

SOILS OF THE COBAR- BARNATO REGION, NSW

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FOREWORD

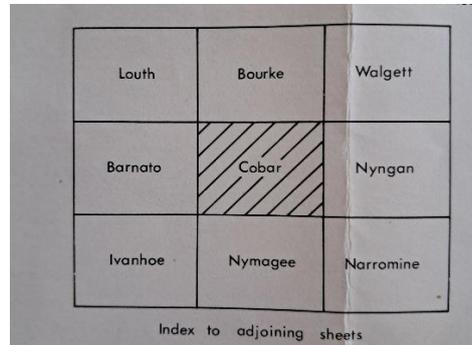
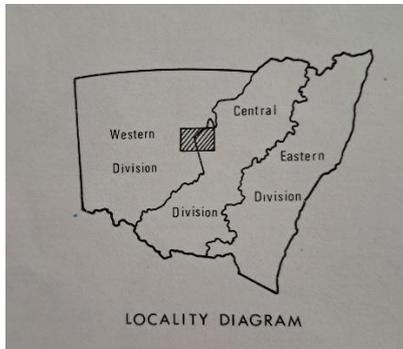
I wrote this paper in about 1980, but it has languished forgotten in my collection of nostalgic papers until 2025. It was typewritten on foolscap paper, but by chance a friend was able, with the assistance of AI, to convert it to an A4 Word document.

So, I have edited and updated and can hopefully make it available to anyone who may be interested.

At the time the Northcote classification of soils and the Great Soil Groups were king and were used in this paper. However, my colleague Brian Murphy has kindly ascribed corresponding Australian Soil Classifications, in Table 1.

I INTRODUCTION

The area covered in this paper comprises land mapped within the Cobar and Barnato 1:250 000 scale mapping sheets (SH55-14 and SH55-13) as defined by the then Central Mapping Authority of NSW.



Previous soil surveys in this region have been small-scale surveys by Prescott (1944), Condon (1961), Stephens (1961), Stannard (1958, 1962) and Northcote et al. (1966). Data from these maps and from extensive field survey work by the author was used to produce a soils map of the Cobar Soil Conservation District (Walker 1978), which encompasses much of the area described in this paper. Similar maps prepared by Lawrie (1974) and Thompson (1982) cover the south-eastern and eastern portions of the area. Land Systems on these sheets were mapped as part of a Western Division-wide program (Walker 1991), and these maps provide and the location and extent of these land systems, along with the most detailed descriptions of landscapes and soil and vegetation types.

So, this paper needs to be read in conjunction with the land systems maps and land unit descriptions.

The reproductions below give an overview of the more general landforms, denoted by colours:

Purple: Ranges

Orange: Hills and Footslopes

Brown: Rolling Downs and Lowlands

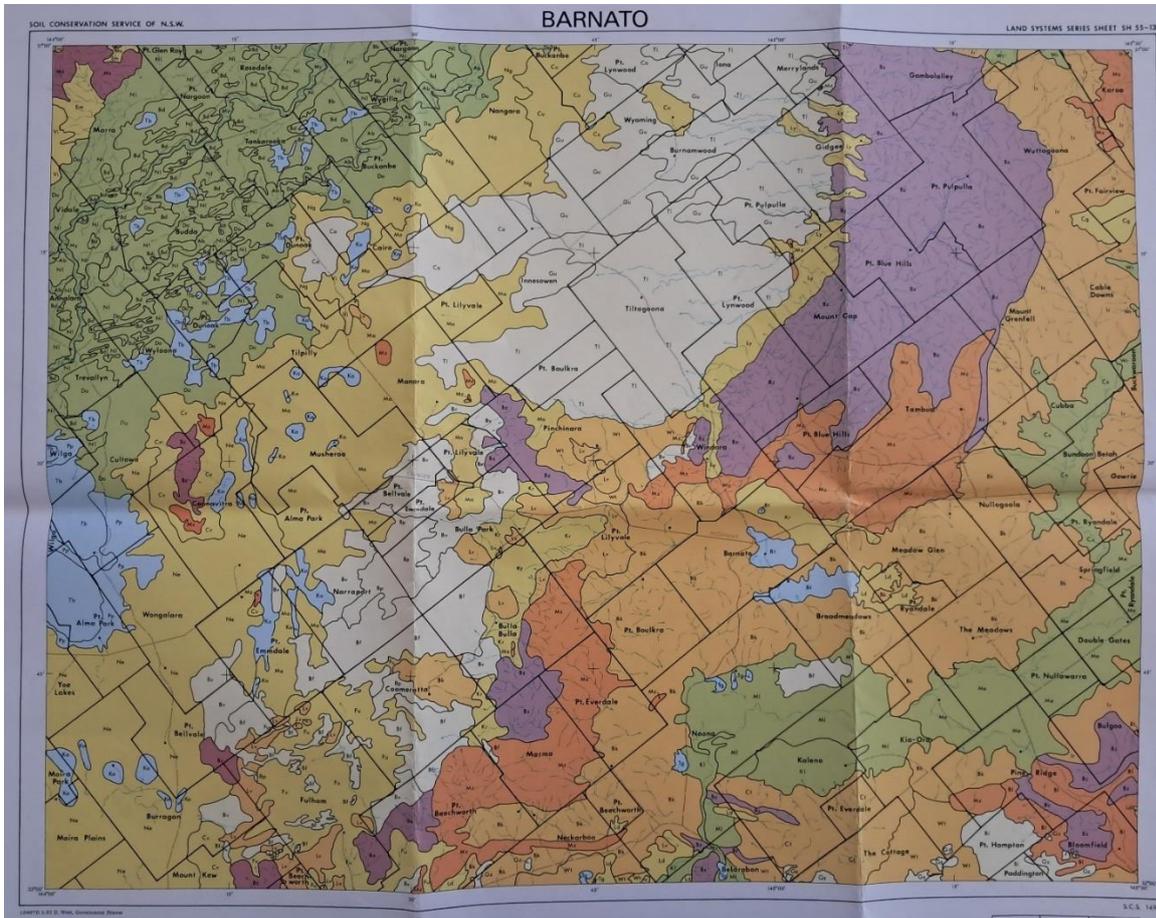
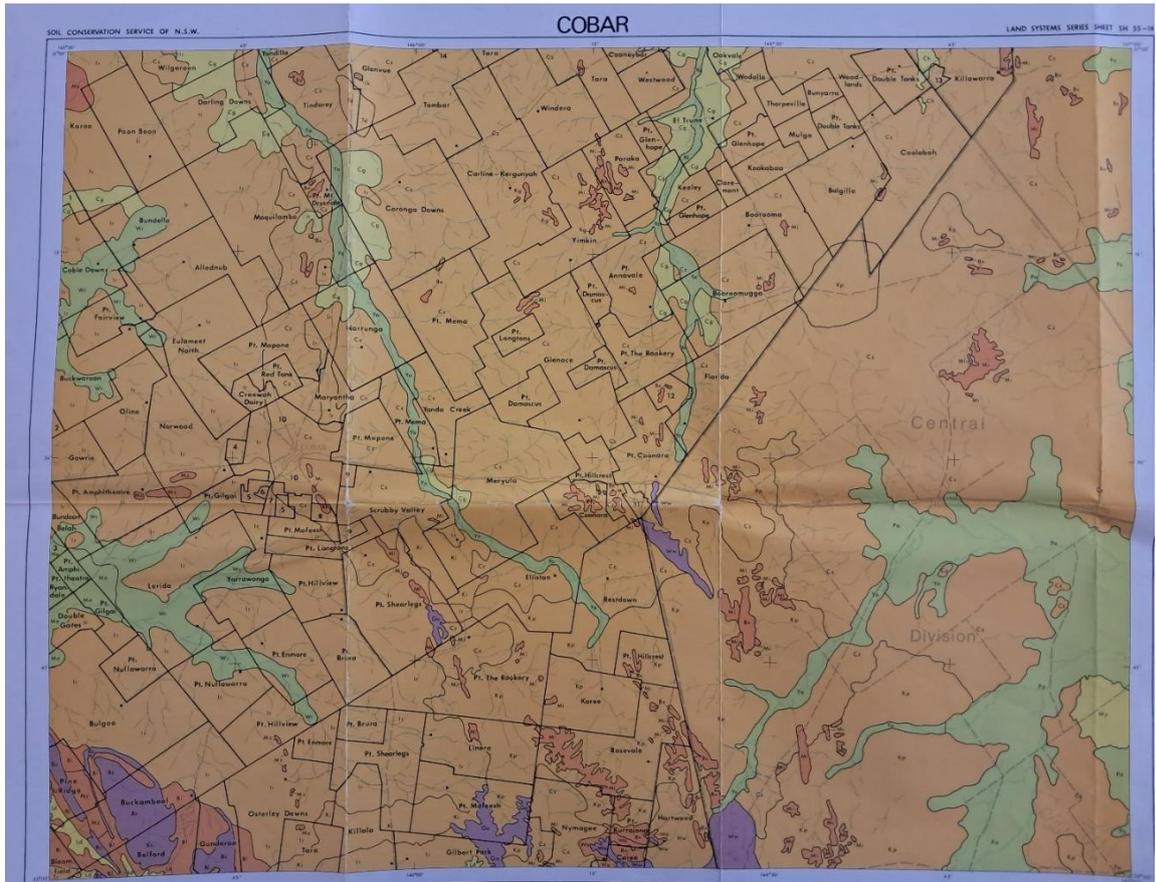
Dark yellow: Plains and Sandplains

Light yellow: Dunefields

Green: Alluvial Plains

Blue: Playas and Basins

By zooming in the maps, the land systems can be identified



II METHODS

Approximately 800 soil profiles from the area have been described in the field since 1970. Much of this work has been done in conjunction with the Western Lands Lease Management Plan programme, though two specific projects also provided considerable and valuable information. In 1974–75 a trench was dug diagonally across the area in a north-west – south-east direction, to carry the Moomba – Sydney Natural Gas Pipeline, and soil samples to depths of 2 metres were taken along this for the entire distance, with a total of 185 profiles described in Section 2, between the Darling River and near Mt Hope (Walker 1980). In 1977 a coaxial cable was laid from Broken Hill to Cobar, along the Barrier Highway, and large holes were dug at 1.4 km intervals. These were also sampled and described. Detailed soil descriptions were made at the Cobar Experimental Area (Walker 1976). Seventy pits were dug in the Cobar district in 1973–74 to characterize soils on different rock types on the Cobar Pediplain. However, most other samples were obtained by hand auger.

Location and detailed soil profile descriptions for most of these are available in the detailed on-line database for NSW soils, SALIS (Soil And Land Information System), which is accessible through the eSpade app. This also has a background land system layer. The descriptions from the Gas Pipeline and the detailed land system descriptions can be accessed through TROVE, the website of the National Library of Australia.

Soil texture was determined by hand manipulation, structure and consistence as in Northcote (1971), and colour was described and named as in the Revised Standard Soil Color Charts prepared for the Ministry of Agriculture and Forestry, Japan (1970). pH was determined using Raupach's indicator and barium sulphate. Carbonates were detected with 0.1N hydrochloric acid, and chlorides by shaking a soil–water mixture with 5% silver nitrate solution. Manganese was detected with a hydrogen peroxide solution.

For all the soils on the Cobar sheet laboratory analyses of particle size distribution (hydrometer method, Black 1965), gravel content, and pH (2.5 soil-water ratio) were made. For most of these and for the soils from the Gas Pipeline, organic matter (Tinsley 1950) and total nitrogen (Kjeldahl) contents were determined (though the latter have not been uploaded to SALIS). For several soils from the Cobar sheet, electrical conductivity, percent soluble chloride, total soluble salts (saturated soil extract), available phosphorus (Bray No. 1 method), exchangeable cations and cation exchange capacity (Tucker 1954) and bulk density (wax block method, Black 1965) were also determined. Infiltration rates were measured on a few soils near Cobar (Walker 1976).

III DISTRIBUTION AND CLASSIFICATION OF SOILS

Soils were classified into the principal profile forms of Northcote (1971), Great Soil Groups, according to the Handbook of Australian Soils (Stace et al., 1968) and soil names from the revised Australian Soil Classification (Isbell 2021). Table 1 shows soils occurring in each unit of each land system and their occurrence in the landscape, as well as further distinguishing soil characteristics. Forty principal profile forms have been identified.

For descriptive purposes, soils have been grouped into 8 Great Soil Groups. At this scale, it was not feasible to map soil types. Rather, their types, occurrences and extent are described in land systems and the units therein, and the land systems are mapped and published (Walker 1991).

LITHOSOLS

Lithosols occur throughout the region, but mainly in the central and eastern areas, on the ranges, hills and foot slopes, and on higher crests of the lowlands. They occur on Ordovician to Silurian sandstones, quartzites, shales, phyllites, conglomerates, cherts and other sedimentary rocks, on various igneous rocks in the east, and on Devonian sandstones, quartzites and conglomerates in the west. Within these landforms they occur on crests, upper slopes and scarps, and sometimes on lower slopes and minor drainage lines.

