	1:100,Soil:0.5M NaH (Colwell)
9G2	Phosphorus (P) acid ext.	1:200,Soil:0.005M H <sub>2</sub> SO <sub>4</sub> (BSES)
18B	Potassium (K) replaceable	5:200,Soil:0.05M HCl
10B	Sulphur (S) extractable	20:100,Soil:0.01M CaHPO <sub>4</sub>
15C	Calcium (Ca)	2.5:100,Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
15C	Magnesium (Mg)	2.5:100,Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
15C	Sodium (Na)	2.5:100,Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
15C	Potassium (K)	2.5:100,Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
15I	CEC (pH 8.5)	2.5:100,Soil:alc 1M NH <sub>4</sub> Cl pH 8.5
12A	Copper (Cu) extractable	25:50,Soil:0.005M DTPA
12A	Manganese ( Mn) extractable	25:50,Soil:0.005M DTPA
12A	Zinc (Zn) extractable	25:50,Soil:0.005M DTPA
12A	Iron (Fe) extractable	25:50,Soil:0.005M DTPA
12C	Boron (B)	10:20,Soil:Hot 0.01M CaCl
6A1	Organic carbon (OC)	Walkley & Black
7A2	Total nitrogen (N)	Kjeldahl digest

# Australian Laboratory Handbook of Soil and Water Chemical Methods  
(Rayment and Higginson 1992)

Appendix 2. (continued)

Soil Unit: NB22

DPI Site No: 20

Location A.M.G. Reference: 277 070 mE 7 156 270 mN Zone 56

Map Sheet No: 9046 (Auburn)

Aust Great Soil Group: Brown clay

Factual Key: Ug 5.34

Aust. Classification: Epicalcareous-Endohypersodic Self-mulching Brown Vertosol

Type of Microrelief: melonhole gilgai Vertical Interval: 1.00 m Horizontal Interval: 30m

Surface condition: Few 2-10% medium pebbles 6-20mm, subrounded siltstone, self-mulching and periodic cracking when dry.

Pedologist: Sue McCarrall

Horizon	Depth	Morphology
A <sub>1</sub>	0 to .06m	Very dark greyish brown (10YR 3/2) light medium clay; medium to coarse fragments; strong <2mm granular, dry; loose; non-calcareous. Abrupt to-
B <sub>21</sub>	.06 to .31m	Dark brown (10YR 3/3) medium clay; no coarse fragments; strong 20-50mm angular blocky largest peds, parting to strong 2-5mm lenticular next size peds; dry, moderately firm; few 2-10% medium 2-6mm calcareous soft segregations Clear to-
B <sub>22</sub>	.31 to .52m	Very dark grey (10YR 3/1) few 2-10% fine <5mm faint brown mottles; medium clay; no coarse fragments, strong 2-5mm lenticular next size peds; dry, moderately firm; few 2-10% coarse 6-20mm calcareous nodules, slightly calcareous. Clear to-
B <sub>23</sub>	.52 to 1.20m	Strong brown (7.5YR 4/6) light medium clay; no coarse fragments strong 2-5mm lenticular next size peds; moderately moist, moderately weak; few 2-10% medium 2-6mm calcareous soft segregations, slightly calcareous, few 2-10% coarse 6-20mm calcareous nodules. Gradual to-
B <sub>3</sub>	1.20 to 1.54m	Brown (7.5YR 4/4) many 20-50% coarse 15-30mm prominent pale mottles, light medium clay; no coarse fragments; strong 2-5mm angular blocky; dry, very firm; non-calcareous
C	1.54 to 1.65m	White (10YR 8/1) common 10-20% fine <5mm prominent brown mottles, light clay; strong 5-10mm angular blocky; dry, very firm; non-calcareous

Appendix 2. (continued)  
 DPI Site No. 20

Depth cm	pH	EC mS/cm	Cl mg/kg	P_Bic mg/kg	PA mg/kg	rep1.K meq%	SO4-S mg/kg	Ca meq%	Mg meq%	Na meq%	K meq %	CEC (8.5) meq %	Org.C %	Tot.N %					
0-10	8.2	0.20	31	22	30	0.45	11	24.00	12.00	1.10	0.56	46	3.3	0.24					
20-30	9.1	0.43	67														Depth (cm)	Field pH	Field EC (mS/cm)
40-50	9.4	0.98	122														0	7.5	0.04
80+	9.0	1.83	358														10	8.0	0.02
																	20	9.0	0.10
																	30	9.0	0.21
																	40	9.0	0.24
																	50	9.0	0.58
																	60	9.0	0.76
																	70	9.0	1.22
																	80	9.0	1.39
																	90	8.5	1.73
																	100	8.5	1.62
																	110	8.5	1.47
																	120	8.0	1.53
																	150	7.5	1.15

Depth cm	Cu-DTPA mg/kg	Zn- DTPA mg/kg	Mn-DTPA mg/kg	Fe- DTPA mg/kg	Ext.B mg/kg
0-10	3.4	0.9	13	21	1.3



**Appendix 2. (continued)**

**Soil Unit:** NB17

**DPI Site No:** 21

**Location A.M.G. Reference:** 277 070 mE 7 156 060 mN Zone 56

**Map Sheet No:** 9046 (Auburn)

**Aust Great Soil Group:** No suitable group

**Factual Key:** Dr 4.13

**Aust. Classification:** Vertic Subnatric Red Sodosol

**Type of Microrelief:** none

**Surface condition:** Few 2-10% medium pebbles 6-20mm, subrounded siltstone, periodic cracking when dry.

**Pedologist:** Sue McCarroll

Horizon	Depth	Morphology
A <sub>1</sub>	0 to .15m	Dark brown (7.5YR 3/4) clay loam; weak 10-20mm subangular blocky; dry, very firm; non-calcareous. Abrupt to-
B <sub>21</sub>	.15 to .29m	Dark reddish brown (5YR 3/2) medium clay; very few <2% large pebbles 20-60mm, subangular siltstone; strong 20-50mm prismatic largest peds, parting to strong 2-5mm lenticular peds; dry, moderately strong; non-calcareous. Clear to-
	.34 to .80m	Reddish brown (5YR 4/4) light medium clay; few 2-10% medium pebbles 6-20mm, subangular siltstone, very few <2% large pebbles 20-60mm, subangular siltstone; strong 2-5mm lenticular; moderately moist, very firm; non-calcareous. Abrupt to-
B <sub>22</sub>	.80 to .97m	Brownish yellow (10YR 6/6) moist light medium clay; few 2-10% medium pebbles 6-20mm, subangular siltstone; strong 5-10mm angular blocky; moderately moist, moderately firm; non-calcareous. Abrupt to-
BC	.97 to 1.50m	Brownish yellow (10YR 6/6) many 20-50% coarse 15-30mm prominent pale mottles, light medium clay; very few <2% medium pebbles 6-20mm, subrounded; strong 5-10mm angular blocky, dry; very firm
C		

Note: This soil forms a complex with a cracking clay. The complex constitutes >60% cracking clay and <40% duplex.

Appendix 2. (continued)  
DPI Site No. 21

Depth cm	pH	EC mS/cm	C1 mg/kg	P_Bic mg/kg	PA mg/kg	rep1.K meq%	SO4-S mg/kg	Ca meq%	Mg meq%	Na meq%	K meq %	CEC (8.5) meq %	Org.C %	Tot.N %				
0-10	7.1	0.10	33	47	53	1.70	11	15.00	8.00	0.35	2.30	37	3.2	0.24	Depth (cm)	Field pH	Field EC (mS/cm)	
20-30	8.5	0.30	35													0	6.5	0.06
40-50	9.0	0.54	71													10	7.5	0.03
80-90	8.6	1.20	236													20	8.5	0.05
															30	9.0	0.17	
															40	9.0	0.24	
															50	9.0	0.38	
															60	9.0	0.62	
															70	9.0	0.69	
															80	9.0	0.90	
															90	7.0	1.00	
Depth cm	Cu-DTPA mg/kg	Zn-DTPA mg/kg	Mn-DTPA mg/kg	Fe-DTPA mg/kg	Ext.B mg/kg													
0-10	5.8	2.6	47	34	1.3													

Appendix 2. (continued)

Soil Unit: NB9

DPI Site No: 22

Location A.M.G. Reference: 277 070 mE 7 156 700 mN Zone 56

Great Soil Group: Brown clay

Factual Key: Ug 5.12

Aust. Classification: Endocalcareous Self-mulching Black, Vertosol

Type of Microrelief: none

Surface condition: Few 2-10% cobbles 6-20mm, subangular andesite, self-mulching and periodic cracking when dry.

