

THE SOILS, GEOLOGY AND VEGETATION OF NORTH-WESTERN SOUTH AUSTRALIA

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SUMMARY

The area described is approximately that which lies north of the transcontinental railway, west of Lakes Torrens and Eyre, and westward toward the edge of the Nullarbor Plain.

The average annual rainfall varies from $4\frac{1}{2}$ "-7". Prolonged droughts are common. The introduced and native animal populations are discussed briefly.

The rocks are mostly sedimentaries - Precambrian-Cambrian complex (largely quartzites), Jurassic sandstones, Cretaceous shales and Pleistocene alluvia. Recent wind-blown sands are widespread in the south. Vast plains from 200 to 500 feet above sea level dominate the topography.

Silicification of the surface (Cretaceous) deposits occurred during the earlier and later Pliocene, with a period between during which the resultant soils and the Cretaceous shales were variously truncated. Further truncation of the Pliocene soils and the Cretaceous shales occurred in the Pleistocene, resulting in exposure of underlying Jurassic sandstones in the south. Alluvium was also deposited in the Pleistocene.

The surface sands were stripped off the Pliocene soils in the arid Recent, and sands formed from the exposed Jurassic sandstones were resorted. Sandhills formed upon soils derived from Pleistocene alluvia and gypsum and sodium chloride accumulated in the soils. Pedological evidence indicates four moisture regimes during the Recent.

The type of soil formed from the Cretaceous shales depends upon the extent of truncation of the profiles. Over the tableland areas (preserved Pliocene topography) the soil is a deep clay with a surface mantle of billy gibbers derived from break-up of the siliceous B horizon of the Pliocene soil. Crabholes are developed and the soil contains heavy gypsum but no lime.

Shallower clay soils have resulted from either Pleistocene truncation of the deep clays or were formed during the second period of silicification from shale exposed by the erosion which occurred in the inter-silicification period. Crabholes may be present in these shallow clays and the soil contains heavy gypsum and a trace of lime. Billy gibbers again occur on the surface.

The Pliocene soils were completely removed from large areas in the Pleistocene to expose bleached shale upon which a very shallow soil has subsequently formed. Pleistocene erosion not only resulted in loss of part or all of the Pliocene soil but often caused complete or almost complete truncation of the Cretaceous shale itself. A very shallow soil overlying limestone hardpan has subsequently formed where a shallow layer of shale remained.

Two different sandy and calcareous soils developed where the Cretaceous beds were completely eroded away and the underlying sandstone was exposed. The shallow sands constitute Bon Bon soil and the deeper sands constitute Wirraminna soil. Coondambo and Mount Eba soils have developed upon Pleistocene alluvium. They both consist of shallow sand over red clay and contain lime and gypsum.

The billy gibbers vary considerably in their structure. Four different types are described. Accelerated erosion has been generally insignificant.

The vegetation consists mainly of chenopodiaceous shrub steppe communities on the heavier textured soils, and acacia woodlands on sandy soils. Two or more associations are commonly grouped together to form association complexes.

The dominant shrubs (12"-36" high) of the shrub-steppe communities vary in their lateral spacing but are rarely touching. The woodlands, which are fairly open, consist of trees 16 to 24 feet high. Beneath the trees there may be an understorey of shrubs with perennial grasses dominating the ground layer, or the shrubs may be absent, depending upon the depth of sand in the soil. Severe tree death has occurred in the woodlands and little regeneration is taking place. The shrub steppe areas may be uniformly bushed but in crabhole country growth is restricted to the depressions, the shelves being too arid and too saline. During drought times the ground between the shrubs and trees is bare.

The trees and shrubs provide a drought reserve of feed, but in prolonged droughts the trees are more valuable because the shrubs become defoliated. Overgrazing depletes the palatable species and causes thinning of the dominant shrubs and increase in the amount of bindyi (*Bassia* spp.). The high protein content of the chenopods is largely responsible for the production of large-framed sheep and high wool yields.

Detailed floristic lists of the species occurring in the associations are given and their relative palatabilities are rated.

The delineation of the boundaries of the different vegetation associations alone does not give an adequate picture of the grazing potential, as it is also necessary to indicate the state of preservation of the country. Five stages of degeneration of bush dominant country are recognised and defined quantitatively, and a portion of the North-West has been mapped on this basis. Two plans have been prepared, one showing the estimated original bush densities prior to stocking and another showing the present densities. From these two plans the amount of bush lost through grazing has been calculated.

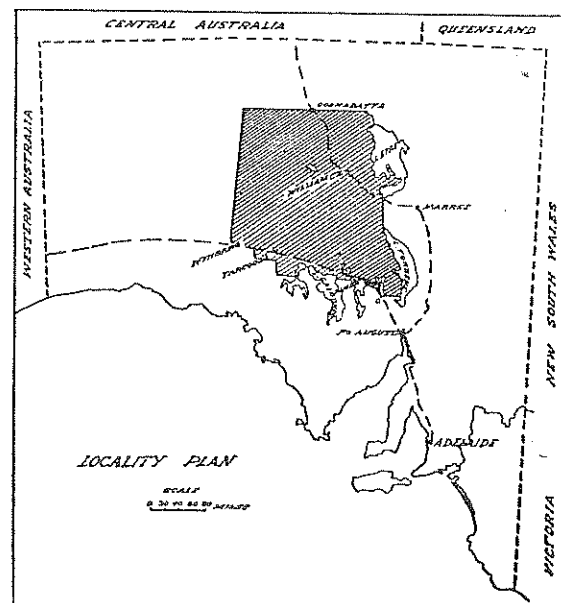


Fig. 1

INTRODUCTION

In 1943 the writer was appointed to the Soil Conservation Branch of the Department of Agriculture to investigate matters pertaining to soil erosion in the arid pastoral areas of South Australia and to provide data that might guide the Government and the pastoralists in the framing of policy with respect to these areas. The work reported herein is a comprehensive review of conditions in the north-western portion of the State, the boundaries of the area being shown in Figure 1. Field investigations were carried out during the period 1945-1950. Prior to the commencement of this work very little precise knowledge of the soils, vegetation and geology of this region was

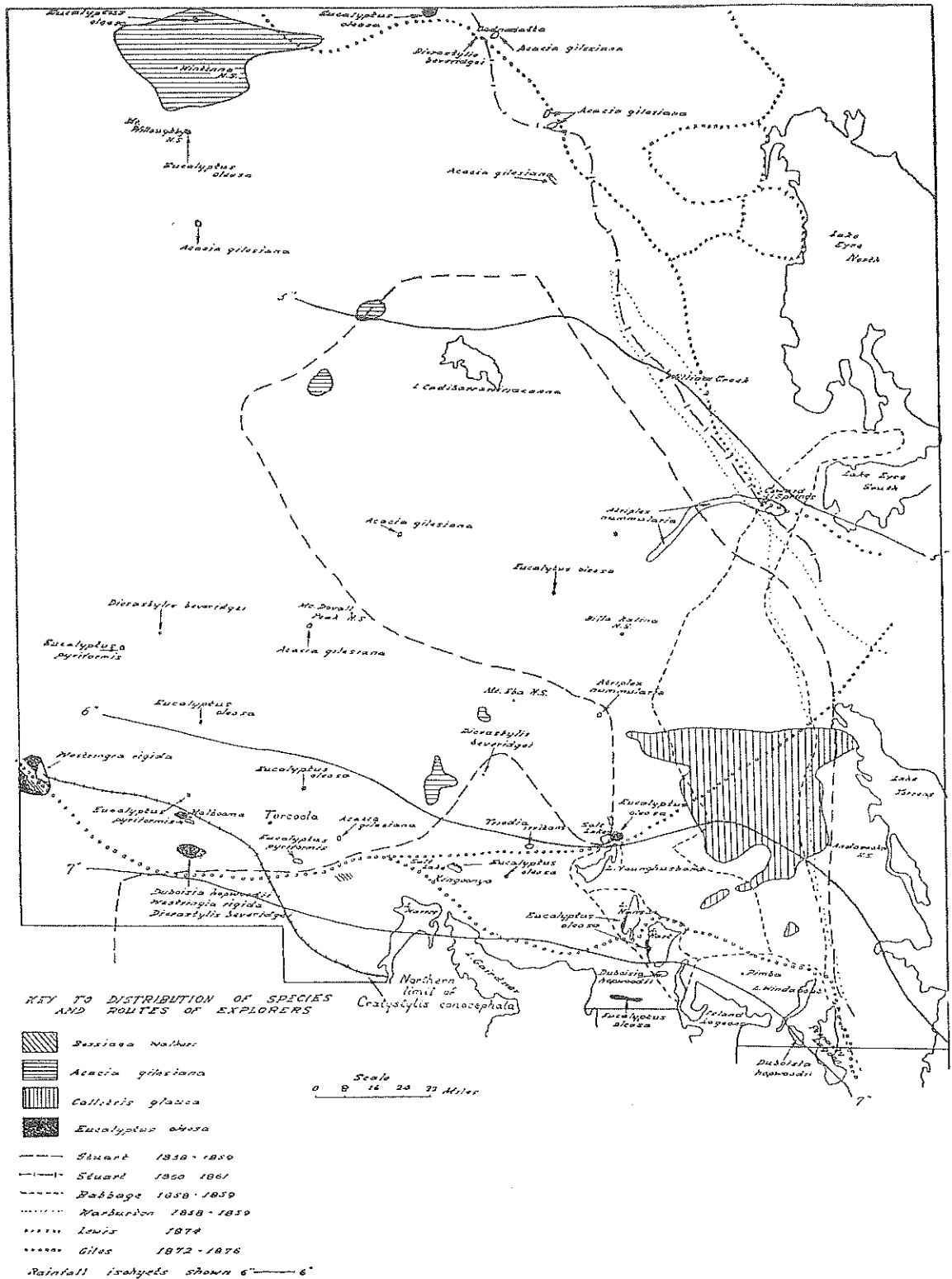


Fig. 2

Showing routes of explorers, rainfall isohyets and distribution of certain plants.

available. A paper dealing with the geography of the area is being published in the journal of the Royal Geographical Society of South Australia.

The southern portion of the North-West with an area of 23,000 square miles is used for the grazing of sheep, while the northern portion (28,000 square miles) carries cattle. Throughout these areas grazing is dependent principally upon native plant species and considerable damage to the perennial plant cover has resulted through overgrazing and other factors.

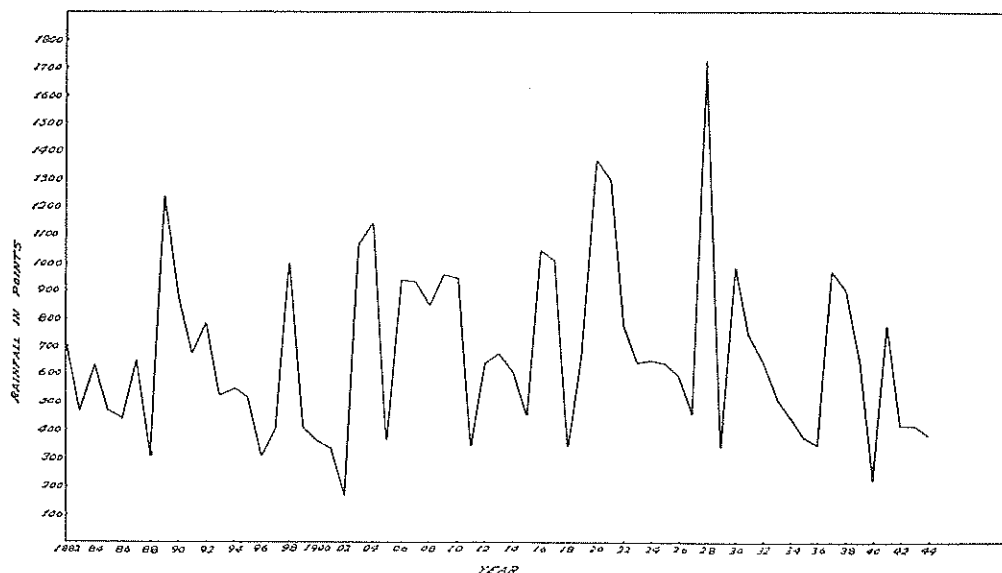


Fig. 3

Graph of annual rainfall of South Gap station for the years 1882 to 1944.

CLIMATE

The average annual rainfall varies from about $4\frac{1}{2}$ " in the Lake Eyre region to 7" in the south (figure 2). However, the average figure has little significance. Thus South Gap Station, which has an average of 652 points per annum for the period 1882 to 1944, has varied in yearly rainfall from a minimum of 168 points in 1902 to a maximum of 1,730 points in 1928. The fluctuations in annual rainfall for South Gap are shown in figure 3.

There is no marked seasonal rainfall as the area lies in a zone where the limits of the southern winter rainfall and the northern monsoonal summer rainfall systems overlap (Table I).

TABLE I

Average monthly rainfalls (in points)

	No. of Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Oodnadatta	.... 51	71	63	43	21	30	63	20	19	26	45	33	42	476
Tarcoola	.... 28	34	71	46	36	65	82	53	71	56	71	53	62	700

The southern portion of the North-West as illustrated by the recordings for Tarcoola (Table II), has its greatest number of rainy days during the winter months May, June, July and August and the summer months November and December. As shown by the Oodnadatta record, in the north the

greatest number of rainy days occurs in the summer months (October, November, December and February) and the winter months June, July and August.

TABLE II
Average number of rainy days

	No. of Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tarcoola	.... 8	2.3	3.1	2.1	3.3	3.4	4.4	5.1	4.5	1.8	3.0	3.4	3.8
Oodnadatta	.... 4	2.5	5.3	2.3	1.3	1.5	3.0	2.8	4.0	2.3	2.8	3.5	4.3

In the southern portion of the North-West rains of greatest intensity fall during the summer months (Table III). Further north the intensity of the winter rains is also fairly high. The records for Oodnadatta are only available for a period of four years, but they might be expected to give some indication of conditions.

TABLE III
Average rainfall per rainy day

	No. of Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Oodnadatta	.... 4	28	12	19	16	20	21	7	5	11	16	10	10
Tarcoola	.... 8	15	23	22	10	19	19	10	16	31	24	16	16

Jessup (1948) has pointed out that severe wind or hail storms occasionally sweep through narrow strips of pastoral country causing much damage to the vegetation. This is illustrated in Plate XIII, Figures 1 and 2.

Figures indicating the temperature regime are shown in Tables IV, V, VI and VII.

TABLE IV
Mean monthly temperatures of Tarcoola and Oodnadatta

	No. of Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tarcoola	.... 18	78.7	78.5	74.4	64.9	58.4	51.9	51.3	54.3	59.9	66.1	71.7	76.0
Oodnadatta	.... 55	83.4	82.9	79.4	70.1	60.7	55.1	54.3	58.4	66.6	71.1	78.3	83.5

TABLE V
Number of days for each month when the maximum temperature is 100° F. or more

	No. of Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tarcoola	.... 8	9.5	6.8	2.1	.3	0	0	0	0	0	.4	3.9	6.3
Oodnadatta	.... 4	16.3	11.0	1.8	0	0	0	0	0	.2	2.0	5.3	8.5

TABLE VI
Number of days when the minimum temperature is 40° F. or less

	No. of Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tarcoola	.... 8	0	0	0	0	5.1	11.9	13.3	9.9	4.5	.9	0	0
Oodnadatta	.... 4	0	0	0	0	.3	4.3	5.0	1.0	0	0	0	0

TABLE VII
Normal mean maximum and normal mean minimum temperatures for each month for William Creek and Tarcoola

		Yrs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yrs.
William Creek—															
Maximum	....	39	96.3	96.4	89.7	80.3	71.4	65.2	64.5	68.1	76.3	84.4	90.0	95.3	81.6
Minimum	....	39	68.8	69.6	63.5	55.0	47.4	43.2	40.7	43.5	49.0	56.3	62.7	67.4	55.6
Tarcoola—															
Maximum	....	18	93.8	94.1	89.5	79.1	71.8	64.6	64.5	67.9	74.9	81.8	87.6	91.8	80.1
Minimum	....	18	63.5	63.0	59.3	50.7	45.0	39.3	37.9	40.6	45.0	50.5	55.8	60.1	50.9

Frosts are of extremely rare occurrence at Oodnadatta, but for the six years 1943-1948 inclusive, the following are the total days for each month when the minimum temperature has been 32° or under at Tarcoola—May 5 days, June 23, July 26, August 9 and September 3. The other months are frost-free.

Although Yudnapinna Station lies slightly to the south of the area dealt with in this paper, the figures in Table VIII, which shows the average greatest daily range of temperatures in degrees Fahrenheit for the period 1941-1948, will be representative of the North-West generally. The greatest daily range occurs during the summer months.

TABLE VIII

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
41.0	37.9	36.9	35.2	33.9	32.9	34.2	37.1	40.6	41.4	41.5	42.3

Evaporation is high and relative humidity is low, particularly during the summer (Table IX).

TABLE IX

	No.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Yudnapinna—	Yrs.												
Evaporation in " ..	8	14.6	12.2	10.6	6.8	4.3	2.8	3.0	4.1	6.5	9.1	11.4	13.3
Tarcoola—													
Saturation deficit													
Mean, 9.00 a.m.	15	.513	.523	.441	.170	.167	.096	.100	.148	.239	.330	.471	.518
Mean relative humidity (saturation													
= 100)	39	32	33	36	43	51	60	55	48	38	31	30.	30

Prevailing winds are from the south-east, although the direction of the winds tends to be variable during the winter months. On account of the tendency of sheep to graze into the wind, the prevailing south-easterly wind results in concentrated grazing in the south-eastern corners of paddocks. The direction of the prevailing winds must have changed since the time the east-west trending sandhills were built up, since Bagnold (1941) has shown that in seif dunes the long axis of the dune is aligned parallel to the direction of the prevailing wind. Furthermore, lunettes, which are aeolian accumulations, are found along the eastern margins of the salt lakes in the North-West. They could only form in this position under the influence of prevailing westerly winds. These east-west trending dunes and lunettes are discussed in the section dealing with geology.

SHEEP, CATTLE AND OTHER ANIMALS

The sheep carried in the pastoral country are large-framed, plain-bodied Merinos (Plate XIII, Figure 3). Fleece weight per head of sheep naturally varies considerably according to the seasons, but a cut of 12 pounds for grown ewes and 13 pounds for grown wethers is an average figure. The wool has a count of 60-64's.

Blowflies are the chief pest of the sheep industry, and to reduce the incidence of fly strike the sheep are generally crutched once a year, and the Mules operation is becoming more widely used of recent years. Recently lice have appeared in the sheep of the North-West, and several stations are dipping to control it. Tick are absent. Wild dogs are now a serious pest only on the most northerly of the sheep stations, that is, those adjacent to the cattle country. One dingo can, however, kill a large number of sheep in

a short time, and their presence in the unfenced cattle country necessitates any sheep carried there being shepherded. Shearing is carried out during either of two periods—February to March or August to September.

The cattle carried on the stations are Shorthorns or Herefords (Plate XIII, Figure 4).

STOCK NUMBERS

The numbers of cattle and sheep carried fluctuate according to the seasons, rising in good years and falling during drought times. Sheep numbers for the whole of the sheep country covered in this survey have fluctuated from a maximum of 410,000 in 1939 to 145,000 in 1946 (Figure 4), while cattle have varied from 13,000 in 1940 to 30,000 in 1947 in the northern cattle country. In addition to the cattle, a few sheep are shepherded in the cattle country. Their numbers have varied from 2,500 in 1935 to 8,000 in 1948.

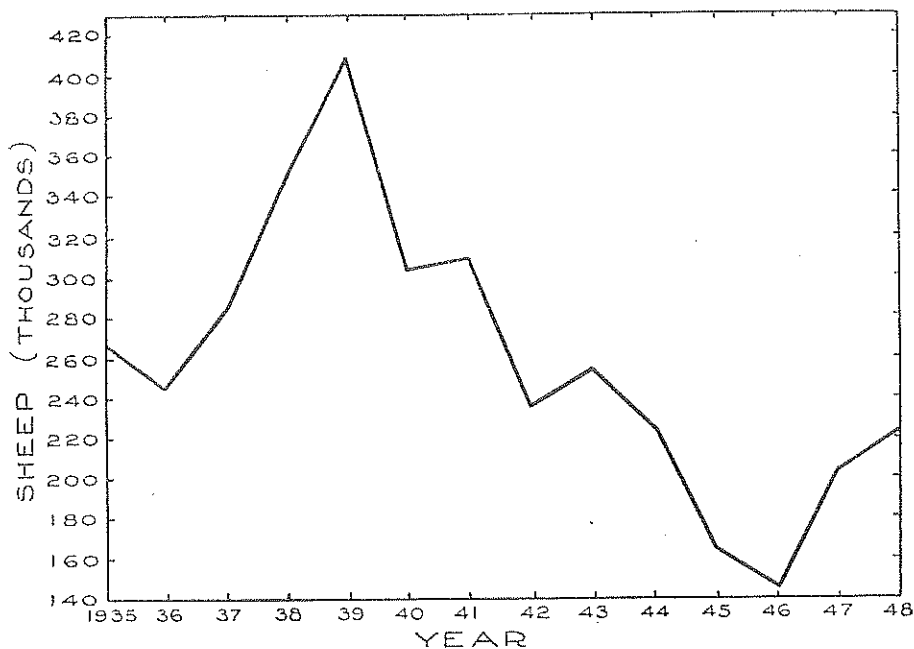


Fig. 4

Owing to this variation in cattle and sheep numbers according to seasonal conditions, the arid pastoral areas have no fixed carrying capacity per square mile of country. Only the drought-resistant perennial vegetation remains under drought conditions, and it may even be difficult to hold a flock of ewes from which to breed when the seasons improve. On the other hand, in good years there is such a wealth of herbage and grass that the perennial vegetation is scarcely grazed and sheep numbers can be greatly increased without harm to the permanent plant cover. The danger is, of course, that at any time a protracted dry period may set in. If sheep numbers are not reduced at the onset of the drought, but are held in the hope that rain will soon fall, not only is the country damaged but eventually the stock either have to be sold at a very low price or it may be impossible to market them, depending upon conditions in the higher rainfall country to the south. Consequently pastoralists now generally build up their flocks to numbers that can be carried in an "average" season.

As indicated above, pastoral country has no fixed carrying capacity and the fluctuations from year to year in stock numbers are great. In spite of this it is of interest to know what stock the North-West as a whole is carrying to the square mile.

It is standard practice to work out the average stocking rate per square mile of country by dividing the average number of sheep carried by the area of the country in square miles. If the following stations are considered on this basis, namely, Mulgathing, Malbooma, Wilgena, Bulgunnia, McDouall Peak, Ingomar, Mount Eba, Bon Bon, Mt. Vivian, Miller's Creek, Coondambo, Wirraminna, Parakylia and Roxby Downs, with a total area of 14,500 square miles and carrying an average of 204,000 sheep for the period 1935-43, the average carrying capacity per square mile is 14.3 sheep. To arrive at this figure 200 square miles have been deducted from the total area of the stations, since this represents the area of salt lakes.

However, this average figure of 14.3 sheep per square mile for the 14 stations as a whole is misleading, because most of them have some areas which are ungrazed or grazed only very lightly. Thus a total of 2,100 square miles is made up of paddocks which do not contain any stock water. The greater portion of this area is not grazed, while other of the paddocks carry stock during very good seasons only, that is, when there is sufficient succulent feed to enable the sheep to exist without water.

In addition to this unwatered country we have to consider that sheep do not graze beyond a four-mile radius of water except after very good rains, when surface water or succulent feed is available. Even when these favourable conditions prevail not all the sheep in the paddock will be grazing beyond four miles of the water. The areas which carry the stock most of the time, and particularly during the critical drought periods, lie, therefore, within four miles of permanent or semi-permanent water.

If the positions of the watering points in each paddock of the 14 stations mentioned above are considered, we find that 8,650 square miles are within four miles of water. This area is carrying stock at the rate of 23.6 sheep to the square mile, and the writer considers that this figure is a more accurate indication of the average stocking rate of the portions of the North-West which actually support sheep. It does not necessarily imply that the stocking is excessive. Until more research stations similar to Yudnapinna (Woodroffe, 1941) but using larger paddocks, are located in the different vegetation types of the North-West, no significant figures for carrying capacity will be available, nor will we know what the area of paddocks should be to balance efficient utilization of forage against economic returns.

At present many paddocks are far too big. Even when the small "holding" paddocks around woolsheds are included the total number of paddocks in the 14 stations is only 442, giving an average size of about 32 square miles.

The total number of waters on these stations is 360. This represents the sum of all watering points at bores, wells and dams as well as tanks along pipelines. On an average, therefore, there is a watering point for every 39.7 square miles of country. To avoid damage to the bush cover through excessive tramping, it is probable that no more than about 600 sheep should regularly water at any one point.

RABBITS

Although stock are the principal cause of the degeneration that has occurred in the pastoral country, nevertheless rabbits have played a very considerable part.

Rabbit numbers fluctuate enormously according to the seasons. Good years result in them breeding up to such an extent that they soon reach plague numbers and the damage they do is everywhere evident. With the onset of hot, dry weather and drying-off of herbage and grass they die quickly and in such numbers that the air in places becomes polluted with the smell of rotting carcasses. After a while it is possible to drive hundreds of miles and scarcely see any rabbits at all. While the damage done by a big rabbit population is easily seen, the difficulty is to assess the damage caused by a medium population.

During 1948 rabbits reached plague numbers in the North-West, but no areas of saltbush or bluebush were actually destroyed by them. On the other hand, many of the bushes suffered some damage, as it was usual to find a litter of twigs on the ground around the base of the bushes. Rabbits, therefore, cannot be held directly responsible for death of saltbush and bluebush except under rare circumstances (see Plate XIV, Figure 1). In fact, as Ratcliffe (1936) has observed, the most vigorous bushes are often found in and around rabbit warrens because of the extra moisture they receive. Rabbits have an important indirect effect upon the bush cover. Plagues only occur in good years when there is an abundance of herbage and grass, but enormous amounts of feed which would otherwise have been available to the stock when conditions become dry are consumed. As a result, stock are forced to graze bush earlier than they would if rabbits had been absent.

As soon as the feed dries off, rabbits are forced to seek moisture and large numbers commence to die. At this stage the worst period of destruction begins. Young shrubs and trees are ringbarked and killed to secure moisture. Even mature shrubs and trees with leaning trunks or intricate branches are climbed and the young shoots are barked (Plate XIV, Figure 2). During 1948, when the plague was at its worst, rabbits could be seen in shrubs throughout the North-West. Their activities could often be traced to a height of 15 feet above the ground in the easily-climbed dead-finish (*Acacia tetragonophylla*) and many rabbits died as a result of becoming caught among the branches.

Most shrub species suffered some damage but greatest devastation occurred among prickly Acacia (*Acacia victoriae*), dead-finish (*A. tetragonophylla*), mulgas (*A. aneura* and *A. brachystachya*) and species of *Cassia* (Plate XIV, Figure 3). *A. victoriae*, being a rapid grower, is not in danger of being exterminated in spite of the fact that most of the young plants and a great many of the mature ones were destroyed by rabbits in the 1948 plague. On the other hand, rabbits will eventually eliminate slow-growing species such as mulgas and myall. Not all the seedlings of these trees were destroyed in 1948, but most of those that survived lost a portion of the bark from their stems. Unless they mature before the next plague (and this is most unlikely) the seedlings that survived will probably be ringbarked.

The numbers of warrens and consequently of rabbits varies according to the type of country. Warrens are rarely found in the clay soils of the Arcoona, Coober Pedy, Mt. Eba or Coondambo types, but are very common in Twins soil and sandy and calcareous soil areas. The sandy soils are those that support trees and the greatest variety of shrubs, and it is unfortunate that the rabbit population is highest in these areas where the perennial vegetation is most susceptible to damage.

It is difficult to control and impossible to eliminate rabbits from pastoral areas by any known technique because of the large areas involved and comparatively few personnel.

NATIVE ANIMALS AND BIRDS

The essential difference in grazing habit between the native animals and birds, and sheep and cattle, is that the former are migratory while the latter are confined to specific areas. Kangaroos (*Macropus rufus*) are the most numerous of the native species and have the greatest effect on the pastures. During droughts they congregate wherever localized thunderstorms may have resulted in a growth of herbage and grass. At other times they are most numerous in paddocks which are not carrying stock, and as a result they decrease the benefits obtained by "spelling" country. While kangaroos are destroyed in large numbers it is probable that they have increased since white settlement owing to the improved water supply.

Birds like the emu (*Dromaius novae-hollandiae*) which occurs throughout the area, and the native turkey (*Eupodotis australis*) which is only seen in good seasons, are not sufficiently numerous to have any significant effect upon the pastures. However, galahs (*Cacatua roseicapilla*), which occur in large numbers, undoubtedly consume large quantities of seed.

Fossil evidence of the former distribution of wombats (*Lafiorhinus latifrons*) and mallee fowls (*Leipoa ocellata*) is found in portions of the North-West. Recession of these species probably occurred in the arid Recent. Mounds (nests) of the mallee fowl occur in dense mulga country in the southern portions of Mt. Vivian and Bon Bon Stations. This was the most northerly occurrence of the species in the area covered in this survey. Old burrows made by wombats are found in calcareous soils as far north as Commonwealth Hill Station.

GEOLOGY AND PHYSIOGRAPHY

Considering north-western South Australia as a whole, the outstanding feature of the geology is the presence of predominantly flat-lying sedimentary rocks, consisting of Precambrian-Cambrian complex, Jurassic and Cretaceous sediments and Pleistocene alluvia. Recent wind-blown sands are a widespread feature especially of the southern portion. Over these vast plains rock outcrops are uncommon, the surface generally being covered with Recent sands, transported material, or soils derived from the underlying strata.