They are shallow, gravelly soils, often occurring only as small pockets between outcropping rocks or large boulders. There has been little horizon differentiation on the higher, rocky areas, but some pedological development has occurred on the lowland crests.

They have been subdivided according to colour, degree of development and texture.

a) Reddish-brown sandy soils (Uc 1).

These occur on ridges of basalt, granite and porphyry and on the scarps and upper slopes of the Devonian ranges and hills, on slopes up to 50 per cent. Those developed on the igneous rocks, particularly basalt, are slightly browner than the other soils. The soils have a sandy loam to loam texture, massive structure and are usually less than 30 cm deep, with much outcropping rock and surface stone. They are acid and often have high organic matter levels. Infiltration rates are moderate, but the shallow depths confine low water-holding capacity, and runoff can be high. There is little erosion problem due to the large proportion of surface stone.

b) Dark brown sandy soils (Uc 1).

These occur on the eastern Ordovician and Silurian hills and ranges, and occasionally on low scarps of Devonian sandstone, on slopes up to 50 per cent. They have a sandy loam texture, massive structure, are dark in colour due to a high content of organic matter and are very acid and hydrophobic. They are rarely more than 30 cm deep and occur as pockets between outcropping rocks and stone. They have low water-holding capacities and may produce high volumes of runoff. However, they are protected from erosion by the stone and rock surface cover.

c) Reddish-brown loamy soils (Um 5.51).

These occur on many lowland crests and upper slopes of the Cobar Pediplain, where slopes are up to 8 per cent. They are shallow, less than 40 cm deep and gravelly, but have

weak texture changes and weak fabric development. Texture is loam, sandy clay loam or clay loam, but sandy loams also occur. Structure is massive. Many of the soils are thought to be truncated red earths. They are acid and compact, with very low infiltration rates and produce very high volumes of runoff. They are often severely eroded by water sheeting and sometimes rilling, and large proportions remain bare of vegetation for much of the time.

d) Reddish-brown gritty soils (Uc 5.21, Uc 1.43).

These occur on low crests and mid-slopes of granite and porphyry ridges, on slopes up to 5 per cent. They are less than 60 cm deep, contain variable amounts of stone and gravel, and have coarse sandy loam texture, massive structure, and usually good vegetative cover. However, they are very susceptible to gully erosion if water is concentrated on bare areas.

e) Stony, crab-hole soils (Um 5.43).

These occupy only very small areas around the toe slopes of certain basalt ridges. The soil surface is covered by stones, and weak crab-hole development has occurred. The soils are less than 30 cm deep, overlying stone layers. Texture is loam fine sandy to clay loam, and weak prismatic structure has developed. The soil is acid and has not been seriously eroded.

ALLUVIAL SOILS

These are of loamy and sandy texture, occupying small areas in some drainage lines in country derived from sedimentary or igneous rocks, and on plains adjacent to ranges. They are deep (greater than 60 cm) soils with uniform texture, though slight changes in texture do occur between layers.

a) Loamy soils (Um 5.52)

These occur in sediments derived from sandstones and quartzites, in drainage lines and on colluvial/alluvial plains adjacent to ranges. They are reddish-brown in colour, have loam to clay loam texture, massive structure and acid to neutral reaction trends. While infiltration rates are high, large volumes of runoff from adjacent slopes often cause gully erosion of drainage lines.

b) Sandy and gritty soils (Uc 5.21)

These occur in drainage lines in igneous sediments. They are up to 2 metres or more deep, and dark reddish-brown in colour, with sandy loam texture, massive structure and acid to neutral reaction trends. A more clayey mottled layer often occurs in the deep subsoil. Infiltration rates are high, but the soils are extremely susceptible to gully erosion when runoff water is concentrated on bare areas.

SANDS AND SANDY EARTHS

These are usually deep red soils, occurring on dunes, low sandy rises, sandplains, lunettes, plains of Quaternary alluvium, and in creek channels and valleys of Devonian sandstone ranges and hills.

They have uniform sandy texture or slightly increasing clay content with depth. The shallower sands overlie an older more clayey subsoil. The dunes, low rises and lunettes

have been formed by aeolian redistribution of sediments, whilst the creek channels are of alluvial origin.

a) Deep sands with no pedological development (Uc 1.23)

These occur on dunes in the western part of the area. The dunes are longitudinal and east-west orientated, except for some round dunes in Gundigoona, Lynwood and Korreo land systems. They are often found abutting the western edges of ranges. The dunes have slopes up to 5 per cent and are up to 7 metres high.

The soils show almost no variation with depth, except a slight increase in pH; most profiles have an alkaline reaction trend. Texture is clayey sand, or less commonly sandy loam. They are reddish brown, have no structure and a loose sandy fabric. Infiltration rates are high, but some runoff does occur. They are usually well vegetated and but are susceptible to wind erosion if the surface becomes bare.

b) Deep sands with weak pedological development (Uc 5.1)

These occur in three topographic locations: as dunes, low sandy rises, and creek channels and valleys, mainly in the western area.

Dunes are longitudinal and east-west orientated, and the soils are like those described above except that slight changes in colour and texture occur within the profiles.

The low sandy rises are irregular in shape and represent local accumulations of sand to 3 metres above the surrounding plains. They are like the soils on the dunes though tend to have a sandy loam texture throughout.

Creek channels and valleys have alluvial sandy soils with changes in texture, colour and consistency between layers. They often overlie more clayey layers at depth. Texture ranges from sand to sandy loam and sometimes to sandy clay loam, while colour ranges from reddish brown to dark brown or dull yellow and white. Variable amounts of gravel also occur. Infiltration rates are very high, but the looseness of the sand prevents much vegetative growth, and drift usually follows the intermittent short-lived but rapid flows of water that occur.

Deep sands also occur in the major valleys of the Devonian sandstone ranges, often as low levees adjacent to the main flow lines, in association with red earths. These are similar to those on the low sandy rises.

c) Shallow sands (Uc 5.13)

These are level shallow sand sheets overlying harder, more clayey and probably older soil layers, in the central mallee areas. They are reddish brown in colour, neutral to slightly acid, and massive, with sandy loam texture. The underlying layer is similar in colour, alkaline with soft calcium carbonate at depth, and massive, with sandy clay texture. Infiltration rate is high and runoff low.

d) Deep sandy earths (Gn 1.13, Gn 1.12)

These occur on lunettes, low dunes and low sandy rises in the western portion of the area and usually occupy only small proportions of land units. They occur on areas where the depth of sand cover over the underlying layer is greater than in the Uc soils.

They are deep reddish-brown soils, sandy throughout, but with a gradual rise in clay content with depth, from sandy loam or clayey sand to sandy clay loam. Most soils have alkaline reaction trends, but some are neutral. They have high infiltration rates and usually good vegetative cover but are susceptible to wind erosion when bare.

The lunette soils are very susceptible to gully erosion when runoff water becomes concentrated.

RED EARTHS

These cover the major proportion of the study area, but occur mainly in the central and eastern portions, being replaced in the west by solonized brown soils. They occur on the foot slopes and in valleys of the ranges, on low hills and foot slopes, on most of the lowlands and on the eastern alluvial plains. They also occupy small areas in drainage sinks further to the west.

They are shallow to deep soils, with surface texture ranging from sandy loam to clay loam and with clay content gradually increasing with depth to clay loam or light clay. The deeper soils on the Cobar Pediplain and adjacent areas have an earthy hardpan at depth. Their colour is dark reddish brown, and structure is massive. Reaction trends range from acid in shallow gravelly soils, to neutral on lower slopes and minor drainage lines, and alkaline on plains and in large drainage lines.

The soils have been subdivided according to depth, stoniness, presence of hardpan and reaction trend.

a) Shallow acid stony red earths (Gn 2.11)

These soils occur on low crests and slopes of lowlands land systems, on slopes up to 3 per cent, and are gravelly and less than 60 cm deep. They have a thin loamy topsoil overlying clay loam subsoil and have acid reaction trends. They are massive and dark reddish brown in colour, with earthy fabric. Some surface gravel is usually present, and infiltration rates are low, resulting in high runoff rates and severe water sheeting.

b) Shallow stony neutral red earths (Gn 2.12)

These occur on the foot slopes of Devonian sandstone ranges and hills, below the main rock outcrops but with plentiful stone cover, on slopes up to 5 per cent.

They are much less compact than the acid soils and usually sandier, but are similar in colour, structure and fabric. They have a neutral reaction trend, and the topsoil is less acid and usually well vegetated. Infiltration rates are moderate to high, but runoff from higher slopes often causes water sheeting and rilling.

c) Deep stony red earths (Gn 2.13, Gn 2.12)

These are deep (greater than 60 cm) soils, occurring mainly on lower ridge slopes (<2% slope) and minor drainage lines of the lowlands, on toe slopes extending onto the eastern alluvial plains, and also on some stony plains and in major creek channels.

The soils are all similar, and most have alkaline or neutral reaction trends, though some acid soils do occur. They have loamy topsoils and light clay subsoils, are dark reddish brown in colour and are massive with earthy fabric. Very small quantities of calcium

carbonate occur in the deep subsoil of the alkaline soils. The stone and gravel present is usually small in size and is not as abundant as on upper slopes. In the more western areas of their occurrence, ferruginous gravel occurs in a layer between the A and B horizons. In the eastern areas, gravel may be scattered throughout or occur in weak layers. Hardpans may be present at depth in the most eastern areas.

Infiltration is moderate to high, and runoff is reduced due to the almost level topography. However, lower slope areas receive much runoff and erosion debris from upper slopes, and water sheeting and rilling may occur.

d) Deep neutral red earths with earthy hardpan (Gn 2.12)

These occur in drainage lines in eastern hills and ranges, and in minor drainage lines in the "hard-red" lowlands of the Cobar Pediplain.

They are deep soils with little if any gravel, but an earthy hardpan is present at a depth of 60 to 70 cm and continues to great depths. The soils have loam to clay loam topsoils and clay loam to light clay subsoils, are dark reddish brown in colour, and are massive and earthy, with neutral reaction trend. The hardpan has been described by Walker (1976), and is a dense, shiny or sandy layer with manganese staining and small amounts of carbonate at depth. Texture ranges from clay loam to sandy loam but is difficult to determine accurately due to poor dispersion of aggregates. It forms an almost impenetrable barrier to water and plant roots and becomes softer only after long wet periods. It is very low in plant nutrients and relatively high in sodium and other salt contents. It is thought to be an older fluvial layer, which has become cemented by iron and possibly by silica and carbonates.

Infiltration rates are considerably higher than on the adjacent ridges due to their level topography, less compact surface and better vegetative cover. The hardpan is thought to form a perched water table after prolonged wet periods. Gully erosion often occurs adjacent to ranges and hills due to concentration of fast-flowing runoff in the drainage lines.

e) Deep calcareous red earths with earthy hardpan (Gn 2.13)

These soils are similar to those described above, except for an alkaline reaction trend, and small amounts of calcium carbonate in the subsoil.

They occur on very gentle lowlands, ridge slopes, on eastern alluvial plains and in the larger drainage lines of the hard-red lowlands and plains. They carry good vegetative cover and are not usually eroded.

f) Deep neutral red earths (Gn 2.12)

These soils occur on lower slopes and in drainage lines of Devonian sandstone hills, and on an area of sandplain in Fulham land system.

They are greater than 60 cm deep, contain a few stones or gravel and have a gradually increasing clay content with depth. The topsoil is sandy to loamy and not as compact as the soils in the previous sections. They are dark-reddish brown in colour, massive with earthy fabric and have a neutral reaction trend.

They have high infiltration rates and generally good vegetative cover, but may become eroded by gully erosion in drainage lines, due to rapid run-on from adjacent ridges.

g) Deep calcareous red earths (Gn 2.13)

These occupy a large area of mainly level country surrounding the Cobar Pediplain, and occur in a variety of situations: on high and low plateaux in lowlands country, on sand-covered ridges in the western area, in the main valleys of the Devonian sandstone ranges, on plains east and south-west of the Cobar Pediplain, on sandy plains in the west, in the swales of dunefields, in drainage lines of western lowlands and alluvial plains, and in drainage sinks and swamps in the west.

The soils are dark reddish brown in colour, massive and earthy, and although termed calcareous red earth contain only small amounts of calcium carbonate in the subsoil, except for the soils in the drainage sinks and some on the sandy plains which are quite calcareous at depth. Topsoils are loam to fine sandy clay loam, and subsoils fine sandy clay loam to light clay.

The soils have high infiltration rates and carry good vegetative cover. Gully erosion may occur in valleys and on sand-covered ridges, and minor wind sheeting may occur on the sandy plains if the surface becomes bare.

SOLONIZED BROWN SOILS

These soils occur in the western part of the region and extend further westward for a considerable distance. They occur on plains, ancient dunes and lunettes, in swales, and occasionally in drainage sinks and along lake shorelines.

