PART II

THE FEATURES OF THE ENVIRONMENT

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CLIMATE[*]

FEATURES OF THE CLIMATE

(i) Precipitation

(1) Types of precipitation: Most precipitation occurs as rain; however, above about 4,500 feet a large proportion of winter precipitation is snow, and a good deal of the high country is snow-covered for much of the winter. There are no local records of contributions by other forms of precipitation such as hail and dew, but they are not expected to add significantly to annual totals, although fog-drip may cause increases in mountainous areas where low cloud is common (Costin and Wimbush 1961).

(2) Distribution over the Catchment: Average annual rainfall in the north of the catchment is about. 28 inches rising to about 30 inches at Leneva in the Middle Creek catchment, and to 38 inches at Yackandandah. There is an increase to about 40 inches at Kancoona, and to 46 inches at Tawonga. Annual rainfall on the Stanley plateau is about 50 inches. At Bogong township in the southern mountains, the average rainfall is 74 inches. The average at Hotham Heights is only 58 inches although the Bogong High Plains station is reported (Carr and Turner 1959) to have an average annual precipitation of 95.5 inches. Average annual isohyets are shown on Figure 1.

(3) *Seasonal Rainfall:* In all seasons there is a gradual increase in rainfall from the north of the catchment to the south, and with increasing elevation of the land. Summer (December-February) is the driest season with averages of about 5 inches in the north to about 12 inches on the high country in the south. Winter rainfall (June-August) is usually about twice as much as in summer. In the north, the winters average about 10 inches and on the high country in the south total winter precipitation may be in excess of 20 inches.

Seasonal averages for a number of stations are set out in Table 1.

TABLE 1 - Average Seasonal Rainfall (inches)

Station	Season			
	Summer (Dec-Feb)	Autumn (March-May)	Winter (June-Aug)	Spring (Sept-Nov)
Middle Creek	4.8	6.8	11.2	7.8
Tangambalanga	5.4	6.6	10.7	7.2
Yackandandah	6.8	8.6	13.6	9.5
Tawonga	6.9	11.0	15.7	11.9
Stanley Nursery	6.9	12.0	17.6	14.0
Bogong (town)	10.2	16.0	28.6	19.5
Hotham Heights	11.9	15.0	16.3	14.9

***(4) Rainfall Intensity* :** The intensity of individual storms is an important factor affecting erosion and run-off but, such information is not available for this catchment. An indication of the erosive power of the rain on a monthly basis is average rain per wet day. These figures are derived from average monthly rainfall and the average number of wet days per month. They have been calculated for a number of localities in the catchment and are graphed in Figure 2 together with the average annual rain per wet day.

When considered together with seasonal variation of ground cover, rain per wet day can provide useful indications of the periods of higher erosion hazard.

The annual average rain per wet day increases with increasing average annual rainfall.

[*] Climatic data has been obtained from Commonwealth Bureau of Meterology (1956 and pers. comm.) and Central Planning Authority (1949).

Fig 1 - Annual rainfall isohyets in the Kiewa catchment

(Based on rainfall records, inferred orographic effects and vegetation)

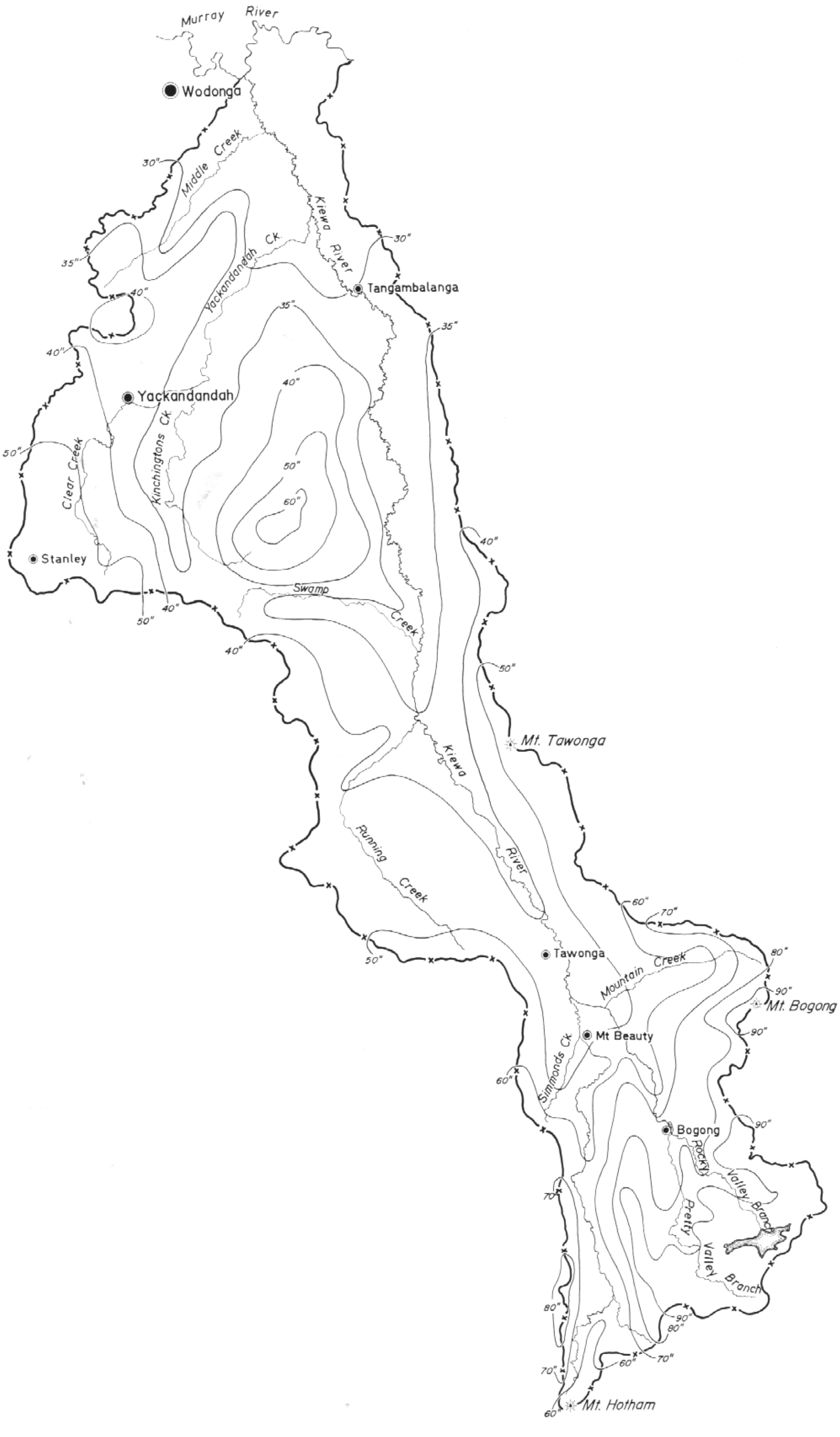


TABLE 2 - Average Monthly Maximum and Minimum and Average Mean Monthly Temperature (^oF)

Station	Approx altitude (ft)	Data	Number of years of record	Monthly temperatures												Year
				Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
Albury*	500	Average maximum temperature	71	91.5	90.7	84.6	74.3	64.5	57.4	56.5	60.4	66.7	73.9	81.9	87.8	74.2
		Average minimum temperature	71	59.6	59.1	54.2	46.7	40.8	38.6	36.5	38.5	42.1	46.9	52.1	56.4	47.6
		Average mean temperature	71	75.6	74.9	69.4	60.5	52.7	48.0	46.5	49.5	54.5	60.4	67.0	72.1	60.9
Hume Reservoir*	650	Average maximum temperature	26	86.9	86.4	80.4	70.3	61.8	54.6	53.5	57.3	63.4	70.0	77.9	84.1	70.6
		Average minimum temperature	26	60.0	59.8	55.5	48.8	43.1	39.3	38.1	40.0	43.3	47.7	52.6	57.4	48.5
		Average mean temperature	26	73.5	73.1	68.1	59.5	52.5	46.9	45.8	48.7	53.3	58.8	65.3	70.7	59.7
Beechworth	1,800	Average maximum temperature	32	80.6	81.2	75.0	65.4	57.4	51.0	49.7	52.6	58.1	64.4	71.5	77.2	65.3
		Average minimum temperature	32	56.6	57.3	53.1	46.5	42.3	39.0	37.7	39.0	41.9	45.7	49.8	53.9	46.9
		Average mean temperature	32	68.6	69.2	64.0	56.3	49.9	45.0	43.7	45.9	50.0	55.0	60.7	65.5	56.1
Bogong	2,150	Average maximum temperature	5	78.3	76.5	71.2	64.0	57.4	51.3	48.3	50.9	57.8	60.8	67.9	73.7	63.2
		Average minimum temperature	5	64.4	64.6	59.6	53.6	48.0	42.6	41.3	42.2	47.7	50.5	56.5	61.0	52.7
		Average mean temperature	5	71.4	70.6	65.4	58.8	52.7	46.9	44.8	46.6	52.8	55.7	62.2	67.4	57.9
Bogong High Plains†	5,300	Average maximum temperature	12	75.8	73.5	69.0	61.3	53.2	45.7	43.4	44.6	50.4	59.4	69.1	73.8	59.9
		Average minimum temperature	12	29.1	29.0	27.1	22.3	21.4	19.9	17.6	18.7	18.9	22.3	24.3	26.8	23.1
		Average mean temperature	12	52.5	51.3	48.0	41.8	37.3	32.8	30.5	31.7	34.7	40.9	46.7	50.3	41.5
Hotham Heights	5,900	Average maximum temperature	16	61.0	59.8	56.3	47.2	40.6	35.0	32.4	33.9	38.2	45.7	52.6	57.5	46.7
		Average minimum temperature	16	44.2	44.2	42.4	35.1	31.1	26.7	24.9	25.7	28.2	33.4	37.9	42.1	34.7
		Average mean temperature	16	52.6	52.0	49.4	41.2	35.9	30.9	28.7	29.8	33.2	39.6	45.3	49.8	40.7

* Stations outside the catchment

† From Carr and Turner (1959)

(ii) Temperature

Table 2 provides temperature data for Albury, Hume Reservoir, Beechworth, Bogong, Bogong High Plains and Hotham Heights.

Because of the paucity of data on temperatures in the region, an attempt has been made to analyse the existing data and relate it to elevation (Rowe 1967). Good correlations were obtained when average monthly mean temperature was used (r = 0.991 for January; r = 0.988 for July, with 4 d.f.). With mean monthly maxima the correlation was still high (r = 0.968 for January), but with mean monthly minima the correlation was not significant (r = 0.756 for January). The lack of correlation may be attributed to the effect of cold-air drainage which is influenced to a greater extent by topography than by elevation.

Table 3 contains estimates of average mean monthly temperatures for Kiewa, Yackandandah and Tawonga, derived from the regression lines based on elevation (Rowe op. cit.).

TABLE 3 - Estimated Average Monthly Temperatures (^{o}F)

Locality	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Kiewa	73	72	69	60	54	58	47	49	53	59	65	70	60
Yackandandah	72	72	68	59	53	48	46	48	53	58	64	69	59
Tawonga	71	70	66	58	52	47	45	47	51	57	63	68	58

Frosts are an important feature of the climate in relation to land-use, particularly for certain frost-sensitive crops such as maize and tobacco. Frost data from Hotham Heights are set out in Table 4 together with data from three stations outside the catchment but adjacent to it, which may be taken as representative of the Bonegilla-Bandiana area (Albury), the plateau country of the Leneva and Baranduda Range areas (Beechworth) and the lower parts of the valley in the Dederang-Tawonga area (Myrtleford).

It should be noted that temperature data is recorded at 4 feet above ground in a meteorological screen. A minimum screen temperature of 36^{o}F is regarded as indicating a light frost at ground level, and 32^{o}F indicates a heavy frost on the ground (Foley 1945).

Generally, the higher the elevation the longer the frosty period, and the more severe the frosts. A comparison of the figures for Albury (530 feet), Beechworth (1,800 feet) and Mt. Hotham (6,100 feet) illustrates this well.

Because cold air drains into valleys, sites in flat-bottomed, narrow valleys will be more frosty than those on the higher, adjacent slopes. A "frost-hollow" may be created by the arrangement of land forms or may also result from the existence of vegetative barriers, such as hedges, windbreaks or the strip of trees left along roads (Geiger 1965).

Myrtleford and Albury, although having similar elevation, differ greatly in frost incidence. Myrtleford is at the junction of several valleys which drain country of relatively high elevation, whereas Albury is on the margin of the Murray flood-plain on rolling country of low elevation.

Where any attempt is made to extrapolate frost data, elevation and topography must be carefully considered.

Fig 2 - Average rain per wet day

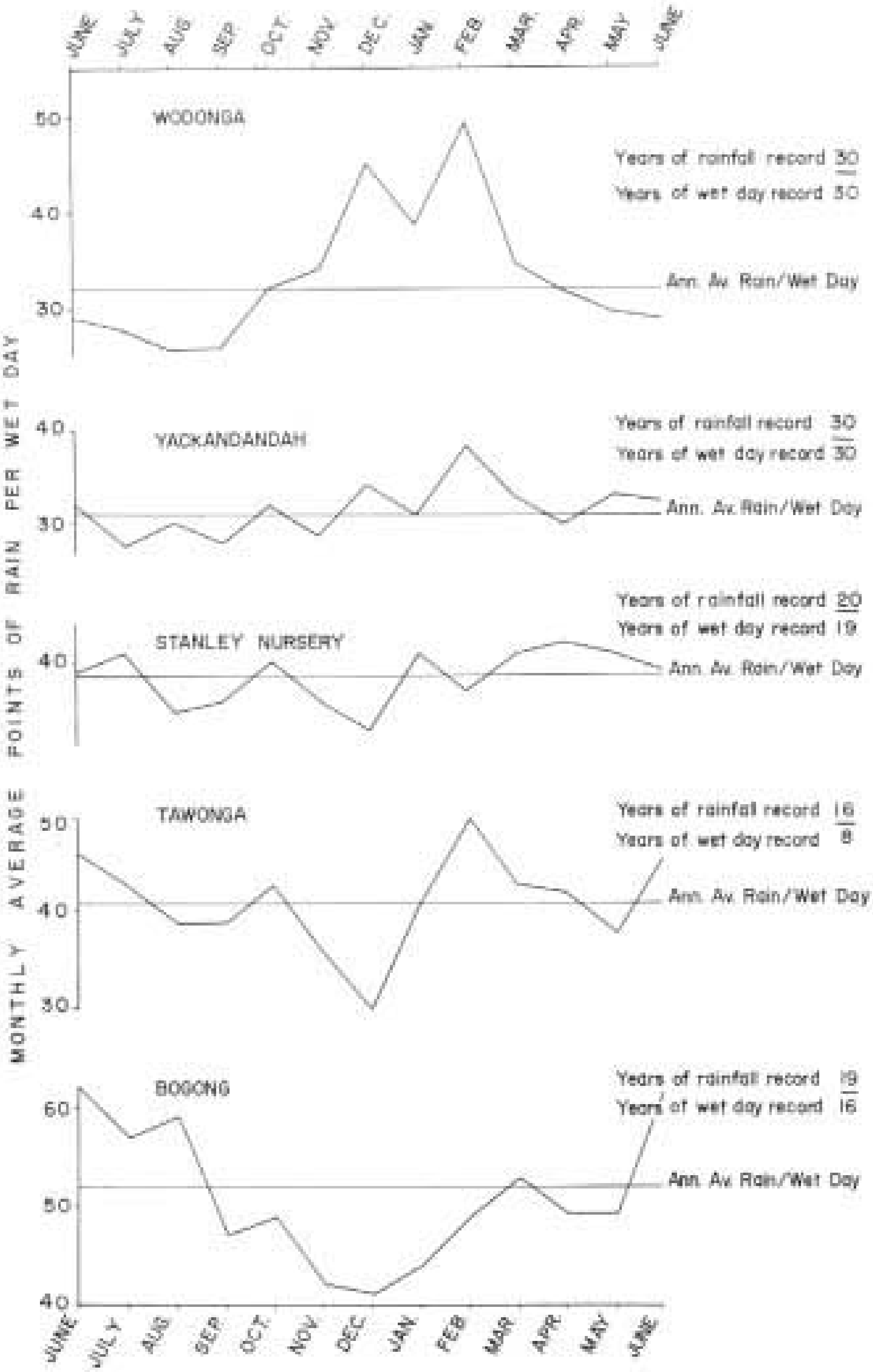


TABLE 4 - Frost Data for Stations in or Adjacent to the Kiewa Catchment (from Fole7 1945)

Station	First 36°F			First 32°F			Last 32°F			Last 36°F			Average frost-free period (36°F + days)
	1	2	3	1	2	3	1	2	3	1	2	3	
Albury	May 17	11	Apr 15	June 15*	12	Apr 30	Aug 1*	15	Oct 23	Sept 9	14	Nov 10	249
Beechworth	Apr 4	30	Jan 16	May 28	29	Mar 21	Sept 18	23	Nov 11	Nov 6	20	Dec 21	148
Myrtleford	Mar 19	29	Jan 8	Apr 29	16	Mar 1	Oct 21	29	Nov 23	Nov 11	12	Dec 10	127
Hotham Heights	Jan 6	3	Jan 3	Jan 12	7	Jan 3	Dec 17	9	Dec 26	Dec 23	5	Dec 26	13

(iii) Humidity

Humidity records are available for Wodonga, Bogong and Hotham Heights (Commonwealth Bureau of Meteorology pers. comm. 1962). These are set out in Tables 5 and 6.

