This savannah woodland type of community is also found on the drier parts of the area on the lighter red-brown earth soils and the light ridges associated with them in the north and north-western parts of the area. It appears to replace the previous community on similar situations in a slightly higher rainfall.

3. Yellow Box (E. *melliodora)* - *Forest* Red Gum *(E. tereticornis)*
The community is found in moist but well-drained situations, particularly along the Broken Creek in the north-eastern part of the area on soils of the Shepparton-Broken Association and also along the creek lines in the southern part of the area on soils of the Earlston-Koonda Association.

4. River Red Gum *(E. camaldulensis)*
This community is found in all parts of the area which are moist and poorly drained and suffer from periodic inundation. It usually occurs in pure stands and is characteristically a "swamp" community.

5. Grey Box (E. *hemiphloia)*
Almost pure stands of grey box are found on the area either as a dry sclerophyll forest or as savannah woodland. It occurs as a dry sclerophyll forest on the hills in the middle of the area, the soils being those of the Gowangardie-Caniambo Association; and as savannah woodland on the soils of the Lemnos-Goulburn Association in the north and north-western parts of the area.

6. Grey Box (E. *hemiphloia)* - River Red Gum *(E. camaldulensis*)
Grey box and red gum form a savannah woodland type of community on the wet, poorly drained areas in the southern part of the area. It occurs almost entirely on the heavy crabholey soil, the Upotipotpon clay.

7. Grey Box *(E. hemiphloia*)-Red Box *(E. polyanthemos)*
This is a savannah woodland community occurring only as a narrow strip between the 22 in. - 24 in. isohyets along the foot of the south-eastern hills. White box (*E. albens)* is an irregularly occurring minor species in this community.

8. Red Box *(E. polyanthemos)* - Red Stringy Bark *(E. macrorrhyncha)*
Red box and red stringy bark are a dry sclerophyll forest type of community occurring along the lower slopes of the south-eastern hills where the rainfall is in the region of 25 inches or more per annum. As the rainfall and elevation increase, its place is taken by the wet sclerophyll forest on the top of the hills.

9. Peppermint *(E. radiata)* - Stringybark *(E. capitellata)* - Blue Gum *(E. globulus)*
This wet sclerophyll forest community occurs on the top of the south-eastern hills where the rainfall is about 28 - 30 inches per annum.

10. Green Mallee *(E. virldis)*
Pure stands of green mallee are found on the tops of some of the hills in the parishes of Gowangardie and Upotipotpon. Such occurrences of mallee are not uncommon in some parts of northern Victoria, eastward from the true mallee area, but this seems to be the most easterly occurrence.

11. Sheoak *(Casuarina stricta)*
Small patches of sheoak are to be found occurring within other communities. It seems to be confined to the more stony areas both on the central and south-eastern hills. There have been some occurrences in the grey box savannah woodland, but most of it has now been removed.

IV. GEOLOGY AND PHYSIOGRAPHY

Although the district presents some interesting geological and physiographical features, practically no former investigations have been made and consequently it is impossible to give an authoritative account of the geological history of the area.

1. Cambrian Chert-Diabase Association

The hills in the vicinity of Dookie are composed of this association which consists of diabase along with interbedded limonitic and manganiferous cherts and volcanic tuffs. The geological explanation of such an association of rocks is not clear and the age is also unconfirmed, but is generally accepted as Cambrian by analogy with a similar association occurring at Heathcote, which is situated about 80 miles to the south-west. This series of rocks provides the parent material for a most interesting group of soils, the Dookie, Major, and Cashel series.

2. Ordovician and Silurian Sedimentary Rocks

The boundary between these two groups has not been defined and since they provide the parent material for a common group of soils consisting of the Gowangardie and Caniambo series, it is reasonable to discuss them under a single heading. The two rock series appear to be similar, consisting of shales, sandstones, quartzites, and slates, and it is only on the basis of fossil evidence from two different parts of the area that the two series are known to exist. On the basis of fossil evidence the sedimentary rocks in the Parish of Currawa are considered to be Ordovician, whereas in the Parish of Tamleugh they are Silurian. Outcrops of these rocks are to be found along the lower slopes of the igneous hills in the south-eastern part of the area, and the fact that they show no undue metamorphism in spite of their proximity to a younger plutonic mass presents a problem for geological study. There is a curious arrangement of the directions of strike of these rocks in the central part of the area. On the eastern side of the area, including the outcrops close to the igneous rocks, the strikes are uniformly N.W.-S.E., and in the Parishes of Currawa and Tamleugh they are E.-W-, but in the southern parts of the Parishes of Gowangardie and Upotipotpon they are N.E.-S.W., gradually swinging around to a N.W.-S.E. direction in the northern part of the Parish of Upotipotpon. Through the central hills in Gowangardie and Upotipotpon there are at least two, and possibly more, outcrops of "buck quartz" which can be traced intermittently across the countryside for several miles in a slightly north of east direction. These outcrops suggest that these series may have been faulted in several places.

3. Devonian Igneous Complex

The mountains of the south-eastern part of the area are composed of igneous rocks which are of variable texture. According to Summers (1914), the part of the Strathbogie igneous complex which lies in this area consists of quartz porphyrites similar to the usual dacites of central Victoria, but further to the south the rocks have a more plutonic character and they have been recorded as adamellites.

4. Tertiary and Recent

These are mainly alluvia, but near the railway line between Pine Lodge and Cosgrove there is a small outcrop of extrusive igneous rock which has been identified as limburgite.[*]

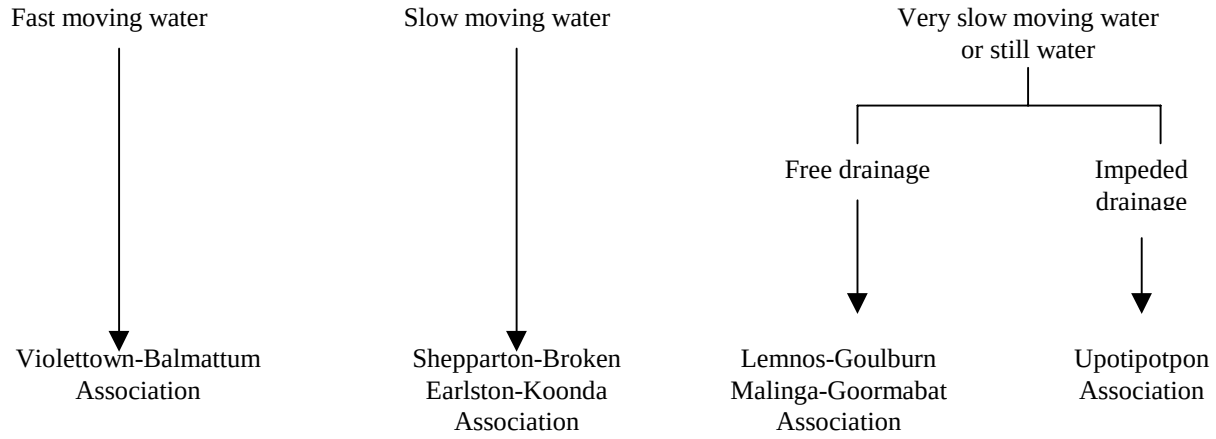
The alluvia are composed of a variety of deposits which constitute the parent materials of the soils over the whole of the flatter parts of the area. The main differences between the deposits are of particle size distribution due to water sorting, and also lime content due to the nature of the drainage conditions existing at the time of their deposition. Broadly, these can be classified on the basis of the different conditions of water movement under which the deposits have been laid down.