The soils are calcareous throughout, though carbonate is not always visible at the surface, and crabholes and gilgais occur locally. They are subdivided according to subsoil structure.

a) Solonized brown soils with massive subsoils (Gc 1.22, Gc 1.12)

These are the most common group of solonized brown soils, occurring on plains, ancient dunes, lunettes and in swales.

They are deep soils, calcareous throughout, with carbonate visible at the surface (Gc 1.12) or detectable at the surface by acid treatment (Gc 1.22). The carbonates may be soft or hard (nodular), or usually both. Topsoils are loam to clay loam, and clay content increases gradually with depth. Colour is reddish brown or dark reddish brown (brownier than the red earths), and structure is massive with earthy fabric, apart from some weak smooth-ped development in the deep subsoil of some profiles. No gravel occurs but hard carbonate nodules usually occur in the subsoil. Gypsum also occurs in lunette soils and sometimes forms hard surface outcrops.

These soils are susceptible to wind sheeting if they become bare, and the sloping surfaces of lunettes and ancient dunes are very susceptible to gully erosion.

b) Solonized brown soils with structured subsoils (Gc 2.22)

These are of only minor occurrence, on western alluvial plains and in drainage sinks and shorelines of lakes in red country.

They are similar to the soils described above except for well-developed smooth-ped structure in the subsoil. They are moderately resistant to erosion.

CLAYS

Two types of clay soils occur in the survey area: the cracking clays associated with the Darling River and lakes, and non-cracking clays associated with western drainage sinks, pans and small areas of plains.

The cracking clays are mostly grey in colour and have self-mulching surface layers overlying large blocky peds with deep cracks and crabholes. In some locations these soils have a compact, scaldy surface and slightly browner subsoil. Reddish brown cracking clays also occur.

The non-cracking clays are mostly structured and often contain crabholes and are reddish brown in colour.

a) Grey cracking clays with self-mulching surface (Ug 5.28, Ug 5.29, Ug 5.24)

These are the most common of the clay soils, occurring on the Darling River floodplain, along the riverbanks, in swamps and drainage lines and in lakebeds. The Ug 5.24 soils occur mainly in lakebeds surrounded by red country, and on the plains of Buckanbe land system.

The deep grey clays (Ug 5.28, Ug 5.29) are uniform in colour. Heavy or medium clays occur throughout, and blocky smooth-ped structure is strongly developed, producing a loose self-mulching surface. The soils in small drainage lines and swamps within the floodplain have very large blocky peds with a harder surface and crack widely when dry. They are alkaline throughout, contain small amounts of carbonate and sometimes gypsum, and are reported to be sodic. The soils have strong shrink-swell characteristics and may exert considerable stress on plant roots during movement. They have a high water-holding capacity but retain a large amount of soil water at normal plant wilting point. They require a considerable amount of water to wet up from the dry state and vegetation is slower to respond to rainfall than on lighter red soils.

They are resistant to erosion.

b) Reddish-brown clays with self-mulching surfaces (Ug 5.35, Ug 5.37)

These occupy small slightly more elevated areas on the floodplain, and along the edges of the floodplain adjacent to reddish texture-contrast soils.

They are similar to the grey clays except for colour, which is due to their more effective drainage and lower frequency of inundation. They are also resistant to erosion.

c) Grey cracking clays with scaldy surface (Ug 5.24)

These are similar to the grey clays described above, but have a compact, smooth surface which may remain bare for considerable periods. Cracks still form deeper in the profile. It is thought that dispersion of clay aggregates after wetting is the cause of the surface condition.

They occupy only small areas along riverbanks, lake and swamp shorelines and on small slightly elevated areas on the floodplain. They all have some element of slope. Along lake shorelines they are often partially covered by a thin sand layer.

They form the so-called “sloping scalds” of the floodplain country.

d) Non-cracking clays (Uf 6.34, Uf 6.31, Uf 6.41, Uf 6.71)

These occur mainly in drainage sinks on the western plains, but also in small areas on the plains themselves and in the canegrass pans of Popelloe land system.

In drainage sinks they occupy the lowest positions and are surrounded by calcareous red earths.

They do not crack at the surface, but crabholes often occur in the Uf 6.3 and 6.4 soils. These soils are deep, smooth structured and mainly whole-coloured (Uf 6.3) or sometimes mottled (Uf 6.41) and reddish brown to light brown in colour. The Uf 6.71 soils are less common and are massive and dark reddish brown in colour. These also occur in yarran (*Acacia homalophylla*) flats in the western Cobar Pediplain. The surface layers have light to medium clay texture, with medium to heavy clay textured subsoils. They are alkaline, slightly calcareous and gravel free.

Their infiltration rates are not known, but little if any runoff occurs due to their topographic position. Their colour indicates moderately free draining soils.

TEXTURE-CONTRAST (DUPLEX) SOILS

These soils occur on mainly level areas, the most common areas of occurrence being adjacent to the Darling River floodplain on plains of older alluvium. They also occur on the lower slopes of sandstone ranges west of the Darling River, on toe slopes and in drainage lines of western lowlands, in drainage sinks and swamps on plains, around some lake shorelines, on ancient dunes and in drainage lines in igneous sediments.

Texture-contrast soils have a sandy (clayey sand to clay loam) topsoil abruptly overlying a more clayey (clay loam to medium clay) subsoil. In most locations this has probably resulted from mass movement and redistribution of sediments rather than clay illuviation. The soils have red, yellow or even brown coloured subsoils which may be massive or strongly structured. Most have a hard setting topsoil, but crusty and sandy topsoils do occur. The soils are deep, stone-free except in some drainage lines, and have alkaline reaction trends, though contain only small quantities of carbonate.

These soils are classified as duplex to reflect their current physical properties and behaviour, but it is likely that most are formed by episodic depositions of materials or deposited new material on older, possibly truncated, surfaces, rather than by textbook clay illuviation.

The soils have been sub-divided according to subsoil colour and structure, and surface features.

a) Red structured texture-contrast soils with crusty surface (Dr 1.13, Dr 1.12)

These soils, the desert loams, are restricted to the west-Darling portion of the survey area, on foot slopes (up to 5 per cent) of sandstone ranges. They have shallow loamy topsoils with a well-defined surface crust overlying red strongly structured clay subsoils. They are deep soils with alkaline or neutral reaction trend and are generally stone-free except for a stony surface mantle. Water-holding capacities are high and runoff is low, but

the saline subsoils are very dispersible and are susceptible to gullyng if the surface stone is removed or water is concentrated on the surface.

b) Red stony structured texture-contrast soils with hard-setting surface (Dr 2.13)

These are restricted to some drainage line in Cottage land system, where a light textured topsoil overlies a structured subsoil containing ferruginous stones. The profiles are thought to be derived from deposition of sediment from upslope over a truncated soil.

The soils have alkaline reaction trends and smooth-ped subsoil structure. The surface layer is shallow (10 to 30 cm) and the subsoils deep (to 150 cm) overlying rock. They are susceptible to water sheeting if the surface becomes bare.

c) Red structured texture-contrast soils with hard-setting surface (Dr 2.13)

These are deep, stone-free soils, occurring mainly on alluvial plains, but also in drainage lines of Euramurtie land system.

They have a loamy to sandy topsoil which sets hard when dry, overlying a dark-reddish brown structured clay subsoil. Reaction trends are alkaline, with small amounts of calcium carbonate in the subsoils. Soils with neutral reaction trends (Dr 2.12) also occur in Euramurtie land system.

The topsoils have a rapid infiltration rate, but subsoils have low permeability. The soils are very susceptible to water-sheeting and scalding.

d) Red stony weakly structured texture-contrast soils with hard-setting surface (Dr 2.53)

These are of minor occurrence in the lowlands land systems with large amounts of ferruginous gravel where they occur on toe slopes and in some drainage lines.

The clay loam to sandy loam topsoils, about 20 cm deep, usually overlie a thin layer of ferruginous gravel or small stones, in turn overlying a clayey, weakly structured dark reddish-brown subsoil which contains small amounts of calcium carbonate. These soils are probably formed by episodic deposition of sediments.

The soils on the lower slopes are often severely water-sheeted and scalded, whilst in the flats are fairly stable due to vegetative cover.

e) Red weakly structured texture-contrast soils with hard-setting surface (Dr 2.53)

These occur on alluvial plains and are like the Gn 2.13 soils except for a more clayey subsoil. They have clay loam to sandy loam topsoils overlying clayey dark reddish brown weakly structured subsoils which are alkaline and contain small amounts of calcium carbonate.

They have moderate to high infiltration rates but are susceptible to wind sheeting and scalding.

f) Red weakly structured texture-contrast soils with sandy surface (Dr 4.53)

These were observed only around lake shorelines in red country and have a deep sandy topsoil (to 45 cm) overlying a dark reddish-brown subsoil which is weakly structured, alkaline and slightly calcareous.

Infiltration into the topsoil is rapid, but wind sheeting and scalding have been severe.

g) Brown structured texture-contrast soils (Db 1.13)

These are of minor occurrence only, in some swamps of Dunoak land system. They have sandy but hard-setting topsoils overlying brown clayey structured subsoils, which are alkaline and slightly calcareous at depth.

Little is known about the infiltration rates of these soils, but the topsoil is suitable for the germination of bumble box (*Eucalyptus populnea*) seedlings, which cannot become established on adjacent clay soils.

h) Yellow structured texture-contrast soils with hard-setting surface (Dy 2.13, Dy 3.13)

Most soils are whole-coloured (Dy 2.13) and occur on alluvial plains adjacent to the Darling River and in drainage sinks on the plains of Kaleno land system. The mottled soils (Dy 3.13) occur in swamps in Pangee land system. These soils have a hard-setting sandy loam to clay loam topsoil, overlying an orange-yellow coloured structured subsoil which is alkaline at depth and contains slight calcium carbonate. The mottled soils contain a large amount of manganese and are poorly drained.

The soils on the plains are susceptible to wind sheeting and scalding.

i) Yellow weakly structured texture-contrast soils (Dy 2.53, Dy 3.53, Dy 4.53)

These soils occur as minor components of several land units. The whole-coloured hard-setting soils (Dy 2.53) occur in association with the structured yellow soils and red texture-contrast soils and with the weakly structured red soils on alluvial plains. They are similar to the latter except for a yellower subsoil.

The mottled hard-setting soils (Dy 3.53) occur in association with gritty uniform soils in the drainage lines in sediments of igneous rocks. They are similar to the uniform soils except for a more clayey (sandy clay loam to sandy clay) subsoil. These soils are probably formed by successive deposition of sediments as well as by clay illuviation. They are very susceptible to gully erosion.

Weakly-structured soils with sandy surface (Dy 4.53) occur on the lower slopes of some ancient dunes on Budda land system. The sandy layer is up to 50 cm deep and overlies an orange sandy clay loam subsoil which is alkaline and slightly calcareous. These soils may have been formed by deposition of sand over an older surface. They are subject to wind sheeting, water sheeting and scalding.

IV PROPERTIES OF THE SOILS

1. PHYSICAL PROPERTIES

a) Surface Features

Most soils in the area have smooth hard-setting surfaces, often with thin surface crusts of soil particles and/or algae and lichens. All red earths, most texture-contrast soils, solonized brown soils, the lithosols on the upper lowlands, the non-cracking clays and the deep gritty soils on igneous rocks are hard-setting. The hardest-setting soils are those of the lowlands and alluvial plains associated with the Cobar Pediplain, particularly where water sheeting has occurred and left exposed a harder, more compact surface than the original topsoil. Surface bulk densities up to 1.55 g cm^{-3} have been measured on lowland ridges near Cobar and infiltration rates on these sites are very low (Walker 1976).

The sands and sandy earths have loose friable topsoils, as do a few of the texture-contrast soils. The lithosols on stony hills and ranges are friable but usually occur only in small pockets separated by rock outcrops.

Most cracking clays have self-mulching surfaces, with deep wide cracks developing in dry times. Crabhole microrelief is common in these soils, whilst gilgais and/or crabholes occur in many of the non-cracking clays in drainage areas. Some cracking clays develop shallow compact, smooth hard surface layers which have a scalded appearance. These usually occur near the main rivers or minor drainage lines and swamps and are often slightly elevated above the local land surface.

Surface parent rock is abundant on the hills and ranges, and smaller stones and gravel also partly cover the lithosols occurring there. Gravel and stones (quartz, ferruginous gravel, and gravel and stones of the local parent rock) occur in varying quantities on the surface and within the topsoil on the lithosols on lowland crests and on some acid and neutral red earths. Where severe water sheeting has occurred these form a relict surface mantle which, when well developed, reduces run-off and soil erosion (Walker and Cunningham 1976).