TABLE 5 - Mean Monthly 9 a.m. Relative Humidity (per cent.)

Station	No. of years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Wodonga	33	47	52	58	68	81	87	87	81	69	60	52	47	66
Bogong	5	60	73	79	79	88	86	90	87	79	71	67	64	77
Hotham Heights	9	65	65	69	73	74	86	94	91	83	73	65	66	75

TABLE 6 - Mean Monthly 3 p.m. Relative Humidity (per cent.)

Station	No. of years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Wodonga	29	29	31	35	45	55	64	64	58	50	40	33	29	44
Bogong	5	42	55	58	64	74	77	79	71	64	64	60	51	63

Relative humidities are higher in the cooler months, partly because of the lower temperatures, but also because of increased availability of moisture.

Exposure to winds which mix the air usually results in reduction of humidity. Thus, exposed situations will have lower humidities than sheltered situations, other things being equal.

The relationship between relative humidities at Bogong (2,150 feet), a sheltered situation, and Hotham Heights (5,900 feet), an exposed situation, is complicated by these factors.

At the northern end of the catchment in an open situation as represented by Wodonga; a difference of about 20 per cent. is maintained between the 9 a.m. and 3 p.m. relative humidities throughout the year. However in the narrow valleys at higher elevations, such as is represented by Bogong, the difference ranges from about 20 per cent in summer months, to about 11 per cent in winter.

(iv) Evaporation and Evapotranspiration

The potential evapotranspiration is the maximum amount of moisture which may be lost by evaporation and transpiration from a fully vegetated area when soil moisture is non-limiting (Thornthwaite 1948). This is a useful parameter when considering the effectiveness of rainfall for plant growth and in estimating water yield from catchments.

The method used to calculate this is the one proposed by Thornthwaite as modified by Leeper (1950). It is based on average mean monthly temperature and the average annual temperature. The basic assumption is that with no factors limiting, the evaporating power of the atmosphere is a function of the temperature. It does not take any account of the important effect of humidity or wind, and in windy areas there would be considerable underestimation.

Because it is an empirical formula its application outside the area for which it was developed may provide unsatisfactory results. Leeper's modifications are intended to adapt it for use in southern Australia. This method has been used because the data necessary for its calculation is available for a few localities and can be easily estimated with reasonable accuracy. Other methods which may give more satisfactory results require data, such as saturation deficit, which is not generally available in this area.

Estimates of potential evapotranspiration for various areas are set out in Table 7. Because of the lack of temperature records for much of the catchment, the estimates of average temperature derived from the regressions of temperature on elevation have been used.

TABLE 7 - Potential Evapotranspiration (inches)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Hotham Heights	2.8	2.3	2.0	1.1	0.6	0.3	0.2	0.3	0.6	1.1	1.7	2.4	15.4
Stanley	4.2	3.5	3.0	1.7	1.1	0.6	0.5	0.7	1.2	2.0	2.8	3.7	25.0
Tawonga	4.8	3.8	3.4	2.0	1.3	0.8	0.7	0.9	1.4	2.3	3.2	4.3	28.9
Yackandandah	5.1	4.2	3.7	2.1	1.4	0.8	0.8	1.0	1.5	2.5	3.4	4.6	31.1
Tangambalanga	5.1	4.2	3.7	2.1	1.4	0.8	0.8	1.0	1.5	2.5	3.4	4.6	31.1

Within the catchment, evaporation has been measured only at the Bogong High Plains station, however figures for Hume Reservoir are included in Table 8 for comparison.

TABLE 8 - Average Monthly and Annual Evaporation from Free Water Surface (inches)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Hume Reservoir✝	7.2	5.7	4.6	2.8	1.4	0.9	0.9	1.1	1.9	3.1	4.7	6.5	40.7
Bogong High Plains✣	7.3	5.7	4.5	3.1	0.9	0.4*	0.4*	0.3*	0.6	3.6	5.7	6.8	38.7

✝ Data supplied by Comm. Bur. Of Met. (Priv. Comm.)
✣ from Carr and Turner (1959)
* Evaporation from snow

The relatively high Bogong High Plains figures probably indicate the effect of the windy environment. It is generally found that potential evapotranspiration calculated by the Thornthwaite formula is about 75 per cent. of evaporation from a free-water surface. The figures for Wodonga and Hume Reservoir show this relationship.

EFFECT OF CLIMATE ON LAND-USE

(i) Effect of Climate on Agriculture

(1) Effective Rainfall: Effective rainfall is defined as the amount necessary to start germination and to maintain plant growth above the wilting point. (Central Planning Authority 1949). Figures of percentage frequency of occurrence of effective rainfall for selected stations have been published by Central Planning Authority (op. cit.) and those relevant to the Kiewa catchment are reproduced in Table 9. The figures for Mitta Mitta and Harrietville are included as they represent situations similar to Tawonga and Bogong respectively. The latter comparison, however, is rather unsatisfactory as Bogong is in a narrower valley at a slightly higher elevation and receives more rain. It may be inferred from these differences that at Bogong the occurrence of effective rain would be even higher than at Harrietville.

TABLE 9 - Percentage Frequency of Occurrence of Effective Rainfall (from Central Planning Authority 1949)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Wodonga	31	33	51	65	85	99	100	95	86	75	42	42
Yackandandah	36	41	60	72	91	99	100	100	98	86	55	55
*Mitta Mitta	52	50	70	76	90	100	99	95	99	90	68	65
*Harrietville	63	68	73	87	97	100	100	99	100	96	87	78

* Included to indicate conditions which may be similar to Tawonga and Bogong respectively.

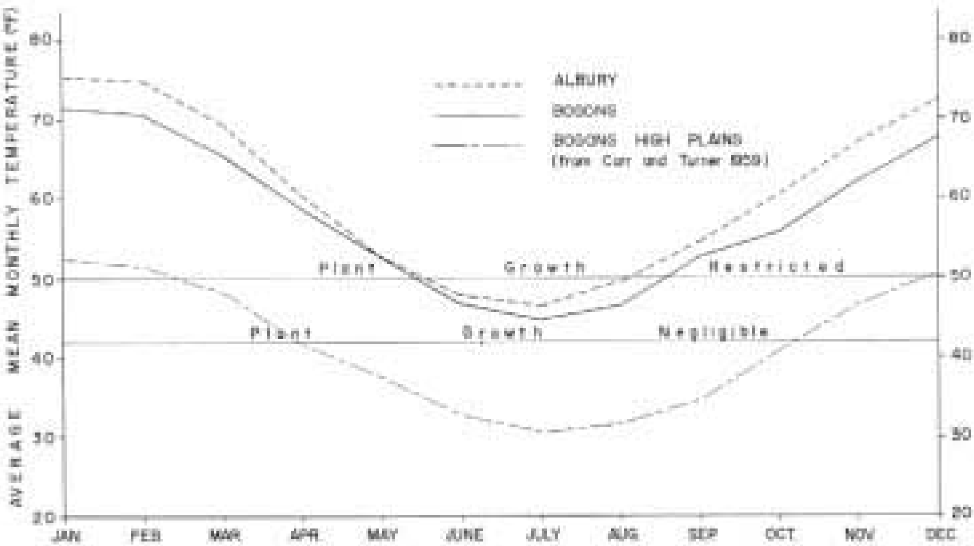
An increase in the occurrence of effective rainfall from north to south in the catchment is clearly indicated in all but the winter months. In January and February, only in about three years in ten can effective rainfall be expected in the north of the catchment, but at the southern end of the agricultural land it can be expected in six to seven years out of ten. During the winter months of June to August, effective rainfall is received in practically all years.

(2) Temperature and Frost effects in Agriculture: Low temperatures, such as occur during the winter months, can restrict or completely inhibit plant growth. Although various plant species have varying tolerances to low temperatures, it is commonly accepted that in a month with an average temperature of 50°F or less, plant growth is retarded (Trumble 1939). Furthermore, it has been suggested (Tumble op. cit., Manley 1945) that in a month which has an average temperature of 42°F or less plant growth is negligible. These temperature limits may be used to indicate the limiting effects of temperature on plant growth during the various months.

Graphs of average mean monthly temperatures for three representative locations are presented in Figure 3 and the 50°F- limit and 42°F-limit lines are indicated. From these graphs it can be seen that over much of the lower elevation country plant growth may be slowed by low temperatures from late May or early June. In the north however, temperatures become favourable for active growth several weeks earlier than in the south and in no month is growth completely inhibited.

At higher elevations, for example on the Bogong High Plains, only during December to February are temperatures high enough for consistently active plant growth, and from April through to October temperatures are low enough to prevent any significant plant growth. This example emphasises the severity of the climate for plant growth at the higher elevations.

Fig 3 - Average mean monthly temperatures and their effect on plant growth



The average frost-free period of an area is a useful guide to the possibility of successfully growing certain frost-sensitive crops. The northern, rolling valley slopes and low hills may be expected to have a frost-free period (36°F + days) of about 250 days, between early September and mid-May (see Table 4). The lower, rolling country in the Tawonga-Dederang area may be expected to have a frost-free period of about 150 days between early November and mid-March. In both localities low lying land will be somewhat more frosty than the better drained country. The high-elevation plains country (Hotham Heights) has an average frost-free period of only 13 days in late December and a high variability.

Horticultural crops vary in their tolerance to frost, some being killed outright by a frost during the growing period. Critical periods for many are during the early flowering or fruit-setting stages. A range of horticultural crops and their frost-critical periods is given by Foley (1943).

At high elevations, frost can be an active agent in soil erosion. Bare soil suffers considerable surface disturbance by the freezing and thawing caused by severe frosts. Following the thawing of the frost or "needle-ice", the soil surface is left loose and friable and is readily eroded by wind or water. On steep slopes, frost action accelerates soil creep.

Also, at high elevations, seedling establishment on bare soil is very difficult because of frost-heave of the shallow-rooted plants.

(3) Length of Growing Season-Growth Patterns: The length of the growing season is strongly influenced by the availability of soil moisture and the suitability of temperatures. In Figures 4 and 5 an attempt has been made to show the monthly availability of soil moisture as influenced by precipitation and potential evapotranspiration, at Tangambalanga in the northern agricultural land and at Tawonga in the south. As the data for precipitation and potential evapotranspiration are for the hypothetical average year, and each represents the total for that parameter over the respective months, the data for both is plotted as an "end-of-month" figure. The plotted data thus represents the situation at the end of each month.

Although there is no way of knowing from this data when the change occurs from a surplus of precipitation over potential evapotranspiration to a deficit, or vice-versa, the slopes of the lines joining the monthly points provide some indication of the relative rates of change of the parameters, so that the actual intersection points of the two graphs may be used as a guide.

Graphs of the moisture available to plants, for soil storage capacities of 1 inch, 2 inches, 4 inches, and 6 inches are shown, and graphs of average mean monthly temperatures are included. The patterns of plant growth through the year for soil/plant combinations resulting in 2 inch and 4 inch of available soil moisture are also shown.

At Tangambalanga (Figure 4), plant-growth is initiated as rainfall exceeds evapotranspiration in early May, however by early June, decreasing temperatures reduce the rate of growth. Increasing temperatures in August produce increases in plant growth, and the spring flush is underway by the end of August. The length of the period of good growth following the early spring flush depends on the available-water capacity of the soil. On shallow, sandy soils with only 1 inch of available-water, growth starts to diminish early in November. With 2 inches or 4 inches of available-water, the decline of growth commences in mid-November or early December, however growth may persist into late December if 4 inches of soil moisture is available. Where 6 inches of available-water is stored in the soil, growth continues into January. These analyses indicate that in the north, about a seven-month growing season may be expected on shallow soil, extending to a little less than nine months on deep soils with at least 6 inches of stored moisture.

At Tawonga (Figure 5) growth is initiated in late March or early April, and continues until low temperatures reduce the growth rate in late May. The spring flush commences in early September in response to rising temperatures, and active growth continues until early December on soils with only 1 inch available-water storage. If 2 inches or 4 inches of stored moisture is available, active growth will continue into January, with the latter giving about 2 weeks more growth. With at least 6 inches of moisture available, soil moisture is sufficient to allow continuous growth throughout the year, the only restriction to growth resulting from low temperatures during the winter months. Thus, if only 1 inch of soil moisture is available, the growing season is a little over eight months, with 2 inches or 4 inches available, it is nine months or a little more, and if at least 6 inches is available, growth may continue for the whole twelve months.

Some plants complete their life cycle in a few months. Obviously the above comments do not apply to such plants, but will indicate the average growth patterns of plants capable of making use of optimum conditions when they become available. Generally, these are perennials, or annuals, the life-cycles of which are controlled by availability of moisture. The patterns of growth discussed above should apply to permanent pastures in the respective areas.

In the agricultural areas of this catchment the frost period coincides with the period of the greatest availability of soil moisture. If frost-sensitive plants are to be grown, irrigation is necessary to provide moisture during the frost-free period.

The evapotranspiration figures used in these analyses are based on the assumption of full leaf cover. Clean cultivation, such as is practised in row-cropping, orchards and vineyards is aimed at reducing transpiration by unwanted vegetation, and increasing the amount of soil moisture available for the cultivated plant. Such crops will not have the same growth patterns as discussed earlier.

Use is sometimes made of the percentage frequency of occurrence of effective rainfall (Table 9) to predict length of growing season. The first month which has a percentage of at least 50, and is followed by other such months, marks the start of the growing season, and the number of consecutive months with frequencies of at least 50 per cent. indicates the length of the growing season. The data for Wodonga (Table 9), which should be similar for Tangambalanga, indicate an eight-month growing season from March to October inclusive, and figures for Mitta Mitta, which is assumed to be similar to Tawonga, indicate a full twelve-month growing season. These figures correspond fairly well with those obtained by the soil-moisture balance method used in this section.

(ii) Effect of Climate on Hydrological Conditions.

The climate influences the quantity of water yielded by the catchment and the rate of yield, which may also affect water quality, depending on other factors such as soil conditions and ground cover.

Although to a large extent total yield of water is closely related to total precipitation, over which man has no sure control at present, the relationship between the availability and utilization of moisture also influences total yield. In this area, potential evapotranspiration is greatest in summer and least in winter. As a high proportion of the total precipitation occurs in winter, so the yield of water is relatively high.

