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BY J. A. PRESCOTT

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Where mean winter temperatures fall below *30°* F. special precautions must be taken to protect the vines.

The temperature characteristics have also been expressed in the harmonic form of annual mean, amplitude and phase and the use of temperature summations over the base level of 50°F. is discussed.

Experience in Australia and California has been examined with reference to the temperature limits established above.

In an appendix, the history of the use of temperature summations in agricultural climatology is briefly reviewed.

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By J. A. Prescott[1]

[Read 8 April 1965]

SUMMARY

An examination has been made of the temperature conditions at the polar limit of the cultivation of the grape vine *Vitis vinifera* L. in Europe. The principal limiting factors are the mean temperature of the warmest monthly period which must be in excess of 66° F. and of the coldest monthly period which must be in excess of 30° F. These are associated with periods of approximately six months during which the mean monthly temperature is in excess of 50° F.

Where mean winter temperatures fall below 30° F. special precautions must be taken to protect the vines.

The temperature characteristics have also been expressed in the harmonic form of annual mean, amplitude and phase and the use of temperature summations over the base level of 50° F. is discussed.

Experience in Australia and California has been examined with reference to the temperature limits established above.

In an appendix, the history of the use of temperature summations in agricultural climatology is briefly reviewed.

In an earlier communication (1947) it was demonstrated that the waveform analysis of the annual temperature curve based on mean monthly temperatures could be applied to the search in Australia for the temperature homoclimes of species of pines native to the Mediterranean environment. Such a method is particularly successful when dealing with perennial species such as *Pinus radiata* and *Pinus canariensis* which have a geographically restricted native habitat. The march of temperature throughout the year takes care of adaptability to the summer heat and winter cold, leaving the question of moisture relations for studies of greater refinement.[2] In the case of a long established cultivated perennial such as the grape vine (*Vitis vinifera*), the question is complicated by the deciduous character of the plant and by the historical factors involved in the spread of its cultivation from its place of origin in the Armenian region, to all parts of the civilised world. In most cases at some time or other, the limits of cultivation have been advanced beyond a reasonable range both in the polar direction and equatorially, but the present polar limits in Europe at least have been stable for well over a century.

It is necessary, moreover, to take note of the introduction of species other than *V. vinifera* to meet special circumstances, such as the use of "direct producers" or hybrids of *V. vinifera* with various American species which bear commercially useful grapes and which are tolerant of cold conditions and which are resistant to phylloxera. Such vines are the basis of the wine industries in

[1] Member of the Council of the Australian Wine Research Institute.

[2] See for example Johnston (1964).

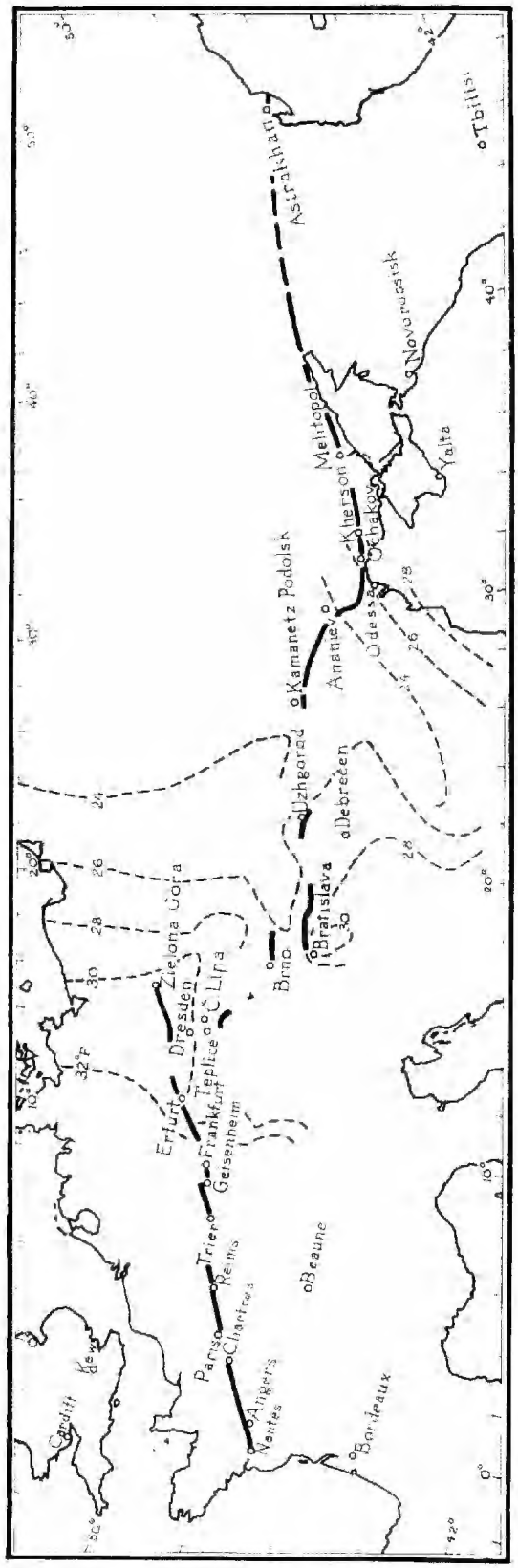

Fig. 1. Map illustrating the northern margin of the cultivation of the vine in Europe. Names and locations of stations with useful temperature records along this margin are indicated. South of this margin is given a selection of stations representing important viticultural areas. The broken lines represent isotherms for the mean temperature of the coldest monthly period.

the States of New York and Ohio in the United States and of the Province of Ontario in Canada. Such an hybrid, *Brandt*, of Canadian origin, has been used to extend the limit of cultivation to Britain, while the Asian species *V. lanata* is grown commercially in Egypt, particularly in the neighbourhood of the Mediterranean Sea.

The purpose of the present study is to examine the temperature conditions which appear to have determined the polar limits of the cultivation of the vine in Europe, to establish any generalisation which emerges and to test this generalisation against the newer experiences of Australia and California.

The present northern limits of the cultivation of the vine in Europe are the result of a process of trial and error extending back first to the Roman occupation and later to the spread of Christian establishments in northern Europe. In Britain at the time of the Norman conquest, the Domesday Book has 38 references to vineyards. An 18th century report from a physiocratic French source on the English counties mentions only Gloucestershire as having vineyards. These are recorded as having been recently abandoned in favour of apple orchards. Generally speaking, Gloucester, Somerset and Kent are regarded as the most favourable counties. In Germany during the middle ages the cultivation of the vine was extended to Lübeck, Stettin, Danzig, Königsberg and Tilsit. Most of these northern vineyards were destroyed, however, by the harsh winter of 1437. In 1592 there were 92 vineyards in Berlin, areas which subsequently reverted to orchards. In what is now Polish Silesia, the cultivation of the vine was introduced by Frankish and Flemish migrants and remained important until the period of the 30 years' war. The most famous wine district in the area is that based on Zielona Góra (Grünberg), including areas at Swiebodzin and Sulechów. The most prosperous period is said to have been between 1830 and 1890, when the area planted reached 1,400 hectares. In Saxony the most important area has been near Meissen and Hoflössnitz, advantage being taken of the favourable climate of the valley of the Elbe. In the late 16th century, 6,000 hectares are said to have been cultivated in this area, but this had decreased by the end of the 19th century to 526 hectares. Further up the valley of the Elbe vineyards were established in Bohemia and these are currently represented by areas at Mihnik and Litomerice. The northern limits of cultivation in Czechoslovakia, Hungary and Rumania are much further south than in Germany and there is no doubt that this limit is determined by the colder winters.

In Russia, the limits have been set by experience gained in extending cultivation into the Ukraine beyond the existing limits in central Europe. With the occupation of the Crimea and its annexation in 1783, a winemaking school was established in that year at Sudak on the coast and this was moved in 1812 to the neighbourhood of Yalta, now one of the important centres in the Soviet Union. Vineyards were established in 1771 by the German settlers on the Volga between Saratov and Tsaritsin (Volgagrad, Stalingrad) but these do not appear to have survived, although mentioned by correspondents of Alph. de Candolle. An important surviving area extends along the banks of the Don. Vines have been grown in Kiev in gardens, but no wine can be made.

The present northern limits of the cultivation of the vine in Europe are shown on the map of Fig. 1. These limits are very similar to those shown on a map by Lenuis (1883) except that the Russian limit is shown on this earlier map as extending to the northern margin of the Caspian Sea. This map also shows the polar limits of the cultivation of the olive as well as of a number of native tree species. He also plotted two sets of isotherms: *isotheres* or lines

TABLE 1.

Climatic Characteristics of Localities Along the Northern Limits of the Cultivation of the Vine in Europe.

Recording Station	Longitude	Latitude	Temperature Characteristics			Season above 50°F			Accumulated day-degrees above 50°F
			Mean °F	Amplitude °F	Phase Days	Beginning April	Ending October	Length months	
Nantes	W 1·6	47·2	52·2	13·0	30·4	9	26	6·55	1,880
Angers	W 0·6	47·4	52·3	13·8	29·1	6	26	6·65	2,000
Chartres	E 1·5	48·4	50·3	14·5	28·5	15	17	6·05	1,710
Paris	2·2	48·8	50·6	14·5	26·7	14	16	6·10	1,750
Reims	4·0	49·3	50·3	15·5	27·9	14	15	6·05	1,820
Trier	6·6	49·7	47·3	14·3	29·7	18	15	5·90	1,700
Geisenheim	8·0	50·0	49·2	16·3	26·4	16	14	5·90	1,790
Frankfurt	8·6	50·2	49·4	16·7	27·0	18	14	5·85	1,820
Erfurt[1]	11·0	51·0	46·8	17·0	29·4	30	6	5·20	1,430
Dresden[2]	13·7	51·1	48·4	16·7	30·4	26	12	5·55	1,660
Teplice[3]	13·8	50·6	48·1	17·8	26·3	21	5	5·45	1,770
Č. Lipa[3]	14·2	50·7	46·5	18·9	27·8	30	5	5·15	1,590
Zielona Góra[4]	15·5	51·9	47·3	17·9	29·9	26	8	5·40	1,630
Brno	16·6	49·2	47·2	19·7	28·1	22	11	5·60	1,780
Uzhgorod	22·3	48·6	49·1	20·4	30·2	17	18	6·00	2,170
Kamenetz-Podolsk	26·6	48·7	45·9	22·7	30·3	29	11	5·40	1,930
Ananiev	29·9	47·6	47·6	23·5	29·6	24	26	5·55	2,310
Odessa	30·7	46·4	49·3	23·5	32·9	24	18	5·80	2,580
Ochakov	31·5	46·6	49·8	24·3	33·4	21	20	5·95	2,730
Kherson	32·6	46·6	50·1	24·0	31·2	18	18	6·00	2,790
Melitopol	35·4	46·8	49·3	25·2	31·5	20	15	5·85	2,810
Astrakhan	48·2	46·4	49·0	29·4	30·3	18	15	5·90	3,160

1. Erfurt for the Saale-Unstrut valleys.
2. Dresden for Meissen and Grossenhain.
3. Teplice and Č. Lipa for the Bohemian areas of Melnik and Litoměřice.
4. Zielona Góra (Grünberg) for Swiebodzin and Sulechow.

of equal summer temperatures and *isocheims* or lines of equal winter temperatures. Commenting on the interpretation of this map, Lennis remarks on the complications associated with the problems involved.

The map of Fig. 1 gives the locations of the temperature stations which provide the most useful available information associated with the limit of cultivation under discussion. In addition, the isotherms of the coldest month are plotted as these obviously play a part in determining the limit.

For each of the stations listed and for others in the vicinity the temperature characteristics of each station have been calculated by wave-form analysis, and in each case a smooth curve has been drawn from the values calculated from the first three harmonics. From these curves has been estimated the length of season over 50° F. and the accumulated "day-degrees" above this limit. These data have been brought together in Table 1.

It is now possible to summarise the data in the form of mean annual temperature and of temperature amplitude. This has been done in Fig. 2 where temperature characteristics have been plotted against longitude across Europe, as it is obvious that the degree of continentality of the temperature regime as determined by longitude is more important than latitude in determining the limit. The German climatologists have observed that a mean temperature of the warmest month of 20° C. (68° F.) is the probable requirement together with a mean temperature of the coldest month not below 0° C. (32° F.) with a mean annual temperature of at least 48° F.

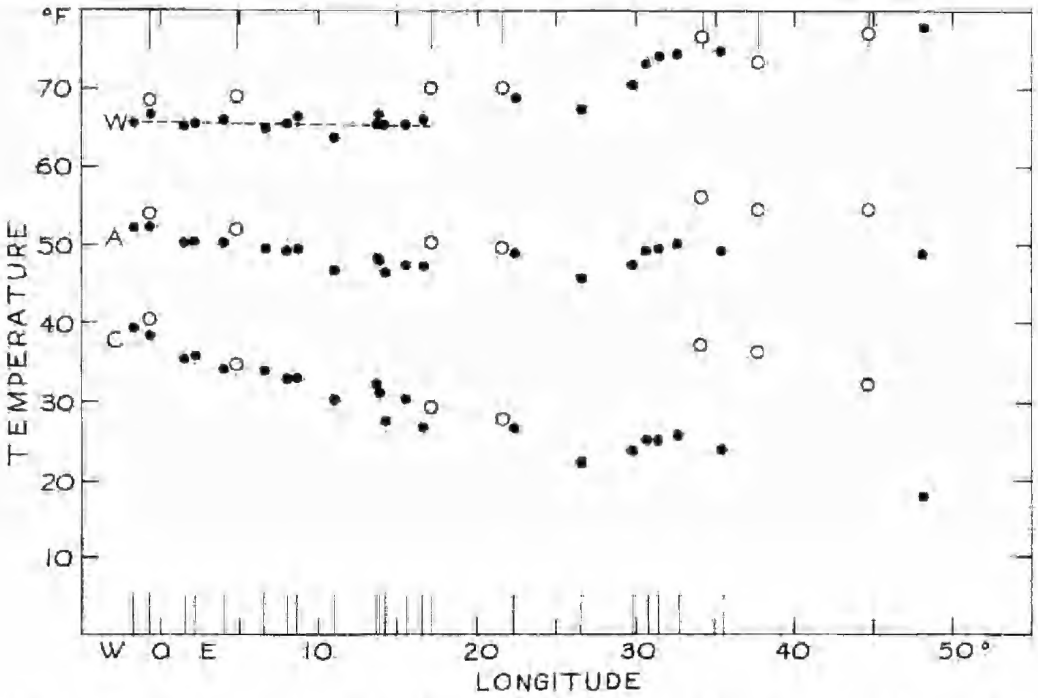

Fig. 2. Illustrating the relationship between temperature and longitude along the northern margin of the cultivation of the vine in Europe. W. Temperature of the warmest monthly period. The broken line is the calculated regression of temperature on longitude over the range 2°W to 16°E. A. Mean annual temperature. C. Temperature of the coldest monthly period. Open circles are for well-established stations well within the northern limits.

In Fig. 2, the calculated line of regression of temperature on longitude has been plotted for the warmest month over the range of longitude 2°W. to 16°E. There is no significant departure over this range from a mean temperature of 65·6° F. On the other hand, the mean temperature of the coldest month falls over this range of longitude from 39° F. to about 30° F. At the lowest temperatures and generally speaking further east at the Ukrainian winter temperatures of about 25° F., it is recognised that protection of the vine in winter is very necessary. French observers regard an absolute minimum of −15° C. to −18° C. (say, 0° F. to 5° F.) as the ultimate limit of danger in winter.

This northern limit of cultivation is reasonably continuous from the coast of the Atlantic to the valley of the Rhine, but east of the Rhine the cultivation is less continuous, edaphic factors of soil and slope being sought as in the Rheingau, the valleys of the Saale and Unstrut and of the Elbe, on dune sands in Silesia and on south-facing slopes at Tokaj in Hungary. The continuity is also interrupted by the mountain ranges such as the Erzgebirge, the Riesengebirge and the Carpathians. It will be noted that the eastern limit of this continuous cultivation is determined by a mean temperature of the coldest month of 32° F.

Another temperature factor which has been considered to be of importance is that controlling the period of vegetative growth. The nineteenth century botanists agreed that for most woody species, bud burst in Spring began when the mean monthly temperature reached 10° C. (50° F.) and this temperature limit has been extensively used in many climatic studies on the vine. From Table 1 it will be noted that over practically the whole range of longitude from Chartres to Astrakhan, the period during which the temperature limit of 50° F. is exceeded varies from approximately 5·5 to 6·0 months. In every case the beginning of this season is in April and the end in October, mean dates being 21 April and 14 October, a period of 5·8 months.

In order to provide some perspective the records of a number of well-established areas south of the northern limit have been examined and these are brought together in Table 2 as well as being plotted in Fig. 2. The length of season over 50° F. is in general between six and seven months and summer temperatures about 3° to 4° F. higher than on the northern limit.

This northern limit of the cultivation of the vine is only valid for early varieties. An historical experience in this connection is that of Boussingault (1837b), who recounts the establishment of a vineyard on the family estate in Alsace in 1818. The varieties first planted were those from the region of Perpignan, presumably *Grenache*, *Carignan* and similar varieties. These thrived, but the grapes did not ripen and the vineyard was replanted in 1828 with early varieties including *Pinot*, *Sauvignon blanc*, *Tokay*, *Riesling* and *Traminer*. It is of interest that the vintage was followed over a period of years and recorded quantitatively from 1833 to 1836. Boussingault records his opinion that the temperature of the warmest month should be 4 or 5 degrees higher than the recorded probable mean of 64° F., for the season to be favourable in Alsace.

It has been pointed out above that a temperature factor which has been considered to be of great importance is that controlling the period of vegetative growth. This temperature limit was established for a number of species by Alph. de Candolle (1855) and for the vine the limit was established at 10° C. (50° F.), and was used extensively by him and adopted by the American workers Amerine and Winkler (1944, 1963) for determining the climatic regions for the cultivation of wine grapes in California.

TABLE 2.

Climatic Characteristics of Important Wine Districts of Europe Immediately South of the Northern Limits of Cultivation of the Vine.

Recording Station	Longitude °	Latitude °	Temperature Characteristics			Season above 50°F			Accumulated day-degrees above 50°F
			Mean °F	Amplitude °F	Phase Days	Beginning April	Ending October	Length months	
Bordeaux	W 0·6	44·9	54·2	13·9	31·5	1	31	7·05	2,390
Beaune	E 4·9	47·1	52·0	16·5	28·7	6	20	6·45	2,300
Bratislava	17·1	48·1	50·4	20·2	28·6	14	20	6·20	2,420
Debrečen[1]	21·2	47·5	49·7	20·8	27·5	12	15	6·10	2,350
							November		
Yalta	34·2	44·5	56·1	18·7	40·6	11	17	7·20	3,300
Novo-rossisk	37·8	44·7	54·6	18·5	39·3	15	9	6·80	2,990
Tbilisi	44·7	41·7	54·7	21·4	33·3	3	2	7·00	3,370

[1] Debrečen for Tokaj

Three examples have been selected from the range of stations in Table 1 so that a comparison may be made between the original use of this temperature limit by de Candolle and the current use by the Californian workers.*

These examples are illustrated and explained in Fig. 3. De Candolle's rule (1855 loc. cit. p. 365) with respect to the limits of cultivation of the vine may be quoted in full:

"The cultivation of the vine, for the manufacture of wine, can be undertaken in Europe, on slopes with a favourable exposure, up to those localities which provide a sum of 2,900 day-degrees (Centigrade) from the day when the mean temperature first reaches 10° C. until the day when the temperature falls below 10° C. in the shade, provided that at the approach of maturity, the number of days with rain does not exceed a dozen per month."

De Candolle's choice of 10° C. was made only after he had satisfied himself that it was better than 8° C. or 9° C. He was, moreover, well aware that this temperature sum could be modified by other factors, the chief of which he regarded as the amount of solar radiation, but as he had no method of estimating this, he noted the effect of latitude in influencing the length of day in summer

* For a fuller account of the history of the development of this concept, see appendix page 20.

Fig. 3. Three selected examples of temperature curves of localities on the northern limit of the cultivation of the vine in Europe. The curves are drawn from the calculated values based on the wave-form analysis of the original mean monthly temperatures following the equation:

$$u = a_0 + a_1 \cos x + a_2 \cos 2x + a_3 \cos 3x + b_1 \sin x + b_2 \sin 2x + b_3 \sin 3x$$

For the three localities the constants of the equation are:
with mid-January as 0°, mid-February 30° etc.

	a_0	a_1	a_2	a_3	b_1	b_2	b_3
Nantes	52·20	−12·92	+0·40	+0·12	−0·77	−0·98	+0·03
Geisenheim	49·25	−16·30	0·00	+0·33	+0·17	−0·42	+0·17
Astrakhan	48·97	−29·35	−0·55	−0·10	−1·67	−1·65	−0·82

For the first harmonic these correspond to the values:

	Annual mean temperature °F	Amplitude F	Phase lag behind the sun days
Nantes	52·2	13·0	30·4
Geisenheim	49·2	16·3	26·4
Astrakhan	49·0	29·4	30·3

The shaded areas correspond to temperature summations, the whole area represents the original summation recommended by de Candolle (Centigrade) and the upper area (Fahrenheit) that currently (1965) adopted by Californian workers. These values are:

	day-degrees	
	California	De Candolle
Nantes	1877	3034
Geisenheim	1786	2886
Astrakhan	3162	3551

in northern latitudes and he also made note as in the rule quoted above of the number of days without rain. Black (1960) has recently calculated values for solar radiation for northern Europe. The southern limit of Black's values coincides approximately with the northern limit of the cultivation of the vine so that a re-appraisal may become possible in these terms.

It will be noted from Fig. 3 that de Candolle, although confining his summations to periods with mean temperatures in excess of 10° C., added the actual temperatures in degrees centigrade so that a new base line of 0° C. was established. For regions, such as Madeira, where the mean temperature of all months of the year exceeds 10° C., he refused to commit himself.

The Californian workers using the Fahrenheit scale have measured temperatures above the base line of 50° F. and where this temperature is exceeded throughout the year an arbitrary selection of the time period has been made, say, April to October, although it is recognised that crop periods such as bud-burst to ripeness, or flowering to ripeness for each specific variety would be more satisfactory.

Phenological observations are not sufficiently numerous to give more than a general confirmation of the soundness of the concepts employed.

In the German regions of the Palatinate, Bavaria and Franconia, the variety *Riesling* begins its vegetative growth about 25 April, begins flowering about 11 June, and the berry begins to ripen about 2 September. The time from bud-

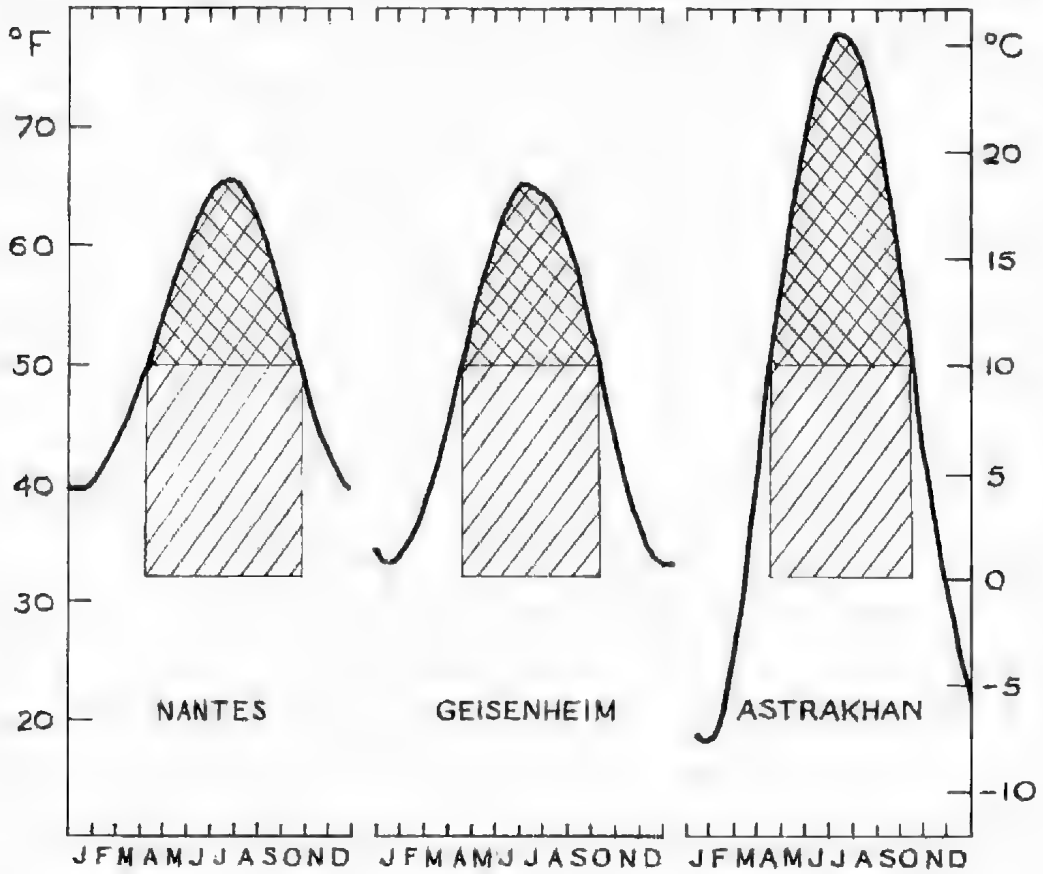

Fig. 3.

burst to the beginning of ripening has a mean value of 126 days. In the Nahe region over a recent period of ten years, the mean date of the beginning of ripening for this variety was 22 August and of the completion of ripening 3 October (Hillebrand, 1963). In these observations the degree of ripeness was based on the specific gravity of the grape juice.

In northern France varieties such as *Gamay* begin vegetative growth from 7-18 April, begin flowering on 9 June and ripen from 17-28 September.

In the commune of Beaune, Burgundy, the proclamation of vintage (*Ban de vendange*), over the years 1909 to 1933, ranged from 15 September to 16 October with a mean date of 28 September. This is to be compared with 20 October, the date ending the mean period above 50° F. at Beaune.

De Candolle quotes a group of observations on the beginning of vegetative growth of the vine at Brussels. Over a period of ten years this is given 25 April.

These dates correspond well with the choice of 50° F. as the basal temperature.

EXTENSION OF EUROPEAN EXPERIENCE TO OTHER COUNTRIES

From the observations made in Europe, it can be assumed that the polar limits of cultivation of the vine are determined climatically by the temperature limit of not less than 66° F. for the mean of the warmest month combined with a mean temperature for the coldest month of not less than 30° F. Below this mean for the coldest month provision has to be made for the protection of dormant vines in winter. The rainfall limit may be taken as an annual mean of 30 inches as a maximum with 20 inches as a possible minimum below which irrigation is likely to be needed. Important areas, such as the Bordeaux region, do, in fact, have areas with an annual rainfall as high as 40 inches, but in such regions fungoid diseases will become increasingly important. A further requirement will be that the length of the season above 50° F. must be in the region of six months and the temperature summation over 50° F. within the period must be of the order of 1,600 to 1,800 day-degrees, corresponding approximately to Alph. de Candolle's original requirements of 2,900 day-degrees on the Centigrade scale. With a seasonal length of six months 1,800 day-degrees corresponds to a de Candolle value of 2,830.

An alternate approach would be the use of appropriate combinations of the harmonic characteristics of the temperature curve for the year. This would mean seeking such appropriate combinations of the annual mean temperature and amplitude as would correspond to the limits set above for the warmest and coldest months. Appropriate combinations would be mean annual values of 52° F. to 48° F. with amplitudes of 14° to 18° and phase values of 26 to 30 days of lag behind solar radiation. Such combinations would be required to reproduce more precisely the temperature conditions along the main northern boundary of cultivation in Europe.

The relevant areas of widest experience with *V. vinifera* outside Europe are likely to be found in South America (Argentina and Chile), in South Africa, in Australia and in California. It is proposed to examine the conditions in Australia and California and to discuss briefly the conditions in England.

Vine Growing in England

It has already been pointed out that English experience goes back for many centuries and that for sentimental and other reasons attempts are always being made to produce wine from grapes grown in England. Generally speaking

the enthusiastic wine-maker is satisfied if he can produce wine, say, once in three or five years. Frequently the vines are grown on walls with a southern aspect as is also the case in Silesia. The varieties grown must be very early and according to Ordish (1953) include the Canadian hybrid: *Brandt*, *Golden Chasselas*, *Gamay Hatif* and *Meslier Précoce*. Commercial wine production in England, however, is based on concentrated grape juice imported principally from Cyprus and Greece.

For an assessment of temperature conditions, Cardiff, Oxford and Kew have been selected as affording probable northern limits for Britain. Appropriate climatic information is given in the following table:

Station	Temperature Characteristics			Temperature of warmest monthly period °F	Length of season over 50°F months	Accumulated day-degrees above 50°F
	Mean °F	Amplitude °F	Phase Days			
Cardiff	49·8	10·7	38·9	61·0	5·6	1,230
Oxford	49·2	11·9	32·9	62·1	5·3	1,110
Kew	49·8	11·9	33·2	62·9	5·5	1,340

Using the accumulated day-degrees above 50° F. as the simplest criterion, none of the values approaches the lower limit set at 1,600 for European continental conditions. Similarly, the mean temperature of the warmest monthly period is significantly below the established limit of 66° F.

California

The grape vine *V. vinifera* is the species commercially established in the western United States, almost entirely in California, although small areas have been noted in the States of Oregon and Washington. There is, of course, a long experience going back to the days of Spanish settlement, and the cultivation of the vine has been adjusted through experience to the geographical limits imposed by climatic conditions. Amerine and Winkler (1944, 1963) have, on the basis of this experience, grouped the California areas into five regions based on accumulated temperatures over 50° F. Here the difficulty arises that was encountered by de Candolle with respect to Madeira in that either all months have mean temperatures above 50° F. or a substantial number of months are so placed. In their first paper they used as a criterion the period from full bloom to ripeness as indicated by a given specific gravity of the grape juice. This is of particular value in the comparison of varieties in different localities and seasons. They obtain as values for their coolest region (No. 1) 1,800 to 2,000 day-degrees. In their second paper they chose the period April to October inclusive which gives a value of less than 2,300 day-degrees for the coolest region.

On the map of California (Fig. 4) have been plotted the criteria mentioned earlier, namely, 66° F. for the warmest month, 30° F. for the coolest month and 30 inches of annual rain. The areas considered climatically suitable for the cultivation of the vine within these limits have been margined. The counties included by Amerine and Winkler in Region No. 1 are indicated by hatching. Below an annual rainfall of 20 inches, irrigation is likely to be needed, above 30 inches special conditions are likely to be encountered. The map has been constructed essentially from the data provided in "Climate and Man" (1941) supplemented by data in the official reports of the U.S. Weather Bureau.

It will be noted that the isotherm of 66° F. for the warmest month is determined in the first place by proximity to the Pacific Ocean and is parallel to the coast, and in the second place by the altitude in the mountains to the east of the central valley.

As an example, Napa (lat. 38·3°N., long. 122·3°W.) has been taken as a recording station in an established wine-growing district.

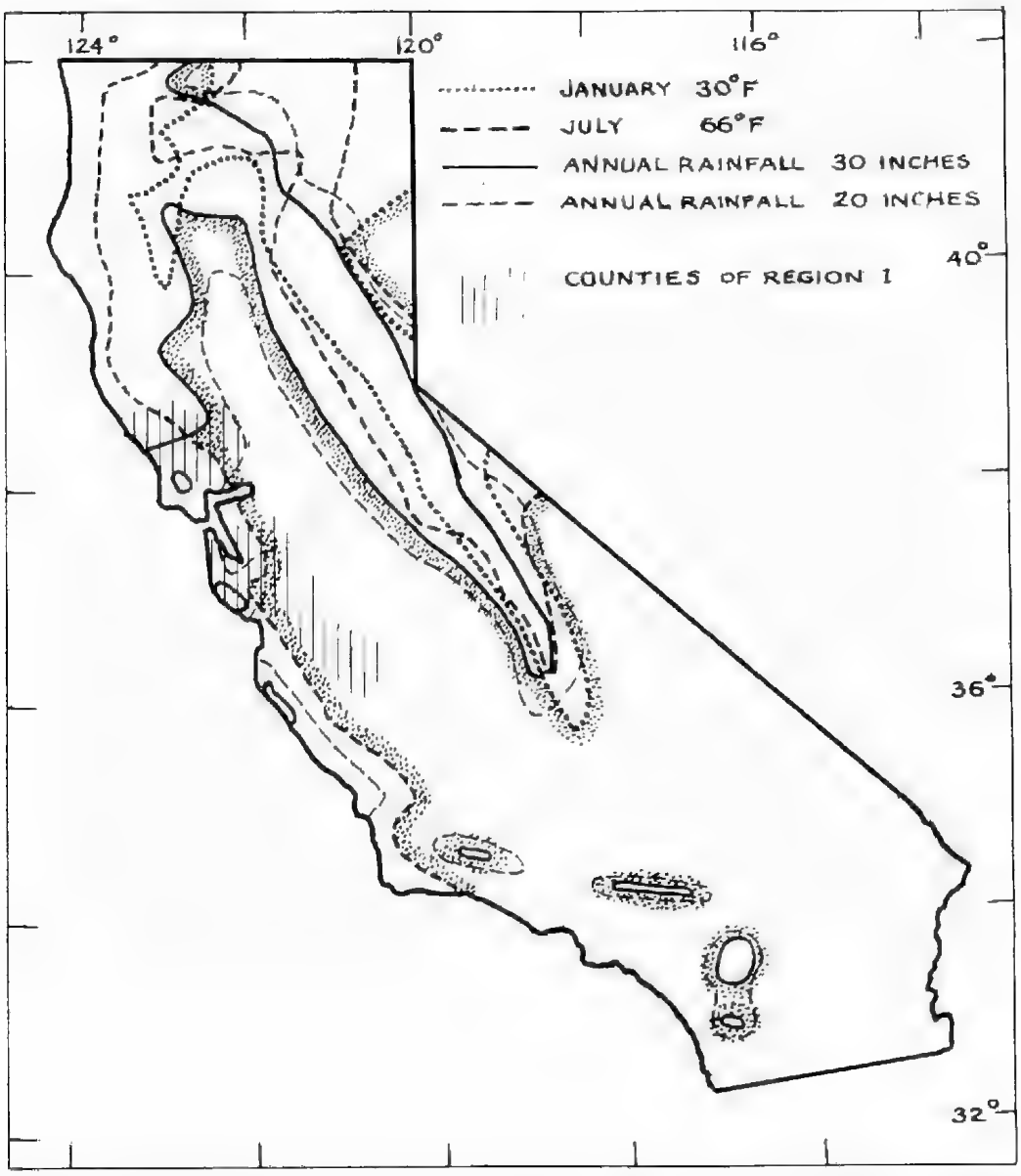

Fig. 4. Map of California on which have been projected temperature limits for the cultivation of the vine established at the northern margin in Europe. The area within which favourable conditions can be expected is margined. Counties included by Amerine and Winkler in their coolest Region I are shaded.

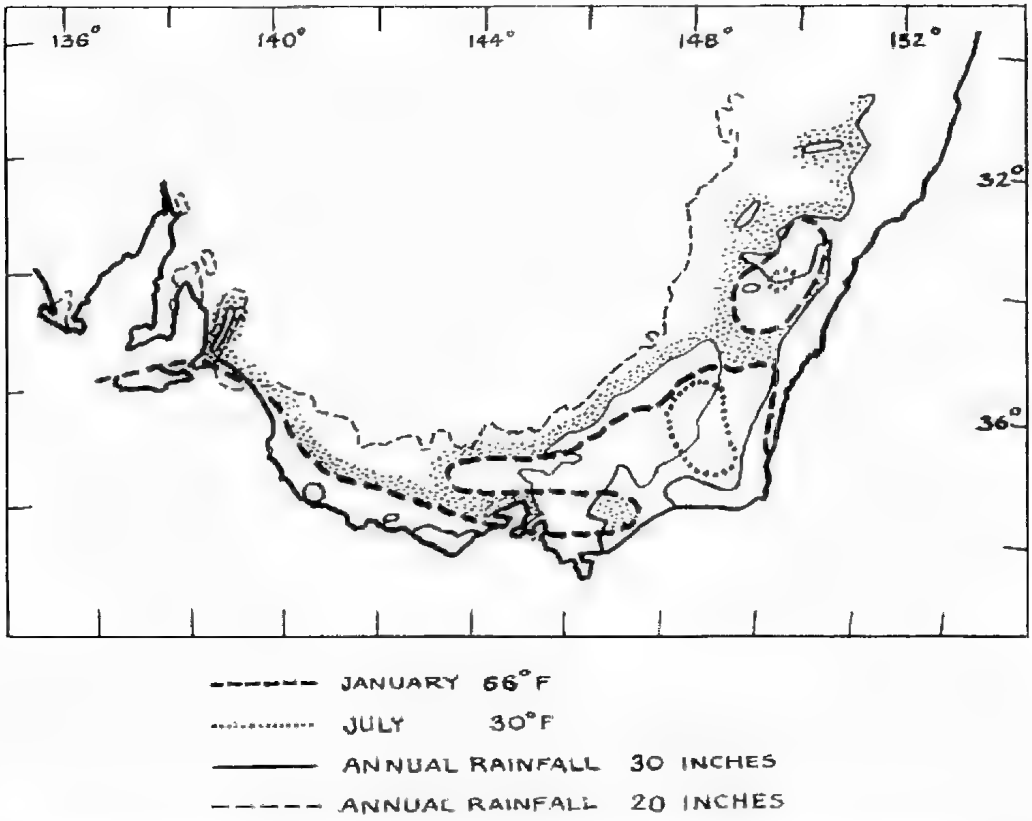

Fig. 5. Map of south-eastern Australia on which have been projected temperature limits for the cultivation of the vine established at the northern margin of cultivation in Europe. The area within which favourable conditions can be expected is margined.