PRECAMBRIAN-CAMBRIAN COMPLEX

West of the Lake Torrens depression there is a widespread occurrence of almost horizontally-bedded sedimentary rock which have been variously referred to the Proterozoic (Adelaide Series), Cambrian, or the Ordovician systems. The sediments are largely quartzites, but include dolomites, conglomerates and green and brown shales. So far they have proved unfossiliferous.

On lithological grounds the beds were originally assigned to the Ordovician. Subsequently there has been an increasing tendency to link the individual formations with various horizons of the vast sedimentary sequence (Adelaide Series and Cambrian) of the Flinders geosyncline lying to the east (David 1932; Segnit 1939; Dickinson 1942). Mawson (1947) has suggested that these formations may be equivalents of the basal portion of the Adelaide Series and agrees with Sprigg (personal communication) that some horizons may include the basal Cambrian quartzite. In early Cambrian times the sea is known to have transgressed the ancient land massif in the Yorke Peninsula locality and from this it may be anticipated that a similar overlapping would also occur further north.

According to Jack (1930), there are three main horizons in the tablelands west of Lake Torrens. The deepest members exposed are shales. Over these were deposited sandstones which have subsequently been partly altered to quartzites, while the uppermost formation is a limestone of sub-crystalline structure. Erosion has completely removed the limestone and exposed the more resistant quartzite in the higher tableland areas. Upon these formations, according to Jack, a much younger one, the Eyrian, has been laid down, the bulk consisting of whitish and mauve clays.

Segnit (1939) gives the following sequence and age of beds:

duricrust	}	Lower Tertiary (Eyrian)
white and mauve clay with boulders and sandstone		
white clay with boulders		Lower Cretaceous
sandstone		Jurassic?
limestone	}	Cambrian-Precambrian complex
quartzite-sandstone		
shale		

while Dickinson (1942) gives the following:

duricrust		Tertiary
white pipeclay		tentatively Cretaceous
sandstone	}	Cambrian-Precambrian complex
dolomitic limestone		
sandstone		
shale		

The writer has observed that west of the tableland country some of the bores and wells have penetrated quartzites below the Jurassic sands. These quartzites are encountered as far west as Bon Bon Station and there are small outcrops in the southern portion of adjacent Wilgena Station. The western boundary of Bon Bon is the western limit, and the east-west railway line west of Kingoonya the northern limit of the quartzites.

In addition to this large area of Precambrian-Cambrian rocks west of Lake Torrens, there are outcrops of granites and metamorphosed rocks of Precambrian age in the Kingoonya-Tarcoola locality and extending northwards to Commonwealth Hill Station. The felspar in the old granite or gneissic granite is weathered and kaolinized as a result of the high rainfall of the Pliocene. In addition to the kaolinization of the felspar, billy⁽¹⁾ pebbles

(1) Billy is the term given to the siliceous product resulting from solution and subsequent deposition of silica as distinct from laterite in which the accumulated material consists of oxides of iron and aluminium.

(remnants of the siliceous B horizon of a Pliocene soil profile) occur on the granites, indicating their pre-Pliocene age. These older rocks have been invaded by a younger granite which is less weathered (Plate XIV, Figure 4). South of Oodnadatta, in the Denison Range, rocks of Precambrian age form a north-south mountain range which rises abruptly from the plain on its eastern side (Plate XV, Figure 1).

JURASSIC

Lying to the west and north of the Precambrian-Cambrian area of the Lake Torrens region and probably overlapping it as Segnit (1939) has indicated are beds of the Great Artesian Basin of Jurassic age. The Jurassics were the first deposits to be laid down over the ancient land surface and are the waterbearing beds of the artesian basin. They are essentially fresh-water deposits, the area then being a vast inland lake (Howchin 1929). The rocks are sandstones, sands, sandy clays and clays of various colours (white, brown, pink, green and yellow). Many of the bore logs show that the basal beds were grits, sandy gravel or waterworn quartz stones. Bores on Commonwealth Hill and Mulgathing (the most westerly stations) penetrate much coarser beds than bores further east such as in the Mt. Eba region, indicating that the westerly stations must be near the old Jurassic shore-line.

Rock outcrops of Jurassic age are very rare, the sandstones being usually covered by sandy soils derived from them or by Cretaceous beds. The only outcrops are very small and are found towards the southern limit of the Jurassic deposits, on Bon Bon Station (in the Gosse Range area), between Lake Labyrinth and Lake Harris on Wilgena Station and along the east-west railway line on Coondambo Station. The outcropping sandstones are very coarse-grained and their exposed surfaces have been silicified. West of Wirraminna Station then, the east-west railway line coincides approximately with the southern boundary of the Jurassic sea.

CRETACEOUS

During Cretaceous times the area in which Jurassic sediments were deposited and the Precambrian-Cambrian area west of Lake Torrens were invaded by the sea. A blue shale was deposited and for a time conditions were so cold that glacier ice was present and erratics of quartzite from the Precambrian-Cambrian and felspar porphyry, gneissic granite and granite from the Gawler Range-Tarcoola area were deposited (Jack 1939).

The upper layers of the blue shales were bleached to a white colour under the influence of the Pliocene climate and were also, in parts, silicified to form jasper. Precious opal is found in the bleached Cretaceous shale at Coober Pedy and Andamooka (Plate XV, Figure 2).

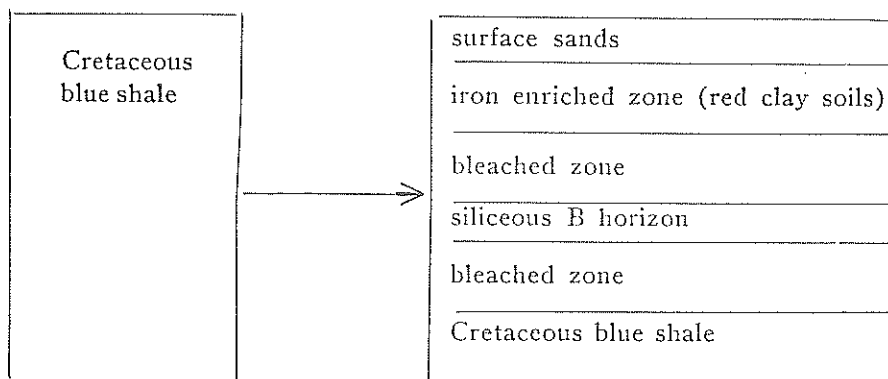
West of Wirraminna the east-west railway line roughly corresponds to the southern limit of the Cretaceous shale. In this area the shallow Cretaceous deposits have largely been eroded away or weathered to a clay soil which overlies the Jurassic sands. The most southerly outliers of Cretaceous age on Wirraminna Station (isolated flat-topped hills around the shores of Lake Hart) show a depth of 30 feet of bleached shale overlying the Precambrian-Cambrian rocks. East of Wirraminna, however, the Cretaceous shale extended further south. In fact, while the Cretaceous beds themselves have been weathered away, soils derived from Cretaceous shales occur in situ along Spencer Gulf in the vicinity of Port Augusta and Whyalla.

TERTIARY CLIMATES AND THEIR EFFECTS ON THE OLDER GEOLOGICAL FORMATIONS

The Pliocene is accepted by Whitehouse (1940) as being a period of high rainfall and warm temperatures. Steady uniform rains prevailed for the earlier and later portions with a period between of seasonal rains. During the periods of steady uniform rains, laterites and allied soils formed throughout much of Australia. However, there is evidence in the North-West which suggests that there must have been a considerable time-lapse between the two periods of silicification⁽²⁾ because a portion of the inter-silicification period must have been arid. Thus some of the billy gibbers⁽³⁾ are a conglomerate type and consist of waterworn pebbles and small stones resulting from break-up of the siliceous B horizon formed during the first period of silicification subsequently cemented together by silica during the second period. The interesting point is that the pebbles and stones within the billy gibbers have red-brown ironstained surfaces similar to the gibbers themselves.

On Billa Kalina Station and north of Coward Springs there is further evidence to support the theory that there were two periods of silicification separated by a drier interval. Here non-fossiliferous siliceous limestones overlie bleached zone material. Billy gibbers resulting from break-up of the siliceous B horizon formed during the second period of silicification are scattered over the surface of the limestone which has been silicified in its upper layers by general infiltration of silica and by the formation of seams of quartz crystals through the limestone. At Moodlampnie Hill (Plate XV, Figure 3) on Miller's Creek Station, the limestones are about 20' in thickness, while north of Coward Springs they are up to 40' in thickness.

It is evident from the present physiography of the country that by the Pliocene the old land surface was eroded down to a peneplain. The dominant topographical features are the more or less preserved tableland areas (Pliocene land surface) and the flat-topped residual hills at a similar height above sea level that are scattered through what is now lower country. Under the influence of Pliocene rainfall, temperature and physiography, silicification of the surface (Cretaceous) deposits occurred in the earlier Pliocene, as follows:



⁽²⁾ As no term has previously existed in soil literature the term silicification has been given to the process which results in the formation of profiles similar to those produced by laterization but in which a siliceous (billy) illuvial horizon is formed instead of a ferruginous one. Another essential difference between the profiles produced by silicification and those formed by laterization is that in the former there is no mottled zone.

⁽³⁾ Gibbers is the term applied to the larger rock fragments which occur on the surface of the soil over large areas of inland Australia.

As a result of the change in the Pliocene from steady uniform rains to seasonal rains, the peneplain was dissected to varying extents. Over portions of the country it remained fairly well preserved, although some of the surface soil was removed, and break-up of the siliceous B horizon was initiated. Elsewhere the soil profile was completely removed and also some of the underlying Cretaceous shale. Then later in the Pliocene (if we accept the theory that both periods of silicification are of this age), uniform steady rains resulted in the second period of silicification. The result is that the Pliocene fossil soils occur at varying levels. There is no evidence that lowering of the water table has been a factor in producing soils at the different levels.

With the onset of a new cycle of erosion in post-Pliocene times, the peneplain residuals from the first Pliocene silicification period were again dissected to varying extents sometimes with complete removal of the soil and elsewhere by removal of the surface soil only. Break-up of the siliceous B horizon continued. The soils formed during the second period of silicification were similarly truncated and there were large areas from which the Pliocene soil was completely stripped, exposing the underlying bleached shale. Towards the southern limits of the Cretaceous deposits, that is, where they were thin, the shale itself was removed and the underlying Jurassic sands and sandstones exposed. Such was the fate of the Cretaceous sediments.

Much of this erosion probably occurred in the pluvial Pleistocene and at the same time alluvial material was deposited. The most interesting of these alluvial deposits is found in the Mt. Eba depression and in the watercourses feeding into it. This alluvium (or rather the soil subsequently formed from it) is described under the Mt. Eba soil (see soil section). Other areas of Pleistocene alluvia are found principally around the margins of salt lakes (see Coondambo soil).

To the south of the tablelands is a system of salt "lakes" of Pleistocene origin (Lakes Hart, Hanson, Island Lagoon, Gairdner, Harris, Windabout, and Pernatty Lagoon). During times of exceptionally heavy rains these "lakes" receive run-off water from the tableland country and may then contain a few inches of water over portions of their surface (Plate XV, Figure 4). This water is driven from shore to shore depending upon the direction and persistence of the winds, but is rapidly evaporated to leave behind the salt which it contained in solution.

Beneath the salt crust which varies in thickness from $\frac{1}{4}$ " to 3" is a thin deposit ($\frac{1}{8}$ " thick) of red slushy sand, with dark red-brown clay containing gypsum crystals below. The clay continues to a depth of about 18". Below this is a layer about 1 ft. in thickness of dark-brown sandy clay containing black inclusions of ferrous iron. These deposits are distinctly laminated. Below these alluvial horizons is red slushy sandy clay underlain by the sandy floor of the lake.

Structures allied to lunettes consisting of powdery gypsum and some grey siliceous sand are found along the eastern margins of the salt lakes. In typical lunettes the steeper slope is towards the lake (Stephens and Crocker 1946), but the lunettes associated with "lakes" in the North-West have the steeper slope on the side of the dune away from the lake. This is probably due to the lack of stabilization of the lunette dune by vegetation. These gypseous deposits must have been built up when conditions were somewhat moister than they are today, that is, before the formation of the salt crusts. Under present rainfall sodium chloride accumulates to form a crust over the lakes.

When the Pliocene land surface was eroded, isolated flat-topped hills composed of bleached Cretaceous shale remained scattered through the lower country (Plate XVI, Figure 1). These features were preserved as a result of their thicker billy cappings. Their flat tops are covered with billy boulders and their uniformly sloping sides are partly covered with billy scree. The hills, therefore, vary in colour when seen from a distance. If the slopes are billy-covered the hills appear red-brown while those in which bleached shale is exposed are white (Plate XVI, Figure 2). A shallow depth of red clay (part of the Pliocene soil profile) may remain on top of these residuals.

The exact depth to which the blue shale was bleached under the influence of the Pliocene climate is not known. Blue shale is never exposed in any of the residual hills. Opal diggings at Coober Pedy (up to a maximum depth of 90') are located principally around the lower slopes of residual hills and penetrate bleached zone material throughout. Logs of bores on Miller's Creek Station indicate about 90' of bleached shale (white above but becoming brown with depth) overlying blue shale. These bores are located in country from which considerable depths of bleached shale have been eroded. From the information available, then, bleaching must have taken place to the unusual depth of at least 120'.

Apart from slight iron-stainings (yellow, red or brown) on the surface of the weathered bleached shale fragments, indications of iron such as mottling are absent. The kaolinized fragments are themselves white and smooth-textured. Lateritic ironstone and gravel do not occur in the North-West.

While the billy on the surface of the tableland is in the form of polished gibbers, blocks of billy up to two feet in thickness and several feet across are found on the tops of the residual hills (Plate XVI, Figure 3). Most of the billy (the polished gibbers especially) has an iron-stained surface, the colour varying from red-brown to black. On the tableland surface, gibbers which have been iron-stained right through are occasionally found. These iron-impregnated stones usually occur in patches. On Miller's Creek Station funnel-shaped pieces of billy are common, each gibber having a curved base coming up to a conical peak, with a circular hole through the peak. Some of the circular cavities contain yellow ochre (limonite).

While much of the siliceous B horizon was broken up as a result of truncation of the overlying soil, over the comparatively well-preserved Pliocene land surface of the non-dissected tableland areas break-up of the B horizon must have proceeded below the soil surface, because the siliceous horizon formed within the bleached zone. The mantle of gibbers on the surface is the result of movement of the clay through alternate wetting and drying which causes the stones to be gradually moved upwards to the soil surface.

The surface sands formed as a result of the Pliocene silicifications were largely stripped off the old land surface during the arid Recent and deposited in the surrounding lower country. The sand contributed to both the sand-hills and the sandy plains. A considerable thickness of surface sand must have covered the Pliocene soils to enable extensive sand dune areas to form within the tableland far removed from any Jurassic sandstone outcrops, the only other source of siliceous sand. Not all the sand was, however, stripped off or piled into these major dune areas, since there are still isolated sand-hills superimposed upon the tableland clays in some localities.

In addition to this Recent stripping and resorting of the sands from the old land surface, sand derived from the Jurassic sandstones was also resorted. This sand was formed from the sandstones after Pleistocene erosion

had removed the overlying Cretaceous beds. As a result of the redistribution of the sand, the depth of the surface sands of the soils varies greatly over a small area and this in turn causes a complex vegetation pattern.

The gypsum and sodium chloride present in the soils must have accumulated after the Pleistocene since these soluble salts would be among the first leached out. It is certainly not suggested, however, that the sodium chloride originated as "cyclic" salt. Gypsum is particularly common in the heavier-textured soils, that is, the Pliocene fossil soils and the soils formed from the Pleistocene alluvia. It occurs within a few inches of the surface in the form of spherical aggregates of micro-crystals and increases in quantity with depth sometimes to the extent of forming crystalline lumps. Over the tablelands of the Lake Eyre region sheets of gypsum (selenite) up to 15" in length and 5" thick protrude from the surface of very friable "bulldusty" patches. Gypsum in the form of a loosely-cemented powdery mass is of general occurrence on the slopes of the residual hills. It has already been pointed out that gypsum (kopi) dunes are associated with the margins of salt lakes. Heavy deposits of gypsum are encountered in the bleached Cretaceous shale in which opals are obtained at Andamooka and Coober Pedy.

There is a correlation between the amount of gypsum in any site and the moisture status. In the well-drained sandy soils gypsum is usually absent, but it is heavy in the soils of the Mt. Eba depression and the Pliocene fossil soils where drainage is impeded and where the moisture status is comparatively high because of the presence of crabholes. The quantities of gypsum become even greater in claypans and salt lakes.

During the Recent period sandhills formed upon the soils derived from the Pleistocene alluvia in some localities. Conditions became moister following this period of aridity, and colonization and stabilization of the sandhills with mulga in the south and canegrass further north took place. However, some of the dunes superimposed upon the tableland, for example, in the Wirraminna, Roxby Downs, Arcoona area and some of those immediately surrounding it are unstable, being scantily vegetated with shrubs like sandhill wattle (*Acacia ligulata*) and hop-bush (*Dodonaea attenuata*), species which precede mulgas in the colonization of sandhills. These dunes are of more recent origin, in fact were built up after the moister period when the stable dunes were colonized with mulga. This indicates a change to somewhat more arid conditions during very recent geological times.

The second piece of evidence in support of a theory of very recent increase in aridity has already been given, namely, that under present climatic conditions sodium chloride is accumulating as a surface crust on the salt lakes whereas in the past there must have been a period when a salt crust was absent (see Plate XVI, Figure 4). If this were not so it is difficult to explain the kopi dunes around the eastern margins of the lakes because this gypsum has obviously been derived from the lake surfaces.

There remains to be discussed the origin of the lime in certain of the soils. Lime cannot be detected in the least truncated Pliocene fossil soil (Arcoona type) which is associated with the tableland country, but a trace of lime can often be found in Coober Pedy soil, that is, where the clay of the old land surface has been partly truncated. Coober Pedy soil profiles may actually be underlain by travertine limestone. Trace to heavy lime is found where all the clay has been removed from the Pliocene soil and bleached Cretaceous shale is exposed. Where the Cretaceous beds have been completely or almost completely eroded away heavy accumulations of lime are a constant feature of the soils. The amount of lime in the soils is therefore

greater with increased truncation which is correlated with increasing soil aridity. It has already been noted that the amount of gypsum in the soils decreases as soil aridity increases.

In the soils with heaviest accumulations, the lime is in the form of rubble overlying hardpan which is underlain by more rubble and friable lime. Small iron-coated billy pebbles are scattered through the lime zone.

The presence of billy pebbles in the lime zone suggests that Crocker's (1946) loessial theory probably accounts for the origin of the lime in the soils. Jack (1921) has suggested that gypsum is formed in the Cretaceous beds as a result of the interaction of lime and sulphates derived from iron pyrites. The writer has already pointed out that calcium is present in the form of carbonate in well-drained soils with low moisture status, while more and more of the calcium is present as gypsum in poorly drained sites, that is, gypsum accumulates where the moisture status of the soil is sufficient to enable sulphates and lime to react and leaching cannot take place. This explains why calcium can have originated as loessial lime and yet the boundary between soils with no lime (but heavy gypsum) and those with heavy lime can be sharply defined.

From pedological evidence, therefore, we can distinguish four moisture regimes during Recent geological times. The early Recent must have been arid because vegetation was largely destroyed. The desert sandhills were built-up, the sandy A horizons were stripped from the Pliocene soils and the surface sands in the sand sheets were re-sorted. Then rainfall must have increased to allow colonization of the sandhills and sandplains with trees. We have already noted that crystalline gypsum, frequently in the form of large sheets, is found on the tableland country today. This gypsum must have been in solution to have been precipitated in crystalline form so that during this moister period of the Recent there must have been a fairly shallow water table. This moist period then gave way to a drier one, during which the gypsum crystals were formed. In this drier period the newer un-vegetated dunes formed on the tableland and about its margins in some localities. Rainfall was sufficient to prevent a salt crust from forming on the surface of the lakes.

Rainfall has continued to decline to the present day. During this period of increased aridity salt has accumulated on the surfaces of the lakes. Evidence from the distribution of myall (*Acacia sowdenii*)—see vegetation section—suggests that rainfall is now lower than it was when tree colonization was taking place.

PHYSIOGRAPHIC FEATURES

The geological framework then is made up of flat-lying sediments while topographically the North-West consists of vast gently-rolling plains mostly between 200 and 500 feet above sea level. The highest hills are Dutton's Bluff (920 feet) and Mt. Gunson (850 feet), while the bed of Lake Eyre is 39 feet below sea level.

Hills and ranges are either residuals of the Pliocene landscape (Plate XVII, Figure 1) or composed of granite or metamorphosed rocks. They are usually less than 200 feet above the surrounding country. Much of the area is quite featureless, so much so that in some cases trigonometrical stations are located on sand ridges. Faulting has played no part in the elevation of the tablelands or residual hills. These features are due to differential erosion, the hills in particular owing their preservation to a thicker capping of billy.

The sandy southern and western portions of the North-West have a drainage pattern made up of short watercourses ending in "swamps" which

contain water only after heavy rains. Further north the tableland country is drained by well-defined creeks which run in an easterly direction and discharge water into Lake Eyre after heavy rains. Before they reach the lake, however, they flood out and consist of a mass of interlacing channels and long narrow waterholes. Practically all these "lakes" are really salt pans—depressing flat expanses with a salt crust or saline mud surface. Portions of the salt lakes are firm and will support a motor vehicle but elsewhere, particularly near the mouths of watercourses and creeks, they are very boggy. During exceptionally wet seasons which may occur one year in every ten, a few of the freshwater "lakes," for example Coolymilka Lake, Lake Richardson, Arcoona Lake and Lake Campbell contain appreciable quantities of water. All of these lakes are depressions within tableland country. Even the water in these becomes very brackish as they dry up.

Sandhills have an east-west trend in the southern portion of the North-West, but in the north their trend is north-west to south-east. The sand has been derived from two sources. Sandhills in the lower country surrounding the tablelands have accumulated sand from Jurassic sandstones weathered *in situ* and from the Pliocene soils. The flats between them are sandy. All the sand in the dunes which are superimposed upon the tableland has been derived from the sandy A horizons of the Pliocene soil. If these dunes are close together the interdune areas are sandy, but if they are scattered the flats between them consist of gibber-strewn clay soils of the Coober Pedy or Arcoona types.

Claypans generally occur in association with sandhills, either in the hollowed-out crests or more often on the flats between the dunes. They are flat expanses of red clay of variable shape but often roundish in outline and vary from a few yards to several miles across (Plate XVII, Figure 2). The surfaces of claypans are often littered with billy gibbers (Plate XVII, Figure 3), while gypsum occurs at shallow depths within the clay. After rains they may contain an inch or two of water, yellow in colour due to suspended clay. Claypans are not, however, restricted to sandhill areas, being frequently developed in Coondambo and sometimes in Wirraminna soil areas. They form in depressions where water containing suspended clay washed out of the sandy soils tends to lie.

The following is a typical claypan profile:

- 0-18" red clay
- 18-24" brown clay with moderate gypsum
- 24-36" (continuing) grey clay with heavy gypsum

SOIL - GEOLOGY RELATIONSHIPS. THE SURFACE DEPOSITS

The type of soil developed upon the Cretaceous rocks depends essentially upon the truncation that has occurred in the profiles. Over the tableland areas where the Pliocene topography is fairly well preserved, the soil overlying the Cretaceous shale is a reddish-brown clay with a surface mantle of billy gibbers and rare glacial erratics which have weathered out of the parent material. The surface which is gently rolling and slopes towards drainage lines (creeks and watercourses) is characterized by a pattern of depressions (crabholes) with mounds (puffs) around the lower side of the crabholes. The clay is about 10 feet in depth and is underlain by bleached shale except in the Kingoonya region where the clay soil directly overlies Jurassic sandstone. In this area the Cretaceous beds were very shallow and were completely weathered to clay. The soil whose surface features are described above, that is, the Arcoona type, is the least truncated of the Pliocene

fossil soils. Morphologically it represents the Pliocene profile minus the sandy A horizons and some clay and with the siliceous B horizon broken up.

Shallower clay soils of the Coober Pedy type have resulted from either Pleistocene truncation of Arcoona soil or were formed during the second period of silicification from shale exposed by erosion which occurred in the Pliocene inter-silicification period.

The Pliocene profiles were completely removed over large areas in the Pleistocene to expose bleached shale. The light red-brown soil subsequently formed on the exposed shale is very shallow and has a surface cover of bleached shale fragments and billy pebbles. This is Twins soil. Pleistocene erosion not only resulted in loss of part or all of the Pliocene soil from Coober Pedy and Twins soil areas but often caused complete or almost complete truncation of the Cretaceous shale itself. Truncation of the shale had its most important pedological effects towards the limits of the Cretaceous sea where the beds were thin even when first laid down. All of this lower country surrounding areas where the Pliocene landscape is more or less preserved is characterized by soils containing large quantities of lime. A very shallow clay loam or clay soil overlying limestone hardpan was formed in post-Pleistocene times in areas where a shallow layer of Cretaceous shale remained. The limestone hardpan may overlie Jurassic sandstone or a shallow band of shale, depending upon the thickness of shale which survived the Pleistocene erosion. This, the Wilgena soil, has its surface more or less covered with iron-coated billy pebbles.

Two different sandy soils containing large quantities of lime developed where the Cretaceous beds were completely destroyed by erosion and the underlying Jurassic sandstones were exposed. Not all the sand in the soils was formed *in situ* from the underlying sandstones as some it was derived from the surface of the Pliocene soils during the arid Recent. Very shallow sands overlying limestone rubble and hardpan (Bon Bon soil) are present in areas from which sand was stripped during the redistributions of the arid Recent. Where comparatively deep red sand overlies limestone (Wirraminna soil) either the sand was not disturbed during the Recent or else these areas received some sand from the surface of the Bon Bon soil areas. Further accumulation of sand results in the formation of sandridges and sandhills. These aeolian accumulations may be superimposed upon a variety of geological materials.

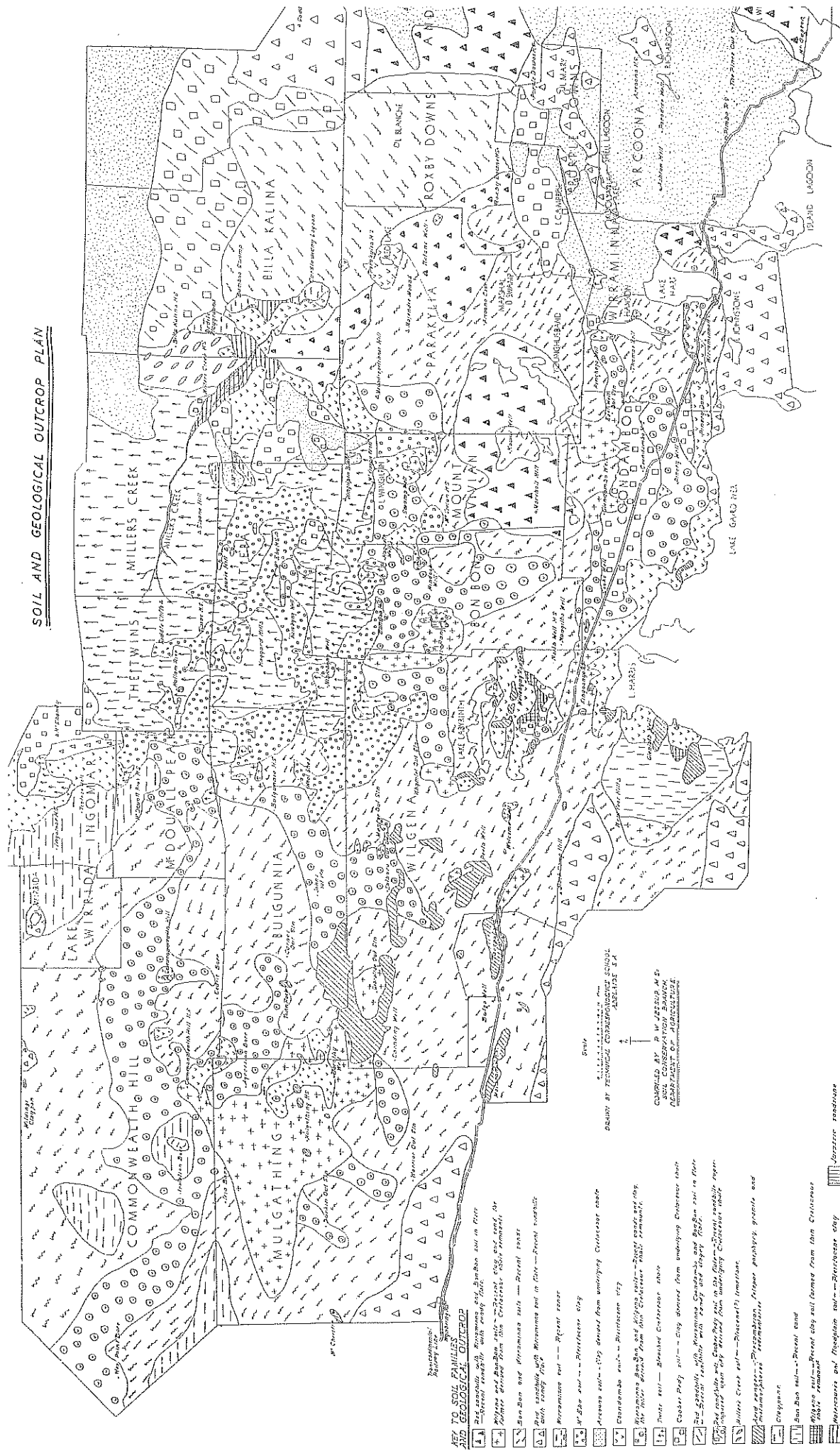
In the Miller's Creek-Billa Kalina area a very shallow brown clay loam or loam soil (Miller's Creek type) has formed upon siliceous limestone. This limestone must have originated during the inter-silicification period of the Pliocene because shale that was bleached during the first period of silicification underlies it and billy pebbles (remnants of the siliceous B horizon of the soil formed during the second silicification period) are scattered over its surface.