Fig 4 - Patterns of growth at Tangambalanga (as influenced by rainfall, potential evapotranspiration, temperature and soil moisture storage)

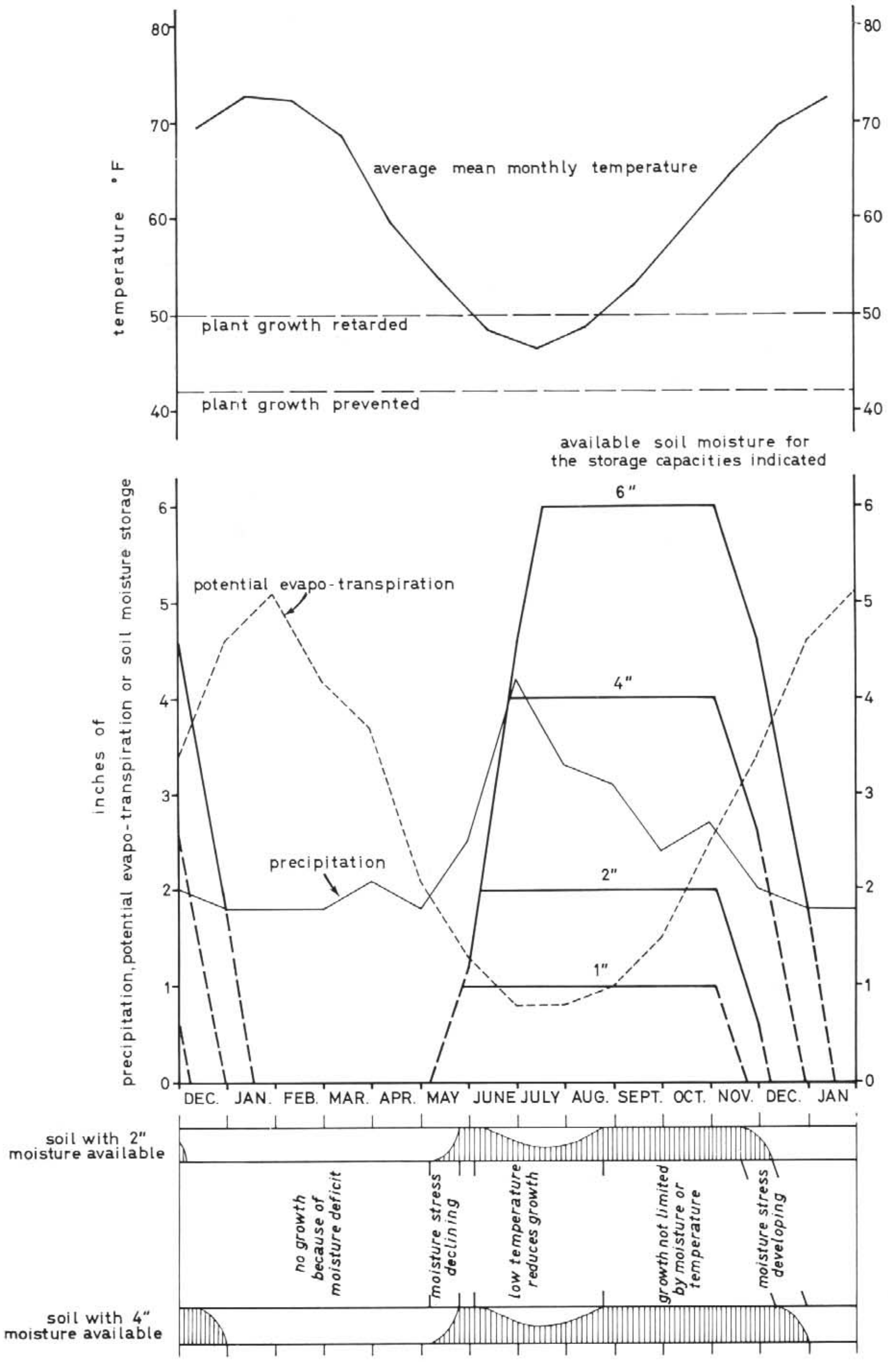
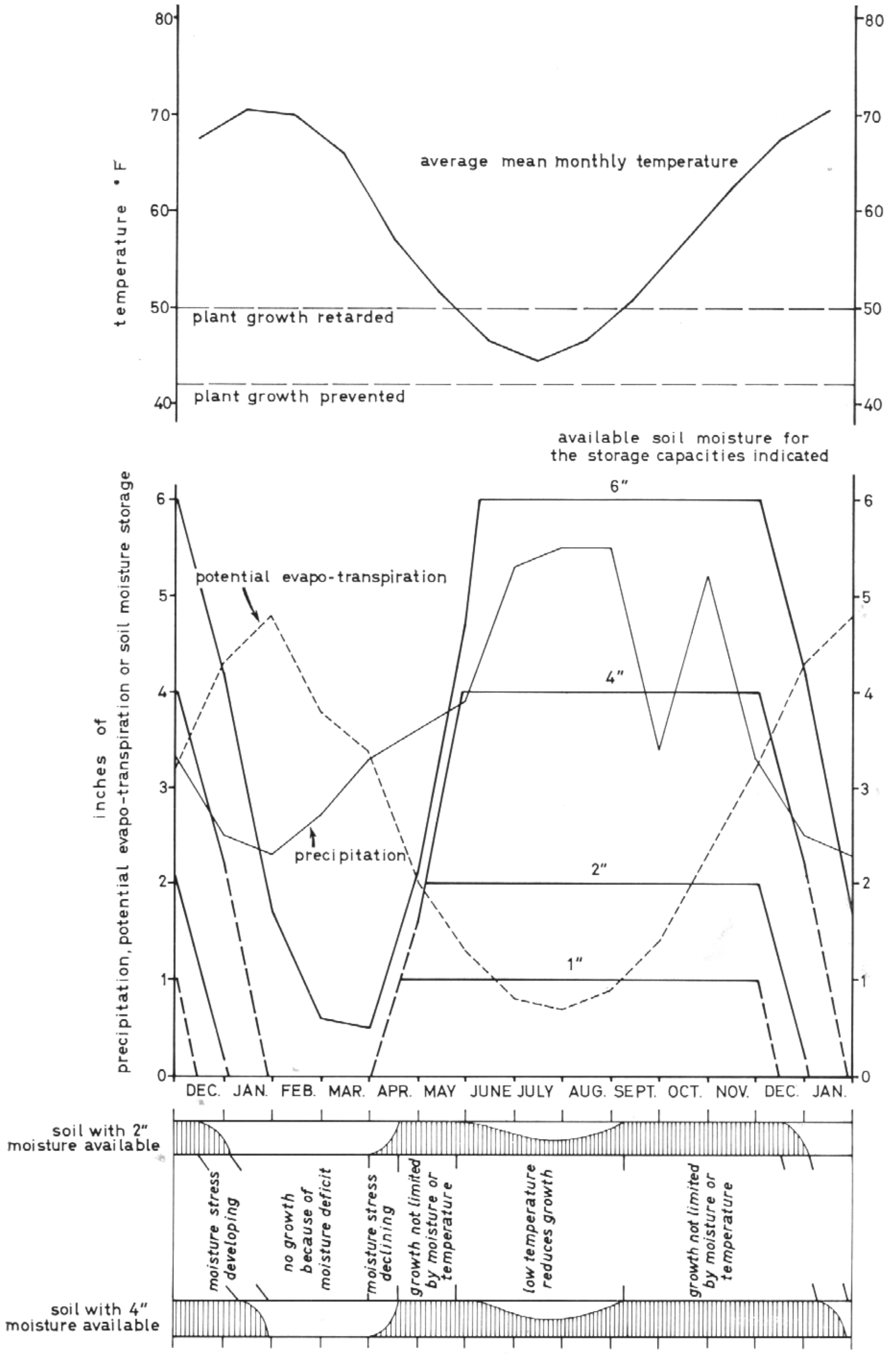


Fig 5 - Patterns of growth at Tawonga (as influenced by rainfall, potential evapotranspiration, temperature and soil moisture storage)



It is possible to alter the relation between availability and use by alteration of the vegetation, for example by replacing deep rooting vegetation by shallow.

Precipitation which falls as snow and forms drifts results in the storage of water. In this catchment snow falls predominantly in the winter, and most of it has melted by early summer. This also results in a high proportion of precipitation becoming available as run-off.

The combination of lower evapotranspiration and higher rainfall at higher elevations results in the higher country providing greater quantities of water for stream flow than lower country. The data presented in Table 10 demonstrates the relative importance of the higher country for water supply. The potential run-off data was obtained by calculating water budgets for country within the stated elevations on the same basis as those in Figures 4 and 5.

TABLE 10 - Proportions of Potential Stream Flow Contributed by Various Parts of the Catchment

Country between elevations stated	Potential run-off (ac.ft/sq mile)	Percentage of Catchment Area	Potential contribution to stream flow as a percentage of potential total yield
Below 1,000 ft	200	26	7
1,000-3,000 ft	650	52	41
3,000-5,000 ft	1,750	14	29
Over 5,000 ft	2,480	8	23

(iii) Effect of Climate on Erosion

High intensity storms generally result in some surface run-off. If the areas subjected to surface flows are not well protected by vegetative ground cover or mechanical impedants such as natural roughness, or contour furrows or banks, soil movement may occur.

Months in which rainfall intensities are higher than average, and during which ground cover is likely to be poor, are hazardous for erosion.

In ungrazed and forested areas, seasonal variation in ground cover is low and there is not normally a period when cover is inadequate. In such areas, the erosion hazard is not generally directly influenced by seasonal conditions. A major modifier of ground cover in forest areas is fire. As the most destructive fires occur in summer, ground cover remaining after a fire may be inadequate to cope with the late summer and autumn storm run-off.

Cultivation for sowing cereal crops or improved pasture results in bare soil, usually from at least late summer through until the crop or pasture has developed a more-or-less closed sward. Clean cultivation of orchards results in bare soil being exposed for much of the year.

In grazing land, the end of the dry season, usually late summer and early autumn, is the period when ground cover is at a minimum. Obviously, the condition of the ground cover depends very largely on the management of the grazing stock.

By comparing the monthly average rain per wet day (Figure 2) and monthly growth patterns (Figures 4 and 5), the months when the potential hazard is high for grazing land may be determined. The actual hazard can be assessed from a consideration of soil conditions and topography in relation to hazardous periods as indicated below.

In the north of the catchment, for example at Tangambalanga (Figure 4), the summer drought generally extends from early January to late April, even with substantial soil-moisture storage. Over this period, annual pastures produce no significant new growth, and perennials are maintained by occasional showers. Heavy grazing may result in very little dry herbage remaining towards the end of the dry period, particularly if the onset of conditions suitable for plant growth is late. Thus, late summer and early autumn (February, March and April), are the periods when the ground cover in the northern grazing areas is at its minimum. The graph of monthly average rain per wet day for Wodonga (Figure 2) indicates above average intensities from November to March with a peak in December and a very high peak in February. February is thus a month of high potential erosion hazard in the Wodonga area. In March, although storm intensities are not as high, ground cover can be expected to be even poorer than in February so that the potential hazard is still high.

At Yackandandah, a peak of rainfall intensity occurs in February and intensities are still above average in March. This indicates that these are hazardous months, but because of the lower intensities and somewhat better growing conditions the potential hazard is not as high as at Wodonga.

At Stanley only small peaks of high intensity rain are indicated in the critical months of March and April. Because of higher rainfalls and lower temperatures generally, the dry period at Stanley is not as prolonged as in the northern varies.

If the Tawonga growth pattern (Figure 5) is used as a guide to conditions on the Stanley plateau, and it is allowed that the somewhat lower temperatures at Stanley result in even less restriction to the growth of grazed pastures during summer, on even the driest soils in the Stanley area only March can be considered a critical month for ground cover. Because only slightly higher than average rainfall intensities are likely, the potential erosion hazard on grazed pasture land is only moderate.

However, orchards and potato growing are also important forms of agricultural land-use in the Stanley area. Clean-cultivated land may be subject to erosion from January to May inclusive and in July, because in these months rainfall intensities are a little above average ; however, the potential hazard is not high. Contour or near contour cultivation would minimise the hazard.

Although at Tawonga high-intensity rains occur in February, this is not a very critical month as pastures usually still provide good ground cover. Only in

March may ground cover be inadequate; however, in that month the rain intensities are only slightly above average so that the potential hazard is only moderate to low on pasture lands.

The highest average rain per wet day at Bogong occurs in winter. The main areas of bare soil in the upper valley and mountain tracts are roads and logging areas. Maintenance of road drainage should be intensified in the winter to ensure that the drainage can cope with the heavier rains. Logging is usually suspended during the wet winter months, but before equipment is withdrawn, snig tracks should be cut to prevent channelling of run-off.

These discussions are based on average data. If a run of good seasons occurs, with little rain of damagingly high intensities even badly overgrazed pastures may not become eroded. However, only one bad storm on an unprotected catchment is necessary to initiate a gully system which may remain active even if subsequent surface run-off is small.

Mass movements of earth such as slumping, and earth flows or mud flows occur on sloping land when the subsoil becomes semi-fluid as a result of prolonged soaking rain. Such conditions are most usual in winter and early spring.

The binding effect on the soil, of deep rooted plants, is particularly valuable in preventing mass movements. Mass movement of soil rarely occurs in forested country. Deep-rooted perennial vegetation also dries the soil to greater depths in summer and autumn, so that more rain is needed to satisfy the soil-moisture deficit and the soil does not become saturated as soon as where shallow rooted vegetation predominates. Southerly aspects are more subject to mass movement erosion than northerly aspects because of the lower soil-moisture usage resulting from less-intense insolation and lower temperatures.

Frost is an important agent of erosion, particularly in alpine and sub-alpine areas. Bare soil, such as on roadside and raceline batters, becomes loose and friable as a result of frost action, and in this condition it is more subject to erosion by wind and water.

Frost is also important in preventing the establishment of herbaceous regeneration on bare soil at high elevations. Shallow-rooted plants may be up-rooted by the development of needle ice. The maintenance of bare areas by frost action is an important contributing factor to erosion in alpine and sub-alpine areas. The frost data for Hotham Heights (Table 4) indicates the length of the frosty period with an average frost-free period of only 13 days.

Although no records of wind directions or intensities are available for the catchment, it is obvious from the form of sheet erosion seen on much of the ex posed alpine areas that the most severe and persistent winds are from the north west.

GEOLOGY AND SOIL PARENT MATERIALS

Geological information has been obtained from a report prepared by D. E. Thomas for the Central Planning Authority (1949), from the detailed study of the geology of the upper Kiewa area by Beavis (1962) and from the Geological Survey of Victoria (1966, 1968).

For most of its length the catchment consists of regionally metamorphosed rocks with scattered outcrops of granite or granodiorite. The long tongue of the Yackandandah Basin granite extends from the south into the catchment to the east of the Stanley plateau and as far north as the Yackandandah-Wodonga road just east of Allan's Flat (Plate 2). Several small granite outcrops are located further down the valley of Yackandandah Creek and on the western side of the Kiewa River at Baranduda. A large block of granodiorite extends south from about the confluence of Rocky Valley and Pretty Valley Creeks, and smaller occurrences are at the Niggerheads and in Rocky Valley. A block of quartz diorite is located on and to the west of Big Hill. The Stanley granite, which extends on to the Stanley plateau north of Mt. Stanley is a separate and younger intrusion from the Yackandandah Basin granite (Geological Survey of Victoria, Wangaratta SJ55-2 Map-sheet, 1968).

Plate 2 - Deeply weathered granite on an ancient, dissected land-surface in the Yackandandah area

Ordovician sandstones, mudstones and shales occur on the Stanley plateau and along the ridge to the head of Commissioners Creek, north-west of Yackandandah. Other areas of these Ordovician rocks are just to the west of Mt. Beauty township, the Pyramid Hill-Mt. Feathertop ridge and the catchment of the upper West Kiewa River.

Tertiary basalts occur on the High Plains where the most extensive area is around Mt. Jim. Smaller occurrences are, at Basalt Hill at the head of Rocky Valley, Ruined Castle to the east of Mt. McKay, and on Mt. Loch.

Extensive areas of alluvium occur in the valley of the Kiewa River north of Mt. Beauty township, and along Yackandandah, Middle and Running Creeks. Much of the undulating to rolling valley bottom is composed of ancient alluvium and colluvium, which now form high terraces, and the dissected slopes between the Recent alluvium and the steep slopes of valley escarpments (Plate 3). The more recent alluvium forms a relatively narrow band along the stream margins and is usually some 20 feet to 40 feet below the level of the upper terrace and truncated ancient pediment. The extensive flood plain of Recent alluvium at the confluence of the Kiewa and Murray Rivers is much dissected by anabranches and lagoons.

Soils are formed in the material produced by the weathering of rocks, so a basic classification of soil parent materials may be based on rock types. In this catchment the separation is made on the basis of basalt, granite and granodiorite, the gneiss and schist of the extensive metamorphic complex and the Ordovician interbedded slates and mudstones.

In the process of weathering, the chemical and physical nature of the rock is altered. The extent of the alteration depends on the nature of the rock itself, the topography, the climate, the organisms (plants and animals) and the length of time which all have been active in producing the present soils.

Some soils are formed on weathered material which has not been moved the material has weathered "in-situ". However, it is more usual for the weathered material to have been transported, perhaps only a short distance down a slope (colluvial transport) or perhaps long distances by streams (alluvial transport). During transport further changes may occur, particularly in the physical nature of the material. Coarse particles are abraded to finer ones and fine material is separated from coarse, as occurs in alluvial transport.

Some present-day soils have formed in material derived from the erosion of earlier soils. Probably all of the transported material in the valleys, on which the present-day soils occur, has undergone at least one cycle of weathering, soil-formation, erosion and transport before becoming stable and again being subjected to soil-forming processes.

Plate 3 - Highly weathered colluvium exposed in a road cutting at Gundowring South. The largest fragments are more than a foot across

It is clear then that the nature of the original rock may not be apparent in the soil parent material. However, there is usually some persistent constituent in the original rock which continues to influence the nature of the soil parent material even after many cycles of alteration.

Quartz and silica-rich material are very resistant to weathering. so that rocks which have a high proportion of such material produce silica-rich soil parent material whatever the intervening processes. However, the relative proportion of quartz will vary as weathering of non-resistant material produces fines which may be preferentially removed.

Basalt contains very little resistant siliceous material such as quartz, and weathers to generally fine textured material. It is relatively rich in calcium and magnesium which help to stabilise soil colloids and are valuable plant-nutrient elements.

The other rocks in the catchment vary in the proportion of quartz, and in the size of the resistant particles. The granite-granodiorite group produces a high proportion of coarse quartz grains. The slates and mudstones, though relatively siliceous, are fine textured. Although they tend to weather irregularly, often producing gravelly weathering products, they do not usually produce coarse sandy material as do the granitic rocks. The schists and gneisses vary considerably. The gneisses weather to similar material to the granitic rocks and the schists usually weather readily to generally fine textured material.

When differences caused by the different processes of transport, and variations in climate, organisms, topography and time are superimposed on the basic differences between rocks, a wide range of soil parent materials results. However, apart from those derived from recently weathered basalt, they are all relatively poor chemically. There are no calcareous soil parent materials in the catchment.