The temperature characteristics are given below:

Station	Temperature Characteristics			Temperature of warmest monthly period °F	Length of season over 50°F months	Accumulated day-degrees above 50°F
	Mean °F	Amplitude °F	Phase Days			
Napa	57·5	10·0	36·2	66·7	9·4	2,890

These temperature characteristics are obviously quite different from those of the European limits, due principally to the length of the season. If the criterion of seven months, April to October, be taken the temperature accumulation is 2,680 day-degrees corresponding to Region II of Amerine and Winkler, the region regarded by them as most important for table wines. For the established viticultural area of California, criteria independent of northern European experience must therefore be established if the summation of temperatures is to be used.

TABLE 3.

Localities in California with Temperature Characteristics Approaching those of the Northern Limit of the Cultivation of Vines in Europe.

Station	Latitude N	Longitude W	Altitude feet	Temperature characteristics			Season over 50 F months	Annual rainfall inches
				Mean F	Amplitude F	Phase days		
Alturas	41·5	120·5	4,346	47	18	32	5·1	13
Cedarville	41·5	120·2	4,675	48	19	33	5·1	12
Mt. Shasta City	41·3	122·3	3,543	49	17	34	5·6	34
Fall River Mills	41·0	121·5	3,340	50	17	31	7·0	17
Susanville	40·4	120·6	4,152	49	18	31	5·4	18
Mineral	40·3	121·6	4,850	46	16	39	4·7	45
Bowman Dam	39·5	120·7	5,347	50	16	43	5·5	70
Nevada City	39·3	121·0	2,600	54	15	39	6·7	49
Dudley's	37·8	120·1	3,000	53	14	36	6·5	37
Yosemite	37·7	119·6	3,985	51	18	31	5·2	34
Giant Forest	36·6	118·8	6,360	48	14	41	4·9	24

The map reveals, however, a number of intersections between the isotherms of 30° F. and 66° F. for the coolest and warmest months respectively. These are inland areas and at some altitude. Recording stations near such intersections are given above (Table 3), together with temperature characteristics.

This Californian experience may be extended to the State of Washington where approximately 8,000 acres of vines are grown, nearly all of which are under irrigation, in the south central portion of the State.[1] Approximately 85 per cent of this acreage is planted to the American variety Concord (*V. labrusca*) and most of the vinifera varieties have to be covered to survive the severest winters. The mean temperature of the warmest month at the Irrigation Experiment Station at Prosser is 71° F. and of the coldest month 29° F. The length of the season over 50° F. is 6·4 months.

Australia

The appropriate temperature and rainfall limits have been plotted on the map of Fig. 5 for south-eastern Australia. Tasmania is well outside the limit of 66° F. for the warmest month, and all of the rest of Australia west of Kangaroo Island comes within the limit. As with California, there is a temperature control imposed by proximity to the oceans and away from these a further control imposed by altitude.

The most interesting locality near the limit is that of Coonawarra (37·3°S., 140·3°E.) in South Australia which in recent years has become an area noted for red table wines. The temperature characteristics of Coonawarra, based on interpolations from long-established recording centres in the general region are given below:

Station	Temperature characteristics			Temperature of warmest monthly period °F	Length of season over 50 F months
	Mean °F	Amplitude F	Phase Days		
Coonawarra	57·5	8·4	31·2	66·4	9·4

These conditions are very similar to those at Napa in California recorded in the preceding section, but the conditions in winter are much milder than those in Europe. In no locality in Australia does the isotherm of 30° F. for the coolest month intersect that of 66° F. for the warmest month.

Mean Summer temperatures of 66° F. are reached at altitudes of approximately 3,800 feet in the northern tablelands of New South Wales, at 3,000 feet in the central tablelands, at 2,500 feet in the southern tablelands and at 1,700 feet in Victoria. The Canberra region comes just within the limit.

In general, the conditions in Australia will need a separate study allowing for wider comparisons with the warmer regions of Europe, western Asia and California.

[1] Personally communicated by W. J. Clore, May, 1965.

APPENDIX

THE SUMMATION OF TEMPERATURES IN AGRICULTURAL CLIMATOLOGY

Soon after his invention of the alcohol thermometer in 1730, Reaumur organised a series of temperature observations in Paris and overseas. He noted (Reaumur, 1735) that the agricultural season of 1735 was much later than in recent years and that the wheat and grape harvests had been delayed by at least a month. He noted that this was associated with lower temperatures in spring and early summer and proceeded to compare the conditions in the months of April, May and June in 1734 and 1735 on the basis of the "sum of the degrees of heat". For each day he determined the mean temperature by taking half the sum of the maximum and minimum and proceeded to add them day by day for each of the three months.

Sums of temperature above freezing point °R at Paris

	April	May	June
for 1734	343	405	512
for 1735	270	328	417

He suggested that by this means different countries and years could be compared.

In view of the fact that the same grain crops can be harvested in countries with very different temperatures, one should be able to compare the sums of degrees of heat for the months during which the cereals made the greatest part of their growth and came to maturity in warm countries such as Spain and Africa, in temperate countries as in France, and in cold countries as in those of the north.

This idea of treating temperature readings as measuring the quantity of heat appears to have been projected forward into the nineteenth century in spite of the discovery and naming of "quantity of heat" and "latent heat" by Joseph Black in 1760. The idea of "absolute temperature" was not to come until after 1850.

The first notable application of this suggestion of Reaumur was made by Boussingault (1837), who compared the temperatures under which wheat, barley, maize and potatoes were grown both in Europe and in the Americas. He was able to make observations on his own farm at Bechelbronn in Alsace. He expressed the requirement in the quantitative form:

"The number of days between the beginning of the growth of an annual plant and its maturation is inversely proportional to the mean temperature during this period of growth, so that the product of the number of days by the temperature is constant."

Of seven examples which he gives for maize, two may be quoted:

Locality	Mean annual temperature C°	Mean temperature during crop C°	Number of days	Product
Bechelbronn (Alsace)	9·8	20·0	122	2,440
Valley of the Magdalena	17·0	27·0	92	2,484

The principal contribution of the botanists who followed Boussingault was to recognise that plant activities ceased below certain temperatures and this information was critically examined by Alph. de Candolle (1855) and applied to a large number of wild species – annual, perennial and woody – in Europe. He then proceeded to extend the concept to cultivated species and established useful minimum temperatures for a number of crops.

De Candolle's table for cultivated species is worth quoting in view of the continued application of the concept to the present day.

Alphonse de Candolle's table of temperature summation:

Crop	Extreme limit in Europe		Minimum useful Temperature		Summation of temperatures above useful minimum day-degrees
	Country	Latitude °N	°C	°F	C
Barley	Norway	70	5	41	1,250
Vine (for wine)	Germany	52·2	10	50	2,900
Maize	Germany	51	13	55	2,500
Date palm (for fruit)	Spain	39·5	18	64	5,100

De Candolle always insisted that mean daily temperatures below the freezing point of water (0° C.) were not to be taken into account, thus establishing a secondary base level below the effective minimum.

De Candolle advocated the regular publication by official meteorological departments of mean temperatures and summation in excess of specified minima and this was, in fact, taken up by the London meteorological office and noted by de Candolle (1884). At this period the London office was already publishing weekly a summation to temperatures above 42° F. These were recorded as "day-degrees", a term invented by the Meteorological Office in London.

De Candolle (1886) attended the 69th Session of the Swiss Society for Natural Sciences in August of that year, at which J. H. Gilbert (1886) of Rothamsted gave an account of the relationship which exists between sums of temperatures and agricultural production. This paper is reported in full. Gilbert reported that in 1881, the London meteorological office on the suggestion of Lawes and himself began to publish weekly sums of temperature above a fixed base, together with hours of sunshine and rain, for the information of agriculturists, the base temperature chosen being 42° F. as stated above.

Gilbert tabulated the sum of temperatures from certain fixed dates until the time of harvest of wheat at Rothamsted for the years 1852 to 1885. For the years 1878 to 1885 these are based on the weekly publications of the meteorological office. Gilbert recorded for winter wheat, over the full period, sums of temperatures of the order of 1,100 to 1,200 day-degrees.[1] The London Meteorological Office is still (1965) interested in accumulated temperatures, above and below 42° F., and these are entered in the monthly returns from all crop-weather stations in Britain. The continued use of accumulated temperatures is, however, currently under discussion.[2]

Modern applications in terms of this concept of temperature summation come mainly from North America. The bridge between the European work of the nineteenth century and the American work of the twentieth is provided

[1] The responsible people at the Meteorological Office in London were R. H. Scott and General Strachey.

[2] Personally communicated by H. L. Penman.

by Abbe (1905). Livingston (1916) compared the summation of direct temperatures with the summations of temperature efficiences based on the physicochemical concepts of Arrhenius and Van't Hoff and with those of physiological efficiencies based on experimental studies. He was a strong advocate of the provision of experimental facilities to enable studies of plant growth to be made in controlled environments.

Of more recent years, Nuttonson (1955, 1957, 1958) of the American Institute of Crop Ecology has applied the summation of temperatures above a fixed base line to the study of the climatic requirements of wheat, barley and rye and found that a base temperature of 40° F. gave the most satisfactory values. This temperature was selected after testing 32°, 36°, 40° and 45° F. Following Livingston, he refers to the method as the *remainder-index* system.

Amerine and Winkler (1944, 1963) have applied the method to the study of the climatology of the grape-vine in California, and Amerine (1963) also gives references to work in the Soviet Union. They classify the vine areas of California into five regions from the coolest to the warmest on this basis. In the earlier publication the physiological period, blooming to harvest, was used; in the later publication a fixed calendar period, April to October inclusive, is employed.

Clore and Drummond (1963, 1964) also have applied the method to the interpretation of seasonal conditions for grape growing in the State of Washington. In view of the increasing use of the concept in horticultural practice in the United States, involving shorter periods and more accurate assessments of temperature summations, Arnold (1960) has proposed a convenient method for estimating degree-days from daily temperatures when the minimum temperature is below the base temperature.

It is evident from the long history of the use of temperature summations in crop physiology, that it will find its most useful applications when restricted to crop periods, such as the emergence of an annual crop to its harvest period, or in the case of a deciduous perennial from bud-burst to leaf-fall or to ripeness of the fruit. In this connection both de Candolle and Gilbert were aware of the need to bring in solar radiation and Gilbert even noted the lag between the time of greatest sunshine and the time of warmest temperature.

As soon as the method is used over a fixed calendar period there is no advantage to be gained over quoting the mean temperature during the period. The use of harmonic characteristics, moreover, can be used to express much of the relevant information and can be used, if required, to calculate the summation of temperatures over any specified period and more particularly the temperatures at the warmest and coolest periods.

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Considerable help has been received in the preparation of the discussion from people who have supplied information. I mention Mr. I. Kaye, Librarian of the Royal Society in London, for confirming early 18th century literature, Miss C. M. Eardley for locating in Australia the 19th century literature, Dr. H. Eichler for the loan of publications in his personal library, Mrs. Joyce Collins whose collection of temperature data, now located at the Waite Institute, was extensively used, and Mr. B. C. Rankine for the loan of personal correspondence with French oenological stations.

To Mr. J. C. M. Fornachon, Director of the Australian Wine Research Institute, I am grateful for his general interest in the project and for making the facilities of the Institute available.

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THE DISTRIBUTION OF EUCALYPTUS SPECIES I[N PORTION OF COUNTY STANLEY, SOUTH AUSTRALIA

BY MARY A. TODD

Summary

This paper reports the distribution of *Eucalyptus* species over an area of about 300 square miles in. part of County Stanley, South Australia, centred on the township of Clare, together with such information as to climate and is as is available.

Eucalyptus leucoxylon var. *pauperita, E. camuldulerias, E. odorata, E. mucrorrhyncha, E. elaeophora,* and the mallee species E. *oleosa,* E. *oleosa* var. *glauca* (=E. *transcontinentulis), E. calciculfrix, E. lansdowneana,* and the mallee form of E. *odorata* occur. Tussock grassland, now greatly modified, is also present.

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by Mary A. Todd*

[Read 13 May 1965]

SUMMARY

This paper reports the distribution of *Eucalyptus* species over an area of about 300 square miles in part of County Stanley, South Australia, centred on the township of Clare, together with such information as to climate and soils as is available.

Eucalyptus leucoxylon var. *pauperita*, *E. camaldulensis*, *E. odorata*, *E. macrorrhyncha*, *E. elaeophora*, and the mallee species *E. oleosa*, *E. oleosa* var. *glauca* (=*E. transcontinentalis*), *E. calcicultrix*, *E. lansdowneana*, and the mallee form of *E. odorata* occur. Tussock grassland, now greatly modified, is also present.

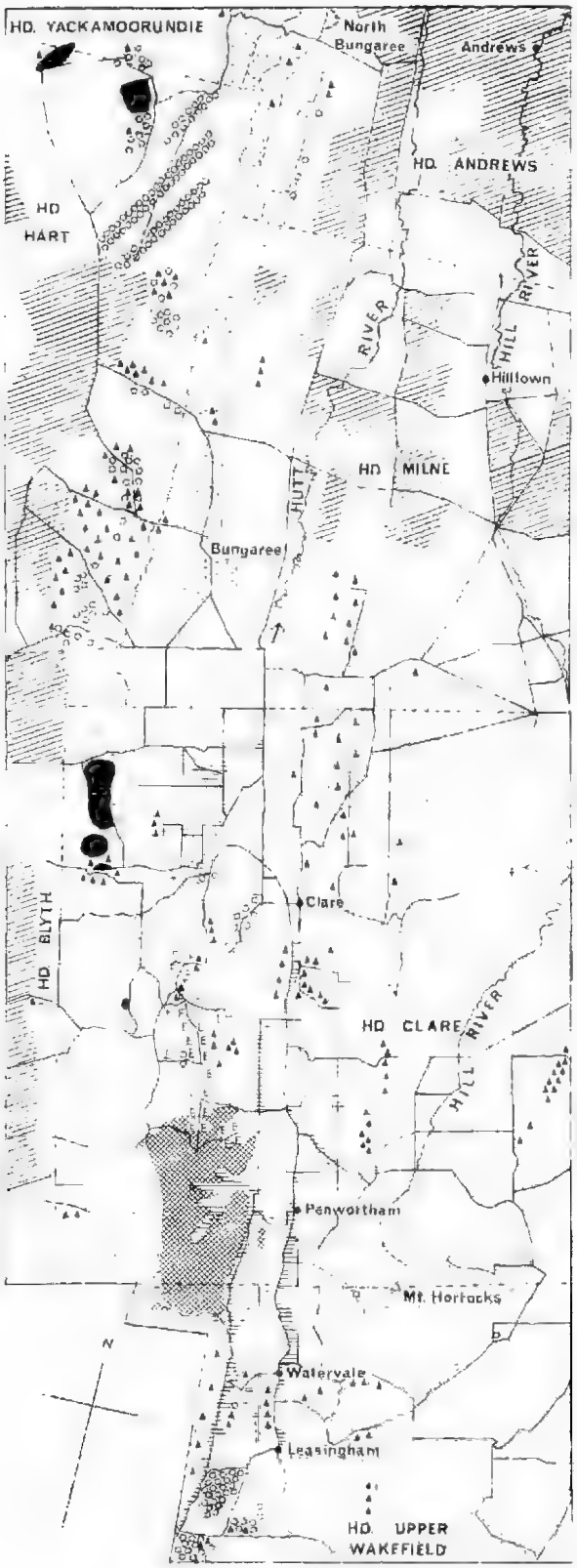
The distribution of Eucalyptus species is here recorded over an area of 300 square miles in part of County Stanley, South Australia, including portion of the Hundreds of Upper Wakefield, Clare, Milne, Andrews, Yackamoorundie, Hart and Blyth. Boomsma (1948) had previously noted this for the western section of the Hd. Clare but much of his area was re-examined and some additional information obtained. Most of the detail recorded was obtained during field observations in 1948-50.

Technique. Most of the available roads and some tracks were traversed and the limits of each species of tree were marked on the appropriate hundred maps. Further information about tree distribution was obtained from aerial photographs. Trees had been removed from much of the area but from the remnants still present some idea of the original distribution could be gained.** However, especially in the north and west, old survey records, at the Lands Department, Adelaide, show that natural grasslands occurred and today it is difficult to distinguish these modified grasslands from cleared areas. Soil profiles were examined at representative sites to enable their classification in great soil groups.

Topography. The area includes the most southerly part of the Flinders Ranges. Two main ridges run north and south along the eastern and western boundaries of Hds. Clare, Milne, and Andrews and there are smaller, less continuous ridges between them. Most of the country is undulating, becoming hilly in the southern and western parts of Hd. Clare, the northern part of Hd. Hart, and the adjacent part of Hd. Yackamoorundie. It is mainly drained by the Hutt and Hill Rivers running northwards through Hds. Clare, Milne, and Andrews, while in the west numerous small streams run westwards from the ridge on the western side of Hds. Clare, Milne, and Andrews, and in the south are tributaries of the river Wakefield. Most of the streams are small and tend to dry up in summer.

* c/- Botany Dept., University of Melbourne, Parkville, N.2, Victoria. Formerly (1948-50) research worker, Agronomy Dept., Waite Agricultural Research Institute, Adelaide.

** In the south, round Watervale and Mintaro, there has been much clearing and also much planting of trees, particularly *Eucalyptus camaldulensis*, so that the existing vegetation does not always indicate the original vegetation. Such evidence as there is suggests that the bulk of that area was originally covered with *E. leucoxylon* var. *pauperita* with *E. odorata* associated in the drier parts.



SCALE IN MILES 1 0 1 2

ROADS TRAVELLED OVER

TRACKS TAKEN APPROXIMATE POSITION

HUNDRED BOUNDARIES

EUCALYPTUS LEUCOXYLON FMuell var PAUPERITA J.E.Brown

E. CAMALDULENSIS Dehnh

E. MACRORRHYNCHA FMuell (for detail of western boundary see Boomsma 1949)

E. ODORATA Behr & Schlechtd.

E. ELAEOPHORA FMuell.

MALLEES (E. CALCICULTRIX FMuell.
E. LANSDOWNEANA FMuell. & J.E.Brown
E. OLEOSA FMuell
E. OLEOSA FMuell var. GLAUCA Maiden
E. ODORATA Behr & Schlechtd.
MALLEE FORM)

CLEARED LAND OR NATURAL GRASSLAND

PRESUMABLY NATURAL GRASSLAND (MARKED "NO TIMBER" OR "OPEN" IN EARLY SURVEYS)

\+ CALLITRIS GLAUCA R.Br

▲ CASUARINA STRICTA Ait

Climate.

Meteorological data for almost all of the area mapped (excepting part of the Hd. Upper Wakefield) is given in the Commonwealth Bureau of Meteorology's Climatological Survey, Region 14—Goyder, South Australia (December 1956) from which some of the following data are extracted.

Temperature. The mean annual temperature is 55-60° F., with an amplitude of about 25° F. Maxima are fairly high in summer, minima in winter relatively low, frosts being common for several months. For the period 1906-39 the average frost free period at Clare was 195 days.

Rainfall. The wettest part of the district is near the highest point, Mt. Horrocks, 1982 ft., about 2½ miles east of Penwortham and Watervale. The highest local mean annual rainfall estimate was 29 in. for an area between these townships; it may be more on the mount itself. Rainfall tends to increase with increasing altitude locally, but falls away on passing northward. It decreases in all directions passing away from the Mt. Horrocks area—being 17-18 in. in the northern region and western boundary of the map, and almost 24 in. at the southern and south-eastern boundaries.

Evaporation. Calculations of evaporation from a free water surface (Commonwealth Bureau of Meteorology, 1963) show mean monthly evaporation varies between 10 in. and 11 in. in December and January, and between 1 in. and 2 in. in June and July at Clare, and is a little higher at Spalding, 6 miles to the north of this survey.

A map showing the mean length of the growing season, in months, is given in the Climatological Survey (ibid, Map No. 2). It has been compiled from a formula (Prescott and Thomas, 1949), as the period during which the rainfall exceeds $0.54\ E^{0.75}$, where E is the evaporation from a free water surface expressed in inches. A growing season of seven months or more is shown in Hd. Clare, southern part of Hd. Milne, and the parts of the Hds. of Hart and Blyth adjoining them. It is also seven months in the surveyed part of Hd. Upper Wakefield. It drops below seven months north and west of these areas, and below six months in the north-eastern portion near Andrews.

The annual period when some water is stored in the soil at Clare has been estimated by the author by the method used by Prescott, Collins and Shirpurkar (1952) and found to be approximately 7.3 months (from the end of April to early to mid-December). It is assumed that the soil can only store 5 inches of rain, the rest being lost as drainage and runoff. Potential evapotranspiration, regarded as $0.8\ E^{0.75}$, where E is the evaporation from a free water surface, is shown on Fig. 1. Evaporation estimates used were from the Bureau of Meteorology's Evaporation Maps of Australia (1963). Soil water storage, calculated from the balance of potential evapotranspiration and rainfall, is also given in Fig. 1 together with other climatological data for Clare, the only station in the area at which fairly full records are kept.

Soils.

The reconnaissance survey made in 1948-49 showed soils belonging to the following great soil groups, with a general distribution as follows:—

1. Podzolic soils. All examined are at the higher altitudes, above 1300 feet or within the area in which rainfall would be influenced by adjacent heights of 1300 feet. They occur mainly to the west, southwest and southeast of the township of Clare.

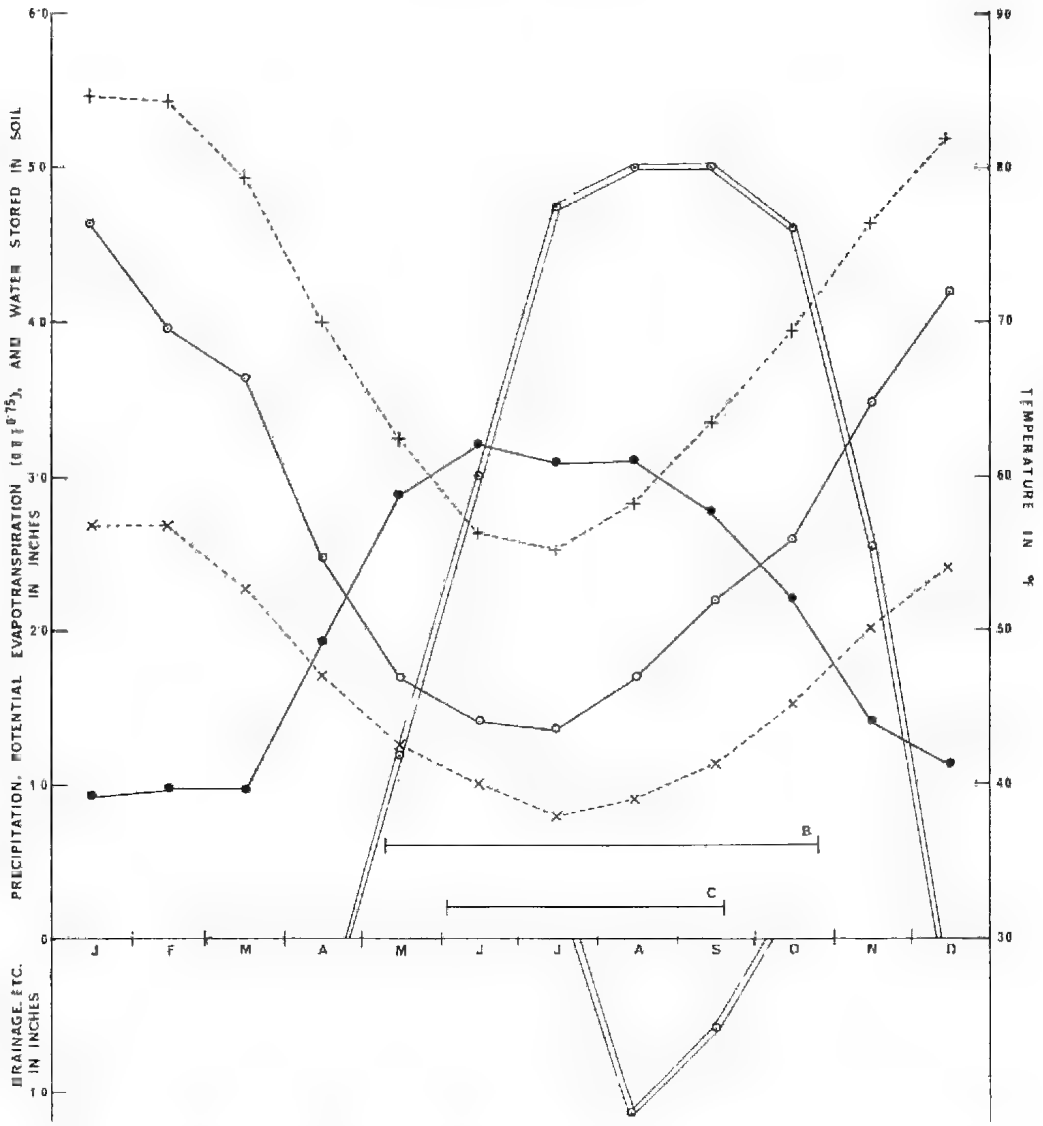


Fig. 1. Rainfall, potential evapotranspiration, water stored in soil, drainage, and temperature data for Clare, South Australia.

●——● Average monthly rainfall in inches (100 years of record to end of 1962).

○——○ $0.8E^{0.75}$, where E is the average monthly evaporation from a free water surface expressed in inches.

—+---+— Average monthly maximum temperature in °F. (1879-1956).

×----× Average monthly minimum temperature in °F. (1879-1956).

○ ○ Estimate of average total water stored in soil, also drainage, both expressed in inches.

B Average dates first and last occurrences of screen minimum of 36° F.: May 9 ± 11 days and October 25 ± 13 days.

C Average dates first and last occurrences of screen minimum of 32° F.: June 2 ± 10 days and September 18 ± 21 days.

(Data from Commonwealth of Australia Bureau of Meteorology)

2. Red-brown earths. Very extensive areas occur, particularly in the northern region through which the Hutt and Hill Rivers run, and to the west on the Blyth plains. Mulcahy (1954) describes those in the east of Hd. Upper Wakefield as shallow and deep (both common), with small areas of hydromorphic red-brown earths, and red-brown earths on travertine. Gilgais may occur locally

3. Grey and brown soils of heavy texture with gilgai microrelief. Small areas were observed in Hds. Milne and Hart. They may be more extensive Presumably these are allied to soils in the east of Hd. Upper Wakefield described by Mulcahy (ibid), as "grey and brown soils of heavy texture in which gilgais are present". In places they form complexes with red-brown earths.

4. Rendzinas, or degraded rendzinas. Two small areas were observed in Hd Milne. They may be more extensive, and were common in the eastern part of Hd. Upper Wakefield surveyed by Mulcahy (ibid).

5. Terra rossa. Scattered areas, often very small, were reported by Mulcahy (ibid) in the eastern part of Hd. Upper Wakefield. This soil was not observed by the author.

6. Skeletal soils.

(a) Brown loams and clay loams over limestones are widespread in Hd. Upper Wakefield, in south-east Hd. Clare, and along the western slopes of the hills abutting the plains towards Blyth and Brinkworth.

(b) Skeletal soils over rocks other than limestone are found on the tops of ridges in all parts.

7. Alluvial soils are found along some water courses.

Ranges of Dominant Eucalypts and Allied Associations.

1. [*] *Eucalyptus leucoxylon* F. Muell. var. *pauperita* J. E. Brown (Plates 1-4).

This is the most widely spread tree in the district. It occurs in hilly and undulating country from the southernmost part surveyed to well beyond North Bungaree, which is at the northern boundary of the survey. The mean annual rainfall varies between 17 in. and 29 in. This is well below the minimum of 25 in. for the species (*sensu stricto*) in the Mt. Lofty ranges (Specht and Perry 1948) and is close to the minimum of 19 in. or slightly less found for the species (*sensu stricto*) to the east in scattered occurrences from south of Burra to Keyneton (Jessup 1948). It is growing on podzolic soils, red-brown earths, brown loams over limestone, and skeletal soils over other rocks, including quartzite and siltstone.

The lower strata beneath this eucalypt vary in different parts of the district Some indication of this is given by the lists of species associated with it in the regions in which the photographs (Plates 1-4) were taken. Extremes which are not shown in these photographs are dense sclerophyll scrub at Penwortham with a relatively high rainfall of 27 in., and *Triodia* grassland, on the hillslopes to the north of North Bungaree, with relatively low rainfall of 18 in.

There are also marked differences in the form of the tree. In the wetter soils to the west of Penwortham it is tall, straight and smooth-barked, very similar in form to *E. camaldulensis* in this area; in the drier parts it tends to be smaller and more spreading, with rough bark at the base or extending right up

[*] Nomenclature of eucalypts and other species follows Black (1948-57).

the main trunk or, rarely, even as far as the secondary branches. Isolated trees are always more spreading than those growing close together, but these differences cannot be entirely accounted for by the fact that the trees are often more isolated in the drier parts. Differences in other characters, such as width of leaf (¾-1 in.), size and shape of buds (operculum conical to rostrate), and shape of fruit are associated with the changes in the form of the tree. No fruits as large as those of *E. leucoxylon* (*sensu stricto*) were observed, though some were nearly as large.

There was never any doubt about assigning any of these individuals to *E. leucoxylon* var. *pauperita*. It is probable that this variation is caused by introgression of the species with *E. camaldulensis* in the wetter parts, and *E. odorata* in the drier parts. Hybrids of *E. leucoxylon* (*sensu stricto*) with both these species have been recorded in the Mt. Lofty Ranges by Specht and Perry (1948). It may well be that in some parts the environmental conditions are more suited to the development of a hybrid than to that of the species itself.

2. *E. camaldulensis* Dehnh. (Plate 5).

This species is found along some of the moister drainage lines in the wetter parts of Hds. Clare and Upper Wakefield, where the annual rainfall is less than 22 in. In one place, between Penwortham and Mt. Horrocks, it extends up from the gully onto the hillslopes naturally. This is the wettest known part of the district with a rainfall of about 29 in. However, it has been planted quite extensively in and around the area in which it occurs naturally, and is growing well in many places where the trees are not directly on a watercourse, e.g. east of Watervale.

At three places in the Hd. Clare the author is indebted to Boomsma (1948) for records of the occurrence of this species i.e. (a) within the boundaries of the *E. macrorrhyncha* association, (b) in northwest Hd. Clare (sects. 1991, 1996), near a mallee patch, and (c) along the Hutt R. to the north of the township of Clare. In two places, on the Hutt R. flats and near Barinia, in the southern part of Hd. Milne, *E. camaldulensis* which has been planted, is flourishing, and there are some similar healthy trees further north. The one soil profile taken was an alluvial soil. Proximity to water courses suggests that the species will be growing mainly in alluvial soils, but trees planted on various other soil types in the district are remarkably healthy. Close proximity to creeks confirms that germination is largely governed by high water requirement, as has been found for this species in other places.

3. *E. odorata* Behr and Schlechtd. (Plate 9).

This species occurs along some of the boundaries of the *E. leucoxylon* var. *pauperita* association, either pure, or in association with it. It is mainly in the tree form, though there are some patches of the mallee form e.g. the one mapped in Hd. Blyth. Near North Bungaree a few isolated trees of the variety *angustifolia* are found.

E. odorata is found in hilly country with a mean annual rainfall of 18-24 in. It has been observed growing in red-brown earths, podzolic soils, and skeletal soils over limestone, and may also be growing on rendzinas and grey and brown soils of heavy texture with gilgai microrelief. These conditions of climate and soil are similar to those in which the species has previously been observed (Specht and Perry, ibid).

4. *E. macrorrhyncha* F. Muell. (Plate 7).

This species extends over an area of about five square miles to the west of Penwortham in a wet region with a rainfall of 24-29 in. It is the only known occurrence of the species in South Australia (Boomsma, 1948). Except for small areas at the northern end, where it occurs in association with *E. elaeophora*, it is a pure stand. Often the crowns of the trees form a fairly complete canopy. The boundaries between this association and those of *E. leucoxylon* var. *pauperita* and *E. camaldulensis*, which adjoin it, are very sharp, suggesting that its distribution is controlled by a soil factor. In most parts the soil is very stony and rocky, with many quartz fragments on the surface.

The ground flora is very varied where it has not been removed completely by grazing (Plate 7), but it is rather sparse, and consists largely of geophytes which flower in the spring. Bracken fern, *Pteridium aquilinum*, occurs in some of the gullies. Further information is given by Boomsma (1948).

5. *E. elaeophora* F. Muell. (Plate 6).

This species occurs in small areas in the hilly country in the western part of Hd. Clare, growing with *E. leucoxylon* var. *pauperita*, or *E. macrorrhyncha*. The association with the former is not always close; there are frequently small areas of one species or the other. No obvious reason for this separation was observed; the aspect of the slopes had no apparent influence on distribution.

All the soil profiles observed were podzolic. The mean annual rainfall is 24 to 27 in.

6. *Mallees* (Plate 5).

Isolated patches of mallee occur in Hds. Clare, Hart, and Yackamoorundie —in particular *E. oleosa*, *E. oleosa* var. *glauca* (=*E. transcontinentalis*), *E. calcicultrix*, *E. lansdowneana*, and the mallee form of *E. odorata* (mapped as *E. odorata* in Hd. Blyth).

Mean annual rainfall lies between 17 and 24 in. Surface soils were very sandy or stony, but no profiles were taken.

7. *Casuarina stricta* Ait. (Plates 1 and 2).

This species occurs in association with *E. leucoxylon* var. *pauperita* and *E. odorata*, and also by itself. It is found alone scattered on the tops of some of the ridges, particularly the stony ridges where the soils are mainly skeletal. It is also met with in places on red-brown earths, at the junctions between *E. leucoxylon* var. *pauperita* and the grassland associations. Present occurrences are at mean annual rainfalls between 17 and 26 in. It is impossible to estimate the original extent of the species, as it is easy to clear, much prized as firewood, and regeneration from seedlings is prevented by grazing animals. Apparently it did not occur originally on all the ridges. Those on the northern part of the eastern boundary of Hd. Milne, and extending into Hd. Andrews (outside the area mapped) are reputed to have originally been treeless, and so are the grassy hills at the extreme northwest of Hd. Clare, and the adjoining part of Hd. Blyth. The ground flora is not luxuriant, and consists mainly of grasses.

8. *Callistris propinqua* R.Br.

This species is found occasionally in the hills in the western part of Hd. Clare. It was formerly much more frequent, but has been removed for timber, and little regeneration appears to be taking place.

9. *Tussock grassland* (Plate 10).

Extensive areas of grassland occur to the north and east in Hds. Clare, Milne, and Andrews, and to the west in Hds. Blyth and Hart. They are now much altered by cultivation and grazing and often cannot be distinguished with certainty from cleared land. Originally the bulk of the natural grassland was probably dominated by species of *Stipa* and *Danthonia*. Tussocks of *Lomandra* and *Lepidosperma* spp. are often present (Plate 10).

The mean annual rainfall ranges from 16 to 26 in. The soils are mainly red-brown earths with some smaller areas of podzolic soils, brown loams over limestone, skeletal soils over other rocks, and grey and brown soils of heavy texture with gilgai microrelief.

Formations.

Notes taken in 1948-49 were not extensive enough to allow a full discussion of the formations (as defined by Wood and Williams, 1960).

Savannah woodland is extensive. This is mainly dominated by *E. leucoxylon* var. *pauperita* or *E. odorata*. Near Penwortham *E. leucoxylon* var. *pauperita* and its associated vegetation tend towards dry sclerophyll forest.

E. macrorrhyncha usually occurs, in other regions, as dry sclerophyll forest (Wood and Williams, 1960), and here, over much of the area dominated by this species, the crowns form a continuous canopy. In places (see Boomsma, 1948) *E. macrorrhyncha* is also growing as savannah woodland. Whether this is due to partial clearing, followed by growth of a grassy ground stratum, is not known.

Mallee and tussock grassland also occur. The latter is much modified by introduced species as pasture and otherwise, and in many places by cultivation.

DISCUSSION

Sufficient evidence to define the factors which control the distribution of the eucalypts in the part of County Stanley surveyed has not yet been collected. With minor exceptions it does not appear to be related to rainfall. Detailed soil survey may show close connections between eucalypt and soil type in some areas; in others the relationship between soil, moisture, and vegetation may be more complex.

Distribution of *E. camaldulensis* is presumably partly controlled by its need for a relatively high water supply, while that of *E. elaeophora*, *E. macrorrhyncha* and the mallees is probably controlled by soil factors. Tussock grassland, *E. leucoxylon* var. *pauperita* and *E. odorata* are found over almost identical rainfall ranges, and (with the exception of the probable absence of the two eucalypts from gilgai soils) in soils of the same great soil groups. More detailed study of the soils, and fuller information as to soil moisture relationships and nutrient status may give a fuller understanding of their distribution.

ACKNOWLEDGMENTS

The author is indebted to Mr. A. J. K. Walker (then of the Waite Agricultural Research Institute) and people in the Clare district for generous assistance, to Mr. K. P. Phillips of the Waite Agricultural Research Institute for taking the photographs, to Mr. K. H. Northcote of the C.S.I.R.O. Division of Soils, to the South Australian Department of Lands for access to the early surveys, and to Dr. R. L. Specht, now of the Botany Department, University of Melbourne, for drawing my attention to work since 1950, reading the present manuscript and helpful criticism.