Pedologist: Sue McCarrall

Horizon	Depth	Morphology
A <sub>1</sub>	0 to .03m	Dark brown (7.5YR 3/2) Light medium clay; strong <2mm granular; dry, loose Abrupt to-
B <sub>21</sub>	.03 to .12m	Dark reddish brown (5YR 3/2) light clay; strong 10-20mm angular blocky largest peds, parting to strong 2-5mm angular blocky peds; dry, moderately firm; non-calcareous. Clear to-
	.12 to .50m	Dark reddish brown (5YR 3/2) light medium clay; very few <2% small pebbles 2-6mm, angular andesite; strong 5-10mm lenticular; slickenside; dry, moderately firm; non-calcareous. Abrupt to-
B <sub>22</sub>	.50 to 1.00m	Strong brown (7.5YR 5/6) light medium clay; many 20-50% small pebbles 2-6mm, angular andesite, few 2-10% medium pebbles 6-20mm, angular andesite; strong 5-10mm angular blocky; dry, moderately firm; few 2-10% medium 2-6mm calcareous soft segregations, highly calcareous. Clear to-
BC	1.00 to 1.55m	Very abundant >90% fragments, andesite; common 10-20% coarse 6-20mm calcareous soft segregations
C		

Appendix 2 (continued)  
 DPI Site No. 22

Depth cm	pH	EC mS/cm	C1 mg/kg	P_Bic mg/kg	PA mg/kg	repl.K meq%	SO4-S mg/kg	Ca meq%	Mg meq%	Na meq%	K meq %	CEC (8.5) meq %	Org.C %	Tot.N %						
0-10	6.5	0.14	86	62	149	1.20	10	34.00	9.00	0.50	1.50	54	3.3	0.30						
20-30	7.9	0.25	10														Depth (cm)	Field pH	Field EC (mS/cm)	
40-50	8.1	0.22	21														0	6.5	0.16	
																10	6.5	0.03		
																20	7.5	0.03		
																30	8.5	0.03		
																40	8.5	0.03		
Depth cm	Cu-DTPA mg/kg	Zn-DTPA mg/kg	Mn-DTPA mg/kg	Fe-DTPA mg/kg	Ext.B mg/kg													50	7.0	0.07
0-10	6.3	4.1	31	21	1.3															

**Appendix 3.** Soil pH and total element data for bulk (15 x 0-10 cm depth) samples from each experimental plot. Samples collected in 1969 by J S Russell, CSIRO Division of Tropical Crops and Pastures. The replicate and plot numbers are those used in Map 2.

**Crop Rotation Experiment**

Rep No	Treatment No	Parent Material	Soil Unit	pH	Total N ppm	Total Elements ppm												
						P	Mn	Cu	Zn	Pb	Co	Ni	V	Be	Ga	Na	Li	K
1	1	DWA,LAR	10,11,15	6.1	3530	1200	3500		120	100	80	60	600	8	50	800	25	8000
	2	LSLAR	14,15	6.9	3940	1200	500	50	40	100	20	200	200	3	60	300	30	4000
	3	DWA	10	6.6	3340	1100	2500	110	100	100	60	50	500	8	50	600	50	10000
	4	LAR,LSLAR	11,15	6.3	4035	1100	490	70	40	40	15	30	500	5	50	200	8	700
	5	LAR, DWA	11,10	7.0	4365	1200	1200	80	60	60	30	30	500	5	50	250	10	700
	6	LAR	11	6.8	3475	1100	770	75	40	40	15	30	500	5	60	200	10	600
	7	LSLAR	14,15	6.8	3955	1200	550	50	40	20	15	15	300	5	20	400	30	600
	8	LSLAR,LAR	15,11	6.7	3490	1100	500	60	40	40	15	30	400	5	40	400	25	700
	9	DWA	10	7.0	3615	1200	4100	140	150	60	120	100	400	8	40	400	10	3000
	10	TA,LSLAR,LAR	20,15,11,25	6.9	3660	1000	550	60	40	60	20	30	500	5	50	300	10	600
	11	LSLAR, TA	15,20	6.8	3690	1000	410	40	40	40	15	40	600	3	40	400	10	800
	12	LSLAR, LAR	15,11	6.8	4335	1200	620	60	50	60	20	40	300	3	50	250	10	400
	13	LSLAR	15,14	6.9	4180	1200	470	40	40	40	20	40	1000	3	40	500	25	800
	14	LSLAR	15,14	7.0	3840	1400	1100	75	60	60	60	60	1000	5	40	500	20	800
2	1	TA, QC	21,20,25	6.0	2940	800	550	50	50	150	60	60	1000	5	40	300	20	800
	2	LAR, LSLAR	11,15b,12	6.9	3700	1000	440	40	40	60	20	40	600	5	50	300	10	4000
	3	TA	20	7.0	3310	1000	370	50	50	80	30	50	600	5	50	300	15	400
	4	TA	20	6.8	3140	800	350	40	50	80	40	50	800	6	40	100	10	1000
	5	TA, QC	20,25	6.8	3515	1000	600	50	40	100	40	50	800	6	50	250	20	700
	6	TA, QC	20,25	6.7	2960	1000	550	50	40	100	40	50	600	6	50	250	20	500
	7	TA, LSLAR	20,15	6.8	3580	1000	530	50	40	100	40	50	800	6	50	600	15	1200
	8	TA	20	6.8	2825	1000	400	45	40	80	40	50	600	6	50	250	15	1000
	9	TA, LSLAR	20,15b	6.8	3065	1000	400	40	40	80	30	50	600	6	50	150	10	1000
	10	TA	20	6.9	3200	1000	420	45	40	60	40	50	800	6	50	400	15	1000
	11	TA, LSLAR, LAR	21,15b,11d	7.0	3345	1000	590	40	40	60	40	50	800	5	50	400	15	1500
	12	TA	20,21	6.3	2550	700	350	40	40	80	50	60	1000	6	50	250	10	1000
	13	TA, QC	20,25	7.0	3595	1100	700	50	40	60	30	50	800	6	50	150	15	1000
	14	LSLAR, LAR	11d,15b,21	6.8	3640	1000	450	40	40	60	15	30	500	6	50	250	10	1000

**Analytical Method**

pH (H<sub>2</sub>O)\*            20:100 Soil: H<sub>2</sub>O  
 Total Nitrogen (N)\*    Kjeldahl digest  
 Other elements        Emission spectroscopy<sup>+</sup>

(Detection limits ppm in brackets with a range to 10000 ppm)

P (100), Mn (10), Cu (1), Zn (20), Pb (10)  
 Co (5), Ni (5), V (10), Be (1), Ga (1)  
 Na (50), Li (1), K (5)

\* CSIRO Division of Soils, Brisbane

<sup>+</sup> Australian Mineral Development Laboratories, Adelaide

Appendix 3. (continued)

Crop Rotation Experiment

Rep No	Treatment No	Parent Material	Soil Unit	pH	Total N ppm	Total Elements ppm												
						P	Mn	Cu	Zn	Pb	Co	Ni	V	Be	Ga	Na	Li	K
3	1	HDWA,GD	18,29	7.2	3145	1100	2500	110	110	60	200	150	600	6	50	800	20	8000
	2	LSLAR,GD	15b29,28	6.8	3105	1100	970	80	70	60	80	100	600	6	50	700	10	10000
	3	LSLAR,LAR	15b,11d	7.0	3770	1000	340	30	30	150	15	20	600	6	50	400	8	3000
	4	LSLAR,Qc	15b,25	7.0	3475	1100	450	40	40	400	20	20	600	6	30	800	15	2000
	5	GD	29	6.9	2845	1000	1200	85	60	150	80	40	500	6	40	4000	10	>10000
	6	GD	29,28	6.9	2655	1000	1200	90	70	30	40	30	300	6	20	2500	10	>10000
	7	Gd,HDWA	29,18	6.8	2380	1000	1700	110	80	60	150	60	500	8	40	4000	20	>10000
	8	HDWA,LAR	18,11d	7.0	3095	1200	2500	90	100	60	150	60	500	5	40	600	20	4000
	9	GD	28	6.8	2515	1100	770	70	50	60	20	20	500	5	30	500	8	10000
	10	GD	28,29	6.8	2370	1000	1200	80	60	80	50	40	500	10	30	1000	10	>10000
	11	LSLAR,TA,Qc	15b,21,25	6.9	3020	1000	550	40	40	60	30	15	600	5	40	800	15	>10000
	12	GD	28	6.9	2500	1000	950	75	60	80	40	15	400	6	40	1200	15	>10000
	13	LSLAR,Qc,GD	15b,28,25	6.9	3020	1100	540	50	40	60	30	10	400	4	40	700	15	3000
	14	LSLAR,LAR	11d,12,18	7.1	4975	1100	460	40	40	40	15	10	500	3	50	8000	15	1000
4	1	GD,HDWA	27,17,28	7.1	2550	1000	1700	100	80	60	200	50	400	10	20	3000	20	>10000
	2	GD,HDWA	27,28,17	7.1	3235	1200	1500	85	70	60	200	50	500	10	20	5000	25	>10000
	3	GD	27	6.9	1945	700	800	90	60	60	60	50	600	10	30	4000	10	>10000
	4	GD	27,28,30	6.5	1915	800	1100	60	60	60	80	50	300	10	30	5000	15	>10000
	5	GD	29	6.7	2855	1000	990	100	70	20	50	30	100	5	20	5000	15	>10000
	6	GD,HDWA	27,27sh,17	7.3	2690	800	1500	110	80	20	50	30	150	5	20	3000	20	>10000
	7	HDWA	17	7.3	3000	1000	1500	110	100	20	60	40	100	6	30	800	15	>10000
	8	GD	29,27	7.1	2785	1000	880	80	70	20	50	30	200	6	30	2500	10	>10000
	9	GD	29,27,28	6.7	1815	1000	1300	70	40	30	50	20	150	6	30	6000	20	>10000
	10	GD	29,29sh	6.6	1860	700	900	70	60	20	40	15	80	6	20	6000	10	>10000
	11	GD	27	6.8	1870	700	880	75	70	15	60	40	300	6	30	6000	15	>10000
	12	GD	29,27	6.6	2225	800	1100	70	70	15	60	40	300	6	30	7000	15	>10000
	13	GD	29,27	6.7	2595	700	820	90	70	15	60	40	200	6	30	4000	15	>10000
	14	GD	29,29sh,30	6.7	1815	700	1700	50	50	20	80	20	150	8	20	10000	15	>10000