TOPOGRAPHY AND GEOMORPHOLOGY

(a) TOPOGRAPHY

Topographically, the catchment is simple. It consists of a major stream, the Kiewa River, with a relatively straight course slightly west of north, which drains a generally narrow catchment with elevations ranging from over 6,000 feet in the south to about 500 feet where it joins the Murray River. Over the northern three-quarters of its length the river flows through broad alluvial flats bordered by higher terraces and fans which rise gently to meet the hilly to mountainous country of the interfluves (Plate 4). In the southern quarter of the catchment the river splits into two main streams which drain steep mountainous country through narrow, gorge-like valleys.

Plate 4. Residual hills and colluvial fans near Kancoona. The valley slopes have been undercut by more recent stream activity. The flats in the foreground are above present-day high floods and are often overlain by younger alluvial fans.

Several important tributaries join the Kiewa from the west in the broad valley tract. The northern-most is Middle Creek which has a north-easterly course and drains a narrow and rather steeply graded valley with narrow and discontinuous terraces and flats, and gently sloping colluvial fans. The valley is bordered on the northern side by steep to hilly country and to the south by the steeper slopes of the Baranduda Range. This range, with its several small plateaux at around 2,000 feet elevation, is the divide between Middle Creek and Yackandandah Creek.

The catchment to the Yackandandah Creek extends to the south-west to include the Stanley plateau, at elevations of about 2,300 feet. After leaving the plateau, the several tributaries of the main stream flow through a mixture of steep and hilly country before emerging onto the somewhat elevated dissected strath bench around Yackandandah, at about 1,500 feet to 1,800 feet elevation. Just east of Yackandandah, the tributaries join to produce the Yackandandah Creek, which continues on a north-easterly course through a broadly rolling valley to the Kiewa River at Baranduda.

The area in the angle formed by the junction of the Kiewa River and Yackandandah Creek is occupied by steeply hilly to mountainous country, which rises to over 3,500 feet towards the south-western end of the Yackandandah Creek catchment. This is the Big Ben massif with Mt. Murramurrangbong at its north-eastern extension. Big Ben is topped by a plateau, and rolling, mildly dissected plateau remnants occur along the ridge to the north-east. Palmer's Gap, a low gap to the south-west of Big Ben, separates the massif from the catchment boundary, which at this point is itself a low saddle at the head of Barwidgee Creek, a tributary of the Ovens River.

The south-western slopes of Big Ben drain into Swamp Creek, which flows south-easterly to join the Kiewa River at Dederang. Although only a small valley, it contains excellent examples of the ancient alluvial-colluvial fans which are relatively extensive in this area.

Running Creek is a major tributary of the Kiewa entering from the west about four miles south of Dederang. It also has alluvial-colluvial fans merging with terraces and recent flats for much of its length. In its upper reaches it flows more or less parallel to the Kiewa River but turns sharply to flow in a north-easterly direction for the last four miles of its course. Except for the valley bottom, most of the country drained by Running Creek is steep and mountainous.

The only major tributary to the Kiewa River from the eastern side of the catchment is Mountain Creek which enters the East Kiewa River just south of its junction with the west branch. The valley bottom of Mountain Creek is relatively broad, and rolling to hilly for much of its length. Recent alluvial flats are not extensive except near its lower end. Apart from the valley bottom, the country drained is steep and mountainous, ranging up to the small plateau top of Mt. Bogong at over 6,500 feet.

Dissection of most of the southern, mountainous quarter of the catchment is deep, and the topography is steep to very steep, with narrow ridges and gorge-like valleys. However, the Bogong High Plains has escaped the major dissection, and the rolling to hilly topography is still preserved, although several very steep gorges have cut back into the plains. Several small plateaux, apparently remnants of the same land-surface represented by the Bogong High Plains, occur on Mt. Fainter, around the Niggerheads, and along the Mt. Lock-Mt. Hotham ridge (Plate 5). Elevations of most of the plains range about 5,500 feet with some areas up to about 6,000 feet.

Plate 5 - Headwaters of the West Kiewa River. Mt. Hotham is on the right and the Razorback is in the foreground. Stream dissection has destroyed all but a small area of the ancient land-surface of low relief in this area.

The East and West Kiewa Rivers are the two branches of the main stream in the south of the catchment. The East Kiewa is further divided into Pretty Valley and Rocky Valley Creeks, each of which rises on the High Plains. Rocky Valley dam and the proposed site for a dam on Pretty Valley are at the nick-points of the two streams.

(b) GEOMORPHOLOGY

The formation of the high country in the south of the catchment and the creation of the northerly draining stream which produced the catchment occurred in late-Tertiary as a result of the Kosciusko uplift. Beavis (1962) has described the combination of faulting and up-warping which occurred in the Kiewa area. A major fault, the Tawonga fault, is located just south of the junction of the

East and West Kiewa Rivers and marks the change from early-mature valley topography to the north to the youthful topography of rejuvenated streams to the south.

The easterly diversion of Running Creek in its lower reaches appears to be attributable to an E-W fault. There is a number of lineaments delimiting the valley of the Yackandandah Creek cast of Yackandandah, and the alignment of streams and saddles on both sides of this valley may be attributable to structural weaknesses. The course of Middle Creek is controlled by the eastern end of another major fault, the Beechworth fault (Thomas, Central Planning Authority, 1949). Many of the faults and probable faults are indicated on the Wangaratta (SJ55-2) and Tallangatta (SJ55-3) 1:250,000 sheets of the Geological Survey of Victoria (Mines Department of Victoria 1968 and 1966 respectively).

It seems likely that the small plateau surfaces on most of the northern interfluves, the Stanley plateau and the High Plains of the south may all have been part of the pre-Kosciusko surface. Variations in elevation may be due to faulting or simply to the distance from the axis of up-lift.

A number of the major tributaries which have a generally E-W trend are located in the northern side of their valleys. The terrace-fan landscape is usually most extensive on the southern sides of these streams. These are asymmetrical valleys with the slopes to the north of the stream being steeper than those to the south. It appears that the streams are migrating to the north. Twidale (1968, p. 174) offers several explanations for the formation of such valleys. A possibility not mentioned by Twidale is that the southerly aspects of the northern slopes result in more rapid weathering, and scarp retreat is more pronounced than on the drier northern aspects.

The area of rolling to hilly country around Yackandandah and to the south is the dissected remnant of an ancient valley floor-a strath bench, some 100 to 200 feet higher than the present valley floor. Highly-weathered river gravels occur to the south of Yackandandah on a spur top at the general level of the ancient surface. The surface has been almost entirely destroyed in the lower part of the valley of Yackandandah Creek, and Kinchingtons Creek has broadened its valley well into the remaining area. Most of the streams flowing from this area have prominent nick-points controlled by rock bars.

The elevated rolling landscape at Baranduda, at the north-eastern end of the Baranduda Range, and the broad gently sloping divide between the Mitta Mitta River and the Kiewa River at Bonegilla may be relatively mildly dissected relics of the same surface. Many of the residual hills which line the main valley may also be relics of this surface.

Extensive, and in some places high alluvial-colluvial fans make up a large part of the rolling valley landscape. Some of these large fans have been cut through by the roads at Dederang and Gundowring South. These cuttings expose highly weathered alluvial-colluvial material with a wide range of sizes up to cobbles a foot or more across (Plate 3). These deposits are at a lower level than that of the Yackandandah strath bench and are therefore more recent.

The main streams have several sets of paired terraces, although some members have been almost entirely eroded away and are now represented by narrow, discontinuous benches. There appear to be at least three terrace levels on what is commonly referred to as: the flood plain or "the flats". The highest of these is probably never inundated by the floods of the present time. These lower terrace levels are abundantly scarred with abandoned stream channels and meanders, many of which contain water throughout the year (Plate 25).

Remnants of at least three and probably four higher terraces can be found along the main valley, particularly in the north. The independence of the two intermediate levels has yet to be confirmed. The highest is represented by a number of shoulders of quartzitic, river gravel just below the catchment boundary at Bonegilla. The gravels exposed in the deep cuttings of the borrow pits below the wall of Lake Hume occur at still higher levels, but do not have the terrace form. Their origin is obscure at this time.

Recognition of the fact that the history of erosion and deposition, as reflected in the depositional and erosional land-forms, has influenced the soils and their distribution has led to the development of techniques for studying these relationships (Butler 1959; van Dijk 1959; van Dijk, Riddler and Rowe 1969).

Data derived from a State Rivers and Water Supply Commission survey of the Kiewa River in 1939 have been used to study changes in stream and floodplain gradients which contribute to, differences in flooding hazard and drainage of the lower terraces. (These effects, on land-use have been considered in subdividing the lowest terrace landscape, the Kiewa land system, into two sub-systems).

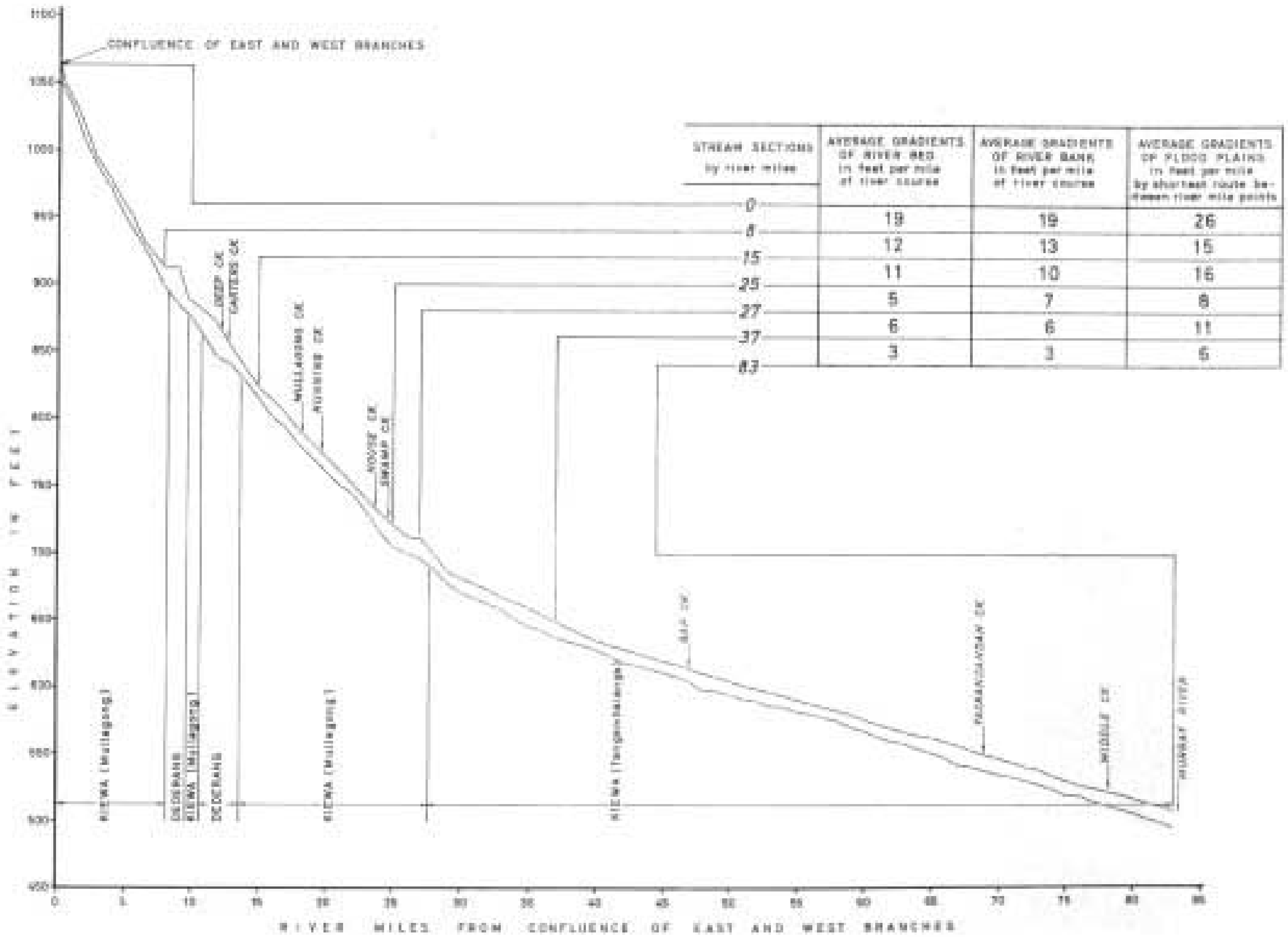
The elevations of points on the bed and banks were plotted against river mileage, and gradients of sections of the stream were calculated. The gradients of the surface over which flood waters would flow was also calculated by using the shortest route between mile points on the river course as the horizontal component. The tracing of the bed and banks heights and the average gradients are, presented in Figure 6.

The bed-gradient is more irregular than the banks, mainly because of rock bars which hold up the grading process, but it may also, be affected by the increased flows where tributaries join the river. The gradient of the flood plain is always steeper than the stream channel.

Throughout most of the course of the river the bed and banks are more or less parallel. A notable exception is in the section at Gundowring Upper, (between the 25- and 27-mile points) where the banks have a steeper gradient than the bed. This part of the stream is the start of a progressive steepening of gradients of both bed and banks. It occurs where the river has a constricted flood plain just, north of its junction with Swamp and House Creeks.

Most of the lower extensive terrace to the south of the constriction does not become flooded-apparently because of the steeper gradient and the less meandering course of the stream channel. However, the constricted flood plain between the 25- and 27-mile points has a much reduced gradient. The combination of reduced flood-plain gradient and constriction of the flood plain, causes this area and that just upstream of it to have a higher flood hazard than the areas further south. This is possibly accentuated by the confluence of three major tributaries, House Swamp and Running Creeks, upstream of this section.
The strongly meandering section of the river north of the 29- mile point, has a uniformly moderately-low gradient and can be expected to flood occasionally. Prolonged flooding of this section should not occur often, except near the confluence with the Murray River.

Fig 6 - Gradients of bed and banks of Kiewa River and their relationship to the Kiewa and Dederang land systems



STREAM SECTIONS by river miles	AVERAGE GRADIENTS OF RIVER BED in feet per mile of river course	AVERAGE GRADIENTS OF RIVER BANK in feet per mile of river course	AVERAGE GRADIENTS OF FLOOD PLAINS in feet per mile by shortest route between river mile points
0–8	19	19	26
8–15	12	13	15
15–25	11	10	16
25–27	5	7	8
27–37	6	6	11
37–83	3	3	6

SOILS

CLASSIFICATION

In this study, the classification and naming of soils are based on properties which are easily determined in the field. Soils with similar combinations of properties are grouped and descriptive names have been applied to them. The four basic groups set out below are derived from the primary profile forms defined by Northcote (1960).

1. *Organic* Soils.-Soil profiles dominated by plant remains.
2. *Uniform Soils.*-Soil profiles dominated by the mineral fraction with small, if any, textural differences throughout.
3. *Gradational Soils.-Soil* profiles dominated by the mineral fraction and gradually becoming increasingly finer textured with depth.
4. *Duplex Soils.*-Soil profiles dominated by the mineral fraction and having a pronounced and clearly defined contrast in texture between the A and B horizons.

The classification and naming scheme used in this study, together with some equivalent names from the more traditional classifications are set out in Table 11. Also included are the reference numbers of sampled profiles for which analytical data are included in Appendix IA.

It is possible to recognise relationships between patterns of distribution of soils and certain landscape features. This has led to the development of techniques for the rapid recognition and mapping of soil assemblages by the use of land form and the presence of certain specific soil features (van Dijk, Riddler and Rowe 1969).

The technique has been employed in this study to assist with the development of an understanding of soil distribution patterns and will be reported in detail elsewhere (van Dijk and Rowe, in preparation).

DESCRIPTIONS OF THE SOILS

(i.) Organic Soils

1. Peats: Peat consists of undecomposed and partly decomposed plant remains; it is usually dark coloured and greasy when wet but becomes friable when dry. When it has dried out it is very difficult to re-wet.

In the alpine and sub-alpine tracts, peat occupies the wetter sites in depressions, and shallow or deep organic loams occur on the better drained slopes.

The preservation of the large amount of plant remains is largely the result of anaerobic conditions maintained by a high water-table. Low temperatures also help to restrict the decomposition of organic matter at the higher elevations. Both fen peats and bog peats occur at the high elevations in the catchment.

Peats vary from a thin surface accumulation on shelving rock to many feet deep in the bogs.

Costin (1954) has described a number of different types of peat from the Monaro region. Their chemistry varies with drainage status and pH of the drainage waters. The peats from the Kiewa area have not been sampled in this study. Data from the above source is used in the following discussion.

Organic carbon figures as high as 45 per cent. are recorded and over 20 per cent. is common. Acidity is rather variable both between and within peats, and may range from about pH 6. 0 to as low as pH 3. 7.

2. Humified Peats: These peats are black, friable, loamy organic soils, usually still containing some fibrous material. Usually they have well-developed crumb structure and may contain coarse sedimentary material. They may rest on gleyed sedimentary material or unweathered rock.

Humified peats are most common near entrenched streams in areas where the gently sloping valley would suggest that bog peat should occur.