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EXPLANATION OF PLATES

Ground Flora in Photographs.

1. *Eucalyptus leucoxylon* var. *pauperita* on rocky outcrop. Note spreading habit. Hd. Milne, Sect. 3009.
   Small tree: *Casuarina stricta*.
   Ground stratum:
   °Homeria collina, Thysanotus australis, °Aira caryophyllea, °Avena fatua, Danthonia sp., *Dichopogon strictus, Ptilotus spathulatus, °Trifolium arvense, °T. procumbens, °Erodium moschatum, °Parentucellia latifolia (=Bartsia latifolia), °Hypochoeris glabra.*

2. *E. leucoxylon* var. *pauperita* in undulating country without rocky outcrops. Note spreading habit. Hd. Milne, Sect. 3013.
   Small tree: *Casuarina stricta*.
   Ground stratum:
   °Homeria collina, Danthonia semiannularis, °Arctlinia michelli, °Briza maxima, °Vulpia myuros, °Vulpia bromoides, Dianella revoluta, Bulbine bulbosa, Dichopogon strictus, Ranunculus lappaceus, Stackhousia sp., *Velleia paradoxa, Lagenophora* sp., *Microseris* sp.

3. *E. leucoxylon* var. *pauperita* in wettish situation—young trees. Hd. Milne Sect. 3011.
   Small trees and large shrubs: *Acacia armata, A. pycnantha.*
   Ground stratum:
   °Homeria collina, °Briza maxima, °Briza minor, °Bromus madritensis, °Agropyron scabrum, Dichopogon strictus, Ranunculus lappaceus, Drosera sp., *Acaena anserina, °Trifolium dubium, °T. glomeratum, °T. tomentosum, Swainsona* sp., *°Stackhousia* sp., *°Anagallis femina, °Parentucellia latifolia (=Bartsia latifolia), Lagenophora* sp., *Craspedia uniflora, Microseris* sp., *°Hypochoeris glabra, °Sonchus* sp.

4. *E. leucoxylon* var. *pauperita* on podzolised soil west of Clare. Note relatively strong development of main trunk. Paddock at rear has been cleared. Hd. Clare, Sect. 2197.
   Small trees and large shrubs: *Callitris propinqua, Casuarina stricta, Acacia pycnantha.*
   Small shrubs: *Pultenaea* sp., *°Lavandula stoechas.*
   Ground stratum:
   °Briza minor, Thysanotus patersonii, Bulbine bulbosa, Dichopogon strictus, °Anagallis femina, Lagenophora sp.

5. *E. camaldulensis* growing along creek near Penwortham. Hd. Clare, Sect. 82.

6. *E. elaeophora*, west of Clare. Hd. Clare.
   Small trees or large shrubs: *Casuarina stricta, Acacia pycnantha.*
   Ground stratum:
   Dianella revoluta, Hibbertia sp., *Goodenia* sp., *Lagenophora* sp., Many grasses.

7. *E. macrorrhyncha* in hilly country south-west of Clare. Hd. Clare, Sect. 2373.
   Ground stretum has been almost completely removed by grazing.

8. Mallee—north-west of Hundred of Clare. Hd. Clare, Sect. 1955.
   Mallees: *E. oleosa, E. oleosa var. glauca (=E. transcontinentalis), E. calycicultrix.*
   Large shrubs: *Melaleuca pubescens, Bursaria spinosa.*
   Ground stratum:
   Lomandra spp.

9. *E. odorata* in Hd. Hart, Sect. 150?
   Ground stratum:
   °Homeria collina, Danthonia sp., *°Vulpia myuros, °Medicago minima, °Parentucellia latifolia (=Bartsia latifolia), °Cryptostemma calendula, °Hedypnois cretica.*

10. Tussock grassland association, Hd. Hart, from Main North Road, west of Anama, looking westwards towards Brinkworth. Tussocks are of *Lepidosperma* sp. and *Lomandra* sp.

° Introduced species.


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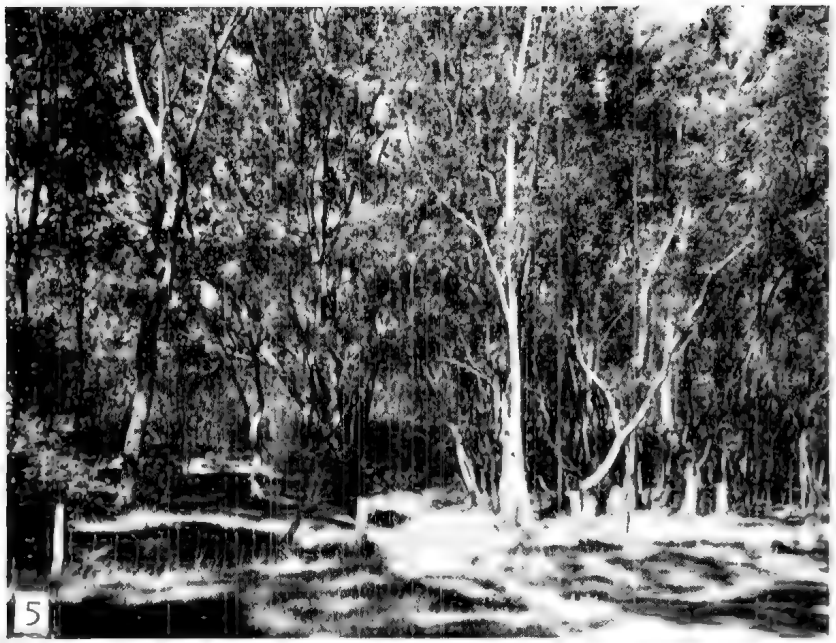

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THE VEGETATION OF KOONAMORE STATION, SOUTH AUSTRALIA

BY B. B. CARRODUS, R. L. SPECHT AND MARGARET E. JACKMAN

Summary

A vegetation map of Koonamore Station in the arid zone of South Australia is presented. Six vegetation form's or sub-forms (semi-arid mallee, arid scrub, low arid scrub, low arid woodland,, shrub steppe, and ephemeral herb and grassland) and 15 plant associations are described for the Station. These ire correlated with the landscape and soils on which they arc found.

A list showing the ecological distribution of 196 native and 16 alien species recorded on the survey is appended.

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by B. B. Carrodus,[1] R. L. Specht[2] and Margaret E. Jackman[3]

[Read 13 May 1965]

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A vegetation map of Koonamore Station in the arid zone of South Australia is presented. Six vegetation forms or sub-forms (semi-arid mallee, arid scrub, low arid scrub, low arid woodland, shrub steppe, and ephemeral herb and grassland) and 15 plant associations are described for the Station. These are correlated with the landscape and soils on which they are found.

A list showing the ecological distribution of 196 native and 16 alien species recorded on the survey is appended.

INTRODUCTION

Koonamore Station is located in the arid zone of South Australia, approximately 40 miles north of Yunta, a small town 200 miles north of Adelaide on the Broken Hill railway line (Fig. 1). A vegetation reserve, a little more than one mile square, was established near the centre of the property by the University of Adelaide in 1925. The present survey of Koonamore Station, an area of 472 square miles, was undertaken to ascertain the degree to which Koonamore Vegetation Reserve (Osborn, 1925; Osborn *et al.*, 1931, 1932, 1935; Wood, 1936; Hall *et al.*, 1964) is representative of the soils and vegetation of the surrounding countryside.

A base map of the Station showing fence lines, tracks, hills, watercourses, salt pans and other landmarks was prepared from aerial photographs. Land traverses by motor vehicle, using odometer distances, were then made to record in detail changes in vegetation along all the roads and tracks on the property, and, where necessary, along cross-country routes. Because of the relatively open nature of the landscape, these traverses were sufficiently close together to allow the plotting of most vegetation boundaries in the field. However, in a few areas, aerial photographs were used to locate these boundaries.

Soil profiles were examined at frequent intervals, usually wherever changes in vegetation were noted, and six intergrading groups of soils are recognised. Six vegetation forms or sub-forms, and 15 plant associations are described for the Station. The landscapes and soils on which these associations are found are summarised in Table 1. Appendix I is a list of 196 native and 16 alien species and the habitats in which they were recorded on the survey. Popular names for the more common plants referred to in the section on Vegetation are listed in Appendix II.

[1] Formerly Research Scholar, Botany Department, University of Adelaide.

[2] Formerly Botany Department, University of Adelaide; now Botany Department, University of Melbourne.

[3] Botany Department, University of Adelaide.

TABLE 1. *Ecological relationships of the vegetation on Koonamore Station.*

Vegetation				Soils	
Form/Sub-Form	Association	Topography	Geology	Group Name	Classification (Northcote, 1960)
I. Semi-arid mallee sub-form	Eucalyptus oleosa	Deep sand dunes over well developed limestone layer.	Quaternary alluvial and aeolian deposits	Bindyeyo	Ue 5.12 (deep surface soil)
		Creek-beds and rocky slopes of adjacent hills.		Oopina	Um 5.11
II. Arid scrub sub-form	*Acacia aneura* (often with *A. burkittii*)	Deep sand dunes with poorly developed limestone layer,	Quaternary alluvial and aeolian deposits.	Bindyeyo	Ue 5.11 (deep surface soil)
III. Low arid scrub sub-form	*Acacia burkittii* *Eremophila stuartii*	Low sand dunes.	Quaternary alluvial and aeolian deposits,	Bindyeyo	Ue 5.11 (deep surface soil)
	Eremophila spp. *Dodonaea* spp.	Creeks and rock strike lines in hills wherever rainfall is concentrated.	Precambrian shales and tillites	Hills	Um 5.12
IV. Low arid woodland sub-form	*Casuarina cristata* (some *Acacia aneura*)—*Kochia sedifolia*	Creeks and rock strike lines in hills wherever rainfall is concentrated.	Precambrian shales and tillites	Hills	Um 5.12
	Casuarina cristata (with *Atriplex* spp. *Kochia sedifolia* or *Stipa nitida*)	Sand plain	Quaternary alluvial and aeolian deposits,	Bindyeyo	Ue 5.12 and Ge 1.12
	Myoporum platycarpum and/or *Heterodendrum oleifolium*–*Atriplex vesicaria*	Plains	Quaternary alluvial and aeolian deposits.	Bindyeyo	Ge 1.12
	Myoporum platycarpum – *Eremophila longifolia* (also *Heterodendrum oleifolium*)	Flood plains between dunes.	Quaternary alluvial and aeolian deposits.	Bindyeyo	Ge 1.12 (periodically flooded)
	Myoporum platycarpum *Nitraria schoberi*	Low rises in drainage basins.	Quaternary alluvial and aeolian deposits.	Lakes	Saline Ge 1.12 (often with gypsum-"Kopi" in profile)

V. Shrub steppe form	*Atriplex vesicaria*	(*a*) low hills and rolling plains (*b*) broad drainage lines from hills.	Precambrian shales and tillites	Oopina Oopina	(*a*) Um 5.11 (*b*) Dr 1.33
	Kochia sedifolia	(*a*) Broken, rocky hills or flats of small area dissected by creek beds (*b*) Plains between Oopina and Koonamore Hills (*c*) Outwash plains to north of Koonamore Hills.	(*a*) Precambrian shales and tillites (*b*) Quaternary alluvial and acolian deposits (*c*) Quaternary alluvial and acolian deposits	Hills Bindyeyo Nillinghoo	(*a*) Um 5.11-12 (*b*) Ge 1.12 (Limestone layer varies from almost absent to almost solid) (*c*) Ge 1.22
	Kochia astrotricha	Saddle through Oopina Hills. Lower slopes of Orama and Koonamore Hills Plains to north of Koonamore Hills.	Quaternary alluvial and acolian deposits from Precambrian shale outcrops.	Oopina and Curnamona	Probably Um 5.11 or Ge 1.22
	Nitraria schoberi — Kochia pyramidata	Drainage systems	Quaternary alluvial deposits.	Lakes	Saline Ge 1.12
	Aetheroenemum haloenemoides — Pachycornia tenuis	Low lying drainage basins.	Quaternary alluvial deposits.	Lakes	Uf 6.61
VI. Ephemeral herb and grassland sub-form	*Stipa nitida — Bassia* spp.	Low, gentle slopes at edge of drainage systems (Oopina Hills area) and in hills (Orama and Koonamore Hills area)	Precambrian shales and tillites	Oopina	Very shallow skeletal soils
	Stipa nitida — Bassia spp. resulting from overgrazing	Plains and hillslopes		Various	
	Eragrophyllum eleleri	Flood plains.	Quaternary alluvial deposits	Bindyeyo	Ge 1.12 (periodically flooded)
	Zygophyllum aurantiocrum	Steep, very rocky slopes and hills.	Precambrian shales and tillites	Hills	Very shallow skeletal soils
Bare areas	-	Lowest point in internal drainage system	Salt pan	Lakes	

CLIMATE

The climate of the area has been examined in detail by Osborn *et al.* (1935). The rainfall averages 7·6 inches per annum (from 50 years of records), but is erratic from year to year, a common feature in arid climates. The mean values for each month (Fig. 2) reveal no distinct seasonal distribution of rainfall, since the area receives falls from the fringes of the southern depression systems in winter, and the northern monsoon systems in the summer. For this reason also, the distribution of rainfall over the area is very uneven, especially when resulting from local thunderstorms.

Throughout the year, mean monthly maximum and minimum temperatures (Fig. 2) show a high diurnal range of as much as 30° F. This accounts for the marked daily fluctuations in relative humidity, often leading to conditions where dew or frost occurs during the night.

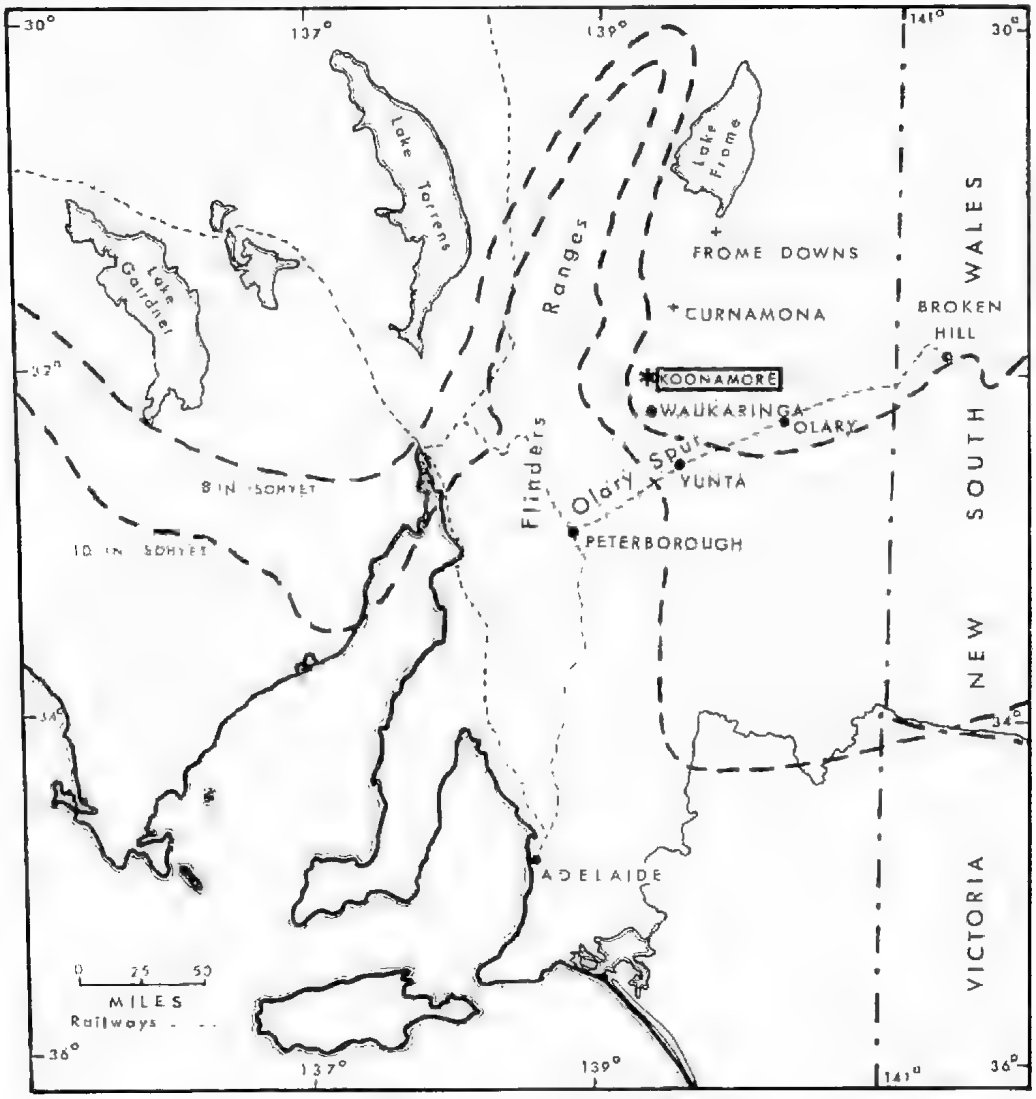

Fig. 1. Locality Map showing the position of Koonamore Station.

LANDSCAPE

Koonamore Station, 500-1,000 feet above sea-level, is situated on a plain sloping gently towards Lake Frome. This plain lies in the angle between the main Flinders Range and the Olary Spur (Fig. 1). The Siccus River, which is generally dry, flows from between these ranges towards Lake Frome and is close to the north-western boundary of Koonamore Station. To the east, the property reaches to the foot of Mt. Victor (1,522 feet); to the south it

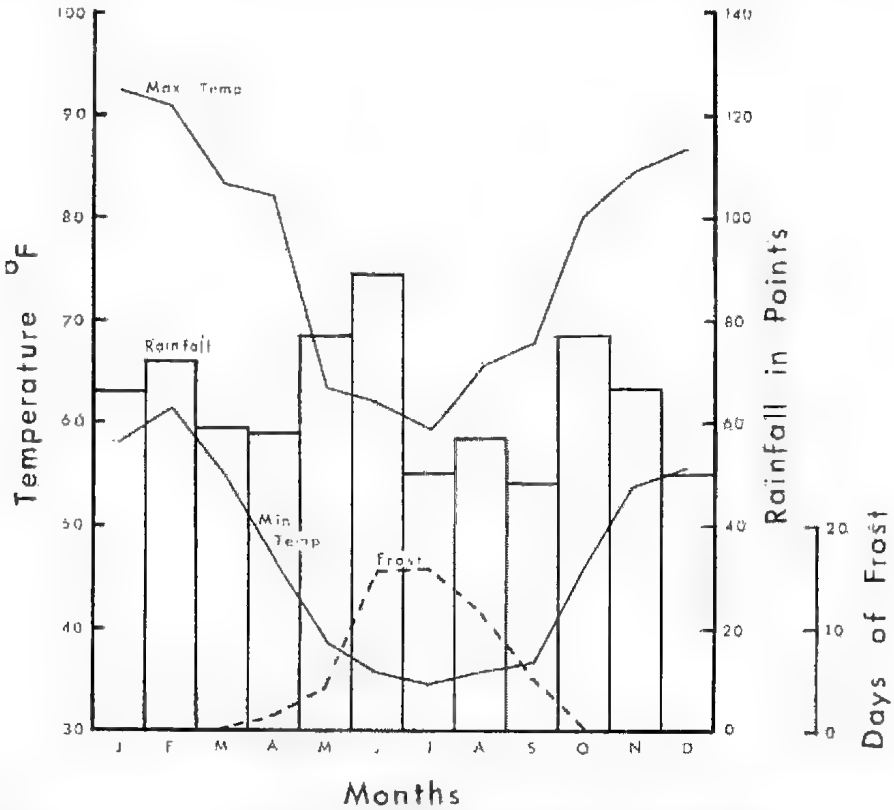

Fig. 2. Mean monthly rainfall, temperature and numbers of frosts at Koonamore Station.

approaches the Waukaringa Hills, the south-eastern corner extending beyond them (Fig. 3). On the Station, three groups of low hills which are part of the Olary Spur rise out of the plain, namely, the Koonamore, Orama and Oopina Hills (Fig. 3). The slopes are usually gentle, although the hills may have steep rocky ridges, particularly where intrusions of more durable rock occur. Between the hills, ridges of wind-blown sand lie across gently undulating plains of deep alluvial deposits. The underlying rock is a Precambrian shale with intrusions of tillites and massive quartz.

Although some of the drainage water of Koonamore Station eventually finds its way into the Siccus River, the drainage of the area is for the most part internal. Numerous watercourses cross the property, but are dry except immediately following heavy rain. Their channels are often well-defined for con-

siderable distances, then fan out onto flood plains, only to reform into channels further down the gradient. These eventually lead into two salt "lakes" or "pans" which rarely hold water, and lie at the lowest sites on the property; one is in the north-east corner of Hills Paddock and the other in the central west of Milang Cross Paddock (Fig. 3).

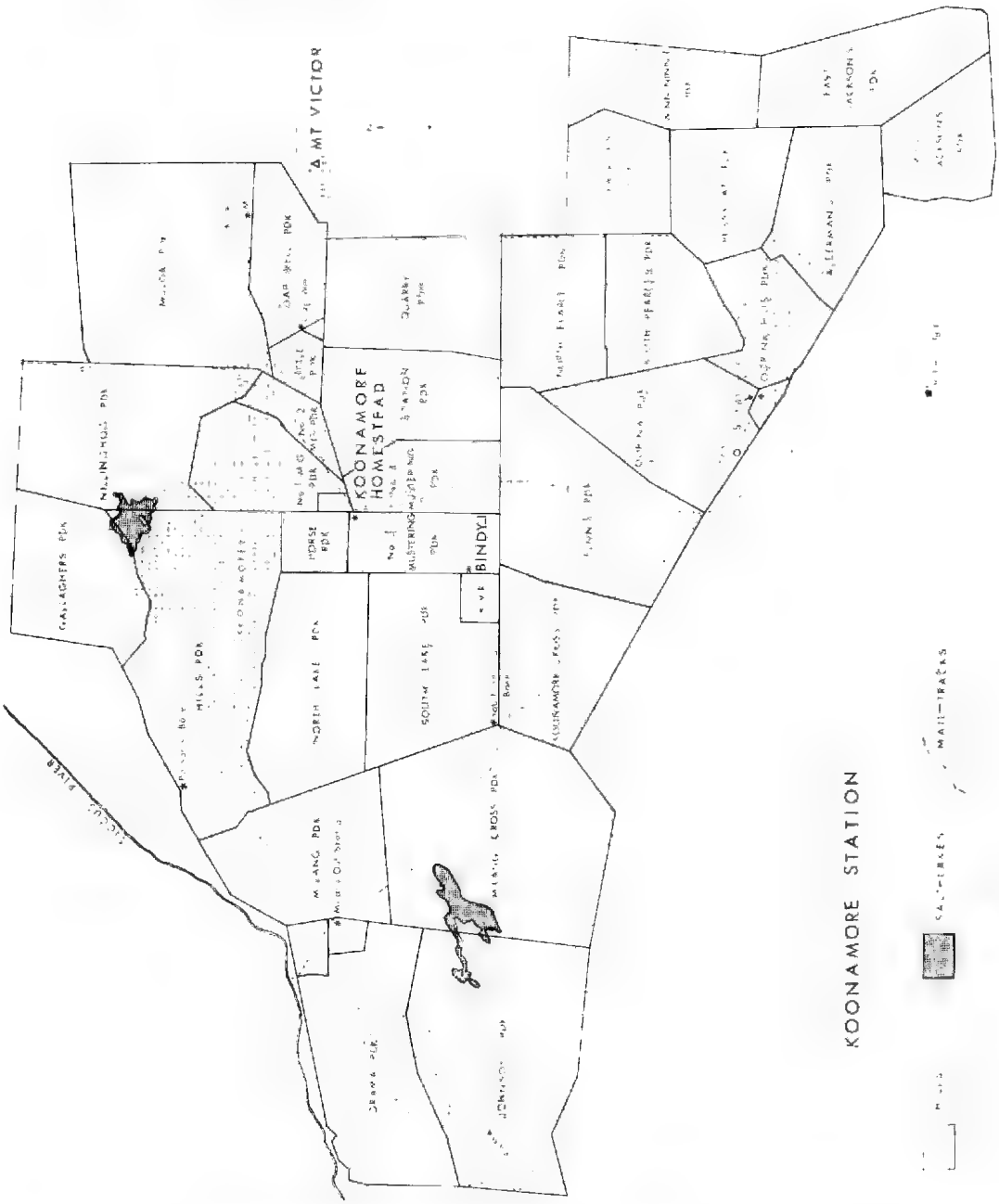

Fig. 3. Map of Koonamore Station showing hills, salt-lakes, paddocks and mail-tracks.

SOILS

1. *Oopina Soils*

The Oopina-Waukaringa Hills and the south-eastern corner of Koonamore Station, and the Orama Hills in the west (Fig. 3), form a distinct landscape of low hills and adjacent rolling plains. Gently-dipping Precambrian shales and tillites have developed a shallow calcareous loamy soil (Um 5·11 of Northcote, 1960) of variable depth. The surface soil,[1] which pulverises when dry, is usually a brown sandy-loam. This grades into a light brown loam at about 9 inches and then into decomposing grey shale. The soil, which contains particles of calcium carbonate throughout, varies in depth from 12 to 36 inches. It supports a shrub steppe form dominated either by *Atriplex vesicaria* on shallow soils or occasionally by *Kochia sedifolia* on sites with deeper soils.[2]

Along broad drainage swales and in pediments at the base of hills, a duplex soil (Dr. 1·33 of Northcote, 1960) has developed. The surface soil,[3] a brown clay-loam, develops a flaky surface crust when dry. Quartz pebbles are often scattered over the surface. No A2 horizon is present and there is a sharp boundary between the A and B horizons. The upper 6-12 inches of the B horizon is a red clay which breaks up into shiny-faced peds. This B1 horizon grades into a brown structureless clay which merges into decomposing, often grey, shale. Particles of calcium carbonate, usually present throughout the profile, increase with depth and may form a coating over the parent rock. This soil also supports a shrub steppe form dominated by *Atriplex vesicaria*.

2. *Hills Soils*

These soils are found on Precambrian shales and tillites on the steeper sections of the three main hills systems on Koonamore Station, and may also occur on other low rises where rock outcrops. They are mainly shallow and skeletal, and are coarser textured (gritty clay loam) than the Oopina Soils, often mixed with rock debris, and filling crevices in the rocks from which they are derived. There is no profile development although the soil may be up to four feet in depth. Calcium carbonate particles are usually present in the soil and the underlying rock is often coated with lime.

On the very shallow soils, the environment is unfavourable for perennial vegetation, and the ephemeral species, *Stipa nitida*, *Bassia* spp., and *Zygophyllum aurantiacum*, a perennial, are chiefly found. But where soil and moisture accumulate along the strike lines and drainage channels, trees of *Casuarina cristata*, and sometimes *Acacia aneura*, and shrubs including *Dodonaea* spp., and *Eremophila* spp., occur. *Kochia sedifolia* is usually found on the minor rocky outcrops, and may extend into the hills where it sometimes constitutes an important element of the shrub layer.

The transition zones between the Hills and Oopina Soils may be extensive and usually carry *Kochia astrotricha*. Thus, there may be large areas of mixed shrub steppe, *Atriplex vesicaria* merging with *Kochia astrotricha*, and this with

[1] This description refers to a typical profile from the centre of Alderman's Paddock. (For mechanical and chemical analyses see Carrodus, 1962.)

[2] In Oopina Hills Paddock the area shown on the vegetation map (Fig. 4) as a mixture of *Kochia sedifolia* and the almost indistinguishable *K. astrotricha* is not in fact a mixture, but a number of small discrete communities which occupy the scarp and dip faces respectively of the homoclinal hills.

[3] This description refers to a typical profile in the north-western corner of Pussycat Paddock.

K. sedifolia, for example, in the eastern end of Koonamore Cross Paddock. Where the transition is abrupt, there are direct ecotones between *A. vesicaria* and *K. sedifolia*, as in the vicinity of the north-west corner of Johnson's Paddock.

3. *Bindyeye Soils*

Across the centre of Koonamore Station, between the Oopina and the Koonamore Hills, lies a belt of country characterised largely by sand-dunes and sand-plains. These sandy soils all show an accumulation of calcium carbonate nodules in the profile but at varying depth: that of the sand-plain lies no more than a foot from the surface, whereas, in the sand-dunes, the layer may be at a depth of 4-5 feet (Uc 5·11 and Uc 5·12 soils of Northcote, 1960). The sands are buff-coloured (Osborn *et al.*, 1935) except for an area of red sand in a valley enclosed by the Oopina Hills. They support *Eucalyptus oleosa*, *Acacia aneura*, *Casuarina cristata*, *Acacia burkittii*, and *Eremophila sturtii* in either a semi-arid mallee, arid scrub, low arid scrub or low arid woodland sub-form.

Intermingled with and marginal to the sand-dunes are areas of solonized brown soil (Gc 1·12 of Northcote, 1960), in which the texture gradually becomes finer with depth; calcium carbonate is obvious in the shallow surface soil and often becomes cemented in the B horizon into a prominent kunkar layer. These soils in general support a shrub steppe of *Kochia sedifolia*, but occasionally a *Myoporum platycarpum-Atriplex vesicaria* association may occur.

Small low-lying areas of these brown solonized soils may be periodically flooded and then a *Myoporum platycarpum-Eremophila longifolia* association with scattered clumps of *Heterodendrum oleifolium* is characteristic. *Erodiophyllum elderi* often forms a dense ground cover when the water recedes.

The following profile with little limestone is characteristic of the soils from St. Patrick's Paddock (Fig. 3) north and west through North Pearce's into Quarry Paddock: 0-9" brown sandy clay loam with platy surface, grading into 9-17", paler sandy clay loam with much nodular limestone; 17-29" as above, with a marked development of lime nodules; 29-36" soft decaying shale. (For mechanical and chemical characteristics, see Carrodus, 1962.)

The soil in No. 2 Mustering Paddock differs from that described above only in the presence of powdery gypsum instead of shale in the deeper subsoil. In Station Paddock and south-west through Koonamore Vegetation Reserve, in a lower-lying area than those described above, the lime layer becomes prominent and almost continuous in a pan. It is noteworthy that this pan is penetrable to roots. (For mechanical and chemical characteristics, see Osborn *et al.*, 1931, 1935, and Carrodus, 1962.)

4. *Nillinghoo Soils*

Extending from the northern foothills of the Nillinghoo section of the Koonamore Hills over a small part of the detrital plains to the north, are soils over eight feet in depth, showing obvious stratification of gravelly sandy clay loam, detrital material. Soil-forming processes are apparent, since a gradational profile has developed in which clay increases gradually with depth, and calcium carbonate particles, present but not clearly visible in the A horizon, are obvious as discrete nodules below 12 inches. (For mechanical and chemical analyses, see Carrodus, 1962.) This is a solonized brown soil (Gc 1·22 of Northcote 1960) and is closely related to that in the Bindyeye group of soils (Gc 1·12).

The Nillinghoo Soils support an extensive stand of *Kochia sedifolia* with some *Casuarina cristata* along the watercourses. Towards the lower levels of and *Casuarina cristata*, characteristic of the sand-dunes and plains of the Bindyeye Soils, replace *Kochia sedifolia*.

5. *Curnamona Soils*

In the area of detrital soils to the north of the Koonamore Hills, the duplex Curnamona Soils (probably Dr 1·13 of Northcote, 1960) are widespread, the Nillinghoo Soils being characteristic of a small section only. The Curnamona Soils have developed on the pediments flanking the northern side of the Koonamore and the Orama Hills and extend northwards into Curnamona Station. They support extensive areas of *Kochia astrotricha*, with patches of *Acacia aneura* and *Casuarina cristata*.

6. *Lakes Soils*

The greater part of the drainage from the five groups of soils discussed above flows into the low-lying saline areas where the Lakes Soils occur. They are heavy textured soils containing high concentrations of soluble salts and often have a puffy structure in the A horizon. The soils are either highly saline solonized brown soils (Gc 1·12) or solonchaks (Uf 6·61 of Northcote, 1960), and in the extreme form become covered with a thin layer of salt to produce a salt-pan such as those in Hills and Milang Cross Paddocks.

Apparently, as the amount of sodium salts in the soil increases, the vegetation grades from a shrub steppe of *Kochia pyramidata* through *Nitraria schoberi* to a samphire association of *Arthrocnemum halocnemoides* and *Pachycornia tenuis*, and finally to a bare salt pan.

VEGETATION

The vegetation map of Koonamore Station (see map) shows the distribution of the dominant species of the six vegetation forms or sub-forms: the semi-arid mallee (*Eucalyptus oleosa*), the arid scrub (*Acacia aneura*), the low arid scrub (*Eremophila, Acacia*), and the low arid woodland (*Casuarina cristata, Myoporum platycarpum, Heterodendrum oleifolium*) sub-forms; the five major associations of the shrub steppe form dominated by *Atriplex* (mainly *A. vesicaria*), *Kochia sedifolia, K. astrotricha, Nitraria-Kochia pyramidata*, and *Arthrocnemum-Pachycornia*; and lastly *Bassia-Stipa* and *Zygophyllum aurantiacum*, dominant species of two associations of the ephemeral herb and grassland sub-form. The structure, composition, and ecological relationships of the vegetation forms and sub-forms are described below and summarised in Table 1.

In addition, the distributions of *Eucalyptus camaldulensis*, along creeks where ground water is nearly always available, and scattered individuals of *Pittosporum phylliraeoides* are included on the map.

1. *Semi-arid Mallee Sub-form* (Williams, 1955).

This sub-form is characterised by a discontinuous stratum of low mallee eucalypt trees (*Eucalyptus oleosa*) up to 8 metres tall (Plate 1, Fig. 1). Scattered chenopodiaceous shrubs and ephemeral species such as *Stipa nitida, Salsola kali* and *Bassia* spp. form the lower strata. In this district *E. oleosa* is found at the driest limit of its distribution, being characteristic of the wetter regions

further south. This sub-form is, therefore, restricted to deep sandy soils with a well-developed limestone layer in the sub-soil (Bindyeye Soils), along creek beds, and occasionally extending into the hills on rocky slopes (Oopina Soils).

II. *Arid Scrub Sub-form* (*Williams*, 1955)

In this sub-form, a layer of low *Acacia aneura* trees up to 8 metres tall and usually branching near the ground is dominant, and forms a discontinuous stratum ranging from open to dense. Scattered bushes of *Acacia burkittii* or *Eremophila sturtii* may be present in the understorey with a few chenopodiaceous shrubs. After rain, ephemerals like *Stipa nitida*, *Salsola kali*, and *Bassia* spp. may form a continuous ground cover.

The *Acacia aneura* association (Plate 1, Fig. 2) is common on the deep sandy Bindyeye soils which, unlike the soils on which the mallee is dominant, lack a well-developed limestone layer in the sub-soil. This sub-form may also extend into the hills along either drainage lines or steeply dipping strata where soil and water accumulate.

III. *Low Arid Scrub Sub-form*

Shrubs 2-3 metres tall of *Acacia burkittii* and *Eremophila sturtii*, which branch close to the ground to give a rounded, bushy appearance, and form a discontinuous stratum ranging from open to dense, are dominant in this sub-form. Lower strata are usually absent, except for ephemeral plants which may cover the ground after rain. This sub-form is common on some of the low sand-dunes of the Bindyeye Soils (Plate 1, Fig. 3). Where water accumulates along the steep rocky strike-lines of the Koonamore-Mt. Victor Hills, narrow bands of low arid scrub sub-form are dominated by *Eremophila* spp. and *Dodonaea* spp.

Williams (1955) included this sub-form in his "Arid Scrub" sub-form. However, on Koonamore Station these communities are structurally so different from the taller *Acacia aneura* association characteristic of the "Arid Scrub" sub-form, that it seems reasonable to describe them separately.

IV. *Low Arid Woodland Sub-form* (*Williams*, 1955)

When low trees, 4-8 metres tall, with single stems and spreading canopies are common in the landscape, they impart a woodland structure to the community. This is the low arid woodland sub-form (Williams, 1955) and contrasts with the arid scrub sub-form in which the *Acacia aneura* trees usually branch close to the ground, and tend to be bushy in habit. The low arid woodland is dominated by *Casuarina cristata* (Plate 1, Fig. 4), *Myoporum platycarpum* or *Heterodendrum oleifolium*. The canopy of the tree stratum ranges from open, when *Myoporum* is the dominant species, to almost continuous, as exhibited often by *Casuarina* or clones of *Heterodendrum*. Chenopodiaceous shrubs are usually present in the understorey, and ephemeral species appear after rain.

Various associations dominated by one or more of the three species listed above are common on the plains and flood plains of the Bindyeye Soils. The *Casuarina* association extends into the hills, and the *Myoporum* association onto the Lakes Soils (Table 1).

V. *Shrub Steppe Form* (*Williams*, 1955)

This form is dominated by low shrubs usually 0·5-1 metre tall, with semi-succulent leaves, which are usually separated from one another by a distance equal to or greater than the diameter of the plants. Ephemeral species are prominent after rain.

This vegetation form is by far the most common found on Koonamore Station. It includes five major associations (Table 1): *Atriplex vesicaria* association is common on the Oopina Soils (Plate 2, Fig. 5); *Kochia sedifolia* association on the solonized brown soils of the Bindyeye (Plate 2, Fig. 6) and Nillinghoo soil groups, and on Hills Soils; *Kochia astrotricha* association on the Curnamona Soils; *Nitraria schoberi-Kochia pyramidata* association (Plate 2, Fig. 7) and *Arthrocnemum halocnemoides-Pachycornia tenuis* association on Lakes Soils.