(a) *Fast moving water*.-The parent materials under these conditions are of coarse sand size, or in some cases even gravelly.
(b) *Slow moving water*.-The parent materials under these conditions are of fine sand size.
(c) *Very slow moving or still water*.-These conditions occur either in swamps or very slow moving flood backwaters, and the parent materials are of clay size. The deposits can be further subdivided according to the nature of the drainage system under which the deposition took place.

[*] Private communication from F A Singleton, University of Melbourne

(i) Impeded drainage system-which would lead to the accumulation of lime and possibly soluble salts due to the continual enrichment from the surrounding countryside.
(ii) Free drainage system-under which conditions there would not be the same accumulation of lime and certainly no accumulation of soluble salts.

So that the soil map can be used as a guide to the distribution of the various kinds of parent materials, the following chart shows the soil associations of the flat country and their relation to the various kinds of deposits:



Physiographically the area can be divided into a number of regions of which the mountain masses are the most distinct:

(1) The south-eastern mountains (maximum elevation 1,800 feet).
(2) The central hills which run in a west to east direction across the area, and then on the eastern side in a northerly direction into the Parishes of Goorambat and Bungeet which lie to the east of Devenish (maximum elevation 700 feet).
(3) The hills around Dookie (maximum elevation 1,200 feet).
(4) The north-western plains in the Parishes of Pine, Lodge and Caniambo (general elevation 420 feet).
(5) The northern plains in the Parishes of Stewarton and Devenish (general elevation 460 feet).
(6) The southern lowland in the Parishes of Shadforth and Wills (general elevation 550 feet).
(7) The southern dissected alluvial fan in the Parishes of Balmattum and Moglonemby (general elevation 550 feet).

An explanation of the sequence of events which, brought about the development of these physiographic regions is most difficult to establish on the evidence available.

The soil map, when used as a guide to the distribution of the various kinds of parent materials, indicated some features of physiographic interest. The most outstanding is the occurrence of extensive areas of fine-grained deposits having a relatively higher lime content on which the Upotipotpon clay has been formed. There are three areas which on the basis of their present levels can be considered as three separate physiographic units:

(a) In the south, between the central and south-eastern hills extending across the whole area; part of this area is now covered by other material, but outliers are found.
(b) In the Parishes of Tamleugh and Caniambo on the northern side of the central hills.
(c) In the northern parts of the Parishes of Upotipotpon and Goomalibee, and also in the Parishes of Currawa, Stewarton, and Devenish.

Of these three areas the one in the south appears to be the most interesting, because the general nature of the present stream pattern and the extensive area of the deposit seems to indicate that the swampy or impeded drainage conditions required for its deposition could only have been obtained by some major event in the geological history of the area. Such an event could possibly have been faulting, general earth movement, or a change in the climatic cycle enabling a change of direction of the flow of existing streams. In addition, on part

of this extensive area there has been the deposition of the alluvial fan and channel deposits which, on the basis of their topographic occurrence, appear to be of more recent origin.

V. SOILS - CLASSIFICATION AND RELATIONSHIPS

The soil that exists in any locality is the result of the interaction of several factors; in particular, climate, parent material, topography, and time. On an area of the size which has been surveyed it is usual to expect that climate will be a relatively constant factor, and that parent material and topography will be more important in producing different soils. On this area, however, the range of annual average rainfall (18 to 30 in.) means that there are big differences in the amount of effective leaching which has taken place in the soils in different localities, and consequently there is to be found a range of soils representative of the two main taxonomic groups, pedalfers, and pedocals. In the north and north-western parts of the area the main soils are red-brown earths (pedocals), but in the south and south-eastern parts of the area they are podsolized soils (pedalfers). In each locality these main soils are associated with various intrazonal soils.

The red-brown earths (Prescott 1931, 1944) constitute a major zonal group in Australia and are found, occurring in the 15 to 22 in. rainfall belt with a characteristic vegetation association of savannah woodland. The podsols in Australia have usually been considered as a single broad group without the subdivisions defined in the United States. The soils of this area which can be classified into this broad group would be better described as podsolized *50118.*

1. Classification of the Soils

The classification of the soils and their relation to parent material and features of the area is given in Table 9 and Figure 8, and a full description and discussion of each soil type is given below.

Red-brown Earths

All the red-brown earth soil types, with the exception of the Currawa loam, have been previously recognized and described by Skene and Freedman (1944) in their survey of the Shepparton Irrigation District. The descriptions given below vary slightly from those given by them and these variations will be discussed later.

Lemnos series. The Lemnos series occurs on the flat country, and is characteristic of the relatively well-drained parts of the plains. The series consists of two types, the loam and the fine sandy loam. The Lemnos loam as the more common and constitutes the upper member of a catena, which includes the Goulburn and Congupna series as lower members.

Lemnos loam

A_1 0- 6 inches.	Brown or grey-brown loam.
A_2 6-10 inches	Light-brown loam or sandy clay loam, sometimes with buckshot ironstone gravel.
B_1 10-18 inches	Brown or reddish-brown heavy clay.
B_2 18-27 inches	Grey-brown heavy clay.
B_3 27-48 inches	Grey-brown heavy clay with slight lime and rubble.

The Lemnos fine sandy loam usually occurs in association with the fine sandy group of soils described below. The fine sandy nature of the surface is probably due to the nature of the parent material, but since the subsoils to a depth of 4 feet show no fine sandy influence, the type appear4 and probably behaves similarly to the Lemnos loam except for the lighter textured surface.

Lemnos fine sandy loam

A_1 0- 6 inches	Brown fine sandy loam.
A_2 6-10 inches	Light-brown fine sandy loam.
B_1 10-28 inches	Reddish-brown clay.
B_2 28-40 inches	Yellow grey-brown or grey-brown clay with light or medium lime.