The humification of the true peats to form these soils has apparently followed the lowering of the valley water-tables which resulted from entrenchment of the streams.

The humified peats from the Kiewa area have not been sampled in this study. Analytical data from other areas (Costin 1954, p. 554, Rowe 1970) indicate similarities to the organic loams of the more freely drained slopes, except for the generally much higher content of organic matter.

TABLE 11 - Soil Groups in the Kiewa Catchment

	The soil groups	Equivalent names from other classifications	Samples profiles included in Appendix 1A
I	***Organic Soils***		
	1 Peats	Peats	
	2 Humified peats	Humified peats	
II	***Uniform Soils***		
	3 Undifferentiated sands and loams	Alluvial soils Regosols	235, 358
	4 Undifferentiated stony loams	Lithosols Skeletal soils	344, 345
	5 Gravelly reddish and brownish loams	Red earths	
	6 Brown loams on alluvium	Minimal prairie soils Meadow soils Alluvial brown earths	237, 238, 359
	7 Shallow organic loams	Alpine humus soils	231
	8 Deep organic loams	Transitional alpine humus soils	232
III	***Gradational Soils***		
	9 Reddish gradational soils on alluvium	Red earths	227, 239, 351
	10 Yellowish-brown gradational soils on alluvium	Alluvial brown earth	349
	11 Massive reddish and brownish gradational soils	Leptopodzols Minimal podsolic soils	
	12 Friable reddish gradational soils	Red amphipodzols	228, 343, 353
	13 Hard reddish gradational soils	Red amphipodzols	342 Krasnozemic soils
	14 Friable brownish gradational soils	Acid brown earths Cryptopodzols Brown mountain soils	229, 230, 233, 234
	15 Weakly bleached yellowish gradational soils	Leotopodzols Minimal yellow padzolic soils	
IV	***Duplex Soils***		
	17 Reddish duplex soils with acid subsoil	Red podzolic soils	236, 341, 354
	18 Yellowish duplex soils with acid to neutral subsoil	Yellow podzolic soils Yellow solodic soils	350
	19 Yellowish duplex soils with alkaline subsoils	Yellow solodic soils	340

(ii.) Uniform Soils

3. Undifferentiated Sands and Loams: Although there may be shallow organic darkening in these soils, they lack any soil organisation such as colour or texture differentiation or structure development. They are most commonly found along streams where their texture may vary from silty loam to sand. Even within a single profile, abrupt changes in texture may exist as, a result of current bedding.

Less common are the undifferentiated sands and loams on alluvial fans. In these soils there is more likely to be a more uniform texture throughout and a higher proportion of fines mixed with coarse material so that when dry they may be quite hard.

There may be iron oxide segregation along root channels where these soils are frequently waterlogged.

The depth of these soils is quite variable but along the main streams gravel usually occurs within about three feet of the surface.

Profile No. 235 (Appendix IA) is an example of an undifferentiated sandy loam on an alluvial fan. It has an almost neutral reaction throughout and moderate fertility status, though a relatively low cation exchange capacity.

Profile No. 358 is an undifferentiated loamy sand of riverine origin. It has a low reaction throughout but is otherwise similar to the soil on the alluvial fan.

4. Undifferentiated Stony Loams: Rock fragments constitute a major part of the profile of these soils. The small quantity of soil between the rock fragments has probably developed from the accumulation of wind-borne dust, weathering of soft rock particles and the decomposition of plant remains. Although the soil may be relatively fertile, available-water capacity is low because of shallowness and during prolonged dry periods moisture would be inadequate to support shallow-rooted plants. Trees and shrubs may be able to persist on the stony loams because they develop extensive root systems in rock fissures and obtain moisture from well below the surface.

Stony loams are common soils on ridgetops and steep exposed slopes.

Analytical data for Profiles No. 344 and 345 (Appendix IA) reflect the features of these soils.

5. Gravelly Reddish and Brownish Loams: These soils are dominated by the gravel fraction (i.e. particle sizes greater than 2 mm.) but have a binding matrix of loam or clay loam. They may be structured but the abundance of gravel makes it difficult to see. The loamy matrix is usually porous.

Colours are commonly brown or reddish-brown, particularly in soils from well-drained sites in moderately high rainfall areas. Some pale brown or even greyish-brown forms may be found where the site tends to be poorly drained but these are not as common.

The gravelly loams are formed in colluvial deposits at the break of slope, usually at the base of long steep slopes, for example where mountain slopes intersect or where the mountain and valley-pediment slopes intersect. They may be very deep.

Though not extensive in area they are relatively common soils in the situations described above.

Because of the mixture of much gravel with some binding fine material, these soils are sought after for road-making or surfacing material.

6. Brown Loams on Alluvium: The brown loams on alluvium are. very dark and highly structured in the surface 6 to, 10 inches but the structure declines and colour pales with increasing depth. Often a bed of gravel is present within about 3 feet of the surface, particularly in the upper valleys. There are deeper soils in the lower reaches of the Kiewa River such as at Little River in the north. There is also a grading from more sandy loams in the upper reaches, to silty loams in the lower reaches.

Soils subject to regular winter flooding tend to be more grey and to have iron staining in root channels. They may even have a gleyed subsoil. These varieties occur mainly at the northern end of the Kiewa Valley.

The brown loams on alluvium occur on the lower terrace-flood plain along the main streams, and occupy fairly significant areas along the Kiewa River below Mount Beauty.

Analyses for three profiles (Nos. 237, 238, 359) are presented in Appendix IA. They are moderately to, strongly acid soils and of moderate, natural fertility.

7. Shallow Organic Loams: The typical profile has a thin surface layer of partly decomposed organic matter, mostly grass litter, below which are 12 to 18 inches of very dark brown or black loam, rich in organic matter and having a strongly developed crumb to granular structure. This horizon has a loose or very friable consistence, and high porosity. At greater depth the organic content diminishes and the colour becomes paler until the yellowish or greyish-brown of the weathering mineral C-horizon is reached at varying depths but commonly at about 24 to 30 inches. Structure, porosity and friability decrease rapidly as the organic content decreases. A conspicuous stone line is often present below the organo-mineral horizon.

Variation in morphology from the typical profile is mainly in the depths of the horizons and the absence of the stone line.

This is the dominant soil of the moist but well-drained slopes of the high mountain country above about 4,500 feet. Precipitation in excess of 60 inches per annum with persistent winter snow are dominant climatic influences. Average annual temperature is about 40°F. and the July average is 30°F or less.

Analyses from a single profile (No. 231) are presented in Appendix IA. From this and other data from similar areas (Costin 1954, pp. 626-667: Rowe, 1967:- both use the term alpine humus soils) it is clear that these are very acid soils of low fertility. Much of the nutrient reserve is associated with the organic colloid in the surface few inches.

There is no significant eluviation of iron or clay. The lack of Podzolisation in soils of this type has been ascribed to biological recycling of mineral elements (Costin 1954, p.662). A similar soil but with less organic matter in the surface horizons is distributed widely on the drier slopes of the rolling high plains.

8. Deep Organic Loams: These soils are similar to the shallow organic loams in the upper part of the profile in that they have a thin surface humus layer and 12 to 18 inches of dark organic loam which has a strongly developed crumb to granular structure, loose to friable consistence, and high porosity. They differ, in having a deeper non-organic, mineral subsoil. As the influence of organic matter decreases, the colour lightens to brown and yellowish brown, and structure and porosity decline. The texture in the lower part of the profile may be clay loam or even sometimes a light clay, however the apparent increase in texture appears to be caused by the decline in the dominating influence of the organic matter. At the surface the clay content is usually about the same as in the subsoil. The soil is commonly 3 to 4 feet deep, but floaters of rock may occur throughout the profile and deeper profiles are found in depressions.

Variation in morphology from the typical profile is mainly in the depths of the horizons.

Soils of this group occur generally at lower elevations than the shallow organic loams but higher than the friable brownish gradational soils. Although their distribution is related to elevation, basically it appears to be controlled by the temperature regime, and so they may be found within the apparent normal elevation range of the adjacent groups where local topography results in suitable temperatures.

The important pedogenetic factors in the formation of the deep organic loams are high rainfall, good drainage, and low but slightly warmer temperatures than where the shallow organic loams occur. Precipitation in excess of 60 inches per annum with some winter snow and average annual temperatures about 44^{o}F are typical climatic conditions.

Analyses for a single profile (No. 232) are presented in Appendix IA. Profiles are typically strongly acid with generally low natural fertility and with much of the nutrients associated with the organic colloid in the upper part of the profile.

(iii.). Gradational Soils

9. Reddish Gradational Soils an Alluvium: The typical reddish gradational soil on alluvium has a gradual increase in redness and in clay content down to about 18 to 24 inches below which both decrease fairly rapidly. The profile commonly varies from a dark brown sandy loam at the surface, through yellowish-red sandy loam to reddish brown or strong brown sandy clay loam at about 18 to 24 inches, and then back to brown sandy loam. The structure is generally only weakly developed except for the well-structured surface, and consistence is friable.

Although sandy textures predominate, fine-textured profiles occur. The extent of iron and clay movement and differences in strength of the colours are the most common variations from the typical profile.

These soils occur throughout the valley tract but have a rather discontinuous distribution. They occur most commonly on remnants of the terrace about 3 feet above the present-day flood plain. In the southern part of the valley, they may occur on fans or hillwash sheets of fine-textured alluvium which overlie the gently sloping valley sides.

Analytical data for three profiles (Nos. 227, 239, 351) are presented in Appendix IA. Reactions are moderately acid to almost neutral, generally with the subsoil being less acid than the surface, and moderate fertility is indicated.

10. Yellowish-brown Gradational Soils on Alluvium: The typical soil of this group consists of about 8 inches of dark brown to very dark brown sandy or fine sandy loam with moderate to strong, fine granular to subangular blocky structure, gradually changing to brown and yellowish-brown sandy loam or sandy clay loam with weak fine subangular blocky or apedal structure. In the Kiewa valley, a coarse gravel bed often occurs at about 3 feet. This results in good internal drainage and an absence of gleying.

The depth of the surface horizon varies somewhat, and textures may range from loams to coarse sandy loams.

These are the predominant soils on the lowest terrace of the Kiewa River and its major tributaries. Although generally above flood level, they may occasionally be inundated, particularly in the north of the Kiewa valley.

Analytical data for one sampled profile (No. 349) is presented in Appendix IA. The reaction in this profile trends from acid at the surface to alkaline at about 5 feet. It appears to be a moderately fertile soil. This profile was from the north of the Kiewa valley where drainage of the low terraces is not as free as higher up the valley. Data from similar soils in the adjacent Ovens valley (Rowe, in preparation) indicate that the better drained forms are more acid though still reasonably fertile.

11. Massive Reddish and Brownish Gradational Soils: Massive reddish and brownish gradational soils have a gradual increase in texture from loam or sandy loam in the A-horizon, to clay loam, sandy clay loam or light clay in the B-horizon, and usually a fairly rapid decrease in clay below the B-horizon. Colours range from dark brown in the A, to yellowish-brown or pale brown in the A-horizon, to brown, yellowish-brown or yellowish-red in the B-horizon. The colour and texture changes are usually gradual but may not coincide. The A/B boundary is usually at about 12 inches. Except for the surface inch or so, where concentrated biological activity maintains moderate structure, the profile is poorly structured or apedal and sets hard when dry. These soils have abundant visible pores resembling pin holes.

Wide variations from the typical profile occur, particularly in colour and texture. On poorly drained sites, subsoil colours are mottled and there may even be a gley horizon. On better-drained sites, colours are more reddish. The depth of the A-horizon is greater where textures are coarse.

Weak eluviation of iron and clay are features of the group. Relic D-horizons of red clays, typical of the reddish duplex soils, are sometimes found beneath these soils.

The massive gradational soils are usually found on alluvial fans and terraces in the north. They occur on relatively extensive concave surfaces made up of gully-fills between low convex slopes of old fans and relic ridges in the main valleys, mainly in the north. On the steeper slopes, soils of this group may occur with the stony loams.

Gleyed forms of this group sometimes occur where a perched water-table occurs for at least part of the year, but these are of a limited occurrence.

None of these soils has been sampled from this catchment. Data for soils of this type from the adjacent Hume catchment (Rowe 1967) indicate that profiles are moderately acid and have moderate to low fertility.

12. Friable Reddish Gradational Soils: Soils *of* this group have a dark brown loamy A-horizon over a yellowish-red or reddish-brown loam to clay-loam A-horizon which merges, over several inches, into the dark red or reddish-brown light clay B-horizon. The A-horizon is usually no deeper than about 8 inches and is moderately structured at the surface, but has only weak, medium subangular-blocky structure in the A-horizon. The B-horizon has moderate, medium subangular-blocky structure which breaks to, very fine subangular-blocky.

The depth of profile depends to a certain extent on the parent material. In deep, old alluvium or colluvium, the profile may be 8 feet or more thick, but generally, weathering rock is encountered at about 4 feet.

Variations occur in depths of horizons and B-horizon colours. Occasionally, yellowish forms occur on less well-drained sites within the normal range of these soils.

Soils of this group are relatively widespread in the southern part of the Kiewa valley where they occur extensively on the upper terrace and fans, and to a lesser extent on the hills and lower montane slopes. They are the dominant soils on the Stanley plateau and also. occur elsewhere on plateau remnants and broad ridge-tops in the north, such as on the Baranduda Range and the Big Ben massif. In general, friable reddish gradational soils are of limited occurrence in the northern valley tract but become more extensive where rainfall exceeds about 35 inches per annum

Analytical data for three sampled profiles (Nos. 228, 343, 353) is presented in Appendix IA. The profiles are acid to very acid and of moderate to low natural fertility.

13. Hard Reddish Gradational Sails: These soils are similar in colour and texture profile to the friable reddish gradational soils but the structure of the B-horizon is more strongly developed to very fine subangular-blocky the peds have shiny surfaces and the consistency is hard when the soil is dry. They occur on the residual surfaces of the plateaux such as at Stanley.

Analytical data for one profile (No. 342) is presented in Appendix IA. It is an acid to very acid profile of moderate to low fertility.

14. Friable Brownish Gradational Soils: The typical friable brownish gradational soil has a thin layer of decomposing organic matter over a very dark brown or black organic loam 3 to 6 inches deep. The surface few inches has a strongly developed crumb structure changing to, fine subangular-blocky. Below the surface horizon, the influence of organic matter rapidly decreases, the texture becomes more clayey, and colours become brown and yellowish-brown. There is only a small increase in clayiness with depth but colours become more yellowish, the structure deteriorates and porosity decreases.

The soil is friable throughout. Weathering rock usually occurs at about 4 feet or deeper, however, numerous fragments of rock may occur in the profile and soil may extend along fissures into the underlying rock.

Variations in morphology from the typical profile are mainly in depth of solum, quantity of rock fragments in the profile, depth of influence of organic matter, and the subsoil colours which may be reddish-brown.

Although there may be evidence of a weak bleaching of the A-horizon in soils of this group from lesser elevations, they do not generally show evidence of iron oxide eluviation The mild temperatures which occur at the higher elevations, together with high rainfall, result in deeper and more complete weathering than in the soils from lesser elevations. Soils at lesser elevations have less organic matter in the A-horizon and may have more rock in the profile.

The friable brownish gradational soils are an extensive group in the high rainfall montane areas of the catchment. They occupy most of the steep country between about 2,000 feet and 4,000 feet elevation. Rainfall of 50 inches or more, and occasional winter snow are typical of these areas.

Analytical data for four profiles (Nos. 229, 230, 233, 234) is presented in Appendix IA. These are acid to very acid soils of generally low natural fertility. There is a high proportion of plant nutrient elements in the surface soil where they are apparently in association with the organic matter.

15. Weakly Bleached Reddish Gradational Soils: These soils and those of the next group combine some of the features of the, friable reddish gradational soils (group 12) and the massive reddish and brownish gradational soils (group 11). They have a weakly structured B-horizon which has a hard consistency when dry. The A-horizon is weakly bleached. Profiles are not usually deep, and may overlie pedal reddish clay or weathered rock which appears to be a truncated relic of an earlier soil.

These soils are typical of the alluvial fans of intermediate size on the valley pediment, particularly in the north, and may also occur on the steeper slopes of residual hills or lower-elevation montane slopes.

No representative profiles have been sampled from this area. In other areas the weakly bleached reddish soils (part of the leptopodzol group described by Rowe 1967) are moderately acid throughout, and of moderate natural fertility.

16. Weakly Bleached Yellowish Gradational Soils: This group is similar to the previous group (group 15) except that the dominant colour of the B-horizon is yellowish. They are the less-well drained form of weakly bleached gradational soils, and occur in the lower topographic positions on the alluvial fans of the valley pediment.

Reaction trends are usually less acid than in the reddish forms, and because of their low catenary position they may be more fertile than the reddish more freely draining group. No representative profiles have been sampled from this area.