Some of the texture-contrast soils have been stripped of their topsoil leaving hard clayey scalded surfaces which provide poor physical and chemical conditions for plant establishment and usually remain bare for long periods. Natural reclamation, usually by saltbushes and copperburrs, does take place, however, during runs of favourable seasons.

b) Depth

The shallowest soils occur on the ranges, hills and lowland crests, and are usually less than 30 cm deep. They are sandy to loamy soils with large gravel and stone contents, and on the ranges and hills occur only as small shallow pockets between outcropping rock.

Soil depth increases gradually down slope, but most soils on slopes greater than 3 per cent are still less than 60 cm deep. On the lower slopes of the ranges and lowlands soils are from 60 cm to 150 cm deep, and on level areas most soils are more than 150 cm deep. Many soils are more than 200 cm deep, notably the dune sands, clays and stone-free texture-contrast soils.

The red earths of most of the lowlands and associated narrow-alluvial plains have a hard soil layer (hardpan) at a depth of 60–70 cm. This restricts water percolation and penetration of plant roots due to its hardness and is very low in available plant nutrients. Thus, although the soil depth may be over 3 metres, the effective plant rooting depth is much less than this.

The soils on some lowland drainage lines contain stony layers which also restrict plant growth, though not to the extent that the hardpan does.

Soils overlie parent rock, soil-like parent material of alluvial or aeolian origin, or older possibly truncated soil profiles. Many soils may consist of two or more layers of differing ages, especially in the western portion of the area. These layers may be similar in colour but differing in pH, structure or texture, or may be of different colours depending on the origin of the layers. Stone layers are often an indication of a break in the time-sequence in soil formation. The hardpan mentioned above is thought to be an older fluvial layer (Jessup 1961, Walker 1976) which has been indurated.

c) Colour

Most of the soils are dark reddish brown in colour, due to their free drainage and abundance of free iron oxides (Jackson 1957). These soils (in the moist condition) are in the 2.5YR and 5YR Munsell colour hue range with value/chroma ratings of 3/6 and 4/8. The most common soil colours are 2.5YR 3/6, 5YR 3/6, 7.5YR 3/6 and 2.5YR 4/8.

In the red earths there is little change in colour in the profile, though organic matter tends to darken the surface slightly (5YR 3/6) and the lower layers and hardpan tend to be lighter (2.5YR 4/8) than the main solum, which is 2.5YR 3/6. A few red colours occur in some of the highly ferruginous soils. The sands are 2.5YR and 3.75YR 3/6 throughout.

The solonized brown soils are also uniform in colour and are very slightly browner than the red earths (5YR 3/6, 4/6, 4/8). The presence of carbonates tends to give the subsoils a lighter brown appearance (value/chroma group 4 – Northcote 1971).

The lithosols on sandstone ranges and on lowland crests and upper slopes, as well as the gritty soils on igneous rocks, are mainly 5YR 3/6 to 5YR 4/8, whilst the lithosols on the eastern hills and ranges are much darker (7.5YR 3/4, 2/2, 3/3; 5YR 3/3, 3/4, 3/5) due to a high organic matter content.

The texture-contrast soils have a range of colours depending on their topographic (drainage) position. The soils in lowland drainage lines are reddish brown throughout (3.75YR 3/6, 4/8; 5YR 3/6, 4/8) due to their rapid drainage and high iron contents. On the alluvial plains, subsoils are reddish brown through bright brown, brown and orange, to dull yellow orange. The most common colours are 5YR 5/8, 3.75YR 4/8 and 5YR 4/8, along with some 7.5YR 4/6, 6/6, 2.5YR 4/8, 5/8 and 10YR 6/3. Topsoils are mainly 5YR 4/8, with 5YR 5/8, 3/6, 5/6, 3.75YR 3/6, 4/8 and 7.5YR 4/4, 5/4. Mottling is common in lower subsoils on the alluvial plains, though the mottles occupy only a small proportion of the colour, and are usually of yellow (10YR and 2.5Y) hues.

The cracking clay soils are mostly grey in colour; the main colours being 2.5Y 6/2, 5/2, 6/3, and 10YR 6/2, 5/2, 5/3, 6/3 and 6/4. The brown cracking clays are 7.5YR 5/4, 5/5,

6/6; 5YR 4/8, 5/6, 5/7 and 6/7 and 10YR 6/3. The colour is due to the nature of the clay mineral and subjection to long periods of inundation or waterlogging. The colour may become yellower or browner with depth, and small quantities of mottling are common.

The non-cracking clays are reddish brown and brown (5YR 4/8, 4/4, 4/6, 5/8, and 7.5YR 4/4, 4/5) with yellower colours at depth (10YR 5/3, 6/4, 7/3, 6.75YR 4/8, 5YR 5/8). These are also often mottled at depth due to periodic waterlogging, but they are better drained than the cracking clays.

A₂ horizons are all but completely absent in this area, though weak bleaching of sub-surface layers rarely occurs.

d) Texture

Texture determination on most profiles was by hand manipulation (Northcote 1971), and particle size analyses were carried out in the laboratory for all soils on the Cobar Sheet.

Textures ranged from sands to heavy clays, though with most in the sandy loam to clay loam range. The sandy soils occur on the ranges (lithosols), dunes and sand plains and in creek beds and igneous sediments. In addition, some texture-contrast soils and red earths have sandy loam topsoils. This sandiness is correlated with the coarse particle size of the parent rocks (quartzites, sandstones, conglomerates, granites), and colluvial and alluvial deposition of sediments from these same rocks associated with reworking by wind. The coarsest sands are those derived from granite and give a gritty appearance and feel, in creek beds and on granite and conglomerate ridges. The other sands are much finer, with most grains in the medium size range (approximately 1.0 to 0.1 mm diameter).

The red earths and solonized brown soils have sandy loam to clay loam and sometimes light clay textures, with gradual increase in clay content with depth. These soils are formed from relatively coarse-grained sedimentary and metamorphic rocks and their alluvial deposits, with possible additions of finer aeolian dust (see later).

The high clay contents of the subsoils of the texture-contrast soils and of the non-cracking clays is thought to be due to deposition of finer sediments in lower alluvial situations, sometimes associated with clay illuviation during soil formation. They are thought to be illitic and kaolinitic in nature.

The cracking clays of the Darling floodplain are thought to be dominantly montmorillitic, with a large shrink-swell capacity, derived from basaltic and other igneous rocks high in the headwaters of the river and its tributaries. The clay type results in the self-mulching nature of the surface and the ability to form large cracks and crabholes.

As Lawrie (1980) found in the north-west corner of the state, field and laboratory textures were not well correlated, the field textures nearly always indicating higher clay contents than laboratory analyses. In this area, this is thought to be due to incomplete dispersion of aggregates in the laboratory. The high iron content of the soils apparently is responsible for strong binding of soil particles, which laboratory chemicals and shaking fail to completely disperse. This discrepancy is especially apparent in the hardpan of the Cobar district and in ferruginous soils. The hardpan particles are extremely strongly bonded and difficult to separate. Additional laboratory shaking and mixing of a hardpan sample which

had a clay field texture raised the laboratory clay determination from 7 per cent to 49 per cent (D. Blandford pers. comm.), indicating a strong degree of sub-plasticity.

Soils with high carbonate and gypsum contents appear more clayey than in reality using hand manipulation, and allowance must be made for this.

e) Structure

Most soils in the area are massive or only very weakly structured.

The sands and sandy earths have loose, single-grain structure with sandy fabric. The lithosols are massive with sandy or earthy fabric, the only aggregation being due to bonding by organic matter in the darker soils of the eastern hills. These soils are very immature and probably contain insufficient clay for development of structure.

The red earths are massive or have a very low proportion of peds in the subsoil. They have an earthy fabric, except in the hardpan which exhibits a smooth, hard, shiny or occasionally sandy surface. Structure has developed in some deep subsoils on the alluvial plains and in a few drainage lines in western lowlands. Peds are smooth-faced, sub-angular blocky and 1 to 2 cm in size. These are associated with more clayey sediments, apparently derived from the finer textured of the sedimentary and metamorphic rocks. The structured layers are often overlain by massive or weakly structured layers or stone layers, indicating possible truncation and re-burying of older soil profiles.

Solonized brown soils have massive to strongly structured subsoils, depending apparently on clay content and topographic position. The less common structured soils appear to be in the lower positions and to be slightly more clayey. Smooth, sub-angular blocky peds 1 to 3 cm in size occur in these soils and often are coated with calcium carbonate and/or gypsum.

The texture-contrast soils have weakly to strongly structured subsoils, the former being the more common. Structure has developed in subsoils of all colours, apparently in the older and more stable soils. Peds are smooth-faced, sub-angular blocky or occasionally blocky, and 1 to 5 cm in size, and are sometimes partially coated with sand grains from the topsoil which have fallen down narrow cracks.

The cracking clays are strongly structured throughout, with a thin finely structured surface layer overlying large coarse blocky and columnar peds to 20 cm wide and 30 cm long, which progressively break down to small sub-angular blocky peds 1 to 2 cm in size. All peds are smooth faced. Small lenses of sand that have fallen down cracks coat ped faces of soils adjacent to sandy areas.

Non-cracking clays may be weakly to strongly structured, with most having medium to strong development of smooth-faced sub-angular blocky peds 1 to 2 cm in size.

f) Infiltration

Infiltration rates are related to soil texture and surface characteristics.

The highest rates are in the loose sandy soils, which do not form a surface seal after initial wetting. These include the sand dunes, sandplains, sandy rises, and drainage lines in igneous sediments, as well as shallower sandy soils (lithosols and topsoils of texture-contrast soils). The latter soils rapidly take in water until they become saturated due to restriction of downward movement, by rock or by less permeable subsoils. The exceptions are the dark organic soils on eastern hills, which are hydrophobic and admit water only gradually.

The loamy lithosols on the lowlands have generally been severely eroded by water sheeting and infiltration is severely restricted by the exposure of a compact, smooth surface which seals up after approximately 5 mm of rainfall and may yield up to 85 per cent of rain from a single storm as runoff (Walker and Cunningham op. cit.). These large volumes of runoff cause further water sheeting as well as rilling on the adjacent lower slopes.

The red earths and solonized brown soils have intermediate infiltration rates when uneroded. Although the topsoils are hard setting, their generally level topography and consequent temporary ponding of surface water aids infiltration. On sloping sites, infiltration is less rapid, and where water sheeting has occurred infiltration is severely restricted as for the loamy lithosols, with consequent serious erosion.

The texture-contrast soils usually have rapid infiltration rates in the topsoil but lower rates in the clayey subsoil. Their level topography allows water to pond while infiltration takes place.

The cracking clay soils absorb large amounts of water when dry, by filling of cracks and crabholes. Once these are full, the clay swells and infiltration then much reduced as a surface seal forms. The level and uneven nature of the surface allows ponding of water until infiltration and/or evaporation take place.

The non-cracking clays are thought to have relatively slow infiltration rates, but again, their level topography and common occurrence in drainage sinks allows time for infiltration to take place.

2. CHEMICAL PROPERTIES

a) Soil Reaction

Soil pH ranges from 4.5 to 9.5 and is strongly related to soil type and profile drainage.

The very acid soils occur in the eastern hills, due to the high organic matter contents, and on the lowland ridges where intense leaching has taken place in past periods of higher rainfall.

In the eastern part of the area, most surface soils have a pH within the range 5.0 to 6.5. pH then gradually increases with depth, and generally the deeper the soils the more alkaline the subsoil becomes, due to decreasing effectiveness of leaching with depth. Hence the shallow stony soils (lithosols and red earths) are acid throughout, with sub-soil pH less than 6.5. The slightly deeper soils on the lower slopes and in small drainage lines of lowlands and ranges (red earths) have neutral subsoils (generally pH 6.5 to 7.5), whilst the deep soils of the large lowland drainage lines and alluvial plains have alkaline subsoils (pH 8.5 to 9) containing small amounts of calcium carbonate.

West of the lowlands and ranges, the soils become more alkaline. Immediately west of the main ranges soils have acid topsoils (pH 5.5 to 6.5) with alkaline subsoils (pH 8. to 9), although some of the deep dune sands remain acid for up to 2 metres. Further west, the solonized brown soils are alkaline and calcareous throughout, with surface pH 7.5 to 9 and subsoil pH 8.5 to 9.5.

The texture-contrast soils on the alluvial plains and the non-cracking clays are neutral to alkaline (pH 7 to 9 at the surface and alkaline at depth (pH 8.5 to 9.5), whilst the cracking clays are alkaline throughout (pH 9 to 9.5). Sand dunes associated with these soils are also alkaline throughout.

However, the few stony hills in this western area have acid soils.

b) Carbonates

Generally, soil carbonates increase from east to west, though carbonate is found in or below soils on all areas but the ranges, hills, upper lowland slopes (and even there, small calcareous pockets do occur) and granite lowlands.

In the eastern part of the area carbonate is restricted to deep (greater than 1 metre) subsoils, in very small quantities and in either powdery or nodular form. This occurs in the larger drainage lines of the lowlands and on the alluvial plains, but not in the creek-beds, which are acid or neutral to great depths. However thin cappings (to 0.5 cm thick) of carbonate are often found on stones or rock below acid or neutral soil profiles in the smaller drainage lines of the lowlands, and thicker calcrete underlies similar soils on some ridges in Ironstone, Taringa, Boulkra and Cottage land systems.