Table 9 - The classification and relationships of the soils to other natural features in the area

Soil Order	Sub-order	Great Soil Group	Soil Series	Climate	Topography and Drainage	Vegetation	Geology
Zonal	Dark coloured soils of the semi arid and sub-humid savannah woodland	Red-brown earths (reddish chestnut soils of USA?)	Lemnos	Sub-humid	Flat with little or no run-off	Savannah woodland	Fine grained Tertiary alluvium
			Goulburn	Sub-humid	Flat with little or no run-off, subject to periodic inundation	Savannah woodland	Fine grained Tertiary alluvium
			Shepparton	Sub-humid	Flat with little or no run-off	Savannah woodland	Coarse grained (fine sand) Tertiary alluvium
			Broken	Sub-humid	Small rises from the plains, little or no run-off	Savannah woodland	Coarse grained channel deposit of Tertiary alluvium
			Grahamvale	Sub-humid	Small rises from the plains, little or no run-off	Savannah woodland	Coarse grained channel deposit of the Tertiary alluvium
			Currawa	Sub-humid	Flat to gently sloping, little run-off	Savannah woodland	Alluvium from Cambrian diabase hills
	Transitional	Transitional	Nalinga	Sub-humid	Relatively flat near the foot of the hills. Little or no run-off	Savannah woodland	Tertiary alluvium and alluvium from near by hills
			Goorambat	Sub-humid	Flat, little or no run-off	Savannah woodland	Mainly fine grained Tertiary alluvia
	Light coloured podsolized soils	Podsols	Violettown	Humid	Relatively flat, periodic inundation	Savannah woodland	On Tertiary or Recent coarse grained alluvium
			Balmattum	Humid	Relatively flat, periodic inundation	Savannah woodland	On Tertiary or Recent coarse grained alluvium
			Earlston	Humid	Relatively flat, little or no run-off	Savannah woodland	On Tertiary or Recent coarse grained (fine sand) alluvium
			Koonda	Humid	Flat, no run-off some inundation	Savannah woodland	On Tertiary or Recent coarse (fine sand) alluvia
			Gowangardie	Humid	Flat, no run-of, some inundation	Savannah woodland	On Tertiary or Recent coarse grained (fine sand) alluvia
			Caniambo	Humid	Upper slopes of hills, some run-off	Sclerophyll forest	Ordovician and Silurian shales, sandstones, etc
			Warrenbayne	Humid	Upper slopes, some run-off	Sclerophyll forest	Devonian igneous complex
			Boho	Humid	Lower slopes, some run-off	Sclerophyll forest	Devonian igneous complex
			Type B	Humid	Slight rises in flat country	Savannah woodland	Channel deposits, coarse in Recent or Tertiary alluvia
			Type C	Humic	Slight rises in flat country	Savannah woodland	Channel deposits, coarse in Recent or Tertiary alluvia
		Red loam	Dookie	Sub-humid to humid	Hill country, some run-off	Savannah woodland	Cambrian diabase

Soil Order	Sub-order	Great Soil Group	Soil Series	Climate	Topography and Drainage	Vegetation	Geology
Intra-zonal	Calcimorphic soils	Chocolate & black earths	Major	Sub-humid to humic	Hill country, some run-off, shallow water table	Savannah woodland	Cambrian diabase
			Cashel	Sub-humid to humid	Hill country, some run-off, shallow water table	Savannah woodland	Cambrian diabase
		Self-mulching	Upotipotpon	Humid	Flat, subject to inundation	Savannah woodland	Lime-enriched alluvium
			Type A	Sub-humid to humid	Flat, subject to inundation	Savannah woodland	Lime-enriched alluvium
	Hydromorphic soils	Swamp soils	Congupna	Humid to sub-humid	Flat, subject to inundation	Savannah woodland	Recent alluvium
Azonal		Lithosola	Unnamed skeltal	Humid, sub-humid to humid	Considerable run-off	Savannah woodland	Devonian igneous complex Cambrian diabase and Ordovician shales and sandstones

Goulburn series.-Only one soil type was mapped in this series, although the surface texture is found to vary between loam and clay loam. It is found on the lower and not so well drained parts of the flat country in association with the Lemnos series.

Goulburn loam

A_1 0- 6 inches	Grey or brownish-grey loam or sometimes clay loam.
A_2 6-10 inches	Light-grey loam or sandy clay loam often with buckshot ironstone gravel.
B_1 10-36 inches	Yellow-grey or yellowish grey-brown heavy clay.
B_2 36-48 inches	Yellow-grey clay with slight lime.

Shepparton series.-The series associated with the fine sandy channel deposits occurring throughout the plain country. Such soils are usually found on the gentle slopes of the slight rises.

Shepparton fine sandy loam

A_1 0- 6 inches	Brown fine sandy loam.
A_2 6-14 inches	Light-brown fine sandy loam or fine sandy clay loam.
B_1 14-24 inches	Brown clay.
B_2 24-30 inches	Yellowish-brown clay.
B_3 30-48 inches	Yellowish-brown fine sandy clay with slight lime.

Orrvale series.-This series is found in association with the Shepparton series on those areas where there has been some restriction of drainage; it Is not a widely occurring soil.

Orrvale fine sandy loam

A_1 0- 6 inches	Grey-brown fine sandy loam.
A_2 6-12 inches	Light grey-brown fine sandy loam to fine sandy clay loam.
B_1 12-36 inches	Grey-brown or yellowish grey-brown clay with slight lime occurring below 27 inches.
36-48 inches	Grey and yellow mottled grey fine sandy clay.

Broken and Grahamvale series.-These two series are only of minor importance on the area. They are associated with the coarse-grained channel deposits of the area which manifest themselves as a series of disconnected rises. They are, of course, more important in the irrigation country of the Shepparton district and have been discussed fully by Skene and Freedman (1944). On this survey they have been mapped together as a group of sandy soils.

Broken sand

0-6 inches.	Brown, often greyish-brown, sand or loamy sand.
6-24 inches	Light-brown sand.
24-45 Inches	Red-brown sandy clay loam.
45-60 inches	Brown sandy loam.

Grahamvale sandy loam

0- 6 inches	Brown, often greyish-brown, sandy loam or loamy sand.
6-18 inches	Light-brown sand or sandy loam.
18-48 inches	Red-brown, brown, or yellow-brown sandy clay or sandy clay loam.
48-60 inches	Grey-yellow sandy loam.

Currawa series.-One soil type has been mapped in the series and it occurs on alluvium close to the diabase hills of the Dookie district. It bears some resemblance to the Katamatite loam described by Butler *et al.* (1942*)* in the Murray Valley Irrigation district.

Currawa loam

0- 6 inches	Brown loam.
6-12 inches	Brown, going to yellowish-brown, friable clay, the texture increasing gradually with depth.
12-27 inches	Brownish-yellow friable clay with black, probably manganiferous inclusions.
27-40 inches	Brownish-yellow, going to yellow friable clay with black inclusions.
40-56 inches	Yellow with brown mottled friable clay, with some black inclusions and slight. lime.
56-72 inches	Brown with yellow mottled clay and black inclusions, not so friable, with heavy lime and rubble.