(iv) Duplex Soils

17. Reddish Duplex Soils with Acid Subsoil: Soils in this group have a pale, moderately bleached A-horizon of loam or sandy loam in which structure has developed only in the biologically active surface inch or two. The change to a yellowish-red, reddish-brown or red clay B-horizon occurs over a shallow depth, usually less than 2 inches, and at about 8 to 10 inches below the surface. The B-horizon has well-developed fine subangular-blocky structure and dense (non-porous) peds. There may be a decrease in redness and in clay content below the B-horizon, however, these soils usually have a deep and relatively uniform B-horizon which grades into the weathered parent material, often through a zone of strong reddish-brown with prominent grey mottles (Plate 6).

The reddish duplex soils are the most widespread soils of the valley slopes where they occur on the freely draining dissected fans and low residual hills.

Analytical data for three sampled profiles (Nos. 236, 341, 354) are presented in Appendix IA. They are acid in the A-horizon but usually only moderately acid in the B-horizon, although, in the higher rainfall areas in the south, they are more acid throughout. Although not very fertile soils, the profiles sampled seem to possess reasonable potassium status in the B-horizon. It is usual for exchangeable magnesium to exceed exchangeable calcium on the colloid of the deeper B-horizon. This also is more pronounced in the drier north of the catchment.

18. Yellowish Duplex Soils with Acid to Neutral Subsoil: These have similar horizon differentiation to the soils of group 17, but they have yellowish-brown B-horizon clay which has a strongly developed medium to coarse subangular-blocky structure. The peds are dense and have shiny surfaces. Slickensides may be present. There are usually some small (i inch diameter) ironstone concretions present in the well-bleached A-horizon and in the upper part of the B-horizon. There may be reddish-brown mottles in the B-horizon.

Soils of this group are most common on the extensive high-level, relatively poorly-drained flats at Bandiana and Bonegilla which appear to be remnants of an ancient high terrace of the Kiewa River.

Analytical data for one sampled profile (No. 350) is presented in Appendix IA. It shows a somewhat variable reaction trend through acid to moderately acid. A notable feature of the chemistry of this profile is the considerable increase in exchangeable magnesium in the B-horizon and also the presence of relatively large quantities of exchangeable sodium.

Plate 6 - A reddish duplex soil on deeply weathered granite near Yackandandah

19. Yellowish Duplex Soils with Alkaline Subsoil: These duplex soils have similar differentiation and colour to the soils of the previous group (group 18) but the B-horizon is not as heavy, the structure is better developed and of finer grade in the B-horizon, and small, hard nodules of lime (calcium carbonate) may be present in the B-horizon and deeper.

Such soils are typically formed from alluvium in the gently graded depressions of the valley slopes, and therefore have poor drainage and generally receive the drainage from a much larger area. They are of relatively small extent, predominantly in the northern part of the catchment where the main valley is wider and the slopes are less dissected.

Analytical data for one sampled profile (No. 340) is presented in Appendix IA. This shows that the deeper part of the B-horizon is highly alkaline (pH 8.8) but that the B- is as acid as the A-horizon. The fertility appears to be relatively low. The notable feature is the predominance of exchangeable magnesium and the relatively large amount of exchangeable sodium in the deeper B-horizon.

PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOILS

A range of profiles, representative of the major soil groups described, was sampled during the survey (Appendix IA.). Analyses are presented for particle size distribution, reaction, chloride, organic carbon, nitrogen, potassium and phosphorus extracted by concentrated HCl, free ferric oxide and the cation exchange capacity and the exchangeable cations.

The laboratory techniques used in the analyses are listed in Appendix IB.

It is possible to make generalisations about the properties of many of the soil groups, and these, together with comments on the exceptions form the basis of this section.

Particle Size Analysis

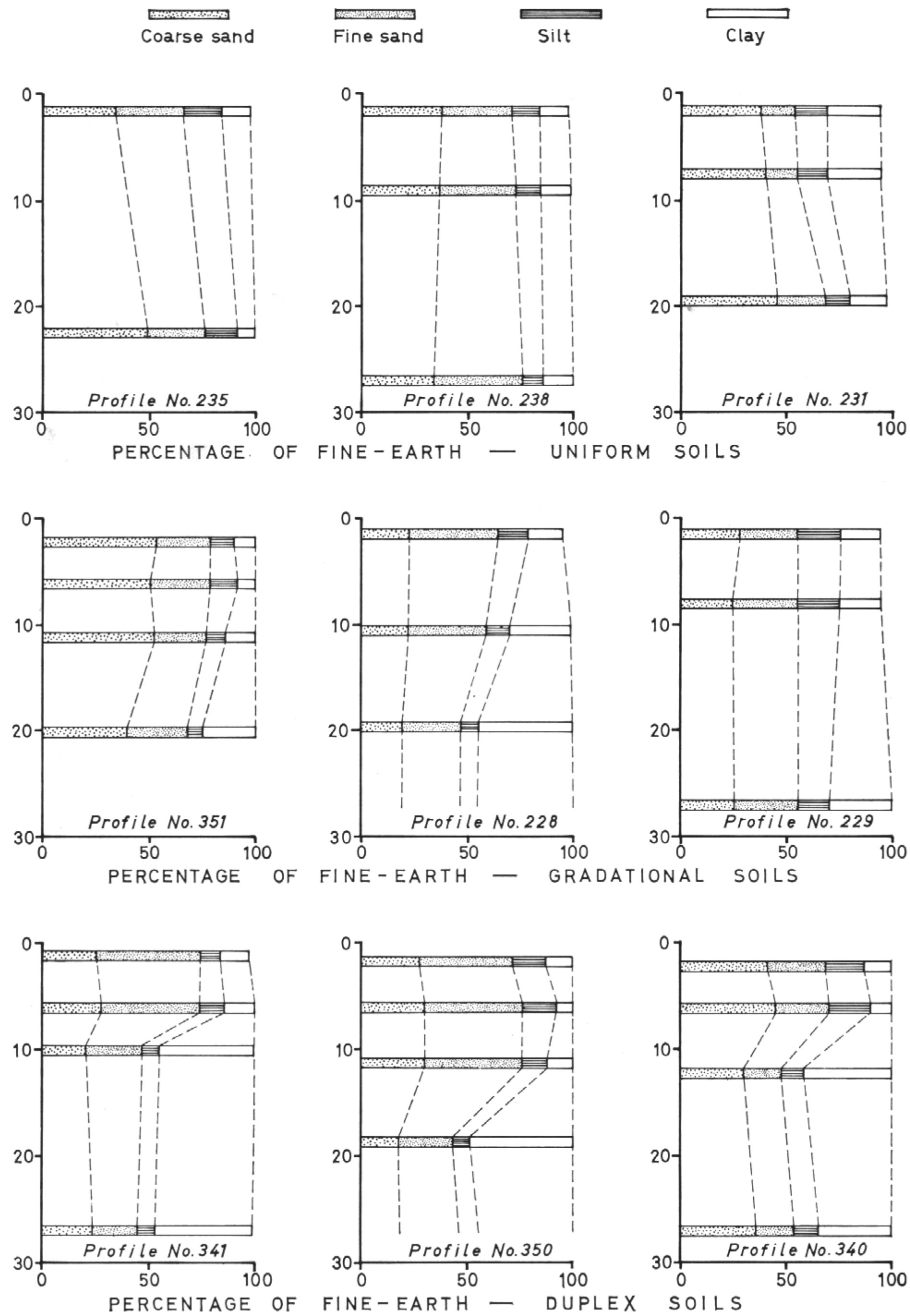
The duplex soils have a marked contrast in clay content between the A- and B-horizons. Differences of the order of 30 to 40 per cent. are found.

The gradational soils have gradual increases in percentage clay with depth and often a decrease occurs below the B-horizon.

The uniform soils from this catchment have predominantly coarse textured profiles. The undifferentiated sands and loams and the alluvial brown loams have high proportions of sand fractions. The shallow organic loams often have more clay in the surface than lower in the profile.

Particle size distribution trends for some soils are shown in Figure 7.

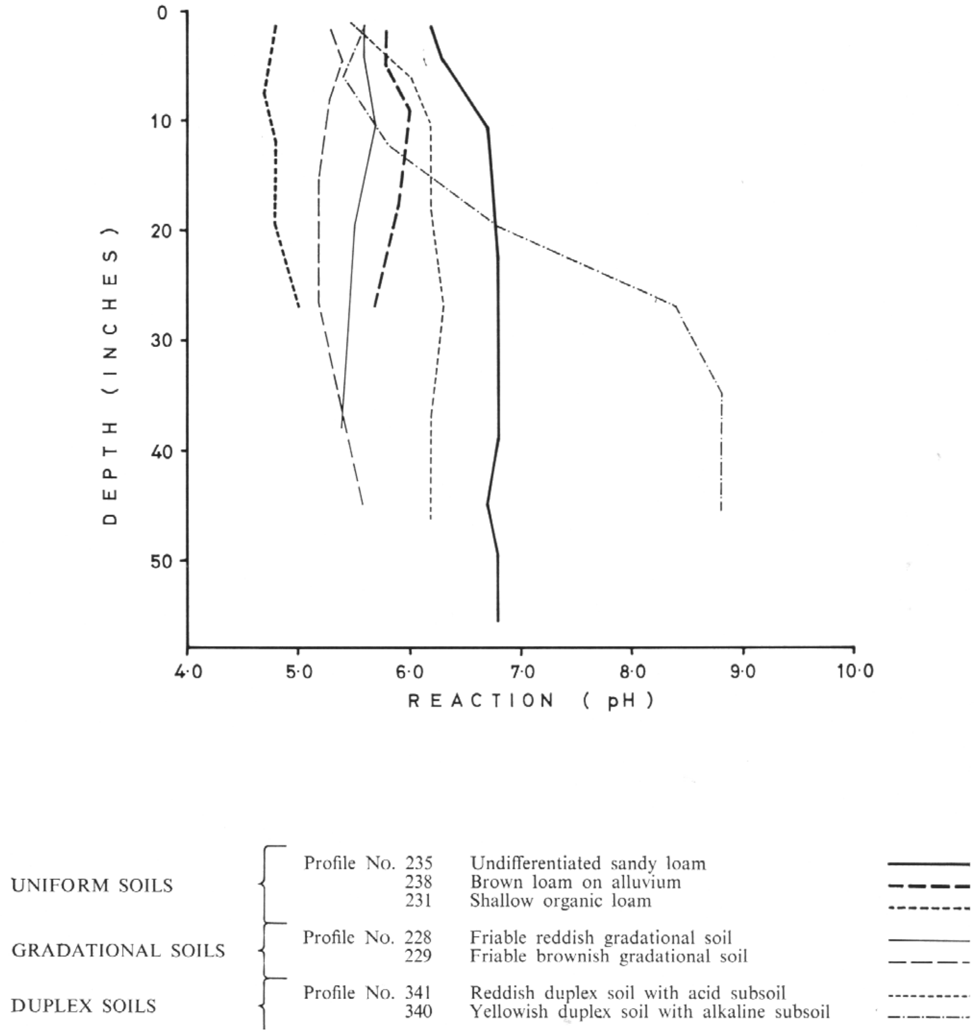
Fig 7 - Particle-size distribution for typical soils



Reaction (pH)

Most of the profiles sampled are acid throughout. The most acid are the organic loams, and the friable brownish gradational soils are generally only slightly less acid. The duplex soils have acid reaction in the A-horizon, but the different trends in the B-horizon have been used to, separate two yellowish groups, one being acid to neutral and the other alkaline. The weakly bleached reddish gradational soils generally become more acid in the B-horizon as also do the friable reddish gradational soils, although the latter are more acid throughout.

Fig 8 - Reaction (pH) trends in typical soils



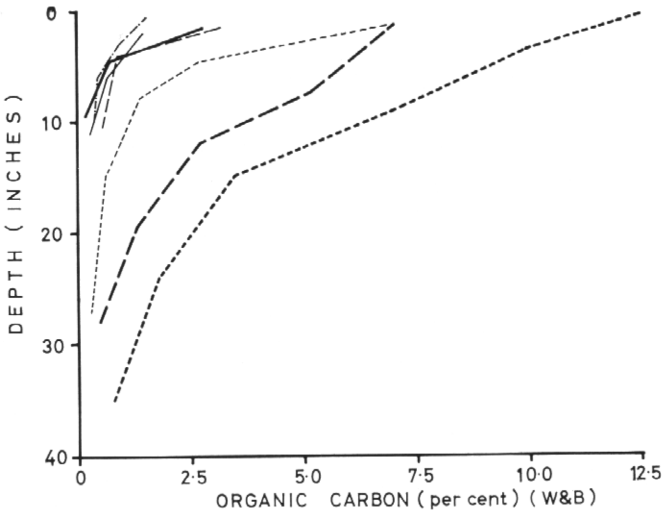
Chloride

Only occasionally are chloride concentrations higher than 0.01 per cent. found in soils of this catchment. The highest concentrations occur where imperfect subsoil drainage results in accumulation of soluble salts generally. Typical concentrations for freely draining profiles are from 0.001 to 0.004 per cent. chloride ion.

Organic Carbon

Organic carbon values are highest at the surface and generally decline rapidly below about 4 inches. Exceptions are the peats, humified peats and the shallow and deep organic loams in which there is still relatively much organic carbon at 15 to 18 inches. The soils from the cooler and moisture areas usually have more organic carbon in the surface and it extends further into the profile. To illustrate these relationships, values of organic carbon for several soils have been graphed in Figure 9.

Fig 9 - Organic carbon in typical soils



UNIFORM SOILS	Profile No. 235	Undifferentiated sandy loam	———
	231	Shallow organic loam	— — —
	232	Deep organic loam	- - - - -
GRADATIONAL SOILS	Profile No. 351	Reddish gradational soil on alluvium	———
	228	Friable reddish gradational soil	— — —
	229	Friable brownish gradational soil	- - - - -
DUPLEX SOILS	Profile No. 341	Reddish duplex soil with acid subsoil (Profile No. 340 is almost identical)	—·—·—

Nitrogen

The pattern of distribution of total nitrogen within the soils closely follows that of organic carbon. However, the ratio of carbon to nitrogen varies ; surface soils under forest usually have higher ratios than soils under grassland.

HCl extract

Analyses for phosphorus and potassium extracted by boiling concentrated HCl is carried out to indicate the total quantities of these elements present. In most of the soils analysed, phosphorus is usually present in only relatively small quantities and could not be regarded as providing a useful reserve. Potassium reserves are generally low in the A-horizons, but in the B-horizons of most of the sampled soils there are moderate quantities.

The highest values recorded were 1.12 per cent. from the A/C horizon of a shallow organic loam on gneiss, 0.76 from the lower B-horizon of a friable brownish gradational soil on schist and also from a shallow stony loam on gneiss.

Exchangeable Cations

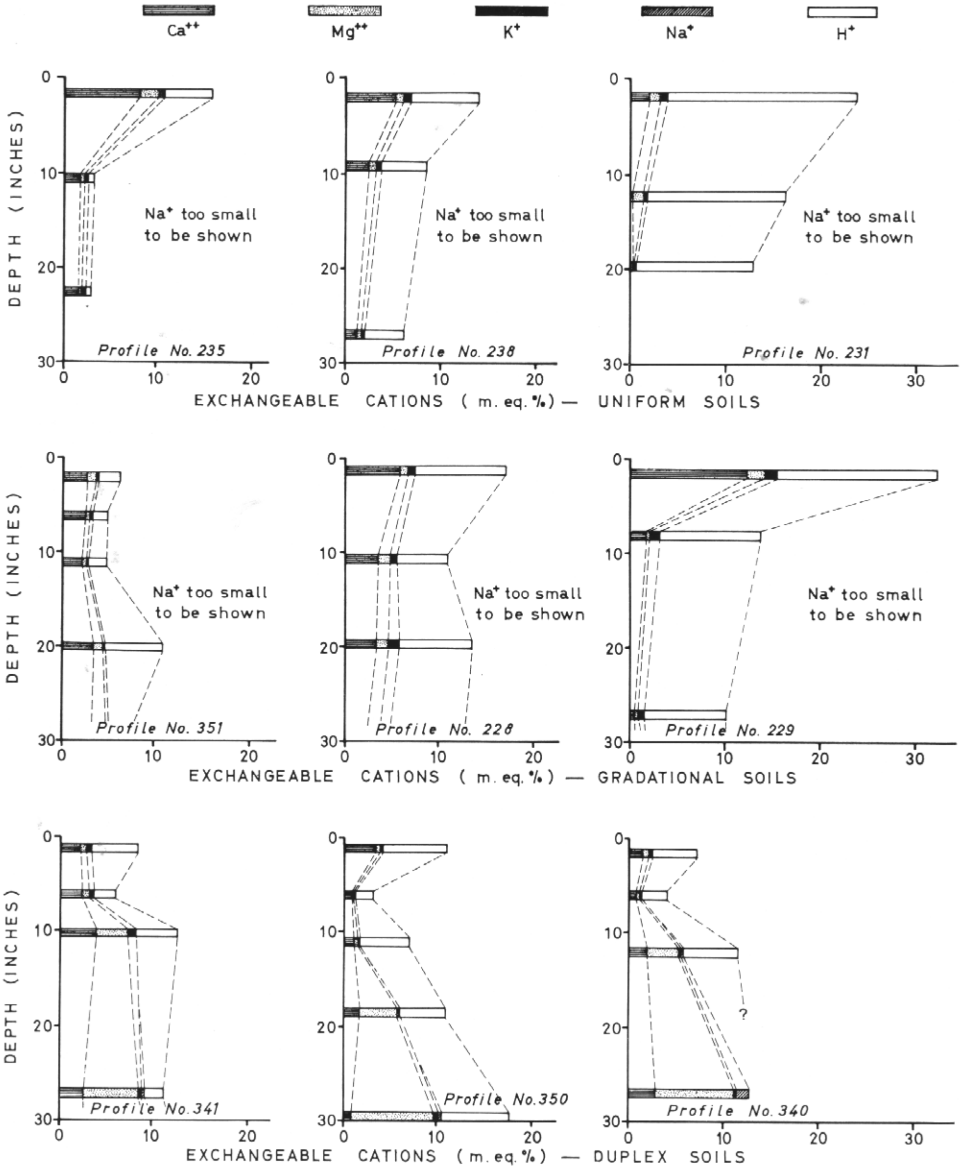
In almost all the soils sampled the highest cation exchange capacities are in the surface soil where it appears that organic colloid is the effective agent. It is also in the surface that the largest quantities of exchangeable cations occur. The decrease in cation exchange capacity with depth is generally accompanied by a decrease in the quantity of cations present.