In western areas carbonates occur in all soils except the lithosols and shallow red earths on the few stony hills. Immediately west of the ranges carbonate is restricted to the deep subsoils and does not always occur in the deep dune sands. Carbonate content of the subsoil increases to the westward, and dense layers of almost pure carbonate occur in some calcareous red earths of Manara land system. As well, carbonate moves closer to the soil surface, and the solonized brown soils, cracking clays and some texture-contrast soils are calcareous throughout. The solonized brown soils have the largest carbonate content, and powdery and nodular carbonate often lies on the surface.

No analyses of actual carbonate contents have been made for this area.

The upper boundary of the carbonate layer is often wavy or discontinuous and falls in localized areas of greater leaching (eg. below creek-beds- see photo at end- gilgais and drainage sinks).

The source of the carbonates is not well understood, but in the east is thought to be derived from weathered country rock and brought to the surface by high ground water, and in the west is thought to come mainly from aeolian deposition (see later).

c) Soluble Salts

Few analyses have been carried out on these soils, but they are not generally considered to be saline.

The red earths and lithosols of the Cobar district generally contain much less than 0.1 per cent total soluble salts, though a few layers with higher levels have been observed in some profiles, notably deep in the hardpan (Walker 1976) where up to 0.27 per cent total salts has been measured. The most common of the salts is thought to be sodium chloride, associated with relatively high exchangeable sodium.

The sandy soils are thought to be low in soluble salts, whilst the cracking clays are thought to be somewhat higher. Northcote et al. (1975) describe solonized brown and texture-contrast soils as having moderately high soluble salt contents in the subsoil. Saline sealed subsoils of texture-contrast soils have been observed by Cunningham et al. (1974), and Jessup (1969) found that chloride concentrations in scalds were higher than on uneroded soil. The growth of a large proportion of chenopods and other halophytes on the cracking clays and scalded texture-contrast soils may provide an indication of relatively high salt levels, but in no areas is plant growth known to be severely affected by salinity.

d) Sodicty

Little information is available for this area, but analyses that have been carried indicate that red earths and loamy lithosols in the vicinity of Cobar have high sodicty, which tends to be greater in the topsoil (exchangeable sodium percentage (ESP) 3–6) than in the subsoil (ESP 1.6–4). (ESP greater than 6 represents sodict soils).

This is probably a major reason for the sealing of these soils when wet, due to clay dispersion. Ferruginous red earths near Cobar (6 profiles) had very low sodicty throughout (ESP 0 to 1.3) as did a gritty red earth in Coolabah land system (ESP 0.5 to 0.7). Neutral and calcareous red earths in Peshurst land system had no exchangeable sodium in the topsoil and low to high sodicty in the subsoil (ESP 0 to 2.2).

One non-cracking clay profile had low surface sodicty (ESP 2 to 4) but relatively high subsoil sodicty (ESP 13 to 23).

Cracking clays tend to have low surface sodicty (ESP 1 to 5) and low to high subsoil sodicty (ESP 4 to 27), and texture-contrast soils have low to high sodicty (ESP 4 to 36) in the surface and high subsoil sodicty (ESP 24 to 63).

e) Sulphates

Crystalline gypsum was observed in the deep subsoils of some cracking clays, both grey and brown, some solonized brown soils, and in calcareous red earths on the plateaux of Cottage land system. The gypsum usually occurs below the layer of maximum calcium carbonate concentration.

Gypsum also occurs in abundance in lunettes, notably in Karumpito and Tiltagara land systems. Here it often forms large hard outcrops surrounded by shallow sandy solonized brown soils and is associated with high rabbit activity.

f) Organic Carbon

Organic carbon levels are generally low. The highest levels are in the shallow, dark-coloured lithosols on the eastern hills, where between 2.92 and 8.77 per cent were recorded.

The lowest levels were in the sandy soils (Uc 5.11 and Gn 1.13) where topsoils contained between 0.08 and 0.55 per cent, and subsoils between 0.04 and 0.08 per cent organic carbon.

Other soils had values intermediate to these, but mostly at the lower end of the range. Red earths had between 0.17 and 1.88 per cent carbon at the surface and 0.05 to 1.03 per cent in the subsoil; solonized brown soils between 0.25 and 0.85 per cent at the surface and 0.09 to 0.23 per cent in the subsoil; texture-contrast soils 0.16 to 1.19 per cent at the surface and 0.06 to 0.39 per cent in the subsoil; non-cracking clays 0.51 to 0.75 per cent at the surface and 0.06 to 0.19 per cent in the subsoil; and cracking clays 0.22 to 0.75 per cent at the surface and 0.07 to 0.24 per cent in the subsoil.

Organic carbon content usually decreased with depth down the profile, though in some shallower soils the opposite trend is apparent, probably due to loss of part of the surface layer by erosion, and the presence of decomposed roots at depth.

g) Total Nitrogen

As for carbon, total nitrogen contents were also low, except for the dark-coloured lithosols where levels between 0.17 and 0.44 per cent were recorded. The sandy soils had the lowest nitrogen contents, between 0.02 and 0.06 per cent at the surface and between 0.01 and 0.03 in the subsoil. Dawson and Ahern (1974) regard total nitrogen contents less than 0.09 per cent as low, and less than 0.05 per cent as very low. Charley and Cowling (1968) reported arid soils of Australia having lower nitrogen contents than humid soils and overseas arid soils.

Nitrogen content generally declined with profile depth. Mallee soils tended to have slightly higher nitrogen content in the surface soils than did similar soils not carrying mallee.

h) Available Phosphorus

Available phosphorus determinations have been made on only a few profiles, using the Bray No. 1 method. Soils tested were red earths, loamy lithosols and one non-cracking clay.

Levels were low and declined rapidly with depth. The highest level was 20.4 ppm in the topsoil of a small drainage flat of Cobar land system. On the ridges of Cobar land system, the highest levels were 11.8 ppm on lithosols and 16.5 ppm on red earths, but most were lower than this, and as low as 7.2 ppm at the surface and 0.4 ppm in the hardpan. The non-cracking clay soil had 14 ppm available phosphorus in the topsoil and as low as 1 ppm in the subsoil. Dawson and Ahern (op. cit.) state that available phosphorus levels, as determined by this method, of less than 10 ppm are very low, and from 10 to 20 ppm are low.

In general, the red earths and lithosols are thought to be low in phosphorus and the solonized brown soils, texture-contrast soils and clays somewhat higher, but no figures for this area are available. Dregne (1976) makes a similar observation for soils in arid areas world-wide. Charley and Cowling (op. cit.) also reported that Australian arid soils have lower total phosphorus levels than humid soils or overseas arid soils.

V. SOIL FORMING FACTORS

1. Parent Material

The parent material of soils in this region ranges from underlying rocks to sedimentary layers of soil-like material. These layers may be of alluvial, colluvial or aeolian origin, or combinations of these.

Soils formed in situ on rocky areas usually reflect the characteristics of the underlying rocks, particularly regarding particle size and mineral composition. Although the rocks are of varying ages, their particle sizes are similar, accounting for lack of morphological differentiation of soils across the different rock types of the lowlands, and particularly the Cobar Pediplain. The extensive deposits of colluvial gravel on these lowlands also obscure the underlying rocks.

The lithosols and red earths formed on Devonian sandstone are very sandy, reflecting the coarse nature of the parent rocks, whilst those of the eastern hills and ranges are sandy to loamy, depending on the nature of the local rock outcrop. The shales and mudstones of the Cobar district tend to produce loamy soils (many lithosols and red earths) which contain fragments of the parent rock as well as quartz and ferruginous gravel. All these soils are acidic, reflecting the generally non-calcareous nature of the parent material. Small calcareous areas do occur on lowland ridges, and a carbonate capping can be found on bedrock surfaces in some drainage lines. The source of this carbonate is possibly precipitation from ground water from pockets of calcareous rock (J. Milovanovic pers. comm.) or leaching of aeolian accessions (Wasson et al. 1979).

The ferruginous gravel occurring in Ironstone and Boulkra land systems and in small amounts in Cobar and other pediplain land systems consists of local rock fragments and an iron-manganese mineral (maghemite). This gravel occurs scattered through uneroded profiles or concentrated on the surface of severely eroded areas and is thought to have been formed during lateritization in the Tertiary and deposited in drainage lines (J. Milovanovic pers. comm.) during later dissection of the landscape. The high iron content of this weathering gravel contributes to the darker red colour of the soils in these land systems.

The red earths of the lower lowland slopes and drainage lines and of alluvial plains are formed on sediments derived from the adjacent higher ridges. Ongley (1974) referred to the in-filling with sediments of once active drainage lines of the Cobar Pediplain (probably in the Quaternary), and evidence of this can be seen in the presence of the hardpan and gravel layers in these soils (Walker 1976). Soil formation in these areas is seen in deep leaching of calcium carbonate, gradual increase in clay content with depth, development of earthy fabric, and weak structural development in some profiles. In the small drainage lines of the western lowlands, successive depositional layers have formed profiles with sandy topsoils, overlying stony layers and clayey subsoils in which strong to weak structure may have developed.

The granitic rocks produce gritty, very coarse sandy soils, held together in weak aggregates by clay particles. These aggregates are very dispersible, and gullyng of these soils after concentration of water is widespread. The few basalt rocks, although of fine texture, also produce sandy soils, though the sand grains are much smaller than those of the granite. Brunner (1968) refers to angular coarse surface residuum on these ridges. Porphyritic rocks form sandy to loamy textured soils.

The deep sands and sandy earths are formed on sedimentary layers, probably originating from the Devonian sandstones, but with possible inputs of aeolian material. These soils are usually in the form of dunes, irregular rises or sand sheets, and it is obvious that aeolian action has determined these forms. This action has been resorting of the alluvial sediments and redistribution into dunes or around obstacles. Accumulation of windblown sand on and against western hills and ranges is apparent in many areas, (e.g. Lilyvale, Coonavitra and Lachlan Downs land systems) and in deep rounded sand deposits occurring in other land systems (e.g. Gundigoona) adjacent to hills. These soils have undergone little pedological development except for deep leaching of (probably aeolian) carbonates.

The origin of the solonized brown soils is not known. Devonian seas in this area were thought to be brackish (D. Dolstra pers.comm.) and may therefore have precipitated salts when they subsequently dried up. Alternatively, carbonate has moved upward by capillary action from shallow groundwater (Dregne (1976). Jessup (1961b) considers aeolian accessions from the Nullabor Plain and other western areas to be the parent material of these soils, as well as the source of the large amounts of carbonates therein. The relatively low carbonate contents of local rocks tend to support this theory. Gunn and Richardson (1979) consider the possibility of marine carbonate accessions via rainfall even at large distances from the coast (including from the Murray Basin transgression in the Miocene). It is further postulated that these soils are the residuals of material that has been stripped and re-sorted by wind to form the sandy soils described above. These soils are of light to heavy texture, though mainly of medium texture, with calcium carbonate throughout, but with differing depths to the zone of maximum concentration. Structure development has also occurred in some areas, notably where drainage is restricted and clay contents higher.

The texture-contrast soils occur on alluvial plains and are thought to have formed on sediments originally derived from the Cobar Pediplain and the Devonian sandstone ranges. The texture-contrast soils along the Darling River (Dunoak land system) are thought to be relicts of an original floodplain which has since been buried by riverine deposits of grey clays. It is doubtful that any of these texture-contrast soils have formed by clay illuviation alone, as evidenced by changes in colour and pH as well as by the presence of layers between horizons. However, no detailed studies have been carried out. Deposition of the topsoil by water and/or wind is thought to be a more likely mechanism, and extensive movement of soil by wind has occurred in recent times (C. Middleton pers. comm., G. Cunningham pers. comm.). The latter found an aboriginal grinding plate between the A and B horizons of a texture-contrast soil near the Bogan River). Development of structure has occurred to varying degrees in the B horizons of these soils.

The non-cracking clays have also formed in sediments, in locations where finer-textured sediments have accumulated. Their usual reddish-brown colour indicates moderate drainage, though they often occur in drainage sinks. Crab holes often occur, suggesting that slightly swelling clays, probably illitic or chloritic, are the main types.

Cracking clay soils have been derived from fine-textured sediments in riverine alluvial deposits, probably originating in the head waters of the Darling River and its tributaries, and significantly affected by the moisture regime of periodic inundation and probable long periods of waterlogging. The extreme shrink-swell characteristics of the clay suggest montmorillonite as the dominant clay type. Similar soils also occur in gilgais, swamps and lakes removed from the river and surrounded by red soils. While some appear to be in ancient watercourses, the presence of a highly swelling clay seems to be the main

reason for gilgai formation, and the subsequent long periods of wetting have contributed to the dark soil colour.