Transitional Soils

On the plains to the south-east of the Dookie hills and also in the Parish of Devenish there occur two soil series, Nalinga and Goorambat, which cannot be grouped strictly with either the red-brown earths or the podsolized soils. The upper portions of the profiles appear to be podsolic in character, but there are accumulations of lime in the subsoil.

Nalinga series.-This series occurs mainly on the flat country to the south of the Dookie hills. It is formed on fine-grained alluvium which is somewhat friable, and this may account for the relatively more leached nature-of the profile in comparison with the red-brown earth types.

Nalinga loam

A_1 0- 9 inches	Grey-brown loam.
A_2 9-12 inches	Light grey-brown sandy clay loam' with some buckshot ironstone gravel.
B_1 12-24 inches	Yellow-brown clay.
B_2 24-36 inches	Yellowish-brown clay with slight lime.
36-52 inches	Yellow with grey-brown. mottled clay with slight lime.
52-68 inches	Yellow and grey-brown clay with medium lime and rubble.

Goorambat series.-.Two types have been mapped in the series, the loam and the sandy loam.

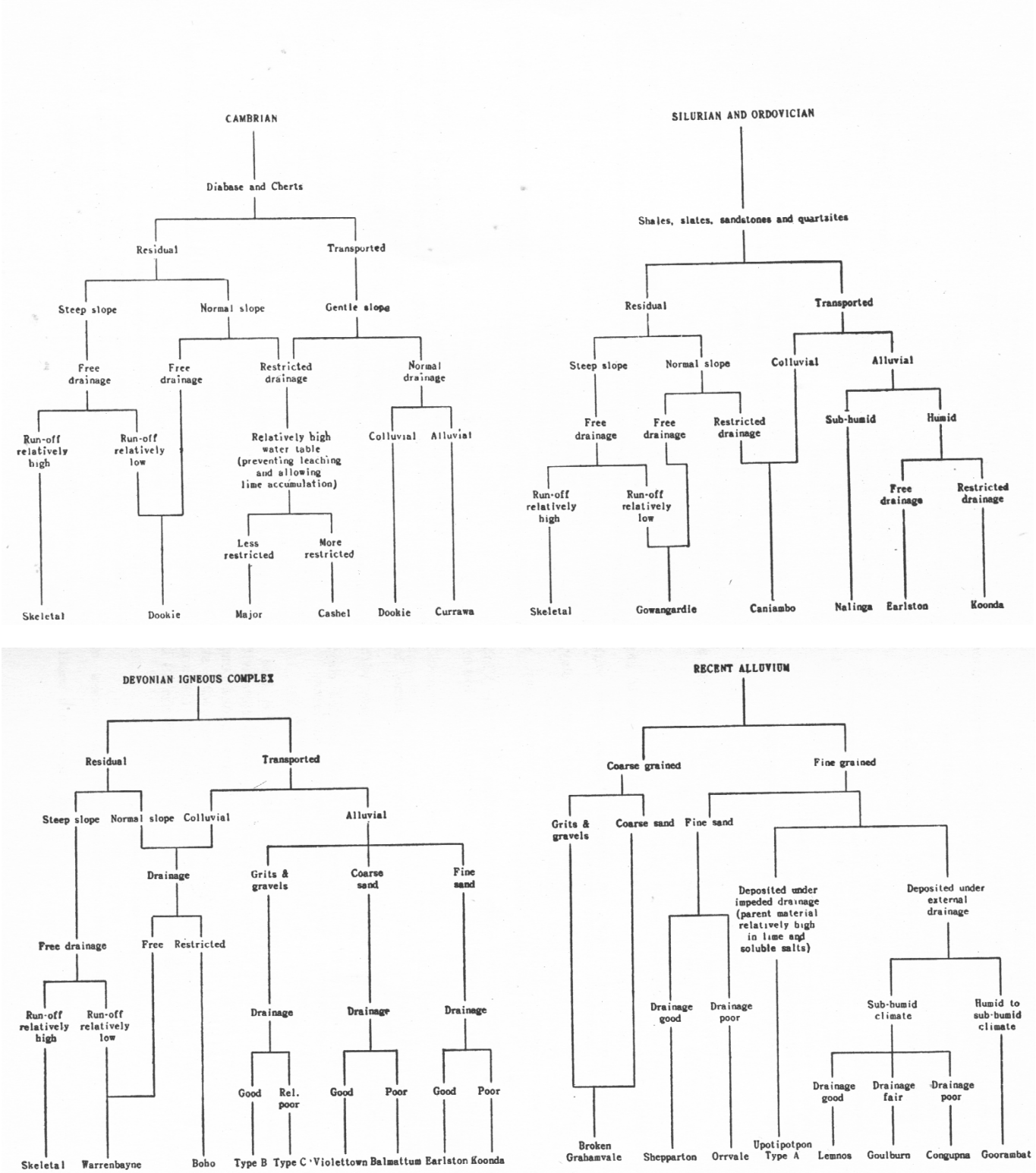
Goorambat loam

A_1 0- 5 inches	Grey to grey-brown loam.
A_2 5-12 inches	Light brownish-grey sandy loam with medium amounts of buckshot ironstone gravel.
B_1 12-22 inches	Yellow, brown, and light-grey mottled clay.
B_2 22-33 inches	Yellow-grey-brown clay.
33-38 inches	Grey-brown clay with light to medium lime.

Goorambat sandy loam

A_1 0-7 inches	Grey to grey-brown sandy loam.
A_2 7-14 inches	Light-grey sandy loam with medium buckshot ironstone gravel.
$B_1$14-36 inches	Yellow and grey with red mottled clay.
B_2 36-42 inches	Yellowish-grey-brown clay.
B_3 42-48 inches	Grey-brown clay with light to medium lime.

Fig 8 - Soil types in relation to parent material, topography, drainage and climate



Podsolized Soils

Violettown series.-This series occurs on coarse-grained alluvial soils in the southern part of the area; one type only was mapped.

Violettown sandy loam

A_1 0- 4 inches	Grey-brown loam to sandy loam with fine quartz gravel on the surface.
A_2 4-10 inches	Light brownish-grey to light-grey sandy loam with light buckshot ironstone gravel.
B_1 10-20 inches	Brownish-yellow, brown, and yellow-grey mottled clay.
B_2 20-42 inches	Greyish-yellow clay with some fine quartz gravel.
42-66 inches	Slightly yellowish-grey with brown mottled clay, slightly friable and with some quartz gravel.

Balmattum series.-This series occurs in association with the Violettown series on the same parent material but occupying the relatively lower areas in the same vicinity.

Balmattum sandy loam

A_1 0-4 inches	Brownish-grey sandy loam or loam with some buckshot ironstone gravel.
A_2 4-12 inches	Light yellowish-grey and light-grey sandy loam with some buckshot ironstone gravel.
B_1 12-27 inches	Grey with some yellow-grey and brown mottled clay, some light quartz gravel and also ironstone buckshot.
B_2 27-48 inches	Greyish-yellow clay with some quartz gravel.