Two different types of soil have formed on Pleistocene alluvia. The Mt. Eba soil which developed principally on alluvium in the Mt. Eba depression and along watercourses feeding into it has a shallow sandy surface overlying red clay. A mantle of billy pebbles occurs on the soil surface and billy pebbles are buried in the profile. As it is formed from transported parent material, Mt. Eba soil may overlie either bleached Cretaceous shale or Jurassic sandstone.

Coondambo soil, which also is formed from Pleistocene alluvium, consists of red clay overlain by shallow sand. Unlike the Mt. Eba soil, little or no billy is associated. Jurassic sandstone underlies the soil at shallow

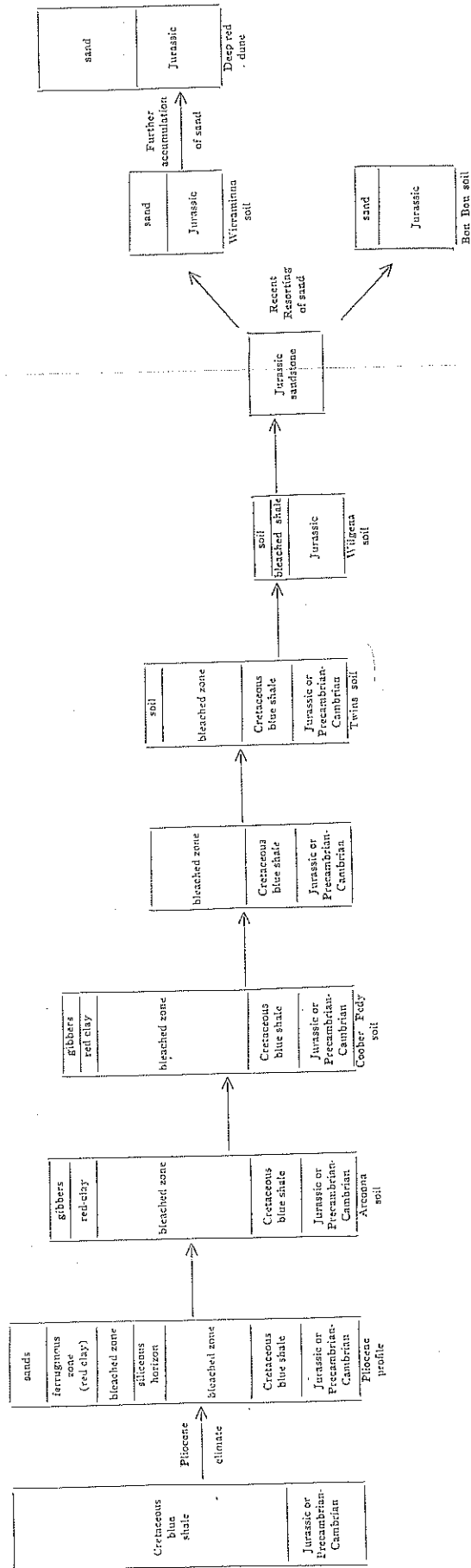


SOIL AND GEOLOGICAL OUTCROP PLAN



9.5

INCREASING TRUNCATION



depth around the salt lakes in the southern portion of the North-West where the largest areas of Coondambo soil are found.

Summing up, then, the following are the ages of the soils—Arcoona and Coober Pedy soils (Pliocene); Twins, Wilgena, Mt. Eba and Coondambo soils (post-Pleistocene); Wirraminna and Bon Bon soils (post-Pleistocene with Recent distribution of surface sands); and deep red dunes (built up during the Recent).

The distributions of the surface deposits are shown on the soil-geology plans (Figures 9 and 11).

TYPES OF BILLY

Billy (fragments of the siliceous B horizon of the Pliocene soils) is not uniform in structure. Four types found in the North-West are described below.

(1) Vitreous: This form has a vitreous appearance on freshly broken faces. It consists of quartz sandgrains and small milky and smokey quartz pebbles cemented together by silica. The surface of vitreous billy gibbers is irregular because the quartz pebbles are more resistant to weathering than the siliceous cement. Large stones of vitreous billy are iron-stained on the surface only, but the small stones may be completely iron-stained except for the quartz pebbles and sandgrains.

The proportion of quartz pebbles and sandgrains to siliceous cement varies considerably. If there are no pebbles and few sandgrains the stones have a smooth surface and a characteristic fracture, breaking up into angular pieces. Because of this quality this type of vitreous billy was commonly used by aborigines for spear heads.

(2) Black: This form of billy is heavily iron-stained right through. It consists of a mass of coarse quartz sandgrains cemented by varying proportions of ferruginous silica and yellow and red ochre.

It has no particular fracture but weathered surfaces are pitted because the sandgrains are more resistant than the cementing material. Another characteristic of the weathering of black billy is the tendency for layers to be irregularly removed from the surface of the gibbers due to the variation in the hardness of the cementing materials.

(3) Grey billy: Grey billy consists of a homogenous mass of grey-white silica which fractures irregularly. Weathering produces a fairly smooth surface.

(4) Conglomerate billy: This consists of waterworn pebbles and small stones of vitreous or grey billy and milky quartz cemented together by silica.

The individual pebbles of vitreous billy within the conglomerate gibbers have red-brown iron-stained surfaces. This iron-staining of the pebbles resulting from break-up of the siliceous B horizon formed during the first period of silicification in the Pliocene indicates that conditions must have been arid during a portion of the inter-silicification period.

The surface of conglomerate billy weathers very unevenly because the pebbles and stones that have been cemented together are more resistant to weathering than the siliceous cement.

THE SOILS

CLASSIFICATION

Prescott (1944) has recognised eighteen soil formations or zones in Australia, four of which are represented in north-western South Australia. These are

A. Stony and rocky areas relatively free from soil.
This formation includes ranges of the arid regions of which the Denison Range is an example.

B. Desert formations.

Prescott suggested four desert formations three of which (desert sandhills, stony deserts and desert loams) are represented in the North-West.

The "stony deserts" include a variety of unrelated soils, but in South Australia they are areas consisting of the Arcoona and Coober Pedy soils described herein. It is suggested that these soils in which the surface stone consists of billy gibbers and which are associated with a partially dissected tableland topography be called stony tableland soils. The term "desert loam" first used by Prescott (1931) is unsuitable for two reasons. In the first place the surface horizons of the soils belonging to this group range in texture from sand to clay and secondly "desert loam" soils occur in South Australia in areas with an average annual rainfall as high as 11-12". As the "desert loams" are the earthy (in contrast to the stony and calcareous) soils of the arid regions it is proposed that they be called arid red earths. A hitherto undescribed group of calcareous soils have been designated calcareous arid soils. These are the arid members of the calcimorphic soils which end with the rendzinas and terra rossas.

The new classification for the arid soils occurring in the North-West is set out below:

Order	Sub-order	Great Soil Group	Families
Pedocals	Arid soils	Arid red earths - -	{ Coondambo Mt. Eba
		Stony tableland soils -	{ Coober Pedy Arcoona Twins
		Calcareous arid soils -	{ Wilgena Miller's Creek Bon Bon Wirraminna
		Deep red dunes - -	{ Wirraminna (in part) Red sandhills
		Arid ranges - - -	{ Denison

GENERAL CHARACTERISTICS OF THE SOILS

Soil horizons are not clearly differentiated and salinity is high except in the deep sands because the soils, as they occur in the present geological period, undergo little or no leaching.

Very shallow A horizons are a feature of all the soils except the very sandy ones as natural erosion in low rainfall areas is much greater than in higher rainfall country and the rate of soil formation is slower. Even in unstocked areas, during drought periods the soil surface is poorly protected by plant growth.

The soils range in colour from brown to red and in texture from sand to clay. They are generally poorly structured. Depending on their drainage,

they contain either heavy lime or heavy gypsum. Billy pebbles or gibbers are associated with all the soils of the North-West with the exception of the aeolian sandridges, but this is not a universal feature of arid soils.

THE SOIL FAMILIES

Arcoona soil

This residual Pliocene fossil soil formed from Cretaceous shale is found on the tableland country, that is, where the Pliocene land surface is least eroded. The tableland is a gently-rolling plateau which is elevated 300-350 feet above the surrounding country around its southern limits.

Depressions (crabholes) with a roughly circular or irregular shape and varying in size usually from 10-50 feet across are a feature of the soil surface. The crabholes are 4-24" deep. Puffs (Plate XVII, Figure 4) 3-12" higher than the shelves are formed around the lower sides of the crabholes which vary from 10-40 yards apart. The height of the puffs increases as the surface slope increases. Gently-sloping gibber-covered shelves separate the crabholes.

Water does not normally penetrate the shelf profile to a greater depth than a few inches, run-off water working its way between the gibbers on the shelf surface into the crabholes. When the crabholes higher up the slope become full of water further rain causes a flow of water to the crabholes lower down the slope. The presence of crabholes means that water only drains off the tableland after exceptionally heavy rains. The clay is easily dispersed with the result that crabhole water is always yellowish in colour immediately after a rain, but the suspended clay soon settles due to the presence of large quantities of gypsum.

Shelf areas constitute a very arid and saline environment and support only a very sparse growth of bindyis and samphire. Saltbushes (*Atriplex vesicaria* and *A. rhagodioides*) and the Composite *Ixiolaena leptolepis* are the dominant shrubs in the crabholes. Due to the heavy texture of the soil, trees are absent except along creeks and watercourses. Although Arcoona soil areas respond quickly to rain and grow more nutritious species than the sandy country they have a fairly low stock carrying capacity because plant growth is practically restricted to the crabholes.

A texture profile is not developed as clay is present on the surface, but salts are zoned according to their solubilities. Lime cannot be detected even with acid, but gypsum is always present at shallow depth and becomes heavy below. Where it is heavy the gypsum is present in bands, a soil horizon containing heavy gypsum being followed by one without gypsum. Near the soil surface it occurs in spherical clusters of white micro-crystals, but where it is heavy gypsum seen in a pit-face resembles the appearance that flour would have if dusted across the face of the pit.

The following is a typical shelf profile:

- 0 - $\frac{1}{2}$ " brown (5 YR 6/6) ⁽⁴⁾ light clay with caked structure containing a trace of gypsum and heavy billy gibbers (boundary fairly definite).
- $\frac{1}{2}$ - 5" reddish-brown (5 YR 6/8) structureless clay with slight gypsum and a trace of billy gibbers (boundary very diffuse).

⁽⁴⁾ The figures refer to the Munsell chart of soil colours. The American interpretation of these colour standards into colour terms has not been followed.

- 5 -16" red-brown (2.5 YR 5/8) massive clay with medium gypsum and a trace of billy gibbers (boundary very diffuse).
 16-22" red-brown (2.5 YR 5/8) massive clay with slight gypsum (sharp boundary).
 22-48" reddish-brown (5 YR 6/8) massive clay with heavy gypsum.

The laminated structure (an extreme case of "surface sealing") of the surface horizon of the shelf profile is interesting. Taylor (see Crocker and Skewes 1941) considers that the mechanical action of raindrops on a wet surface dispenses the surface layer of a sodium-saturated clay.

Polished brown or reddish-brown pebbles and stones (gibbers) $\frac{1}{4}$ " to 2 feet across and of irregular outline more or less cover the shelf soil surface. The bigger pieces are in the form of flat plates. The gibbers are grey-white inside and consist principally of grey and some vitreous billy. Glacial erratics of quartz and quartzite weathered out of the parent material are of rare occurrence.

A typical crabhole profile is given below:

- 0 - $\frac{1}{8}$ " grey-brown (5 YR 6/6) sand with light billy gibbers (sharp boundary).
 $\frac{1}{8}$ - 4" grey-brown (7.5 YR 6/6) clay with angular cloddy structure (boundary diffuse).
 4 -16" brown (5 YR 5/6) massive clay (boundary diffuse).
 16-26" brown (5 YR 5/6) massive clay with slight gypsum (boundary diffuse).
 26-36" brown (5 YR 5/6) massive clay with heavy gypsum.

Crabholes may be gibber-free or carry a few surface stones. Large cracks form in the crabholes when they dry out.

The following is a typical puff profile:

- 0 - $\frac{1}{8}$ " light reddish-brown (5 YR 7/6) sand with heavy billy gibbers (boundary definite).
 $\frac{1}{8}$ - 1" light reddish-brown (5 YR 6/6) irregular nutty structured clay with heavy gibbers (very diffuse boundary).
 1 - 9" reddish-brown (5 YR 5/6) nutty clay with medium billy gibbers (boundary sharp).
 9 -17" red-brown (2.5 YR 5/8) coarse nutty clay with light billy gibbers and slight gypsum (boundary sharp).
 17-24" red-brown (2.5 YR 5/8) structureless clay with light billy gibbers and slight gypsum (boundary sharp).
 24-36" reddish-brown (5 YR 6/8) structureless clay with heavy gypsum.

Figure 5 shows the structure of the clay and the depth at which slight and heavy gypsum appear in the shelf, crabhole and puff profiles.

Coober Pedy soil

This is a residual Pliocene fossil soil which has been more heavily truncated than the Arcoona soil. Crabholes may or may not be present, depending upon the depth of the soil. There must be at least two feet of clay overlying the parent material for crabholes to be formed. When they are present they are smaller and generally more scattered than those associated with Arcoona soil. The depressions vary from 3-40 feet across and 3-10" in depth. Puffs are absent in flat country and smaller than those associated with Arcoona soil on sloping land.

A shallow solonized (bleached) horizon $\frac{1}{10}$ "-1" thick is usually present within an inch or two of the soil surface in the shelf profiles. Gypsum is always present,

appearing at depths of 3-24". It may be only a trace throughout the profile but it usually becomes moderate or heavy with increasing depth. Most shelf profiles contain a trace of lime which usually appears at depths of 6-24". The lime is generally only present in the profile for a few inches. While Coober Pedy soil normally rests on bleached shale occasional profiles are underlain by lime hardpan.

Billy gibbers $\frac{1}{8}$ -12" across more or less cover the surface of the shelves, or where crabholes are absent, the whole of the soil surface (Plate XVIII, Figure 1). Vitreous billy predominates but some grey billy is present. Rare quartz and quartzite glacial erratics from the Cretaceous shale also occur on the surface, the smaller pieces of billy and the quartzites having iron-stained surfaces. Stone in the profile varies from heavy near the surface to trace or none below.

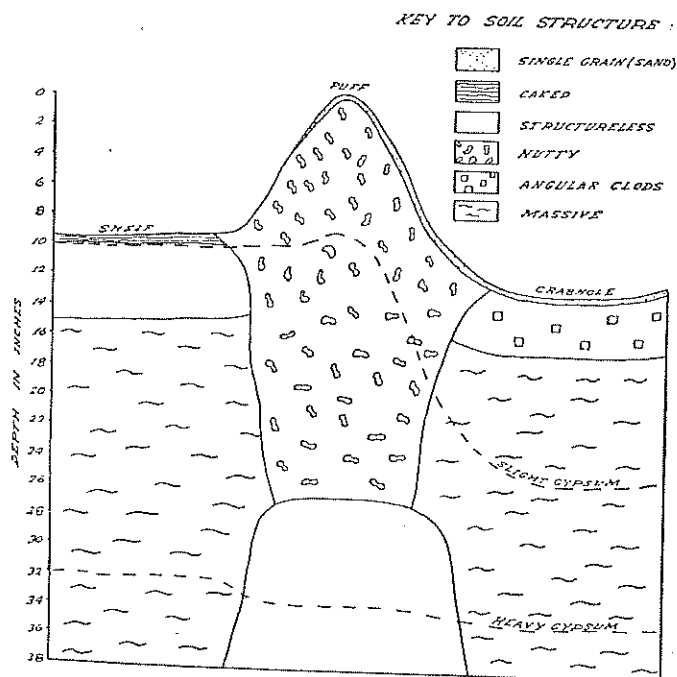


Fig. 5

Showing the structure of the clay and the depths at which slight and heavy gypsum appear in the shelf, crabhole and puff profiles of the Arcoona soil.

The following is a typical shelf profile:

- 0 - 1" red-brown (2.5 YR 6/8) slightly laminated sandy loam of finely vesicular structure containing heavy billy gibbers (boundary fairly sharp but irregular).
- 1 - 6" dark red (2.5 YR 3/6) angular nutty clay with a trace of billy gibbers (boundary sharp).
- 6 - 14" red (10 R 5/8) nutty to crumb structured clay (boundary very diffuse).
- 14 - 24" lightish red (2.5 YR 5/8) angular nutty to crumb structured clay with a trace of billy gibbers (boundary fairly sharp).
- 24 - 32" brownish red (2.5 YR 4/8) clay of angular blocky to crumb structure with slight lime and slight gypsum (boundary sharp).
- 32 - 40" red (10 R 5/8) massive clay with medium gypsum (boundary sharp).

The surface horizon varies in texture from sandy loam to clay, while some profiles have brownish-red clay throughout the B horizons.

As indicated below, crabhole profiles are similar to those of the Arcoona soil except that a trace of lime is usually present:

- 0-12" brown clay.
- 12-20" brown clay with a trace of lime.
- 20-24" brown clay with heavy gypsum.

Coober Pedy soil areas carry saltbush (*Atriplex vesicaria*) as the dominant species and have a fairly low stock carrying capacity. Growth is practically restricted to the crabholes where they are present, while a sparse growth of saltbush occurs scattered over the whole surface where crabholes are absent.

Twins soil

This residual soil developed upon bleached Cretaceous shale is characterized by a very shallow profile without gypsum. The soil surface is littered with whitish shale fragments $\frac{1}{8}$ -3" in size and iron-stained billy pebbles $\frac{1}{8}$ -8" across. Vitreous billy predominates but grey billy is common. In addition rare glacial erratics of quartz and iron-stained quartzite lie on the surface. Jasper is present on the surface and through the profile where the shale has been silicified.

The soil consists of light reddish-brown to light red-brown loam, clay loam or sandy clay loam subsoil overlain by shallow red-brown sand or light reddish-brown to light red-brown sandy loam as illustrated by the following profile:

- 0- $\frac{1}{2}$ " red-brown (2.5 YR 4/6) sand with heavy bleached shale fragments and billy pebbles (boundary sharp).
- $\frac{1}{2}$ -3" light reddish-brown (5 YR 6/4) loam to clay loam with weak crumb structure and containing slight lime (boundary diffuse).
- 3-5" light red-brown (2.5 YR 6/6) clay loam with crumb structure and containing light lime and heavy bleached shale fragments (boundary fairly sharp).
- 5-8" mixed brown soil, lime rubble and shale fragments. The colour of the soil fraction is light reddish-brown.

The sand horizon may be absent and even in areas where it occurs the sand is found principally around plant growth. Lime is not always as heavy as that indicated in the above profile, in fact, it is occasionally absent altogether.

Twins soil carries treeless shrub steppe vegetation dominated by bluebush (*Kochia planifolia*). The poor water-retaining capacity of the soil has resulted in widespread bush death under drought conditions even in ungrazed paddocks, with the result that living bush is practically confined to watercourses and slopes of undulations which receive run-off water. Grass and herbage only grow in large quantities on Twins soil during very good seasons.

Wilgena soil.

This residual calcareous soil has a shallow profile over lime hardpan. The surface is more or less covered with billy pebbles (Plate XVIII, Figure 2). Wilgena soil is found in country from which the Cretaceous deposits have been largely eroded away. The profiles may overlie shallow bleached Cretaceous shale or, where the shale has all weathered to soil, Jurassic sandstone. The Wilgena soil shows the influence of two parent materials. At the present

time the parent material is the lime rich layer, but the billy pebbles are a residue from the originally overlying older soil formed from shale. This older soil has also influenced the texture of the Wilgena soil.

The surface soil is reddish-brown, light reddish-brown or light red clay loam, sandy loam or rarely light clay. A sand horizon up to $\frac{1}{2}$ " in thickness sometimes occurs on the surface. The subsoil is reddish-brown or light reddish-brown clay loam, sandy clay loam or light clay. Lime may be present from the surface and heavy lime (rubble or hardpan) always occurs between $\frac{1}{2}$ " and 9".

A heavy accumulation of pebbles and stones generally $\frac{1}{8}$ " to 4" in diameter occurs on the soil surface and in the top of the profile. On the tops of some hills the billy occurs in the form of boulders up to 12-18" across. Vitreous billy predominates but some grey and conglomerate type billy is also found, while Cretaceous quartzite and milky quartz glacial erratics are of occasional occurrence. The smaller billy stones and the quartzite have an iron-stained red-brown surface.

The following is a typical profile:

0- $\frac{1}{2}$ " light red (2.5 YR 6/6) clay loam with a cakey somewhat laminated structure and containing medium lime. The surface is covered with billy pebbles and some lime flakes (boundary fairly sharp).

$\frac{1}{2}$ -4" light reddish-brown (5YR 6/6) clay loam containing heavy lime rubble. This overlies lime pan.

Wilgena soil supports a shrub community dominated by bluebush (*Kochia sedifolia*), but scattered trees of mulga or myall may be associated. The ground layer is dominated by bindyis (*Bassia* spp.) and grasses (principally *Enneapogon* spp.). The density of bluebush is lower on this type of soil than it is on Bon Bon soil and the growth of herbage and grass is always sparse.

Bon Bon soil

Bon Bon soil is a residual calcareous soil with a fairly shallow profile overlying lime rubble and hardpan. Morphologically it differs from Wilgena soil in three ways. The heavy lime layer generally occurs at slightly greater depth, while the soil is lighter in texture and only has a trace of stone associated with it.

Red-brown sand up to about 6" deep overlies reddish-brown or light-brown sandy loam with light red-brown or light reddish-brown sandy clay loam or loam to clay loam below. The sandy loam horizon is absent in the shallowest profiles. Lime is always present at, or within a few inches of, the soil surface and becomes heavy (rubble and hardpan) at depths of 1-10". Flakes and pebbles of limestone $\frac{1}{8}$ "-2" across and very rare iron-stained billy pebbles $\frac{1}{8}$ "-2" in diameter are scattered across the soil surface. A trace of billy pebbles usually occurs in the profiles.

A typical profile is given below:

0-2" red-brown (2.5 YR 5/8) sand.

2-5" light red-brown (5 YR 7/6) crumb structured sandy loam with moderate lime.

5-12" light reddish-brown (5 YR 6/6) structureless sandy clay loam with heavy lime.

12-16" lime hardpan.

16-20" brown clay loam with moderate lime.

20-33" brown clay loam with moderate lime and a trace of gypsum.

33-54" light reddish-brown clay loam with light lime and slight gypsum.

54-72" brown clay loam with light lime and a trace of gypsum.

Wirraminna soil

Areas with sandy soils received sand from several different sources and the sand has undergone considerable re-distribution during the arid Recent. Where

Wirraminna soil occurs in extensive sheets across the country, the sandy horizons have largely resulted from the weathering of underlying Jurassic sandstones. Throughout large areas of the North-West aeolian sandridges alternate with Bon Bon soil areas. Much of the sand in the ridges has been stripped from the intervening soils. Sand from the Pliocene soil has also contributed to the sand sheets and ridges.

As a result of the resorting of surface sands which occurred in the Recent, the sandy horizons of the Wirraminna soil vary considerably in depth. The deepest sands are found in the sandridges which grade into sandhills, while with decreasing depth of surface sand Wirraminna soil grades into Bon Bon soil.

The amount of lime and the depth at which it appears varies with the depth of sand. Trace to light lime occurs at considerable depth in the sandridges, while in those areas where the sand forms extensive sheets heavy lime is found at much shallower depth. Thus there are two variants of Wirraminna soil—a small sandridge type of aeolian origin and the soils of the extensive sand sheets.

These variations in the depth of the surface sands result in a complex vegetation pattern. On the deepest sands the dominant species are mulgas (*Acacia aneura* and *A. brachystachya*), while bluebush is absent. Where the surface sands are shallower and lime is present nearer the surface, scattered bluebushes (*Kochia sedifolia*) appear among the mulgas. Finally bluebush forms a shrub layer beneath the mulgas on the shallowest of the Wirraminna soils.

Wirraminna soil consists of up to four feet of red sand (deepest in the sandridge type) overlying clayey sand or sandy loam. The subsoil is brownish-red, reddish-brown or red (the latter in the sandridge type only) sandy clay loam. Lime is present at depths of between 8 and 50" and except in the sandridge type becomes heavy with depth. Rubble overlies friable lime but hardpan is also common. Some of the profiles on Commonwealth Hill station have up to three feet of sand directly overlying limestone hardpan about two feet in thickness with lime rubble below. Mine shafts at the Glenloth goldfield indicate a lime-rich layer four feet in thickness overlying the Precambrian rocks with hardpan varying from 3-12" in thickness. Billy pebbles are absent in all but the shallowest of the profiles and even then only a trace of stone occurs. Gypsum was found in a few profiles at depths of 4-5 feet but can rarely be detected.

The following profile is typical of the soils of the sand sheets:

- 0-18" brownish-red sand.
- 18-23" red-brown sandy loam.
- 23-26" red-brown sandy clay loam.
- 26-30" reddish-brown sandy clay loam with light lime.
- 30-32" reddish-brown sandy clay loam with moderate lime.
- 32-36" reddish-brown sandy clay loam with heavy lime.
- 36-45" grey-brown sandy clay loam with heavy lime.

A typical sandridge profile is given below:

- 0-29" red (10 R 4/6) sand (boundary diffuse).
- 29-40" red (10 R 4/6) sand with light lime (boundary fairly diffuse).
- 40-41" pale red to red (2.5 YR 6/2) and (2.5 YR 4/6) clayey coarse sand in the form of an indurated massive pan bleached through solonization (boundary sharp).
- 41-53" red (10 R 4/6) massive sandy clay loam.

Miller's Creek soil

In the Miller's Creek - Billa Kalina area siliceous limestones formed during the inter-silicification period of the Pliocene are exposed. They are underlain

by Cretaceous shale which was bleached as a result of leaching during the first period of silicification, while a siliceous soil profile formed upon the limestones during the second period of silicification. Subsequent erosion removed the soil, leaving only billy pebbles on the surface of the limestone upon which a very shallow soil has subsequently formed. It is heavy-textured (clay loam or clay) and contains lime and sometimes gypsum. Pieces of siliceous limestone $\frac{1}{8}$ -4" across and occasional iron-coated billy pebbles $\frac{1}{4}$ -1" in diameter occur on the surface of the soil.

The following is a typical profile:

0-3" brown clay with light lime.

3-6" brown clay with light lime and a trace of gypsum.

Miller's Creek soil carries bluebushes (*Kochia planifolia* and *K. sedifolia*) and saltbush (*Atriplex vesicaria*). Its poor water-retaining capacity is reflected in the severe bush death that has occurred even with the extremely drought-resistant *Kochia sedifolia*. The growth of herbage and grass is always sparse.

Mt. Eba soil

Mt. Eba soil is developed upon Pleistocene alluvium mainly in the Mt. Eba depression and in the broad watercourses which drain into it.

The following features are typical of the soil:

Surface stone—The soil surface is more or less covered with red-brown iron-stained pebbles ranging from $\frac{1}{8}$ -3" in diameter, the majority being $\frac{1}{8}$ - $\frac{1}{4}$ " in diameter (Plate XVIII, Figure 3). These pebbles consist of vitreous and grey billy and rare conglomerate billy, quartz and quartzite. The surface of the quartz pebbles is not iron-stained.

Stone through the profile—Heavy accumulations of pebbles occur in the profiles for the first few inches (sometimes up to 12"), then trace to light stone is found to the bottom of the profiles or it may be heavy again above the underlying rock.

Surface soil—The surface soil is most commonly a 3" horizon of reddish-brown or sometimes red sandy clay loam but rarely red clay loam overlies the subsoil clay. Other profiles have shallow brownish-red sandy loam and/or $\frac{1}{4}$ - $\frac{1}{2}$ " of red sand overlying the sandy clay loam.

Subsoil—Clay subsoil occurs at depths of 4-10". The upper portion of the clay is generally reddish-brown in colour but it becomes red below. Trace to light lime is encountered between 9 and 36". The lime usually remains trace or light but sometimes becomes moderate with increasing depth. Gypsum is usually present at depths of between 12" and 30". It is often moderate and rarely becomes heavy with increasing depth.

A typical profile is set out below:

0-3" reddish-brown sandy loam.

3-6" reddish-brown sandy clay loam.

6-9" brownish-red clay.

9-12" brownish-red clay with light lime.

12-21" brownish-red clay with light lime and light gypsum.

21-34" red clay with light lime and light gypsum.

34-42" red clay with light lime and moderate gypsum.

42-54" reddish-brown clay with bleached shale fragments.

This soil may carry mulgas but the characteristic feature of the vegetation is the dominance of the ground layer by bindyis (principally *Bassia divaricata*, *B. paradoxa* and *B. uniflora*).

There are two other variants of the Mt. Eba soil. The first occupies low terraces between watercourses, that is, slightly more elevated sites than the soil described above, and while similar in other respects has a light reddish-brown sandy clay loam solonized (bleached) zone $\frac{1}{4}$ -2" thick overlying the clay.