Sand dunes on the Darling floodplain (Budda land system) predate the grey clays, which overlie their flanks. The higher dunes are sandy throughout, but many lower dunes have relatively thin sandy layers overlying more clayey “cores”.

Over the whole survey area, a relatively small proportion of soils can be clearly shown to be directly derived from the underlying rock material, and the larger proportion are formed from various sedimentary layers. This layering can make classification of soils by the Northcote (1971) Key difficult, due to difficulty in determining, without extensive laboratory analyses, the extent of the solum.

2. Climate

As outlined in the previous section, most of the soils in the area are developed on sediments derived from water and wind erosion. Cycles of dry and wet periods are believed to have occurred in the late Tertiary – Quaternary periods (Bowler 1975, Wasson 1979, Jessup 1961c). Erosion-deposition occurs in dry, unstable (arid) phases, whilst soil formation occurs during wetter, stable phases when the soil is protected by vegetation (Jessup *op. cit.*, Ongley 1969).

Moist periods in the Tertiary were associated with lateritization and deep weathering of rocks. High runoff resulted in erosion and dissection of the landscape, leaving ferruginous gravel which later influenced the high iron content and the dark red colour of the soil. This iron is the main bonding agent for the hardpan in lowland soils. The high water table in (probably later) wet periods was also responsible for bringing to the surface carbonate salts previously dissolved from rock deep underground. These salts were responsible for the carbonate now occurring in eastern soils and as rock cappings and calcrete layers (J. Milovanovic *pers. comm.*, R. Glen *pers. comm.*).

Heavy rainfall must have occurred during or at the close of dry periods, to produce the enormous loads of erosion debris of the Cobar Pediplain. These in-filled the drainage-lines with soil-like material, gravel and stones to produce the present-day hardpan, and younger overlying soil layers.

Most of the present soil layers appear to be of Quaternary age, formed by erosion and deposition of Tertiary and Quaternary sediments. Periods of high rainfall within that Age have caused leaching of carbonates and replacement of exchangeable cations by hydrogen, resulting in acid soils (e.g. loamy lithosols, acid and neutral red earths) where one would expect, under present climate conditions, to find alkaline soils. This leaching must have occurred before loss of topsoil to allow high rates of infiltration. The calcareous soils in the west must have either formed after the wet periods or did not receive the same amount of rainfall as further east. Alternatively, like the situation at Coomealla, N.S.W. (Northcote 1951), these soils are the subsoils of former soils whose more acid topsoils were removed by wind to form the dunes and other sandy soils.

The annual rainfall has apparently increased from west to east throughout the Quaternary, as indicated by the depth to calcium carbonate. In the east carbonate is restricted to small amounts in the deep subsoils or rock cappings below acid soils, while to the west

calcareous red earths occur, with large amounts of carbonate in the subsoil. Further westward again, this carbonate approaches closer to the surface westward, until in the far west solonized brown soils occur, with carbonate at the surface.

Dry conditions also favour movement of soil by wind, and aeolian accessions have been significant in many soil types, even in areas extending to the NSW Tablelands and Coast. During such periods in the Quaternary, formation of dunes and other sandy rises also occurred. Small accumulations of sand have also occurred on the Cobar Pediplain, built up around trees, stumps and other obstructions (e.g. Walker 1976). These deposits are of localized origin and are now relatively stable.

3. Relief

Relief affects soil formation in two ways. It is an important factor determining the amount of soil erosion and runoff that may take place, and it affects the internal drainage of soil profiles.

Soils on higher sloping areas are more liable to water erosion than soils on level areas. Movement of water over bare sloping surfaces may remove soil as fast as it forms from decomposing rock, so preventing the development of soils and preventing the pedological development of soils that do form. This same action may also deposit extensive layers of erosion debris over lower slopes and in drainage lines, truncating and/or burying the soils already in those locations. This process has led to the formation of texture-contrast soils in the western lowlands and the presence of stone or hardpan layers in soils of lower topography as well as providing the parent material for the development of new soils. The loss of water from the sloping areas affects the moisture regime of the soils there, reducing infiltration and leaching of the profile. This affects the growth of plants which in turn further affects infiltration rates, runoff rates and erosion. At the same time, soils in the lower areas receive more water, more erosion debris, seeds and plant nutrients by runoff and provide a better medium for plant growth, which in turn affects infiltration, build-up of soil organic matter and plant nutrients.

Soil depth is greater on level areas than on sloping areas due to lower runoff and erosion rates.

Profile drainage is faster on sloping areas than on level areas, and this affects leaching of minerals and nutrients, the soil flora and fauna and the chemistry of certain elements. Well drained soils are normally acid to neutral (at least near the surface) due to leaching of carbonates and additions of hydrogen to the exchange complex, and this affects the mobility and availability to plants of several elements. Iron is less easily leached and in well drained conditions is present mainly as the ferric ion, giving the soil a reddish colour. In poorly drained conditions iron is in the ferrous form and gives the soil a yellow or grey colour.

Most soils in the area are reddish, even when occurring on level areas. This is due to the low rainfall of the area, which allows the soils to dry out between rainfall events, and the presence of drainage lines or sink holes in which much of the water moves. These sinks may have yellowish-grey soils or, more commonly, orange-coloured soils. The only grey soils are those on the riverine plains and in gilgais and lakes, which may remain wet for considerable periods, and which may not contain as much iron as the red soils.

4. Flora and Fauna

Flora and fauna, both micro and macro affect soil formation in several ways.

Microflora, mainly algae and lichens, form a surface cover on many soils, particularly those of medium texture. The chemical effects of these are not known, but some may be nitrogen-fixing, and they protect the soil surface to some degree from raindrop action and erosion (Rogers 1972) and can even increase infiltration.

The main role of vegetation is to stabilize the soil by increasing organic matter and improving the structure of the topsoil, maintaining high infiltration rates and reducing runoff and erosion. It also protects the soil surface from raindrop impact. Once vegetation decreases, runoff rates are increased producing soil surfaces unfavourable to plant establishment and growth. This has occurred on the ridges of Cobar and Ironstone land systems, where little growth of ground vegetation occurs.

Deep rooted vegetation can extract nutrients from the subsoil, eventually enriching the topsoil by leaf fall.

Leguminous trees, shrubs and forbs fix varying amounts of nitrogen but increased levels in total soil nitrogen are not apparent, and all but a few soils are low in nitrogen.

Climate and herbivorous fauna control the vegetation cover, and overgrazing, particularly during and following drought, may reduce vegetative cover to such an extent that irreversible changes in plant composition or quantity may occur. Loss of perennial grasses and decline in cover results in soil erosion which further decreases the capacity of the soil to produce vegetation. Grazing by native fauna prior to European settlement is thought to have been in balance with the environment, due to lack of water and relatively low numbers of animals. Domestic stock and rabbits, and increased native animal population by provision of water, led to intense pasture degradation and erosion. The Cobar district (Cobar and Ironstone land systems) is a prime example of this decline.

Trampling by cloven hooved stock has destroyed the structure and caused compaction of many surface soils, resulting in lower infiltration and higher runoff rates. Most of the red soils have a surface layer to approximately 15 cm deep which is harder than the underlying layer.

Rabbits have caused much mixing of soil by their digging activities and are found in all areas except the steeper parts of ranges and hills, and the cracking clays.

Ants, termites and other burrowing insects also cause mixing of soil layers. Subterranean ant nests are almost impenetrable to water, forming level circular permanently bare areas to 2 metres diameter on most red soils. Other insects make smaller holes in the topsoil with apparent compaction of soil around the edges.

Activities such as road making, dam sinking, mining, urban development and other construction have had localized impacts on the drainage and erosion of soils and have caused burying of soils with excavated material and inversion of soil layers.

VI. SOIL EROSION

Most soils in the area have suffered to some degree from erosion.

In the eastern and central districts, water erosion is by far the most important type of erosion, whilst in the western plains wind erosion is more common.

Water erosion may be in the form of sheeting, rilling or gullying, or a combination of these, whilst wind erosion may be in the form of sheeting, drift or scalding.

The most severely eroded soils in the area are the stony red earths and loamy lithosols of Cobar and Ironstone land systems. These have been severely water sheeted, with large amounts of topsoil removed and deposited in adjacent drainage lines and on lower slopes. In many areas the topsoil has been completely removed, exposing a hard, compact, shiny surface with varying amounts of gravel. This erosion surface yields up to 85 per cent of rainfall in a single storm as runoff (Walker and Cunningham *op. cit.*) and further exacerbates the soil erosion problem on lower slopes, where concentration of runoff forms rill-lines and, where soil is deep enough, gullies. The only ground vegetation on such areas is on small areas of residual topsoil or in stabilized rill-lines filled with sandier sediments. A study of erosion rates and rainfall erosion hazard for this country has been carried by McCaffrey (1980).

Lithosols on ranges and hills appear to be stable by virtue of the rock and stone surface cover and separation of the soil into small pockets. However, water sheeting may occur, especially where large numbers of goats have congregated and powdered the soil by trampling. The shallow nature and hence low water holding capacity of these soils, combined with their steep topography can, however, lead to the generation of large volumes of runoff, which causes gully erosion of the lower slopes and surrounding lowlands (red earths).

Red earths on the western lowlands, where topsoil is somewhat sandier than in the east, have a greater infiltration rate, better ground cover, and lower runoff rate, and erosion has been much less severe. However, water erosion, mainly sheeting, has occurred in these areas. Red earths on alluvial plains have suffered only minor water sheeting and wind sheeting, due to their level topography, slow runoff rate and usually good pasture cover.

The sandy lithosols in country derived from igneous rock are susceptible to water erosion when runoff water is concentrated on bare areas. This results in rilling and, in gritty red earths on lower slopes and deep sandy soils and texture-contrast soils in associated drainage lines, severe gullying. Most drainage lines in granite country are gullied, especially when in proximity to steeper hills (eg Warrowie land system). However, this country usually supports a good vegetative cover, and erosion is usually confined to the drainage lines.

The steep sandy soils on dunes and rises show evidence of past movement by wind (hummocking, shallow blowouts etc) but are generally stable. Some scalding of dune bases has occurred in Budda land system, where a shallow layer of sandy soil overlies the clayey dune core, and the sandy layer has been washed or blown away to expose this clayey layer. The deep sand in major creek beds is loose, grows little vegetation and is subject to drift during flows of water. The sandy-textured lunettes are very susceptible to gullying when water is concentrated into stock or vehicle tracks.

The solonized brown soils are relatively stable but are susceptible to wind erosion in dry times. There is abundant evidence of drift in Nelia land system, where hummocks have formed around trees, but this is thought to have occurred many decades ago.

The texture-contrast soils are susceptible to windsheeting and scalding; particularly those in Popelloe, Dunoak and Budda land systems. Popelloe land system has been worst affected, with large areas devoid of original topsoil. Scalding is an advanced form of wind sheeting, where the topsoil has been removed to expose the clayey subsoil which is compact with a very low infiltration rate, and low nutrient levels (Charley and Cowling op. cit.). Some scalds have reclaimed naturally during the favourable seasons of the mid 1970's.

The clays are the most resistant to erosion, due to their particle size, self-mulching surface and level to depressed topography. However, scalds do sometimes occur due to dispersion of clay at the surface, and water sheeting, scalding and gullying may occur on the steeply sloping areas adjacent to the rivers.

VII SOIL AND LAND MANAGEMENT

The susceptibility of the soils to erosion has been outlined above, and it is critical to note that in this semi-arid environment erosion of these soils results in irreversible degrading changes.

Rehabilitation measures such as contour furrowing (on sloping hard red soils) and waterponding (on scalded texture-contrast soils) have been developed and proven but are high cost in proportion to land value, and in reality virtually no areas are now suited for contour furrowing because of dense encroachment of woody shrubs and trees, and scalds occupy a tiny proportion of the region.

Accordingly, soil management must be aimed at avoiding, or at least minimising, soil loss. In the pastoral situation this requires retention and management of groundcover, particularly perennial species, by managing domestic, feral and native livestock grazing. At least 40% cover of ground plants and litter needs to be maintained to protect soils from water erosion, and 50% of standing cover for wind erosion. This especially important leading into, during, and recovery from drought conditions. This will require periodic destocking, or confined feeding of nucleus breeding stock in sacrifice paddocks or yards, and ongoing control of feral animals.

So, the key to management of the soils of this region is vegetation management.

Waterspreading, with cropping or pasture, is a useful technique for improving the soil water regime of the broader flats of the Cobar Pediplain, but the difficulty in obtaining clearing approval and the costs of clearing are major impediments.

In those few areas suitable for fodder cropping, or, in the east more regular cropping, and waterspread areas, fallow management and particularly stubble retention during summer is critical. The red earth soils are susceptible to surface crusting and hardsetting and to compaction, affecting runoff and infiltration. Soil organic matter needs to be maintained or increased to counter these effects. Cultivation should follow the land contours. Testing of soil

properties, particularly phosphorus and pH, and amelioration of chemical deficiencies should be carried out.