Earlston series.-This and the Koonda series occur on the fine sandy alluvium in the southern part of the area and also in association with the Ordovician and Silurian hills. Although there are some broad expanses mapped it is usually confined to narrow alluvial lines associated with streams flowing out of the hills. In some, profiles, particularly those in the southern part of the area, the fine sandy parent material may not occur within 48 inches.

Earlston fine sandy loam

A_1 0- 4 inches	Brownish-grey fine sandy loam.
A_2 4- 8 inches	Light-grey and light grey-brown fine sandy loam or fine sandy clay loam.
B_1 8-15 inches	Brown, red-brown with grey mottled clay, with a small nutty structure when dry.
B_2 15-44 inches	Yellow, grey, grey-brown, and red-brown mottled clay with small nutty structure when dry.
B_3C 24-44 inches	Brown, yellow, and grey mottled fine sandy clay.
44-60 inches	Brown and greyish-yellow fine sandy clay.

Koonda series.--This series is associated with the Earlston, being the lower member of the catena, and occurring in the lower not so well-drained parts of these alluvial areas. It seems to be more widespread than the Earlston series.

Koonda fine sandy loam

A_1 0- 4 inches	Grey fine sandy loam.
A_2 4-10 inches	Light-grey and light yellowish-grey fine sandy clay loam with light buckshot ironstone gravel.
B_1 10-20 inches	Yellow with grey-brown mottled clay.
B_2 20-40 inches	Yellow with light-grey mottled clay.
C 40-50 inches	Brown to light-brown fine sandy clay.

Gowangardie series.-The Gowangardie, with the Caniambo series, constitutes one of the most widespread groups of soils occurring in the area. It occurs on the upper, well drained portions of the slopes of the Ordovician and Silurian hills.

Gowangardie loam

A_1 0- 4 inches	Brownish-grey loam with some pieces of iron-impregnated parent rock.
A_2 4- 9 inches	Light grey-brown loam to sandy loam with some pieces of iron-impregnated parent rock.
B_1 9-27 inches	Brown to red-brown with slight greyish mottling, heavy clay. Small nutty structure when dry, but sticky, plastic when wet.
B_2C 27-36 inches	Brown to red-brown clay with purple and yellow pieces of decomposing parent rock.

Caniambo series.-This series occurs on the lower and not so well drained portions of the slopes of the hills in association with the Gowangardie series.

Caniambo loam

A_1 0- 4 inches	Grey loam with pieces of iron-impregnated parent rock.
A_2 4- 8 inches	Grey to light-grey loam with pieces of iron-impregnated rock.
B_2 8-12 inches	Grey and yellowish-grey heavy clay with some stone. Small nutty structure when dry, but plastic and sticky when wet.
B_2 12-20 inches	Yellowish-grey with grey-brown, brown, and some red mottled heavy clay having a similar kind of structure to the previous horizon.
20-36 inches	Yellow-grey heavy clay.
36-72 inches	Yellowish-grey-brown, going to yellowish-grey and grey heavy clay.

Warrenbayne series.-This series is formed on the igneous rocks of the south-eastern hills in places where the drainage is good. Fine quartz gravel persists throughout the profile.

Warrenbayne sandy loam

A1 0- 4 inches	Brown to grey-brown sandy loam with fine quartz gravel.
A_2 4- 8 inches	Light-brown sandy loam with fine quartz gravel and soft iron-cemented sand.
B_1 8-20 inches	Red-brown clay with nutty structure when dry.
B_2 20-30 inches	Red-brown clay with some fine quartz gravel.
B_3C 30-40 inches	Red-brown and yellowish-brown clay with fine quartz gravel.

Boho series.-The Boho series is found in association with the Warrenbayne series usually occupying the lower and less well-drained portions of the area.

Boho sandy loam

A_1 0- 4 inches	Grey sandy loam.
A_2 4-12 inches	Light-grey (slightly yellowish) sandy clay loam with fine quartz gravel.
B_1 12-30 inches	Yellow with red-brown mottled clay.
B_2 30-50 inches	Yellow with brown mottled clay and sometimes purplish and white streaks.

Unnamed series of podsolized soils.-There are two minor series of coarse textured soils which occur in the southern part of the area in association with the Violettown and Balmattum series. They occur on slight rises which are the remnants of old channel deposits.

Type B

A_1 0- 5 inches	Grey-brown sandy loam.
A_2 5-13 inches	Light greyish-brown sand with moderate fine quartz gravel.
B_1 13-16 inches	Light-brown and red-brown sandy clay loam with fine quartz gravel.
B_2C 16-60 inches	Red-brown clay with moderate to heavy fine quartz gravel.

Type C

A_1 0- 3 inches	Brownish-grey sandy loam.
A_2 3- 8 inches	Light grey-brown sandy loam
A_3 8-15 inches	Light yellowish-grey sand.
B_1 15-20 inches	Grey and yellow with red mottled clay.
B_2 20-40 inches	Yellow and grey with some red mottled gravelly clay, rather "panny."
B_3C 40-60 inches	Light yellowish-grey clayey fine gravel, compact and cemented.

(d) Red Loams

Dookie series.-The Dookie series is a most important soil which occurs on the Cambrian diabase and cherts.

Dookie clay loam

A_1 0-10 inches	Brown to red-brown friable clay loam.
B_1 10-25 inches	Dark red-brown to red-brown friable clay.
B_2 25-50 inches	Red-brown clay with friable to small nutty structure, having black inclusions (probably manganiferous).
B_3C 50-72 inches	Brown to red-brown clay and also sometimes slight lime at 70 inches.

(e) Calcimorphic Soils

The calcimorphic group includes the chocolate and black earths and the lowland self mulching soils.

Chocolate and black earths

The group of soils includes two soil series, the Major and Cashel. These series are both found on the Cambrian diabase in association with the Dookie series, but they occur in areas, where, for some reason, the water-table lies much closer to the surface and allows an accumulation of lime in the profile.

Major series-Only one type has been mapped in the series and it occupies only small areas.

Major clay loam

0- 6 inches	Dark-brown friable clay loam.
6-12 inches	Brown to dark-brown friable clay with some soft lime.
12-40 inches	Brown friable clay with medium lime.
40-66 inches	Brown friable clay.

Cashel series.-The Cashel series occurs more extensively than the major series and is more important agriculturally.

Cashel clay loam

0-6 inches	Very dark-grey or black friable clay loam.
6-20 inches	Black clay, large nutty structure.
20-36 inches	Black clay with small limestone rubble.
36-54 inches	Brown and dark-grey clay with slight lime.
54-78 inches	Yellowish brown clay.