The following profile is typical of this soil type:

- 0- $\frac{1}{4}$ " red (2.5 YR 4/8) sand (boundary definite).
- $\frac{1}{4}$ -1" brownish-red (2.5 YR 5/8) structureless sandy loam (boundary irregular but fairly definite).
- 1-3" light reddish-brown (5 YR 6/6) somewhat domed sandy clay loam bleached horizon (boundary very irregular).
- 3-11" red (10 R 4/6) clay with a nutty to angular crumb structure (boundary diffuse).
- 11-20" brownish-red (2.5 YR 4/8) clay with irregular nutty to crumb structure and containing light lime and a trace of gypsum (boundary diffuse).
- 20-44" brownish-red (2.5 YR 4/8) clay with irregular nutty to crumb structure and containing light lime and medium gypsum (boundary more or less abrupt).

This soil type supports a scattered growth of bluebush (*Kochia planifolia*) in addition to bindyis.

The other variant of the Mt. Eba soil occurs in the bottoms of watercourses in the Mt. Eba depression, that is, in the lowest sites. Red clay subsoil which is encountered between 0" and 7" may be overlain by shallow red sand or red sandy loam (or sandy clay loam) and shallow red loam (or clay loam). Lime, when it is present in the profile, occurs between 12" and 18" from the surface. It may become moderate or heavy in amount with increasing depth. Gypsum is encountered between 26" and 45". This soil type has a redder surface, deeper gypsum and lighter stone on the surface and through the profile than the other Mt. Eba soils.

A typical profile of this type is set out below:

- 0-3" red sandy clay loam.
- 3-6" red clay loam.
- 6-18" red clay.
- 18-30" red clay with a trace of lime.
- 30-45" brownish-red clay with light lime.
- 45-48" light reddish-brown clay with light lime and light gypsum.

Soil with this type of profile carries mulgas, dead finish (*Acacia tetragonophylla*) and bindyis.

A feature of the Mt. Eba soils, especially in areas liable to fairly frequent inundation, is the presence of "sinkholes", small crabholes of irregular shape with either sloping or vertical sides. The largest holes are about three feet across and one foot deep, but holes 6-12" across and 6" deep are most common. Puffs are not developed around the holes nor do shelf areas separate them. The lowest portions of small "swampy" areas, for example, may simply have half-a-dozen of these holes in them.

Coondambo soil

This arid red earth is formed from Pleistocene alluvium in low sites such as around salt lakes, in watercourses and around the lower slopes of hills and tablelands. The underlying rock occurs at depths of 6" to 4 feet.

The following features are characteristic of Coondambo soil:

Surface soil—The surface horizon consists of red sand $\frac{1}{8}$ –2" in thickness except in watercourses where it is usually deeper. This is underlain by either light red-brown to red-brown loamy sand, sandy loam, sandy clay loam or rarely loam or clay loam.

Subsoil—Red clay which often becomes sandy or gritty with increasing depth occurs between 3" and 15" from the surface. A very shallow solonized (bleached) horizon frequently overlies the red clay. Trace to light lime is found at depths of 14–30" and may increase to medium at greater depths. Trace to light gypsum which often becomes moderate with increased depth appears at 12–40".

Stone—Stone is generally absent but trace to light billy pebbles usually not exceeding 1" in diameter but rarely 4–5" across may be present.

The following is a typical profile:

- 0– $\frac{1}{2}$ " red (2.5 YR 4/6) coarse sand (boundary sharp).
- $\frac{1}{2}$ –3" red-brown (5 YR 4/6) massive loamy sand (boundary sharp but irregular).
- 3–4 $\frac{1}{2}$ " light red-brown (5 YR 6/6) loamy sand. This bleached horizon has a slightly domed structure (boundary sharp).
- 4 $\frac{1}{2}$ –15" red (2.5 YR 4/6) massive light clay (boundary fairly sharp).
- 15–20" dark red (10 R 4/4) massive sandy light clay with slight gypsum and light lime (boundary fairly sharp).
- 20–31" red (2.5 YR 5/8) crumb structured sandy light clay with slight gypsum and light lime (boundary fairly sharp).
- 31–45" red (2.5 YR 4/8) crumb structured sandy light clay with medium lime and trace of gypsum.

Very shallow soil profiles of the Coondambo type which are superimposed upon Bon Bon or Coober Pedy soil occur on flats between sandhills in some localities. These Coondambo soils have originated in the same way as claypans, that is, by downward percolation through the sandhills and subsequent drainage on to the flats of water containing clay in suspension. This downward percolation and outward movement of water from the base of the dunes probably occurred during the moist period of the Recent referred to in the chapter on geology. A patchy cover of sand over the clay has resulted both from washing and blowing of sand from the foot of the dunes.

Coondambo soil areas carry a very dense growth of saltbush (*Atriplex vesicaria*) and bluebush (*Kochia planifolia*) and have a greater stock carrying capacity than any other type of country in the North-West.

Deep red dunes

The sandhills are aeolian formations built up during the Recent arid period. Under subsequent moister conditions the dunes were colonized by mulgas (*Acacia linophylla* and *A. ramulosa*) in the south and sandhill canegrass (*Zygochloa paradoxa*) in the Anna Creek - Oodnadatta area, so that they are now all fixed dunes.

The source of the sand, nature of the interdune areas and the trend of the dunes have already been discussed. Red sand (10 R 4/6) to a depth of more than 9 feet (the maximum depth of boring) is characteristic of the crests of the dunes. Down the slopes variable depths of red sand (depending upon the distance from the crest) overlie red clayey sand. This clayey sand horizon has resulted from downward persolation of water containing suspended clay.

The distribution of all the soils is shown in the soil plans (fig. 9 and 11).

EROSION

Natural erosion of soils carrying native vegetation in arid areas is considerably greater than in higher rainfall areas. Most erosion occurs during drought years when the soil surface is not perfectly protected even where the original bush cover is not depleted through stocking. Thus mounds of soil always accumulate around the bushes even in unstocked country. Partly as a result of this natural erosion, all the arid soils except those consisting of sand accumulations have shallow A horizons.

No measurements of soil loss caused by accelerated erosion have been made, as estimates on the basis of profile comparisons are considered impracticable on account of the natural variations in depth of the A horizons. However, it is the general impression that accelerated erosion has been insignificant throughout most of the North-West but moderate in a few localities.

From the point of view of erodability the soils may be divided into three groups: (1) those with a surface mantle of stones; (2) soils with sandy A horizons; and (3) Miller's Creek soil which is heavy-textured and has little surface stone. Included in the first group of soils are the Mount Eba, Coober Pedy, Arcoona, Wilgena and Twins types. The surface cover of stones helps to protect the soils from wind erosion, especially in the case of Arcoona and Coober Pedy soils where the stones are large and the cover is more complete. While most of the North-West is not prone to water erosion, the Arcoona and Coober Pedy soils would be if it were not for the surface stone and the crabholes on account of the topography with which they are associated. Of the five stony soils Twins soil has suffered greatest erosion.

With the exception of Coondambo soil, the soils with sandy A horizons (Wirraminna, Bon Bon, Coondambo and deep red dune soils) carry a fairly dense growth of trees and are therefore well protected from wind action. However, tree death is widespread and there is little regeneration, so that eventually a severe erosion problem can be expected on these sandy soils.

Coondambo soil with its very shallow sandy horizons overlying clay subsoil is liable to the most serious damage by wind erosion. Moderate sheet erosion has occurred in some areas but most Coondambo soil is located around saltlakes where it is difficult to obtain underground supplies of stock water, with the result that these areas are largely ungrazed. Soil loss from Miller's Creek soil areas has been moderate because widespread bush death has occurred on account of the poor water-retaining capacity of the soil.

ANALYTICAL DATA ON THE SOILS

Soil family -	ARCOONA (SHELF)						ARCOONA (CRABHOLE)						ARCOONA (PUFF)					
	Mount Eba Station						Mount Eba Station						Mount Eba Station					
Locality -	15405	15406	15407	15408	15409		15415	15416	15417	15418	15419		15410	15411	15412	15413	15414	
Soil number -	0-1	1-5	5-16	16-22	22-36		1-4	4-8	8-16	16-26	26-36		1-1	1-9	9-17	17-24	24-28	
Depth (inches) -	6-82	6-97	7-26	7-44	7-28		7-99	8-21	7-68	7-00	7-30		9-22	9-12	9-56	8-46	8-08	
Reaction pH -	%	%	%	%	%		%	%	%	%	%		%	%	%	%	%	
Gravel in original sample -	22	10	8	1	0		<0.01	0	0	—	—		34	30	16	4	0	
Calcium carbonate -	—	—	—	—	—		15 $\frac{1}{2}$	—	—	—	—		0.01	—	0.07	—	<0.01	
Coarse sand -	18 $\frac{1}{2}$	13 $\frac{1}{2}$	—	—	12 $\frac{1}{2}$		15 $\frac{3}{4}$	—	12 $\frac{1}{2}$	—	—		18	—	12 $\frac{3}{4}$	—	17 $\frac{1}{2}$	
Fine sand -	39 $\frac{1}{2}$	38 $\frac{1}{2}$	—	—	26 $\frac{1}{2}$		33 $\frac{1}{2}$	—	30 $\frac{3}{4}$	—	—		41 $\frac{1}{2}$	—	34 $\frac{3}{4}$	—	35 $\frac{1}{2}$	
Silt -	18 $\frac{1}{2}$	23 $\frac{1}{2}$	—	—	3		5 $\frac{1}{2}$	—	5 $\frac{1}{2}$	—	—		14 $\frac{1}{2}$	—	16 $\frac{1}{2}$	—	10 $\frac{1}{2}$	
Clay -	18 $\frac{1}{2}$	17 $\frac{3}{4}$	—	—	47 $\frac{1}{2}$		42 $\frac{1}{2}$	—	48 $\frac{1}{2}$	—	—		24 $\frac{1}{2}$	—	34	—	33	
Loss on acid treatment -	2.4	3.7	—	—	11.7		—	—	2.3	—	—		—	—	—	—	—	
Loss on ignition -	4.0	4.9	5.3	4.1	4.9		4.1	4.2	4.3	4.5	4.3		3.7	4.1	3.9	3.9	3.6	
Organic carbon C -	0.21	—	—	—	—		—	—	—	—	—		—	—	—	—	—	
Nitrogen N -	0.033	—	—	—	—		—	—	—	—	—		—	—	—	—	—	
Phosphoric acid P ₂ O ₅ -	0.101	—	—	—	—		—	—	—	—	—		—	—	—	—	—	
Total soluble salts -	1.60	2.26	2.46	2.39	3.02		0.045	0.195	1.04	2.42	2.22		0.061	0.032	0.142	1.56	1.94	
Chlorides as NaCl -	1.24	1.80	1.84	1.93	1.77		0.021	0.103	0.645	1.02	0.878		0.025	0.017	0.025	1.17	1.14	
Exchangeable cations	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%		m.e.%	m.e.%	m.e.%	m.e.%	m.e.%		m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	
Calcium Ca -	—	—	—	—	—		13.9	—	—	—	—		10.7	—	—	—	—	
Magnesium Mg -	—	—	—	—	—		7.0	—	—	—	—		5.7	—	—	—	—	
Potassium K -	—	—	—	—	—		1.91	—	—	—	—		3.34	—	—	—	—	
Sodium Na -	—	—	—	—	—		4.71	—	—	—	—		6.36	—	—	—	—	
Total metal ions	—	—	—	—	—		27.5	—	—	—	—		26.1	—	—	—	—	
Moisture in air dry sample	4.3	5.9	7.0	7.2	9.0		5.9	6.8	7.0	8.3	8.9		4.0	6.3	6.3	6.8	6.7	

Soil family -	COOBER PEDY (SHELF)				TWINS		WILGENA	
	Mt. Eba Station				Mt. Eba Station		Bon Bon Station	
Locality -								
Soil number -	15420	15421	15422	15423	15424	15425	15426	15427
Depth (inches) -	0-1	1-6	6-14	14-24	24-32	32-41	0-1	1-2 1/2
Reaction pH -	7.48	7.60	7.21	7.11	8.09	8.00	8.78	9.15
Gravel in original sample -	28	3	1	—	—	—	31	5
Calcium carbonate -	—	—	—	—	0.09	—	0.27	0.12
Coarse sand -	34	15 1/2	—	—	19 1/2	—	54	44 1/2
Fine sand -	43 1/2	20 1/2	—	—	19 1/2	—	31 1/2	28 1/2
Silt -	13 1/2	6	—	—	3	—	4 1/2	8
Clay -	7	53 1/2	—	—	53 1/2	—	8	15 1/2
Loss on acid treatment -	—	—	—	—	—	—	—	1.3
Loss on ignition -	2.1	5.8	5.7	5.8	5.8	5.0	2.2	3.2
Organic carbon C -	0.21	0.29	—	—	—	—	—	0.35
Nitrogen N -	0.028	0.043	—	—	—	—	—	0.035
Phosphoric acid P ₂ O ₅ -	0.040	0.054	—	—	—	—	—	0.035
Total soluble salts -	0.073	0.534	0.914	1.88	1.88	2.50	0.037	0.031
Chlorides as NaCl -	0.033	0.348	0.648	1.45	1.55	1.29	0.011	0.009
Exchangeable cations	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%
Calcium Ca -	—	19.5	—	—	—	—	—	—
Magnesium Mg -	—	7.0	—	—	—	—	—	—
Potassium K -	—	2.06	—	—	—	—	—	—
Sodium Na -	—	4.59	—	—	—	—	—	—
Total metal ions	—	33.2	—	—	—	—	—	—
Moisture in air dry sample	1.6	7.4	9.3	10.5	9.7	10.0	1.3	2.6

Soil Family - Locality -	-	MT. EBA				WIRRAMINNA						
		Mt. Eba Station				Bon Bon Station						
Soil number -	-	15399	15400	15401	15402	15403	15404	15436	15437	15438	15439	15440
Depth (inches) -	-	0-1	1-1	1-3	3-11	11-20	20-44	0-3	3-29	29-40	40-41	41-52
Reaction pH -	-	7.93	8.64	8.95	8.98	9.36	8.19	7.35	7.08	7.95	8.21	8.41
Gravel in original sample -	-	%	%	%	%	%	%	%	%	%	%	%
Calcium carbonate -	-	<0.01	<0.01	<0.01	<0.01	6	8	0	0	1	2	8
Coarse sand -	-	66	51½	43½	—	—	—	61½	63½	64½	62½	59½
Fine sand -	-	28½	31	27½	—	—	—	31½	28½	29½	29½	22½
Silt -	-	2½	11½	15½	—	—	—	4½	4	4	5½	3
Clay -	-	2½	5½	11	—	—	—	2½	2½	2½	1½	12½
Loss on ignition -	-	1.4	2.4	2.9	6.3	6.6	6.0	1.4	1.3	1.3	1.2	2.1
Organic carbon C -	-	0.16	0.21	—	—	—	—	0.14	—	—	—	—
Nitrogen N -	-	—	0.026	—	—	—	—	0.016	—	—	—	—
Phosphoric acid P ₂ O ₅ -	-	—	0.055	—	—	—	—	0.023	—	—	—	—
Total soluble salts -	-	0.015	0.018	0.010	0.032	0.198	0.994	0.006	0.004	0.007	0.007	0.015
Chlorides as NaCl -	-	0.003	0.006	0.006	0.013	0.079	0.393	0.001	nil	0.001	0.002	0.007
Exchangeable cations -	-	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%
Calcium Ca -	-	1.6	3.1	3.7	13.4	—	—	—	—	—	1.9	—
Magnesium Mg -	-	1.4	2.7	3.2	10.2	—	—	—	—	—	1.1	—
Potassium K -	-	0.46	1.02	1.09	3.02	—	—	—	—	—	0.38	—
Sodium Na -	-	0.15	0.69	1.37	5.29	—	—	—	—	—	0.13	—
Total metal ions -	-	3.6	7.5	9.4	31.9	—	—	—	—	—	3.5	—
Moisture in air dry sample -	-	0.6	1.4	2.0	8.1	7.6	7.8	0.5	0.6	0.7	0.7	1.9

Soil family - Locality - Soil number - Depth (inches) - Reaction pH -	COONDAMBO Wilgena Station										BON BON Bon Bon Station			
	15441	15442	15443	15444	15445	15446	15447	15430	15431	15432	15433			
Gravel in original sample	0.1	1-3	3-4½	4½-15	15-20	20-31	31-45	0.1	1-1½	1½-4½	lime pan			
Calcium carbonate	8.40	8.65	8.34	7.72	8.49	8.51	8.66	8.76	9.12	9.16	9.15			
Coarse sand	%	%	%	%	%	%	%	%	%	%	%			
Fine sand	3	2	2	1	3	2	7	18	15	23	39			
Silt	<0.01	<0.01	—	—	3.0	—	5.8	—	16.8	28.4	39.5			
Clay	57½	53½	—	38	26½	—	31½	—	34½	30	24			
Loss on acid treatment	33	35½	—	28	30½	—	29½	—	27½	21	19½			
Loss on ignition	4½	7½	—	10	18½	—	8½	—	6½	5	6½			
Organic carbon C	3	2½	—	22	19½	—	22½	—	12½	12½	11			
Nitrogen N	—	—	—	—	3.8	—	7.3	—	—	—	—			
Phosphoric acid P ₂ O ₅	1.4	1.5	1.6	3.2	5.5	5.5	5.5	6.2	10.8	12.0	12.5			
Total soluble salts	—	0.09	—	—	—	—	—	—	0.55	—	—			
Chlorides as NaCl	0.021	—	—	—	—	—	—	—	0.039	—	—			
Exchangeable cations	—	0.028	—	—	—	—	—	—	—	—	—			
Calcium Ca	0.013	0.010	0.031	0.311	0.921	0.932	0.789	0.031	0.032	0.033	0.039			
Magnesium Mg	0.003	0.005	0.018	0.204	0.683	0.660	0.547	0.005	0.004	0.004	0.004			
Potassium K	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%	m.e.%			
Sodium Na	—	2.2	—	5.4	—	—	—	—	—	—	—			
Total metal ions	—	1.8	—	4.5	—	—	—	—	—	—	—			
Moisture in air dry sample	—	0.68	—	0.97	—	—	—	—	—	—	—			
	—	0.40	—	3.29	—	—	—	—	—	—	—			
	—	5.1	—	14.2	—	—	—	—	—	—	—			
	0.6	0.8	1.4	3.9	6.7	5.4	4.1	0.8	1.6	1.8	2.6			

Except for the Bon Bon, Twins, Wilgena and Wirraminna families the soils show chemical data consistent with marked solonization. The reaction is alkaline in all except the top of the Arcoona shelf profile (pH 6.8). The highest value recorded was a pH of 9.6 in the Arcoona puff. A high total soluble salt content (1.60%) in the surface ½" of the Arcoona shelf profile indicates a complete lack of leaching and hence a very arid environment for plant growth. This aridity combined with the high salt content is responsible for the sparse occurrence of plants on the shelves (Crocker and Skewes 1941).

Phosphates are low to moderate, ranging from .02% - .05% except in the Arcoona shelf (.10%) where the phosphate content is fairly high by comparison with other Australian soils. Figures for organic carbon (all less than .6%) indicate a very low organic matter content. Nitrogen is correspondingly low but the carbon:nitrogen ratio is generally about 9:1, which is a favourable figure.

THE VEGETATION

CLASSIFICATION OF THE PLANT COMMUNITIES

In this survey the basic unit used in the classification of the vegetation is the plant association as defined by Crocker and Wood (1947), and wherever possible this unit has also been used in the vegetation mapping (Figures 8 and 10). The associations and the factors determining their distribution are set out in Table X. However, over large areas certain of the associations are constantly grouped together and it has not been possible to map the individual associations on the scale used in the survey (two miles to the inch). In any case, from a practical viewpoint these association groups form definite land types.

TABLE X

Association	Soil	Geology	Annual rainfall	Formation
<i>Acacia linophylla</i> – <i>A. ramulosa</i>	deep red dunes	Recent sand-hills	5½–7½"	arid woodland
<i>Zygochloa paradoxa</i>	deep red dunes	Recent sand-hills	<5½"	desert sclerophyllous grassland
<i>Acacia aneura</i> – <i>A. brachystachya</i>	Wirraminna, Bon Bon and Wilgena	Recent sand and clay	4½–7½"	arid woodland to shrub-arid woodland
<i>A. sowdenii</i> – <i>Kochia sedifolia</i>	Bon Bon and Wilgena	Recent sand and clay	5½–9"	shrub-arid woodland
<i>Atriplex vesicaria</i> – <i>Bassia</i> spp.	Coober Pedy	Cretaceous shale	5–9"	shrub steppe
<i>Atriplex vesicaria</i> – <i>Kochia planifolia</i>	Coondambo	Pleistocene alluvium	5–9"	shrub steppe
<i>K. sedifolia</i>	Bon Bon and Wilgena	Recent sand and clay	5–9"	shrub steppe
<i>Acacia aneura</i> – <i>A. brachystachya</i> – <i>A. tetragonophylla</i>	Mt. Eba	Pleistocene alluvium	5½"–6"	arid woodland
<i>K. planifolia</i> – <i>Bassia</i> spp.	Mt. Eba	Pleistocene alluvium	5½"–6"	shrub steppe
<i>Eremophila</i> <i>freelingii</i> – <i>Acacia aneura</i> – <i>A. brachystachya</i>	Arid ranges	Precambrian	—	arid hill woodland
<i>Atriplex vesicaria</i> – <i>Ixiolaena</i> <i>leptolepis</i>	Arcoona	Cretaceous shale	5½–9"	shrub steppe
<i>A. rhagodioides</i>	Arcoona	Cretaceous shale	<5½"	shrub steppe
<i>Kochia planifolia</i>	Twins	Cretaceous shale	5–7"	shrub steppe
<i>Kochia planifolia</i> – <i>Atriplex vesicaria</i> – <i>K. sedifolia</i>	Miller's Creek	Pliocene (?) Limestone	5½"	shrub steppe

In past ecological studies in South Australia the "edaphic complex" (see Crocker and Wood, 1947) has been widely used as a mapping unit but it has been applied to two different types of complexes. It has been used in the mapping of areas where two or more floristically unrelated plant associations are randomly

ASSOCIATION COMPLEXES DUE TO THE PRESENCE OF SANDHILLS

ASSOCIATIONS	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>	<i>A. aneura</i> — <i>A. brachystachya</i>	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>	<i>A. aneura</i> — <i>A. brachystachya</i>
LAND SURFACE				
AVERAGE WIDTH (YARDS)	250	350	250	350
SOIL	DEEP RED DUNE	WIRRAMINNA	DEEP RED DUNE	WIRRAMINNA

ASSOCIATIONS	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>	<i>A. aneura</i> — <i>A. brachystachya</i>	<i>Acacia</i> <i>Sowdenii</i> — <i>Kochia</i> <i>sedifolia</i>	<i>A. aneura</i> — <i>A. brachystachya</i>	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>
LAND SURFACE					
AVERAGE WIDTH (YARDS)	200	700	400	700	200
Proportion of Area occupied by each Association	$\frac{1}{4}$	$\frac{2}{3}$	$\frac{1}{5}$		
SOIL	DEEP RED DUNE	WIRRAMINNA	BON BON	WIRRAMINNA	DEEP RED DUNE

NOTE: The above sequence is not always maintained as some of the dunes are separated by Wirraminna soil flats only, i.e. the myall-bluebush community is absent.

ASSOCIATIONS	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>	<i>Atriplex</i> <i>vesicaria</i> — <i>Bassia</i> spp.	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>	<i>Atriplex</i> <i>vesicaria</i> — <i>Bassia</i> spp.
LAND SURFACE				
SOIL	DEEP RED DUNE	COOBER PEDY	DEEP RED DUNE	COOBER PEDY

ASSOCIATIONS	<i>Zygochloa</i> <i>paradoxa</i> — <i>Bassia</i> spp.	<i>Atriplex</i> <i>vesicaria</i> — <i>Acacia</i> <i>brachystachya</i>	<i>Zygochloa</i> <i>paradoxa</i> — <i>Acacia</i> <i>brachystachya</i>	<i>Acacia</i> <i>aneura</i> — <i>Acacia</i> <i>brachystachya</i>
LAND SURFACE				
SOIL	DEEP RED DUNE	COOBER PEDY	DEEP RED DUNE	WIRRAMINNA

ASSOCIATIONS	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>	<i>Atriplex</i> <i>vesicaria</i> — <i>Kochia</i> <i>planifolia</i>	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>	<i>Atriplex</i> <i>vesicaria</i> — <i>Kochia</i> <i>planifolia</i>	<i>Acacia</i> <i>aneura</i> — <i>Acacia</i> <i>brachystachya</i>	<i>Atriplex</i> <i>vesicaria</i> — <i>Kochia</i> <i>planifolia</i>	<i>Acacia</i> <i>linghylla</i> — <i>Acacia</i> <i>ramulosa</i>	<i>Acacia</i> <i>aneura</i> — <i>Acacia</i> <i>brachystachya</i>
LAND SURFACE								
AVERAGE WIDTH (YARDS)	250	300	250	300	500	300	250	500
Proportion of Area occupied by each Association	$\frac{4}{15}$	$\frac{1}{3}$			$\frac{2}{5}$			
SOIL	DEEP RED DUNE	COONDAMBO	DEEP RED DUNE	COONDAMBO	WIRRAMINNA	COONDAMBO	DEEP RED DUNE	WIRRAMINNA

Fig. 6

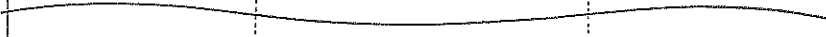
or regularly distributed on different soils, for example, the *Zygochloa paradoxa* — *Triodia basedowii* edaphic complex of the Simpson Desert (Crocker 1946) where the *Z. paradoxa* association occurs on the sandhills and the *T. basedowii* association occurs on the sandy flats between the dunes.

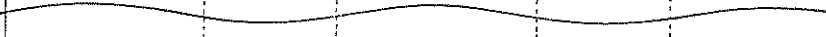
Secondly, the edaphic complex has been used, for example by Specht and Perry (1948) in the "stringybark edaphic complex" of the Adelaide Hills, in the

sense defined by Crocker and Wood who state: "... We have used one feature of the habitat, namely, allied soils, associated with related floristic composition of species as a basis for classification. Within definite climatic limits, associations on nearly related soil types and with related floristic composition are grouped together as an edaphic complex."

If the term "edaphic complex" is to have any significance it is obvious that it should only be used in the sense of the definition, and that a new term must be introduced into ecological nomenclature for the other type of complex. The "association complex" is a group of two or more associations which occur on unrelated soils and which show random distribution within an area. Each individual association invariably occurs on the one soil so that within the complex

ASSOCIATION COMPLEXES DUE TO THE PRESENCE OF LOW SANDY RISES

ASSOCIATIONS	<i>Acacia aneura</i> - <i>Acacia brachystachya</i>	<i>Acacia Sonderii</i> - <i>Kochia setifolia</i>	<i>Acacia aneura</i> - <i>Acacia brachystachya</i>
LAND SURFACE			
AVERAGE WIDTH	$\frac{3}{4}$ MILE	1 MILE	$\frac{3}{4}$ MILE
SOIL	WIRRAMINNA	BON BON AND WILGENA	WIRRAMINNA

ASSOCIATIONS	<i>Acacia aneura</i> - <i>Acacia brachystachya</i>	<i>Kochia setifolia</i>	<i>Acacia aneura</i> - <i>Acacia brachystachya</i>		
LAND SURFACE					
AVERAGE WIDTH	$\frac{3}{4}$ MILE	$\frac{2}{5}$ MILE	$\frac{3}{5}$ MILE		
SOIL	WIRRAMINNA	BON BON AND WILGENA	WIRRAMINNA		

ASSOCIATION COMPLEX DUE TO THE PRESENCE OF WATERCOURSES SEPARATED BY LOW TERRACES


ASSOCIATIONS	<i>Acacia aneura</i> - <i>A. brachystachya</i> - <i>A. tetragonophylla</i>	<i>Kochia planifolia</i> - <i>Bassia</i> spp.	<i>Acacia aneura</i> - <i>A. brachystachya</i> - <i>A. tetragonophylla</i>	<i>Kochia planifolia</i> - <i>Bassia</i> spp.
LAND SURFACE				
SOIL	M ^T . EBA	M ^T . EBA WITH BLEACHED ZONE	M ^T . EBA	M ^T . EBA WITH BLEACHED ZONE

Fig. 7

each association becomes a soil indicator. The *Eucalyptus oleosa* - *E. dumosa* association which is found on the brown solonized soil flats and the *E. angulosa* - *Melaleuca uncinata* association which occurs on the solonetz sandhills in the Murray Mallee (Jessup 1946) form an association complex. In the North-West a particular expression of the association complex occurs as a consequence of the regular and parallel spacing of the sand dunes. With this type of topography, when the contours are traversed at right angles there is a regular repetition of associations. For convenience this particular expression of the association complex has been styled an association repetition on the vegetation map.

The association complexes occurring in the North-West are set out in fig. 6 and 7.

Only one of these complexes requires further discussion. The *Zygochloa paradoxa* -- *Acacia aneura* -- *A. brachystachya* -- *Atriplex vesicaria* -- *Bassia* spp. association complex occurs in the Lake Eyre region where sandhills are superimposed upon tableland. The flats between the dunes are sandy where they are close together or clayey (Coober Pedy soil) where the dunes are scattered. *Acacia linophylla* and *A. ramulosa* are absent, their place on the dunes being taken by canegrass (*Z. paradoxa*). In contrast to the adjacent Simpson Desert (Crocker 1946), spinifex is absent from the sandy interdune soils which carry a modified mulga community. *Atriplex vesicaria* -- *Bassia* spp. association occurs where the flats separating the sandhills have clay soils.

The plant associations may be classified into five formations.