The plants of *Nitraria schoberi* may be much larger than the other shrubs, sometimes up to 2 metres tall and several metres in diameter, but are included here for convenience.

VI. *Ephemeral Herb and Grassland Sub-form*

The absence of trees and shrubs, and the presence of a carpet of ephemeral herbs and grasses following rain, are characteristics of the ephemeral herb and grassland sub-form on Koonamore Station, which was not described by Williams (1955). It is common wherever the environment is seasonally too dry for the establishment of perennial vegetation, and hence, perennial herbs and grasses are rarely found. In addition to these areas of presumably natural ephemeral herb and grassland, this sub-form includes disclimax communities resulting from excessive over-grazing of shrub steppe associations. This is evident along the fence separating South Pearce's Paddock from Oopina Hills and Pussycat Paddocks, and along the fence separating No. 3 Mustering Paddock from Finn's Paddock (Plate 2, Fig. 6).

Stipa nitida and *Bassia* spp. usually dominate both the overgrazed areas, and the natural herb and grassland occurring on very shallow skeletal soils along drainage channels and at the base of hills (Plate 2, Fig. 8). *Erodiophyllum elderi* is often dominant on flood-plains of the Bindyeye Soils. For example, the large flood-plain (area 3·5 square miles) extending south-west from Southern Cross Bore into Milang Cross Paddock, is covered with ephemeral herb and grassland apparently dominated by *Erodiophyllum*. On its western margin are clumps of *Muehlenbeckia cunninghamii*. *Zygophyllum aurantiacum*, a perennial, dominates this sub-form on the driest habitats of the Koonamore Hills.

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KOONAMORE STATION

VEGETATION MAP

FENCES CREEK BEDS ------ TRACKS

0 1 2 3 4

MILES

N

Atriplex (chiefly A. vesicaria)

Kochia astrotricha

Nitraria, Kochia pyramidata

Kochia sedifolia

M Myoporum platycarpum

A Acacia aneura

P Pittosporum phyllıraeoides

Zygophyllum aurantiacum

Eremophila, Acacia

Eucalyptus oleosa

Bassia, Stipa

Eucalyptus camaldulensis

H Heterodendrum oleifolium

C Casuarina cristata

Ψ Arthrocnemum, Pachycornia

Trans. Roy. Soc. S. Aust. (1965), Vol. 89.

Appendix I

DISTRIBUBTION OF SPECIES RECORDED ON KOONAMORE STATION

The following Table lists the species recorded on Koonamore Station and indicates the habitats in which the species have been found. The data thus presented are by no means complete as the survey was undertaken during the drought period 1960-61. However, the list was supplemented by information gathered by other workers in more favourable seasons.

The identification of many of the specimens was checked by Dr. Hj. Eichler, Mr. P. Wilson and Mr. E. H. Ising of the State Herbarium of South Australia, where a voucher set of specimens has been deposited. The nomenclature follows Black (1943-57) or the forthcoming Supplement thereto, prepared by Hj. Eichler. An asterisk before the species indicates that the plant is an introduction to Australia.

The species have been recorded in the twelve habitats listed below: the numbers preceding each habitat refer to those used at the head of the vertical columns in the Table.

Semi-arid mallee, low arid woodland, arid scrub, low arid scrub sub-forms:

(1) Rocky hills

(2) Creek beds

(3) Sand-hills and sand-plains

(4) Flood-plains

Shrub steppe form:

(5) *Nitraria schoberi-Kochia pyramidata* association (Lakes Soils)

(6) *Arthrocnemum halocnemoides-Pachycornia tenuis association* (Lakes Soils)

(7) *Atriplex vesicaria* association (Oopina Soils)

(8) *Myoporum platycarpum-Atriplex vesicaria* association on Solonized brown soils (Bindyeye Soils)

(9) *Kochia astrotricha association* (Curnamona Soils)

(10) *Kochia sedifolia* on Solonized brown soils (Bindyeye Soils)

(11) *Kochia sedifolia* on Solonized brown soils (Nillinghoo Soils)

Ephemeral herb and grassland sub-form:

(12) *Stipa nitida-Bassia* spp. association.

The following species have been recorded on Koonamore Station but no details regarding their ecological distribution are available.

Danthonia penicillata, *Enneapogon nigricans*, *Tragus australianus*, *Atriplex lindleyi*, *Atriplex velutinella*, *Helipterum variabile*, *Acacia tetragonophylla*, **Vella annua*.

Species	1	2	3	4	5	6	7	8	9	10	11	12
Family Polypodiaceae												
Cheilanthes lasiophylla	+	-			-		—	—	—		-	-
Pleurosorus rutifolius	+	—	—	-	-		-	-		—		
Family Marsileaceae												
Marsilea			—	—								
Family Gramineae												
Cymbopogon exaltatus		+	—	—	—	—	—	—	—	-		—
Dactyloctenium radulans	—	—	—	+	—	—	—	—	—	—	—	-
Enneapogon avenaceus	—	—							+			-
E. cylindricus												
E. polyphyllus			-	—	-	-	-		+			—
Eragrostis dielsii			-	—	-							-
**Schismus barbatus*	+	+	—	-	—	-	+	+	—	-	—	—
Stipa nitida		-	+	+			+	+	+		-	+
S. platychaeta	—	—			+		-					
Triodia irritans			+			—	-		-		-	—
T. longiceps (?)		-	-	—	+	—	—			-		—
Triraphis mollis	-			-	-	—	—		+	-	—	-
**Trisetum pumilum*			+	-				+				
Family Liliaceae												
**Asphodelus fistulosus*†		+	-	+	—	—	—	-	-			—
Family Casuarinaceae												
Casuarina cristata	+	+	+	-								
Family Urticaceae												
Parietaria debilis	—	—	—	+							—	
Family Proteaceae												
Hakea leucoptera	+		—	-	-	—	—	—				—
Family Santalaceae												
Eucarya acuminata			+									
E. spicata		—	+									
Exocarpos aphyllus			+	-	-	-	-	-	-		-	
Santalum lanceolatum			+	+	+	—	-	-				-
Family Loranthaceae												
Amyema maidenii	+	+	+									
A. pendula	—		+			-						
A. preissii		—	+		-	—	—		-		—	-
Lysiana exocarpi	+		+	+	—	—	—		-			-

†Roark (1955) reported an invasion of this weed into the *Nitraria schoberi* community on the southern boundaries of Mjang Cross and Johnson's Paddocks.

Species	1	2	3	4	5	6	7	8	9	10	11	12
Family Polygonaceae												
Muehlenbeckia cunninghamii					-							
**Rumex vesicarius*				+								
Family Chenopodiaceae												
Arthrocnemum halocnemoides var. *pterygosperma*						+		-	-	-		
Atriplex angulata					+	+						
A. cardiegae	-			+		-		+				
A. inflata	-	-	-	-	+	-		-				
A. spongiosa					+		+	-		-		
A. stipitata			+					+				
A. vesicaria	+	+	+		+		+	+				
Babbagia acroptera			—		-	+	+		+			
Bassia bicornis	-				*		-		-	-		
B. brachyptera				+			+			-		
B. diacantha			+									
B. divaricata	+		+	+	—	-	—	—		+	+	-
B. lanicuspis							—	—		+		
B. limbata				-			—			-	-	
B. obliquicuspis							+			+		
B. paradoxa			+	+				+		-		+
B. patenticuspis			+	+	—		+	+	—	+		+
B. sclerolaenoides			—	+	-			-		+		
B. ventricosa					—		+	-	-	-	—	
Chenopodium cristatum			+					+		-	-	
C. pumilio		+								-		
Enchylaena tomentosa	+		+	—	+	—	—	—	-	+		
Kochia aphylla					-	—		—	+			
K. astrotricha	+	-			—	-			-	-		-
K. brevifolia				-	-					-	-	
K. eamonii					+							
K. ciliata	+		-	-	—			+	+			+
K. erioclada	+		+	-				-	-		-	
K. excavata					-					+		-
K. georgei						—	—	+				-
K. lobiflora						-		*				-
K. pyramidata	+	-			+		-	-	-	-		
K. sedifolia	+							-		+	+	
K. tomentosa				+						+		
Puchycarnia tenuis						+			-			-
Rhagodia gaudichaudiana	--		-	-	-	-	-	+	+			
R. spinescens var. *deltophylla*	+	-		+	+	--						
Salsola kali			-				-	+		+		

Species	1	2	3	4	5	6	7	8	9	10	11	12
Family Amaranthaceae												
Amaranthus sp.	—				—	—	—	—	—	—	—	
Ptilotus nobilis	+		+			—	—	—	—	—	—	—
P. obovatus	+	—		+			—					
P. polystachyus	+			—								
Family Nyctaginaceae												
Boerhavia diffusa	—	—	—	+	—	—	+			—	—	
Family Aizoaceae												
Tetragonia eremaea	—	+	—	+	+		+	+	+	+	+	—
Trianthema triquetra	—			+	—	—		—	—	—	—	—
Family Portulacaceae												
Calandrinia eremaea	—	—										
Portulaca oleracea		+			—	—					—	
‡Family Cruciferae												
Blennodia blennodioides		—	—	—		—		?				—
B. trisecta	—	—		—	—		—	?	—	—	—	—
**Diplotaxis tenuifolia*				+	—	—	—			—	—	—
Geococcus pusillus		—		—			—		—	—		
Stenopetalum lineare			+					+				
Family Resedaceae												
**Reseda luteola*	—			+								
Family Crassulaceae												
Crassula colorata		—	—	—	—			—	—		—	
C. sieberiana			—									
Family Pittosporaceae												
Pittosporum phillireoides	—		—		+	—		—			—	—
Family Leguminosae—Mimosoideae												
Acacia aneura	+	+	—									
A. burkittii	—		+									
A. carnei		+	—		—	+	—	—			—	
A. ligulata	+					—					—	—
A. osvaldii												
A. salicina	+											
A. stenophylla	—	—	+									
A. victoriae	—	+	+			—			—	—	—	
Family Leguminosae—Caesalpinioideae												
Cassia artemisioides	+	—										
C. nemophila	—	—	—	+				+			—	+
C. phyllodinea	—		—	+	—	—	—	—	—		—	—
C. sturtii	—	—	+	+	—	—	—	+	—	+	—	—

‡ Modified by E. A. Shaw. A critical revision of some endemic Australian genera of Cruciferae. Trans. Roy. Soc. S.A. (Vol. 89, p. 145).

Species	1	2	3	4	5	6	7	8	9	10	11	12
Family Leguminosae—Papilionatae												
Clianthus formosus	—		+	+					—	—	—	—
Lotus cruentus	—	—		+	—	—	—	—		+		
**Medicago denticulata*	—	—	—	+	—	—	—	—				
Psoralea patens	—	—	—	+					—	—	—	—
Swainsona phacoides		+						—	—	—		
Templetonia egena				+	—		—		—			—
Trigonella suavissima				+							—	—
Family Geraniaceae												
Erodium crinitum	—		+	—			+					
E. cygnorum ssp. *glandulosum*	+	+	+	+	—		+	+	+	+	—	+
Family Oxalidaceae												
Oxalis corniculata	+			—	—	—	—		—	—		—
Family Zygophyllaceae												
Nitraria schoberi				+	+			—			—	—
Peganum harmala			—	—	+							
Tribulus occidentalis	—	—	—	+	—	—	—	—	—	+	—	—
Zygophyllum ammophilum		+	+			—		—	—	—	—	—
Z. aurantiacum	—				+	—			—			
Z. billardieri			—				—	—	—	—	—	—
Z. crenatum				+								
Z. iodocarpum		+		+								
Z. ovatum	—	—		+				+				
Z. prismatothecum		—		+	+	+		+				
Family Rutaceae												
Eriostemon linearis	+											
Family Euphorbiaceae												
Euphorbia drummondii	+		+				+	+		+		+
E. eremophila	+						+					
Phyllanthus rigens	—											
Family Sapindaceae												
Dodonaea attenuata		—	+	—		—	—	—	—	—	—	—
D. lobulata	+	—				—						
D. microzyga	+											
Heterodendrum oleifolium	—		+	+				+	+	+		+
Family Malvaceae												
Abutilon fraseri	—	—	—	+	—	—	—	—	—	—	—	—
Lavatera plebeja		—	+	—	—				—	—	—	—
Malvastrum spicatum				+								
Sida corrugata			—	+	—							
S. fibulifera (?)	—	—	—	+	—	—	—	—	—	—		
S. intricata			—	+	—	—	—	—	—	—	—	—
S. petrophila	+											—

Species	1	2	3	4	5	6	7	8	9	10	11	12
Family Myrtaceae												
Eucalyptus camaldulensis†	–	+	–	–	–		–	–	–	–		
E. oleosa	+	+	+	–	–	–	–	–	–	–	–	–
Melaleuca lanceolata	–	+			–	+	–	–	–	–	–	–
Family Umbelliferae												
Daucus glochidiatus	–	–	+	–	–	–	–	–	–		–	–
Family Asclepiadaceae												
Marsdenia australis	+			–	–		–	–	–	–	–	–
Sarcostemma australe					+							
Family Convolvulaceae												
Convolvulus erubescens	–	–	–	+	–	–	+	–	–	+		
Family Boraginaceae												
**Echium lycopsis*	+	+	+	+			+	–	+	–	+	+
**Heliotropium europaeum*	–	–	–	+	–	–	+	–	–	–	–	
Lappula concava	–	–	+	–	–							
Omphalolappula concava		–	+	–	–	–	–	–	–	–	–	–
Plagiobothrys plurisepalus	–		+	–			–	+	–	–	–	
Family Verbenaceae												
Verbena supina				+	–			–	–	–	–	–
Family Labiatae												
Prostanthera striatiflora	+			–	–	–	–		–	–	–	–
Teucrium racemosum	–	–	–	+								
Family Solanaceae												
Lycium australe	–			+	–	–	–	+	+	–		
**Nicotiana glauca*	+	–	–	–	+	–	–	–	–	+	–	–
N. goodspeedii				+	–	–	–	–	–	–		
Solanum ellipticum	–	–	–	+		–			–			+
**S. nigrum*		–		+						+		
S. sturtianum	+	–	–	–	–	–		–	–	–	–	–
Family Myoporaceae												
Eremophila alternifolia	+											
E. duttonii		–		+	–	–	–	–	–	–		–
E. freelingii	+	–	–	–	–		–		–	–		–
E. longifolia			–	+	+	–	–	–	–	–		
E. maculata	–	–	–	+								
E. oppositifolia	+	–	–									
E. scoparia	–	–	+	–	–	–	–	+	+	+	+	–
E. serrulata	+			–	–	–	–	–	–	–		
E. sturtii			+	+				+	–	–	–	
Myoporum platycarpum	+	–	+	+	+	–		+	–	+		+
Family Cucurbitaceae												
Citrullus lanatus	–	–	–	+	–	–	–	–	–	–	–	–
Cucumis myriocarpus				+	–			–		+		

†Creekbeds in Johnson's Paddock and along Sieeus River north of Orania Paddock.

Species	1	2	3	4	5	6	7	8	9	10	11	12
Family Campanulaceae												
Wahlenbergia bicolor	–	+	–	+	–	–	–	–	–	–	–	–
W. consimilis	–	–	–	+	–	–	–	–	–	–	–	–
W. sieberi		–		+	–	–	–			–		
Family Goodeniaceae												
Goodenia subintegra	–	–	–	+	–	–	–	–	–	–	–	–
Family Compositae												
Angianthus burkittii		–	+	+	–	–	–	–	–	–	–	–
Brachyscome pachyptera	–		–				–	+	–	–	–	–
Calotis cymbacantha	–	–	?	–	–	–	–	–	–	–	–	–
C. hispidula	–	+	+	–	–	–	–	–	–	–		+
**Carthamus lanatus*				+				–	–	–	–	–
Cassinia laevis	+	–	–	–	–	–	–	–	–	–	–	–
**Centaurea solstitialis*				+		–	+	–	–	+	+	–
Craspedia pleiocephala	–	–	+	+	–	–	–	–	–	–	–	–
Erodiophyllum elderi	–		+	+	–	–						
Gnaphalium luteoalbum			–	+	–				–	–		–
Gnaphalodes uliginosum	–	–	+	–	–	–					–	–
Helipterum floribundum			–	+	–	–	–	–	–	–	–	–
H. moschatum	–	–	+	–	–	–	–	–	–			
H. strictum	–			+						–	–	–
**Inula graveolens*		–	–	+	+	–	–	–	–	–	–	–
Isoetopsis graminifolia	+		+	–	–			–		–	–	+
Ixiolaena leptolepis		–	+	–	–	–	–	–	–	–	–	–
Millotia macrocarpa	–		+	–	–	–						
M. myosotidifolia			+									
Minuria cunninghamii	–		–		+	–	–		–	–	–	–
Olearia pimeleoides	–	+	–	–	–	–	–	–	–	–	–	–
Podocoma nana	–	–	–	+	–	–	–	–				
Pterocaulon sphacelatum	+	+			–				–		–	–
Rutidosis multiflora			+	–				+			–	–
Senecio anethifolius	+	–	–	–	–	–	–	–	–	–	–	–
S. gregorii	–	–	+									
S. magnificus	–	+	–		–							
S. quadridentatus			–	?	–		–		–	–	–	
**Sonchus oleraceus*	–	–	+	+	–	–		–	–	–	–	–
Toxanthes muelleri	–	–	+									–
Vittadinia scabra		–		+	–	–	–	–			–	–
V. triloba		–	–	+		–	–	–	–	–	–	
**Xanthium spinosum*	–	–	–	+	–	–	–	–	–	–	–	–

Appendix II

POPULAR NAMES OF SOME BETTER-KNOWN PLANTS FOUND ON KOONAMORE STATION

Scientific Name	*Popular Name*
Acacia aneura	Mulga
Arthrocnemum halocnemoides	Samphire
Atriplex vesicaria	Bladder Saltbush
Bassia—various species	Bindyeye
Casuarina cristata	Black Oak
Dodonaea spp.	Hop Bush
Eremophila sturtii	Turpentine Bush
Eremophila longifolia	Long-leaved Eremophila, Emu Bush
Erodiophyllum elderi	Koonamore Daisy
Eucalyptus camaldulensis	River Red Gum
Heterodendrum oleifolium	Bullock Bush
Kochia pyramidata	Black Bluebush
Kochia sedifolia	Bluebush
Muehlenbeckia cunninghamii	Lignum
Myoporum platycarpum	False Sandalwood
Nitraria schoberi	Nitre-bush
Pachycornia tenuis	Samphire
Pittosporum phylliraeoides	Native Willow
Salsola kali	Roly-poly
Stipa nitida	Spear Grass
Zygophyllum spp.	Squash Bush

EXPLANATION OF PLATES

Plate 1

Fig. 1. Semi-arid mallee, *Eucalyptus oleosa* association on Koonamore Station.

Fig. 2. Arid scrub, *Acacia aneura* association on Koonamore Station.

Fig. 3. Low arid scrub, *Acacia burkittii-Eremophila sturtii* association on Koonamore Station.

Fig. 4. Low arid woodland, *Casuarina cristata* association on Koonamore Station.

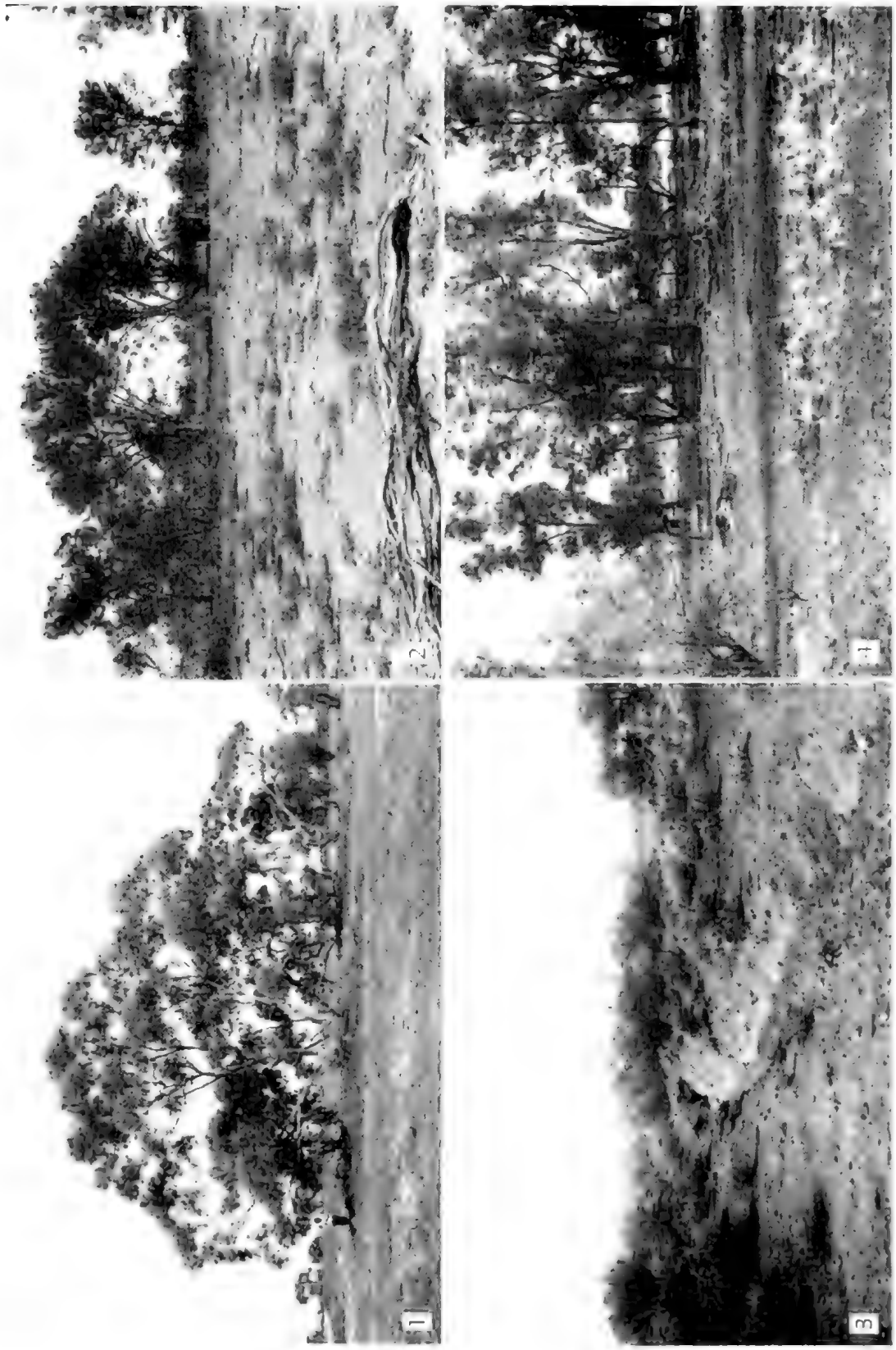
Plate 2

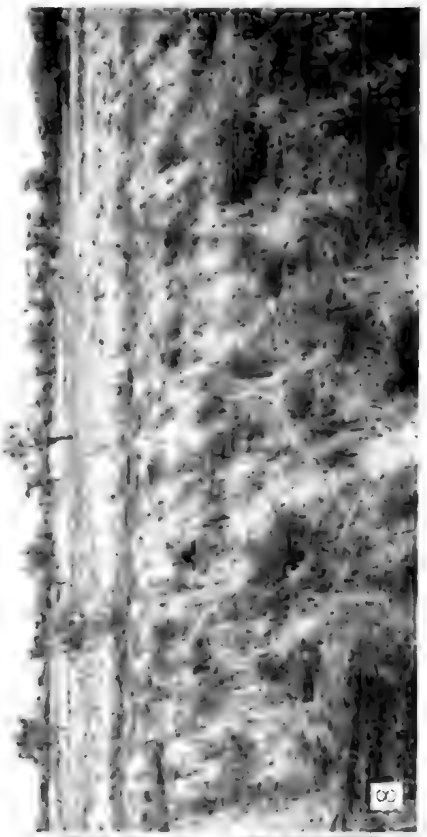
Fig. 5. Shrub steppe, *Atriplex vesicaria* association on Koonamore Station.

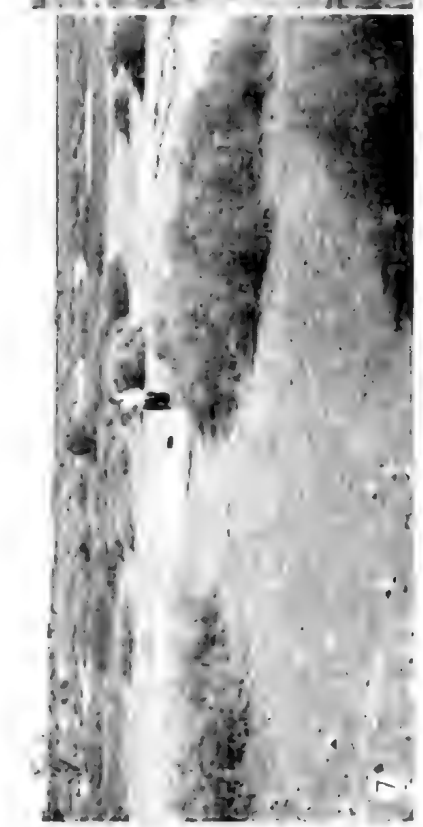
Fig. 6. Shrub steppe, *Kochia sedifolia* association on Koonamore Station with overgrazed community (during drought) on right.

Fig. 7. Shrub steppe, *Nitraria schoberi* association on Koonamore Station.

Fig. 8. Ephemeral herb and grassland, *Stipa nitida-Bassia* spp. association on Koonamore Station; *Myoporum platycarpum* trees in the background.


1
2
3
4





MOUNT TOONDINA BEDS – PERMIAN SEDIMENTS IN A PROBABLE PIERCEMENT STRUCTURE

BY IAN B. FREYTAG

Summary

Mount Toondina lies near to the centre of the Arckaringa Sub-Basin, herein re-defined somewhat provisionally on seismic evidence, as a significantly thicker development of Upper Palaeozoic sediments.

The Mount Toondina Beds are formally described. Their type-section consists of 263 feet of shale and argillaceous siltstone with interbeds of fine sandstone and coal. These sediments were deposited mainly in a lake environment, but also during intermittent swampy phases, and their flora indicates an Early Permian age.

So far, the Mount Toondina Beds are limited in exposure to the small area of the type locality, where they are severely deformed and dislocated together with remnants of Upper Jurassic Algebuckina Sandstone. The surrounding outcropping Lower Cretaceous strata, and underlying Upper Jurassic and Upper Palaeozoic sequences inferred from seismic surveys, are only mildly deformed.

An isolated, small, positive gravity anomaly coincides approximately with the Permian inlier.

To explain the structurally anomalous occurrence of the Permian sediments at Mount Toondina, it is suggested by present geological and geophysical findings that they were elevated by piercement of the overlying strata, probably in Middle or Late Tertiary time. The question of motivation for such a piercement has not been resolved.

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[Read 10 June 1965]

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INTRODUCTION

Geological mapping of the area of the Oodnadatta 4-mile Military Sheet by the South Australian Geological Survey led to the discovery in 1962 of *Glossopteris*-bearing Lower Permian sediments at Mount Toondina. Subsequent detailed mapping, shallow stratigraphic drilling, and gravimetric and seismic surveys have furnished important additional information about this anomalous Permian inlier.

Mount Toondina is a singular landmark in desolate, undulating country, some 28 miles approximately south of Oodnadatta township (see Fig. 1). The point is conspicuous not so much in elevation but in its solitary, dark patch of vegetation which is supported by nearly a dozen springs around the hill-slope. Indeed, Mount Toondina owes its preservation mainly to resistant limestones deposited by ancestral Pleistocene mound-springs.

The Permian exposure is the best and most interesting one in northern South Australia and will provide an important reference section for both surface and subsurface work in the future. It is therefore opportune to formally

* Petroleum Section, Geological Survey of South Australia.

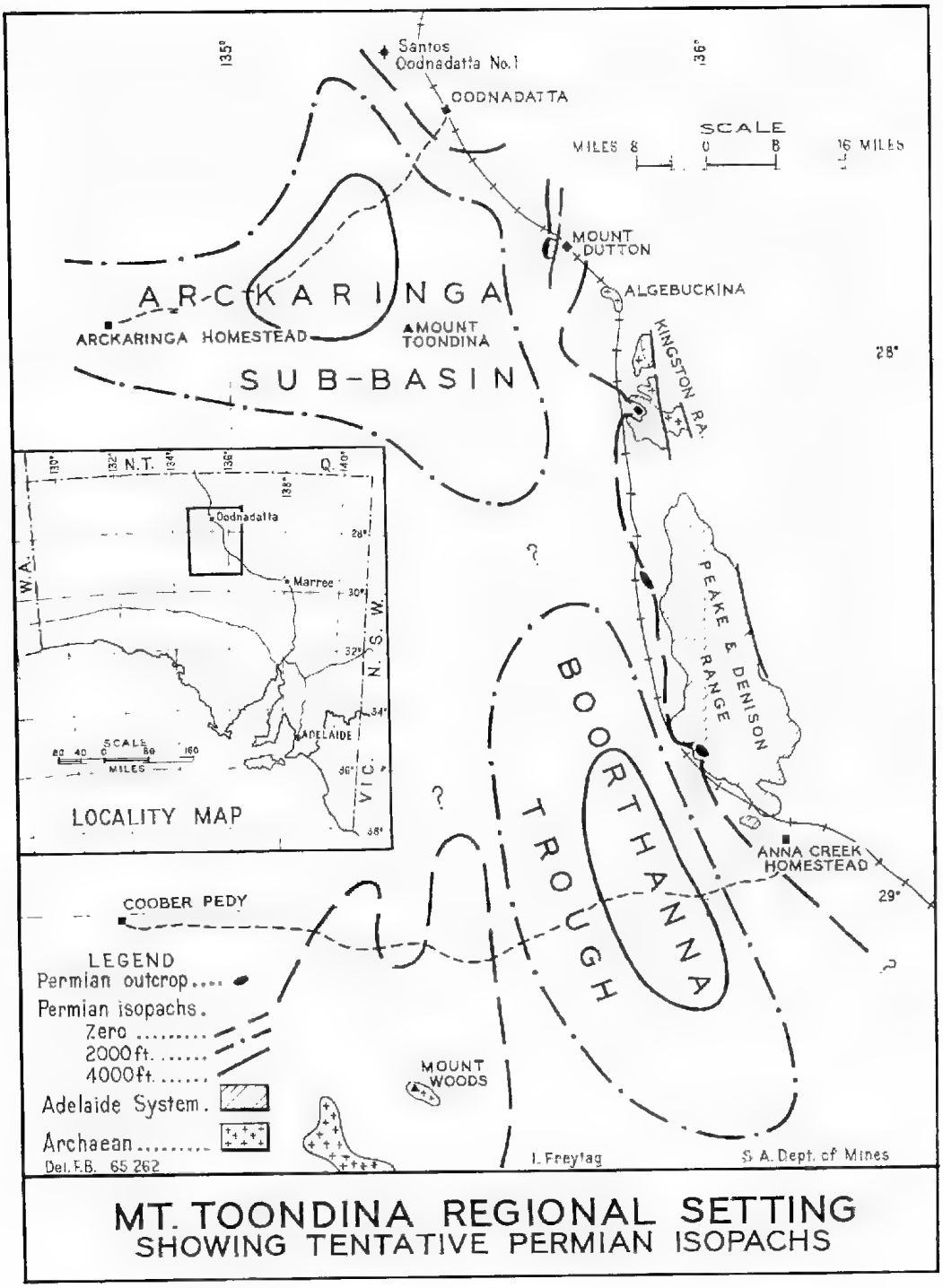

Fig. 1. Mount Toondina regional setting.

define the Permian sediments. Their unusual structural position within an apparent pierceement will also be discussed.

For the purposes of discussion, the important subsurface pre-Upper Jurassic sequence in the region will be termed Upper Palaeozoic in this paper. The age is inferred from seismic refraction data.

REGIONAL SETTING AND THE ARCKARINGA SUB-BASIN

Mount Toondina lies north-west of the Peake and Denison Ranges proper (see Fig. 1) and has a survey cairn elevation of 382 feet above mean sea level. Geologically it is situated within that portion of the far western Great Artesian Basin referred to informally as the Arckaringa embayment (Sprigg and Stall in Glaessner and Parkin, 1958), and later as the Arckaringa sub-basin (Sprigg, 1961). The latter term was related, as a sub-unit, to the "Permian-Mesozoic Artesian Basin" (p. 53).

It has been demonstrated clearly by Wopfner (1964) that Mesozoic deposition in the area of the western margin of the Great Artesian Basin was separated from the Permian by a period of 80 to 90 million years, essentially of uplift and erosion climaxed by peneplanation. Thus, the Permian sediments do not constitute a part of the Great Artesian Basin, which is essentially an intra-cratonic basin of Mesozoic age.

It is proposed that "Arckaringa Sub-Basin" should remain as a useful term referring to the relatively thick Late Palaeozoic sediments in the Arckaringa-Mount Toondina area, shown by isopachous contours in Fig. 1. This use is preferred to "Arckaringa embayment" applied to the Great Artesian Basin, as the Jurassic-Lower Cretaceous sequence in the region lacks evidence of a sedimentary history or configuration differing significantly from that of the region east of the Peake and Denison Precambrian inliers. Sub-unit status is therefore not necessary.

The Arckaringa Sub-Basin is analogous to the Boorthanna Trough, a term recently introduced for the thick development of Upper Palaeozoic sediments situated between the Proterozoic Peake and Denison ranges and the Archaean of Mount Woods (Wopfner, 1964). To what extent these thicker bodies of sediment are primary features or structural remnants of the former extensive Late Palaeozoic sedimentation indicated by Wopfner (his Fig. 1, p. 119) is not yet known. Their recognition is based on aeromagnetics, water bore data and Mines Department seismic investigations.

The consistent high-speed refracting layer, below which in some places ordered reflections still originate from sub-horizontal strata (Moorcroft, 1964) is interpreted as the base of the Upper Palaeozoic section in the Arckaringa Sub-Basin. This implies that sediments probably not younger than Ordovician and possibly as old as Willouran underlie the Arckaringa Sub-Basin.

The Peake and Denison, Mount Kingston, Algebuckina and Mount Dutton inliers expose moderately folded sediments of Willouran, Torrensian and Sturtian age, together with upthrown blocks of (?) Archaean metamorphics of the Peake Series (Reyner, 1955).

This author and others (Parkin, 1956; Chugg, 1957; Heath, 1965) assigned a tentative Permian age to several small, isolated outcrops of coarse clastics, reworked in part, along the western edge of the ranges (see Fig. 1), on grounds of stratigraphic position and glacigene characteristics. Chugg also recorded gravimetric and borehole evidence for the presence of "Permian to (?) Jurassic"

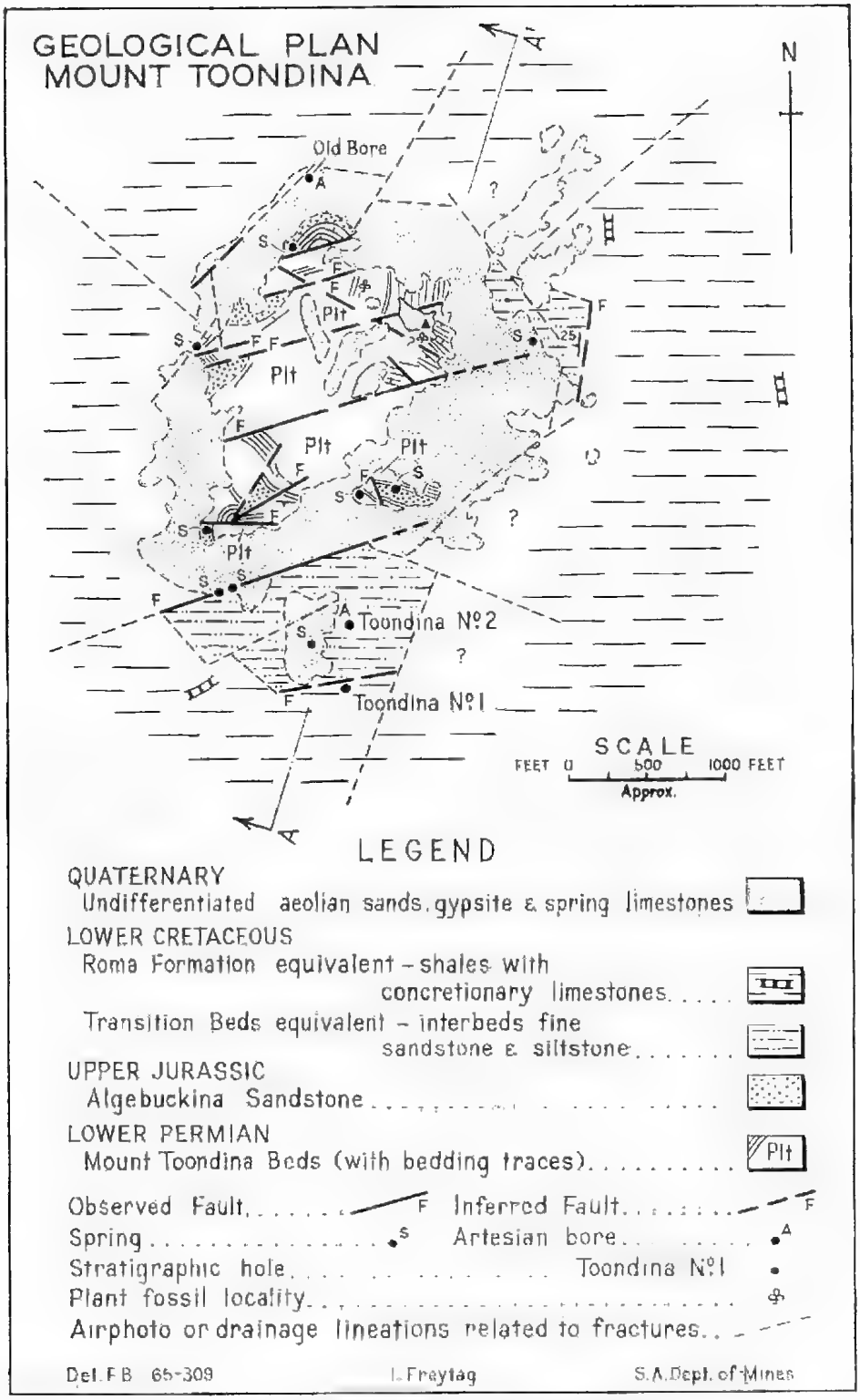

Fig. 2. Geological plan – Mount Toondina.

sediments west of the Peake and Denison Ranges. This view was later confirmed by Ludbrook (1961) in extending the Lower Permian section dated by Balme (1957) in Lake Phillipson bore to several water bores in the Boorthanna Trough.