Appendix 3. (continued)

Grazing experiment

Rep No	Treatment No	Parent Material	Soil Unit	pH	Total N ppm	Total Elements ppm												
						P	Mn	Cu	Zn	Pb	Co	Ni	V	Be	Ga	Na	Li	K
I	1	DWA,Qb	10,23	7.0	3235	1300	1700	140	220	20	400	80	300	10	20	700	20	>10000
	2	WA,Qb	24,1,6,7,8	7.1	4190	1100	2500	75	100	15	60	60	150	6	20	2000	20	>10000
	3	WA,Qb	1,4,7,23	7.1	3460	1100	4000	90	140	10	150	60	150	8	20	4900	25	>10000
	4	WA	5,6,8,7	7.0	3955	1100	1900	80	100	10	20	60	60	8	20	700	15	>10000
	5	WA,Qb	23,1,3,7	7.0	2995	1000	6400	100	170	10	200	80	100	8	20	3900	30	>10000
	6	Qb,WA	24,6,7,8	6.9	3835	1300	5600	110	150	10	100	100	100	6	30	700	15	>10000
	7	WA,Qb	1,24,6	7.2	3890	1100	2900	70	100	10	80	40	200	7	30	2000	20	3000
	8	WA,Qb	1,3,8,23	7.1	3745	1200	5800	110	180	10	150	60	200	4	20	1500	20	>10000
	9	Qb,LSLAR,DWA	23,10,13,16	6.7	2715	1200	3700	100	110	10	80	30	150	4	20	1500	20	10000
	10	LSLAR,HDWA,Qb	13,12,16	6.7	3955	1200	1900	75	60	10	20	20	150	5	20	500	15	10000
	11	LSLAR	13,12	6.9	3625	1200	2600	70	70	10	40	20	150	3	20	300	10	10000
	12	LSLAR,HDWA,Qb	13,24,12,17	6.9	3090	1200	5000	90	110	10	40	40	150	3	30	2600	15	>10000
II	1	WA	2,9	6.9	3405	800	1500	70	90	15	30	40	150	6	30	2400	15	>10000
	2	WA	5,2,6	7.2	3305	800	1400	60	70	10	30	50	150	6	30	700	15	>10000
	3	WA	6,2,9,5	7.2	3765	800	1800	75	110	15	60	60	150	8	30	1300	20	>10000
	4	Qc,Qb,HDWA	25,23,16	6.9	2390	1100	1900	70	80	15	40	20	200	5	30	1500	20	>10000
	5	WA,HDWA,Qb	9,17,24	7.3	3780	1000	1600	90	110	15	40	40	300	3	30	1200	20	>10000
	6	WA,Qb	5,6,24,7,8	7.1	3090	1000	1700	90	70	10	20	60	50	4	30	800	15	>10000
	7	Qc,Qb	25,23	6.9	2630	1100	3000	100	90	40	200	60	300	6	20	1500	20	>10000
	8	HDWA,LSLAR,WA	17,13,16	7.0	3100	1600	1800	80	90	10	20	20	100	4	20	700	15	>10000
	9	WA,HDWA,Qb	17,6,5,4,24	6.9	3180	1000	2600	90	110	5	40	50	50	6	30	1000	15	>10000
	10	WA,Qb	6,24,5	7.2	3155	800	2300	80	80	5	40	80	100	6	30	1500	15	>10000
	11	HDWA,Qc	16,17,25	6.9	3130	1100	1400	60	60	40	40	40	400	5	30	500	10	>10000
	12	WA,HDWA	9,17	7.2	3485	1000	1800	90	120	10	40	40	200	6	30	800	15	>10000
III	1	Qc	25	6.9	2740	1100	2900	100	100	15	80	50	300	5	20	1000	15	10000
	2	Qa,HDWA	22,19,17	7.5	2720	700	1500	60	60	5	40	20	150	5	20	2500	20	>10000
	3	HDWA	17	7.1	3120	1000	1800	80	100	20	40	30	300	5	30	1000	20	>10000
	4	HDWA,WA	17,6	7.2	3340	1000	2200	90	100	10	30	30	100	5	20	1000	20	>10000
	5	HDWA,WA	17,9,6	7.3	2740	1000	2000	90	100	10	50	40	100	6	20	600	15	>10000
	6	Qc,HDWA,Qa	26,25,17,22	7.2	3160	1000	1400	60	60	20	30	20	100	4	20	1000	20	>10000
	7	Qc	25,26	7.2	2600	1000	2600	90	100	20	80	40	200	6	20	2000	25	>10000
	8	HDWA,Qa	19,17,22	7.4	1460	800	750	70	60	20	30	15	200	5	20	800	10	5000
	9	HDWA,Qc,WA	17,25,26,6	7.3	2890	1000	1700	80	80	20	60	40	200	6	30	1000	20	>10000
	10	HDWA,Qc,Qa	22,19,17,25	7.4	3180	800	690	40	50	15	30	15	200	4	20	600	10	>10000
	11	HDWA,Qa	19,22,17,24	7.5	2900	1000	1500	50	40	30	50	20	300	6	30	2500	15	10000
	12	HDWA,Qa	19,17,22	7.5	3675	800	750	40	40	20	30	15	100	4	20	1000	10	10000

**Appendix 4.** Descriptions of soil cores from the 1977 extension to the crop rotation experiment (map 12).

*Soil core: 1*

**Location:** Middle of replication 1  
**Parent material:** Nerangy Creek alluvium

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	8.5	0-4	Very dark brown (7.5YR 3/2) light medium clay; moderate (?) fine blocky 5-10mm, plastic moist; few sand grains and fine black ironstone gravel; many roots. Gradual to:
B <sub>21</sub>	8.5	4-20	Dark brown (7.5YR 3.5/4) medium heavy clay; moderate blocky (10-12mm), plastic moist; few sand grains, fine silica and ironstone gravels; many grass roots. Gradual to:
B <sub>22</sub>	9.0+	20-90	Brown (7.5YR 4/4) medium heavy clay; dense blocky peds, firm moist; few sand grains, fine silica and ironstone gravels; very few fine CaCO <sub>3</sub> nodules below 50cm; grass roots to 90cm. Gradual to:
B <sub>3</sub>	9.0+	90-110	Yellowish brown (10YR 4/6) medium heavy clay; dense blocky peds, very firm moist; few sand grains, fine ironstone gravels, Mn segregations, CaCO <sub>3</sub> nodules, and charcoal fragments. Diffuse to:
B <sub>3</sub> -C	9.0+	110-160	Yellow brown (10 YR 5/6) medium heavy clay, lenticular peds and slickensides, very firm moist, few sand grains, feldspar and ironstone gravels, CaCO <sub>3</sub> nodules and Mn segregations. Continuing below 160cm.

**Classification**

A Factual Key: Ug 5.34  
 ASC: Epihypersodic-Endocalcareous Epipedal Brown Vertisol

*Soil core: 2*

**Location:** Middle of replication 2  
**Parent material:** Nerangy Creek alluvium over truncated weathered granodiorite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	7.5	0-5	Very dark brown (7.5YR 3/2) light medium clay; moderate fine (?) blocky 5-10mm, plastic moist; few sand grains and fine black ironstone gravel; many roots. Gradual to:
B <sub>21</sub>	8.5	5-40	Dark brown (7.5YR 4/4) medium heavy clay; moderate (?) blocky 10-12mm, plastic moist; very few sand grains and fine black ironstone gravel; many roots. Gradual to:



B <sub>22</sub>	9.0	40-60	Brown (7.5YR 4/6), with large patches of very dark brown (7.5YR 3/2), medium heavy clay; dense blocky peds, firm moist; few sand grains, fine ironstone and quartz gravels; diffuse and nodular CaCO <sub>3</sub> . Sharp to:
D	9.0	60-90	Brown (7.5YR 4/6) with large patches of reddish brown (5YR 4/6) and much white speckling, sandy light clay; massive, firm to friable moist; much grit of weathering minerals; (?) weathered granodiorite continuing below 90cm; roots to 85cm.