Shrub-steppe formation

This includes treeless areas dominated by shrub species belonging to the genera *Atriplex* (*A. vesicaria* and *A. rhagodioides*) and *Kochia* (*K. planifolia* and *K. sedifolia*), small shrubs which grow to a height of 12-36". Trees are absent because of the comparative heavy texture of the surface soils.

The dominant shrubs vary greatly in their density of growth according to species, associated soil and rainfall. In ungrazed stands of bladder saltbush (*Atriplex vesicaria*) and low bluebush (*Kochia planifolia*) there may be as many as 170 to 180 bushes on 2/33 acre (see quantitative estimates). On the other hand, stands of bluebush (*Kochia sedifolia*) may have a density as low as 20 to 25 bushes on 2/33 acre.

During drought times the ground between the shrubs is devoid of growth but in good seasons may, depending upon the soil and also upon the density of the shrubs, be almost completely covered with herbage and grass. Where the growth of bush is very dense competition is so severe that even in good seasons little herbage or grass appears between the bushes.

Arid woodland formation

Trees (*Acacia* spp.) form a woodland of variable density on the lighter textured soils and normally vary from 20 to 50 yards apart. In previous literature the *Acacia* woodland country has been referred to as a scrub formation but this term is misleading when applied to country in which trees are frequently very scattered and there is a scarcity of undershrubs. Grasses, of which *Aristida* spp. (*A. arenaria* and *A. browniana*) and *Enneapogon* spp. (*E. polyphyllus* and *E. avenaceus*) are most widespread, are most prominent in the ground layer especially after summer rains. *Bassia uniflora* is common following winter rains.

Shrub-arid woodland formation

This includes areas where an understorey of shrubs occurs beneath the trees. The formation grades into the shrub-steppe formation on the one hand and the arid woodland formation on the other according to the density of the trees and shrubs.

Arid hill woodland formation

In previous literature the arid hill communities have been called scrubs but are better regarded as woodlands. The formation is represented in the North-West by the community on the Denison Range.

Desert sclerophyllous grassland formation

The dominant species on the sandhills of the desert or near desert areas is the sclerophyllous grass *Zygochloa paradoxa* (sandhill canegrass). Herbaceous grasses are the principal associated species.

THE PALATABILITY OF THE SPECIES

The plants occurring in the communities of the North-West have been assigned to five palatability groups: those with a palatability rating of 1 are very palatable, 2 are quite palatable, 3 are moderately palatable, 4 are slightly palatable and 5 are unpalatable. The palatabilities were largely assessed from observations of selectivity of grazing around watering points.

The palatability of any plant to stock depends upon a number of factors, which are determined by both the grazing animal and the plant species. Palatability ratings given here are the preferences of mature merino sheep. The most important factors influencing the palatability of any plant species are its growth stage and the plants with which it is associated. The growth stage is particularly important in the case of species which produce spiny fruits, for example, the *Bassias*, and which are therefore more palatable when young than when mature. The palatability ratings given here are an average for the whole of the life cycle. The importance of the collection of plants available to the grazing animal is illustrated by the fact that even some of the unpalatable species (palatability 5) like *Kochia pyramidata* are grazed under drought conditions when nothing else is available, in fact under extreme conditions sheep will eat dry sticks and twigs.

Palatability ratings have been given to about 170 species. Shrubs and trees with a palatability of 1 are few in number. Very palatable trees are not destroyed by stock because a portion of their foliage is out of reach, but the very palatable shrubs like *Cassia sturtii* and *Eremophila latrobei* have been considerably depleted. There are more very palatable herbaceous species (grasses being prominent) than trees and shrubs and many of them, for example *Erodium cygnorum*, *Clianthus speciosus*, *Convolvulus erubescens*, *Trichinium exaltatum* and *Eragrostis dielsii* are suppressed by grazing. Others like *Stipa nitida* remain of common occurrence because they are prolific seeders.

Again there are very few shrubs and trees with a palatability of 2, but this group includes the widespread *Kochia planifolia* and *Atriplex vesicaria*, species which are destroyed by heavy stocking. Herbaceous species with a palatability of 2, among which grasses are prominent, are also few in number and most of them are suppressed in heavily grazed country. More plants occur in group 3 than in either groups 1 or 2, and herbaceous species are more numerous than shrubs and trees. Moderately palatable species are not often suppressed except under conditions of very heavy stocking.

Slightly palatable species (palatability 4) are not suppressed by grazing and more plants fall into this group than in either groups 1, 2, 3, or 5. The majority of the shrubs and herbaceous species do not spread in heavily grazed country but they do persist. There are exceptions however like the free-seeding *Bassia paradoxa* and *Atriplex halimoides* which spread on certain soil types. Genera represented by the largest number of slightly palatable species are *Zygophyllum* with *Z. crenatum*, *Z. ammophilum*, *Z. iodiocarpum*, and *Z. compressum* and *Eremophila* with *E. scoparia*, *E. duttonii*, *E. serrulata*, *E. alternifolia*, *E. oppositifolia* and *E. maculata*.

Group 5 (plants of no value) contains about the same number of species as group 3 but shrubs are more numerous than herbaceous species. Some of the free-seeding species like *Kochia triptera* var. *eriolada*, *K. pyramidata* and *Bassia*

divaricata spread where competition with more palatable species has been reduced through grazing.

The palatability ratings of species of *Bassia*, *Kochia*, *Atriplex*, *Acacia* and grasses occurring in the North-West are set out in Table XI.

THE PLANT ASSOCIATIONS

Acacia aneura - *A. brachystachya* association ("mulga country").

The dominant species of this community are *A. aneura* and *A. brachystachya*, small trees which grow to a height of 16-24 feet. These species cannot be distinguished on vegetative characters alone. Although *A. aneura* most commonly has one main trunk and *A. brachystachya* two or three, the reverse is frequently found. Black (1929) gives the length of the phyllodia in *A. aneura* as 3-7 centimetres but lengths of up to 10 centimetres are not uncommon, thus overlapping the range for *A. brachystachya* which is 5-18 centimetres. However, the pods of the two species are fairly easily distinguished and in August-September of 1946, when their distributions were determined by reconnaissance survey, the two species were both fruiting prolifically. The community is found on sandy soils of the Wirraminna type, calcareous Bon Bon soil and occasionally the heavier textured calcareous Wilgena soil.

On the deepest sands mulgas form a woodland of variable density (Plate XVIII, Figure 4 and Plate XIX, Figure 1). They become more scattered on Bon Bon soil and sparse (or more usually absent) on Wilgena soil. The understorey also varies greatly. Where more than three feet of sand overlies lime rubble or hardpan bladder saltbush and bluebush are both absent. Bladder saltbush appears where two to three feet of sand overlies heavy lime, while bluebush will only grow where less than two feet of sand overlies the lime. The mulga community therefore varies from a fairly dense woodland with a grass layer beneath the trees to a shrub-woodland with scattered trees and an understorey of shrubs. All gradations occur between these two extremes and because the surface sands were redistributed during the Recent the pattern is very complex.

The following are the chief floristic characteristics of the association on the three soils:

1. *Mulga on Wirraminna (sandy) soil*

The mulgas usually form a fairly dense woodland. Bluebush is absent from the deepest sands but forms an understorey where the surface sands are shallower. Prior to stocking bladder saltbush was common, but the ecotype associated with sandy soil is easily destroyed by grazing, so that little remains in stocked country. The ground between trees and shrubs is dominated by mulga grass (*Aristida arenaria*), black heads (*Enneapogon polyphyllus* and *E. avenaceus*) and bindyi (*Bassia uniflora*), which form a complete ground cover in favourable years. *Danthonia bipartita* and *Eragrostis eriopoda* are also prominent on sandridges with the above herbaceous species.

A wide variety of shrubs and herbaceous species are associated, the commonest of which are *Kochia georgei* (erect form), Australian boxthorn (*Lycium australe*), tomato bush (*Enchylaena tomentosa*), *Sida virgata*, firebush (*Kochia triptera* var. *eriolada*), bundy bush (*Cassia eremophila* var. *platypoda*), cat tail (*Trichinium alopecuriodeum*) and buck bush (*Salsola kali*). Of these species *K. georgei*, tomato bush, bundy bush and cat tail are of little value to the grazer. Australian boxthorn, which sheds its leaves under drought conditions, and *Sida virgata* are moderately palatable. Firebush is a free-seeding rapid growing species which colonizes overgrazed country where competition with other species

VEGETATION PLAN

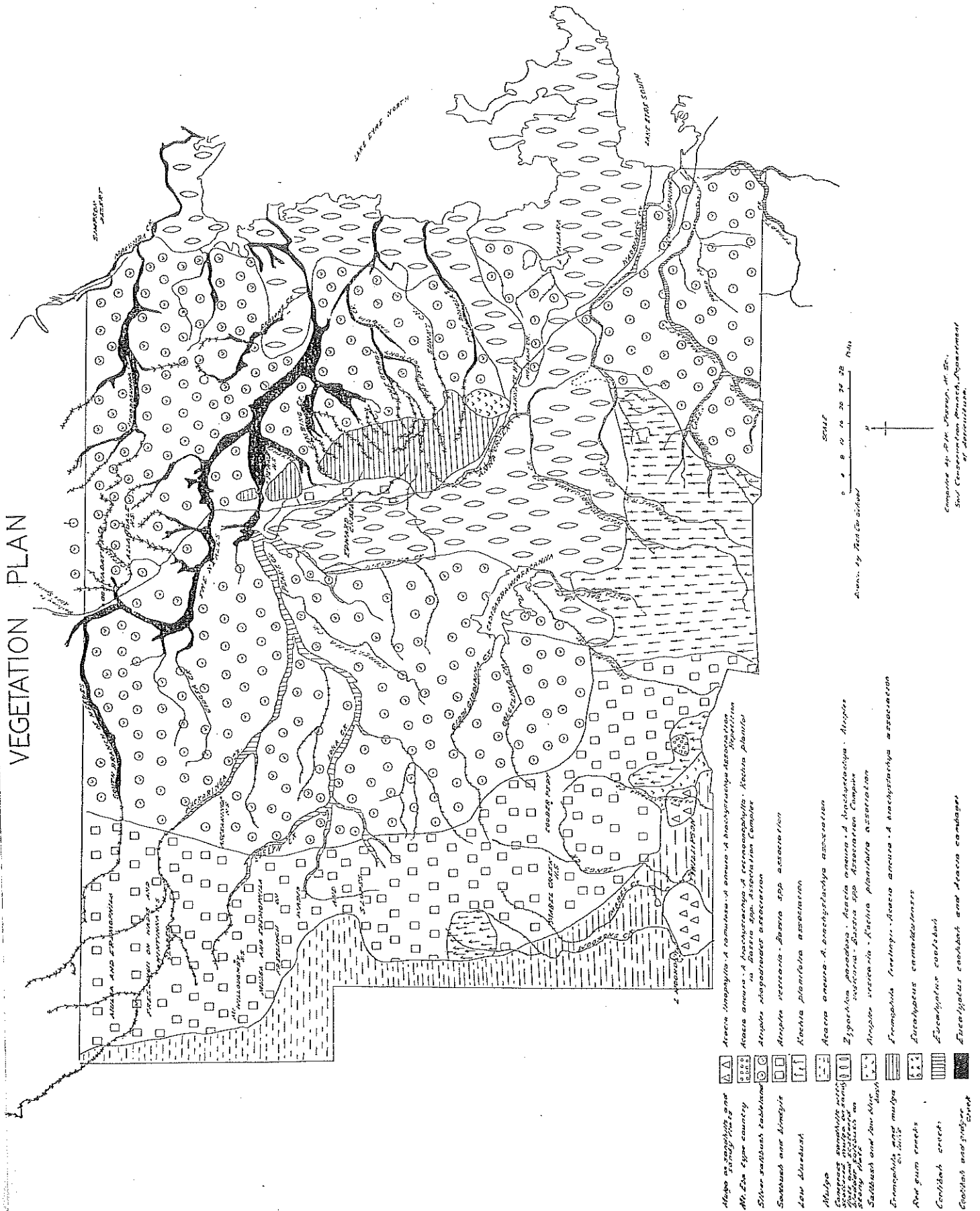


TABLE XI Showing the palatability ratings of certain species

Palatability	1	2	3	4	5
Bassia	uniflora	patenticuspis eriacantha	sclerolaenoides decurrrens lanicuspis obliquicuspis ventricosa	paradoxa brachyptera	divaricata bicornis tricuspis
Kochia	—	planifolia eriantha	sedifolia	aphylla tomentosa var. appressa	pyramidata triptera var. erioclada triptera var. pentaptera
Atriplex	—	vesicaria	spongiosa	halimoides	quinii, rhagodioides, velutinellum
Acacia	aneura brachystachya	—	victoriae oswaldii	rigens linophylla ramulosa sowdenii tetragonophylla kempeana	ligulata burkittii
Grasses	Eriochloa longiflora Eragrostis dielsii Sporobolus actinocladius Eulalia fulva Danthonia semi- annularis Stipa nitida	Paspalidium sp. Enneapogon E. avenaceus E. polyphyllus Dactyloctenium radulans Iseilema vaginiflorum Eragrostis setifolia	Triaraphis mollis Chloris truncata C. acicularis Eragrostis falcata Astrebla pectinata Panicum decompositum Plagiosetum refractum Aristida anthox-anthoides A. arenaria Enneapogon caerulescens E. cylindricus	Eragrostis australasica Aristida browniana Eragrostis eriopoda Danthonia bipartita	—

has been reduced. It is unpalatable. Bundy bush colonizes sandy mulga country where the trees have been destroyed by firing. Tomato bush is always found beneath tree canopies.

2. *Mulga on Bon Bon soil*

The mulgas are more scattered and the herbaceous growth is sparser as the sandy A horizons of the soils become shallower. Bluebush forms an understorey beneath the trees. The only associated shrubs of common occurrence are bird's-eye Cassia (*Cassia sturtii*) and *Acacia kempeana*. *Sida virgata* and the small-leaved form of *Chenopodium nitrariaceum* are fairly common. Bladder saltbush was once common but has largely been destroyed by grazing.

The chief herbaceous species are bindyi (*Bassia obliquicuspis*), mulga grass (*Aristida arenaria*), black heads (*Enneapogon cylindricus*, *E. caerulescens*, *E. polyphyllus* and *E. avenaceus*), while *Bassia uniflora*, *B. sclerolaenoides*, geranium (*Erodium cygnorum*) and *Zygophyllum prismatothecum* are fairly common. Of these species *B. obliquicuspis*, *B. sclerolaenoides*, *Enneapogon cylindricus* and *E. caerulescens* are most prominent on the shallowest of the Bon Bon soils. Where the surface sands are slightly deeper mulga grass, *E. polyphyllus*, *E. avenaceus* and *B. uniflora* become the dominants.

Bird's-eye Cassia is very palatable and although it is still of common occurrence has been depleted through grazing. *Acacia kempeana* and the small-leaved form of *Chenopodium nitrariaceum* are only slightly palatable.

In addition to the mulga association, Bon Bon soil also supports myall-bluebush or occasionally bluebush without trees (*K. sedifolia* association). Apart from tree species the three associations are floristically similar when associated with Bon Bon soil.

3. *Mulga on Wilgena soil*

When it supports *A. aneura* - *A. brachystachya* association Wilgena soil carries very scattered mulgas and herbaceous species form a sparse growth. The bluebush understorey is often not as dense as it is on Bon Bon soil. Mulga association is actually rarely found on Wilgena soil. Where the mulga and myall-bluebush association complex occurs the latter community is usually found on Wilgena soil, while further north where myall is absent, that is, in the *A. aneura* - *A. brachystachya* - *K. sedifolia* association complex country, Wilgena soil carries treeless bluebush (*K. sedifolia* association). Apart from tree species the communities are floristically similar when associated with Wilgena soil.

The mulga community on Wilgena (and Bon Bon) soil contains fewer species than it does on deep sandy (Wirraminna) soil. Apart from bluebush, fairly common shrubs are sagebush (*Trichinium obovatum*), bird's-eye Cassia and *Kochia triptera* var. *pentaptera*. Dominant herbaceous species are the bindyis (*Bassia obliquicuspis* and *B. sclerolaenoides*) and black heads (*Enneapogon cylindricus*). *E. caerulescens* and *Zygophyllum prismatothecum* are fairly common. Mistletoes (*Loranthus exocarpi* and *L. murrayi*) are common parasites on the mulgas. A complete list of species found in the association, the soils on which they grow and their palatabilities to stock are shown in Table XII.

Mulga death has been severe throughout the North-West. From numerous counts which were made it is estimated that about one-third of the mature mulgas have died on the sandy soils, while on the heavier-textured soils the proportion of dead trees is even greater. Mulga is very susceptible to death by firing. Although the fires that occur are only "grass fires" they kill up to two-thirds of the mulgas and those that survive never recover completely and die earlier than unburnt trees. On the other hand, regeneration is sometimes increased and there

may be up to half as many established mulga seedlings in the burned country as there were mature trees prior to the fire.

Changes which have occurred with grazing

The frequency of occurrence of the species on Wirraminna soil in the mulga country of the Lake Wirrida block, which has never been stocked, was compared with adjacent stocked areas. As the shrub growth on the deep sandy soils is comparatively sparse, stocking would be expected to cause rapid changes in the density and floristic composition of the shrub component of the vegetation. This is found to be the case.

Common shrubs on Wirraminna soil in ungrazed country are bluebush (*K. sedifolia*), saltbush (*A. vesicaria*), *Eremophila latrobei*, bundy bush (*Cassia eremophila* var. *platypoda*), tomato bush (*Enchylaena tomentosa*) and *Kochia georgei* (erect form). Sagebush (*Trichinium obovatum*), tar bush (*Eremophila glabra*) and *Sida virgata* are fairly common.

In grazed country bundy bush and tomato bush are still common because they are rarely grazed. The erect form of *Kochia georgei* is only slightly palatable but is thinned out to some extent under heavy grazing. *S. virgata*, which is moderately palatable, remains fairly common because of its free-seeding habit. Bluebush is moderately palatable but is very hard to kill by grazing. The very palatable *Eremophila latrobei* becomes of very rare occurrence in stocked country, while sagebush and tar bush, which are moderately palatable, become fairly rare. The ecotype of saltbush associated with sandy soils is rapidly destroyed by stock.

Australian boxthorn is protected from excessive grazing by its spines and although moderately palatable has increased. There has been a marked increase in the amount of the unpalatable firebush.

Dominant herbaceous species in ungrazed country are mulga grass (*Aristida arenaria*), *Enneapogon polyphyllus*, *E. avenaceus* and *Bassia uniflora* and on sandridges *Danthonia bipartita* and *Eragrostis eriopoda*. Although mulga grass is only moderately palatable it is an excellent drought reserve. It is not grazed to any extent when other herbaceous feed is available, but during drought times the dry grass is completely eaten. It has the additional advantage of producing new growth rapidly after a dry period following light rain and provides grazing for stock before annual herbage appears. *E. polyphyllus*, *E. avenaceus* and *B. uniflora* are much more palatable than mulga grass and are suppressed under heavy stocking. The proportion of these species to mulga grass is the best indication of the stocking to which the country is subjected.

Mulga country as a grazing unit

It has been pointed out that the mulga community is most commonly associated with sandy soils of the Wirraminna type and that shrubs are of sparse occurrence on the deeper sands. As a consequence the bush drought reserve is comparatively small. This can be readily seen by reference to the quantitative map showing the present bush density of Commonwealth Hill Station (see fig. 12) where there are large areas of mulga country not interspersed with other plant associations. When this survey was carried out most of Commonwealth Hill was virgin country.

However, the foliage and pods of the mulgas themselves are very palatable, and although stock soon trim the foliage up to the height they can reach, dry leaves are constantly shed from the trees. The dominant shrubs of the shrub-steppe communities shed their leaves during drought times and live in a state of anabiosis. The result is that the shrubs are a valuable reserve in the early stages of drought but if the dry period is prolonged they provide little more than sticks

for the stock to graze. The mulgas, however, continue to shed leaves from their canopies, so that in a prolonged drought they are of much greater value as a food reserve than shrubs.

After mulga country has been grazed for some time and an equilibrium between stocking and vegetation has been reached, the most important species in the community to the grazier are *A. arenaria*, *E. polyphyllus*, *E. avenaceus* and *Bassia uniflora*. It is not possible in practice to economically graze mulga country and maintain the balance between stock and plants to enable the ecotype of salt-bush found on sandy soils or the very palatable *Eremophila latrobei* to be maintained except as very rare species.

TABLE XII

List of species found in the *Acacia aneura* - *A. brachystachya* association.
D = dominant, VC = very common, C = common, FC = fairly common,
FR = fairly rare, R = rare, VR = Very rare.

	Palat- ability	Natural frequency	Frequency in grazed country	Associated soil
<i>Acacia aneura</i> - - -	1	D	D	All three; rare on Wilgena
<i>Acacia brachystachya</i> - -	1	D	D	All three; rare on Wilgena
<i>Atriplex vesicaria</i> - - -	2	VC	VR	All three
<i>Kochia sedifolia</i> - - -	3	VC	VC	Absent from deep sands
<i>Stipa nitida</i> - - -	1	FR	FR	Absent from deep sands
<i>Enneapogon polyphyllus</i> -	1	D	D	All three but most on Wirra.
<i>Bassia uniflora</i> - - -	1	D	D	All three but most on Wirra.
<i>Bassia obliquicuspis</i> - -	3	FR	FC	Absent from Wirraminna
<i>Bassia paradoxa</i> - - -	4	VR	R	Bon Bon and shallow Wirra.
<i>Aristida arenaria</i> - - -	3	D	D	All three but rare on Wilgena
<i>Enchylaena tomentosa</i> - -	4	FC	FC	All three
<i>Rhagodia spinescens</i> var. -	4	VR	R	All three
<i>Kochia triptera</i> var. <i>eriodlada</i> -	5	VR	FC	All three, particularly Wirra- minna; rare on Wilgena
<i>Lycium australe</i> - - -	3	FR	FC	All three
<i>Cassia eremophila</i> var. <i>platypoda</i>	4	FC	FC	Wirraminna only
<i>Kochia georgei</i> (erect form) -	4	C	FC	Wirraminna only
<i>Salsola kali</i> - - -	2	FC	FC	All three
<i>Enneapogon avenaceus</i> - -	1	C	C	All three
<i>Erodium cygnorum</i> - - -	1	FR	FR	All three, particularly Bon Bon
<i>Tetragonia expansa</i> - - -	1	R	R	Wirra. and Bon Bon
<i>Tetragonia eremaea</i> - - -	1	R	R	Wirra. and Bon Bon
<i>Tragus australianus</i> - - -	3	VR	VR	All three, partic. Wirraminna
<i>Euphorbia drummondii</i> - -	4	R	R	All three
<i>Portulaca oleracea</i> - - -	2	VR	VR	Wirra. and Bon Bon
<i>Sida virgata</i> - - -	3	C	FC	All three, particularly Wirra.
<i>Eremophila latrobei</i> - - -	1	FC	VR	All three, particularly Wirra.
<i>Eremophila glabra</i> - - -	3	FC	VR	Wirra. and Bon Bon
<i>Eremophila scoparia</i> - - -	4	VR	VR	All three
<i>Acacia burkittii</i> - - -	5	VR	VR	Wirra. and Bon Bon
<i>Kochia pyramidata</i> - - -	5	VR	R	Wirra. and Bon Bon
<i>Eucarya spicata</i> - - -	4	FC	VR	All three
<i>Heterodendron oleifolium</i> -	1	VR	VR	Wirra. and Bon Bon
<i>Eremophila paisleyi</i> - - -	4	R	R	—
<i>Grevillea nematophylla</i> - -	4	R	R	Wirra. and Bon Bon
<i>Pentatropis kempeana</i> - - -	—	VR	VR	Wirra. and Bon Bon

			Palat- ability	Natural frequency	Frequency in grazed country	Associated soil
<i>Eremophila duttonii</i>	-	-	4	VR	VR	Bon Bon and Wilgena
<i>Eremophila longifolia</i>	-	-	3	VR	VR	Wirra. and Bon Bon
<i>Eremophila alternifolia</i>						
var. <i>latifolia</i>	-	-	4	FR	FR	Wirra. and Bon Bon
<i>Sida intricata</i>	-	-	3	VR	VR	Bon Bon and Wilgena
<i>Abutilon leucopetalum</i>	-	-	5	R	R	Wirra. only
<i>Bassia divaricata</i>	-	-	5	VR	VR	Bon Bon and Wilgena
<i>Solanum ellipticum</i>	-	-	5	VR	VR	All three
<i>Goodenia spinescens</i>	-	-	5	VR	VR	—
<i>Acacia kempeana</i>	-	-	4	FR	FR	All three, partic. Bon Bon
<i>Acacia oswaldii</i>	-	-	3	VR	VR	All three, partic. Bon Bon
<i>Dodonaea microzyga</i>	-	-	4	VR	VR	Bon Bon and Wilgena
<i>Gummiopsis quadrifida</i>	-	-	2	VR	VR	Wirra. only
<i>Sida petrophila</i>	-	-	4	VR	VR	All three
<i>Cassia artemisioides</i>	-	-	3	VR	VR	All three
<i>Zygophyllum fruticosum</i>						
var. <i>eremaeum</i>	-	-	4	FR	FR	All three
<i>Chenopodium nitrariaceum</i>			4	VR	VR	Bon Bon and Wilgena
(small-leaved form)	-	-				
<i>Bassia sclerolaenoides</i>	-	-	3	FC	FC	Wilgena and Bon Bon
<i>Cassia sturtii</i>	-	-	1	FC	FR	Bon Bon and Wilgena
<i>Templetonia egena</i>	-	-	4	VR	VR	Wirra. and Bon Bon
<i>Eucarya acuminata</i>	-	-	2	VR	VR	All three
<i>Kochia triptera</i> var. <i>pentaptera</i>	-	-	5	FR	FR	Bon Bon and partic. Wilgena
<i>Acacia tetragonophylla</i>	-	-	4	FR	FR	All three, least on Wirra.
<i>Kochia tomentosa</i>	-	-	5	VR	VR	Bon Bon and Wilgena
<i>Dodonaea attenuata</i>	-	-	4	VR	VR	Wirra. only
<i>Eragrostis eriopoda</i>	-	-	4	FC	FC	Deep sands only
<i>Danthonia bipartita</i>	-	-	4	FC	FC	Deep sands only
<i>Eremophila serrulata</i>	-	-	4	VR	VR	All three
<i>Trisetum pumillum</i>	-	-	—	VR	VR	—
<i>Phyllanthus lacunarius</i>	-	-	5	VR	VR	Wirra only
<i>Chenopodium cristatum</i>	-	-	4	VR	VR	Wirra only
<i>Calandrinia remota</i>	-	-	1	VR	VR	Wirra only
<i>Cucumis myriocarpus</i>	-	-	4	VR	VR	Wirra. and Bon Bon
<i>Swainsona burkittii</i>	-	-	5	VR	VR	Wirra. only
<i>Triraphis mollis</i>	-	-	3	R	R	Wirra. only
<i>Clianthus speciosus</i>	-	-	1	VR	VR	Wirra. and Bon Bon
<i>Zygophyllum ammophilum</i>	-	-	4	VR	VR	All three
<i>Euphorbia eremophila</i>	-	-	3	R	R	Wirra only
<i>Trichinium alopecuroideum</i>	-	-	4	FC	FC	Wirra only
<i>Calotis cymbacantha</i>	-	-	3	VR	VR	Wirra. and Bon Bon
<i>Aristida anthoxanthoides</i>	-	-	3	VR	VR	—
<i>Lepidium papillosum</i>	-	-	4	VR	VR	All three
<i>Lepidium oxytrichum</i>	-	-	4	VR	VR	All three
<i>Goodenia cycloptera</i>	-	-	4	FR	FR	Wirra and Bon Bon
<i>Citrullus vulgaris</i>	-	-	5	VR	VR	Wirra and Bon Bon
<i>Stenopetalum lineare</i>	-	-	—	VR	VR	All three
<i>Convolvulus erubescens</i>	-	-	1	VR	VR	Wirra. only
<i>Angianthus pusillus</i>	-	-	4	R	R	All three
<i>Chenopodium desertorum</i>	-	-	3	R	R	Wirra. only

			Palat- ability	Natural frequency	Frequency in grazed country	Associated soil
<i>Myriocephalus stuartii</i>	-	-	5	VR	VR	Wirra. only
<i>Didiscus glaucifolius</i>	-	-	—	VR	VR	Wirra. only
<i>Trichinium exaltatum</i>	-	-	1	R	VR	Wirra. and Bon Bon
<i>Enneapogon caerulescens</i>	-	-	3	FC	FC	Bon Bon and Wilgena
<i>Enneapogon cylindricus</i>	-	-	3	FC	FC	Bon Bon and Wilgena
<i>Helipterum floribundum</i>	-	-	5	FR	FR	Wirra. and Bon Bon
<i>Bassia eriacantha</i>	-	-	2	FR	VR	All three
<i>Loranthus exocarpi</i>	-	-	1	C	C	On mulgas (parasitic)
<i>Loranthus murrayi</i>	-	-	1	C	C	On mulgas (parasitic)
<i>Zygophyllum prismatothecum</i>	-	-	5	FC	FC	All three
<i>Dactyloctenium radulans</i>	-	-	2	VR	VR	Wirra. and Bon Bon
<i>Tribulus terrestris</i>	-	-	2	VR	VR	Wirra. and Bon Bon
<i>Acacia aneura</i> var. <i>latifolia</i>	-	-	1	FR	FR	All three
<i>Atriplex spongiosa</i>	-	-	4	VR	VR	All three
<i>Nicotiana</i> sp.	-	-	5	VR	VR	All three
<i>Craspedia pleiocephala</i>	-	-	4	VR	VR	Wirra. and Bon Bon
<i>Atriplex quinii</i>	-	-	5	VR	VR	—
<i>Trichinium obovatum</i>	-	-	3	FR	VR	All three
<i>Codonocarpus cotinifolius</i>	-	-	5	VR	VR	Wirra. only

Acacia sowdenii—*Kochia sedifolia* association (pl. xix, fig. 3)

In this shrub-woodland community an understorey of bluebush is present beneath an open woodland of small trees of *A. sowdenii* (myall) which vary from 16-28 feet in height. Myall is the most attractive tree found in the arid country of South Australia. Prior to being grazed by stock its branches and foliage sweep to the ground (pl. xix, fig. 2) and the new foliage produced after heavy rains has a silvery-grey colour. Death of myall has not been as severe as mulga and amounts to only 15-20 per cent. of the mature trees.