SURFACE GEOLOGY AT MOUNT TOONDINA

The surface geology of Mount Toondina is depicted in Fig. 2, which is a geological map based on portion of an enlarged aerial photograph.

The Mount Toondina survey cairn stands on a small, flat-lying remnant, about 3 to 5 feet thick, of gypsite-covered Plio-Pleistocene arenaceous limestone, which rests mushroom-like on a column of steeply inclined Permian sediments (see Fig. 3; also Plate 2).

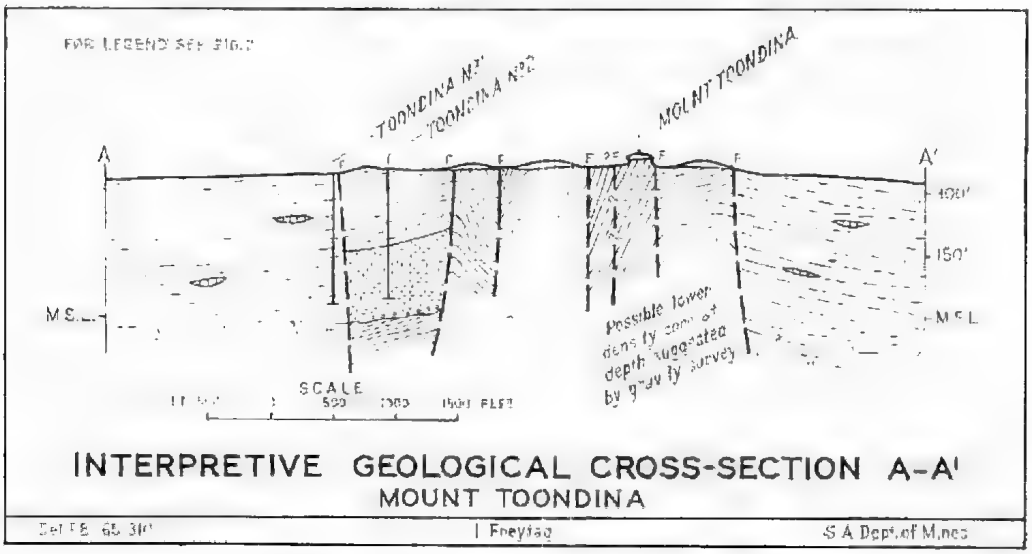

Fig. 3. Interpretative geological cross-section A-A' — Mount Toondina.

Permian outcrops occur within a circular area about one-third of a mile across. In detail, the outline of Permian exposure is probably polygonal, but it is obscured by an annular mound of Quaternary limestones, gypsite and aeolian sands. Most outcrops inside this mound are encrusted with recently deposited travertine, or have been affected by calcareous replacement. Between outcrops, the ground surface is a thin saline, clayey crust.

Travertinized Permian rocks can be distinguished from the coarse, massive Algebuckina Sandstone by their well-bedded and fine-grained character. Usually the base of the Algebuckina Sandstone is defined by an angular quartz conglomerate, up to three feet in thickness.

Although the Algebuckina Sandstone is generally lacking in visible bedding (perhaps due mainly to calcareous replacements), it is apparently structurally conformable with the Permian. The regionally unconformable relationship between Permian and Upper Jurassic sediments of this area (Wopfner, 1964, p. 123; Heath, 1965) is not evident within the compass of the small Mount Toondina exposure. Both Permian and Jurassic strata are strongly deformed and dip in excess of 55 degrees.

Permian plant fossils were discovered in two places (see Fig. 2) and details of the flora appear in the definition of the Mount Toondina Beds. The fossils from 500 feet north-west of the cairn occur in finely-bedded pink siltstones associated with gritty sandstones not present in the type section.

Outcrops of gently-dipping dark-brown, ferruginous sandstones with micaceous silty interbeds and calcareous oolitic horizons occur on the southern and eastern slopes of Mount Toondina. Similar sediments are known from numerous localities surrounding the Peake and Denison basement inliers, where their stratigraphic position is above the Algebuckina Sandstone but below the Lower Cretaceous marine formations. For this reason, and until formally described, these sediments are related to the Transition Beds of Whitehouse (1955), of the Blythesdale Group in Queensland. A feature of their occurrence in proximity to basement highs (e.g. Mt. Alice, Mt. Dutton, Algebuckina, Peake and Denison Range) is one or more horizons of rounded, water-worn boulders ranging up to several feet in maximum diameter, and of diverse lithology. At Mount Toondina, however, the boulders are absent, and the significance of this is to be discussed.

Lower Cretaceous marine sediments crop out widely in the region surrounding Mount Toondina. These grey shales exposed in erosional gutters, apparently are undisturbed within a few hundred feet of the Permian. Scattered limestone concretions in the shales protrude a few inches above the surrounding plain and one mile approximately north of Toondina cairn they contain *Inoceramus carsoni*, *Maccoyella reflecta* and *Barcoona trigonalis*, a molluscan assemblage placed in the lower portion of the Albian section by Dr. N. H. Ludbrook (1966, in press). In comparison with Santos Oodnadatta No. 1 Well, this horizon is about 600 feet above the base of the marine Cretaceous sequence.

Indications of fractures both on and around Mount Toondina are numerous. These are classified on the map as:—

1. Observed faults—visible truncation or displacement of beds.
2. Inferred faults—displacement apparent from surface trend, repetition of beds, or subsurface data.
3. Probable faults and radial fractures—airphoto lineations assumed peripheral to the Permian and Jurassic sub-crop covered by Quaternary deposits and drainage lineations.

The fractures strike in many directions. The predominating set is in the WSW-ENE direction, and less prominent sets lie NNW-SSE and NE-SW. Hades are not evident, but are probably small.

Minor drag-folds occur in the Permian and Jurassic sediments, and also in the Transition Beds equivalents on the slopes of Mount Toondina.

Viewed overall, the geological map suggests that the Permian of Mount Toondina forms the centre of a very steeply, south-westerly plunging structure with its culmination centred on the north-eastern side. The nature of the structure will be discussed further in detail.

MOUNT TOONDINA BEDS – FORMAL CONCEPT

The Australian Code of Stratigraphic Nomenclature states that a sequence of strata "whose thickness and lithology are incompletely known" may be referred to formally as "Beds". The Permian sequence at Mount Toondina is within this category and the following formal definition is proposed:

Name: Mount Toondina Beds.

Type Locality: Mount Toondina, 28 miles at 10 degrees west of south from Oodnadatta township. Lat. 27°56′42″S., long. 135°21′41″E. (survey cairn by astrofix).

Type Section: North-east to south-west section channeled on flat ground one chain south-east of Mount Toondina survey cairn (see Fig. 4). Base of section (Unit 1) is covered by Quaternary deposits. Top of section (Unit 31) is chosen arbitrarily at a structural break.

MOUNT TOONDINA BEDS—FIELD DESCRIPTION

Unit		Thickness ft.	in.
1	Sandstone, greyish to off-white, weathers brownish, fine to very fine-grained, soft, friable. Dominantly well-sorted, sub-rounded quartz grains. Slightly calcareous, occasional carbonaceous laminae and cross-lamination. Few thin intercalations grey laminated siltstone. Irregular veinlets and nobbly concretions of calcite	15	
2	Siltstone, grey grading to black (carbonaceous) in top half, soft, argillaceous, slightly micaceous, minor cross-bedding. Laminae and lenticles off-white, friable quartz siltstone	2	6
3	Sandstone as in Unit 1	2	6
4	(Interbeds) Shale, light- to dark-grey, silty, finely micaceous, fissile, carbonaceous in part, clayey; and siltstone, light- to dark-grey, argillaceous, finely micaceous, carbonaceous flecks and laminae. Intermittent laminae light-grey, very fine-grained argillaceous sandstone	22	0
5	Sandstone, pale greenish-grey, weathers light brown, fine-grained, sub-angular to subrounded quartz, very silty, very micaceous, biotitic, soft, friable, fissile, calcareous, few thin streaks carbonaceous matter	12	0
6	Coal (strongly weathered in outcrop), black, soft and puggy below surface, drying to crumbly, sooty powder. Numerous tiny (¼ in.) lenticles quartz silt, white, porous, very clean, unconsolidated. (See analysis Appendix A)	7	0
7	Shale, dark grey, very clayey, plastic when damp, silty, micaceous, becoming very carbonaceous in top 4 ft. Numerous fine interlaminations in lower half of siltstone and very fine off-white sandstone	10	0
8	Coal as in Unit 6. Silt-filled cracks on top surface indicate normal facing. (See analysis Appendix A.)	7	6
9	Silt or very fine sand, white at base grading through yellow to red-brown at top. Essentially clear angular to subangular quartz grains, unconsolidated, very clean, uniform and porous texture. Possible post-leaching skeletal rock	3	0
10	Coal as in Unit 6. (See analysis Appendix A.)	7	6
11	Siltstone, grey and light-grey, very argillaceous, micaceous, finely bedded with carbonaceous plant fragments on bedding planes. Numerous laminae and lenses very fine quartz sandstone and siltstone. Some carbonaceous smears	6	6
12	Carbonaceous clay grading to coal as in Unit 6	2	6
13	(Interbeds) Clay-shale, grey and light-grey, plastic when damp, laminated in part; and siltstone, light-grey, very argillaceous, micaceous, laminated. Coaly band 3 in. thick at 2 ft. above base	15	0
14	(Interbeds) Sandstone, off-white to light-grey, soft, fine-grained, micaceous, argillaceous; and siltstone, light-grey to grey, micaceous, fissile in part, argillaceous, grading to silty clay-shale in some layers. Abundant carbonaceous flecks and fragments on bedding planes	10	0
15	Siltstone, with lesser clay-shale as in Unit 13. Minor interbeds greyish-white, laminated fine sandstone, weathering yellow-brown. Plant macrofossil horizons 5 ft. above base of unit	28	0
16	Carbonaceous clay grading to coal (as in Unit 6) in top 4 ft. 6 in. (See analysis Appendix A.)	10	0

MOUNT TOONDINA BEDS—FIELD DESCRIPTION—*continued*.

Unit		Thickness ft.	in.
17	Silt to very fine sand as in Unit 9. At middle, 2 in. bed paper-fine laminated carbonaceous siltstone	4	0
18	Coal as in Unit 6. (See analysis Appendix A.)	5	0
19	Siltstone with clay-shale interbeds and minor very fine sandstone in upper 3 ft., lithologies as in Unit 15	8	6
20	Coal as in Unit 6	1	0
21	Shale, grey and light-grey, soft, fissile, very silty, micaceous, and minor clay-shale. 3 in. coaly band 1 ft. above base	9	6
22	Sandstone, light-grey, very fine, very argillaceous, micaceous	2	0
23	Clay-shale grading to finely laminated siltstone. Lithologies as in Unit 13	11	0
24	Sandstone, light-grey, very fine, silty, argillaceous, carbonaceous flecks	3	0
25	Siltstone as in Unit 11	11	0
26	Sandstone, reddish-grey, very fine-grained, argillaceous, finely laminated	3	0
27	Siltstone as in Unit 11, grading to silty shale in part	15	0
28	(Interbeds) Siltstone, light-grey to grey, argillaceous, micaceous, laminated, carbonaceous fragments; and sandstone, weathered red-brown to yellow-brown, fine-grained, silty, argillaceous. At middle, 3 ft. clay-shale with white quartz siltstone lenses	19	0
29	Sandstone, greyish-white, fine to very fine, soft, friable, argillaceous matrix	3	0
30	Interlocking lenticles coaly material and white quartz silt, scattered gypsum crystals	1	0
31	Sandstone as in Unit 29	6	+

Environment

The Mount Toondina Beds consist in the main of well-stratified variants of a silt-clay deposit, with lesser interbeds of fine sandstone and coal. The sediments are considered to be freshwater in origin with characteristics of a lake bottom-environment. Frequent fine bedding, laminations, the presence of unbroken leaves and an abundance of carbonaceous flecks and mica on bedding planes indicate quiet-water conditions. Furthermore, the bulk admixture of fine clastics and organic material would not survive a higher energy environment.

Coals attest to several phases of swamp development.

Boundary Relationships: These are not established. The base of the unit is not exposed and, it is anticipated, will be defined only by drilling.

Thickness: Total thickness of the type-section computed from surface measurement and dip values is 263 feet. A distinct similarity between units 7 to 13 and 15 to 21 (see Fig. 4) suggests a repetition of strata, for which, however, no structural evidence was seen.

Flora and Age: In a collection of fragmented leaf impressions from Unit 5, W. K. Harris (1962) identified the following:

Glossopteris indica Schimper
Sphenophyllum sp.
Cordaites australis (McCoy)
Gangamopteris cyclopteroides Feist (tentative)
Schizoneura sp. (tentative)
(These forms, excepting *Sphenophyllum*, also occur in siliceous siltstones 500 feet north-west of Toondina cairn.)

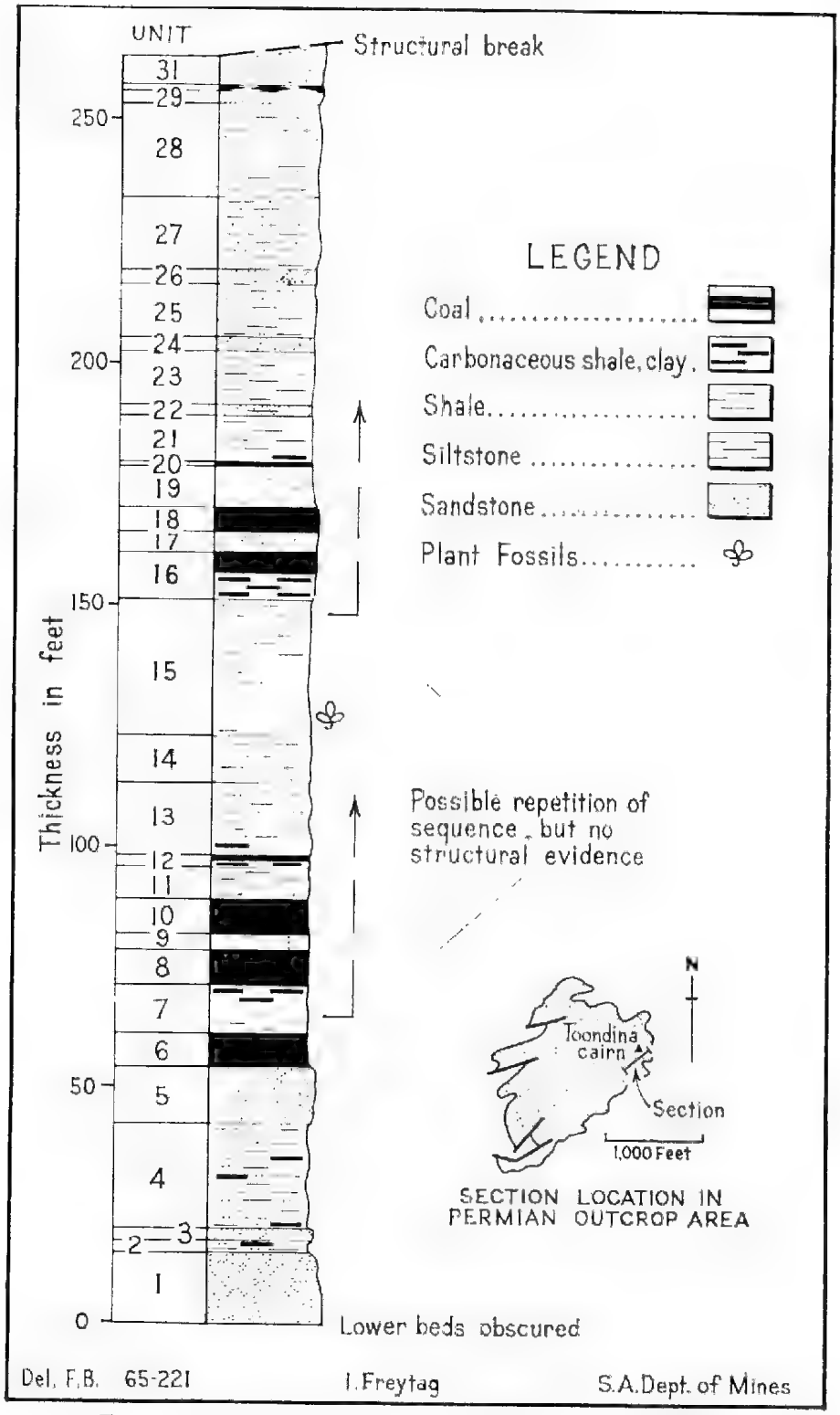

Fig. 4. Mount Toondina Beds – columnar stratigraphic section.

Harris stated that whereas *Glossopteris indica* is indicative of a Permian age, ". . . the presence of *Cordaites australis*, a typically Devonian to Carboniferous species, associated with *G. indica* would support a Lower Permian age for the flora . . . ".

The Bordeaux laboratories of Compagnie Francais des Petroles have produced a well-preserved microflora from specimens from two horizons at Mount Toondina, one of which approximates to Unit 4 of the type-section. Kieser (1965) points out that several previously regarded index forms for the Greta Coal Measures and the Upper Coal Measures of the Sydney Basin occur mixed at Mount Toondina. Thus correlations at present seem to be limited by long ranging species. Kieser, however, regards with some confidence the assemblages of Mount Toondina as being closely allied to those of the Greta and Upper Coal Measures, and the Lake Phillipson section. Balme (1957) ranged the assemblages in Lake Phillipson bore from ?Late Carboniferous through Sakmarian to Lower Artinskian.

STRUCTURAL INVESTIGATIONS AT MOUNT TOONDINA

Gravimetric Survey

The aim of a gravimetric survey which followed the discovery of the Permian exposure was to delineate the form of the Permian body in the subsurface, and thus endeavour to explain the anomalous, isolated outcrop.

The survey was conducted late in 1963 by J. McG. Hall, Exploration Geophysicist, of the S.A. Mines Department. Stations at 500 feet spacing were

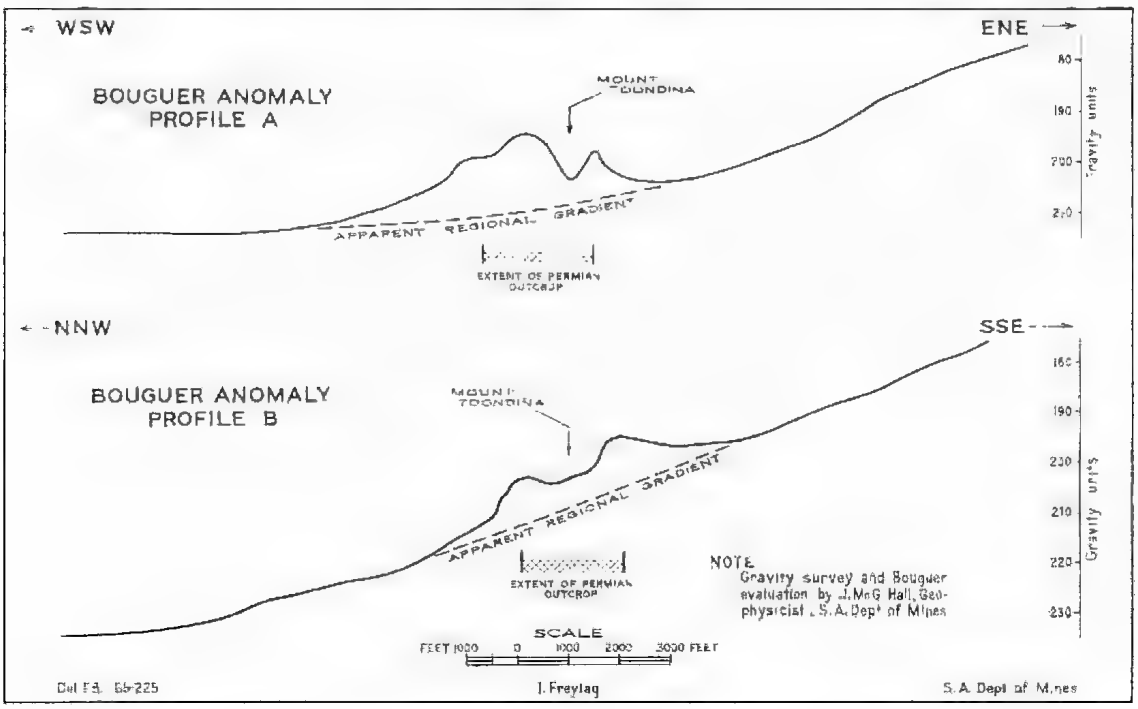

Fig. 5. Bouguer gravity profiles through Mount Toondina.

read on a 10,000 feet rectilinear grid with origin at Mount Toondina cairn. Bouguer profiles along the traverses through the origin are presented in Fig. 5.

Mount Toondina clearly has an associated minor but discrete positive gravity anomaly of about 1·5 milligals magnitude, which coincides with the Permian outcrop. The anomaly can be attributed to a density contrast between the more compacted Permian sediments and the surrounding Cretaceous shale blanket.

The significance of the small negative trough, intersected transversely and longitudinally by profiles A and B respectively (Fig. 5), is not yet known. The reversal could relate to material at depth with a density relatively lower than the Permian sediments, or it may originate in a complex of faulting.

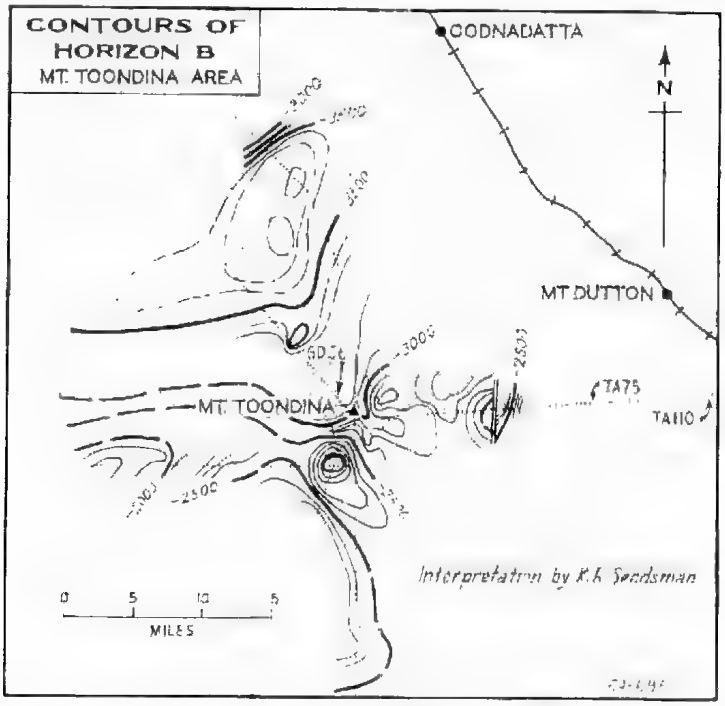

Fig. 6. Contours of horizon B, Mt. Toondina area (after Moorcroft).

Shallow Drilling

The results obtained from two shallow drill-holes each 305 feet deep, south of Mount Toondina, are of particular interest. Locations of these holes are shown in Fig. 2.

S.A. Government Toondina No. 1 intersected Lower Cretaceous marine shales through its entire depth. Samples from 50 feet and 305 feet yielded good microfloral assemblages of similar character, which date the sediments as Aptian (Harris, 1964).

The No. 2 hole was located 450 feet north of No. 1, at the edge of outcropping ferruginized Transition Beds equivalents. These, in the form of fine-grained micaceous sandstones and argillaceous siltstones, were intersected to about 150 feet, followed to total depth by fine to coarse, occasionally pebbly, sandstones of the Algebuckina Sandstone, which produced artesian water.

Thus, assuming bedding dips to be low, there appears to be a relative vertical displacement exceeding 300 feet between these two holes (see cross-section, Fig. 3). Further, an aggregate relative vertical displacement exceeding 600 feet is inferred between Toondina No. 1 and the Permian outcrop about 1,200 feet north of it.

These results can be interpreted as severe faulting at and near the margin of Permian outcrop.

Seismic Surveys

The main source of regional subsurface information south-west of Oodnadatta is the surveys of the Mines Department Seismic Section conducted in 1961, 1963 and 1964. This work, under the direction of K. R. Seedsman, B. E. Milton and E. Moorcroft, was responsible for the discovery of a substantial sedimentary sequence presumed now to be largely Upper Palaeozoic which, in this paper, is identified with the Arckaringa Sub-Basin. It must be remembered that in the absence of deep drilling in the area, correlation of seismic events with stratigraphic horizons can be made only provisionally by extrapolating stratigraphic relationships established around the basin.

Moorcroft (1964) presented some results of seismic work in the vicinity of Mount Toondina where rather more detailed procedures were carried out. Of basic importance is the identification by refraction probe, of a high-speed layer (found consistently in the Sub-Basin) with velocities in the 17,000 to 19,000 feet per second range. This layer can be interpreted with some certainty as the pre-Upper Palaeozoic "basement", the bedrock of the Arckaringa Sub-Basin. Its age is considered to be Ordovician or older, and depths to this refractor afford an indication of the overlying Upper Palaeozoic-Mesozoic thickness.

In particular, Moorcroft cites shot-point GD56 (see Fig. 6) less than two miles north-west of Toondina cairn, as having depth to high-speed refractor of 4,200 feet. Nearby, ordered reflections with two-way times of about 1·6 seconds (unpublished plan 63-274) originate apparently from depths greater than the refracting surface, and therefore imply a mildly deformed, stratified "basement" in the surrounds of Mount Toondina. He also points out that the spread across the outcropping Mount Toondina Beds recorded a maximum velocity of 16,000 feet/sec., which is somewhat lower than the usual "high-speed" velocity. The geological significance of this is not known.

Several reflecting horizons were persistent in the Toondina area. Two of them assumed to originate within the Upper Palaeozoic sequence, could be contoured with sufficient control to show some interesting structural aspects (Fig. 6).

One is that deformation even at the deepest horizon (i.e. 3,000 feet) near Mount Toondina is only mild, and therefore the severe dislocations at Mount Toondina must be limited to little more than the area of Permian outcrop. Secondly, a circular domal closure of 300 to 400 feet and two miles diameter occurs some four miles SSW of Mount Toondina (see Fig. 6). The structure opens and loses its circular shape in successively higher horizons and merges into an elongate anticlinal fold nosing just south-east of Mount Toondina. One is therefore tempted on grounds of proximity and shape, to interpret the seismic dome as a structure at depth, similar to that of Mount Toondina. This view can be tested only by drilling.

MOUNT TOONDINA AS A PROBABLE PIERCEMENT STRUCTURE

The foregoing geological and geophysical findings imply strongly that Mount Toondina is a piercement structure. The very mild deformation of the enclosing Cretaceous sediments suggests further that it is of isostatic rather than tectonic origin.

Some pertinent points favouring a piercement are now reviewed:

1. Geological mapping has shown Mount Toondina to be a small inlier of steeply-dipping, severely dislocated Permian sediments, surrounded immediately by sub-horizontal Cretaceous strata.
2. Photo-lineations in polygonal outline suggest that the inlier is fault-bounded, and this has been verified to some degree by drilling.
3. Probable radial fractures are consistent with a "point intrusion".
4. Gravimetric results show that Mount Toondina has an associated small positive anomaly. This approximates to the area of Permian outcrop, but gravimetrically it is isolated in an area of regular north-westerly gradient.

   A small reversal within the anomaly may be due to core material of differing composition. The position of the reversal coincides with the structural apex indicated by surface mapping.
5. The absence of boulders at the Transition Beds level suggests that the Permian rocks were not elevated topographically in Early Cretaceous time.
6. Lack of brecciation in the faulted Permian sediments is noteworthy. It indicates in these rocks a degree of plasticity which can be attributed probably to their high proportion of soft clays.

The question of primary motivation remains unanswered. The subsurface sequence in the region is unknown and strata with a potential for plastic deformation, be they evaporite, shale or otherwise, cannot be identified. In age the rock would be Early Permian or older and in this respect, a sedimentary "basement" in the area may be significant. An original 5,000 feet of Upper Palaeozoic-Mesozoic sediments at Mount Toondina could provide a loading sufficient to mobilize rock of lower density deep in the section. Certainly, Mount Toondina is located in the deeper portion of the Sub-Basin.

The maximum velocity of 16,000 feet/sec. recorded from the refraction probe on Mount Toondina could be attributed equally well to clastic sediment, tectonic breccia or rock-salt.

It is interesting to compare Mount Toondina with the "probable salt dome" described by Veevers and Wells (1959) at Woolnough Hills in the south Canning Basin (W.A.). These two structures have similar shape, size and geological setting. At Woolnough Hills, however, the centre of the dome is occupied by sheared gypsum and blocks of brecciated dolomite, thought to be exposed cap-rock, and Permian overlain by Cretaceous sediments crop out on the flanks. Peripheral faulting was not observed. Mount Toondina could well be such a structure either now at a shallower stage of erosion or else less-developed as a piercement.

Although the geological environment of Mount Toondina is completely unlike that of diapirs in the Flinders and Peake and Denison Ranges (Coats, 1964), sediments of Willouran age which Coats considers contribute the breccia core complexes, crop out in great thickness in the Peake-Denison-Mt. Dutton trend, only 30 miles to the east of Toondina.

The age of the Toondina piercement is known to be post-Lower Cretaceous and pre-Quaternary. There is little doubt that the piercement has led to the development of the mound-springs and their limestones which, from field relationships, are Plio-Pleistocene in age. Piercement may well be associated with Middle or Late Tertiary tectonics which have had the most profound influence on the present structure of this region.

The abutment of the Pleistocene gypsite land surface on the north-eastern slopes of Mount Toondina, at a level lower than that of the same surface at the survey cairn could be due to continuing upward movement of the Permian body during Quaternary time. This theory could also explain the undulating (?deformed) base of the limestone shown in Plate 2, and the advanced state of erosion of the ancestral mound-springs.

In conclusion, it is the author's opinion that the data now on hand is best explained by piercement inherent beneath the deformed Permian rocks. An alternative structural explanation may be found in a complex of fault intersections but faults of this magnitude would surely have been detected by continuous seismic survey immediately around Mount Toondina. Either theory would be tested effectively only by drilling.

ACKNOWLEDGMENTS

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The author is indebted to colleagues at the Geological Survey of South Australia who have contributed in various ways to this investigation. Special thanks are due to Mr. K. A. Rochow for his supervision of shallow drilling and the field logging of samples, and to Mr. G. R. Heath for co-operation with section measurement. Criticism of the manuscript has been made by Dr. H. Wopfner, Dr. B. C. Forbes and Mr. K. A. Rochow. The drafting of figures was ably done by Mr. F. Barrett.

The author is indebted also to the French Petroleum Company (Aust.) Pty. Ltd. in kindly providing palynological information.

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APPENDIX A.

Analyses of Permian Coals from Mt. Toondina and Lake Phillipson Bore

Sample No. (A.M.D.L.)		Ash %	Fixed Carbon %	Volatile Matter %	Moisture %	Sulphur %	Calorific Value B.T.U./lb.
A 503/62	(1)	42·94	13·91	29·96	13·19	2·54	3605
Unit 6	(2)	43·53	14·10	30·37	12·00	2·57	3655
A 504/62	(1)	37·54	19·56	29·45	13·45	2·14	4175
Unit 8	(2)	38·17	19·89	29·94	12·00	2·18	4245
A 505/62	(1)	41·53	14·01	32·39	12·07	2·91	4045
Unit 10	(2)	41·57	14·02	32·41	12·00	2·91	4050
A 506/62	(1)	46·03	14·19	29·60	10·18	2·48	3430
Unit 16	(2)	45·10	13·90	29·00	12·00	2·43	3360
A 507/62	(1)	42·87	14·96	31·17	11·00	1·92	3705
Unit 18	(2)	42·39	14·79	30·82	12·00	1·90	3665
Lake Phillipson 310′ 11″ 312′ 10″	(3)	18·54	11·64	61·00	8·82	—	—
Lake Phillipson 377′ 10″ 393′ 2″	(3)	6·38	33·12	39·48	21·02	—	—

(1) denotes sample "as received"

(2) denotes 12% moisture basis

(3) data from Brown (1905)

N.B.—Mount Toondina samples are from weathered outcrop

Analyses by Australian Mineral Development Laboratories

EXPLANATION OF PLATES

PLATE I.

Stereoscopic pair of aerial photographs of Mount Toondina, spaced for standard pocket stereoscope.

PLATE II

Fig. 1. Mount Toondina capping of limestone and gypsite overlying with strong unconformity steeply dipping Mount Toondina Beds. View to south-west.

Fig. 2. North-eastern slope below Mount Toondina capping, showing undulating (? deformed) base of Cainozoic deposits. Dark rocks are Permian coal seams.

PLATE III

Permian plant fossils from the Mount Toondina Beds. Preservation of all specimens is poor.

(a) Equisitalian stem impression. (x 2.)

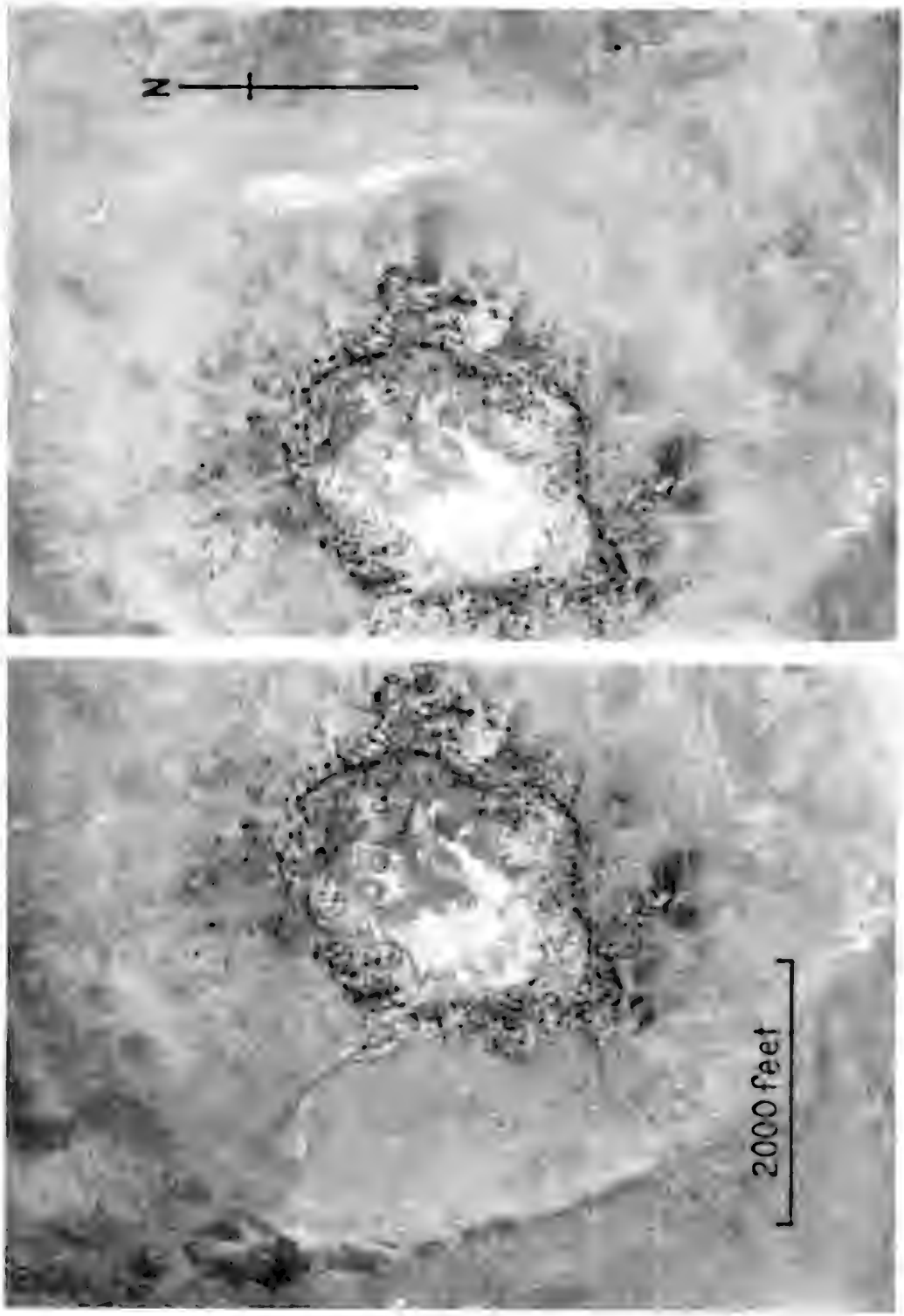
(b) *Cordaites sp.*, fragmented. (x $\frac{3}{4}$.)