### Classification

A Factual Key: Ug 5.32  
 ASC: Endocalcareous - Endohypersodic Epipedal Brown Vertosol

*Soil core: 3a*

**Location:** Middle of larger area of replication 3  
**Parent material:** Nerangy Creek alluvium over alluvium from granodiorite

Horizon	Field pH	Depth cm	Morphology
A <sub>1p</sub>	6.5	0-15	Very dark brown (7.5YR 3/2) light clay; moderate (?) blocky 5-10mm, friable to firm moist; few sand grains; fine black ironstone gravel; fine CaCO <sub>3</sub> modules and grass roots. Gradual to:
B <sub>21</sub>	6.8	15-30	Dark brown (7.5YR 3/4) medium heavy clay; moderate blocky 8-10mm, firm moist; few sand grains, fine black ironstone gravel; fine CaCO <sub>3</sub> nodules and diffuse patches, and grass roots. Gradual to:
B <sub>22</sub>	9.0+	30-60	Brown (7.5YR 4/4) with patches of dark brown (7.5YR 3/4) medium heavy clay; dense blocky peds, very firm moist; few fine ironstone gravel; quartz gravel (15mm), CaCO <sub>3</sub> nodules and grass roots. Diffuse to:
B <sub>3-C</sub>	9.0+	60-90	Brown (7.5YR 4/4) with patches of yellowish brown (7.5YR 3/4) medium heavy clay; dense blocky peds, very firm moist; common gravels of quartz, ironstone, CaCO <sub>3</sub> nodules and Mn nodules (3mm); grass roots to 80cm. Diffuse to:
D	9.0+	90	As above but with common white weathering (?) feldspar (?) alluvium derived from granodiorite continuing below 90cm.

### Classification

A Factual Key: Ug 5.32  
 ASC: Epicalcareous-Epihypersodic Epipedal Brown Vertosol

**Soil core: 3b**

**Location:** Middle of smaller area of 3b  
**Parent material:** Nerangy Creek alluvium

<b>Horizon</b>	<b>Field pH</b>	<b>Depth cm</b>	<b>Morphology</b>
A <sub>1p</sub>	8.0+	0-10	Very dark brown (7.5YR 3/2) light medium clay; moderate (?) fine blocky 5-10mm, friable to plastic moist; few sand grains; fine black ironstone gravel and grass roots. Gradual to:
B <sub>21p</sub>	8.5+	10-30	Dark brown (7.5YR 3/4) with very dark brown (7.5YR 3/2) patches of A <sub>1p</sub> ; (?) moderate blocky 10-15mm, plastic moist; few sand grains, fine ironstone gravel; and Mn concretions (102mm); very few soft CaCO <sub>3</sub> patches, few grass roots. Diffuse to:
B <sub>22</sub>	9.0	30-60	Brown (7.5YR 4/6) medium heavy clay; (?) moderate blocky 10-20mm, moist plastic; diffuse soft CaCO <sub>3</sub> and in concentrated patches; few fine ironstone gravel, Mn segregations, charcoal and grass roots. Gradual to:
B <sub>23</sub>	9.0	60-90	Brown (7.5YR 4/6) medium heavy clay; very few slickensides evident, hard dense peds; common ironstone gravel <8mm, few Mn segregations, soft CaCO <sub>3</sub> in patches, charcoal, no roots. Not penetrable by tube but continuing below 90cm.

**Classification**

A Factual Key: Ug 5.3 (?4)  
ASC: Epicalcareous-Epihypersodic Epipedal Brown Vertosol

**Soil core: 4**

**Location:** Middle of replication 4  
**Parent material:** Nerangy Creek alluvium

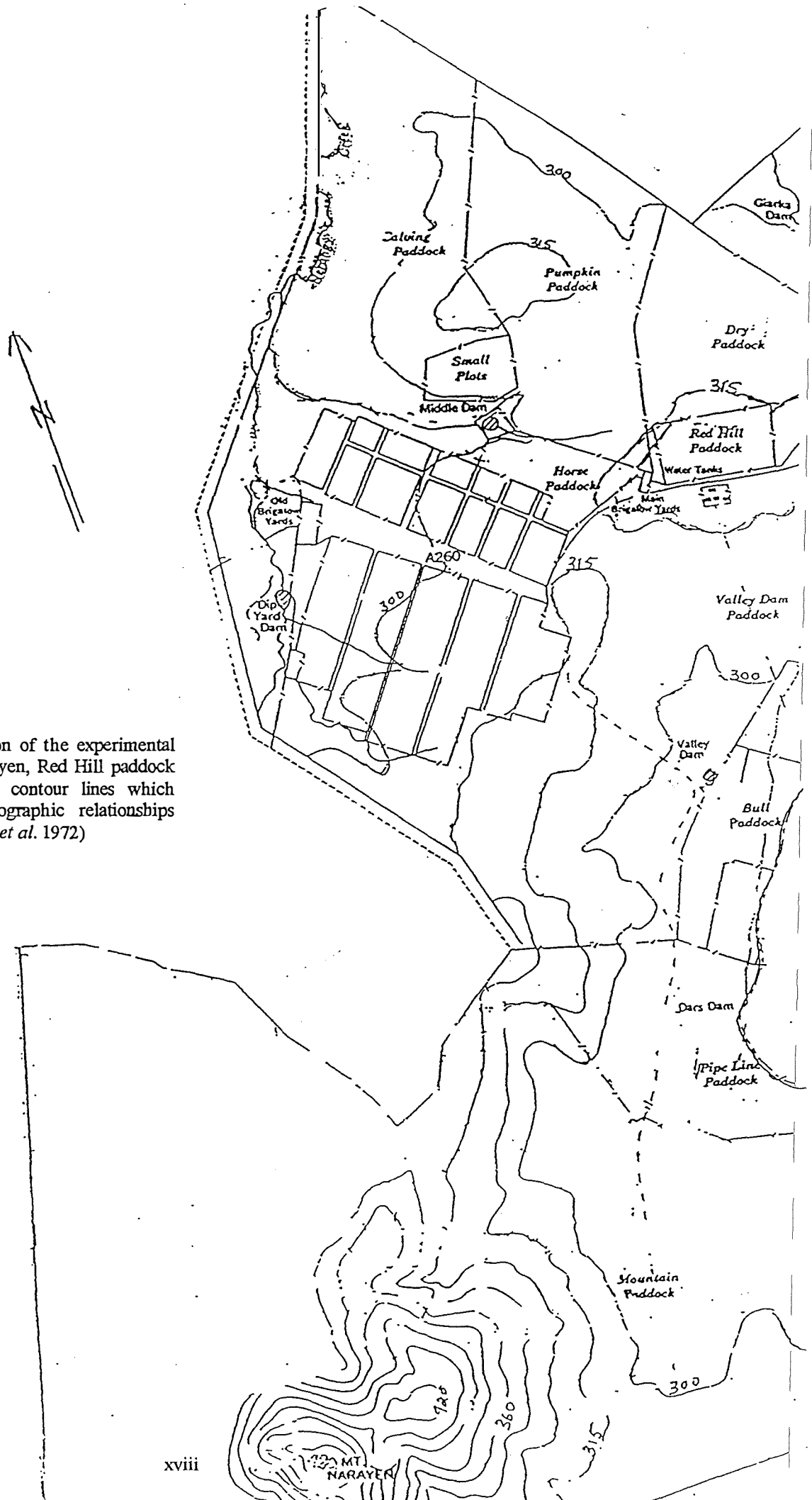
<b>Horizon</b>	<b>Field pH</b>	<b>Depth cm</b>	<b>Morphology</b>
A <sub>1p</sub>	6.5	0-12	Very dark brown (7.5YR 3/2) light medium clay; moderate subangular blocky and blocky 8-10mm, friable to plastic moist; few fine black ironstone gravels and grass roots. Gradual to:
A <sub>1</sub> /B <sub>2p</sub>	7.0	12-30	Dark brown (7.5YR 3/4) with very dark brown (7.5YR 3/2) patches, medium heavy clay; moderate blocky 10-15mm, plastic moist; few ironstone gravels; lateritic gravel, charcoal and grass roots. Gradual to:
B <sub>21</sub>	9.0	30-60	Dark brown (7.5YR 3/4) medium heavy clay; slickensides evident, very dense peds, very firm moist; few ironstone and laterite gravels, soft CaCO <sub>3</sub> patches; very few grass roots. Diffuse to:

B <sub>22</sub>	9.0+	60-90	Brown (7.5YR 4/6) medium heavy clay; slickensides evident, very dense peds; few ironstone and laterite gravels, soft CaCO <sub>3</sub> patches. Diffuse to:
B <sub>23</sub>	9.0	90-160	Brown (7.5YR 5/4-5/6) medium heavy clay; slickensides evident, very dense peds; hard dry; common ironstone, laterite and silcrete gravels; field pH decreasing to 8.5 below 120; horizon continuing below 160cm.