A. Sowdenii has a curious distribution. Both the species itself and the myall-bluebush association occur particularly on Bon Bon but also on Wilgena soils. There are, however, large areas of these soils normally colonized by myall from which it is absent, for example in the country to the north-west of Kingoonya where the *A. aneura*—*A. brachystachya*—*K. sedifolia* association complex occurs. Here species normally associated with myall occur but myall itself is lacking. Rainfall is slightly lower than in most of the myall country, but the species does occur in more arid areas than this, for example, occasional myalls occur along wadis and creeks as far north as the south branch of the Neales River and in parts of the Denison Range.

The limited distribution of the species is probably the result of restricted colonization. The recession of plant species in South Australia during the arid Recent and their subsequent spread from centres of survival has been discussed by Crocker and Wood (1947), who suggested that myall survived in the Gawler Ranges. There were also other minor survival centres such as along creeks like the Neales "River" and in the Denison Range. The implication of the restricted spread of myall following the lifting of climatic stress during the Recent is that the period of increased rainfall was of too short duration to enable the species to migrate to all the areas it is capable of colonizing. The present rainfall is lower than during the moist period of colonization.

The species occurring in the myall-bluebush association vary with the depth of the sandy surface horizons of the soils. On the shallowest Bon Bon soils and

on Wilgena soil the herbaceous layer is dominated by black heads (*Enneapogon cylindricus*) and bindyi (*Bassia obliquicuspis*), the latter increasing with depletion through grazing of the bluebush cover. *E. caerulescens* and *B. sclerolaenoides* are prominent. On the deeper soils *E. cylindricus* and *Bassia obliquicuspis* are again dominants, but *B. sclerolaenoides* and *E. caerulescens* are of rare occurrence. *E. polyphyllus*, *E. avenaceus*, mulga grass and *B. uniflora* are very common. *B. paradoxa* may become very common when the community suffers very heavy grazing and bush death.

Bluebush is the dominant shrub but *Cratystylis conocephala* replaces it in some of the southern myall country. Australian boxthorn (*Lycium australe*) is fairly common, while *Chenopodium nitrariaceum* (small-leaved form) and firebush (*Kochia triptera* var. *eriolada*) are fairly rare. Complete floristics of the association and the palatabilities of the species are given in Table xiii.

Changes which occur with grazing

The most noticeable effects of heavy grazing are an increase in the amount of bindyi (*Bassia obliquicuspis*) and sometimes *B. paradoxa*. Black bluebush (*Kochia pyramidata*) and firebush may also spread. These species, with the exception of *B. obliquicuspis*, are of slight or no value. At the same time bluebush is depleted and *Enneapogon polyphyllus*, *E. avenaceus* and *Bassia uniflora* are suppressed. Bird's eye Cassia and bladder saltbush were more common prior to grazing. Overgrazing and death of bluebush containing an admixture of bladder saltbush may, on the sandier Bon Bon soils, result in a saltbush dominant understorey because saltbush frequently seeds heavily prior to death.

The community as a grazing unit

The foliage of *A. sowdenii* is always grazed by stock to as high as they can reach but its foliage is actually only slightly palatable, so that it is only under drought conditions that any leaves which are shed are eaten by sheep. The principal drought reserve of the myall-bluebush country is *K. sedifolia*. Apart from bluebush the most important species in the community to the grazier are black heads (*Enneapogon polyphyllus*, *E. avenaceus* and *E. cylindricus*), the bindyis (*Bassia uniflora* and *B. sclerolaenoides*) and mulga grass (*Aristida arenaria*).

TABLE XIII, showing a complete list of species found in the
A. sowdenii - *K. sedifolia* association

Species	Palatability	Frequency of occurrence
<i>Acacia sowdenii</i> - - - - -	4	D
<i>Kochia sedifolia</i> - - - - -	3	D
<i>Bassia obliquicuspis</i> - - - - -	3	VC
<i>Lycium australe</i> - - - - -	3	FC
<i>Chenopodium nitrariaceum</i> - - - - -	4	FR
<i>Bassia paradoxa</i> - - - - -	4	FR
<i>Kochia triptera</i> var. <i>eriolada</i> - - - - -	5	FR
<i>Enchylaena tomentosa</i> - - - - -	4	R
<i>Rhagodia spinescens</i> var. <i>deltophylla</i> - - - - -	4	R
<i>Cassia eremophila</i> var. <i>platypoda</i> - - - - -	4	R
<i>Cassia sturtii</i> - - - - -	1	R
<i>Kochia pyramidata</i> - - - - -	5	R
<i>Eremophila scoparia</i> - - - - -	4	R
<i>Sida virgata</i> - - - - -	3	R
<i>Atriplex vesicaria</i> - - - - -	2	R
<i>Bassia divaricata</i> - - - - -	5	VR
<i>Kochia georgei</i> (erect form) - - - - -	4	VR

Species	Palatability	Frequency of occurrence
<i>Eucarya acuminata</i> - - - - -	2	VR
<i>Eucarya spicata</i> - - - - -	4	VR
<i>Grevillea nematophylla</i> - - - - -	4	VR
<i>Kochia triptera</i> - - - - -	—	VR
<i>Cassia eremophila</i> - - - - -	4	VR
<i>Exocarpus aphylla</i> - - - - -	4	VR
<i>Templetonia egena</i> - - - - -	4	VR
<i>Eucarya persicarius</i> - - - - -	—	VR
<i>Dodonaea microzyga</i> - - - - -	4	VR
<i>Myoporum platycarpum</i> - - - - -	2	VR
<i>Eremophila duttonii</i> - - - - -	4	VR
<i>Eremophila serrulata</i> - - - - -	4	VR
<i>Heterodendron oleifolium</i> - - - - -	1	VR
<i>Acacia tetragonophylla</i> - - - - -	4	VR
<i>Eremophila rotundifolia</i> - - - - -	5	VR
<i>Eremophila alternifolia</i> - - - - -	4	VR
<i>Eremophila alternifolia</i> var. <i>latifolia</i> - - - - -	4	VR
<i>Acacia kempeana</i> - - - - -	4	VR
<i>Acacia oswaldii</i> - - - - -	3	VR
<i>Trichinium obovatum</i> - - - - -	3	VR
<i>Acacia burkittii</i> - - - - -	5	VR
<i>Eremophila latrobei</i> - - - - -	1	VR
<i>Eremophila paisleyi</i> - - - - -	4	VR
<i>Sida intricata</i> - - - - -	3	VR
<i>Pittosporum phillyreoides</i> - - - - -	2	VR
<i>Eremophila longifolia</i> - - - - -	3	VR
<i>Cassia artemisioides</i> - - - - -	3	VR
<i>Zygophyllum fruticosum</i> - - - - -	4	VR
<i>Kochia tomentosa</i> - - - - -	5	VR
<i>Kochia triptera</i> var. <i>pentaptera</i> - - - - -	5	VR
<i>Enneapogon cylindricus</i> - - - - -	3	D
<i>Aristida arenaria</i> - - - - -	3	C
<i>Bassia uniflora</i> - - - - -	1	FC
<i>Enneapogon polyphyllus</i> - - - - -	1	FC
<i>Enneapogon avenaceus</i> - - - - -	1	FC
<i>Zygophyllum prismatothecum</i> - - - - -	5	FC
<i>Salsola kali</i> - - - - -	2	FC
<i>Bassia sclerolaenoides</i> - - - - -	3	R
<i>Tetragonia expansa</i> - - - - -	1	R
<i>Tetragonia eremaea</i> - - - - -	1	R
<i>Erodium cygnorum</i> - - - - -	1	R
<i>Enneapogon caerulescens</i> - - - - -	3	R
<i>Stipa nitida</i> - - - - -	1	FR
<i>Euphorbia drummondii</i> - - - - -	4	VR
<i>Chenopodium desertorum</i> - - - - -	3	VR
<i>Eragrostis setifolia</i> - - - - -	2	VR
<i>Goodenia cycloptera</i> - - - - -	4	VR
<i>Tribulus terrestris</i> - - - - -	2	VR
<i>Sida petrophila</i> - - - - -	4	VR
<i>Tragus australianus</i> - - - - -	3	VR
<i>Triraphis mollis</i> - - - - -	3	VR
<i>Babbagia dipterocarpa</i> - - - - -	5	VR

Zygophyllum ammophilum	-	-	-	-	-	4	VR
Craspedia pleiocephala	-	-	-	-	-	4	VR
Atriplex spongiosa	-	-	-	-	-	4	VR
Clianthus speciosus	-	-	-	-	-	1	VR
Zygophyllum compressum	-	-	-	-	-	4	VR
Loranthus exocarpi	-	-	-	-	-	1	VR
Loranthus murrayi	-	-	-	-	-	1	VR

Kochia sedifolia association (Plate XIX, Figure 4)

Treeless shrub steppe areas dominated by bluebush are found on Bon Bon and Wilgena soils beyond the range of myall. The floristics of the community vary according to the soil.

1. *K. sedifolia* association on Wilgena soil

K. triptera var. *pentaptera* is a common associated shrub and sagebush (*Trichinium obovatum*) is fairly common. Dead-finish (*Acacia tetragonophylla*) is fairly rare. The dominant herbaceous species are bindyis (*Bassia sclerolaenoides* and *B. obliquicuspis*) and *Enneapogon cylindricus*, while *E. caerulescens*, buck bush (*Salsola kali*) and *Bassia uniflora* are fairly rare.

2. *K. sedifolia* association on Bon Bon soil

Soapbush (*Zygophyllum fruticulosum*), sagebush (*Trichinium obovatum*) and bird's eye Cassia (*Cassia sturtii*) are fairly common associated shrubs. Broombush (*Eremophila scoparia*) is fairly rare. The dominant herbaceous species are bindyi (*Bassia obliquicuspis*) and *Enneapogon cylindricus*, while *E. caerulescens*, *E. avenaceus*, *E. polyphyllus*, *Bassia sclerolaenoides* and buck bush (*Salsola kali*) are fairly rare. Complete floristics of the association are given in Table XIV.

Changes which occur with grazing

Heavy grazing of the community on both Wilgena and Bon Bon soils causes depletion of bluebush, bladder saltbush and *Cassia sturtii* and increase in bindyi (*Bassia obliquicuspis*). Sagebush (*Trichinium obovatum*) is depleted where the community is on Wilgena soil. The grasses *Enneapogon polyphyllus* and *E. avenaceus* and the bindyi *Bassia uniflora* are also suppressed under heavy grazing.

TABLE XIV
showing complete floristics of the *K. sedifolia* association

Species	Frequency on Bon Bon soil	Frequency on Wilgena soil	Palatability
<i>Kochia sedifolia</i>	D	D	3
<i>Bassia obliquicuspis</i>	VC	C	3
<i>Zygophyllum fruticulosum</i>	FC	VR	4
<i>Trichinium obovatum</i>	FC	FC	3
<i>Cassia sturtii</i>	FC	VR	1
<i>Eremophila scoparia</i>	FR	VR	4
<i>Lycium australe</i>	R	VR	3
<i>Rhagodia spinescens</i> var. <i>deltophylla</i>	VR	VR	4
<i>Enchylaena tomentosa</i>	VR	VR	4
<i>Cassia artemisioides</i>	VR	VR	3
<i>Sida virgata</i>	VR	VR	3
<i>Chenopodium nitrariaceum</i>	VR	R	4
<i>Sida corrugata</i>	VR	VR	4
<i>Sida intricata</i>	VR	VR	3

Species	Frequency on Bon Bon soil	Frequency on Wilgena soil	Palatability
<i>Casuarina cristata</i> - - - - -	VR	VR	4
<i>Eremophila rotundifolia</i> - - - - -	VR	R	5
<i>Kochia tomentosa</i> - - - - -	VR	R	4
<i>Kochia pyramidata</i> - - - - -	VR	—	5
<i>Eremophila duttonii</i> - - - - -	VR	VR	4
<i>Acacia oswaldii</i> - - - - -	VR	VR	3
<i>Acacia tetragonophylla</i> - - - - -	VR	FR	4
<i>Dodonaea microzyga</i> - - - - -	VR	VR	4
<i>Goodenia spinescens</i> - - - - -	VR	—	5
<i>Eremophila alternifolia</i> - - - - -	VR	VR	4
<i>Eremophila alternifolia</i> var. <i>latifolia</i> -	VR	—	4
<i>Solanum ellipticum</i> - - - - -	VR	VR	5
<i>Bassia paradoxa</i> - - - - -	VR	VR	4
<i>Acacia kempeana</i> - - - - -	VR	VR	4
<i>Eremophila latrobei</i> - - - - -	VR	VR	1
<i>Bassia divaricata</i> - - - - -	VR	VR	5
<i>Kochia triptera</i> var. <i>pentaptera</i> - -	VR	C	5
<i>Enneapogon cylindricus</i> - - - - -	D	D	3
<i>Enneapogon caeruleus</i> - - - - -	FR	FR	3
<i>Bassia sclerolaenoides</i> - - - - -	FR	VC	3
<i>Enneapogon avenaceus</i> - - - - -	FR	VR	1
<i>Enneapogon polyphyllus</i> - - - - -	FR	VR	1
<i>Salsola kali</i> - - - - -	FR	FR	2
<i>Bassia uniflora</i> - - - - -	R	FR	1
<i>Aristida arenaria</i> - - - - -	R	VR	3
<i>Atriplex vesicaria</i> - - - - -	VR	VR	2
<i>Kochia triptera</i> var. <i>eriodactyla</i> - -	VR	VR	5
<i>Zygophyllum prismatocarpum</i> - - - -	VR	R	5
<i>Vittadinia triloba</i> - - - - -	VR	—	4
<i>Stipa nitida</i> - - - - -	R	R	1
<i>Sida petrophila</i> - - - - -	VR	VR	4
<i>Portulaca oleracea</i> - - - - -	VR	—	2
<i>Abutilon leucopetalum</i> - - - - -	VR	—	5
<i>Blennodia trisecta</i> - - - - -	VR	—	—
<i>Stenopetalum lineare</i> - - - - -	VR	VR	—
<i>Calotis cymbacantha</i> - - - - -	VR	—	3
<i>Danthonia semiannularis</i> - - - - -	VR	—	1
<i>Lepidium oxytrichum</i> - - - - -	VR	VR	4
<i>Lepidium papillosum</i> - - - - -	VR	VR	4
<i>Helipterum floribundum</i> - - - - -	VR	—	5
<i>Craspedia pleiocephala</i> - - - - -	VR	—	4
<i>Zygophyllum iodiocarpum</i> - - - - -	VR	—	4
<i>Erodium cygnorum</i> - - - - -	VR	VR	1
<i>Goodenia cycloptera</i> - - - - -	VR	—	4
<i>Bassia eriacaantha</i> - - - - -	—	VR	2
<i>Santalum lanceolatum</i> - - - - -	VR	VR	1
<i>Euphorbia drummondii</i> - - - - -	VR	VR	4

Acacia linophylla – *A. ramulosa* association (Plate XX, Figure 1)

These two species, which grow to a height of 9-14 feet, are the dominants on the sandhills in the southern portion of the North-West. Black oak (*Casuarina*

cristata) is of common occurrence with the acacias on the sandhills south of the east-west railway line. North of the railway line black oak is of rare occurrence on the dunes but pine (*Callitris glauca*) partly or completely replaces the acacias on some of the sandhills (pl. xx, fig. 2). Shrub species, with the exception of *Cassia eremophila* var. *platypoda* which is very common on Roxby Downs Station, are of rare occurrence in the community. *Aristida browniana* is the dominant herbaceous species. Commonly associated with it are *Plagiosetum refractum*, *Enneapogon polyphyllus*, *E. avenaceus*, *Salsola kali* and *Atriplex vellutinellum*. *Triraphis mollis* is fairly common. The following species are common after winter rains: parakeelya (*Calandrinia remota*), *Blennodia canescens*, Stuart's daisy (*Myriocephalus stuartii*), *Angianthus pusillus*, *Calotis cymbacantha* and *Helichrysum semifertile*.

Practically all of the dunes in the southern sandhill country carry this stable climax community, but some of the dunes superimposed upon the tableland and immediately surrounding it are unstable. Primary colonizers of these unstable dunes are *Salsola kali*, *Atriplex vellutinellum*, *Crotalaria dissitiflora* and *Myriocephalus stuartii*. The first shrubs to appear are sandhill wattle (*Acacia ligulata*) and hop bush (*Dodonaea attenuata*).

Complete floristics of the association are given in Table XV.

The sandhills as a grazing unit.

The dominant acacias have unpalatable foliage and shrubs are practically absent, so the sandhill country is of little value in drought times. Further, the dominant herbaceous species (*Aristida browniana*) is a coarse unpalatable grass. The community is most valuable to the grazier following winter rains when a dense growth of ephemeral species is produced. However, if the preceding summer rains have been heavy the growth of grass, particularly *A. browniana*, is frequently so dense as to allow little space for annual species.

TABLE XV

showing complete floristics of the *Acacia linophylla* - *A. ramulosa* association.

Species	Palatability	Frequency of occurrence
<i>Acacia linophylla</i> - - - -	4	D
<i>Acacia ramulosa</i> - - - -	4	D
<i>Casuarina cristata</i> - - - -	4	C
<i>Callitris glauca</i> - - - -	5	C
<i>Cassia eremophila</i> var. <i>platypoda</i> -	4	FC
<i>Acacia ligulata</i> - - - -	5	VR
<i>Heterodendron oleifolium</i> - - -	1	R
<i>Dodonaea attenuata</i> - - - -	4	VR
<i>Abutilon leucopetalum</i> - - - -	5	R
<i>Eucarya spicata</i> - - - -	4	VR
<i>Duboisia hopwoodii</i> - - - -	5	VR
<i>Eremophila paisleyi</i> - - - -	4	R
<i>Pittosporum phillyreoides</i> - - -	2	VR
<i>Kochia triptera</i> - - - -	—	R
<i>Enchylaena tomentosa</i> - - - -	4	R
<i>Hakea leucoptera</i> - - - -	5	VR
<i>Sida intricata</i> - - - -	3	VR
<i>Grevillea nematophylla</i> - - - -	4	R
<i>Myoporum montanum</i> - - - -	—	VR
<i>Phyllanthus fuernrohrii</i> - - - -	5	R

Species	Palatability				Frequency of occurrence
<i>Cassia sturtii</i>	-	-	-	1	VR
<i>Phyllanthus lacunarius</i>	-	-	-	5	FR
<i>Bassia uniflora</i>	-	-	-	1	R
<i>Eucalyptus pyriformis</i>	-	-	-	5	VR
<i>Bossiaea walkeri</i>	-	-	-	5	VR
<i>Aristida browniana</i>	-	-	-	4	D
<i>Plagiosetum refractum</i>	-	-	-	3	C
<i>Enneapogon polyphyllus</i>	-	-	-	1	C
<i>Enneapogon avenaceus</i>	-	-	-	1	C
<i>Salsola kali</i>	-	-	-	2	C
<i>Atriplex velutinellum</i>	-	-	-	5	C
<i>Triraphis mollis</i>	-	-	-	3	FC
<i>Stipa nitida</i>	-	-	-	1	R
<i>Citrullus vulgaris</i>	-	-	-	5	R
<i>Cucumis myriocarpus</i>	-	-	-	4	R
<i>Didiscus glaucifolius</i>	-	-	-	—	R
<i>Aristida arenaria</i>	-	-	-	3	FR
<i>Euphorbia drummondii</i>	-	-	-	4	R
<i>Euphorbia eremophila</i>	-	-	-	3	VR
<i>Lepidium oxytrichum</i>	-	-	-	4	VR
<i>Lepidium papillosum</i>	-	-	-	4	VR
<i>Zygophyllum iodocarpum</i>	-	-	-	4	R
<i>Crotalaria dissitiflora</i>	-	-	-	4	VR
<i>Convolvulus erubescens</i>	-	-	-	1	R
<i>Clianthus speciosus</i>	-	-	-	1	VR
<i>Calandrinia remota</i>	-	-	-	1	FC
<i>Biennodia canescens</i>	-	-	-	2	FC
<i>Myriocephalus stuartii</i>	-	-	-	5	FC
<i>Angianthus pusillus</i>	-	-	-	4	FC
<i>Calotis cymbacantha</i>	-	-	-	3	FC
<i>Helichrysum semifertile</i>	-	-	-	—	FC
<i>Tetragonia expansa</i>	-	-	-	1	R
<i>Tetragonia eremaea</i>	-	-	-	1	R
<i>Trisetum pumillum</i>	-	-	-	—	VR
<i>Nicotiana</i> sp.	-	-	-	5	VR
<i>Goodenia cycloptera</i>	-	-	-	4	R
<i>Zygophyllum ammophilum</i>	-	-	-	4	R
<i>Stenopetalum lineare</i>	-	-	-	—	VR
<i>Atriplex spongiosa</i>	-	-	-	4	R

Zygochloa paradoxa association (Plate XX, Figure 3)

Sandhills in the Lake Eyre region are completely covered with scattered plants of sandhill canegrass (*Zygochloa paradoxa* formerly *Spinifex paradoxus*), a sclerophyllous grass which is more akin to the hard-leaved shrubs than the usual soft-leaved herbaceous grasses. It has a palatability rating of 4. In the adjacent Simpson Desert the crests of the dunes are bare (Crocker, 1946). Herbaceous growth is always much sparser than on the *Acacia* spp. sandhills further south.

Shrub species which commonly occur with the canegrass are sandhill wattle (*Acacia ligulata*) and hop bush (*Dodonaea attenuata*), while *Trichinium obovatum* and *Phyllanthus fuernrohrii* are fairly common. Common herbaceous species are caltrop (*Tribulus terrestris*), *Aristida browniana* and *Crotalaria dissitiflora*,

while the following are fairly common: mulga grass, bur grass (*Tragus australianus*), buck bush, *Plagiosetum refractum*, *Myriocephalus stuartii* and *Euphorbia drummondii*. Complete floristics are given in Table XVI.

The sandy flats between the dunes carry a modified mulga community. Spinifex (*Triodia basedowii*), which is the dominant species between the dunes in the Simpson Desert (Crocker, 1946), is absent. The mulgas are very scattered. Hop bush, sandhill wattle, *Eremophila duttonii* and needlebush (*Hakea leucopetala*) are the most common shrubs. Canegrass sometimes extends onto the flats where the sands are very deep. Mulga grass is the dominant herbaceous species on the sandy flats. Typical associated species are *Enneapogon polyphyllus*, *E. avenaceus*, *Citrullus vulgaris*, *Cucumis myriocarpus*, *Abutilon leucopetalum*, *Euphorbia drummondii*, *Crotalaria dissitiflora* and button grass (*Dactyloctenium radulans*).

TABLE XVI
showing the species present in the *Zygochloa paradoxa* association

Species	Frequency of occurrence					
<i>Zygochloa paradoxa</i>	-	-	-	-	-	D
<i>Acacia ligulata</i>	-	-	-	-	-	C
<i>Dodonaea attenuata</i>	-	-	-	-	-	C
<i>Trichinium obovatum</i>	-	-	-	-	-	FC
<i>Phyllanthus fuernrohrii</i>	-	-	-	-	-	FC
<i>Eremophila</i> sp.	-	-	-	-	-	FR
<i>Acacia aneura</i>	-	-	-	-	-	VR
<i>Acacia brachystachya</i>	-	-	-	-	-	VR
<i>Sida virgata</i>	-	-	-	-	-	VR
<i>Sida petrophila</i>	-	-	-	-	-	VR
<i>Gumniopsis quadrifida</i>	-	-	-	-	-	VR
<i>Tribulus terrestris</i>	-	-	-	-	-	C
<i>Aristida browniana</i>	-	-	-	-	-	C
<i>Crotalaria dissitiflora</i>	-	-	-	-	-	C
<i>Aristida arenaria</i>	-	-	-	-	-	FC
<i>Tragus australianus</i>	-	-	-	-	-	FC
<i>Salsola kali</i>	-	-	-	-	-	FC
<i>Plagiosetum refractum</i>	-	-	-	-	-	FC
<i>Myriocarpus stuartii</i>	-	-	-	-	-	FC
<i>Euphorbia drummondii</i>	-	-	-	-	-	FR
<i>Phyllanthus lacunarius</i>	-	-	-	-	-	FR
<i>Triraphis mollis</i>	-	-	-	-	-	FR
<i>Portulaca oleracea</i>	-	-	-	-	-	FR
<i>Enneapogon polyphyllus</i>	-	-	-	-	-	FR
<i>Enneapogon avenaceus</i>	-	-	-	-	-	FR
<i>Cucumis myriocarpus</i>	-	-	-	-	-	R
<i>Atriplex spongiosa</i>	-	-	-	-	-	R
<i>Abutilon leucopetalum</i>	-	-	-	-	-	VR
<i>Trianthema crystallina</i> var. <i>clavata</i>	-	-	-	-	-	VR
<i>Trichodesma zeylanicum</i> var. <i>sericeum</i>	-	-	-	-	-	VR
<i>Nicotiana</i> sp.	-	-	-	-	-	VR
<i>Eragrostis eriopoda</i>	-	-	-	-	-	VR
<i>Zygophyllum howittii</i>	-	-	-	-	-	VR
<i>Aristida anthoxanthoides</i>	-	-	-	-	-	VR
<i>Citrullus vulgaris</i>	-	-	-	-	-	VR
<i>Tetragonia</i> spp.	-	-	-	-	-	VR

Eremophila freelingii–*Acacia aneura*–*A. brachystachya* association.

The Denison Range south of Oodnadatta supports a hill-woodland community dominated by *E. freelingii* and mulgas (*Acacia aneura* and *A. brachystachya*).

Acacia aneura–*A. brachystachya*–*A. tetragonophylla* association
(Plate XX, Figure 4)

These species are the dominants of the association found in watercourses and "swamps" on transported soils in the Mount Eba depression. Shrubs are generally not conspicuous, the community being an arid woodland. Prickly acacia (*Acacia victoriae*) and *Sida virgata* are fairly rare, while *Trichinium obovatum*, *Eremophila rotundifolia*, *Bassia divaricata* and cotton bush (*Kochia aphylla*) are rare.

The dominant herbaceous species are mulga grass (*Aristida arenaria*) and bindyi (*Bassia paradoxa*), while button grass (*Dactyloctenium radulans*) and *B. uniflora* are fairly rare. *Salsola kali*, *Eragrostis falcata*, *Enneapogon polyphyllus* and *E. avenaceus* are rare. Complete floristics are given in Table XVII.

TABLE XVII
showing the species present in the *A. aneura*–*A. brachystachya*–
A. tetragonophylla association.

Species	Palatability	Frequency of occurrence
<i>Acacia aneura</i> - - -	1	D
<i>Acacia brachystachya</i> - - -	1	D
<i>Acacia tetragonophylla</i> - - -	4	D
<i>Bassia paradoxa</i> - - -	4	C
<i>Bassia uniflora</i> - - -	1	FR
<i>Acacia victoriae</i> - - -	3	FR
<i>Sida virgata</i> - - -	3	FR
<i>Trichinium obovatum</i> - - -	3	R
<i>Eremophila rotundifolia</i> - - -	5	R
<i>Bassia divaricata</i> - - -	5	R
<i>Kochia aphylla</i> - - -	4	R
<i>Cassia sturtii</i> - - -	1	VR
<i>Kochia pyramidata</i> - - -	5	VR
<i>Eremophila paisleyi</i> - - -	4	VR
<i>Zygophyllum fruticulosum</i> - - -	4	VR
<i>Santalum lanceolatum</i> - - -	1	VR
<i>Eremophila longifolia</i> - - -	3	VR
<i>Pittosporum phillyreoides</i> - - -	2	VR
<i>Exocarpus aphylla</i> - - -	4	VR
<i>Eremophila duttonii</i> - - -	4	VR
<i>Rhagodia spinescens</i> - - -	4	VR
<i>Sida intricata</i> - - -	3	VR
<i>Bassia eriacantha</i> - - -	2	VR
<i>Eremophila serrulata</i> - - -	4	VR
<i>Cassia artemisioides</i> - - -	3	VR
<i>Cassia desolata</i> - - -	4	VR
<i>Cassia phyllodinea</i> - - -	4	VR
<i>Heterodendron oleifolium</i> - - -	1	VR
<i>Acacia oswaldii</i> - - -	3	VR
<i>Eremophila scoparia</i> - - -	4	VR
<i>Eremophila maculata</i> - - -	4	VR

Species	Palatability	Frequency of occurrence
Bassia patentiuspis - - -	2	VR
Enchylaena tomentosa - - -	4	VR
Solanum ellipticum - - -	5	VR
Bassia sclerolaenoides - - -	3	VR
Atriplex vesicaria - - -	2	VR
Kochia lobiflora - - -	—	VR
Aristida arenaria - - -	3	D
Dactyloctenium radulans - - -	2	FR
Salsola kali - - -	2	R
Eragrostis falcata - - -	3	R
Enneapogon avenaceus - - -	1	R
Enneapogon polyphyllus - - -	1	R
Sida petrophila - - -	4	VR
Stenopetalum lineare - - -	—	VR
Zygophyllum ammophilum - - -	4	VR
Abutilon leucopetalum - - -	5	VR
Zygophyllum compressum - - -	4	VR
Stipa nitida - - -	1	VR
Lepidium papillosum - - -	4	VR
Blennodia trisecta - - -	—	VR
Teucrium racemosum - - -	3	VR
Helichrysum cassinianum - - -	—	VR
Erodium cygnorum - - -	1	VR
Minuria leptophylla - - -	4	VR
Eragrostis setifolia - - -	2	VR
Marsilia drummondii - - -	4	VR
Rhagodia nutans - - -	3	VR
Goodenia cycloptera - - -	4	VR
Phyllanthus lacunarius - - -	5	VR
Eragrostis dielsii - - -	1	VR
Atriplex spongiosa - - -	4	VR
Citrullus vulgaris - - -	5	VR
Aristida anthoxanthoides - - -	3	VR
Portulaca oleracea - - -	2	VR
Cucumis myriocarpus - - -	4	VR
Euphorbia drummondii - - -	4	VR
Tetragonia expansa - - -	1	VR
Tetragonia eremaea - - -	1	VR
Convolvulus erubescens - - -	1	VR
Tribulus terrestris - - -	2	VR
Enneapogon cylindricus - - -	3	VR
Clianthus speciosus - - -	1	VR
Eulalia fulva - - -	1	VR
Ixiolaena leptolepis - - -	4	VR
Helipterum floribundum - - -	5	VR

Kochia planifolia – *Bassia* spp. association (Plate XXI, Figure 1).