The lowest ratio of metal cations to exchange capacity is found in the organic loams and the friable brownish gradational soils. The friable reddish gradational soils are not quite as poor and the soils from the lower rainfall areas, such as the weakly bleached reddish and yellowish gradational soils and the duplex soils, have the highest ratios. However, none of the soils sampled has a completely saturated cation exchange capacity.

In the graphs of exchangeable cations presented in Figure 10, that part of the exchange capacity not occupied by metal ions is depicted as being occupied by hydrogen ions

Calcium is the most abundant of the metal ions in all the soils except for the B-horizons of the duplex soils from the lower rainfall areas where magnesium assumes dominance or at least co-dominance. Profile No. 236 a reddish duplex soil from Tawonga, a moderately high rainfall area, has calcium as the dominant cation in the B-horizon. Magnesium is usually the next most abundant metal ion, after calcium, and potassium is slightly less abundant. Sodium is only present in measurable quantities in the B-horizons of the duplex soils and in the deeper horizons of some of the soils on the flood-plain.

Fig 10 - Exchangeable cations in typical soils



VEGETATION

CLASSIFICATION

In all instances attempts have been made to ascertain the pre-settlement vegetation, although in many areas most of the vegetation has been cleared. Even in the more remote areas changes have been brought about by changes in fire frequency and severity, and by grazing and logging. The pre-settlement or climax vegetation is considered to be a useful guide in assessing land-use capability, as it is assumed that it reflects the influence of the combined effect of all environmental factors on plant growth.

The classification is based on the scheme proposed by Beadle and Costin (1952) and is set out in Appendix 11B.

The vegetation of the Kiewa catchment is similar to that of the adjacent Hume catchment (Rowe 1967), and for this reason the classification used is basically the same. A notable difference is the absence from the Kiewa area of the savannah woodland of candlebark gum and snow gum *(E. rubida-E. pauciflora* alliance). The savannah woodland of forest red gum, white box and long-leaf box *(E. tereticornis*[*]*-E. albens-E. goniocalyx* alliance) of the Hume is a dominant alliance in the northern Kiewa, but long-leaf box is not usually present and apple box *(E. bridgesiana) is* more common.

The vegetation of the Bogong High Plains has been previously described by Costin (1957b).

DESCRIPTIONS OF THE VEGETATIVE COMMUNITIES

(i) Feldmark

The feldmark is an open community of dwarf plants dominated by cushion-forming or prostrate species only a few inches high. Bare ground separates the scattered members and is a notable feature of the community.

Costin (1957a) has commented that the typical feldmark of this area appears to be the wind-exposure type, in contrast to the cold-determined type which, in Australia, occurs only in the Kosciusko area. It is not clear whether this community is climax, or whether it has been induced by accelerated soil erosion. It is clear however that frost action, associated with severe wind erosion, are important factors in maintaining the community in its present form.

The species which occur mostly in this formation are brown edelweiss *(Ewartia nubigina),* and alpine sunray *(Helipterum incanum var. alpinum)* with scattered prostrate shrubs of yellow Kunzea *(Kunzea muelleri)* and coral heath *(Epacris microphylla).*

This vegetation occupies the wind-swept tops of ridges and prominences at the highest elevations, such as the north-west aspects of Mt. Loch, Mt. Hotham, Mt. Nels and parts of the Razorback ridge. Its area, in relation to many of the other vegetative communities is small, but it is an important community, although possibly seral.

(ii) Alpine herbfield

This is a community in which both grasses and forbs occur together to form a continuous sward. In the Kiewa area it corresponds to the grassland "C" community of Carr and Turner (1959), (Plate 7).

Plate 7 - Alpine herbfield with a mosaic of low shrubs on Mt Bogong

[*] Now accepted by National Herbarium Melbourne as E. *blakelyi.*

They describe several forms of grassland "C" in which the dominant herbs differ. In the Mt. Nels area snow daisy (*Celmisia longifolia*) is the co-dominant of snow grass (*Poa australis*); in Pretty Valley, scaly buttons (*Leptorrhynchus squamatus*) is the co-dominant, and in the Mt. Fainter area sorrel (*Rumex acetosella*) is the co-dominant forb. The fencing experiment of Carr and Turner in Rocky Valley indicates that where stock are excluded, the trend is towards a herbfield of snow grass and snow daisy. They suggest that lowland herbs, such as sorrel, have assumed importance in this community because they are strong colonisers of the bare ground which resulted when the original vegetation was damaged by over-grazing, fire or insect attack. Such damage could easily have been caused by over-grazing during drought times when the access routes to the plains, and those areas close to reliable water would have suffered most. The Fainter ridge and Pretty Valley would have been such areas.

Even the apparent near-climax form in the Mt. Nels area has a higher proportion of bare ground than that indicated by the fencing experiment in Rocky Valley.

Thus, although the climax vegetation is a mosaic of snow grass and snow daisy, the latter may be replaced by several other herbs, the more common being scaly buttons, and sorrel. Common buttercup (*Ranunculus lappaceus)* and sedge (*Carex breviculmus*) are other common species in the herbfield.

Alpine herbfield vegetation occurs on well-drained, relatively exposed sites, particularly at the higher elevations. Such areas are the northern and western aspects of Mt. Nels, Spion Kopje, Bogong, Hotham and Feathertop, and the generally north-westerly drainage of Pretty Valley.

(iii) Alpine shrub community

The alpine shrub vegetation consists of an open or more-or-less closed community, varying from less than a foot to several feet high. In severely exposed situations the shrubs usually assume a prostrate habit, their thick, gnarled trunks and limbs indicating that they are relatively old. In general, they have small sclerophyll leaves and are much branched from the base.

The ecology of the shrubs of the Bogong High Plains, the area where this community is most extensive, has been described by Carr (1962). Although shrubs occur in the alpine grassland and herbfield, they are usually scattered and suppressed when the dominant vegetation is in a sound and vigorous condition.

Shrubs are the typical vegetation in several types of situation. Areas where the water-table is high for part of the year usually have a short shrub community in which thyme heath *(Epacris serpyllifolia)* is dominant and which often includes yellow Kunzea *(Kunzea muelleri).* In rocky areas, shrubs of golden Oxylobium *(Oxylobium ellipticum)*, and mountain Orites *(Orites lancifolia)* occur, with tree violet *(Hymenanthera dentata)* always growing against the rocks, where they are frequently espaliered by the strong prevailing winds. Long-leaf Hovea *(Hovea longifolia),* alpine Grevillea *(Grevillea australis),* alpine mint-bush *(Prostanthera cuneata),* mountain beard-heath *(Leueopogon hookeri),* and alpine Phebalium *(Phebalium podocarpoides)* occur in closed communities on well-drained and exposed areas, and these species may occur with coral heath *(Epacris microphylla)* scattered throughout grassland or herbfield. Leafy Bossiaea *(Bossiaea foliosa),* golden Oxylobium, alpine everlasting *(Helichrysum hookeri)* and long-leaf Hovea usually occur in scattered patches within the sub-alpine woodland. The thyme heath community is well represented in the poorly-drained floor of Pretty Valley. Examples of the Hovea-Oxylobium community occur on Mt. Cope and most of the low stony ridges and knobs surrounding the drainage lines of the High Plains.

(iv) Alpine grassland

This grassland community consists of discrete tussocks, the tops of which form a closed canopy of interlacing leaves. The spaces between the tussocks may be occupied by shade-tolerant herbs.

Snow grass (*Poa australis)* is the dominant species of this vegetation and although shrubs do occur they are normally scattered and suppressed. Most of the members of the alpine herbfield may occasionally occur in the grassland.

A number of different forms of snow grass, described by Carr and Turner (1959), may occur in the grassland. In this catchment, the grassland appears to be type "A" of Carr and Turner and also types "B" and "B1", both of which are probably derived from the alpine grassland by damage of the vegetation and erosion.

Alpine grassland occurs in the less-well-drained, but not water-logged situations, generally in areas where cold-air drainage occurs. It is the typical vegetation of the sloping sides of shallow drainage depressions, and occurs from above the tree line down into the sub-alpine woodlands, where along drainage lines, temperature inversions, resulting from cold-air drainage, prevent the establishment of the tree species. It may occur at elevations as low as 3,000 feet.

(v) Bog

The bog community consists of hummock-forming mosses and other hygrophilous plants. Permanent wetness is essential for their existence.

Costin (1954) describes both raised and valley bogs from the Monaro Region of New South Wales.

Sphagnum moss *(Sphagnum cristatum) is* the most important hummock-forming moss in this area. Sedge *(Carex gaudichaii.diana),* candle heath *(Richea continentis),* spreading rope-rush *(Calorophus lateriflorus),* swamp heath *(Epacris palduosa)* and alpine bottle-brush *(Callistemon sieberi)* are other species usually associated in bog vegetation.

Bogs appear to have been the main vegetation along many of the streams on the Bogong High Plains, however extensive deterioration has occurred, to the extent that frequently only small, degenerate patches of moss, or only the more hardy members of the community remain scattered along the margins of the streams. Small raised bogs occur commonly in relatively steep drainage hollows, particularly where ground-water emerges from the slopes below the Plains.

There is also evidence that bogs occurred in the Kiewa valley north of Tawonga (Rowe 1968) but few now remain.

(vi) Fen

The fen is a community of herbaceous plants which grows in saturated soil but lacks hummock-forming mosses.

Sedge (*Carex gaudichaudiana)* is the dominant member of this community which occurs most commonly as small patches in the beds of shallow streams or shallow drainage lines on the High Plains.

(vii) Sub-alpine woodland

This is a sub-alpine community characterised by trees which form a more-or-less closed canopy, and in which the crown depth is greater than the length of the bole. A continuous ground flora of grasses and forbs is present. It often has an open woodland form, and at the upper limits of its range it may be reduced to a scrub or wet mallee formation. (Plate 8).

Plate 8 - The Bogong High Plains viewed from near Mt. Fainter. Open, sub-alpine woodland of snow gum is seen in the foreground with dense low shrub community and patches of alpine grassland.

Snow gum *(Eucalyptus pauciflora)* is the only tree species occurring in this community. Species typical of the alpine grassland, herbfield or shrub communities may occur in the ground flora, although snow grass *(Poa australis)* is usually the dominant. The shrub species appear to become more common after fire or possibly where over-grazing has opened the sward.

If the stunted forms of this vegetation be included, it ranges from near 6,000 feet on Mt. Bogong, over stony alpine peaks such as Mt. Cope, down to about 4,000 feet where it merges with the wet sclerophyll forest of mountain gum and snow gum *(E. dalrympleana-E. pauciflora)* or gives way to alpine ash (*E. delegatensis)* forest.

(viii) Wet sclerophyll forest

The dominant stratum consists of tall trees with interlacing crowns, and the subordinate strata contain moisture-loving species. A shrub layer, tall or short, may or may not be present, but a continuous ground cover of grasses, herbs and/or litter is always present. (Plates 9, 10, 11).

Plate 9 - Dense ground cover under narrow-leaf peppermint forest, made up of low shrubs of handsome flat-pea, bracken-fern and tussock grass

Three distinct communities with this form are recognised.

(1) The most extensive community contains narrow-leaf peppermint *(E. radiata),* candlebark gum (*E. rubida)* and broad-leaf peppermint *(E. dives)* as dominants. (Plate 12.) Manna gum *(E. viminalis),* blue gum *(E. bicosta!a),* and at the southern end of the catchment, Bogong gum *(E. chapmaniana) occur,* occasionally amongst the dominants. Broad-leaf peppermint is the most tolerant of these species, and consequently is most usually found on the drier or colder sites within the normal range of the community. Manna gum and blue gum are generally to be found in sheltered and moister sites. Bogong gum appears to be restricted mainly to the upper part of the range of the community, particularly in the upper East and West Kiewa valleys.

The shrub layer ranges from short shrubs of handsome flat-pea *(Platylobium formosum)*, gorse bitter-pea *(Daviesia ulicina),* prickly bush-pea *(Pultenaea juniperina),* and bracken fern *(Pteridium esculenium)* in the drier areas, through a taller shrub layer in which hop bitter-pea *(Daviesia latifolia)* and some or most of the above species occur, to a tall shrub layer with silver wattle *(Acacia dealbata)*, common Cassinia *(Cassinia aculeata),* rough Coprosma *(Coprosma hirtella)* and many of the above species in the moister areas. In wet and sheltered gullies, hazel Pomaderris *(Pomaderris apetaila),* silver wattle, musk daisy-bush *(Olearia argophylla)* and blanket-leaf *(Bedfordia salicina)* may occur with ground ferns *(Blechnum* spp.) and shield fern *(Polystichum proliferum).*

Ground cover ranges from predominantly dry litter through scattered herb's and tussocks of tussock grass *(Poa australis)* to a more-or-less closed sward of tussock grass.

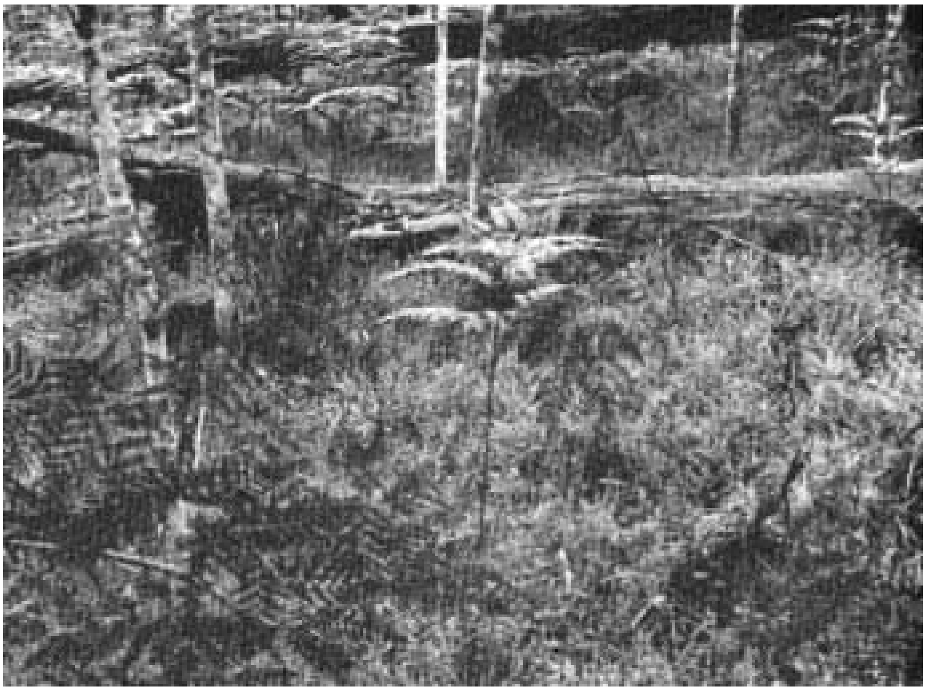


Plate 10 - Herbaceous ground cover with scattered bracken-fern and tall shrub stratum of silver wattle under narrow-leaf peppermint forest

Plate 11 - Complete ground cover of forest litter, tussock grass and scattered bracken-fern under forest of alpine ash

The peppermint-gum community occurs over most of the mountainous country in the catchment where the rainfall is between about 40 inches and 60 inches, and at elevations from about 1,000 feet up to the edge of the alpine ash (*E. delegatensis)* forests at about 3,500 feet. At the drier end of its range it grades into the red stringybark *(E. macrorhyncha)* forests through a broad ecotone.