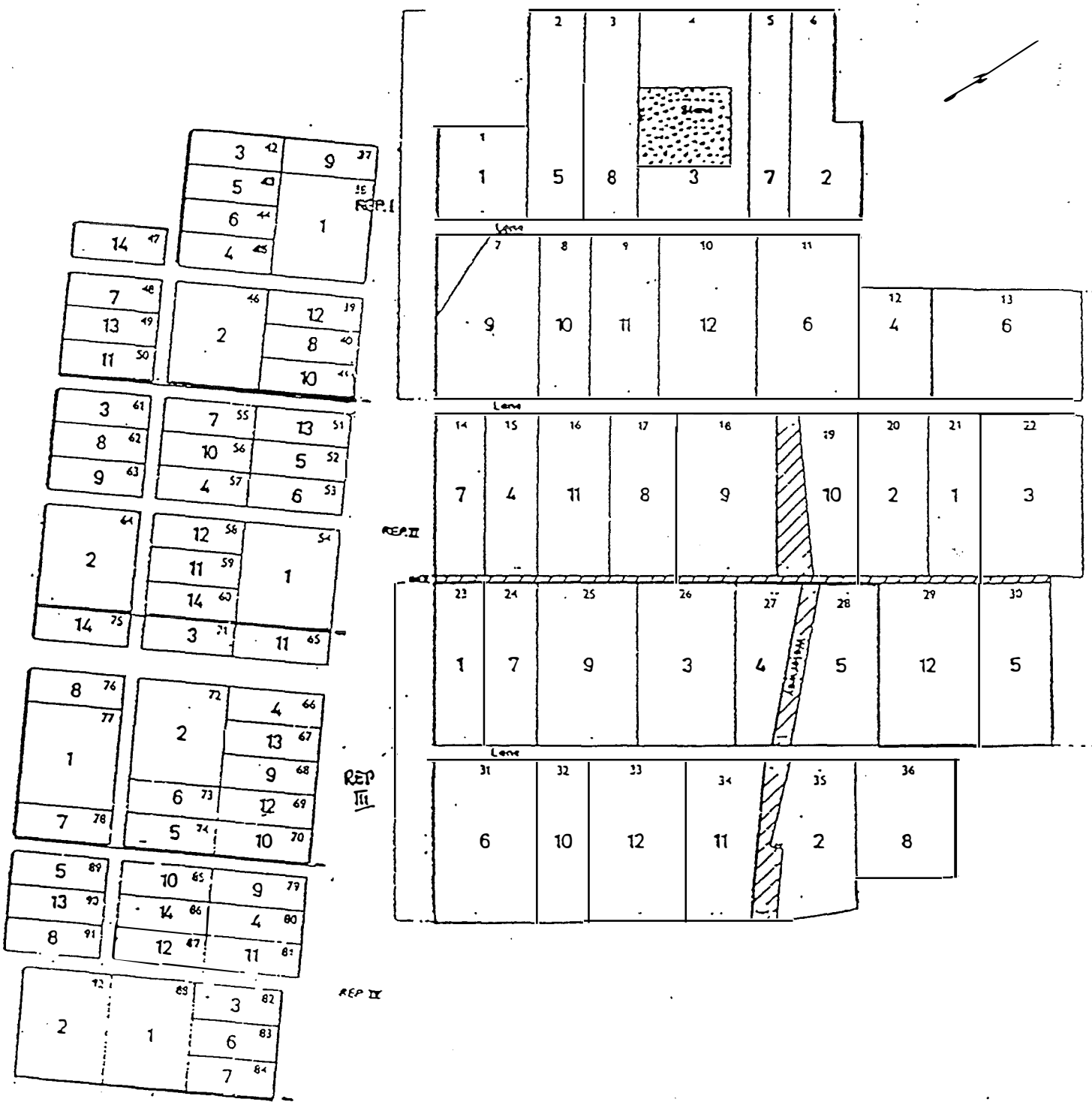
**Classification**

A Factual Key:  
ASC:

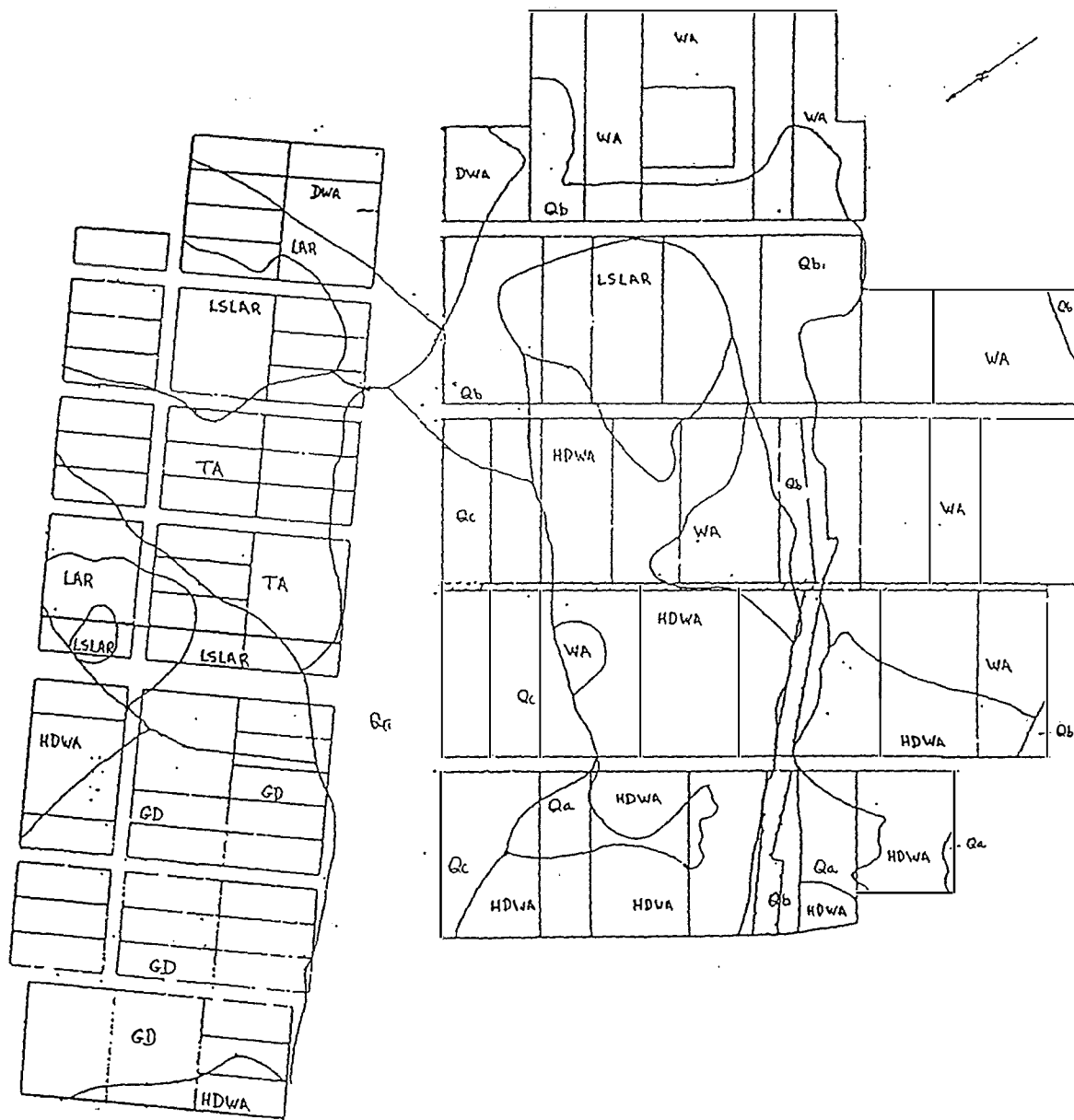
Ug 5.34  
Epihypersodic-Endocalcareous Epipedal Brown Vertosol



Map 1.  
 Plan showing the location of the experimental plots relative to Mt Narayan, Red Hill paddock and the 300 and 315m contour lines which indicate the major topographic relationships (Adapted from Coaldrake *et al.* 1972)



Map 2. Experimental layout showing treatments, replications and plot numbers (1-92) for the Crop Rotation and Grazing Experiments (del. G.W. McHarg)