Self-mulching lowland soils

The group includes two series, both of which appear to have been developed on fine-grained alluvium deposited under conditions of impeded drainage. The relatively high lime content of the parent materials is a result of accumulation within a system of mainly internal drainage.

Upotipotpon series.-This is a widespread important series occurring mainly but not exclusively to the south of the Broken River. The one member of the series described has a clay or clay loam surface characterized by a "crabholey" formation. The degree of crabhole development is variable in different parts of the area.

Upotipotpon clay

A_1 0- 3 inches	Dark-grey clay loam to light clay-granular structure with some rusty mottling.
B_1 3-10 inches	Grey with yellow-grey and light-grey mottled heavy clay with iron staining and some soft and hard ironstone concretions.
B_1 10-18 inches	Dark-grey and yellow-grey mottled heavy clay with ironstone concretions.
B_2 18-44 inches	Yellow-grey heavy clay with ironstone concretions and also light to medium lime and rubble.
44-60 inches	Yellow-grey clay, lime diminishing.
60-80 inches	Grey with slight brown mottling, heavy clay.

The above profile is characteristic of the area between a "puff" and a depression. The "puff" profile is virtually a truncated version of this, the surface being the 18-44 in. horizon which is a highly structured self-mulching clay with limestone nodules. The depressions show a greater depth of the 0-3 in. horizon given above and in some profiles there may be even about 1 inch of bleached horizon beneath the A1.

Type A.-Type A is a soil formed on recent swamp formations which have been drained. The type is normally crabholey but it can be cultivated following drainage and is a fertile soil in normal seasons.

0- 2 inches	Dark-grey to grey friable clay.
2- 5 inches	Very dark-grey clay with light lime.
5-36 inches	Grey clay with medium lime and rubble.

(f) Hydromorphic Soils

The hydromorphic soils are represented by only one series, the Congupna, with one soil type.

Congupna series

Congupna clay.-This type includes all the areas which at times of the year are definitely swampy. There are some variants from the type, but these have not been separated on this survey and consequently it would be better to consider areas on the maps shown as Congupna clay to be a group of soils, generally heavy in texture and poorly drained. The occurrence of variants is very limited and the general description of the Congupna clay will in most cases agree with the soil occurring in these areas.

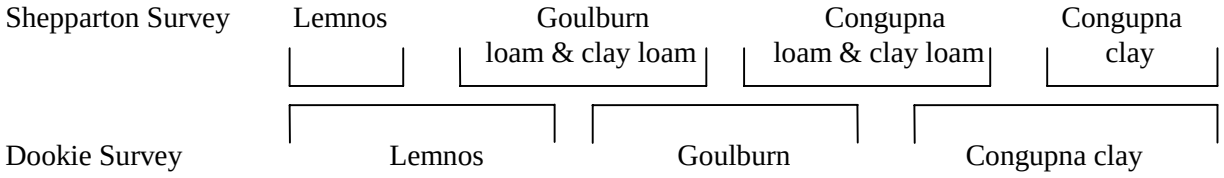
A 0- 6 inches	Grey to grey-brown clay with some rusty mottling.
B_1 6-14 inches	Grey and light-grey clay.
$B_2$14-18 inches	Yellow, grey, and light-grey mottled clay.
18-24 inches	Yellowish grey clay.
24-48 inches	Greyish yellow clay. Sometimes with lime.

2. Soil Types in Relation to those of other Surveyed Areas

Detailed soil surveys have been made of two areas within reasonably short distance of the present survey: the Shepparton Irrigation District (Skene and Freedman 1944) almost adjoins on the western boundary and the Murray Valley Irrigation Area (Butler et al. 1942) is situated about 20 miles to the north.

Skene and Freedman have already indicated the similarities between some of the major types of the above areas and also other parts of the Goulburn Valley. It has been indicated earlier that soil types of the red-brown earth group in this surveyed area conform with certain types described at Shepparton, but there has been a slight extension of the limits of some types to enable a broader scale of surveying, which raises a problem requiring some explanation. When a sequence of soils occurs to form a catena based on internal drainage, there is a gradual transition in the nature of the profile from the best to the poorest drained conditions. The previous detailed survey work in irrigation districts has lead to the recognition in such catenas of four soil series, but on this survey the same catena has only been divided into three series.

The most extensively occurring catena corresponds with the Lemnos-Goulburn-Congupna sequence of Skene and Freedman. On this survey the Lemnos has been broadened to include some of the browner members of the Goulburn and the Goulburn series to include all of the Congupna loam and clay loam. The Congupna clay is the real bottom member of the catena. Thus the situation is as shown in the diagram.



The other red-brown earth types on this survey are sufficiently similar to those of the Shepparton soils to be given the same name.

The Currawa loam shows some similarity to the Katamatite loam of the Murray Valley area, particularly with respect to the nature of the friable subsoils. Field observations enabled a link between the soils at Katamatite and Dookie to be established, for it was found that soils having similar friable subsoils occur intermittently from Katamatite to the Katandra hills where the soil type undoubtedly is Currawa loam.

3. Pedological Significance of the Soils of the Area

(a) Transitional Soils

The soils of the surveyed area constitute an interesting group pedologically because they show the transition from the pedocals to the pedalfers. At first it was thought that a reasonably large belt of intermediate soils similar to the Nalinga and Goorambat series might exist, but subsequent survey has revealed that this is not so. These soil types occur in a belt only about 2 miles in width and therefore can only be considered in this area as a transitional group of soils. Further the belt is discontinuous, but this is probably due to the topography of the country south of the Broken River, which causes a relatively steep climatic gradient in that locality. Such soils as the Nalinga and Goorambat could for classification purposes best be placed with the red-brown earths provided this group was broadened.

(b) Podsolized Soils

The podsolized soils of the area consist of four groups of morphologically similar soil series. These groups are the Gowangardie-Caniambo, Earlston Koonda, Warrenbayne-Boho, and the Violettown-Balmattum. These soils and others similar to them are widespread in north-eastern Victoria and extend northward into New South Wales along a zone of climatically similar country. They occur so extensively and on such varying parent materials that they obviously constitute a zonal group of soils in south-eastern Australia. Their morphology, however, differs from the standard conception of the podsol and consequently some effort should be made to classify them as a sub-group of the podsolized soils. Their morphology can be characterized by the following general description.

A_1 horizon	Grey or brownish-grey loam or sandy loam.
A_2 horizon	Light yellowish grey or light brownish grey loam or sandy loam
B horizon	Red-brown or yellow, slightly mottled heavy clay. This horizon has a small nutty structure when dry, but when wet disperses readily to become sticky and plastic.

Similar soils occur in the high mountain districts of north-eastern Victoria and in these cases there may be an A_0 horizon of decomposed organic matter and the A_1 horizon may be considerably darker. The surface texture varies from loam to sandy loam, depending largely on the type of parent material.