Clay soils on the Darling floodplain are likely to be sodic and would need careful management if ever developed for irrigated cropping.

Mining, exploration, industrial, and road and track-making activities require careful management of runoff and exposed soil, with established soil conservation measures. Granite-based soils are especially susceptible to gully formation when water is concentrated or drainage gradients too high, as in the Nymagee area in the south

TABLE 1 SOIL DESCRIPTIONS AND OCCURRENCE

SOIL CHARACTERISTICS			SITES OF OCCURRENCE	LAND SYSTEM & UNIT
Lithosols	Shallow, stony; sandy or loamy texture with no pedological development; less than 40cm deep	Reddish-brown sandy and loamy Uc1, (Um1) <i>Order – Rudosols Suborder – Leptic Great Group – Lithic and paralithic</i>	Higher basalt, granite, and porphyry ridges	Kergunyah 1 Florida 1 Hartwood 1 Wynwood 1
			Scarps and higher ridges of Devonian sandstone ranges and hills	Mt Pleasant 1,2 Booroondarra 1,2 Mulga Downs 1,2 Belford 1
		Dark-coloured, sandy Uc1 <i>Order - Tenosols Suborder – Chernic (suggestion organic A) Great Group -Lithic</i>	Higher ridges of Ordovician and Silurian ranges and hills	Mineshaft 1,2 Boppy 1,2 Glenown 1 Wynwood 1

		Reddish-brown loamy soils Um5.51, (Uc5.21) <i>Order - Tenosols</i> <i>Suborder – Red Orthic/</i> <i>Leptic</i> <i>7Great Group - Lithic</i>	Lowland crests and upper slopes on sedimentary and metamorphic rocks	Cottage 2 Ironstone 1,2 Cobar 1 Kopyje 1,2 Boulkra 1,2 Taringa 1 Lilyvale1
		Reddish-brown sandy, gritty soils Uc5.21, (Uc1.43) <i>Order - Tenosols</i> <i>Suborder – Red Orthic/</i> <i>Leptic</i> <i>Great Group - Lithic</i>	Lower ridges on igneous rocks	Warrowie 1 Wynwood 3 Florida 2 Tindera 1 Hartwood 2
		Stony, crab-hole Um6.43 <i>Order – Tenosols</i> <i>?????(No Fe data to confirm Ferrosol)</i> <i>Suborder – Chernic (structured A)</i> <i>Great Group -Lithic</i> <i>Note – this soil does not fit ASC very well?</i>	Footslopes of basalt ridges	Kergunyah 2
Alluvial Soils	Deep soils with weak pedological development	Loamy and sandy clay loam soils Um5.52 <i>Order – Tenosols (Kandosols???)</i> <i>Suborder – Red Orthic/various colours?</i> <i>Great Group – Basic, some Calcareous?</i>	Drainage lines	Booroondarra 4 Barnato 4 Tiltagara 3 (Boulkra 6) (Hartwood 3) (Pangee 4)
			Plains	Lynwood 1, (3)

		Sandy and gritty soils Uc5.21 <i>Order – Tenosols</i> <i>Suborder – Red Orthic</i> <i>Great Group – Basic, some</i> <i>Calcareous?</i>	Drainage lines in sediments of igneous rocks	Florida 3 Wynwood 4 Warrowie 3
Sands and Sandy Earths	Deep sands	No pedological development Uc1.23 <i>Order – Arenosols</i> <i>Suborder – Red</i> <i>Great Group – Tenic or</i> <i>Palic</i>	Dunes	Lachlan Downs 1 Lynwood 2 Korreo 1,2 Gundigoona 1 (2) Tiltagoona 1 Curranyalpa 1 Cairo 1 Euramurtie 3
		Weak pedological development Uc5.11 <i>Order – Arenosols</i> <i>Suborder – No colour indicated, commonly Red?</i> <i>Great Groups –</i> <i>Kandic (subsoil 10 to 15% clay)</i> <i>Tenic (subsoil clayey sand to loamy sand < 10% clay)</i> <i>Palic - < 5% clay in subsoil</i>	Dunes	Fulham1 Kaleno 2 Meadows 1 Gundigoona 2 Glenlea 1 Bindi 1 Bulla Park 1 Bell Vale 1 Tiltagoona 2 Nelia 1 Budda 1
			Low sandy rises and sandplains	Mulchara 1 Blackfella/Narraport 1 Vidale 2 (Nangara 3) (Manara 2) (Curranyalpa 3)

			Creek channels	Belford 6 Pangee 5 Kaleno 5 Mulchara 4 Mt Pleasant 4 Meadows 5 Lynwood 4 BellVale 4 Tiltagoona 5
	Shallow sands	Overlying more clayey soils Uc5.13 <i>Order – Tenosols</i> <i>Suborder – Leptic or Red</i> <i>Ochric</i> <i>Great Groups – Duric</i>	Sandplains	Lachlan Downs 2 (Bindi 2)
	Deep sandy earths	Gn1.13, (Uc5.31) <i>Order – Kandosols (subsoil</i> <i>> 15% clay?, otherwise Tenosol)</i> <i>Suborder – Red</i> <i>Great Groups – Dystrophic</i>	Lunettes	Thackenzie 1
Gn1.13 (Gn1.12) <i>Order – Kandosols (subsoil</i> <i>> 15% clay?, otherwise Tenosol)</i> <i>Suborder – Red</i> <i>Great Groups – Dystrophic</i>			Dunes	(Manara 1) (Gundigoona 2) (Nangara 1) (Fulham 1)
			Low sandy rises	(Blackfella 1) (Mulchara 1) (Manara 2) (Nangara 3) (Curranyalpa 3)
Red Earths	Shallow, stony; less than 60cm deep	Loamy topsoil, acid reaction trend Gn 2.11 <i>Order – Kandosols</i>	Low ridge slopes	Cobar 2 (3) Cottage 3

		<i>Suborder – Red</i> <i>Great Groups – Dystrophic</i> <i>Family – Moderate depth</i>		(Taringa 2) (Ironstone 3)
		Loamy topsoil, neutral reaction trend Gn 2.12 <i>Order – Kandosols</i> <i>Suborder – Red</i> <i>Great Groups – Mesotrophic</i> <i>Family – Moderate depth</i>	Lower slopes of sandstone ranges	Booroondarra 3 Mulga Downs 3
Deep, stony		Loamy topsoil, alkaline and neutral reaction trend Gn2.13, Gn2.12, (Gn2.11) <i>Order – Kandosols</i> <i>Suborder – Red</i> <i>Great Groups – Mesotrophic</i> <i>Family – Deep to very deep</i>	Plains	Fulham 2 Barnato 1
			Low ridge slopes and drainage lines	Boulkra 4,5 Taringa 2 Cobar 3 Coronga 1 Yanda 1 Lilyvale 3 Tindera 1 Ironstone 3 Coolabah 1 Wrightville1 Euramurtie 5
			Creek channels	Yanda 4
Deep, with earthy hardpan at depth		Loamy topsoil with neutral reaction trend Gn 2.12 <i>Order – Kandosols</i> <i>Suborder – Red</i> <i>Great Groups – Duric</i> <i>Family – Deep</i>	Drainage lines in hills and ranges	Glenown 3 Boppy 3 Mineshaft 3

Red Earths			Smaller drainage lines in hard-red country	Ironstone 4 Cobar 4 Coolabah 2 Tindera 2
		Loamy topsoil, alkaline reaction trend Gn2.13 <i>Order – Kandosols Suborder – Red Great Groups – Duric Family – Deep</i>	Low ridge slopes	Killala 1 Wilson's Tank 1
			Plains	Coronga 2 Wrightville 2 Cubba 1 Yanda 2
			Drainage lines and sinks	Taringa 4 Ironstone 5 Cobar5 Kopyje 3 Killala 3
	Wilson's Tank 3,4 Coronga 3 Wrightville 3,4 Cubba 2 Yanda 3 Pangee 2			
	Deep, no hardpan	Sandy to loamy topsoil, neutral reaction trend Gn2.12 <i>Order – Kandosols Suborder – Red Great Groups – Mesotrophic Family – Deep to very deep</i>	Lower hill slopes	Belford 2 (Mulga Downs 3)
			Drainage lines in hills and on plains	Mulga Downs 4 Belford 3,4 Fulham 3
			Plateaux	Cottage 1

		Sandy to loamy topsoil, alkaline reaction trend Gn2.13 <i>Order – Kandosols</i> <i>Suborder – Red</i> <i>Great Groups –</i> <i>Mesotrophic</i> <i>Family – Deep to very deep</i>		Killala 2 Boulkra 3
			Sand-covered ridges	Lilyvale 2 Coonavitra 1
			Valleys in ranges	Booroondarra 5 Belford 5 Mulga Downs 5
			Plains	Taringa 3 Wilson's Tank 2 Pangee 1 Meadows 2 Mulchara 2 (Barnato 3)
			Sandplains	Lynwood 1,3 Korreo 3 Bindi2,3 Glenlea 2,3 Manara 2 Nangara 3 Curranyalpa 3 Coonavitra 2 Euramurtie 2
			Swales	Tiltagoona 3 Gundigoona 3 Bell Vale 2 Blackfella 2
			Drainage lines	Boulkra 6 Hartwood 3

				Cubba 3 Pangee 4 Meadows 4 Korreo 4,5
Red Earths			Drainage sinks and swamps	Meadows 3 Lynwood 5 Gundigoona 4 Bulla Park 3 Bell Vale 3 Tiltagoona 4 Blackfella 3 Manara 4 Cairo 3 Nelia 3 Curranyalpa 5 (Nangara 5)
Solonized Brown Soils/Calcareous Earths	Deep, loamy surface	Weakly structured Gc 1.22, Gc 1.12 <i>Order – Calcarosols</i> <i>Suborder – Hypocalcic: Fine carbonate</i> <i>Hypercalcic: 0 – 20% hard carbonate and > 20% soft carbonate</i> <i>Supracalcic: 20 – 50% hard carbonate</i> <i>Lithocalcic: > 50% hard carbonate</i> <i>Great Groups – Insufficient information</i>	Lunettes	Barnato 2 Karumpito 1 Tiltagara 1
			Ancient Dunes	Nangara 2 Curranyalpa 2 Budda 2 Dunoak 1
			Plains	Manara 3 Nangara 4 Curranyalpa 4 Nelia 2

		<i>Family – Deep to very deep</i>		Vidale 1
		Structured subsoil Gc 2.22 <i>Order – Calcarosols</i> <i>Suborder – Hypocalcic: Mainly fine carbonate</i> <i>Hypercalcic: 0 – 20% hard carbonate and > 20% soft carbonate</i> <i>Supracalcic: 20 – 50% hard carbonate</i> <i>Lithocalcic: > 50% hard carbonate</i> <i>Great Groups – Pedal</i> <i>Family – Deep to very deep</i>	Swales	Cairo 2
			Plains	(Dunoak 3)
			Drainage sinks	(Karumpito 3)
			Lake shorelines	(Karumpito 2)
Clays	Cracking clays with self-mulching surface	Deep, grey coloured Ug5.25, Ug 5.29 <i>Order – Vertosols</i> <i>Suborder – Grey</i> <i>Great Groups – Self-mulching</i> <i>Family – Deep to very deep</i>	Plains	Acres Billabong 2 Nelyambo 4 Budda 4
			River loops	Mid Darling 1 Acres Billabong 1
			River banks and beds	Mid Darling 2 Acres Billabong 3
			Swamps and drainage lines	Nelyambo 5,6 Thackenzie 4
			Lakebeds	Thackenzie 3 Popelloe 3
		Deep, grey-coloured with brownish subsoil Ug 5.24	Plains	Buckanbe 1 (Budda 4)

		<p><i>Order – Vertosols</i> <i>Suborder – Grey</i> <i>Great Groups – Self-mulching</i> <i>Family – Deep to very deep</i></p>	Sinks and lakebeds in red country	<p>Nelia 3 Karumpito 3 Tiltagoona 4 Barnato 6 (Euramurtie 6)</p>
		<p>Deep reddish-brown coloured Ug 5.35, Ug 5.37 <i>Order – Vertosols</i> <i>Suborder – Red and Brown</i> <i>Great Groups – Self-mulching</i> <i>Family – Deep to very deep</i></p>	Plains	<p>Dunoak 4 Nelyambo 2 (Buckanbe 1) (Budda 4)</p>
	Cracking clays with scaldy surface	<p>Deep grey-coloured, often with sandy surface deposit Ug 5.24 <i>Order – Vertosols</i> <i>Suborder – Red and Brown</i> <i>Great Groups – Crusty</i> <i>Family – Deep to very deep</i></p>	River banks, lake and swamp shorelines	<p>Nelyambo 3 (Mid Darling 2) Thackenbie 2 Karumpito 2 Tiltagara 2</p>
	Non-cracking Clays	<p>Deep, reddish-brown-coloured, structured subsoil Uf6.34, Uf6.31, Uf6.41, (Uf6.71) <i>Order – Ferrosols</i> <i>Suborder – Red and Brown</i> <i>Great Groups – Eutrophic</i> <i>Family – Deep to very deep</i></p>	<p>Plains</p> <p>Drainage sinks</p>	<p>(Dunoak 4) (Bell Vale 2)</p> <p>Dunoak 5 Euramurtie 6 Nangara 5 (Manara 4) (Bulla Park 3) (Cairo 3) (Curranyalpa 5) (Bell Vale 3) (Blackfella 3) (Tiltagoona 4)</p>