Map 3. Distribution of soil parent materials.  
Scale 1:3960

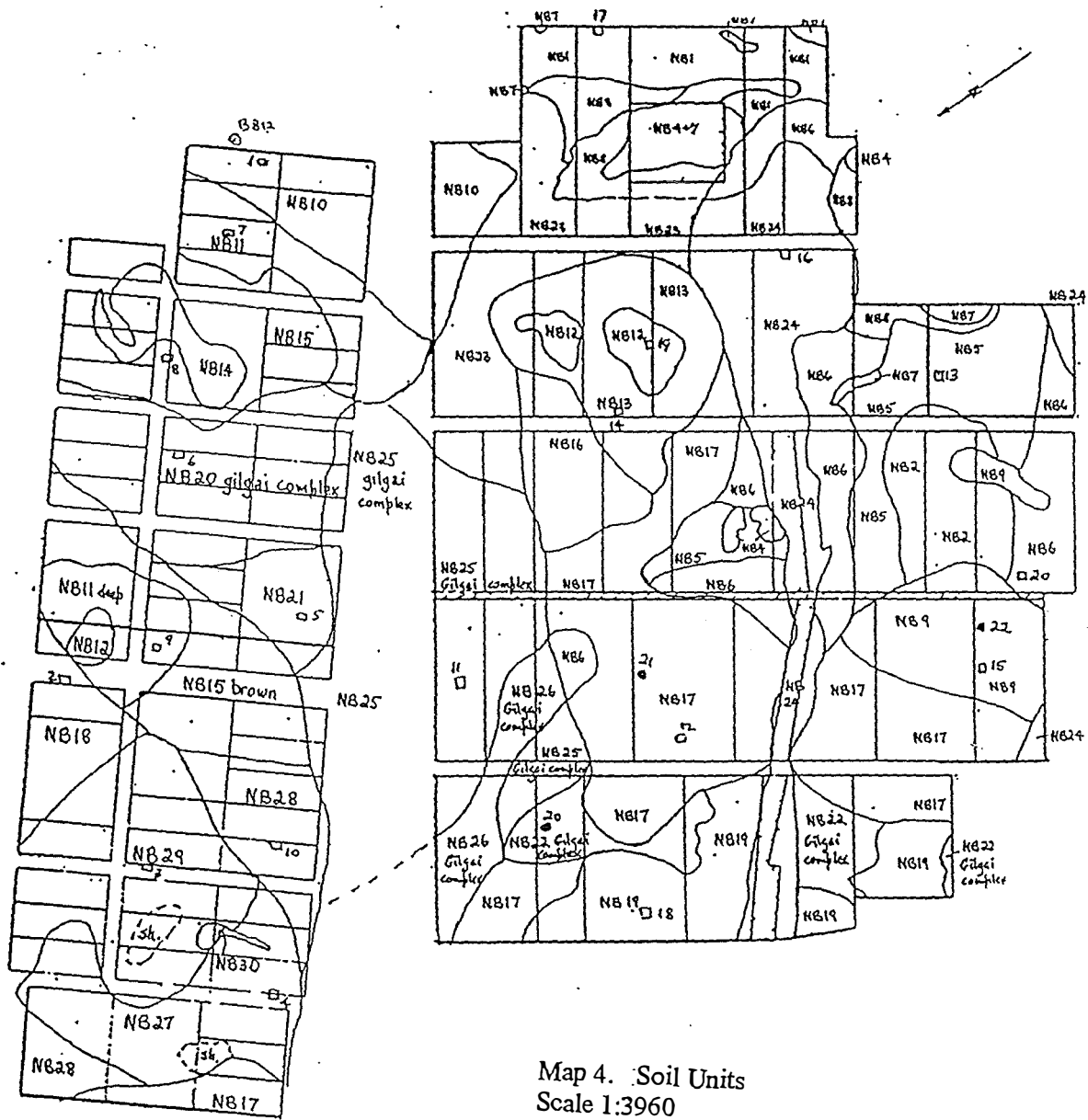
Pedologist C.H. Thompson 1968

WA Weathered andesitic rocks  
 DWA Deeply weathered andesitic rocks  
 LAR Lateritized andesitic rocks  
 LSLAR Lateritized sediments over  
 lateritized andesitic rocks  
 HDWA Hillslope deposits over weathered  
 andesitic rocks

TA Tertiary alluvia  
 Q Quaternary alluvia  
 (a) over weathered andesitic rocks.  
 (b) over truncated soils on Tertiary alluvia  
 (c) local alluvia >1.2m thick  
 GD Granodiorite

Map 4. Distribution of soil units  
Legend

	Soils on weathered andesitic rocks
NB1	Narayan Brigalow 1
NB2	Narayan Brigalow 2
NB3	Narayan Brigalow 3
NB4	Narayan Brigalow 4
NB5	Narayan Brigalow 5
NB5	Narayan Brigalow 6
NB7	Narayan Brigalow 7
NB8	Narayan Brigalow 8
NB9	Narayan Brigalow 9
	Soils on deeply weathered andesitic rocks
NB10	Narayan Brigalow 10
	Soils on lateritized andesitic rocks
NB11	Narayan Brigalow 11
NB11	Narayan Brigalow 11 deep phase
	Soils on lateritized sediments over lateritized andesitic rocks
NB12	Narayan Brigalow 12
NB13	Narayan Brigalow 13
NB14	Narayan Brigalow 14
NB15	Narayan Brigalow 15
NB15	Narayan Brigalow 15 brown phase
	Soils on hillslope deposits on weathered andesitic rocks
NB16	Narayan Brigalow 16
NB17	Narayan Brigalow 17
NB18	Narayan Brigalow 18
NB19	Narayan Brigalow 19
	Soils on Tertiary alluvia
NB20	Narayan Brigalow 20 gilgai complex
NB21	Narayan Brigalow 21
	Soils on Quaternary alluvia
NB22	Narayan Brigalow 22 gilgai complex
NB23	Narayan Brigalow 23
NB24	Narayan Brigalow 24
NB25	Narayan Brigalow 25 gilgai complex
NB26	Narayan Brigalow 26
	Soils on granodiorite
NB27	Narayan Brigalow 27
NB27	Narayan Brigalow 27 shallow phase
NB28	Narayan Brigalow 28
NB29	Narayan Brigalow 29
NB29	Narayan Brigalow 29 shallow phase
NB30	Narayan Brigalow 30



Map 4. Soil Units  
Scale 1:3960

Pedologist: CH Thompson 1968

- Soil Sample Sites
- CSIRO profile samples
  - DPI soil sites
  - CSIRO 0-10cm sites