This shrub steppe community is also found on transported soils in the Mount Eba depression but on slightly more elevated sites than the *Acacia aneura* – *A. brachystachya* – *A. tetragonophylla* association. It is associated with low terraces between watercourses. *Kochia planifolia* is always of sparse occurrence on Mount Eba soil. Because of this low natural density of low bluebush grazing

causes rapid destruction of the bush cover. Further, fairly heavy bush death occurs on this soil under drought conditions even when stocking is light.

The association is generally devoid of trees but scattered mulga (*Acacia aneura* and *A. brachystachya*) and dead finish (*A. tetragonophylla*) may be present. In addition to low bluebush, *Bassia paradoxa* and *B. divaricata* are very common species. Dominant herbaceous species are *Bassia eriacantha*, *B. uniflora* and mulga grass. Complete floristics are given in Table XVIII.

Small crabholes are a common feature of the country and here, in addition to species mentioned above, the following occur: cotton bush (*Kochia aphylla*) is a dominant shrub, while *Ixiolaena leptolepis* is very common and *Atriplex vesicaria* is common. *Eremophila maculata* is fairly common. *Eragrostis falcata* is a common grass in the crabholes.

Changes which occur with grazing:

The *A. aneura*–*A. brachystachya*–*A. tetragonophylla* and *Kochia planifolia*–*Bassia* spp. associations form an association complex and are best discussed together. Heavy grazing results in increase in the amount of *Bassia paradoxa* and *B. divaricata*, while *B. uniflora* and *B. eriacantha* are suppressed. Low bluebush and bladder saltbush are depleted under grazing. The free-seeding rapid growing prickly acacia (*A. victoriae*) has spread in the watercourses during the last few years.

The association complex as a growing unit:

Due to the common occurrence of clay very near the soil surface the herbaceous cover is fairly patchy, even in good seasons. During drought years much of the country is completely devoid of plant growth. However, the community occurs in low lying sites and is particularly valuable to the grazier in good seasons. The principal drought reserve is now mulga, low bluebush having practically all been destroyed through grazing. Many of the most common shrubs are of little or no value. Most important species in the pasture are *Bassia uniflora*, *Acacia victoriae*, *Sida virgata*, mulga grass, button grass and *Bassia eriacantha*.

TABLE XVIII

showing the species found in the *K. planifolia*–*Bassia* spp. association.

Species					Palatability	Frequency of occurrence
<i>Kochia planifolia</i>	-	-	-	-	2	D
<i>Bassia eriacantha</i>	-	-	-	-	2	D
<i>Bassia paradoxa</i>	-	-	-	-	4	D
<i>Bassia divaricata</i>	-	-	-	-	5	D
<i>Bassia uniflora</i>	-	-	-	-	1	D
<i>Acacia aneura</i>	-	-	-	-	1	R
<i>Acacia brachystachya</i>	-	-	-	-	1	R
<i>Acacia tetragonophylla</i>	-	-	-	-	4	R
<i>Atriplex quinii</i>	-	-	-	-	5	FC
<i>Trichinium obovatum</i>	-	-	-	-	3	FR
<i>Bassia brachyptera</i>	-	-	-	-	4	R
<i>Eremophila rotundifolia</i>	-	-	-	-	5	R
<i>Eremophila duttonii</i>	-	-	-	-	4	R
<i>Atriplex vesicaria</i>	-	-	-	-	2	R
<i>Cassia sturtii</i>	-	-	-	-	1	VR
<i>Kochia pyramidata</i>	-	-	-	-	5	VR
<i>Sida virgata</i>	-	-	-	-	3	VR
<i>Pittosporum phillyreoides</i>	-	-	-	-	2	VR

Species	Palatability	Frequency of occurrence
Cassia eremophila - - -	4	VR
Kochia triptera var. pentaptera -	5	VR
Bassia obliquicuspis - - -	3	VR
Sida intricata - - -	3	VR
Cassia artemisioides - - -	3	VR
Acacia oswaldii - - -	3	VR
Enchylaena tomentosa - - -	4	VR
Bassia tricuspis - - -	5	VR
Exocarpus aphylla - - -	4	VR
Eremophila alternifolia - - -	4	VR
Solanum ellipticum - - -	5	VR
Eremophila paisleyi - - -	4	VR
Ixiolaena leptolepis - - -	4	VR
Bassia lanicuspis - - -	3	VR
Cassia desolata - - -	4	VR
Cassia phyllodinea - - -	4	VR
Eremophila latrobei - - -	1	VR
Dodonaea microzyga - - -	4	VR
Aristida arenaria - - -	3	D
Salsola kali - - -	2	FR
Enneapogon polyphyllus - - -	1	R
Enneapogon avenaceus - - -	1	R
Angianthus pusillus - - -	4	VR
Stenopetalum lineare - - -	—	VR
Portulaca oleracea - - -	2	VR
Nicotiana sp. - - -	5	VR
Zygophyllum ammophilum - - -	4	VR
Lepidium oxytrichum - - -	4	VR
Stipa nitida - - -	1	VR
Babbagia dipterocarpa - - -	5	VR
Lepidium papillosum - - -	4	VR
Blennodia trisecta - - -	5	VR
Helichrysum cassinianum - - -	—	VR
Erodium cygnorum - - -	1	VR
Goodenia cycloptera - - -	4	VR
Panicum decompositum - - -	3	VR
Dactyloctenium radulans - - -	2	VR
Euphorbia drummondii - - -	4	VR
Tribulus terrestris - - -	2	VR
Enneapogon cylindricus - - -	3	VR
Clanthus speciosus - - -	1	VR
Eulalia fulva - - -	1	VR
Helipterum floribundum - - -	5	VR
Euphorbia eremophila - - -	3	VR
Astrebla pectinata - - -	3	VR
Tragus australianus - - -	3	VR
Kochia aphylla - - -	4	D
Eremophila maculata - - -	4	FR
Bassia echinopsila - - -	—	VR
Bassia ventricosa - - -	3	VR
Eragrostis falcata - - -	3	C
Rhagodia nutans - - -	3	VR
Chloris acicularis - - -	3	VR

Kochia planifolia association.

This shrub steppe community is associated with Twins soil. Low bluebush is the dominant species but bladder saltbush is of common occurrence. These species may be uniformly distributed (Plate XXI, Figure 2) but over wide areas growth is restricted to slight depressions where the soil is an inch or two deeper and where the moisture status is somewhat higher (Plate XXI, Figure 3).

Sagebush (*Trichinium obovatum*) and *Aizoon zygophylloides* are shrubs of fairly common occurrence, while broombush (*Eremophila scoparia*) and native pittosporum (*Pittosporum phillyreoides*) are fairly rare. The principal herbaceous plants in the community are buck bush (*Salsola kali*), button grass (*Dactyloctenium radulans*) and *Aristida anthoxanthoides*. Fairly common are *Enneapogon cylindricus* and *Trianthema crystallina* var. *clavata*. Complete floristics are given in Table XIX.

The community as a grazing unit.

The *K. planifolia* association has a lower carrying capacity than any other community in the North-West. The density of low bluebush and bladder saltbush is generally fairly low even where the community is well preserved. Further, the poor water-retaining capacity of the soil has resulted in widespread bush death under drought conditions, with the result that living bush is restricted to water-courses and slopes of undulations over much of the country. Due to its greater regeneration capacity there is a tendency for bladder saltbush to become the dominant species in place of low bluebush.

During most seasons the growth of herbage and grass is extremely sparse, large areas where shale is exposed being devoid of growth.

TABLE XIX
showing the species present in the *K. planifolia* association.

Species	Palatability	Frequency of occurrence
<i>Kochia planifolia</i> - - - -	2	D
<i>Atriplex vesicaria</i> - - - -	2	VC
<i>Aizoon zygophylloides</i> - - - -	5	FC
<i>Trichinium obovatum</i> - - - -	3	FC
<i>Pittosporum phillyreoides</i> - - - -	2	FR
<i>Eremophila scoparia</i> - - - -	4	FR
<i>Acacia tetragonophylla</i> - - - -	4	R
<i>Kochia tomentosa</i> - - - -	4	VR
<i>Rhagodia spinescens</i> var. <i>deltophylla</i>	4	VR
<i>Solanum ellipticum</i> - - - -	5	VR
<i>Sida corrugata</i> - - - -	4	VR
<i>Eremophila rotundifolia</i> - - - -	5	VR
<i>Eremophila oppositifolia</i> - - - -	4	VR
<i>Atriplex quinii</i> - - - -	5	VR
<i>Bassia patentiscuspis</i> - - - -	2	VR
<i>Acacia oswaldii</i> - - - -	3	VR
<i>Bassia divaricata</i> - - - -	5	VR
<i>Kochia aphylla</i> - - - -	4	VR
<i>Kochia pyramidata</i> - - - -	5	VR
<i>Bassia eriacantha</i> - - - -	2	VR
<i>Bassia lanicuspis</i> - - - -	3	VR
<i>Bassia biflora</i> - - - -	—	VR
<i>Heterodendron oleifolium</i> - - - -	1	VR
<i>Santalum lanceolatum</i> - - - -	1	VR

Species	Palatability	Frequency of occurrence
Enchylaena tomentosa - - -	4	VR
Bassia obliquicuspis - - -	3	VR
Bassia uniflora - - -	1	VR
Bassia paradoxa - - -	4	VR
Kochia triptera var. pentaptera -	5	VR
Arthrocnemum sp. - - -	5	VR
Kochia eriantha - - -	1	VR
Chenopodium nitrariaceum (small leafed form) - - -	4	VR
Sida virgata - - -	3	VR
Bassia sclerolaenoides - - -	3	VR
Lycium australe - - -	3	VR
Eremophila alternifolia - - -	4	VR
Cassia sturtii - - -	1	VR
Zygophyllum apiculatum - - -	5	VR
Eremophila longifolia - - -	3	VR
Zygophyllum fruticulosum - - -	4	VR
Salsola kali - - -	2	C
Dactyloctenium radula - - -	2	C
Aristida anthoxanthoides - - -	3	C
Enneapogon cylindricus - - -	3	FC
Trianthema crystallina var. clavata -	—	FC
Chloris acicularis - - -	3	FR
Aristida arenaria - - -	3	R
Portulaca oleracea - - -	2	R
Enneapogon avenaceus - - -	1	R
Enneapogon polyphyllus - - -	1	R
Tribulus terrestris - - -	2	VR
Lotus australis var. parviflorus -	4	VR
Zygophyllum prismatothecum -	5	VR
Tetragonia eremaea - - -	1	VR
Stipa nitida - - -	1	VR
Euphorbia drummondii - - -	4	VR
Convolvulus erubescens - - -	1	VR
Euphorbia eremophila - - -	3	VR
Tragus australianus - - -	3	VR
Sporobolus actinocladius - - -	1	VR
Panicum decompositum - - -	3	VR
Babbagia dipterocarpa - - -	5	VR
Zygophyllum ammophilum - - -	4	VR
Erodium cygnorum - - -	1	VR
Bassia brachyptera - - -	4	VR
Chloris truncata - - -	3	VR
Sida petrophila - - -	4	VR
Trichinium erubescens - - -	—	VR

Atriplex vesicaria - *Kochia planifolia* association (Plate XXI, Figure 4).

This shrub steppe community is associated with Coondambo soil. The dominant species are bladder saltbush and low bluebush. Scattered trees of mulga (*Acacia aneura*), umbrella mulga (*A. brachystachya*) or myall (*A. sowdenii*) are occasionally present. Coondambo soil is characterised by light-textured A horizons overlying clay at shallow depth. However, watercourses which drain

Coondambo soil areas frequently have deeper sandy A horizons overlying the clay. On these soils little *K. planifolia* is associated with bladder saltbush.

Star bush (*Gummiopsis quadrifida*) is a common associated shrub, while *Bassia ventricosa*, *B. decurrens*, broombush (*Eremophila scoparia*) and *Sida virgata* are fairly rare. The dominant herbaceous species are *Enneapogon polyphyllus*, *E. avenaceus*, *Bassia uniflora* and mulga grass (*Aristida arenaria*), while button grass (*Dactyloctenium radulans*) and neverfail (*Eragrostis dielsii*) are fairly common. Complete floristics are given in Table XX.

The community as a grazing unit:

The *A. vesicaria* - *K. planifolia* association has a greater stock carrying capacity than any other plant community found in the North-West. Bladder saltbush and low bluebush are both palatable species and constitute an excellent drought reserve. In this association they form a very dense bush stand in ungrazed areas and competition for moisture is so severe that even in favourable seasons little herbage and grass appears among the bushes. Some thinning of bush is necessary to enable herbage and grass to appear in the community and thus increase its grazing value.

Gummiopsis quadrifida is the most important associated shrub to the grazier. All of the common herbaceous plants are very valuable species.

Changes which occur with grazing:

Bladder saltbush and low bluebush are both grazed to about the same extent but saltbush is not as resistant to grazing as bluebush, so that heavy grazing results in alteration of the proportion of saltbush to bluebush in favour of bluebush. However, saltbush is a more prolific seeder and regenerates much more readily than bluebush, so that spelling or reduced stocking of country which has been heavily grazed restores the original proportion of saltbush and bluebush.

Under heavy grazing the herbaceous species *Enneapogon polyphyllus*, *E. avenaceus*, *Bassia uniflora* and *Eragrostis dielsii* are suppressed. All these species are quite palatable and together with button grass and mulga grass constitute the principal pasturage. *Bassia paradoxa*, which is of little value, colonizes sand mounds where scalding has occurred. On the exposed clay of the scalded areas *Bassia divaricata*, *B. ventricosa* and *B. obliquicuspis* are common.

TABLE XX
showing the species present in the *A. vesicaria* - *K. planifolia* association.

Species	Palatability	Frequency of occurrence
<i>Atriplex vesicaria</i> - - - -	2	D
<i>Kochia planifolia</i> - - - -	2	D
<i>Gummiopsis quadrifida</i> - - - -	2	C
<i>Bassia uniflora</i> - - - -	1	C
<i>Bassia ventricosa</i> - - - -	3	FR
<i>Sida virgata</i> - - - -	3	FR
<i>Eremophila scoparia</i> - - - -	4	FR
<i>Bassia decurrens</i> - - - -	3	FR
<i>Bassia lanicuspis</i> - - - -	3	VR
<i>Kochia tomentosa</i> var. <i>appressa</i> -	4	VR
<i>Kochia pyramidata</i> - - - -	5	VR
<i>Bassia paradoxa</i> - - - -	4	VR
<i>Kochia aphylla</i> - - - -	4	VR
<i>Cassia sturtii</i> - - - -	1	VR
<i>Eremophila duttonii</i> - - - -	4	VR
<i>Bassia obliquicuspis</i> - - - -	3	VR
<i>Bassia divaricata</i> - - - -	5	VR

Species	Palatability	Frequency of occurrence
Kochia triptera var. erioclada - - - - -	5	VR
Kochia ciliata - - - - -	—	VR
Heterodendron oleifolium - - - - -	1	VR
Acacia burkittii - - - - -	5	VR
Goodenia spinescens - - - - -	5	VR
Solanum ellipticum - - - - -	5	VR
Dodonaea microzyga - - - - -	4	VR
Eremophila alternifolia - - - - -	4	VR
Acacia tetragonophylla - - - - -	4	VR
Pittosporum phillyreoides - - - - -	2	VR
Kochia triptera var. pentaptera - - - - -	5	VR
Eremophila longifolia - - - - -	3	VR
Sida intricata - - - - -	3	VR
Sida corrugata - - - - -	4	VR
Trichinium obovatum - - - - -	3	VR
Cassia phyllodinea - - - - -	4	VR
Euphorbia eremophila - - - - -	3	VR
Enneapogon polyphyllus - - - - -	1	D
Enneapogon avenaceus - - - - -	1	D
Aristida arenaria - - - - -	3	D
Dactyloctenium radulans - - - - -	2	FC
Eragrostis dielsii - - - - -	1	FC
Tragus australianus - - - - -	3	FR
Salsola kali - - - - -	2	FR
Portulaca oleracea - - - - -	2	FR
Atriplex spongiosa - - - - -	4	FR
Erodium cygnorum - - - - -	1	FR
Euphorbia drummondii - - - - -	4	R
Triraphis mollis - - - - -	3	VR
Zygophyllum crenatum - - - - -	4	VR
Convolvulus erubescens - - - - -	1	VR
Zygophyllum ammophilum - - - - -	4	VR
Zygophyllum compressum - - - - -	4	VR
Tribulus terrestris - - - - -	2	VR
Lepidium papillosum - - - - -	4	VR
Enneapogon cylindricus - - - - -	3	VR
Tetragonia eremea - - - - -	1	VR
Enneapogon caerulescens - - - - -	3	VR
Trianthema crystallina var. clavata - - - - -	—	VR
Chenopodium cristatum - - - - -	4	VR
Stipa nitida - - - - -	1	VR
Stenopetalum lineare - - - - -	—	VR
Lotus australis var. parviflorus - - - - -	4	VR
Craspedia pleiocephala - - - - -	4	VR
Helipterum floribundum - - - - -	5	VR
Clanthus speciosus - - - - -	1	VR
Atriplex halimoides var. conduplicatum - - - - -	4	VR
Citrullus vulgaris - - - - -	5	VR
Bassia brachyptera - - - - -	4	VR
Babbagia dipterocarpa - - - - -	5	VR
Angianthus pusillus - - - - -	4	VR
Bassia sclerolaenoides - - - - -	3	VR
Brachycome iberidifolia var. glandulifera - - - - -	4	VR

Atriplex vesicaria - *Bassia* spp. association (Plate XXII, Figure 1).

This shrub steppe community, whose occurrence at Yudnapinna station has previously been described by Crocker and Skewes (1941), is associated with Coober Pedy soil. Growth is practically restricted to the crabholes where they are present, while elsewhere a sparse growth occurs over the country as a whole.

A. vesicaria and *Bassia* spp. are the dominant shrubs. Of the *Bassias*, *B. ventricosa* is common while *B. paradoxa* and *B. tricuspis* are fairly rare. *B. divaricata* and *B. lanicuspis* are rare. In addition to these cotton bush (*Kochia aphylla*) and low bluebush (*K. planifolia*) are of fairly rare occurrence. Dominant herbaceous species are *Eragrostis falcata*, button grass (*Dactyloctenium radulans*), *Enneapogon polyphyllus*, and *E. avenaceus*. Mitchell grass (*Astrebla pectinata*) is common, while the following are fairly common: *Aristida anthoxanthoides*, pop saltbush (*Atriplex spongiosa*), sugar grass (*Eulalia fulva*) and *Bassia brachyptera*.

Changes which occur with grazing:

Even in ungrazed areas the density of bladder saltbush is low on Coober Pedy soil, so that under drought conditions the bush that is present is subjected to heavy grazing. Little saltbush therefore remains in most of the stocked paddocks. If, however, the country is spelled while sufficient seed-producing plants remain, regeneration during favourable years is fairly rapid as the ecotype of saltbush associated with these clay soils is a prolific seeder and a vigorous plant.

Bindyis, particularly *Bassia paradoxa* and *B. divaricata*, but also *B. ventricosa*, increase under heavy grazing. Annual species like pop saltbush (*Atriplex spongiosa*) also spread. At the same time the black head grasses (*Enneapogon polyphyllus* and *E. avenaceus*) become thinned out.

TABLE XXI

showing the species present in the *A. vesicaria* - *Bassia* spp. association.

Species	Palatability	Frequency of occurrence
<i>Atriplex vesicaria</i> - - - -	2	D
<i>Bassia ventricosa</i> - - - -	3	C
<i>Bassia paradoxa</i> - - - -	4	FR
<i>Bassia tricuspis</i> - - - -	5	FR
<i>Bassia divaricata</i> - - - -	5	R
<i>Bassia lanicuspis</i> - - - -	3	R
<i>Kochia aphylla</i> - - - -	4	FR
<i>Kochia planifolia</i> - - - -	2	FR
<i>Atriplex quinii</i> - - - -	5	VR
<i>Sida intricata</i> - - - -	3	VR
<i>Ixiolaena leptolepis</i> - - - -	4	VR
<i>Sida virgata</i> - - - -	3	VR
<i>Minuria denticulata</i> - - - -	4	VR
<i>Trichinium obovatum</i> - - - -	3	VR
<i>Kochia pyramidata</i> - - - -	5	VR
<i>Bassia eriacantha</i> - - - -	2	VR
<i>Bassia tricornis</i> - - - -	—	VR
<i>Eragrostis falcata</i> - - - -	3	D
<i>Dactyloctenium radulans</i> - - - -	2	D
<i>Enneapogon polyphyllus</i> - - - -	1	D
<i>Enneapogon avenaceus</i> - - - -	1	D
<i>Astrebla pectinata</i> - - - -	3	C

Species	Palatability	Frequency of occurrence
<i>Aristida anthoxanthoides</i> - - -	3	C
<i>Atriplex spongiosa</i> - - -	4	C
<i>Eulalia fulva</i> - - -	1	C
<i>Bassia brachyptera</i> - - -	4	C
<i>Bassia uniflora</i> - - -	1	FR
<i>Salsola kali</i> - - -	2	FR
<i>Portulaca oleracea</i> - - -	2	FR
<i>Trianthema crystallina</i> var. <i>clavata</i> —	—	FR
<i>Panicum decompositum</i> - - -	3	FR
<i>Aristida arenaria</i> - - -	3	R
<i>Minuria leptophylla</i> - - -	4	R
<i>Sida corrugata</i> var. <i>trichopoda</i> -	4	VR
<i>Lotus australis</i> var. <i>parviflorus</i> -	4	VR
<i>Convolvulus erubescens</i> - -	1	VR
<i>Euphorbia drummondii</i> - - -	4	VR
<i>Tragus australianus</i> - - -	3	VR
<i>Babbagia dipterocarpa</i> - - -	5	VR
<i>Sporobolus actinocladus</i> - - -	1	VR
<i>Enneapogon cylindricus</i> - - -	3	VR
<i>Erodium cygnorum</i> - - -	1	VR
<i>Iseilema vaginiflorum</i> - - -	2	VR
<i>Goodenia cycloptera</i> - - -	4	VR
<i>Frankenia serpyllifolia</i> - - -	5	VR
<i>Rhagodia nutans</i> - - -	3	VR
<i>Zygophyllum ammophilum</i> - - -	4	VR
<i>Tetragonia eremaea</i> - - -	1	VR
<i>Atriplex halimoides</i> var. <i>conduplicatum</i> - - -	4	VR
<i>Cucumis myriocarpus</i> - - -	4	VR
<i>Citrullus vulgaris</i> - - -	5	VR
<i>Epaltes cunninghamii</i> - - -	—	VR
<i>Marsilia drummondii</i> - - -	4	VR
<i>Chloris acicularis</i> - - -	3	VR

Atriplex vesicaria – *Ixiolaena leptolepis* association (Plate XXII, Figure 2).

This community is found on Arcoona soil in the tableland country west of Lake Torrens. Murray (1931) has described the vegetation of a portion of the tablelands and called the community the "saltbush association". It is advisable, however, to retain the name *Atriplex vesicaria* association for the saltbush dominant community found in north-eastern South Australia, where saltbush occurs almost to the exclusion of other tree or shrub species (Wood 1937). Murray (1931) includes bluebush (*Kochia sedifolia*) and black bluebush (*K. pyramidata*) in the tableland vegetation. These species are constituents of other plant associations and are never present in the *A. vesicaria* – *I. leptolepis* association of the tableland proper.

The habitat is a gently rolling plateau characterised by the complete absence of trees and tall shrubs except along creeks. Most of the vegetation does not exceed a height of 18". There are really two habitats, the crabholes where most of the vegetation is found and the more arid and saline shelves which are practically devoid of growth.

The dominant species are *A. vesicaria* and *I. leptolepis*. *Minuria leptophylla* is usually associated. Common shrubs and under-shrubs are samphires (*Arthro-*

nemum leiostachyum and *Pachycornia tenuis*) and *Psoralea* sp., while *Minuria denticulata*, *Sida corrugata* var. *trichopoda*, *Abutilon halophilum*, *Bassia ventricosa*, *Atriplex halimoides* and *A. halimoides* var. *conduplicatum* are fairly common. The most prominent herbaceous species are the grasses *Eragrostis setifolia* and *E. falcata*. Very common are mitchell grass (*Astrebla pectinata*), *Panicum decompositum*, ray grass (*Sporobolus actinocladius*) and *Lotus australis* var. *parviflorus*, while *Paspalidium* sp., *Swainsona stipularis*, *Bassia brachyptera*, *Erodium cygnorum*, *Eulalia fulva*, *Atriplex spongiosa*, *Helipterum strictum* and *Goodenia cycloptera* are fairly common.

The gibber-covered shelves between the crabholes are either devoid of plant growth or carry a very scattered growth of *Bassia ventricosa* and *B. brachyptera*. Less common on the shelves are *Arthrocnemum leiostachyum*, *Pachycornia tenuis*, *B. divaricata* and *Kochia tomentosa* var. *appressa*, while *B. sclerolaenoides* and *K. eriantha* are very rarely present.

In addition to the species listed above for the tableland, there are other plants which are only associated with creeks. The following small trees and shrubs are typical of tableland creeks: *Acacia brachystachya*, *A. aneura*, *A. tetragonophylla*, *A. rigens*, *A. oswaldii*, *Eremophila alternifolia*, *E. serrulata*, *E. duttonii*, *E. oppositifolia*, *E. glabra*, *Pittosporum phillyreoides*, *Santalum lanceolatum*, *Hakea leucoptera*, *Dodonaea lobulata*, *Prostanthera striatiflora*, *Cassia sturtii*, *Heterodendron oleifolium* and *Casuarina cristata*. Commonly occurring smaller shrubs and undershrubs are *Enchylaena tomentosa*, *Rhagodia spinescens*, *Kochia aphylla*, *K. spongiocarpa*, *Atriplex vesicaria*, *Sida virgata*, *S. petrophila* and more rarely *K. planifolia* and *Bassia limbata*.

Herbaceous plants typical of creek beds are *Aristida nitidula*, *Isotoma petraea*, *Morgania glabra*, *Trichinium erubescens*, *Cucumis myriocarpus*, *Citrullus vulgaris*, *Eragrostis australasica* and rarely *Psoralea patens*, *Helipterum floribundum*, *Bassia uniflora*, *Aristida anthoxanthoides*, *Orobanche australiana*, *Thysanotus baueri* and *Abutilon leucopetalum*.

Following the exceptionally heavy rains of 1946 and 1947 Coolymilka Lake, which is a depression in tableland country, contained about 20 feet of water at its deepest part. By October 1947 the water level had fallen about five feet. Near the waterline *Erythraea australis*, *Epaltes cunninghamii*, *Calotis hispidula*, *Atriplex spongiosa*, *Trigonella suavissima* and *Heliotropium curassavicum* were recorded. The lake is fringed by ti-trees (*Melaleuca pubescens* and *M. pauperifolia*).

In addition to the normal crabholes of the tableland some large depressions occur which are best regarded as swamps. Canegrass (*Eragrostis australasica*) is usually the dominant species, but occasionally *Chenopodium nitrariaceum* and *Muehlenbeckia cunninghamii* occur as dominants. Associated species are *Calotis hispidula*, *Trigonella suavissima*, *Teucrium racemosum*, *Erythraea australis*, *Ranunculus parviflorus* and nardoo (*Marsilia drummondii*). Around the fringes of these swamps species typical of the *A. vesicaria* - *I. leptolepis* association are found.

The community as a grazing unit:

The tableland country has a fairly low stock-carrying capacity because much of the area is occupied by gibber-covered shelves largely devoid of plant growth. However, the presence of crabholes into which water drains from the surrounding shelf areas ensures some grazing for stock after most rains. An outstanding feature of the wool from sheep grazing on tableland country is its cleanliness. This is due to the mantle of gibbers on the soil surface.

With the exception of *A. vesicaria* most of the common and fairly common shrub species are only slightly palatable. Bladder saltbush is therefore the prin-

cipal drought reserve. Grasses (*Eragrostis setifolia*, *E. falcata*, *Sporobolus actinocladius*, *Eulalia fulva*, *Astrebula pectinata* and *Panicum decompositum*) are the most valuable members of the community to the grazier.