Such a description as given above indicates a translocation of the clay from the A to B horizon and the degree of development of the bleached A_2 horizon puts them into the general category of podsols. They seem on a descriptive basis to be similar to the soils in the United States which have been classified as grey-brown podsolic soils, although on the surveyed area the climate is not as wet as the area of their occurrence in the United States. Nevertheless it is almost certain that the mean climatic conditions of this zone in south-east Australia would approximate more closely to the United States conditions and these soils are probably at the lower climatic limit for the group, lying as they do, adjacent to the pedocalic group, the red-brown earths.

Unfortunately, many descriptions of the red and yellow podsolic soils in America also appear to tally closely with these soils, and the fact that soils similar to those found on this area occur well north in New South Wales, where there is some summer rainfall (e.g. Bathurst, Orange) throws some doubt on their classification in the grey-brown podsolic group. There is one point of contrast between these soils and those of the podsolic groups in America, namely the much higher clay content of the B horizon of the Australian series.

The redness of the B horizon of the upper member of each catena is undoubtedly associated with the better drainage conditions prevailing, but the degree of redness seems to be influenced by the degree of desiccation or the summer temperature, for it will be found in Victoria that between Melbourne (77^o F)* and Euroa (83^o F)* there is a gradual increase in the degree of redness exhibited by the B horizon of the upper member of the catena in each locality. South of the dividing range the upper member of the catena has a B horizon which is mainly bright yellow, but at Broadford (about 80^o F)† over the range the colour is reddish yellow while just north of Seymour (83^o F) there occur soils with bright red B horizons similar to the Gowangardie and Warrenbayne series.

(c) Crabhole Soils

Both the Upotipotpon clay and Type A have a crabholey micro-relief. The areas of Type A are small and as they have mostly been cultivated, there is consequently little original crabhole formation left. The Upotpipoton clay is an extensively occurring type little of which has been cultivated, and so the crabhole formations are to be seen in varying stages of formation on different parts of the area. Generally the maximum crabhole development is to be found on the more northerly occurrences of this soil type.

The formation of crabholes is considered to be the result of uneven infiltration of water into a heavy soil with certain subsoil properties. Howard (1939) has put forward a theory of crabhole development as a result of a detailed study of the phenomenon in the Murrumbidgee Irrigation Area, N.S.W., which, in general, seems to apply to the crabhole formations found on this area.

The main points of Howard's hypothesis can be summarized in the following way: Crabhole formation will take place on soils which allow an uneven infiltration into the B horizon which, because of its physical nature, swells and shrinks differentially. It is possible that the incidence of a dry season is important in the development of crabholes, for it is only the intermittent wetting and drying that can give rise to the mechanics required for formation. It is doubtful whether the Upotipotpon clay has even been solonetzic as required by Howard, but the nature of the clay with its self-mulching properties would allow of the same process. Examples of the various stages of formation can be found in different parts of the areas, which seems to indicate that rather special environmental circumstances may be required to set the process moving. Howard suggests this point in an unpublished report dealing more fully with the subject than the paper quoted above.

There is a feature associated with the Caniambo loam which is related to crabhole formation. On the lower slopes of the hills where this soil type occurs, mounds are frequently found which show a certain amount of cracking but unlike the lime puffs' of the crabhole areas they do not show the self-mulching tendencies. The formation of these mounds is also thought to be the result of uneven infiltration into the easily dispersed B horizon of the soil and has been discussed in a previous publication (Downes 1946).

(d) The Dookie-Cashel Series

In the diabase hills in the vicinity of Dookie the main soil type is the Dookie clay loam but associated with it are fairly extensive areas of the Cashel clay loam and some smaller areas of Major clay loam. Pedologically these soils are of great interest, for they show how entirely different soils may be developed from the same parent material if one or more of the factors of soil formation are sufficiently different. The factor of soil formation whose difference has caused the divergence of end product in the Major and Cashel series as opposed to the Dookie series, is that of drainage.

The Dookie clay loam is a leached soil, the surface soil reaction being pH 5 to 6 and the subsoil values not much higher. The pH of the parent material is neutral or slightly alkaline. The Cashel clay loam, however, is neutral or even slightly alkaline in the surface and the pH rises rapidly with depth to a value of pH 8 and then remains fairly constant with increasing depth. Both are highly structured soils and it is possibly this property which renders them so highly fertile. The Dookie clay loam is red and the Cashel clay loam is black; the former has a high free Fe_20_3 content, the value being about 10 per cent, while in the latter it is only 2 to 3 per

* Mean maximum temperature fro months December to March

† Estimated from map of isotherms for Victoria

cent. There is little difference in the organic carbon content of the surface horizons of the two soils but in the Cashel clay loam it is of the type common in humus-carbonate soils imparting an intense black colour.

The Cashel clay loam occurs in areas where there is restricted drainage, which causes the development of a generally higher watertable and as a result there has been calcium enrichment rather than calcium loss. Under these moist alkaline conditions the clay minerals formed are different from those formed in the acid well-drained environment typical of the Dookie clay loam. This is indicated to some extent by the difference between the. total amounts of exchangeable cations of the two soil types, the Dookie clay loam having 17 mg. equivalents and the Cashel clay loam 47 mg. equivalents per 100 g. of soil. The Major clay loam is an intermediate type which has been formed probably as the result of calcium enrichment, but the free Fe_20_3 content of 5 to 6 per cent is still sufficiently high to impart its effect to the soil colour. The net result is a chocolate colour due to a blending of the red from Fe_2Q_3 and the black from the organic matter. Full comparative results of analyses of these three soils are given in Appendix B.

4. Soil Maps

There are two soil maps accompanying this bulletin, the first being a detailed map showing the distribution of soil types in the parishes of Dookie, Currawa, Gowangardie, and Upotipotpon and the second a soil map of the sixteen parishes using the soil association as the mapping unit. No comment is required concerning the detailed soil map, but it is necessary to explain the objectives and the constitution of the soil associations in the broad scale map.

Over broad areas much useful information can be obtained from reconnaissance surveys provided the relationships between the individual soil types have been first established. It is found that the soils of an area constitute themselves into groups which are distributed according to a definite landscape pattern. This method of mapping has already been used by Butler *et al.* (1942) and Smith (1945). Such maps have limited application in the study of small units such as individual farms, but on a broader scale they present a useful synthesis which enables experience gained on a certain group of soils to be used on other parts of a large area where the same groups may be occurring.

5. Soil Associations

Gowangardie-Caniambo

The major soils of this association are the Gowangardie and Caniambo loams, but there may be included as minor components such soils as the Earlston and Koonda types which frequently follow small creek lines in the hill country on which this association occurs, and in rare cases some small areas of Nalinga loam are included. Unnamed skeletal soils of the Gowangardie type are found only in small patches within this association. The topography is hilly and the vegetation associated with the group is dry sclerophyll forest, grey box *(E. hemiphloia)* being the main species. (Plate 2, Fig. 2.)