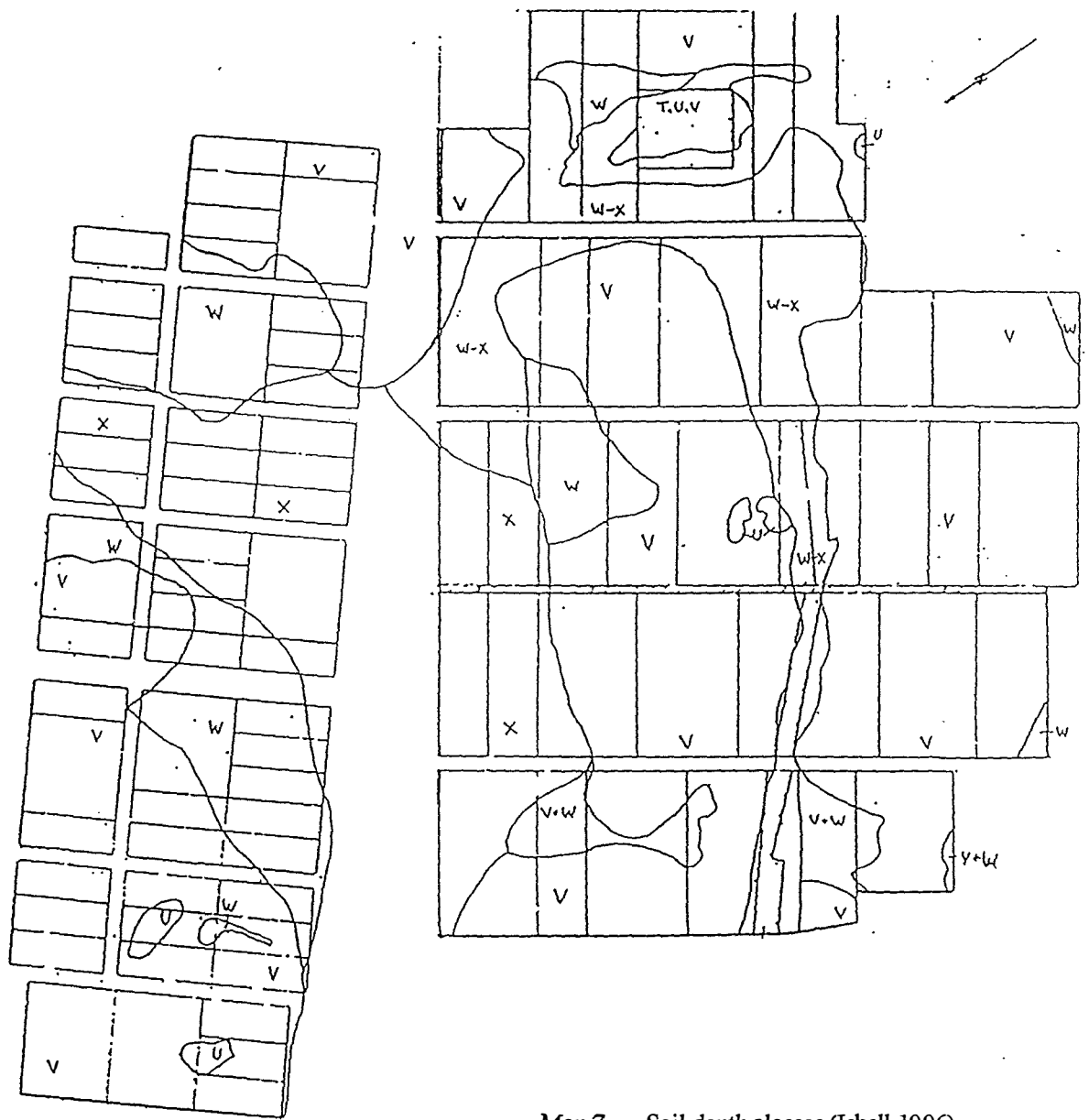


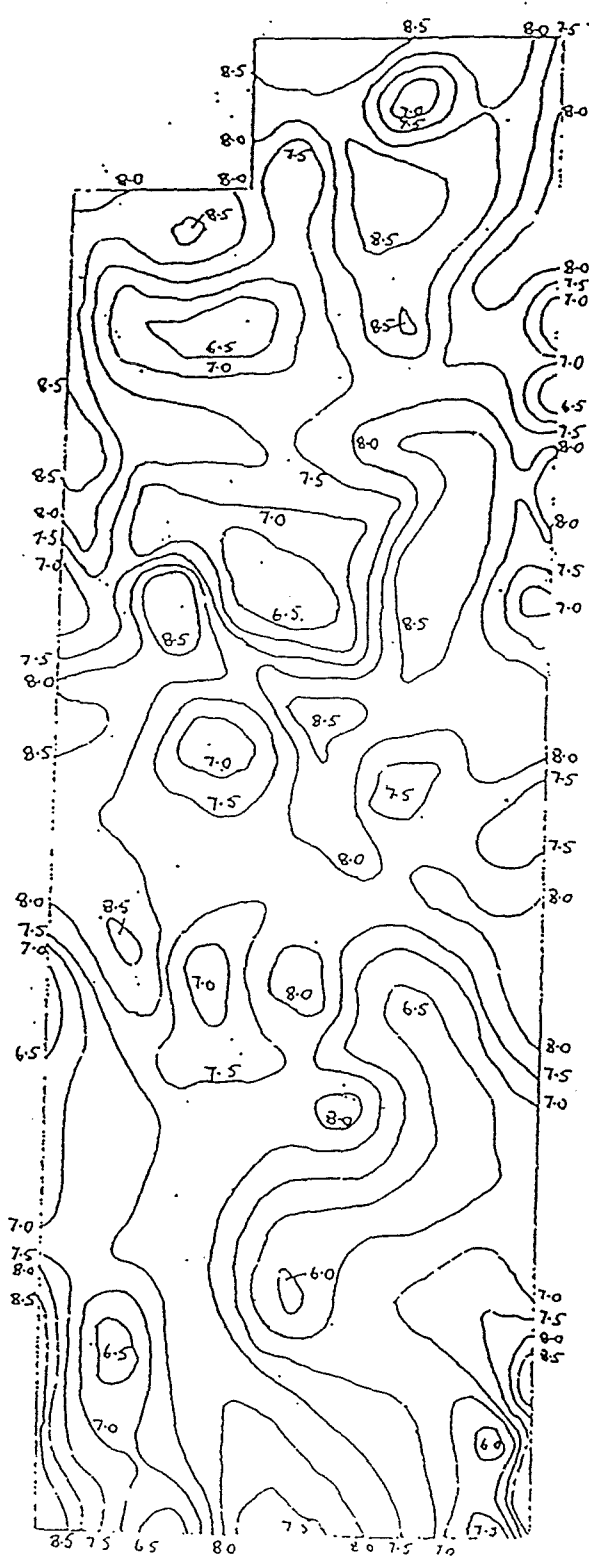


Map 6. Distribution of soil units classified to subgroup level of the Australian Soil Classification Legend

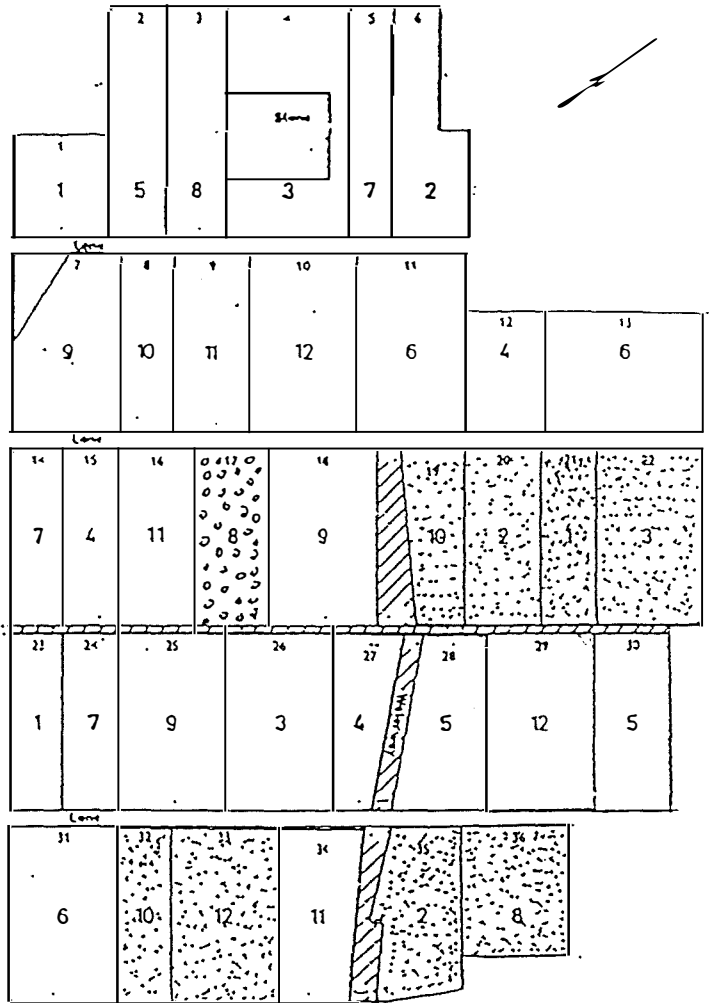
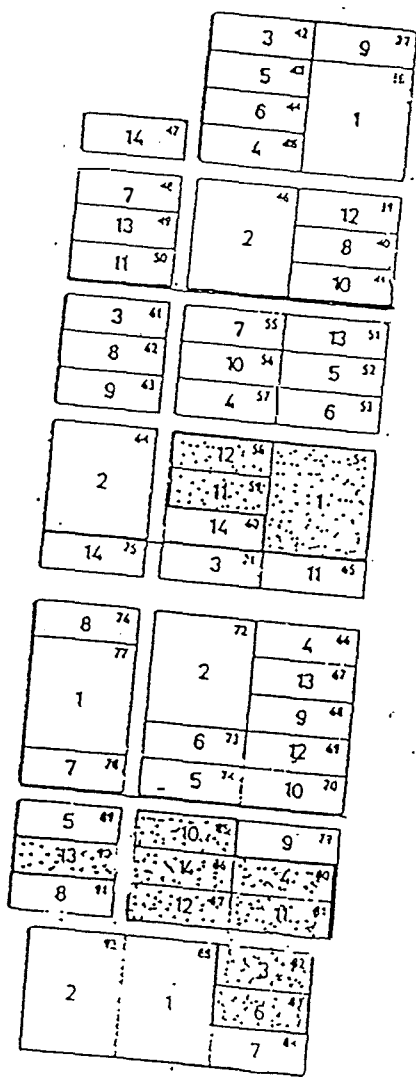
VEAMGSGL	Endo-acidic mottled Epipedal Aquic Vertosol
VEAAEIFZ	Endocalcareous Self-mulching Red Vertosol
VEABGSFZ	Endocalcareous Epipedal Brown Vertosol
VEABE1GM	Epicalcareous Endohyposodic Self-mulching Brown Vertosol
VEADGSCD	Haplic Epipedal Grey Vertosol
VEADGSFZ	Endocalcareous Epipedal Grey Vertosol
VEAEGSFY	Epicalcareous Epipedal Black Vertosol
VEAEGSCD	Haplic Epipedal Black Vertosol
VEAEGSFZ	Endocalcareous Epipedal Black Vertosol
SOADESDC	Manganic Subnatric Grey Sodosol
SOAEESCV	Hypocalcic Subnatric Black Sodosol
CHAAAHCD	Haplic Eutrophic Red Chromosol
CHAACVCD	Haplic Hypocalcic Red Chromosol
CHAACVEO	Sodic Hypocalcic Red Chromosol
CHABCVEO	Sodic Hypocalcic Brown Chromosol
CHADAHCD	Haplic Eutrophic Grey Chromosol
CHADCVEO	Sodic Hypocalcic Grey Chromosol
CHAEAHEX	Vertic Eutrophic Black Chromosol
CHAECVCD	Haplic Hypocalcic Black Chromosol
CHAEBDEO	Sodic Calcic Black Chromosol
FEAABCCD	Haplic Calcareous Red Ferrosol
FEAABCED	Sodic Calcareous Red Ferrosol
DEAACQEX	Vertic Hypercalcic Red Dermosol
DEAABDEX	Vertic Calcic Red Dermosol