(c) *Gangamopteris sp.* (x 2.)

(d) *Glossopteris indica*, impression. (x $\frac{1}{2}$.)

(e) *Glossopteris indica*, impression showing more detailed venation. (x $\frac{3}{2}$.)

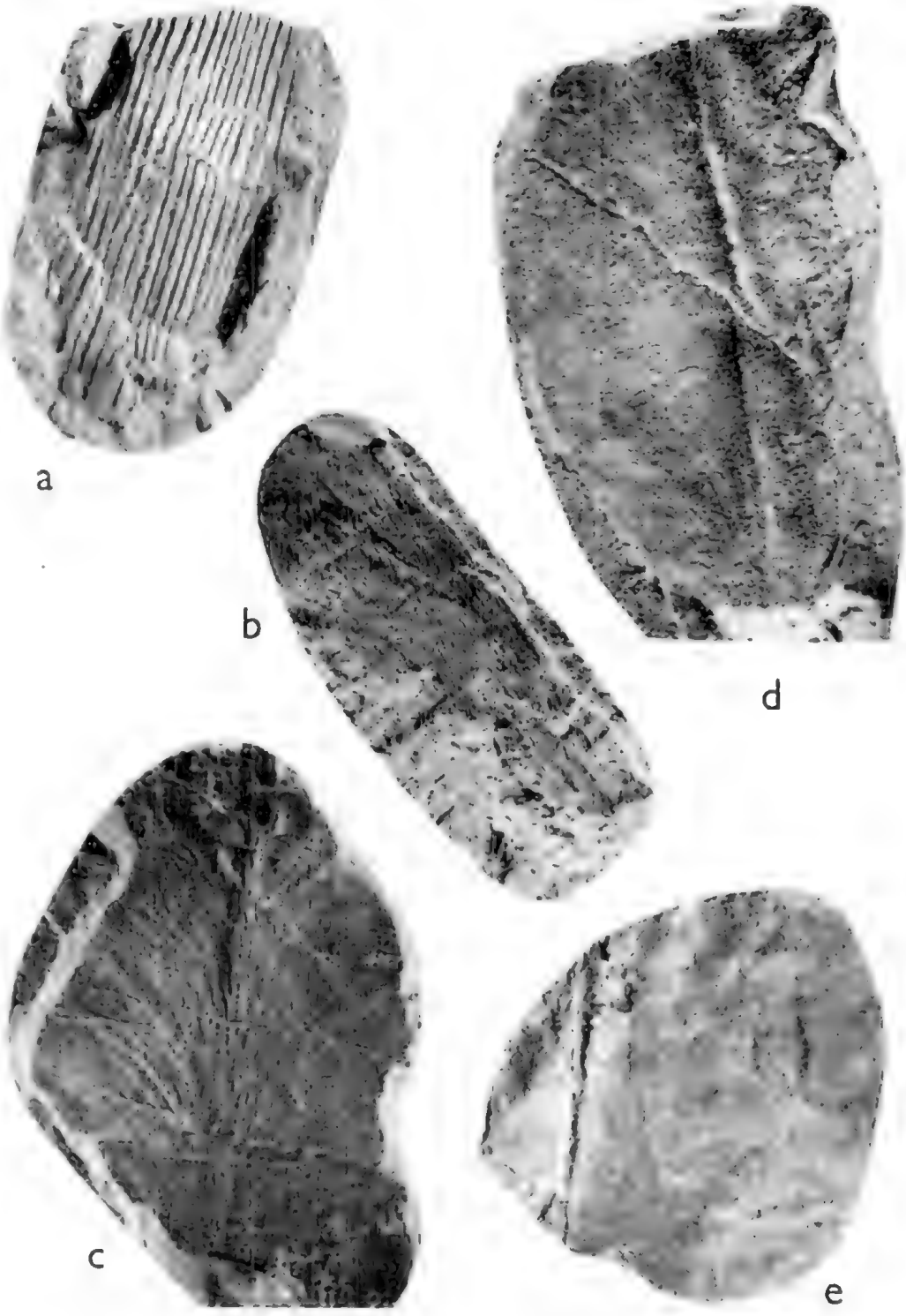
Determinations by W. K. Harris, Palynologist, Geological Survey of South Australia.



(*S.A. Lands Dept. Survey*)

(Author's photo)

(Author's photo)



(Photography by Palaeontology Section)

REVISION OF THE TATE MOLLUSC TYPES – PART 3
LIMOPSIDAE, GLYCYMERIDAE, ARCIDAE, CUCULLAEIDAE

BY N. H. LUDBROOK

Summary

Twenty-nine species of Tertiary mollusca in the Tate Collection of the Geology Department, University of Adelaide, have been redescribed. All but five of the species have restricted time-ranges, there being a significant difference both at the generic and specific level between Upper Eocene species and those of mid and late Tertiary age.

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by N. H. Ludbrook*

[Read 10 June 1965]

SUMMARY.

Twenty-nine species of Tertiary mollusca in the Tate Collection of the Geology Department, University of Adelaide, have been redescribed. All but five of the species have restricted time-ranges, there being a significant difference both at the generic and specific level between Upper Eocene species and those of mid and late Tertiary age.

INTRODUCTION.

The paper is the third of the series in which the Tertiary mollusca in the Tate type collection in the Geology Department of the University of Adelaide are redescribed. These include all of Tate's primary types and mounted specimens to which he referred without necessarily figuring them. Where the holotypes are located elsewhere the following abbreviations have been used for their repositories:

N.M.V.	National Museum of Victoria, Melbourne.
M.U.G.D.	Melbourne University Geology Department.
Tas. Mus.	Tasmanian Museum, Hobart.

In determining the stratigraphic range of the species belonging to the four taxodont families only the specimens mounted in the Tate Collection have been taken into consideration. Where it has been possible to confirm the type locality from material available in the collection of the Geological Survey of South Australia, this has been done.

The time ranges of the species are tabulated in Table 1. No stage name has been used for the Upper Eocene, since two names, "Johannian" and "Aldingan" have been used in recent publications for the same microfaunal units of the Upper Eocene. The name "Yatalan" is included to designate the Pliocene fauna of the Dry Creek Sands underlying the Adelaide Plains (Ludbrook, 1963, p. 13).

The composition of both the Eocene and Miocene faunas is essentially that of warmer waters. *Arca*, *Cucullaearca* and *Cucullaea* are represented only in tropical faunas of the present day.

* Geological Survey of South Australia; published with the permission of the Director of Mines.

TABLE 1.

	Upper Eocene	Upper Oligocene	Miocene								Pliocene	
	Upper Eocene	Janjukian	Longfordian	Batesfordian	Balcombian	Bairnsdalian	Mitchellian	Cheltenhamian	Kalimnan	Yatalan		
LIMOPSIDAE												
Limopsis beaumariensis												
Limopsis chapmani												
Limopsis maccoyi												
Limopsis morningtonensis												
Limopsis multiradiata												
GLYCYMERIDAE												
Glycymeris (Glycymeris) cainozoica												
Glycymeris (Glycymeris) halli												
Glycymeris (Grandaxinea) granti												
Glycymeris (Grandaxinea) maccoyi												
Glycymeris (Grandaxinea) ornithopetra												
Glycymeris (Tucetona) convexa												
Glycymeris (Tucetona) decurrens												
Glycymeris (Tucetona) gunyoungensis												
Glycymeris (Tucetona) lenticularis												
Glycymeris (Tucetona) subtrigonalis												
ARCIDAE												
Arca capulopsis												
Arca pseudonavicularis												
Arcopsis dissimilis												
Barbatia (Barbatia) consutilis												
Barbatia (Barbatia) limatella												
Barbatia (Barbatia) pumila												
Barbatia (Acar) celleporacea												
Barbatia (Acar) crustata												
Barbatia (Acar) simulans												
Barbatia (Cucullacarca) equidens												
Barbatia (Plagiarca) cainozoica												
Anadara interclathrata												
CUCULLAEIDAE												
Cucullaea adelaidensis												
Cucullaea corioensis												

Family LIMOPSIDAE

Genus LIMOPSIS Sassi, 1827

Limopsis beaumariensis Chapman

(pl. 1, figs. 10, 14, 15, 16)

1875. *Limopsis belcheri* McCoy, Prod. Pal. Vict., dec. 2, 26 (in part).

1911. *Limopsis beaumariensis* Chapman, Proc. Roy. Soc. Vict., 23 (2), 423, pl. 84, fig. 6; pl. 85, fig. 12.

1955. *Limopsis beaumariensis*; Ludbrook, Trans. Roy. Soc. S. Aust., 78, 23, pl. 5, fig. 7.

Description. Shell subtrigonal, about as high as long, subequilateral, thick, moderately convex; umbo central, small, acute, incurved; dorsal margin short and slightly curved, both anterior and posterior margins gently curved, ventral margin curved; hinge line arched, with 7-9 posterior and 7-9 anterior teeth, ligamental area relatively short and narrow, ligament pit large and triangular; ornament of conspicuous slightly undulating primary riblets crossed and cancellated by concentric growth lines, in the juvenile stage the radials and concentrics are approximately equal, but in the later stages the concentrics are stronger than the radials; inner margin smooth, slightly concave; anterior adductor high and small, posterior adductor a little lower than the anterior, broadly ovate; pallial line entire, interior of shell inside the pallial line conspicuously radially striate.

Dimensions. Topotype T1023G length 21, height 22 mm.

Types. Holotype N.M.V. P12583; hypotypes A.U.G.D. T1023G, H (topotypes), T1030A, B.

Material. The species is represented in the Tate Collection by two specimens G and H from Cheltenham on tablet T1023, the other specimens on the tablet being *L. maccoyi*, and 7 specimens from "Gippsland Lakes" on T1030. Both tablets are labelled "*Limopsis belcheri* Adams & Reeve".

Type Locality. Beaumaris, Victoria (Cheltenhamian).

Stratigraphic Range. Cheltenhamian (Upper Miocene)* and Pliocene.

Limopsis chapmani Singleton

(pl. 1, figs. 1-9)

1875. *Limopsis aurita* McCoy, Prod. Pal. Vic., dec. 2, 23 (pars); pl. 19, figs. 5, 6, 6a-b, 7, *non Arca aurita* Brocchi.

1885. *Limopsis aurita* Tate, Pap. Proc. Roy. Soc. Tas. for 1884, 212 (*non* Brocchi).

1886. *Limopsis insolita* Tate, Trans. Roy. Soc. S. Aust., 8, 134, *non Trigonocoelia insolita* Sowerby.

1886. *Limopsis aurita* Tate, ibid. (*pars*) (*non* Brocchi).

1888. *Limopsis aurita* Johnston, Geol. Tas., pl. 32, fig. 7.

1897. *Limopsis insolita* Harris, Cat. Tert. Moll. Brit. Mus. 344 (*non* Sowerby).

1911. *Limopsis insolita* Chapman, Proc. Roy. Soc. Vict., 23 (2), 425-429, pl. 84, fig. 5; pl. 85, fig. 11.

1932. *Limopsis chapmani* Singleton, Proc. Roy. Soc. Vict., 44 (2), 296, pl. 24, figs. 12-14; pl. 25, fig. 16.

Description. Shell thick, obliquely ovate, inequilateral, convex, particularly near the umbo; umbo situated a little to the anterior, small, acute, incurved; dorsal margin curved, slightly shouldered, anterior and ventral margins rounded,

* Present opinion is that the Cheltenhamian is of Pliocene rather than Upper Miocene age.

posterior margin only slightly arcuate and a little produced ventrally, slightly concave below the hinge line in topotypes; hinge line arched, high, with 8 anterior and 8 posterior teeth, the anterior teeth usually more or less erect, straight and narrow, the posterior teeth short, wide and hooked; ligamental area long and high, ligament pit large, prominent, broadly triangular, with concave sides, encroaching on the hinge teeth. Ornament of numerous concentric growth lamellae, imbricating towards the ventral margin; between the ridges are fine, weak, irregular radiating grooves; inner margin smooth, broadly flattened; anterior adductor high, small, narrowly ovate, posterior adductor low, broad, somewhat quadrately ovate; pallial line entire, conspicuous, interior of shell inside the pallial line radially striate.

Dimensions. Topotype T1022A length 18, height 20, inflation (both valves) 11 mm.; T1032B length 28, height 30, inflation (both valves) 18 mm.

Types. Holotype M.U.G.D. 1317, paratypes M.U.G.D. 1318-9. Hypotypes A.U.G.D. T1022A, T1022E, T1025B, T1025C, T1025E, T1025H, T1032B, T1032C.

Material. The species is represented in the Tate Collection by three tablets: T1022, with 13 mounted specimens A-M in a growth series, labelled "*Limopsis insolita* G. B. Sowerby. Eocene, Spring Creek". These are topotypes of Singleton's species from Jan Juc Formation, Bird Rock Cliffs near Spring Creek, Torquay, Victoria; T1025, with 19 mounted specimens A-R, labelled "*Limopsis insolita* Sow. Eocene Aldinga; Adelaide". The large specimens A-D (28 x 30 mm.) in the top row appear to be from the *Limopsis* bed at the top of the Blanche Point Marls, Aldinga Bay; other smaller specimens have the matrix of the "glauconitic greensands of the Adelaide Bore", i.e. the Upper Eocene greensands at a depth of 150-218 feet in Engineering and Water Supply Department Bore at Kent Town, Adelaide; T1032, with 10 specimens A-J in a growth series, labelled "*Limopsis insolita* Sowerby, Miocene? Aldinga Cliffs". The locality is presumably the *Limopsis* bed at the top of the Blanche Point Marls, Aldinga Bay.

Type Locality. Bird Rock Cliffs near Spring Creek, Torquay, Victoria: Jan Juc Formation, Oligocene.

Stratigraphic Range. Upper Eocene to Oligocene.

Limopsis maccoyi Chapman

(pl. 1, figs. 17-22)

1875. *Limopsis belcheri* McCoy, Prod. Pal. Vict., dec. 2, 25, pl. 19, figs. 8, 9 (*non* Adams and Reeve) (in part).

1886. *Limopsis belcheri* Tate, Trans. Roy. Soc. S. Aust., 8, 134 (*non* Adams and Reeve) (in part).

1911. *Limopsis maccoyi* Chapman, Proc. Roy. Soc. Vict., 23 (2), 421, pl. 83, fig. 2; pl. 85, fig. 8.

1955. *Limopsis maccoyi*; Ludbrook, Trans. Roy. Soc. S. Aust., 78, 24, pl. 1, fig. 10.

Description. Shell subtrigonal, obliquely ovate, moderately convex, umbo slightly to the anterior, small, acute, incurved; dorsal margin slightly curved, anterior and posterior margins curved, the posterior margin produced towards the ventral margin, ventral margin gently curved; hinge line arched, with as

many as 11 teeth on each side, teeth strong and high, slightly hooked; ligamental area small and broadly subtriangular, ligament pit large and deep; ornament of numerous narrow radial riblets with secondary riblets intercalating between them, crossed by less prominent concentric undulating ridges. Inner margin smooth, bevelled, and bounded on the inner side by a fine narrow ridge extending as far as the hinge on both sides; anterior adductor high, elongate-ovate, posterior adductor low and broadly ovate; pallial line entire, interior of shell inside the pallial line conspicuously radially striate.

Dimensions. T1023A length 20, height 19·5; T1023K length 20·5, height 18·5; T1027A length 18, height 20 mm.

Types. Lectotype (here designated) N.M.V. P12376, the specimen figured by McCoy pl. 19, fig. 8; syntypes N.M.V. P12377 (McCoy pl. 19, fig. 9), P12579, P12580, P12581 (figured Chapman pl. 83, fig. 2). No holotype was designated by Chapman, nor did he consider it necessary to redescribe the species described and figured by McCoy as *Limopsis belcheri* (Adams and Reeve). The two specimens from Balcombe Bay P12376, P12377, figured by McCoy, and the three P12579, P12580 (Grice's Creek) and P12581 (Gellibrand River) figured by Chapman, form the type series from which P12376 is selected as lectotype and Balcombe Bay designated type locality. Tate Collection hypotypes are T1023A, T1023C, T1023D, T1023K, T1027A, T1027E.

Material. The species is represented in the Tate Collection on two tablets T1023 and T1027. T1023 has 28 mounted specimens A-F from Muddy Creek, I-J from Camperdown, K-L, T-W from Gellibrand River, M-O, X-Z, a-b from Spring Creek, O-R from Mornington, S from Fyansford. G and H from Cheltenham are *Limopsis beaumariensis*; T1027 has 16 specimens A-P, all from "River Murray Cliffs", i.e. Cadell Marl Lens, Morgan.

Type Locality. Balcombe Bay, Balcombe Clay, Balcombian.

Stratigraphic Range. Jan Juc Formation to Dry Creek Sands; ?Upper Oligocene to Upper Pliocene.

Limopsis morningtonensis Pritchard

(pl. 1, figs. 11, 12, 13)

1875. *Limopsis aurita* McCoy, Prod. Pal. Vict., dec. 2, 23 (pars) (*non Area aurita* Brocchi).

1886. *Limopsis aurita* Tate, Trans. Roy. Soc. S. Aust., 8, 134 (pars) (*non* Brocchi).

1901. *Limopsis morningtonensis* Pritchard, Proc. Roy. Soc. Vict., 14 (1), 24, pl. 2, figs. 6, 6a.

1911. *Limopsis morningtonensis*; Chapman, Proc. Roy. Soc. Vict., 23 (2), 420, pl. 83, fig. 1; pl. 85, fig. 7.

Description. Shell of moderate size, roundly quadrate, depressed, slightly oblique; umbo situated slightly to the anterior, small, prominent, acute, and incurved; anterior margin convexly rounded, posterior margin gently rounded with a tendency to angulation at the dorsal and ventral borders; slightly produced posteriorly. Hinge line straight or very slightly curved, half the length of the shell, ligamental area fairly long, ligament pit conspicuous; 5 to 9 anterior and 4 to 7 posterior teeth of unequal size. Ornament of strong flat concentric ridges of unequal strength, the ridges crossed by fine radial striations; inner margin smooth, broadly flattened.

Dimensions. T1020A (topotype) length 15·5, height 15 mm.; T1021A (Muddy Creek) length 19·5, height 18·5 mm.

Types. Holotype M.U.G.D. 1778; topotypes A.U.G.D. T1020 A-D; hypotypes T1020A, T1021A.

Material. There are two tablets in the Tate Collection: T1020 with 4 specimens (A-D) from "Eocene, Gellibrand River", the fifth specimen T1020E is *Limopsis chapmani* from Table Cape; T1021 with 9 specimens (A-I) in a growth series from Muddy Creek.

Type Locality. Gellibrand Marl, coast section below Curdie's Steps, Bairnsdalian.

Stratigraphic Range. Miocene, Batesfordian to Bairnsdalian.

Limopsis multiradiata Tate

(pl. 1, figs. 23-27)

1886. *Limopsis multiradiata* Tate, Trans. Roy. Soc. S. Aust., 8, 135, pl. 12, figs. 1a-b.

1897. *Limopsis multiradiata*: Harris, Cat. Tert. Moll. Brit. Mus., 1, 346.

1911. *Limopsis multiradiata*: Chapman, Proc. Roy. Soc. Vict., 23 (2), 423, pl. 84, fig. 4; pl. 85, fig. 10.

Description. Shell suborbicular, slightly inequilateral and oblique, thick, moderately convex; umbones situated slightly to the anterior, prominent, incurved; shell slightly shouldered; anterior, posterior and ventral margins gently rounded, the posterior-ventral margin slightly produced; hinge line arched, fairly long, high, with 7 hooked teeth on each side; ligamental area long and conspicuous, concave; ligament pit large, equilateral, moderately deep with concentric striations. Juvenile shell smooth but for concentric ribs and very faint radials, adult shell ornamented with numerous fine bifurcating radial riblets broken by crenulated concentric growth lamellae producing a conspicuously tessellated surface; inner margin smooth, flattened; anterior adductor high, small, ovate; posterior adductor low, broadly ovate, pallial line inconspicuous.

Dimensions. A.U.G.D. T1031A length 10·5, height 9·5 mm.

Types. The type series T1031 consists of 17 specimens mounted in a growth series; T1031A is the holotype; a right valve which in Tate's figure pl. 12, fig. 1 has been reversed.

Material. Tablet T1031 only.

Type Locality. "Adelaide Bore", i.e. bore at Engineering and Water Supply Department, Kent Town, at 150-218 feet depth.

Stratigraphic Range. Upper Eocene (lower part).

Observations. The species also occurs in the Upper Eocene Blanche Point Marls of Aldinga Bay and in glauconitic sands at 75-80 feet depth at Adelaide Children's Hospital, North Adelaide, 1 mile from the type locality. The species occurs at a lower level than *L. chapmani*.

Family GLYCYMERIDAE

Genus GLYCYMERIS Da Costa, 1778

Subgenus GLYCYMERIS s.str.

Glycymeris (Glycymeris) cainozoica (Tenison Woods)

(pl. 1, figs. 28-34)

1877. *Cucullaea cainozoica* Tenison Woods, Pap. Roy. Soc. Tas. for 1876, 111.

1886. *Pectunculus cainozoicus*; Tate, Trans. Roy. Soc. S. Aust., 8, 136, pl. 10, figs. 8a, 8b; p. 137 (in part).

1888. *Pectunculus cainozoicus*; Johnston, Geol. Tas., pl. 31, figs. 13, 13a, b.

1897. *Pectunculus cainozoicus*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 340 (? in part).

Description. Shell large, roundly trigonal to orbicular, solid, slightly oblique, globose, subequilateral, a little longer than high; umbones central, prominent, inflated, finely radially ribbed, strongly incurved, slightly overhanging the ligamental area; ligamental area of moderate size, arched, broad, with six grooves on each side; hinge area long, gently arched, with as many as 13 teeth on each side but usually encroached upon by the ligamental area; anterior adductor subovate, posterior adductor ovate with a ridge on the anterior side; inner margin finely denticulate, the denticulations sometimes smooth, but marked with fine closely spaced radial striae and fine concentric growth striae.

Dimensions. Topotype, T1055Q, length 33, height 31, inflation (one valve) 12 mm.

Types. Holotype Tas. Mus. Z204A, paratype Z204B. The type tablet in the Tate Collection contains 19 specimens T1055 A-W, T1055C was figured by Tate and T1055B and C by Chapman and Singleton. T1055A-H, K-P are from Muddy Creek without any indication of whether from the lower (Muddy Creek Marl) or upper (Grange Burn Coquina) beds. T1055H, K-P are *Glycymeris halli* indistinguishable from topotypes collected by the writer from the Grange Burn Coquina. T1055J is from "Spring Creek", T1055 Q-T from Table Cape, and T, U-W from "Adelaide" (i.e. Kent Town Bore).

Material. The type tablet and tablet T1068 with specimens A-E from Cheltenham, Victoria, and F from Camperdown.

Type Locality. Table Cape, Tasmania; Freestone Cove Sandstone of Table Cape Group, Longfordian.

Stratigraphic Range. Upper Eocene to Upper Miocene. The oldest known occurrence of the species is in the Upper Eocene of Kent Town Bore, Adelaide, its youngest occurrence is in the Cheltenhamian of Beaumaris and also of the Bookpurnong Beds at their type locality, Loxton.

Glycymeris (Glycymeris) halli Pritchard

(pl. 1, figs. 35-36)

1886. *Pectunculus cainozoicus*, Tate, Trans. Roy. Soc. S. Aust., 8, 137 (in part), *non* Tenison Woods.

1897. *Pectunculus cainozoicus*, Harris, Cat. Tert. Moll. Brit. Mus., 1, p. 340 (in part), *non* Tenison Woods.

1903. *Glycymeris halli* Pritchard, Proc. Roy. Soc. Vict., 15 (2), 89, pl. 14, figs. 10-12; pl. 15, figs. 1, 2, 8, 9.

1925. *Glycymeris halli*; Chapman and Singleton, Proc. Roy. Soc. Vict., 37 (1), 40, pl. 3, fig. 23; pl. 4, fig. 15.

Description. Shell of moderate size, orbicular, tumid, thick, solid, equilateral; about as long as high; umbones central, tumid, incurved, overhanging the ligamental area; ligamental area small, short and very weakly grooved; hinge line long, gently curved, with about 12 teeth on each side; anterior adductor ovate, posterior adductor quadrately ovate; inner margin with numerous fine denticles. Surface ornamented with as many as 50 low slightly convex radial riblets with linear interspaces, each riblet finely radially striate; radial sculpture crossed by undulating growth folds.

Dimensions. T1055H length 23, height 22, inflation (both valves) 17 mm.

Types. Holotype M.U.G.D. 1783. On Tate's tablet T1055 labelled "*Pecten culus cainozoicus* T. Woods sp. Muddy Creek, (1) Table Cape, (2) Adelaide, (3) Spring Creek", specimens H, K-P are regarded as topotypes of *Glycymeris halli* from the upper beds at Muddy Creek (Grange Burn Coquina).

Material. T1055H, T1055K-P, which have been compared with topotypes in the G.S.S.A. Collection.

Type Locality. Grange Burn, between Forsyth's and Henty's, Grange Burn Coquina.

Stratigraphic Range. Kalimnan (Lower Pliocene).

Subgenus Grandaxinea Iredale, 1931

Glycymeris (Grandaxinea) granti Singleton

(pl. 2, figs, 3, 6)

1932. *Glycymeris (Grandaxinea) granti* Singleton, Proc. Roy. Soc. Vict., 44 (2), 294, pl. 24, figs. 10, 11.

Description. Shell large but not heavy, about as high as long, suborbicular tending to become irregularly orbicular in the adult; umbo subcentral, incurved, small; ligamental area relatively long and narrow, with 10 striae on each side, hinge line nearly straight in the middle but strongly arched at each end, with 5 or 6 anterior and 9 posterior teeth, scarcely curved and rather low and broad; anterior adductor subtrigonal, posterior adductor subovate, the shell within the pallial line and between the adductor scars excavate; inner margin nearly flat, weakly denticulate with about 20 denticles which become obsolete on either side. Surface ornamented with 33 to 37 radial costae crossed by concentric growth striae which are weaker on the ribs than in the interspaces, the costae tend to be angulate on the side and flattened in the middle appearing dichotomous when the shell is wet; ribbing on the anterior and posterior rather flattened dorsal areas discrepant with narrow ribs and wider interspaces particularly on the dorsal side.

Dimensions. T1071D length 53, height 53 mm.

Types. Holotype M.U.G.D. 1315, paratype M.U.G.D. 1316; hypotype Tate Collection T1071D.

Material. Tate's tablet T1071 labelled "*Pectunculus laticostatus* Quoy and Gaimard, Eocene, (1) Bird Rock Bluff; Muddy Creek", contains 3 specimens B, D and E from Muddy Creek, all of which may be identified as *G. (G.) granti.*

Type Locality. Muddy Creek, Hamilton, Victoria; Muddy Creek Marl, Balcombian to Bairnsdalian.

Stratigraphic Range. Balcombian to Bairnsdalian, Miocene.

Observations. The three species *G. (G.) granti, G. (G.) maccoyi* and *G. (G.) ornithopetra* are very difficult to separate. The fewer ribs (29 to 31), orbicular and more convex shape, and inconspicuous dorsal areas distinguish *maccoyi; ornithopetra* has 32 to 40 ribs which become narrow and more widely spaced on a posterior-dorsal area; *granti* has a broader hinge line, flattened dorsal areas, and more angulate ribs. Most of these differences could be attributed to ecological conditions. The lineage described by Singleton (1932, 295) should be reversed, the stratigraphic order being from Janjukian (Upper Oligocene) to Balcombian (Lower Miocene): *ornithopetra–maccoyi–granti.*

Glycymeris (Grandaxinea) maccoyi (Johnston)

(pl. 3, fig. 1)

1880. *Pectunculus MacCoyii* Johnston, Pap. Roy. Soc. Tas. for 1879, 41.

1885. *Pectunculus MacCoyi* Johnston, Pap. Roy. Soc. Tas. for 1884, 199, 200.

1886. *Pectunculus McCoyii*; Tate, Trans. Roy. Soc. S. Aust., 8, 137.

1897. *Pectunculus laticostatus*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 341 (in part).

1914. *Glycimeris maccoyi*; Chapman and Gabriel, Proc. Roy. Soc. Vict., 26 (2), 303, pl. 24, fig. 4 (*non* 1-3, 5).

1916. *Glycimeris maccoyi*; Chapman, Rec. Geol. Surv. Vict., 3 (4), pl. 67, fig. 4 (*non* 1-3, 5).

1925. *Glycymeris maccoyi*; Chapman and Singleton, Proc. Roy. Soc. Vict., 37 (1), 27, pl. 1, figs. 7a, 7b; pl. 4, fig. 5.

Description. Shell large, orbicular, convex, about as high as long, equilateral; dorsal margin short, slightly curved; anterior, posterior and ventral margins evenly curved; umbo central, small; ligamental area relatively long with about 8 striae on each side, hinge line fairly long and broadly arched with 8 teeth on each side; anterior adductor large, reniform; posterior adductor subtrigonal and ridged on the inner margin: pallial line entire, inner margin of shell flattened with 20 broad denticulations between the external radial ribs. Surface ornamented with 29 to 31 radial convex ribs separated by narrow interspaces, weaker and somewhat more widely separated on the anterior and posterior dorsal area, but without any discrepancy between the anterior and posterior.

Dimensions. T1066A. length 42, height 42 mm.

Types. Neotype N.M.V. 13326; hypotype (topotype) T1066A.

Material. Of the two specimens mounted on Tate's tablet T1066, labelled "*Pectunculus McCoyii* R. M. Johnston, Eocene, Table Cape Tasmania" only specimen A is considered to be *Glycymeris maccoyi*, as redefined by Chapman and Singleton. T1066B is *Glycymeris ornithopetra* with discrepant ornament between the anterior and posterior dorsal areas.

Type Locality. Table Cape, Tasmania; Table Cape Group, Freestone Cove Sandstone, Longfordian.

Stratigraphic Range. Lower Longfordian (Lower Miocene).

Glycymeris (Grandaxinea) ornithopetra Chapman and Singleton

(pl. 2, figs. 1, 2, 4, 5; pl. 3, fig. 14)

1875. *Pectunculus laticostatus* McCoy: Prod. Pal. Vict., dec. 2, 26-27, pl. 19, figs. 10, 11, 14 (numbered 9 in error on plate (*non* 12, 13)); (*non* Quoy and Gaimard).

1886. *Pectunculus laticostatus* Tate, Trans. Roy. Soc. S. Aust., 8, 137 (in part) (*non* Quoy and Gaimard).

1888. *Pectunculus McCoyi* Johnston, Geol. Tas., pl. 31, figs. 1, 1a, 1b (*non* 1c, 1d) (*non* Johnston, 1885).

1914. *Glycimeris maccoyi*; Chapman and Gabriel, Proc. Roy. Soc. Vict., 26 (2), 303, 304, pl. 24, figs. 2, 3 (*non* 1, 4, 5)

1925. *Glycymeris ornithopetra* Chapman and Singleton, Proc. Roy. Soc. Vict., 37 (1), 32, pl. 2, figs. 9a, 9b; pl. 4, fig. 7.

Description. Shell large, thick, convex, about as high as long, suborbicular but tending to become irregularly orbicular in the gerontic stage with the ventral margin tending to be produced on the umbonal-ventral axis and the posterior margin to become angulate; umbo subcentral, incurved, small; ligamental area short and high, with as many as 14 striae on each side; hinge broadly arched, encroached upon by the ligamental area, leaving about 8 arched teeth on each side. Anterior adductor pyriform, posterior adductor roundly quadrate, pallial line entire, inner margin of shell bevelled, with 24-28 denticulations corresponding to the intercostal spaces. Surface ornamented with from 32 to 40 radial costae crossed by concentric growth striae becoming more conspicuous and lamellose towards the ventral border; the radials are discrepant on the posterior-dorsal triangular area in which they are narrower and tending to become obsolete, the interspaces becoming correspondingly wider.

Dimensions. T1070A length 73, height 70 mm.

Types. Holotype N.M.V. 12465; hypotypes Tate Coll. T1066B, T1070A, T1071A, C.

Material. The species is represented on three tablets in the Tate Collection: T1066 labelled "*Pectunculus McCoyii* R. M. Johnston Eocene, Table Cape, Tasmania", on which specimen B is *G.* (*G.*) *ornithopetra*. T1070 labelled "*Pectunculus laticostatus* Quoy and Gaimard, Eocene, Spring Creek", with 9 specimens A-I, all topotypes. T1071 labelled "*Pectunculus laticostatus* Quoy and Gaimard. Eocene (1) Bird Rock Bluff; Muddy Creek". Two specimens A and C are from Bird Rock.

Type Locality. Bird Rock, Torquay, Victoria; Jan Juc Formation.

Stratigraphic Range. Janjukian to Longfordian, Upper Oligocene and Lower Miocene.

Subgenus Tucetona Iredale, 1931

Glycymeris (Tucetona) convexa (Tate)

(pl. 3, figs. 15-20)

1886. *Pectunculus convexus* Tate, Trans. Roy. Soc. S. Aust., 8, 138, pl. 11, figs. 7a, b.

1897. *Pectunculus convexus*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 342.

1914. *Glycimeris maccoyi* Chapman and Gabriel, Proc. Roy. Soc. Vict., 26 (2), 304, pl. 24, fig. 5 (*non* 1-4), *non* Johnston.

1916. *Glycimeris maccoyi* Chapman, Rec. Geol. Surv. Vict., 3 (4), pl. 67, fig. 5 (*non* 1–4), *non* Johnston.

1925. *Glycymeris concexa*; Chapman and Singleton, Proc. Roy. Soc. Vict., 37 (1), 38, pl. 2, figs. 16a, 16b, 17-20; pl. 4, figs. 12, 13.

1947. *Tucetona crama* Cotton, Rec. S. Aust. Mus., 8 (4), 660, pl. 20, figs. 1, 2.

1955. *Glycymeris* (*Tucetona*) *concexa*; Ludbrook, Trans. Roy. Soc. S. Aust., 78, 26.

Description. Shell large for the subgenus, thick, tumid, suborbicular, subequilateral, about as long as high; umbones central, approximate, incurved; ligamental area small, with 5 striae on each side, hinge area wide, strongly arcuate, with about 10 teeth on each side; anterior adductor subovate, posterior adductor subquadrate with a slight ridge on the anterior side below which the shell is excavate; inner margin bevelled, strongly denticulate with 20 intercostal denticulations; surface strongly ornamented with 22 to 24 rounded elevated costae equal to the concave interspaces, ribs and interspaces crossed by close set concentric growth striae; the ornament is weaker on the anterior and posterior dorsal areas.

Dimensions. Holotype, T1017C, length 33, height 31, inflation (one valve) 11 mm.

Types. Tate's type series T1017A-R mounted on a single tablet contains the holotype T1017C and 15 paratypes, all from "Muddy Creek" (upper beds).

Material. In addition to the type series, there is a tablet T1010 A-F with six well-preserved and typical specimens from "Cooke's Plains, 90-mile desert". The exact locality and formation from which these were obtained is at present uncertain.

Type Locality. Grange Burn Coquina, Muddy Creek, near Hamilton, Victoria; Kalimnan.

Stratigraphic Range. Kalimnan and Yatalan. In South Australia the species is present in the Pliocene generally: Norwest Bend Formation, Hallett Cove Sandstone and Dry Creek Sands.

Glycymeris (Tucetona) decurrens Chapman and Singleton

(pl. 3, figs. 9-10)

1925. *Glycymeris decurrens* Chapman and Singleton, Proc. Roy. Soc. Vict., 37 (1), 42, pl. 3, figs. 24a, 25b, 25a, 25b; pl. 4, fig. 16.

Description. Shell small, rather thin, subtrigonal to suborbicular, moderately depressed, equilateral, about as long as high; umbones very small, central, acute, opisthogyrous; ligamental area very small, hinge area deeply arcuate, with about 13 strong teeth on each side; anterior adductor ovate, posterior adductor roundly quadrate with a ridge on the anterior side; inner margin bevelled, with about 20 strong denticulations; surface ornamented with about 31 radial costae of even strength over the whole shell, somewhat flattened, crossed by regular concentric lines, more conspicuous in the interspaces than on the ribs.

Dimensions. T1065A, length 13·5, height 13·5 mm.

Types. Holotype N.M.V. 13332, paratype N.M.V. 13333; the two Tate Collection hypotypes T1065A, B.

Material. Tablet T1065, labelled "*Pectunculus McCoyii* R. M. Johnston, Miocene, Gippsland", has 2 left valves both juveniles. They are conspecific with topotypes from Muddy Creek and presumably came from Jemmy's Point Formation from which Chapman and Singleton (p. 43) recorded the species.

Type Locality. Forsyth's, Grange Burn, near Hamilton, Victoria; Grange Burn Coquina, Kalimnan.

Stratigraphic Range. Kalimnan, Lower Pliocene.