			Pans	Popelloe 2
Texture-contrast/ Duplex soils	Red, structured subsoil	Crusty surface Dr1.13, Dr1.12 <i>Order – Chromosols</i> <i>Suborder – Red</i> <i>Great Groups – Eutrophic</i>	Footslopes of west-Darling sandstone ranges	Mount Pleasant 3 Euramurtie 1
		Hard-setting surface, stony Dr2.13 <i>Order – Chromosols</i> <i>Suborder – Red</i> <i>Great Groups – Eutrophic</i>	Drainage lines	Cottage 4
		Hard-setting surface, stone-free Dr2.13, (Dr2.12) <i>Order – Chromosols</i> <i>Suborder – Red</i> <i>Great Groups – Eutrophic</i>	Plains	Dunoak 3 Popelloe 1 Barnato 3 (Euramurtie 2)
	Drainage lines		Euramurtie 4	
	Drainage sinks		Mulchara 3	
	Red, weakly-structured subsoil	Hard-setting surface, stony Dr 2.53 <i>Order – Kandosols</i> <i>Suborder – Red</i> <i>Great Groups – Mesotrophic</i>	Lower slopes	(Ironstone 3) (Boulkra 4)
			Drainage lines	(Boulkra 5)
		Hard-setting surface, stone-free Dr 2.53 <i>Order – Kandosols</i> <i>Suborder – Red</i> <i>Great Groups – Mesotrophic</i>	Plains	Kaleno 1,2 (Bindi 2) (Dunoak 3)
		Sandy surface, stone-free Dr 4.53 <i>Order – Chromosols</i>	Lake shorelines	Barnato 5

		<i>Suborder – Red</i> <i>Great Groups – Eutrophic</i>		
Brown, structured subsoil	Hard-setting surface Db1.13 <i>Order – Chromosols</i> <i>(Hydrosols?)</i> <i>Suborder – Brown</i> <i>Great Groups – Eutrophic</i>		Swamps	(Dunoak 5)
Yellow, structured subsoil	Hard-setting surface, subsoil whole-coloured Dy2.13 <i>Order – Chromosols</i> <i>Suborder – Yellow</i> <i>Great Groups – Eutrophic</i>		Plains	Budda 3 Dunoak 3 Buckanbe 2 (Kaleno3)
			Drainage sinks	Kaleno 4
	Hard-setting surface, subsoil mottled Dy3.13 <i>Order – Chromosols</i> <i>Suborder – Yellow</i> <i>Great Groups – Eutrophic</i>	Swamps	Pangee 3	
Yellow, weakly structured subsoil	Hard-setting surface, whole-coloured subsoil Dy2.53 <i>Order – Kandosols</i> <i>(Chromosols?)</i> <i>Suborder – Yellow</i> <i>Great Groups – Mesotrophic</i>		Plains	(Dunoak 3) (Kaleno 3)
	Hard-setting surface, mottled subsoil Dy3.53 <i>Order – Kandosols</i> <i>(Chromosols?)</i> <i>Suborder – Yellow</i> <i>Great Groups – Mesotrophic</i>		Drainage lines in igneous sediments	(Wynwood 4) (Florida 3) (Warrobie 3)
	Sandy surface, whole-coloured subsoil Dy4.53		Ancient dunes	(Budda 2)

		<i>Order – Kandosols</i> <i>(Chromosols?)</i> <i>Suborder – Yellow</i> <i>Great Groups – Mesotrophic</i>		
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VIII REFERENCES

- Black, C.A. (ed) (1965) "Methods of Soil Analysis Part I." Monograph No. 9, American Society of Agronomy.
- Bowler, J.M. (1975) "Deglacial Events in Southern Australia: Their Age, Nature and Paleoclimatic Significance" In: Suggate R.P. and Cresswell M.M. (eds) Quaternary Studies Roy. Soc. N.Z., Wellington. pp 75–82.
- Brunker, R.L. (1968) "Explanatory Notes on Bourke 1:250,000 Geological Series Map. Sheet SH/55-10." Geological Survey of N.S.W.
- Charley, J.L. and Cowling, S.W. (1968) "Changes in Soil Nutrient Status Resulting from Overgrazing, their Consequences in Plant Communities of Semi-Arid Australia." Proc. Ecol. Soc. Aust. 3: 28–38
- Condon, R.W. (1961) "Soils and Landforms of the Western Division of New South Wales" J. Soil Cons. NSW, 17: 31–46
- Cunningham, G.M., Quilty, J.A. and Thompson, D.F. (1974) "Productivity of Water-ponded Scalds" J. Soil Cons. NSW, 30(4): 185–200
- Dawson, N.M. and Ahern, C.R. (1974) "Soils" pp 18–46. In Western Arid Region Land Use Study – Part I. Tech. Bull. No. 12 Div. Land Utilization Dept. Primary Industries Qld.
- Dregne, H.E. (1976) "Soils of Arid Regions" Development in Soil Science 6. Elsevier Scientific Publishing Co. New York.
- Gunn, R.H. and Richardson, D.P. (1979) "The Nature and Possible Origins of Soluble Salts in Deeply Weathered Landscapes of Eastern Australia". Aust. J. Soil Res., 17, 197-215.
- Isbell, R.F., National Committee on Soil and Terrain (2021) "The Australian Soil Classification" 3rd Edition, CSIRO Publishing Melbourne
- Jackson, E.A. (1957) "Soil Features in Arid Regions with Particular Reference to Australia". J. Aust. Inst. Agric. Sci. 23: 196–208
- Jessup, R.W. (1961a) "Evolution of the Two Youngest (Quaternary) Soil Layers in the South-eastern Portion of the Australian Arid Zone. I. The Parakylia Layer. J. Soil Sci. 12(1):52-63
- Jessup, R.W. (1961b) "Evolution of the Two Youngest (Quaternary) Soil Layers in the South-eastern Portion of the Australian Arid Zone. II. The Bookaloo Layer" J. Soil Sci. 12(1): 64-72
- Jessup, R.W. (1961c) "A Tertiary-Quaternary Pedological Chronology for the South-eastern Portion of the Australian Arid Zone". J. Soil Sci. 12(2): 199-213

- Jessup, R.W. (1964) "Soil Salinity in Saltbush Country of North-eastern South Australia"
Trans. Roy. Soc. S.A. 93: 69–78
- Lawrie, J.W. (1974) "Soils". In: Condobolin District Technical Manual. Soil Cons. Service
NSW Sydney.
- Lawrie, J.W. and Stanley, R.J. (1980) "Soils and Vegetation of the Natural Gas Pipeline
Section 1 Queensland Border to the Darling River Soil Cons. Serv. NSW Sydney
- Lawrie, J.W. (1991) "Soils of the North-West Corner of NSW" In: Lands of the North-West
Corner of NSW, Milthorpe, P.L. et al. Technical Report No.12 Soil Cons. Serv. NSW
Sydney
- Mc Caffrey, L.A.H. (1980) "Contemporary Rates of Erosion on the Cobar Pediplain".
Western District Technical Bulletin No. 22 Soil Cons. Serv. NSW Sydney
- Ministry of Agriculture and Forestry, Japan (1970) Revised Standard Soil Color Charts
- Northcote, K.H. (1951) Pedology of Soils at Coomealla, NSW CSIRO Bulletin No. 264
Melbourne.
- Northcote, K.H. (1966) Atlas of Australian Soils Sheet 3. CSIRO and Melbourne University
Press.
- Northcote, K.H. (1971) A Factual Key for the Recognition of Australian Soils Rellim
Publications, Glenside, S.A.
- Northcote, K.H. et al (1975) A Description of Australian Soils. CSIRO Australia.
- Ongley, E.D. (1969) "A First Estimate of Absolute Age for Residual Soils in the Cobar Area
of the Cobar Pediplain". Aust. J. Sci. 31(12): 432–3
- Ongley, E.D. (1974) "Fluvial Morphometry on the Cobar Pediplain" Annals Assoc. Am.
Geographers 64(2): 281–292
- Prescott, J.A. (1944) A Soil Map of Australia CSIRO Bulletin No. 177. Melbourne.
- Rogers, R.W. (1972) "Soil Surface Lichens in Arid and Subarid South-Eastern Australia. Part
III The Relationship between Distribution and Environment" Aust. J. Bot. 20: 301–
16.
- Stace, H.C.T. et al (1968) A Handbook of Australian Soils Rellim Technical Publications,
Glenside, SA.
- Stannard, M.E. (1958) "Erosion Survey of the South-West Cobar
Peneplain Part II Soils and Vegetation" J. Soil Cons NSW 14(1): 30–45.
- Stannard, M.E. (1962) "Erosion Survey of the Central East-Darling Region.
Part II Soils" J. Soil Cons. NSW 18(4): 173–182

- Stephens, C.G. (1961) *The Soil Landscapes of Australia* CSIRO Soils Publication No. 18.
- Thompson, D.F. (1982) "Soils" In *Nyngan District Technical Manual*. Soil Cons. Serv. NSW Sydney.
- Tinsley, J. (1950) "Determination of Organic Carbon in Soils". *Trans. 4th International Congress Soil Sci.* Vol 1: 161-4.
- Tucker, B.M. (1974) "Laboratory Procedures for Cation Exchange Measurements on Soils" CSIRO Melbourne
- Walker, P.J. (1976) "Soils of the Experimental Area. In: *Rehabilitation of Arid Lands*. G.M. Cunningham et al. Soil Cons. Serv. NSW Sydney pp 2-1 to 2-40.
- Walker, P.J. (1978) "Soils" In *Cobar District Technical Manual*, Soil Cons. Serv. NSW Sydney
- Walker, P.J. and Cunningham, G.M. (1976) "Runoff Studies Using Small Plots" In: *Rehabilitation of Arid Lands*. G.M. Cunningham et al. Soil Cons. Serv. NSW Sydney pp 4-1 to 4-33
- Walker, P.J. (1980) "Soils and Vegetation of the Natural Gas Pipeline Section 2 Darling River to Kilparney" Soil Cons. Serv. NSW Sydney
- Walker, P.J. (1982) "Aeolian Landforms in the Cobar-Tilpa Area NSW". In: *Quaternary Dust Mantles of China, New Zealand and Australia*. Ed. R.J. Wasson ANU 197-199
- Walker, P.J. (1984) "Landscape and Soil Development in the Cobar-Tilpa District NSW" Working Papers Australia-New Zealand Geomorphology Group 2nd Conference Broken Hill
- Walker, P.J. (1991) "Land Systems of Western NSW" Technical Report No. 25. Soil Cons. Serv. NSW Sydney
- Wasson, R.J. (1979) "Sedimentation History of the Mundi Mundi Alluvial Fans, Western New South Wales" *Sedimentary Geology* 22: 21-51
- Wasson, R.J., Hunt, P.A., and Clarke, M.F. (1979) "A Re-evaluation of the "Silcretes" of the Cobar Area, Australia". *Geoderma* 22,137-159.

The following plates show a selection of soils and land treatments from the survey region

As most sampling was done by auger there are few photographs, and photos from soil pit have been lost with the disappearance of the Cobar and Condobolin slide libraries



Typical ridge soil on the Cobar Pediplain: shallow stony red earth. Note pedestalling and rock exposure



Exposure of hardpan over dipping shale in a small gully near the Peak gold mine



More photos of the exposed hardpan



Solonized Brown Soil in Cairo land system

P68 from the Natural Gas Pipeline. At top is the spoil from the trench. The top 10cm of soil has been removed. Full profile description is given in Walker (1980). In Taringa land system, unit 4, drainage line. Gn2.12 over pallid sandstone with a lateritic capping, and some calcium carbonate





P80 in Bindi land system, unit 2; swale in mallee dunefield. Gn2.13 with sandy surface



P90 Bindi land system, unit 1, dune in mallee dunefield. Uc5.11. Trench collapsing



P91 in Wilsons Tank land system, unit 3, in creek bed. Uc5.11 over an older soil. Calcium carbonate layer has been truncated



P107 in Kaleno land system, unit 3, level plain. Dr2.53 but probably 2 profiles: light sandy clay loam to 62cm overlying light clay and then lateritic stone layer with carbonate



P179A Sequential depositional layers of sand and clay at toe of dune bordering Acres Billabong



New contour furrows at "Yarrowonga" Cobar 1972



Cobar Experimental Area. Ungrazed centre, grazed on left



Ground level in same area