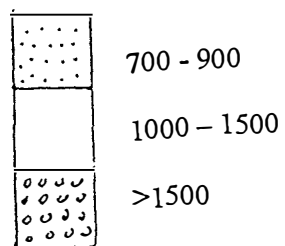


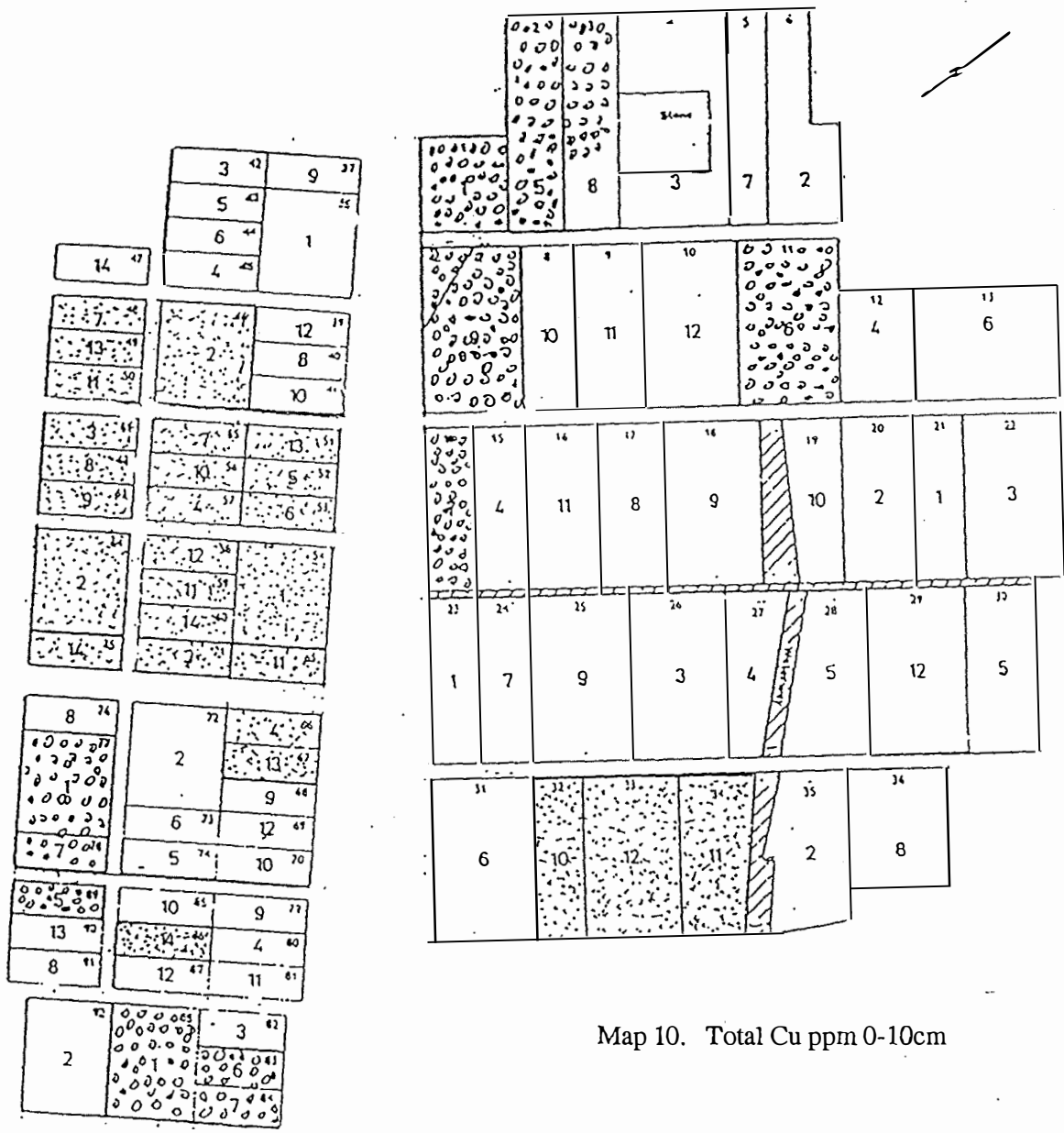


Map 8. Computer-produced map showing calculated isopleths for field pH of 0-2cm depth in the crop rotation experiment

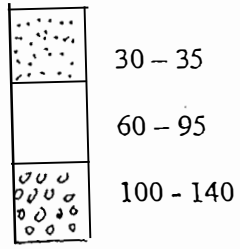


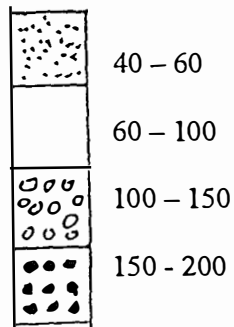
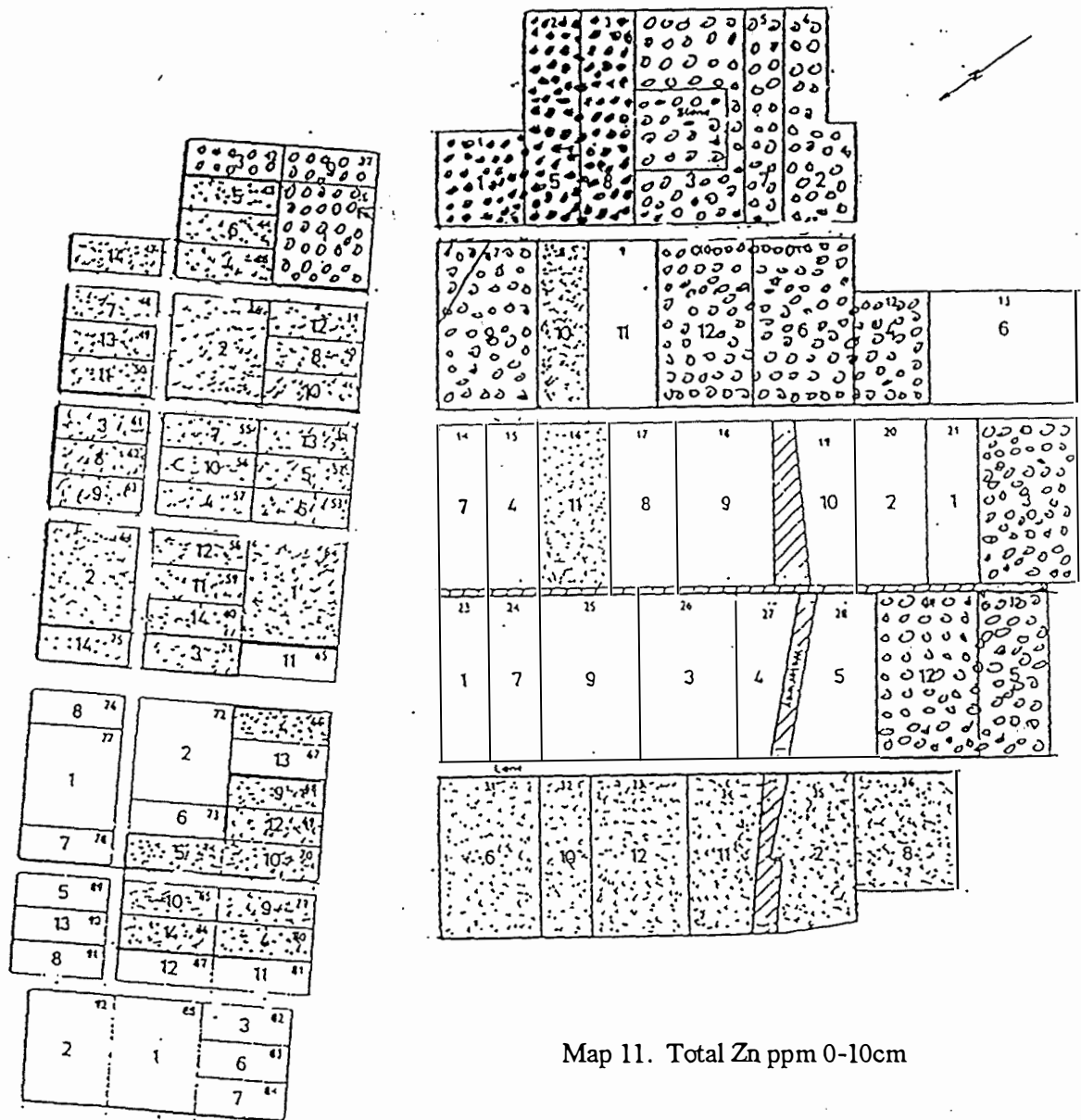
Map 9. Total P ppm 0-10cm





Map 10. Total Cu ppm 0-10cm







Map 12. Plan of 1977 extension to the A260 Crop Rotation Experiment, immediately downslope of Rep 4 (del. J.R. Marchant)

⊗ soil cores