Glycymeris (Tucetona) gunyoungensis Chapman and Singleton

(pl. 3, figs. 5-8)

1875. *Pectunculus laticostatus* McCoy, Prod. Pal. Vict., dec. 2, 26, 27, pl. 19, figs. 12, 13 (*non* 9, 10, 10a, 11) (*non* Quoy and Gaimard).

1886. *Pectunculus laticostatus* Tate, Trans. Roy. Soc. S. Aust., 8, 137 (in part) (*non* Quoy and Gaimard).

1886. *Pectunculus McCoyii* Tate, ibid. (in part) (*non* Johnston).

1888. *Pectunculus McCoyi* Johnston, Geol. Tas., pl. 31, figs. 1c, 1d (*non* 1, 1a, 1b); *non* Johnston, 1885.

1897. *Pectunculus laticostatus* Harris, Cat. Tert. Moll. Brit. Mus., 1, 341 (in part) (*non* Quoy and Gaimard).

1914. *Glycimeris maccoyi* Chapman and Gabriel, Proc. Roy. Soc. Vict., 26 (2), 303, 304, pl. 24, fig. 1 (*non* 2-5); *non* Johnston.

1916. *Glycimeris maccoyi* Chapman, Rec. Geol. Surv. Vict., 3 (4), pl. 67, fig. 1 (*non* 2-5); *non* Johnston.

1925. *Glycymeris gunyoungensis* Chapman and Singleton, Proc. Roy. Soc. Vict., 37 (1), 23, pl. 1, figs. 5a, 5b, 6; pl. 4, fig. 4.

Description. Shell of moderate size, suborbicular, depressed, a little longer than high; umbo central, small, inconspicuous, slightly opisthogyrous; ligamental area small, with 4 striae on each side; hinge line of moderate length, arcuate, with 10 to 11 short and slightly uncinate teeth in each series; anterior adductor elongate-rhomboidal, posterior adductor sub-trapezoidal with a thin ridge on the anterior side; inner margin only slightly flattened, with 21 intercostal denticulations, interior of shell within the pallial line radially grooved. Surface ornamented with 33 radial costae, rounded, wider than interspaces, crossed by concentric growth lamellae which become more irregular and imbricating towards the ventral margin.

Dimensions. T1067b, length 29, height 27 mm.

Types. Holotype N.M.V. 13324, paratype N.M.V. 13325, hypotype T1067B, C, J.

Material. The species is represented in the Tate Collection by 20 examples mounted on tablet T1067 labelled "*Pectunculus McCoyii* Johnston, Eocene, Muddy Creek, Schnapper Point, Corio Bay, Gellibrand River, Fyansford". T1067A-D, G, H, J, K, N-P, R-T are from Muddy Creek, I from Schnapper Point, Q from Corio Bay, E-F from Gellibrand River, L-M from Fyansford.

Type Locality. Grice's Creek, Bairnsdalian.

Stratigraphic Range. Balcombian to Bairnsdalian.

Glycymeris (Tucetona) lenticularis (Tate)

(pl. 3, figs. 11-13)

1886. *Pectunculus lenticularis* Tate, Trans. Roy. Soc. S. Aust., 8, 138, pl. 11, fig. 1.

1925. *Glycymeris lenticularis*; Chapman and Singleton, Proc. Roy. Soc. Vict., 37 (1), 31, pl. 1, figs. 8a, 8b; pl. 4, fig. 6.

Description. Shell of moderate size, rather thin, orbicular, depressed, equilateral, a little longer than high; umbones small, approximate, incurved; ligamental area small, narrow, with 5 widely diverging striae on each side; hinge line long and roundly arched, with 12 teeth on each side; anterior adductor elongate-subovate, posterior adductor subquadrate, with a ridge on the anterior side; inner margin flattened, with 32 conspicuous denticulations; surface ornamented with usually from 30 to 50 fine radial costae crossed by frequent imbricating growth striae.

Dimensions. Holotype T1011 A-B, length 31, height 29, inflation (both valves) 12 mm.

Types. Holotype T1011A-B, both valves of a single specimen mounted separately on tablet. Tate's figure appears to be that of T1011B, the left valve; both valves were figured by Chapman and Singleton (pl. 1, figs. 8a, 8b); the tablet also contains 9 paratypes C-L in a growth series. Chapman and Singleton, who were under the impression that *G. lenticularis* was of Lower Miocene age, considered that T1011C and T1011C-K belonged to *G. gunyoungensis*, but this is not so, although all of these specimens have fewer ribs than the finely ribbed holotype.

Type Locality. "Adelaide" (Kent Town) Bore, at 150-218 feet in greensands equivalent to Blanche Point Marls.

Stratigraphic Range. South Maslin Sands and equivalents of Blanche Point Marls. Upper Eocene.

Observations. This species also occurs in foundation bores at Adelaide Children's Hospital at depths between 65 and 76 feet, mostly below the level at which *Limopsis chapmani* occurs (62-66 feet).

Glycymeris (Tucetona) subtrigonalis (Tate)

(pl. 3, figs. 2-4)

1886. *Pectunculus subtrigonalis* Tate, Trans. Roy. Soc. S. Aust., 8, 137, pl. 11, figs. 6a-6b.

1897. *Pectunculus subtrigonalis*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 340.

1925. *Glycymeris subtrigonalis*; Chapman and Singleton, Proc. Roy. Soc. Vict., 37 (1), 34, pl. 2, figs. 10-12; pl. 4, fig. 8.

Description. Shell of moderate size, solid, roundly subtrigonal, subequilateral, convex, a little longer than high; ligamental area relatively small, with 6 deep striae on either side; hinge line fairly short, arcuate, with from 8 to 10 short, uncinate teeth in either series; anterior adductor subtrapezoidal, posterior adductor ovate, with a ridge on the anterior side; inner margin bevelled, with 17 denticulations; interior within the pallial line excavate and radially striate; surface ornamented with from 26 to 30 radial costae, rounded and separated by narrow interspaces crossed by concentric growth lamellae which become imbricating towards the ventral margin in adult shells.

Dimensions. Holotype T1069C, length 30, height 29, inflation (one valve) 9 mm.; paratype T1069D, length 32, height 31·5, inflation 9 mm.

Types. The type tablet T1069 contains the holotype T1069C and 11 paratypes T1069A-B, D-M.

Type Locality. Cadell Marl Lens, section C, Hundred of Cadell, 4 miles south of Morgan.

Stratigraphic Range. Lower Miocene, Batesfordian.

Family ARCIDAE

Genus ARCA Linné, 1758

Arca capulopsis Pritchard

(pl. 4, figs. 1-3)

1901. *Arca capulopsis* Pritchard, Proc. Roy. Soc. Vict., 14 (1), 23, pl. 2, figs. 1, 2.

Description. Shell elongate-trapeziform, subpyramidal, with a flat shallow medial sulcus from the umbo to near the ventral margin; hinge margin straight, ventral margin curved and approximately parallel to the hinge margin, anterior margin gently rounded, posterior margin concave, ventral margin gently curved, insinuated; posterior slope with a well-defined angular carina which delimits the concave posterior dorsal area; umbones widely separated, situated at the anterior one-third, small, slightly opisthogyrous; ligamental area large and wide, with one or two radiating grooves; hinge long and narrow with about 12 small transverse teeth under the umbo and 12 posterior and 6 anterior larger somewhat oblique teeth; adductor impressions not discernible; inner margin weakly crenulate. Surface ornamented with from 5 to 11 radial riblets on the posterior area and numerous fine radial riblets on the rest of the shell crossed and fimbriated by frequent growth lamellae which are weaker on the posterior area than on the rest of the shell.

Dimensions. T1064A, length 9, height 4·5 mm.

Types. Holotype M.U.G.D. 1773; topotypes A.U.G.D. Tate Collection T1064 A-D.

Material. Tablet T1064 labelled with the Tate MS. name "*Fossularca eminula*" containing 4 specimens, A-C, from Fyansford (topotypes of Pritchard's species) and D from Muddy Creek.

Type Locality. "Orphanage Hill, Geelong", Fyansford Clay, Bairnsdalian.

Stratigraphic Range. Miocene (Bairnsdalian). Pritchard (p. 23) observes that the species in the Pliocene ("Miocene") of Grange Burn is probably derived. T1064D on Tate's tablet has the appearance of a derived shell.

Arca pseudonavicularis Tate

(pl. 3, figs. 30-31)

1886. *Arca pseudonavicularis* Tate, Trans. Roy. Soc. S. Aust., 8, 139, pl. 11, fig. 8.

Description. Shell elongate-subtrapeziform, tumid, gaping ventrally; hinge margin straight, ventral margin slightly curved and excavate in the middle,

anterior margin gently rounded, posterior margin nearly straight; umbones at the anterior one-third, widely separated, acute, incurved; ligamental area large with radiating grooves typical of the genus; hinge long and narrow with numerous transverse teeth, all roughly transversely grooved; anterior adductor subtriangular, inner margin of valve smooth, pallial line distinct, area within pallial line finely striate. Surface ornamented with irregular radial riblets crossed on all but the posterior dorsal area by concentric fimbriating folds, on the posterior dorsal area the radial ornament is dominant, on the rest of the shell the concentric ornament dominates.

Dimensions. Holotype T1057A, length 27·5, height 12·5, inflation (one valve) 8 mm.

Types. The holotype T1057A and two paratypes T1027B, C, mounted on a single tablet.

Material. The type tablet only.

Type Locality. Adelaide (i.e. Kent Town) Bore at 150-218 feet, Upper Eocene.

Stratigraphic Range. Upper Eocene of Blanche Point Marls equivalents. Tate recorded (p. 139) that R. M. Johnston had the species from Table Cape, but there are no specimens to confirm this in the Tate material.

Genus Arcopsis von Koenen, 1885

(– *Fossularca* Cossmann, 1887)

Arcopsis dissimilis (Tate)

(pl. 5, figs. 26-30)

1886. *Barbatia dissimilis* Tate, Trans. Roy. Soc. S. Aust., 8, 140, pl. 11, figs. 4, 5.
1897. *Area (Fossularca) dissimilis*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 336.

Description. Shell small, transversely oblong, tumid, convex anteriorly but with a flattened triangular posterior dorsal area; hinge margin straight, oblique; ventral margin gently rounded, anterior margin gently rounded, posterior margin nearly straight or very gently curved meeting the hinge margin at an angle of about 120°; umbones near the anterior one-third, fairly wide apart, prominent, incurved, overhanging the ligamental area; ligamental area rather narrow with a triangular pit beneath the umbo; hinge area slightly arcuate with about 8 anterior and 14 posterior teeth all slightly oblique; adductor impressions faint but apparently triangularly ovate with a narrow ridge on the inner side; pallial line entire, inner margin simple. Surface ornamented on the left valve with radial riblets crossed by concentric striae which interrupt the riblets in a tessellated pattern; the pattern is absent on the right valve except in the triangular dorsal areas, elsewhere the surface of the shell is pitted in a concentric and radial pattern as if these were scars left after the tessellated riblets had rubbed off.

Dimensions. T1059D, length 7·5, height 5 mm.

Types. The type tablet T1059 has 18 mounted specimens A-T from Eocene of Aldinga and Adelaide Bore, there being no distinction between the two locali-

ties. The syntypes figured are the left valve T1059D and the right valve T1059L; both are stated to have come from "Adelaide bore".

Material. The type tablet. The species also occurs in Adelaide Children's Hospital Bore 5 at 63-76 feet (G.S.S.A. Collection).

Type Locality. Adelaide (i.e. Kent Town) Bore at 150-218 feet, Upper Eocene.

Stratigraphic Range. Upper Eocene of Blanche Point Marls and their equivalents in and near the city area, Adelaide.

Observations. The stratigraphic range of *Arcopsis* is Upper Cretaceous to Recent, with greatest abundance in the Eocene (Reinhart, 1935, p. 32).

Genus BARBATIA Gray, 1842

Subgenus BARBATIA s. str.

Barbatia (Barbatia) consutilis Tate

(pl. 3, figs. 24-27)

1886. *Barbatia consutilis* Tate, Trans. Roy. Soc. S. Aust., 8, 142, pl. 2, fig. 15.
1897. *Arca (Barbatia) consutilis*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 332.

Description. Shell moderately large, narrowly ovate-oblong, twice as long as high, with a medial-ventral depression; ventral margin more or less parallel to the hinge margin; anterior margin rounded, posterior margin rounded, produced; ventral margin gently rounded, insinuate; posterior slope slightly flattened; umbones at the anterior one-quarter, prosogyrous; ligamental area narrow, faintly grooved; hinge margin straight, with numerous oblique teeth; adductor scars not clear, internal margin smooth. Surface ornament consists of numerous fine radial threads crossed by concentric growth folds and fine concentric threads with granules at their intersections with the radials, particularly in the immature shell.

Dimensions. Holotype T1053A, length 41, height 20, inflation (one valve) 8 mm.

Types. The type tablet contains the holotype T1053A and 12 paratypes T1053B-N; most are from "Eocene, Muddy Creek"; T1053C is from Cheltenham, Victoria, and T1053K from "R. Murray Cliffs". The figure of the holotype has been reversed on Tate's plate.

Material. Tablet T1053 only.

Type Locality. Muddy Creek, Hamilton, Victoria; Muddy Creek Marl, Balcombian to Bairnsdalian, Miocene.

Stratigraphic Range. Lower Miocene (Batesfordian) to Lower Pliocene (Kalimnan). The species is recorded by Dennant (1889, p. 50) from both upper and lower beds at Muddy Creek.

Observations. Specimen T1053C from Cheltenham may not belong to the species. It bears some resemblance to a specimen of *Barbatia simulans* T1054B from Norwest Bend. A range of specimens is, however, lacking to enable the two specimens to be determined with any confidence.

Barbatia (Barbatia) limatella Tate

(pl. 3, figs. 21-23)

1886. *Barbatia limatella* Tate, Trans. Roy. Soc. S. Aust. 8, 141, pl. 10, fig. 2.

Description. Shell large, oblong-ovate, tumid, medially depressed in juvenile specimens, ventral margin more or less parallel to the hinge margin, anterior margin rounded, posterior margin rounded and meeting the hinge margin at an obtuse angle, ventral margin gently rounded, usually insinuated medially, posterior slope convex; umbones at the anterior one-fifth, prosogyrous; ligamental area very narrow, with four divaricating furrows; hinge margin straight with numerous small transverse teeth in the centre becoming oblique and larger towards the ends; anterior adductor elongate-pyriform, posterior adductor rhomboidal; internal margin showing faint fine denticulations in oblique light. Surface ornamented with numerous fine dichotomously dividing radial threads crossed by fine concentric threads and imbricating growth folds.

Dimensions. Holotype T1048B, length 50, height 28, inflation (one valve) 9 mm.

Types. Tate's tablet T1048 contains the holotype T1048B and 10 paratypes T1048A, C L; T1048A has been marked (in Howchin's handwriting) "fig'd", but the measurements given by Tate and the figure, although it is a very poor one, appear to correspond more closely to T1048B which is accepted as the holotype.

Material. Tablet T1048 only.

Type Locality. "Adelaide", i.e. Kent Town, Bore at 150-218 feet depth.

Stratigraphic Range. Upper Eocene of Blanche Point Marls and their equivalents in subsurface sections at Adelaide.

Barbatia (Barbatia) pumila Tate

(pl. 3, figs. 15-18)

1886. *Barbatia pumila* Tate, Trans. Roy. Soc. S. Aust., 8, 142, pl. 10, fig. 7.
1897. *Arca (Barbatia) pumila*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 334.

Description. Shell small, ovate, convex, inequilateral, ventral margin diverging slightly in a posterior direction from the hinge margin; hinge margin straight, anterior and posterior margins rounded, ventral margin gently rounded; umbones at the anterior one-third, prosogyrous; ligamental area narrowly triangular and slightly encroaching on the hinge at about the middle of the posterior side; hinge with numerous transverse teeth; anterior adductor small and high, subovate; posterior adductor small, elongate-subtriangular; inner margin crenulated, particularly on the posterior. Surface ornamented with flatly rounded radial riblets, broader than the interspaces, wider and more prominent on the posterior slope where they are bifurcated by a longitudinal sulcus; riblets crossed and granulated by numerous concentric threads and concentric growth folds.

Dimensions. T1052D, length 8, height 5·7 mm.

Types. There is no clear indication on the tablet as to which is the figured specimen and T1052D is selected as lectotype. T1052D has been marked (in Howchin's writing) 'fig'd', but this is a small specimen not agreeing with Tate's measurement or very well with the type figure. The type figure has presumably been reversed, as with other figures of Tate's types. Tablet T1052 contains also 14 paratypes T1052A-C, E-N, of which all are from Muddy Creek but P and Q, which are from Gellibrand River.

Material. Tablet T1052 only.

Type Locality. Muddy Creek, Hamilton, Victoria; Muddy Creek Marl. (Balcombian to Bairnsdalian). In his type description Tate states that the species is "not uncommon in the upper beds at Muddy Creek, Hamilton". Tate's tablet T1052, Harris (1897, p. 334) and Dennant (1889, p. 50), Dennant and Kitson (1903, p. 120) all clearly state that the species occurs only in the lower beds.

Stratigraphic Range. Muddy Creek Marl and Gellibrand Marl; Miocene (Balcombian to Bairnsdalian).

Subgenus Acar Gray, 1857

Barbatia (Acar) celleporacea Tate

(pl. 5, figs. 10-14)

1886. *Barbatia celleporacea* Tate, Trans. Roy. Soc. S. Aust., 8, 141, pl. 10, fig. 10.
1897. *Area (Barbatia) celleporacea*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 332.
1947. *Acar coma* Cotton, Rec. S. Aust. Mus., 8, (4), 657, pl. 20, figs. 25, 26.
1955. *Barbatia (Acar) coma*; Ludbrook, Trans. Roy. Soc. S. Aust., 78, 22.

Description. Shell of moderate size, elongate-oblong, rather compressed, with a shallow umbo-ventral depression, ventral margin divergent from the hinge margin in a posterior direction; anterior margin gently curved; posterior margin nearly straight, oblique, forming an obtuse angle with the hinge margin; posterior slope with a sharply defined carina delimiting a flat posterior area; ventral margin slightly insinuate; umbones prosogyrous, situated at the anterior one-quarter; hinge margin straight, hinge with a narrow cardinal area and teeth transverse in the middle, becoming more oblique towards the ends, all grooved across the top; both the anterior and posterior adductor scars are drop-shaped and raised above the level of the shell interior; internal margin crenulated between the external ribs. Surface ornamented with strongly fimbriate concentric lamellae crossed by radial riblets which on the adult shell develop into hollow elongated tubercles on the posterior carina, the ornament elsewhere being tegulate.

Dimensions. Holotype T1062A-B, length 26, height 10, inflation (both valves) 7·5 mm.

Types. The type tablet contains the holotype, a pair of valves, T1062A, B, mounted separately, and 14 paratypes T1062C-P.

Material. The type tablet only.

Type Locality. "Schnapper Point, Mornington, Victoria." There is nothing on Tate's tablet to distinguish specimens from "Schnapper Point" from those from Muddy Creek. As Tate specifically states (l.c. 6, 157) that the figured specimen is from Schnapper Point, Balcombe Bay must be accepted as the type locality.

Stratigraphic Range. Lower Miocene to Upper Pliocene, from Lower Miocene of the Freestone Cove Sandstone of Table Cape to the Upper Pliocene of the Dry Creek Sands. The species occurs in both the Muddy Creek Marl (Balcombian to Bairnsdalian) and Grange Burn Coquina (Kalimnan) at Muddy Creek.

Barbatia (Acar) crustata Tate

(pl. 5, figs. 19-25)

1886. *Barbatia crustata* Tate, Trans. Roy. Soc. S. Aust., 8, 140, pl. 2, fig. 16.
1897. *Arca (Barbatia) crustata*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 333.

Description. Shell small, elongate-rhomboidal, tumid, with a conspicuous medial sulcus and corresponding shallow sinus in the ventral margin, anterior side relatively short and narrow, posterior margin concave, forming an obtuse angle with the hinge margin; posterior slope with a well-defined carina delimiting a concave posterior area; ventral margin insinuate, diverging from the hinge margin in a posterior direction; umbones at the anterior one-fifth, prosogyrous; straight, long; hinge with about 7 anterior and 14 posterior oblique teeth, the posterior series sometimes at a lower angle than the anterior series; adductor impressions large, the anterior subpyriform, the posterior elongate-subtriangular, inner margin plain. Surface strongly ornamented with concentric lamellae, about 14 per mm. in the middle of the shell, crossed and granulated by fine radial riblets, about 7 per mm.

Dimensions. Holotype T1061B, length 7·3, height 4·3 mm.

Types. Tablet T1061 contains 9 specimens A-J of which only T1061B was marked by Tate as from Norwest Bend. As only Norwest Bend is referred to in the original description, it must be assumed that this is the type locality and T1061B the holotype. The type figure is so poor and probably reversed that it is difficult to relate it to any particular specimen on the tablet. T1061B has been marked 'fig'd' and 'holotype' by later workers. Specimens T1061A and C-J are paratypes from Muddy Creek. Tablet T1060 has 10 paratypes: A-O from Gellibrand River, E from Fyansford, and F-J from "River Murray".

Material. T1061A-J, T1060A-J.

Type Locality. In describing the species Tate referred only to "Oyster beds of the River Murray Cliffs at North-West Bend". It is unlikely that the small shell came from the hard sandy limestone of the Norwest Bend Formation; both the preservation and stratigraphic affinities suggest that if it came from Norwest Bend it was taken from the Morgan Limestone underlying the Norwest Bend Formation. Specimens have been collected from the Cadell Marl Lens at the type section of the Morgan Limestone from which Tate's specimens T1060F-J are presumed also to have come. The species is stated by Dennant (1889, p. 50) to occur only in the older (Miocene) beds at Muddy Creek.

Stratigraphic Range. Miocene, Batesfordian to Bairnsdalian.

Barbatia (Acar) simulans Tate

(pl. 3, figs. 28-29)

1886. *Barbatia simulans* Tate, Trans. Roy. Soc. S. Aust., 8, 142, pl. 11, fig. 10.
1897. *Arca (Barbatia) simulans*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 333.

Description. Shell of moderate size, transversely trapezoidal, relatively high, moderately inflated, very inequilateral, with a weak broad medial sulcus particularly in juvenile specimens; anterior margin rounded and meeting the hinge margin at an obtuse angle; posterior margin concave, forming an angle of 130° with the hinge margin; posterior slope with a somewhat rounded

carina delimiting the concave posterior area: ventral margin weakly insinuate, slightly curved; umbones situated at the anterior one-quarter, prosogyrous, well separated, hinge area fairly narrow, hinge margin straight, with numerous oblique slightly grooved teeth; anterior adductor ovate, posterior adductor not visible because of mounting of specimens; inner margin finely crenulate. Surface ornamented with fine radial riblets weaker and finer in the medial area, those in the posterior being broader and longitudinally sulcate, all crossed and granulated by concentric growth ridges weaker than the radials.

Dimensions. Holotype T1054A, length 34, height 18, inflation (one valve) 7 mm.

Types. Tablet T1054 contains the holotype T1054A and three paratypes T1054C, E, F from Muddy Creek, two paratypes T1054B, D from Norwest Bend, and one paratype T1053 from "Well near Blanchetown".

Material. Tablet T1054 only.

Type Locality. Muddy Creek, Hamilton, Victoria; Muddy Creek Marl, Balcombian to Bairnsdalian.

Stratigraphic Range. Miocene (Balcombian) to Lower Pliocene (Kalimnan).

Subgenus Cucullaearca Conrad, 1865

Barbatia (Cucullacarca) equidens (Tate)

(pl. 4, figs. 4-7)

1886. *Area equidens* Tate, Trans. Roy. Soc. S. Aust., 8, 139, pl. 11, fig. 9.
1897 *Area equidens*: Harris, Cat. Tert. Moll. Brit. Mus., 1, 331.

Description. Shell small, elongate-subtrapeziform, with a marked umbo-ventral depression and a corresponding broad insinuation in the ventral margin, hinge margin straight, oblique, anterior margin meeting the hinge margin at 90° but sloping away in a gentle curve to meet the ventral margin, posterior margin insinuated in the concave posterior-dorsal area then roundly curving to the ventral margin, umbones situated at the anterior one-third, wide apart, prominent, strongly incurved and slightly overhanging the ligamental area; ligamental area long and wide with a long narrow oblique triangular pit posterior to the umbo obliquely striated with as many as ten close-set striae, the ligamental area otherwise is smooth or faintly striate; hinge area straight dorsally and gently curved ventrally with seven or eight teeth on each side usually more or less horizontal near the centre and becoming more oblique towards the interior and posterior borders, all the teeth are conspicuously grooved on both sides. Anterior adductor triangularly-ovate, posterior adductor subquadrate, both adductors weakly buttressed on the inner side; pallial line entire, inner margin of shell simple. Surface of shell strongly ornamented with concentric imbricating ridges and radial riblets which are interrupted by the growth ridges in the adult stages; there is a tendency to discrepancy between the two valves, the ornament on the left valve being fimbriate, that on the right valve cancellate, but becoming fimbriate near the ventral margin.

Dimensions. Holotype T1058C, length 9·9, height 6, inflation (one valve) 4 mm.

Types. Tate's tablet consists of the holotype T1058C and 17 paratypes T1058A-B, D-T, all from "Eocene, Adelaide Bore". As in other cases the figure of the holotype (pl. 11, fig. 9) has been reversed.

Material. The type tablet. Both Tate and Harris recorded the species also from Aldinga. It occurs in Bore 5 at Adelaide Children's Hospital at 63-64 feet and 72-73 feet (G.S.S.A. Collection).

Type Locality. Adelaide (i.e. Kent Town) Bore at 150-218 feet, Upper Eocene.

Stratigraphic Range. Upper Eocene of Blanche Point Marls and their equivalents in bores in and near the city area, Adelaide.

Subgenus Plagiarca Conrad, 1875

Barbatia (Plagiarca) cainozoica (Tate)

(pl. 5, figs. 1-9)

1886. *Macrodon cainozoicus* Tate, Trans. Roy. Soc. S. Aust., 8, 143, pl. 10, fig. 4.
1897. *Arca* (*Plagiarca*) *cainozoica*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 335.

Description. Shell small, subrhomboidal, with a broad depression from the umbo to the ventral margin and a corresponding very slight shallow sinus in the ventral margin; anterior side short, acutely angulate, posterior side elongated, with a slight concave triangular dorsal area and truncated by a well-defined posterior slope; hinge margin straight, ventral margin slightly curved with a median insinuation; umbo situated at the anterior one-quarter, prominent, incurved; ligamental area narrow with a few faint striae; hinge very slightly curved with about five short, oblique teeth on the anterior and thirteen slightly oblique or laminar teeth on the posterior side of the edentulous central area, all teeth finely rugose; anterior adductor ovate, posterior adductor subquadrate; inner margin smooth, bevelled. Surface ornamented with concentric flat ridges carrying fine radial threads sometimes producing a fimbriate ornament towards the ventral margin; the ridges are separated by deep grooves narrower than the ridges.

Dimensions. Holotype T1056C, length 27·5, height 10, inflation (one valve) 5 mm.

Types. The holotype T1056C and 26 paratypes T1056A-B, D-U, T1063A-H.

Material. Tate's type series is mounted on two tablets. The first T1056 carries 10 specimens from Muddy Creek, 4 from Schnapper Point, 1 from "Corio Bay" and 4 from "Adelaide". Of these T1056B is marked "fig'd", but it is obvious from the dimensions of the type figure that the specimen is T1056C. As with others, the figure has been reversed. Tablet T1063 carries 3 specimens, A-C, from Gellibrand River and 5, D-H, from "River Murray" (i.e. Cadell Marl Lens).

Types Locality. Muddy Creek, Hamilton, Victoria; Muddy Creek Marl, Balcombian to Bairnsdalian.

Stratigraphic Range. Upper Eocene of Blanche Point Marls equivalents beneath Adelaide; Miocene (Batesfordian to Bairnsdalian) in Victoria.

Genus ANADARA Gray, 1897

Anadara interclathrata Ludbrook (ex Tate) sp. nov.

(pl. 4, figs. 8-10)

1893. *Barbatia interclathrata* Tate in Tate and Dennant, Trans. Roy. Soc. S. Aust., **17**, (1), 224 (*nom. nud.*).

Description. Shell small, thick but fragile, broadly trapeziform, tumid, with a shallow umbo-ventral depression; ventral margin parallel to the hinge margin, anterior margin very gently rounded and meeting the hinge margin at about 90°, posterior margin curved and meeting the hinge margin at a little more than 90°, ventral margin insinuated, anterior and posterior slopes somewhat flattened; umbones fairly widely separated, at the anterior one-third, prosogyrous; ligamental area long and fairly wide, triangular; hinge margin straight, with numerous teeth becoming slightly oblique towards the extremities; adductor impressions obscured, inner margin coarsely denticulate. Surface ornamented with 22 to 24 strong radial costae somewhat narrower than the interspaces crossed by fine frequent concentric threads which are stronger on the interspaces than on the ribs.

Dimensions. Holotype T1051A, length 12, height 8, inflation (one valve) 4 mm.

Types. The holotype and T1051A and 5 paratypes T1051B-F.

Material. The type tablet only.

Type Locality. Spring Creek, Torquay, Victoria, believed from the matrix to be Jan Juc Formation.

Stratigraphic Range. Janjukian, Upper Oligocene.

Observations. The species though named and recorded was not described by Tate. Its rarity as an ancestral species of the genus *Anadara* and its restricted occurrence necessitates its description.

Family CUCULLAEIDAE

Genus CUCULLAEA Lamarck, 1801

Cucullaea adelaidensis Tate

(pl. 4, figs. 11-15)

1886. *Cucullaea adelaidensis* Tate, Trans. Roy. Soc. S. Aust., 8, 144, pl. 11, fig. 14.
1932. *Cucullaea adelaidensis*; Singleton, Proc. Roy. Soc. Vict., 44, (2), 304, pl. 26, figs. 21-24.

Description. Shell of moderate size, rather thin, obliquely trapezoidal, inequilateral, tumid, longer than high; hinge margin straight, meeting the anterior and posterior margins at 120°, posterior margin straight, produced; anterior margin rounded, ventral margin gently rounded; umbones large, prominent, strongly incurved and overlapping the ligamental area, situated slightly to the anterior; ligamental area small, with as many as five divaricating furrows meeting under the umbo at a low angle; hinge area narrow, long, with from three to five longitudinal laminar teeth on the posterior and anterior sides and

about nine small, transverse, central teeth increasing in size and obliquity outwards, teeth rugose on the upper and lower surfaces; anterior adductor elongate-subtriangular, posterior adductor pyriform, bounded by a thickened but not plate-like ridge; pallial line entire, area within radially striate, inner margin more or less coarsely denticulate. Surface ornamented with fine narrow radial riblets developing a median linear groove towards the ventral margin, crossed by frequent undulating growth laminae; the ornament on the left valve is finer than that on the right and is always more definite on the juvenile shell.

Dimensions. Holotype T1047B, length 43, height 30, inflation (one valve) 15 mm.

Types. The holotype T1047B and eight paratypes T1047A, C-J mounted on a single tablet, most of these were taken from the tablet for photographing and remounted by Singleton so that the interior of the shell could be examined and figured, T1047B is the specimen measured and figured by Tate, although Chidley's figure, like many others in the Tate papers, has been reversed.

Material. The type tablet T1047 only.

Type Locality. Adelaide (i.e. Kent Town) Bore at 150-218 feet; Upper Eocene.

Stratigraphic Range. Upper Eocene equivalents of Blanche Point Marls.

Cucullaea corioensis McCoy

(pl. 4, figs. 16-24)

1876. *Cucullaea corioensis*; McCoy, Prod. Pal. Viet., 3, 32, pl. 27, figs. 4, 5 (?*non* figs. 3 5a).

1886. *Cucullaea corioensis*; Tate, Trans. Roy. Soc. S. Aust., 8, 144.

1888. *Cucullaea corioensis*; Johnston, Geol. Tas., pl. 29, figs. 4, 4a.

1897. *Cucullaea corioensis*; Harris, Cat. Tert. Moll. Brit. Mus., 1, 330.

1932. *Cucullaea corioensis*; Singleton, Proc. Roy. Soc. Viet., 44, (2). 300, pl. 26, figs. 19a, b.

Description. Shell moderately large, heavy, obliquely trapezoidal, inequilateral, tumid, longer than high, left valve overlapping the right valve ventrally, hinge margin straight, meeting the anterior and posterior margins at 110°, anterior margin rounded, posterior margin slightly produced; umbo large, prominent, strongly incurved, with a shallow median radial depression, overhanging the ligamental area; ligamental area broad, flattened, with as many as four deep furrows on either side; hinge line moderately long, straight, with four longitudinal teeth in each series and a median series of 14 or more transverse to oblique teeth more or less encroached upon by the ligamental area. Anterior adductor subtriangular, posterior adductor subquadrate with an elevated plate extending from the pallial line to below the umbo on the posterior side, pallial line entire, area within the pallial line radially striate, inner margin crenulate. Surface ornamented with fine flat radiating riblets separated by linear grooves, in the adult shell the riblets have a median longitudinal groove; radial riblets crossed by fine concentric growth lines more or less undulating over the riblets.

Dimensions. T1049A (topotype), length 41, height 33, inflation (left valve) 17 mm.

Types: Lectotype N.M.V. 12236, paratype N.M.V. 12237; hypotypes Tate Collection T1046 A, B, E; T1049 A, C; T1050 A, B, C.

Material. The Tate material consists of three tablets; T1046 with 8 mounted specimens in a growth series from "River Murray Cliffs"- Cadell Marl Lens, 4

miles downstream from Morgan; T1049 with two mounted specimens A from "Eocene, Spring Creek" and B from Cheltenham; T1050 with 10 specimens in a growth series A-B, E-M, from Muddy Creek, no indication being given of whether they were from the Pliocene or Miocene, 2 specimens C, D from Table Cape.

Type Locality. Bird Rock Cliffs, near Spring Creek, Torquay; Janjukian.

Stratigraphic Range. ? Upper Oligocene to Upper Pliocene.

ACKNOWLEDGMENTS

The author's most grateful thanks are due to Miss Lynette Linke of the Palaeontology Section of the Geological Survey of South Australia for photographing the specimens, a task made difficult by the fact that they are mounted in rows on wooden tablets. Some stratigraphic details were clarified by Messrs. R. C. Glenie and P. E. Bock of the Geological Survey of Victoria. Information on the type series of *Limopsis beaumariensis* and *L. maccoyi* was provided by Mr. T. A. Darragh of the National Museum of Victoria.

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Explanation of Plates

Plate 1

1–9 *Limopsis chapmani* Singleton
1. Complete specimen T1032B view of right valve; Aldinga, Blanche Point Marls, "Limopsis Bed" Upper Eocene to Lower Oligocene.
5. T1032B dorsal view.
2. Complete specimen T1032C, view of left valve; Aldinga, as T1032B.
3. Left valve T1025C, interior view; Aldinga, as T1032B.
4. Left valve T1025A, exterior view; Aldinga, as T1032B.
6. Complete specimen T1025E, view of left valve; "Adelaide" (Kent Town) Bore, Upper Eocene.
7. Right valve T1025H, interior view; Kent Town Bore, as T1025E.
8. Complete specimen, topotype T1022A, view of left valve, "Spring Creek", Bird Rock, Jan Juc Formation, Upper Oligocene.
9. Left valve T1022E topotype, interior view.

10, 14, 15, 16 *Limopsis beaumariensis* Chapman
10. Right valve T1023G, topotype, "Cheltenham" (Beaumaris), Black Rock Sandstone, Cheltenhamian, Upper Miocene.
16. Left valve T1023H, topotype.
14. Left valve T1030B, "Gippsland Lakes", Jemmy's Point Formation, Kalimnan, Lower Pliocene.
15. Complete specimen T1030A, mounted with valves separated, "Gippsland Lakes", as T1030B.

11–13 *Limopsis morningtonensis* Pritchard
11. Topotype T1020A; Gellibrand Marl, Gellibrand River, Bairnsdalian.
12. T1020E. Freestone Cove Sandstone, Table Cape, Longfordian.
13. T1021A. Muddy Creek Marl, Muddy Creek, Balcombian to Bairnsdalian.

17–22 *Limopsis maccoyi* Chapman
17. Right valve, T1023A, somewhat rounded, Muddy Creek, Muddy Creek Marl.
18. Left valve, T1023C, interior view; Muddy Creek Marl.
19. Left valve, T1023D, an oblique and rather depressed specimen; Muddy Creek Marl.
20. Right valve, T1023K, Gellibrand Marl, Gellibrand River.
21. Right valve, T1027A; "River Murray Cliffs", Cadell Marl Lens, 4 miles downstream from Morgan, Batesfordian.
22. Left valve, T1027E; Cadell Marl Lens.

23–27 *Limopsis multiradiata* Tate
23. Holotype, T1031A, "Adelaide" (Kent Town) Bore, Upper Eocene. X 2·5.
26. Holotype X 1.
24. Paratype, T1031L; Kent Town Bore. X 2·5.
27. T1031L. X 1.
25. Paratype, T1031K; Kent Town Bore. X 2·5.

28–34 *Glycymeris* (*Glycymeris*) *cainozoica* (Tenison Woods)
28. Left valve, T1055Q, topotype; Freestone Cove Sandstone, Table Cape, Longfordian.
29. Right valve, T1055E; Muddy Creek Marl.
30. Right valve, T1055C; Muddy Creek Marl.
31. Left valve, T1068B; "Cheltenham" (Beaumaris), Black Rock Sandstone, Cheltenhamian.
32. Right valve, T1068C, Cheltenhamian.
33. Left valve, T1068F; "Camperdown" (Lake Bullen Meri), Gellibrand Marl, Bairnsdalian.
34. Left valve, T1055U; "Adelaide" (Kent Town) Bore, Upper Eocene.