Earlston-Koonda

The major soils in this group are the Earlston and Koonda fine sandy loams but there may also occur small areas of the Upotipotpon clay. The association is confined to flat or gently sloping areas since it is associated with creek lines and alluvial fans. The, vegetation is savannah woodland, the main species being yellow box (*E. melliodora)* and forest red gum *(E. tereticornis).* The association occurs in broad expanses south of the Broken River, particularly in the central part of the area. To the north the group gives way to the Shepparton and Orrvale series and to the south the areas diminish in extent until they are entirely creek line formations.

Dookie-Currawa

The main soils are the Dookie clay loam and the Currawa loam, although there may be some small areas of the Major and Cashel clay loams included. The association occurs on the hills and colluvial slopes of the Cambrian diabase, and the vegetation is mainly yellow box (*E. melliodora)* and pine *(Callitris robusta).* (Plate 1, Fig. l.)

Major-Cashel

The main soils are the Major and Cashel clay loams, although there may be included some small areas of Dookie clay loam and Currawa loam. Practically the whole of these areas has been cleared and is now cultivated, and consequently the nature of the original vegetation is uncertain. (Plate 1, Fig. l.)

Upotipotpon

The major type is the Upotipotpon clay and in most occurrences this is the only type, but where the broader expanses have been subject to some dissection there may occur small areas of other minor types in association with the Upotipotpon clay. The vegetation is mainly grey box (*E. hemiphloia)* savannah woodland, but in places red gum *(E. camaldulensis)* may be found associated with it.

Warrenbayne-Boho

The two major types in this association are the Warrenbayne and Boho sandy loams. These occur as residual soils on the igneous rocks or on the steep colluvial formations at the base of the mountains. The vegetation is sclerophyll forest of red box *(E. polyanthemos)* and red stringy bark (*E. macrorrhyncha)*. (Plate 2, Fig. l.)

Violettown-Balmattum

The Violettown and Balmattum sandy loams are the main types of this association, but it also includes areas of the minor types B and C. In some places there may be small patches of Upotipotpon clay and Earlston and Koonda fine sandy loams, the latter being along small dissecting creek lines. The association occurs on the gently rolling alluvial fans near the south-eastern hills. The vegetation is savannah woodland of grey box *(R. hemiphloia), with* yellow box *(E. melliodora)* and forest red gum *(E. tereticornis)* occurring in areas where the moisture conditions are sufficiently good.

Nalinga-Goorambat

This association occurs on the flat areas east of the Ordovician hills in the southern part of the Parish of Currawa, and also at the foot of the hills in the eastern part of the Parish of Devenish. The main types are the Nalinga loam formed chiefly at the foot of the Ordovician hills, and the Goorambat loam which occurs on the plain country. They have been placed together as a group only because of their limited occurrence and the fact that both are transitional podsol to red-brown earth soils. The vegetation is grey box *(E. hemiphloia)* savannah woodland.

Lemnos-Goulburn

This association includes all the soils of the Lemnos-Goulburn-Congupna catena (Skene and Freedman loc. cit.), except for the Congupna, clay of which there are few areas. Lemnos and Goulburn loam are the major soils and the vegetation is grey box (*E. hemiphloia)* savannah woodland. The association forms the major part of the plains in the north-western part of the area.

Shepparton-Broken

This association includes the Shepparton and Orrvale series along with the Lemnos fine sandy loam as the major soils, but the light-textured rises of the Broken and Grahamvale series have also been included. The vegetation is yellow box *(E. melliodora)* and grey box *(E. hemiphloia)* savannah woodland, with some yellow box and pine *(Callitris robusta)* on the lighter ridge soils.

Swamps

All areas which are inundated during the winter have been included in this group. The main type is the Congupna clay.

Unnamed skeletal soils

The rough stony country has been divided into two groups, on the basis of the geological formation on which they occur.

(a) That of the Devonian igneous country in the south.
(b That of the Cambrian diabase country in the north.

The significance of these associations in relation to agriculture and soil erosion is described in the relevant section later in the Bulletin.

VI. SOILS - CHEMICAL AND PHYSICAL CHARACTERISTICS

The chemical and physical properties have been studied both in the laboratory and in the field. So far as the soils of this survey are concerned, the chemical data are mainly of theoretical value, providing confirmation of the ideas concerning the pedogenesis of the soils which had been developed from their study in the field. The physical properties, however, are particularly important in a survey of this kind, where the main purpose is the study of the soils in relation to erosion. Structure and permeability are the physical properties which have been studied, for it is these which will determine the behaviour of a soil under conditions likely to cause erosion.

The complete analytical data are given in Appendix A, and extracts have been made to illustrate various points of interest which will be discussed below.

1. Mechanical Analysis

The data for mechanical analysis are self-explanatory and require little comment except for two minor points.

Table 10 - Comparison of fine sand silt content in Earlston and Koonda fine sandy loams formed on alluvial parent material derived from different sources

Earlston Fine Sandy Loam						**Koonda Fine Sandy Loam**					
Parent Material Derived from Igneous Rocks			**Parent Material Derived from Sedimentary Rocks**			**Parent Material Derived from Igneous Rocks**			**Parent Material Derived from Sedimentary Rocks**		
Depth (in)	**Fine Sand (%)**	**Silt (%)**	**Depth (in)**	**Fine Sand (%)**	**Silt (%)**	**Depth (in)**	**Fine Sand (%)**	**Silt (%)**	**Depth (in)**	**Fine Sand (%)**	**Silt (%)**
0-5	51.0	24.2	0-3	34.5	37.9	0-2	47.8	30.5	0-4	32.5	43.6
5-9	50.9	26.0	3-6	31.1	42.2	2-5	45.6	28.8	4-9	31.0	44.1
9-12	49.4	27.0	8-13	20.2	33.4	5-15	28.9	24.5	10-18	25.5	35.2
12-20	39.5	27.1	13-24	19.0	25.0	15-40	38.2	21.6	18-38	19.7	31.8
20-24	27.9	25.9	24-44	29.8	31.1	40-45	29.3	11.0	38-48	18.3	36.6
24-38	27.8	22.3	44-60	35.5	25.2	45-65	39.1	28.8			
39-60	35.2	22.4									

The Earlston and Koonda series have been formed on fine sandy alluvial parent materials which have been derived from two sources, in the south from the igneous rocks of the south-eastern mountains and in the central parishes from the Ordovician and Silurian sedimentary rocks of the central hills. No difference between the soils formed on the different alluvia was observable in the field, but the mechanical analyses indicate a slight difference in the proportions of fine sand and silt in soils from the different localities. These are given in Table 10.

The field textures of. all horizons of the Dookie, Major, and Cashel series of soils are lighter than mechanical analysis figures seem to indicate, which is a reflection of the good structure of the soils.