Changes which occur with grazing:

With intensive grazing of the crabhole vegetation the bindyis *Bassia divaricata*, *B. ventricosa*, *B. paradoxa* and *B. tricuspsis* spread. Apart from *B. ventricosa* these species are of little or no value. Competition with other plants in ungrazed and lightly grazed crabholes restricts the bindyis principally to the crabhole fringes and the arid shelves. Heavy grazing also causes an increase in annual or unpalatable species like *Atriplex spongiosa*, *Trianthema crystallina* and the poisonous *Lotus australis* var. *parviflorus*. *A. vesicaria* tends to be replaced by the less palatable and less drought resistant *A. halimoides* and *A. halimoides* var. *conduplicatum*.

TABLE XXII
showing the species occurring in the *A. vesicaria* - *I. leptolepis* association.

Species	Palatability	Natural frequency	Frequency in grazed country
<i>Atriplex vesicaria</i> - - - - -	2	D	D
<i>Ixiolaena leptolepis</i> - - - - -	4	D	D-
<i>Minuria leptophylla</i> - - - - -	4	C	VC
<i>Pachycornia tenuis</i> - - - - -	4	C	C
<i>Arthrocnemum leiostachyum</i> - - - - -	4	C	C
<i>Psoralea</i> sp. - - - - -	3	C	C
<i>Minuria denticulata</i> - - - - -	4	FC	FC
<i>Sida corrugata</i> var. <i>trichopoda</i> - - - - -	4	C	C
<i>Abutilon halophilum</i> - - - - -	4	FC	FC
<i>Atriplex halimoides</i> - - - - -	4	R	FC
<i>Atriplex halimoides</i> var. <i>conduplicatum</i> - - - - -	4	R	FC
<i>Bassia divaricata</i> - - - - -	5	R	FR
<i>Bassia ventricosa</i> - - - - -	3	FR	FC
<i>Bassia tricuspsis</i> - - - - -	5	VR	FR
<i>Bassia paradoxa</i> - - - - -	4	R	FR
<i>Acacia rigens</i> - - - - -	4	R	R
<i>Kochia aphylla</i> - - - - -	4	R	R
<i>Bassia brachyptera</i> - - - - -	4	FC	FC
<i>Kochia georgei</i> (low form) - - - - -	2	VR	VR
<i>Kochia planifolia</i> - - - - -	2	VR	VR
<i>Kochia spongiocarpa</i> - - - - -	—	VR	VR
<i>Kochia ciliata</i> - - - - -	—	VR	VR
<i>Kochia tomentosa</i> var. <i>appressa</i> - - - - -	4	VR	VR
<i>Bassia biflora</i> - - - - -	—	VR	VR
<i>Bassia lanicuspis</i> - - - - -	3	VR	VR
<i>Sida intricata</i> - - - - -	3	VR	R
<i>Sida corrugata</i> - - - - -	4	VR	VR
<i>Atriplex fissivalve</i> - - - - -	—	VR	VR
<i>Sarcostemma australe</i> - - - - -	5	VR	VR
<i>Kochia eriantha</i> - - - - -	1	VR	VR
<i>Eragrostis falcata</i> - - - - -	3	VC	VC
<i>Eragrostis setifolia</i> - - - - -	2	VC	VC
<i>Astrebula pectinata</i> - - - - -	3	VC	VC
<i>Panicum decompositum</i> - - - - -	3	VC	VC
<i>Sporobolus actinocladius</i> - - - - -	1	VC	VC
<i>Lotus australis</i> var. <i>parviflorus</i> - - - - -	4	C	VC

Species	Palatability	Natural frequency	Frequency in grazed country
<i>Paspalidium</i> s p. - - - - -	2	FC	FC
<i>Swainsona stipularis</i> - - - - -	---	FC	FC
<i>Erodium cygnorum</i> - - - - -	1	FC	FC
<i>Eulalia fulva</i> - - - - -	1	FC	FC
<i>Helipterum strictum</i> - - - - -	4	FC	FC
<i>Goodenia pinnatisecta</i> - - - - -	4	FC	FC
<i>Trianthema crystallina</i> - - - - -	---	R	FR
<i>Dactyloctenium radulans</i> - - - - -	2	FR	FR
<i>Atriplex spongiosa</i> - - - - -	4	FR	FC
<i>Eragrostis australasica</i> - - - - -	4	FR	FR
<i>Trigonella suavissima</i> - - - - -	1	FR	FR
<i>Eriochloa longiflora</i> - - - - -	1	FR	FR
<i>Euphorbia eremophila</i> (leafless form) - - - - -	3	FR	FR
<i>Calotis hispidula</i> - - - - -	5	FR	FR
<i>Plantago varia</i> - - - - -	---	FR	FR
<i>Stipa nitida</i> - - - - -	1	R	R
<i>Babbagia dipterocarpa</i> - - - - -	5	R	R
<i>Enneapogon avenaceus</i> - - - - -	1	R	R
<i>Daucus glochidiatus</i> - - - - -	---	R	R
<i>Aristida anthoxanthoides</i> - - - - -	3	R	R
<i>Mesembryanthemum aequilaterale</i> - - - - -	4	R	R
<i>Frankenia serpyllifolia</i> - - - - -	5	R	R
<i>Teucrium racemosum</i> - - - - -	3	R	R
<i>Ranunculus parviflorus</i> - - - - -	---	R	R
<i>Marsilia drummondii</i> - - - - -	4	R	R
<i>Marsilia hirsuta</i> - - - - -	4	R	R
<i>Chloris truncata</i> - - - - -	3	R	R
<i>Helipterum floribundum</i> - - - - -	5	R	R
<i>Epaltes cunninghamii</i> - - - - -	4	R	R
<i>Eragrostis dielsii</i> - - - - -	1	R	R
<i>Lepidium oxytrichum</i> - - - - -	4	R	R
<i>Zygophyllum fruticosum</i> var. <i>eremaeum</i> - - - - -	4	R	R
<i>Zygophyllum ammophilum</i> - - - - -	4	R	R
<i>Zygophyllum compressum</i> - - - - -	4	R	R
<i>Tetragonia eremaea</i> - - - - -	1	R	R
<i>Erythraea australis</i> - - - - -	---	R	R
<i>Bassia uniflora</i> - - - - -	1	R	R
<i>Tragus australianus</i> - - - - -	3	R	R
<i>Portulaca oleracea</i> - - - - -	2	R	R
<i>Bassia sclerolaenoides</i> - - - - -	3	VR	VR
<i>Trichinium erubescens</i> - - - - -	---	VR	VR
<i>Anacampseros australiana</i> - - - - -	1	VR	VR
<i>Iseilema vaginiflorum</i> - - - - -	2	VR	VR

Atriplex rhagodioides association (Plate XXII, Figure 3).

On the Arcoona soils of the tableland country west of Lake Eyre a shrub steppe association dominated by silver saltbush (*Atriplex rhagodioides*) is found. This community is floristically similar to the *A. vesicaria* - *I. leptolepis* association which occurs on similar soils further south, but a few of the southern species are absent. Most of the growth is restricted to the crabholes.

Chenopods are prominent among the shrubs. Common species associated with *A. rhagodioides* are flat-topped saltbush (*A. halimoides* and *A. halimoides*

var. *conduplicatum*) and *Bassia ventricosa*, while *Abutilon halophilum*, *Sida corrugata* var. *trichopoda*, cotton bush (*Kochia aphylla*) and *Ixiolaena leptolepis* are fairly common. The most prominent herbaceous species are grasses of which *Eragrostis falcata*, *E. setifolia*, flinders grass (*Iseilema vaginiflorum*), mitchell grass (*Astrebula pectinata*), *Aristida anthoxanthoides* and ray grass (*Sporobolus actinocladius*) are most common. Fairly common are *Panicum decompositum*, *Bassia brachyptera*, pop saltbush (*Atriplex spongiosa*), *Threlkeldia proceriflora*, sugar grass (*Eulalia fulva*) and *Swainsona stipularis*.

There are several interesting differences between this association found in the northern tableland country and that occurring west of Lake Torrens. *Atriplex rhagodioides* replaces *A. vesicaria* as the dominant species and *Ixiolaena leptolepis* is not as common as it is further south. Samphires (*Arthrocnemum leiostachyum* and *Pachycornia tenuis*) are of less frequent occurrence, but *Kochia aphylla* is much more conspicuous. The common grasses are the same in both associations except that flinders grass (*Iseilema vaginiflorum*) is much more common in the Lake Eyre region than further south. Canegrass (*Eragrostis australasica*), which is present in the crabholes of the southern tableland country and which gives a characteristic facies to the vegetation, is not present in the crabholes further north.

The community as a grazing unit:

The *A. rhagodioides* association has a very low stock-carrying capacity. Apart from the absence of growth on the shelves between the crabholes, areas of highly gypseous soils totally devoid of plant growth are common and the rainfall of the habitat is the lowest recorded in Australia.

A. rhagodioides is unpalatable, so that *Bassia* species do not invade heavily grazed crabholes as they do in the *A. vesicaria*–*I. leptolepis* association.

TABLE XXIII

showing the species present in *Atriplex rhagodioides* association.

Species	Frequency of occurrence
<i>Atriplex rhagodioides</i> - - - - -	D
<i>Atriplex halimoides</i> - - - - -	C
<i>Atriplex halimoides</i> var. <i>conduplicatum</i> -	C
<i>Bassia ventricosa</i> - - - - -	C
<i>Abutilon halophilum</i> - - - - -	FC
<i>Sida corrugata</i> var. <i>trichopoda</i> - - -	FC
<i>Kochia aphylla</i> - - - - -	FC
<i>Ixiolaena leptolepis</i> - - - - -	FC
<i>Arthrocnemum leiostachyum</i> - - -	FR
<i>Pachycornia tenuis</i> - - - - -	FR
<i>Bassia divaricata</i> - - - - -	FR
<i>Atriplex vesicaria</i> - - - - -	R
<i>Bassia paradoxa</i> - - - - -	R
<i>Minuria leptophylla</i> - - - - -	R
<i>Kochia eriantha</i> - - - - -	VR
<i>Eragrostis falcata</i> - - - - -	VC
<i>Eragrostis setifolia</i> - - - - -	VC
<i>Iseilema vaginiflorum</i> - - - - -	VC
<i>Astrebula pectinata</i> - - - - -	VC
<i>Aristida anthoxanthoides</i> - - - - -	VC
<i>Sporobolus actinocladius</i> - - - - -	VC
<i>Panicum decompositum</i> - - - - -	FC
<i>Bassia brachyptera</i> - - - - -	FC
<i>Atriplex spongiosa</i> - - - - -	FC

Species						Frequency of occurrence
<i>Threlkeldia proceriflora</i>	-	-	-	-	-	FC
<i>Eulalia fulva</i>	-	-	-	-	-	FC
<i>Swainsona stipularis</i>	-	-	-	-	-	FC
<i>Enneapogon polyphyllus</i>	-	-	-	-	-	R
<i>Enneapogon avenaceus</i>	-	-	-	-	-	R
<i>Euphorbia drummondii</i>	-	-	-	-	-	R
<i>Marsilia drummondii</i>	-	-	-	-	-	R
<i>Salsola kali</i>	-	-	-	-	-	R
<i>Dactyloctenium radulans</i>	-	-	-	-	-	R
<i>Portulaca oleracea</i>	-	-	-	-	-	VR
<i>Trianthema crystallina</i> var. <i>clavata</i>	-	-	-	-	-	VR
<i>Chloris acicularis</i>	-	-	-	-	-	VR
<i>Babbagia dipterocarpa</i>	-	-	-	-	-	VR
<i>Tragus australianus</i>	-	-	-	-	-	VR
<i>Goodenia cycloptera</i>	-	-	-	-	-	VR
<i>Calotis hispidula</i>	-	-	-	-	-	VR
<i>Erodium cygnorum</i>	-	-	-	-	-	VR
<i>Trigonella suavissima</i>	-	-	-	-	-	VR
<i>Paspalidium</i> sp.	-	-	-	-	-	VR
<i>Daucus glochidiatus</i>	-	-	-	-	-	VR
<i>Aristida arenaria</i>	-	-	-	-	-	VR
<i>Lotus australis</i> var. <i>parviflorus</i>	-	-	-	-	-	VR
<i>Atriplex quinii</i>	-	-	-	-	-	VR
<i>Frankenia serpyllifolia</i>	-	-	-	-	-	VR
<i>Bassia lanicuspis</i>	-	-	-	-	-	VR
<i>Bassia uniflora</i>	-	-	-	-	-	VR
<i>Sarcostemma australe</i>	-	-	-	-	-	VR
<i>Lepidium oxytrichum</i>	-	-	-	-	-	VR

Kochia planifolia – *Atriplex vesicaria* – *K. sedifolia* association.

K. planifolia is a species which grows upon soils with a clay subsoil at shallow depth, while *K. sedifolia* is associated with soils containing heavy lime. Both heavy textured and calcareous soils are suitable for the growth of *A. vesicaria*. As a consequence these three species are the codominants of a shrub steppe community on the heavy textured calcareous Miller's Creek soil.

Very few shrubs are associated with the dominants, the following being the only ones recorded: *Trichinium obovatum*, *Kochia tomentosa*, *Sida corrugata* and very rare *Acacia oswaldii*, *Heterodendron oleifolium* and *Sida virgata*.

The principal herbaceous species are bindyis (*Bassia obliquicuspis* and *B. sclerolaenoides*), *Enneapogon cylindricus*, *Zygophyllum prismatothecum* and *Salsola kali*. Of rare occurrence are *Z. glaucescens*, *E. caerulea*, *Goodenia cycloptera*, *Erodium cygnorum*, *Tribulus terrestris* and *Convolvulus erubescens*, while the following are very rare: *Euphorbia drummondii*, *Bassia uniflora*, *Citrullus vulgaris*, *Cucumis myriocarpus*, *Enneapogon avenaceus* and *E. polyphyllus*.

The community as a grazing unit:

Severe bush death has occurred through grazing and droughts on the Miller's Creek soil even among the very hardy *K. sedifolia*, with the result that there is now little drought reserve. Further, even in good seasons the growth of herbage and grass is very sparse, so the community has a very low stock-carrying capacity.

The plant communities associated with swamps, watercourses and creeks.

Mulga Swamps

Small depressions liable to inundation following heavy rains are a feature of the mulga and myall woodlands. A well-defined drainage pattern is lacking, the "swamps" being merely the result of very local drainage. They are characterized typically by a dense thicket of mulgas (*A. aneura* and *A. aneura* var. *latifolia*) and umbrella mulga (*A. brachystachya*). *Chenopodium nitrariaceum* commonly forms an understorey with nardoo (*Marsilia drummondii*) as a ground layer. Lignum (*Muehlenbeckia cunninghamii*) is found occasionally. *Epaltes cunninghamii* and *Eragrostis falcata* are not as prominent as nardoo in the ground layer but are usually present. *Chenopodium nitrariaceum* replaces mulgas in the centre of swamps which have a larger water intake.

Many species are found around the fringes of the swamps where the mulgas are less dense. Sometimes broombush (*Melaleuca uncinata*) or ti-tree (*M. pubescens*) form a ring around the mulga thicket. The following shrubs are of general occurrence around the fringes: Australian boxthorn (*Lycium australe*), dead finish (*Acacia tetragonophylla*), *Bassia paradoxa*, tomato bush (*Enchylaena tomentosa*) and *Rhagodia spinescens*. More rarely *Ixiolaena leptolepis*, *Kochia triptera* var. *eriodclada*, *K. triptera* var. *pentaptera*, *Sida intricata* and *B. obliquicuspis* are found.

Very rarely broombush (*Eremophila scoparia*), *Santalum lanceolatum*, *B. divaricata*, *B. tricusps*, bullock bush (*Heterodendron oleifolium*), *Cassia artemisioides*, *Trichinium obovatum*, *Acacia ligulata*, *A. oswaldii*, *Kochia planifolia*, *K. pyramidata*, *Atriplex vesicaria*, *Grevillea nematophylla*, *Eucarya acuminata*, *Zygophyllum glaucescens*, *Z. fruticosum*, *Acacia burkittii*, *Eremophila serrulata*, *E. alternifolia* and *Sida virgata* are found.

The three herbaceous species characteristically found in the centre of swamps are *Marsilia drummondii*, *Epaltes cunninghamii* and *Eragrostis falcata*. Composites are very common in the area surrounding the centre of the swamps where the following plants were recorded: *Euphorbia drummondii*, *Eragrostis dielsii*, *Calotis hispidula*, *Tetragonia expansa*, *T. eremaea*, *Atriplex spongiosa*, *Brachycome iberidifolia* var. *glandulifera*, *Dactyloctenium radulans*, *Calotis cymbacantha*, *Chenopodium cristatum*, *Goodenia subintegra*, *Craspedia pleiocephala*, *Helichrysum cassinianum*, *Stipa nitida*, *Aristida arenaria*, *Lepidium papillosum*, *L. oxytrichum*, *Gnephosis cyathopappa*, *Teucrium racemosum*, *Rutidosia helichrysoides*, *Brachycome ciliaris* var. *lanuginosa*, *Gnaphalium luteo-album*, *Helipterum semifertile* and *H. strictum*.

Of rarer occurrence are *Stenopetalum lineare*, *Convolvulus erubescens*, *Tri-raphis mollis*, *Lotus australis* var. *parviflorus*, *Salsola kali*, *Erodium cygnorum*, *Euphorbia eremophila*, *Enneapogon avenaceus*, *E. polyphyllus*, *Cucumis myriocarpus*, *Erythraea australis*, *Rhagodia nutans*, *Aristida anthoxanthoides*, *Emex australis*, *Bassia uniflora*, *B. sclerolaenoides*, *Blennodia canescens*, *Danthonia semiannularis*, *Vittadinia triloba*, *Chianthus speciosus*, *Portulaca oleracea*, *Stipa eremophila* and *Chenopodium murale*.

Melaleuca spp. swamps.

Some of the larger swamps carry broombush (*Melaleuca uncinata*) and ti-tree (*M. pubescens*) as the dominant species. In other cases *M. uncinata* is found throughout the centre of the swamp surrounded by a ring of *M. pubescens* or the reverse may occur. These swamps generally have a larger water intake than the mulga swamps, being fed by well-defined watercourses. Ti-tree indicates more saline soil conditions due to intake of more saline waters than broombush. As a result the two species are a useful surface indication of the quality of the ground water; better stock water being obtained by boring in broombush rather

than ti-tree swamps. On Ingomar station the red sandridges around the claypans carry *M. uncinata*. Bamboo Swamp on Billa Kalina station, which is a large claypan carrying some canegrass, is fringed by *M. uncinata*. *Atriplex nummularia* (old man saltbush) swamps.

The only *A. nummularia* swamp in the sheep country of the North-West is on Miller's Creek station in a small depression in tableland country (fig. 2). *A. nummularia* is found on saline soils of floodplains and along some of the creek channels in the vicinity of Coward Springs. The principal associated species are nitre bush (*Nitraria schoberi*) and samphire (*Arthrocnemum* sp.).

Canegrass (Eragrostis australasica) swamps.

The largest swamps are characterised by the absence of mulgas and *Melaleuca* spp. except in the fringes. There are three zones in the vegetation. In the centre, that is in the area most frequently flooded, canegrass is the dominant species. Around the canegrass is a zone dominated by *Chenopodium nitrariaceum*, while mulgas and a number of shrub and small tree species occur around the margins.

The only shrubs associated with canegrass in the centre of the swamps are lignum (*Muehlenbeckia cunninghamii*) and *Chenopodium nitrariaceum*. The following herbaceous species form a sparse ground cover: *Teucrium racemosum*, *Aristida anthoxanthoides*, neverfail (*Eragrostis dielsii*), nardoo (*Marsilia drummondii*), button grass (*Dactyloctenium radulans*), pop saltbush (*Atriplex spongiosa*), bur grass (*Tragus australianus*), munyeroo (*Portulaca oleracea*) and *Trianthema crystallina* var. *clavata*. Native clover (*Trigonella suavissima*) grows in a few of the swamps.

Apart from the dominant species the most characteristic plants of the *Chenopodium nitrariaceum* zone are *Eragrostis falcata* and *Teucrium racemosum*. Associated herbaceous species are the same as those found in the fringes.

Around the margins of the swamps scattered *Chenopodium nitrariaceum* occurs with a variety of small trees and shrubs. The most characteristic of these are mulgas (*Acacia aneura*, *A. aneura* var. *latifolia* and *A. brachystachya*), dead finish (*A. tetragonophylla*), prickly acacia (*A. victoriae*), button bush (*Kochia aphylla*), and tar bush (*Eremophila glabra*). Occasional native plum trees (*Santalum lanceolatum*), broombush (*Melaleuca uncinata*), *Muehlenbeckia cunninghamii*, *Grevillea nematophylla* and *Sida intricata* are also present. Herbaceous species are *Eragrostis falcata*, *Teucrium racemosum*, *Aristida arenaria*, *A. anthoxanthoides*, *Salsola kali*, *Bassia obliquicuspis*, *B. lanicuspis*, *Dactyloctenium radulans*, *Euphorbia drummondii*, *Trianthema crystallina* var. *clavata*, *Portulaca oleracea*, *Atriplex elachophyllum* and *Morgania glabra*. *Frankenia serpyllifolia* is found around the margins of the more saline swamps. *Smaller watercourses and creeks in shrub steppe areas.*

The watercourses and smaller creeks which run through Twins and Coober Pedy soil areas are lined by mulga (*Acacia aneura*) and umbrella mulga (*A. brachystachya*) and a number of shrub species, some of which are absent from the surrounding country. Commonly occurring shrub and small tree species are dead finish (*Acacia tetragonophylla*), native pittosporum (*Pittosporum phillyreoides*) and saltbush (*Atriplex vesicaria*). Associated with these are *Eremophila scoparia*, *E. duttonii*, *E. longifolia*, *Atriplex quinii*, *Kochia planifolia*, *K. pyramidata*, *Enchylaena tomentosa*, *Rhagodia spinescens* var. *deltophylla*, *Santalum lanceolatum*, *Lycium australe*, *Trichinium obovatum*, *Heterodendron oleifolium*, *Sida intricata*, *Solanum ellipticum*, *Acacia victoriae*, *A. oswaldii*, *Cassia artemisioides*, *Abutilon leucopetalum*, *Bassia paradoxa* and *B. divaricata*. Some of the creeks carry *Eucalyptus oleosa* (Plate XXII, Figure 4).

Herbaceous species are *Enneapogon polyphyllus*, *E. avenaceus*, *Dactyloctenium radulans*, *Eulalia fulva*, *Chloris acicularis*, *C. truncata*, *Bassia patentiscuspis*, *B. lanicuspis*, *B. obliquiscuspis*, *B. uniflora*, *Zygophyllum ammophilum*, *Paspalidium gracile*, *Eragrostis falcata*, *E. dielsii*, *Convolvulus erubescens*, *Aristida arenaria*, *A. anthoxanthoides*, *Euphorbia drummondii*, *Tetragonia eremaea*, *T. expansa*, *Tragus australianus*, *Trianthema crystallina* var. *clavata*, *Cucumis myriocarpus*, *Citrullus vulgaris*, *Goodenia cycloptera*, *Rhagodia nutans*, *Themeda avenacea* and *Chenopodium cristatum*.

Larger watercourses and creeks in shrub steppe areas.

The larger creeks consist of one or two main channels with occasional long narrow waterholes, but where they flood out they assume more the characteristics of watercourses and consist of numerous interlacing channels with a few waterholes (Plate XXIII, Figure 1). The main channels and waterholes are fringed by coolibah trees (*Eucalyptus coolabah*)—Plate XXIII, Figure 2—and sometimes mulga (*Acacia aneura* and *A. brachystachya*). In and between the channels the characteristic shrub species are canegrass (*Eragrostis australasica*), cotton bush (*Kochia aphylla*), lignum (*Muehlenbeckia cunninghamii*) and *Bassia bicornis*. The following are comparatively rare: *Ixiolaena leptolepis*, *Santalum lanceolatum*, *Hakea leucoptera*, *Eremophila glabra*, *Acacia victoriae*, dead finish (*A. tetragonophylla*) and *Minuria leptophylla*. Rarely creeks are found carrying Broughton willows (*Acacia salicina*) and *A. stenophylla*.

Associated common herbaceous species are *Eragrostis falcata*, Murray lily (*Crinum pedunculatum*), pop saltbush (*Atriplex spongiosa*) and *Portulaca oleracea*. Of rarer occurrence are *Dactyloctenium radulans*, *Chloris acicularis*, nardoo (*Marsilia drummondii*), *Epaltes cunninghamii*, *Teucrium racemosum*, *Frankenia serpyllifolia*, *Bassia divaricata*, *B. ventricosa*, *Enneapogon polyphyllus*, *Aristida anthoxanthoides*, *Cucumis myriocarpus*, *Citrullus vulgaris*, *Chenopodium cristatum*, *Morgania glabra*, *Eragrostis dielsii*, *Lavatera plebeja*, *Astrebla pectinata*, *Plantago varia*, *Erodium cygnorum*, *Calotis hispidula*, *Iseilema vaginiflorum*, *Euphorbia drummondii*, *Paspalidium gracile* and *Goodenia cycloptera*.

Creeks of the northern tableland country.

The tableland country west of Lake Eyre is drained by a large number of creeks which have their origin in tableland "ranges", that is, in high tableland areas or among residual hills. In addition some of the creeks, like the Douglas and Umbum, rise in the Denison Range south of Oodnadatta, that is among hills consisting of Precambrian rocks.

Numbers of small creeks originating near the western margin of the tableland link up as they progress in an easterly direction and form very large creeks the most important of which are The Neales, Peake, Margaret and Warriner creeks and the Macumba creek which more or less separates the tableland country from the sandy Simpson Desert. The creek beds are sandy or stony in their upper reaches and clayey in the flood plains around Lake Eyre. Unlike the creeks which reach Lake Eyre on its eastern side, those draining the tableland on the western side of the Lake frequently discharge water into it after heavy rains.

Red gums (*Eucalyptus camaldulensis*) fringe the main creek beds in their upper reaches where the soils are sandy and stony. Here the soil moisture is less saline and the moisture-status is considerably higher than further down the creeks because water flows in their upper reaches after rains which are not sufficient to cause a general flow. Apart from an occurrence on Elizabeth and Pernatty creeks red gums are restricted to creeks in the far north, the most southerly gums being on Anna and Evelyn creeks. Red gums are restricted to the

main creek beds, the subsidiary creeks carrying mulgas (*Acacia aneura* and *A. brachystachya*), *Eremophila freelingii* and *A. gilesiana* in the western portion and *E. freelingii* and gidgea (*Acacia cambagei*) in the eastern portion of the North-West.

Red gums are confined to the upper reaches of the creeks. Further down they carry coolibah (*Eucalyptus coolabah*) with mulga in the western portion and gidgea in the eastern portion of the North-West. The most southerly gidgea creek is the so-called Mulga Creek south of Coward Springs. This is an isolated occurrence, the nearest gidgea being on Douglas Creek about 60 miles north of Mulga Creek. Along the north-south railway line the most southerly gidgea creek is north of Edward's Creek railway siding. In the western portion of the North-West gidgea is not found far south of The Neales, while its most westerly occurrence is at Gypsum Bore about 50 miles west of Oodnadatta. Throughout the area where gidgea and coolibah occur on the creeks the main channels carry more coolibah than gidgea, while subsidiary creeks carry gidgea alone (pl. xxiii, fig. 3). South of the gidgea country the creeks are fringed by coolibah either alone or with mulga. The most southerly coolibah is on Miller's and Birthday Creeks.

Associated shrubs and small trees are *Acacia stenophylla*, lignum (*Muehlenbeckia cunninghamii*) prickly acacia (*A. victoriae*), *A. salicina*, *A. tetragonophylla*, *Rhagodia spinescens* var. *deltophylla*, *Grevillea nematophylla*, *Dodonaea attenuata*, *Cassia sturtii*, *Solanum ellipticum* and *Ixiolaena leptolepis*. Nitre bush (*Nitraria schoberi*) is common on the floodplains.

QUANTITATIVE ESTIMATIONS AND MAPPING OF BUSH DENSITY

The dominant shrub species, that is the bluebushes (*Kochia sedifolia* and *K. planifolia*) and saltbush (*Atriplex vesicaria*), are very important constituents of arid pastures. Although sheep cannot exist for long periods on any of these species, when they are partly defoliated under drought conditions and when no herbage or grass is available, they are extremely valuable as a drought reserve and play a very important role in minimising soil erosion. The presence of these quite palatable and highly drought-resistant perennials means that fluctuations in sheep numbers due to seasonal conditions are much smaller than in areas where shrubs are absent and grazing is dependent on herbage and grass.

When this survey was commenced it was recognised that some rapid method of estimating the density of shrub dominants and of mapping pastoral areas on this basis would have to be developed. The delineation of the boundaries of the different vegetation associations alone does not give an adequate picture of the grazing potential. It is also necessary to indicate the state of preservation of the country. To enable the large areas involved to be traversed a method depending upon visual estimations of density was used but at the same time the method had to give a sufficiently detailed picture to enable station managers to see what bush losses had occurred through grazing on the properties under their control, and to enable significant changes in bush density that might occur in the future to be measured.

Certain fairly well-defined stages of degeneration of shrub dominant vegetation can be recognised and the following categories were adopted:

- Stage 1 Unstocked country or country which has suffered only slight bush thinning.
- Stage 2 Noticeable bush thinning but the country still very well preserved. Slight increase in the amount of *Bassia* spp.
- Stage 3 Marked bush thinning. Pronounced growth of *Bassia* spp.