(2) Alpine ash *(E. delegatensis)* occurs in virtually pure, relatively even-aged stands, mixing with adjacent communities only in a narrow ecotone. Mountain gum *(E. dalrympleana)* occurs occasionally in the upper-elevation-range of the community. Beneath the tall tree stratum there is usually a tall shrub stratum in which silver wattle (*A. dealbata),* hickory wattle (*A. obliquinervia),* holly Lomatia *(Lomatia ilicifolia),* rough Coprosma *(Coprosma hirtella),* prickly currant-bush (*C. quadrifida)* and elderberry panax *(Tieghemopanax sambucifolius)* are the most common species. (Plate 13) A number of low shrubs may also, be present, the most

common of which are prickly bush-pea *(Pultenaea juniperina),* hop bitter-pea *(Daviesia latifolia),* bitter-pea *(D. corymbosa var. laxiflora),* tall rice-flower *(Pimelia ligustrina),* and common Cassinia *(Cassinia aculeata).* The ground cover may consist mainly of forest litter or scattered herbs and grasses, mainly tussock grass (*P. australis),* or a more-or-less closed sward of tussock grass.

Plate 12 - West sclerophyll forest of narrow-leaf peppermint and candlebark gum with a dense bracken-fern understorey

The natural distribution of alpine ash is regulated by seed dormancy, the breaking of which requires low temperatures (Grose 1961). Suitable conditions for breaking the dormancy are found where snow lies for at least a few weeks in winter. Thus, the alpine ash forests are found at the lower end of the range of winter snowfall, mainly from about 3,500, feet to about 4,500 feet. (Plate 14.) The main areas of occurrence in this catchment are in the uppermost parts of the Mountain Creek catchment and in the East and West Kiewa valleys below the High Plains.

Plate 13 - West sclerophyll forest of young alpine ash with a dense shrub stratum

(3) The community dominated by mountain gum *(E. dalrympleana)* and snow gum *(E. pauciflora)* is not as tall nor as luxuriant as the other wet sclerophyll forest communities. Its form is variable and may approach tall woodland, and at times is transitional to

sub-alpine woodland. The mountain gum is usually a tall tree but snow gum is generally a multi-stemmed mallee, some 15 to 20 feet tall. The ground flora is usually a more-or-less closed sward of "the broad-leaved form of tussock *(Poa australis)* with much forest litter, and may contain scattered or numerous shrubs of hop bitter-pea *(Daviesia latifolia)* and handsome flat-pea *(Platylobium formosum)* on warmer sites, of leafy Bossiaea *(Bossiaea foliosa)* and golden Oxylobium. *(Oxylobium ellipticum)* on cooler sites.

Plate 14 - The Bogong High Plains with the rocky outcrop of the Niggerhead in mid-picture. The foreground is dominated by alpine ash forests on the upper slopes of the West Kiewa valley. The sharp transition to snow gum woodland can be seen.

This vegetation may occur between about 3,000 feet and 4,500 feet elevation, and appears to be restricted to areas where soil moisture is lower than optimum for alpine ash *(E. delegatensis).* It often occurs within the alpine ash forest on dry, exposed ridges. It occurs extensively on the Rocky Valley road, north of Falls Creek village where the rain shadow of the Fryingpan Spur appears to he a significant factor. The distribution of this vegetation may also be influenced by the length of period of snow cover and the early melting of snow, both of which may adversely affect alpine ash regeneration.

(ix) Dry sclerophyll forest

Trees of the dry sclerophyll forest have poorer form and are not as tall as those of the wet sclerophyll forest, and also the ground flora is poorer in species and abundance. Species which tolerate dry conditions are present. The ground flora is usually discontinuous and forest litter is an important component of the ground cover. (Plate 15.)

Red stringybark *(E. macrorhyncha)* is the dominant tree species in this community. It occurs with a number of other species, not all of which are always present. The more commonly associated species are broad-leaf peppermint *(E. dives),* white box *(E. albens),* red box *(E. polyanthens),* long-leaf box *(E. goniocalyx),* and to a lesser extent, apple box *(E. bridgesiana),* forest red gum *(E. blakelyi),* candlebark gum *(E. rubida)* and yellow box *(E. melliodora).*

The ground flora consists mainly of scattered tussocks of tussock grass *(Poa australis),* occasional kangaroo grass *(Themeda australis)* and wallaby grass *(Danthonia spp.),* and scattered small shrubs such as handsome flat-pea *(Platylobium formosum),* golden guinea flower *(Hibbertia sp.),* purple coral-pea *(Hardenbergia violaceae)* and shrubby lignotuberous eucalypt regrowth.

The dry association of this alliance which is dominated by black cypress-pine *(Callitris endlicheri),* described from the Hume catchment (Rowe 1967), has not been recorded from this catchment.

Plate 15 - Dry sclerophyll forest of red stringybark and long-leaf box with sparse herbaceous ground cover and dry forest litter.

The red stringybark forests occur extensively at the northern end of the catchment on well-drained rolling to hilly country, and on steep slopes where the rainfall is about 30 inches to 35 inches. On less-well-drained soils it is replaced by savannah woodland of forest red gum and white box *(E. blakelyi-E. albens),* and where rainfall is higher, by the peppermint-gum *(E. radiata-E. rubida-E. dives)* forests. It extends as far south as the northern part of the East Kiewa valley where broad-leaf peppermint and long-leaf box are the dominant species on steep northerly aspects.

(x) Tall woodland

The tall woodland community is composed of trees which have crown depths more-or-less equal to the length of the bole and the crowns usually in contact. The ground flora is composed of grasses and forbs.

The dominant species are swamp gum *(E. camphora)* and black sallee *(E. stellulata)* with tussocks of tussock grass *(Poa australis)* providing more-or-less complete ground cover. Hygrophilous herbs are usually present. (Plate 16.)

This vegetative community occurs as narrow strips along small perennial streams in the cooler parts of the catchment, generally between about 1,00 feet and 3,000 feet elevation.

Swamp gum grows on the wet flats which may remain saturated for much of the year. It replaces river red gum (*E. camaldulensis)* in areas where low temperatures are a feature of the climate. Black sallee, though usually associated with swamp gum, prefers the better-drained banks of the streams.

(xi) Savanna woodland

This is a woodland in which the trees are separated by a distance about equal to the diameter of the crowns of the trees. The ground flora consists of grasses and forbs.

There are two distinct vegetative communities with this form.

(1) River red gum *(E. camaldulensis)* forms a community which occurs on the lowest river flats and elsewhere in the north of the catchment where the ground is periodically flooded (Plate 17). It is a major vegetative community in the north of the catchment, occupying the relatively extensive Kiewa-Murray flood plain and extending up the Kiewa to a little south of Running Creek. The periodic flooding, which seems to be necessary for the regeneration of river red gum, results in the widespread occurrence of a number of hygrophilous plants such as knot weed *(Polygonum minus),* smart weed *(P. hydropiper)* and dock *(Rumex crispis)* as well as rushes *(Juncus* spp.). These, together with tussock grass *(Poa australis)* and other grasses form the ground cover.

(2) The second of the savannah woodland communities has forest red gum *(E. blakelyi),* white box (*E. albens)* and apple box *(E. bridgesiana)* as dominants (Plate 18). Other species which occur in the community but are not always present are red box *(E. polyanthemos)* and yellow box *(E. melliodora).* This association appears to range in species composition and form from almost pure forest red gum through the mixed species form to the dry end of the dry sclerophyll forest community where white box assumes dominance. White box occurs only in the drier northern parts of the range of the community.

Plate 16 - Tall woodland of swamp gum with a closed sward of tussock grass.

Plate 17 - Savannah woodland of river red gum

Plate 18 - Savannah woodland of white box and forest red gum near Bandiana

This community is the dominant vegetation of the upper terrace and rolling landscape in the north of the catchment. It is particularly widespread in the Bandiana-Bonegilla area, and extends south to about Dederang. Further south it is replaced by the red stringybark forests *(E. macrorhyncha* alliance). In areas where the close dissection of the landscape results in generally free drainage, it is generally confined to the drainage lines.

This vegetative community has been extensively modified for grazing, and the climax ground flora can no longer be determined, but it may be assumed that it was similar to that of the dry sclerophyll forest but probably lacked the low shrub component.

ECOLOGY OF THE VEGETATIVE COMMUNITIES

If the conditions which control the distribution of naturally occurring indigenous species are known, the occurrence of different types of vegetation may be used to predict the existence of certain environmental conditions. Combinations of tree species may be very useful as indicators, and if the vegetation has not been seriously modified, the form of the trees can also provide useful information, the better form generally indicating better growth conditions.

The feldmark vegetation *(Ewartia nubigena* association) is possibly not climax, but its occurrence is a general indication of a harsh environment in which exposure to severe winds and cold is a dominant feature. Frequent and severe frosts limit plant growth, and strong winds dry the soil and maintain the erosion-pavement between the plants.

The most widespread of the alpine plant communities is the herbfield of snow grass *(Poa australis)* and snow daisy (*Celmisia longifolia).* Winter snow, which prevents the soil from freezing, is an important climatic feature of this environment. Alpine herbfield generally occurs on the well-drained organic loams, and is therefore characteristic of sloping but not usually excessively exposed country at elevations of about 6,000 feet.

Within the sub-alpine to alpine tract, the alpine shrub community *(Hovea longifolia-Oxylobium ellipticum* alliance) is apparently the climax vegetation of the rocky areas and the exposed slopes where snow is least persistent. The shrubs are also very common in the sub-alpine woodland of snow gum *(E. pauciflora).* The natural distribution of the shrub community may be influenced by the absence of the prolonged snow cover. However, the shrubs are strong primary colonisers of bare ground (Carr 1962) and it may be inferred that the occurrence of vigorous shrubs in typically grassland or herbfield situations is indicative of the opening of the climax sward in the past. Carr suggests that in these situations shrubs are the primary stage in a succession which leads back to the original grassland or herbfield vegetation, thus, in these situations the shrub community is only seral. The rocky areas and the woodland areas may be shrubby because of stock damage early in history of grazing the high mountains before the dates of entry and removal of stock were controlled, and when the cattle followed the retreating snow, or were forced down as persistent snow covered the grazed vegetation. Stock sheltering in such areas when early or late cold weather occurred could have damaged the herbaceous vegetation in these areas, thus allowing the shrubs to become established.

Thyme heath *(Epacris serpyllifolia)* and yellow Kunzea (*K. muelleri)* occur on the poorly drained soils adjacent to the peats of the alpine drainage lines where poor soil aeration is an important factor (Costin 1954).

Grassland of snow grass *(Poa australis)* occurs on the lower slopes of the alpine valleys where imperfect soil aeration and abnormally low and severely fluctuating temperatures, caused by cold air drainage, are apparently determining factors (Costin 1954, 1962). Shelter from severe winds may also be important (Carr and Turner 1959).

The snow gum woodland (*E. pauciflora* association) is the tree-line vegetation. It occurs above 4,500 feet elevation, where fairly persistent winter snow occurs. It appears to succeed above the alpine ash forests *(E. delegatensis* association) and the mountain gum-snow gum forests *(E. dalrympleana-E. pauciflora* association) because of greater tolerance to low temperatures. It persists at higher than normal elevations in rocky areas. This may be the result of the protection afforded the regenerating trees by the rocks, either from dessicating winds, frost action or snow damage. In marginal situations at the limit of its range, and particularly on slopes exposed to the prevailing winds, the snow gum vegetation is reduced to a scrub of twisted mallee-like shrubs. Optimum conditions appear to be well drained soils at elevations of about 4,500 feet and sheltered from the prevailing north-westerly winds.

The sphagnum-moss bog vegetation *(Sphagnum cristatum* association) occurs in areas which are permanently wet. This is also a primary condition for the fen vegetation *(Carex gaudichaudiana* association) although elevation, or more specifically temperature, is more important in influencing the species present in the fen. Costin (1954) claims that the base status of the drainage waters is the important factor determining whether fen or bog develops. Fen vegetation requires a higher base status than bog and is usually found in still or very slowly moving water. The poor aeration associated with both fen and bog vegetation favours the accumulation of peat. Although both of these forms of vegetation are characteristic of the high mountain environment, they also occur in the valleys, where suitable drainage conditions occur.

The wet sclerophyll forest to tall woodland of mountain gum and snow gum *(E. dalrympleana-E. pauciflora* association) often occurs between the alpine ash forest *(E. delegatensis* association) and the snow gum woodland *(E. pauciflora* association). The reasons for the failure of alpine ash to occupy these sites is not clear although the following arguments may be relevant. Grose (1961) found that most seeds of alpine ash have a primary dormancy which is broken by low-temperature stratification. Under natural conditions this is achieved by the low temperatures associated with light and relatively non-persistent winter snow. A secondary dormancy may be induced by unfavourable temperature or moisture conditions in the following spring. With this fairly complex mechanism of germination control, some situations within the normal elevational range of the species may permanently exclude alpine ash. The lack of adequate low-temperature stratification and the early drying out of surface soil, as may occur on exposed northerly or westerly aspects, may prevent regeneration and therefore limit the distribution of alpine ash on such sites. Snow gum and mountain gum are both slower growing species than alpine ash and are apparently tolerant of the low temperatures experienced in these areas. They are thus excluded by competition from sites which meet the requirements of alpine ash but succeed on the sites where conditions are not suitable for ash regeneration.

Thus, the mountain gum-snow gum vegetation is usually found on drier and more exposed sites between about 4,000 feet and 5,000 feet.

The typical alpine ash *(E. delegatensis)* sites have well-drained, deeply weathered soils, annual precipitation of about 50 inches or higher and light falls of snow through the winter. The elevation range is from about 3,000 feet on southerly aspects to about 5,000 feet.

The peppermint-gum forest *(E. radiata-E. rubida-E. dives* association) is the most extensive vegetative community in the catchment. The general occurrence of these forests is at elevations from about 1,000 feet in the valleys up to the lower edge of the alpine ash forests at about 3,000 feet. Annual rainfall within the area is about 40 inches or higher. It is thus a mild to cool and moist environment. The soils are well drained but often contain abundant rock fragments. The broad-leaf peppermint and candlebark gum are dominant on the drier and more stony soils. The narrow-leaf peppermint is the most mesophilic of the three dominant species. It often occurs with blue gum (*E. bicostata)* on moist, southerly aspects. Manna gum (*E. viminalis)* also prefers the moister situations in valley bottoms. Bogong gum (*E. chapmaniana)* is scattered within the community, generally towards the upper elevations.

The factors limiting the distribution of the peppermint-gum association appear to be decreasing soil-moisture availability at the lower elevations and the superior competitive ability of alpine ash where temperatures become suitable for seedling regeneration of that species at the higher elevations.

The dry sclerophyll forest, dominated by red stringybark *(E. macrorhyncha)* contains a number of species. Although the general environment is fairly well defined, the distribution of the individual species in relation to micro-environmental differences is not as easy to determine.

The general environment is more-or-less the driest within the catchment. This is brought about by the combination of rainfall of less than about 35 inches per annum and the generally freely-draining slopes and relatively stoney soils, which result in lower soil-moisture availability than in most of the other vegetative communities.

Red stringybark occurs throughout most of the range of the community but is most abundant, and dominant in form where soil-moisture availability throughout the year is higher than is general for the community. It is generally confined to the warmer aspects. Its upper elevation limit appears to be about 2,000 feet where temperature may be the limiting factor.

Red box *(E. polyanthemos)* becomes dominant on the driest exposed slopes and particularly on spurs where the soil is shallow. It also occurs in the savannah woodland association in situations where soils may be very wet in winter but dry in summer. It appears that a seasonal alternation between wet and dry soil may be an important factor in the distribution of this species.

Apple box *(E. bridgesiana)* and forest red gum *(E. blakelyi)* often occur in small numbers in the more northerly parts of the dry sclerophyll forest, where they are most commonly found in drainage lines or where the soil is seasonally very wet. These conditions represent an extension of the lower slopes or terrace environment into the steeper country.

Long-leaf box *(E. goniocalyx)* occurs extensively at the moister end of the range, particularly on cooler aspects.

Yellow box *(E. melliodora)* grows most abundantly adjacent to gently sloping drainage lines or in more freely draining depressions on northerly and westerly aspects. These locations would have seasonally wet and dry soils and be relatively warm.

Brittle gum (E. *mannifera)* grows on the dry, exposed slopes and spurs and candlebark gum *(E. rubida)* grows on moister slopes and at higher elevations.

The tall woodland of swamp gum *(E. camphora)* and black sallee *(E. stellulata)* indicates a wet soil in an area where low temperatures are common and severe frosts may occur throughout the cooler months.

The savannah woodland of river red gum *(E. camaldulensis)* occurs on the lower river flats which are periodically flooded, and where a high water-table for a large part of the year may be expected. Minimum temperatures are lower than on adjacent higher ground because of cold-air-drainage.

The savannah woodland in which forest red gum *(E. blakelyi),* white box *(E. albens)* and apple box *(E. bridgesiana)* are dominants, occurs on the northern upper terraces and the gentle slopes where soil drainage is slow. This results in seasonal extremes in soil-moisture availability which, with the generally warm temperatures typical of these areas, appear to be the main ecological factors controlling the occurrence of this community. Red gum and apple box appear to be more tolerant of water-logged soil than white box. Red box *(E. polyanthemos),* which is often present in this community, generally occurs on the better drained rises.