35–36 *Glycymeris* (*Glycymeris*) *halli* Pritchard.
35. T1055L, immature specimen; ?Grange Burn Coquina, Muddy Creek, Kalimnan.
36. T1055K, complete specimen (immature); ?Grange Burn Coquina, Muddy Creek.

(*All figures natural size except* 23, 24, 25)

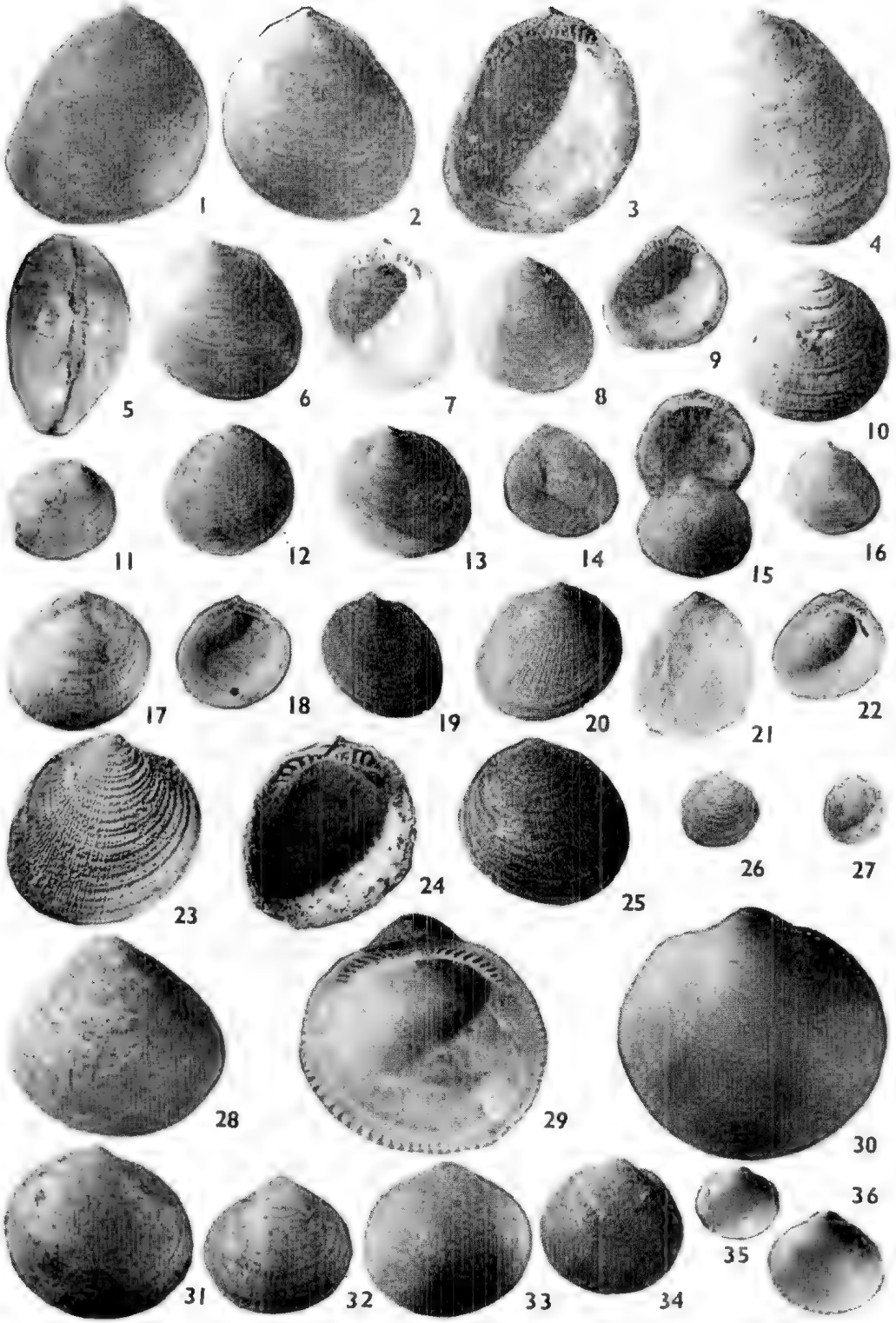
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Plate 2

1, 2, 4, 5 *Glycymeris* (*Grandaxinea*) *ornithopetra* Chapman and Singleton.

1. Topotype T1070A; produced ventrally; Bird Rock, Jan Juc Formation, Janjukian.
2. Topotype T1071C, complete specimen.
4. Topotype T1071A, round form, exterior view.
5. Topotype T1071A, interior view.

3, 6 *Glycymeris* (*Grandaxinea*) *granti* Singleton.

3. Topotype T1071D, exterior view.
6. Topotype T1071D, interior view. Muddy Creek Marl, Muddy Creek, Balcombian to Bairnsdalian.

(*All figures natural size*)


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PLATE 3

1 *Glycymeris* (*Grandaxinea*) *maccoyi* (Johnston).
1. Topotype T1066A, Freestone Cove Sandstone, Table Cape, Longfordian.

2–4 *Glycymeris* (*Tucetona*) *subtrigonalis* (Tate).
2. Holotype T1069C; Cadell Marl Lens, 4 miles south of Morgan, Batesfordian.
3. Paratype T1069E; Cadell Marl Lens.
4. Paratype T1069A, round form; Cadell Marl Lens.

5–8 *Glycymeris* (*Tucetona*) *gunyoungensis* Chapman and Singleton.
5. Topotype T1067I; "Schnapper Point"; Balcombe Clay, Balcombe Bay, Balcombian.
6. T1067C, Muddy Creek Marl, Balcombian to Bairnsdalian.
7. T1067B, Muddy Creek Marl.
8. T1067J, Fyansford Clay, Fyansford, Bairnsdalian.

9–10 *Glycymeris* (*Tucetona*) *decurrens* Chapman and Singleton.
9. T1065A, "Gippsland", ?Jemmy's Point Formation, Kalimnan.
10. T1065B from same locality.

11–13 *Glycymeris* (*Tucetona*) *lenticularis* (Tate).
11. Holotype T1011A, "Adelaide" (Kent Town) Bore, Upper Eocene.
12. Paratype T1011B, Kent Town Bore.
13. Paratype T1011D, Kent Town Bore.

14 *Glycymeris* (*Grandaxinea*) *ornithopetra* Chapman and Singleton.
14. T1066B, Freestone Cove Sandstone, Table Cape, Longfordian.

15–20 *Glycymeris* (*Tucetona*) *convexa* (Tate).
15. Holotype T1017C; Grange Burn Coquina, Muddy Creek, Kalimnan (Lower Pliocene).
16. Paratype T1017A.
17. Paratype T1017N (immature).
18. Paratype T1017D.
19. Paratype T1017K (immature).
20. Paratype T1017G (juvenile).

21–23 *Barbatia* (*Barbatia*) *limatella* Tate.
21. Holotype T1048B; left valve, "Adelaide" (Kent Town) Bore, Upper Eocene.
22. Paratype T1048A, right valve; Kent Town Bore.
23. Paratype T1048D, left valve; Kent Town Bore.

24–27 *Barbatia* (*Barbatia*) *consutilis Tate.*
24. Holotype T1053A; Muddy Creek Marl, Muddy Creek.
25. Paratype T1053D, left valve; Muddy Creek Marl.
26. Paratype T1053B, right valve; Muddy Creek Marl.
27. Paratype T1053N, right valve; Muddy Creek Marl.

28–29 *Barbatia* (*Acar*) *simulans* Tate.
28. Holotype T1054A, right valve; Muddy Creek Marl, Muddy Creek.
29. Paratype T1054D, left valve; "Norwest Bend".

30–31 *Arca pseudonavicularis* Tate.
30. Holotype T1057A, right valve; "Adelaide" (Kent Town) Bore, Upper Eocene.
31. Paratype T1057B, left valve; Kent Town Bore.

(*All figures natural size*)

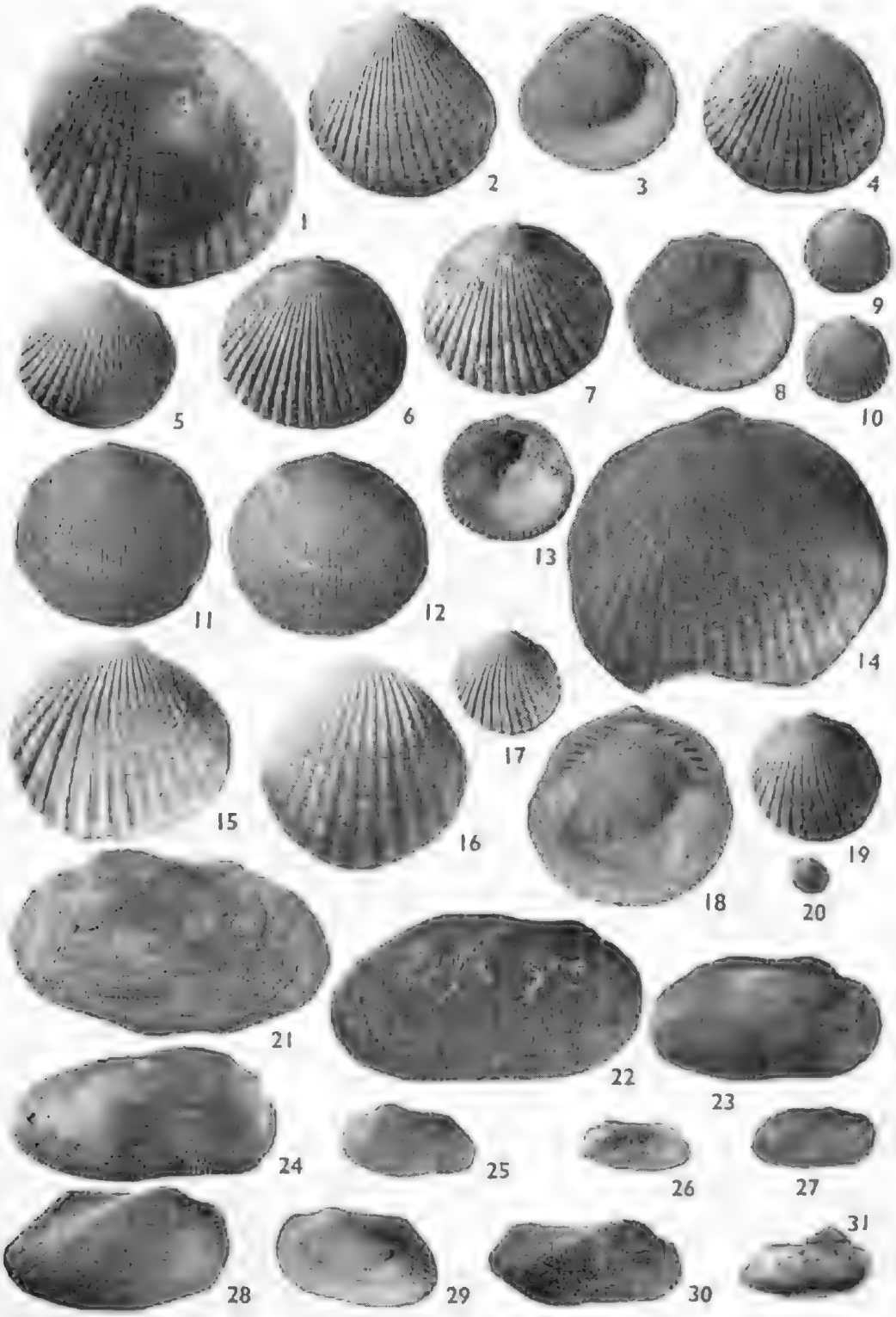
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PLATE 4

1–3 *Arca capulopsis* Pritchard.

1. Topotype T1064A, right valve; Fyansford Clay, Fyansford, Bairnsdalian. X 3·3.
2. Topotype T1064C; Fyansford Clay. X 3·3.
3. T1064D; Muddy Creek, ?Grange Burn Coquina. X 3.

4–7 *Barbatia* (*Cucullaearca*) *equidens* Tate.

4. Holotype T1058C, left valve; "Adelaide" (Kent Town) Bore, Upper Eocene. X 4.
5. Paratype T1058K; Kent Town Bore. X 4.
6. Paratype T1058P; Kent Town Bore. X 4.
7. Paratype T1058Q; Kent Town Bore. X 4.

8–10 *Anadara interclathrata* Ludbrook.

8. Holotype T1051A, left valve; Jan Juc Formation, Bird Rock, Janjukian (Upper Oligocene). X 3.
9. Paratype T1051D; Jan Juc Formation. X 3.
10. Paratype T1051F; Jan Juc Formation. X 3.

11–15 *Cucullaea adelaidensis* Tate.

11. Paratype T1047A, left valve; "Adelaide" (Kent Town) Bore, Upper Eocene. X 1.
12. Holotype T1047B, right valve; Kent Town Bore. X 1.
13. Paratype T1047E, X 1; 14. Paratype T1047F, X 1; 15. Paratype T1047D, X 1.

16–24 *Cucullaea corioensis* McCoy.

16. T1049A, left valve, topotype, Jan Juc Formation, Bird Rock, Janjukian. X 1.
17. T1046A; Cadell Marl Lens, 4 miles south of Morgan, Batesfordian. X 1.
18. T1049C; Beaumaris, Cheltenhamian. X 1.
19. T1050C; Freestone Cove Sandstone, Table Cape, Longfordian. X 1.
20. T1046E; Cadell Marl Lens; 21. T1046B, Cadell Marl Lens, X 1; 22. T1046C, Cadell Marl Lens, X 1.
23. T1050B; Muddy Creek Marl, Balcombian to Bairnsdalian. X 1.
24. T1050A; Muddy Creek Marl. X 1.

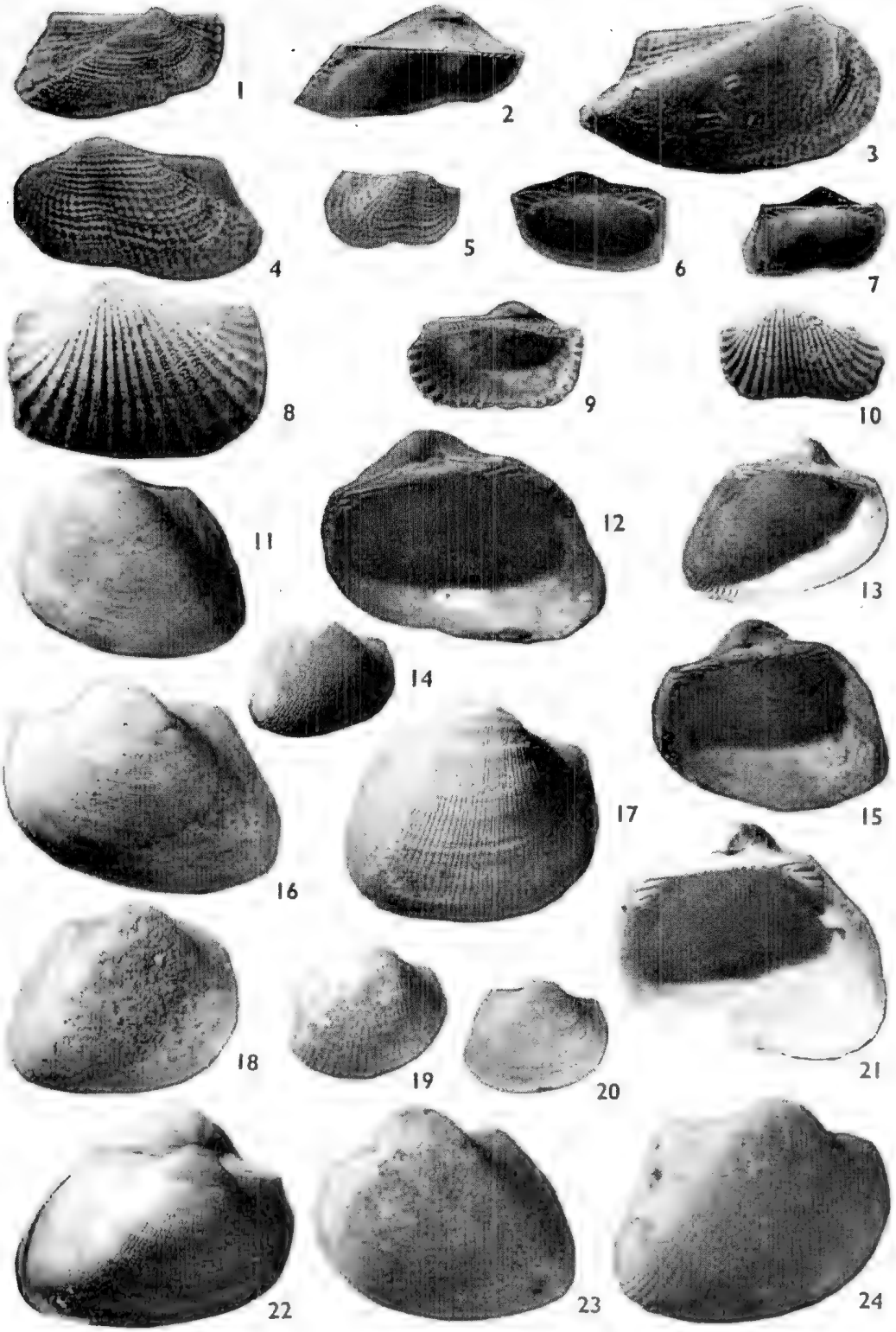
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PLATE 5

1–9 *Barbatia* (*Plagiarca*) *cainozoica* (Tate).

1. Holotype T1056C, right valve; Muddy Creek Marl, Muddy Creek, Balcombian to Bairnsdalian. X 2.
2. Paratype T1056E, complete specimen; Muddy Creek Marl. X 2·5.
3. Paratype T1056D; Muddy Creek Marl. X 2.
4. Paratype T1063B; Gellibrand Marl, Gellibrand River, Bairnsdalian. X 2·5.
5. Paratype T1063F; Cadell Marl Lens, 4 miles south of Morgan, Batesfordian. X 3.
6. Paratype T1063E; Cadell Marl Lens. X 3.
7. Paratype T1056M; "Corio Bay", Fyansford Clay, Bairnsdalian. X 3.
8. Paratype T1056T; "Adelaide" (Kent Town) Bore, Upper Eocene. X 3.
9. Paratype T1056S; Kent Town Bore. X 3.

10–14 *Barbatia* (*Acar*) *celleporacea* Tate.

10. Holotype T1062A, left valve; "Schnapper Point", Balcombe Clay, Balcombe Bay, Balcombian. X 1.
11. Holotype T1062B, right valve. X 1.
12. Paratype T1062N; Balcombe Bay. X 1.
13. Paratype T1062O; Balcombe Bay. X 1.
14. Paratype T1062D; complete specimen, Balcombe Bay. X 1.

15–18 *Barbatia* (*Barbatia*) *pumila* Tate.

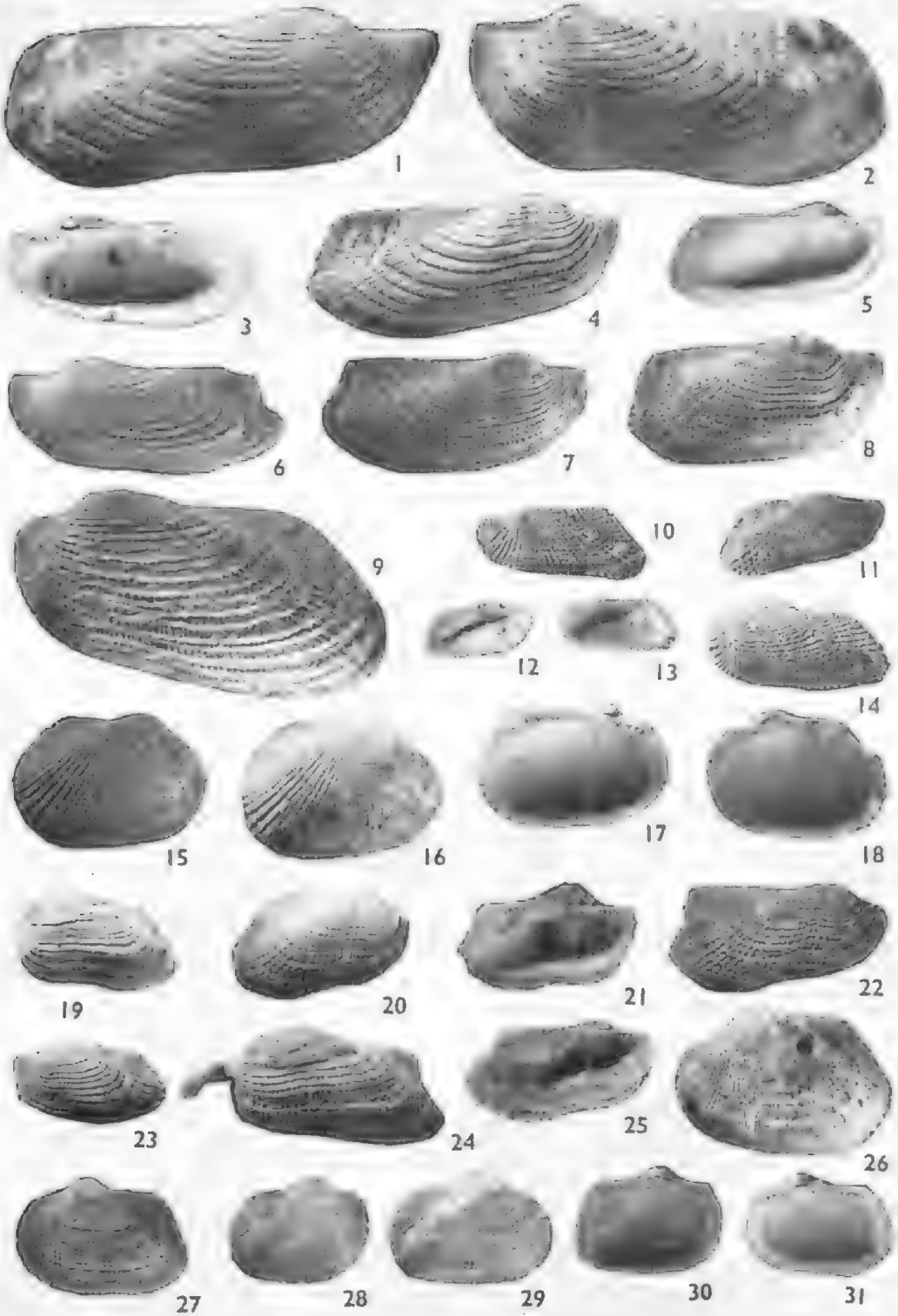
15. Lectotype T1052D, right valve; Muddy Creek Marl, Muddy Creek. X 3.
16. Paratype T1052F; Muddy Creek Marl. X 3.
17. Paratype T1052J; Muddy Creek Marl. X 3.
18. Paratype T1052K; Muddy Creek Marl. X 3.

19–25 *Barbatia* (*Acar*) *crustata* Tate.

19. Holotype T1061B, left valve; Muddy Creek Marl, Muddy Creek. X 3.
20. Paratype T1060H; Cadell Marl Lens, 4 miles south of Morgan, Batesfordian. X 3.
21. Paratype T1061F; Muddy Creek Marl. X 3.
22. Paratype T1060A; Gellibrand Marl, Gellibrand River, Bairnsdalian. X 3.
23. Paratype T1060J; Cadell Marl Lens. X 3.
24. Paratype T1061E; Muddy Creek Marl. At the anterior end is an attached foraminifer *Carpenteria proteiformis* Goës. X 3.
25. Paratype T1060B; Gellibrand Marl, Gellibrand River. X 3.

26–30 *Arcopsis dissimilis* (Tate).

26. Paratype T1059B, left valve; Blanche Point Marls, either at Aldinga or their equivalents in Kent Town Bore. X 4.
27. Syntype T1059D, left valve; 28. Syntype T1059L, right valve, Kent Town Bore, Upper Eocene. X 3.
29. Paratype T1059N. X 3·3.
30. Paratype T1059R. X 3·3.
31. Paratype T1059S. X 3·3.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PATTERNS IN SOIL GEOGRAPHY IN AND NEAR ADELAIDE, SOUTH AUSTRALIA

BY C. B. WELLS

Summary

The pattern of distribution of the soils near Adelaide, and the kinds of soils, are shown to be generally quite orderly and consistent with the solid geology.

Two aberrant cases not conforming with solid geology are the black clay soils and the coastal calcimorphic soils. The clay soils are shown to be related to a Tertiary plain as elucidated in the Barossa district, and the calcimorphic soils require the postulate of calcium carbonate accession from an unspecified external source.

PATTERNS IN SOIL GEOGRAPHY IN AND NEAR ADELAIDE, SOUTH AUSTRALIA

by C. B. Wells

[Read 10 June 1965]

SUMMARY

The pattern of distribution of the soils near Adelaide, and the kinds of soils, are shown to be generally quite orderly and consistent with the solid geology. Two aberrant cases not conforming with solid geology are the black clay soils and the coastal calcimorphic soils. The clay soils are shown to be related to a Tertiary plain as elucidated in the Barossa district, and the calcimorphic soils require the postulate of calcium carbonate accession from an unspecified external source.

INTRODUCTION

In putting together at one scale with an unified interpretation the soil maps made over the years* for Adelaide and its environs (Wells, 1961) it became evident that the soil pattern could be schematically expressed quite simply, as in Map 1, and thence interpreted to reveal some major factors in local pedogenesis.

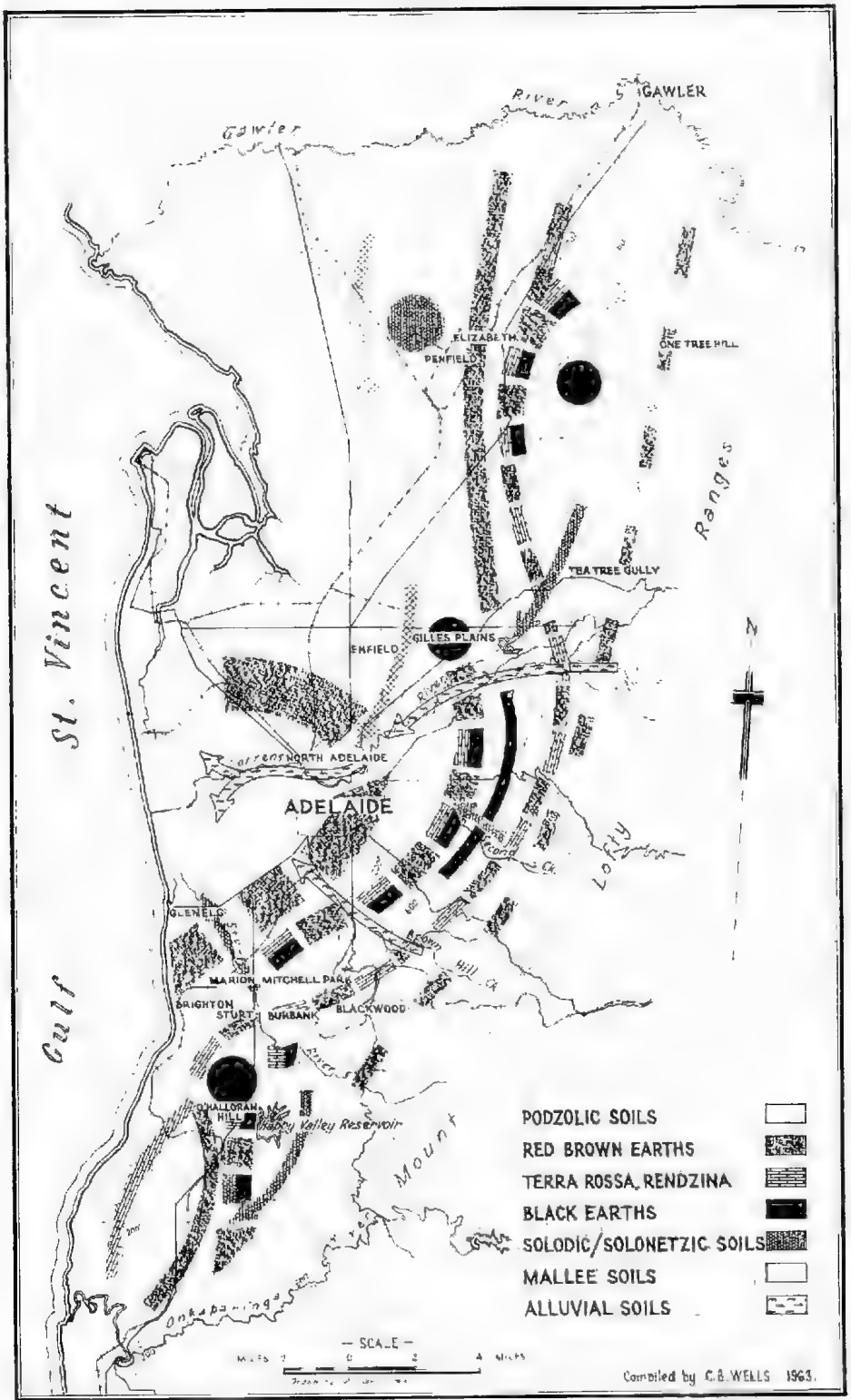
GENERALIZED PATTERN OF SOILS

The pattern may conveniently be described by dividing the map into three parts, the central area around the city and inner suburbs of Adelaide, a northern and a southern portion.

To generalize for the Adelaide area, an arc of red brown earths is surrounded on the landward side as far as the foothills by another arc of red brown earths and terra rossas intermingled with black earths and rendzinas. In the Gilles Plains area this latter is replaced by an isolated unbroken expanse of black-earth-like soils. Up into the foothills there is another arc of red brown earths and terra rossas, then red brown earths and podzolic soils. Finally there is a line of podzolic soils along the main backbone of the Mount Lofty Ranges. The tidy concentric distribution is interrupted by three radially distributed and completely different kinds of soils; solodic soils cut across the system at Marion and Stonyfell, alluvial soils follow the radial paths of the Torrens River and Brown Hill Creek, and mallee soils come in through Enfield and North Adelaide.

Extending the generalization from Adelaide to Gawler, the soil distribution has a more linear pattern, conforming to the lineation of the Para fault. On the coastal side through the Penfield area, solodic soils occur, then toward the hills there are bands first of red brown earths only, then of red brown earths with terra rossa and alluvial soils at the base of the hills, red brown earths, terra rossas and rendzinas up into the hills, then red brown earths and podzolic soils further up, and finally podzolic soils in the highest parts. These are all continuations, more or less, from the Adelaide area, except that again the regularity of the pattern is interrupted by an isolated extensive occurrence of black earths. It is on a high plain south west of One Tree Hill, and its influence can be seen to have extended beyond its present limits coastwards as far as the Town Centre at Elizabeth by the appearance of black earths and rendzinas in the

* See Aitchison, Sprigg and Cochrane, 1954; Litchfield, 1951, 1960; Northcote, 1960; Specht and Perry, 1948; Ward, 196-; Wells, 1961.



Map. 1. The general pattern of soils distribution in and near Adelaide, South Australia

otherwise continuous are of red brown earths and terra rossas. Again, as at Adelaide, there is through Tea Tree Gully a prominent transgression of solodic soils across the general lineation.

South from the Adelaide area to the Onkaparinga River, the red brown earth arc runs out to the coastline between Glenelg and Brighton. In contrast to this, the mixed red brown earth and terra rossa band, after continuing in the same general line from the Adelaide area, crosses the hills near Sturt, and then bifurcates into terra rossas along the coast and red brown earths inland. The podzolic and red brown earth zone continues straight through from the Adelaide area to run along the high country southwards through Blackwood. The red brown earth-terra rossa-black earth-rendzina arc turns south at Mitchell Park and is lost at the base of the hills below Burbank. However, it re-appears in the same line on the opposite side of the hills where the black earths are in concentration in the O'Halloran Hill-Happy Valley area, as at Gilles Plains, and extends southwards in a line from there as a mixture of black earth and solodic soils. It is a repetition of the situation south west of One Tree Hill. With the juxtaposition of the mixed red brown earth-terra rossa-black earth-rendzina arc and the red brown earth-terra rossa arc are where they cross over in the Burbank-Darlington area, the red brown earth-podzolic soil band is now separated from the mixed red brown earth-terra rossa-black earth-rendzina band by a band of solodic soils derived from arenaceous Tertiary sediments stranded at the back of the fault block. Except that here the solodic soils do not transgress the general lineation, it is a repetition of the situation at Tea Tree Gully.

GENERALIZED PATTERN OF GEOLOGY

Treatment of the geology of the area in a manner similar to that used for the soils reveals a pattern, Map 2, not unlike the soil pattern. In broad terms, the various pre-Quaternary rocks (excluding quartzites) and sediments have been rated as giving rise to arenaceous, argillaceous (including arkosic), calcareous, or magnesic parent materials as in Table 1. The Quaternary sediments have been collected into one alluvial/aeolian group.

TABLE 1.

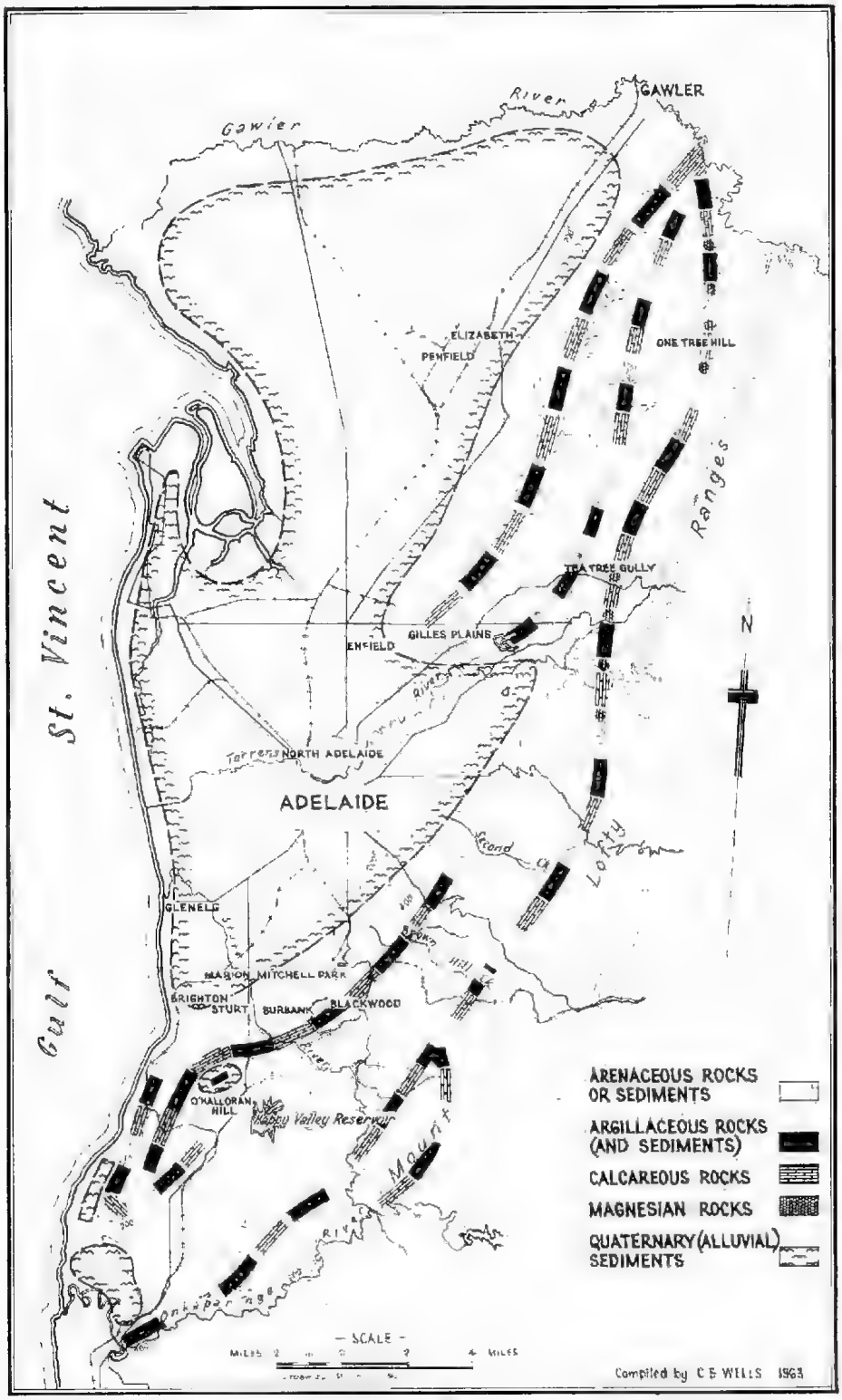
The nature of Adelaide System and Tertiary sediments* as soil parent materials at Adelaide.

Era	Formation	Characteristics as soil parent material
Archaean		Arenaceous
Proterozoic	Aldgate sandstone	Arenaceous
	Torrensian	Argillaceous, calcareous in parts, arenaceous, magnesic
	Sturtian	Argillaceous, calcareous
	Marinoan	Arenaceous, argillaceous, calcareous
Tertiary		Arenaceous and/or argillaceous

DISCUSSION

Red brown earths occur over a large proportion of the area, and therefore in a rainfall regime rising from 17 inches to 27 inches per annum, and on a

*Interpretation of legends accompanying S.A. Dept. of Mines, Geological Survey of South Australia, Sheets Gawler (1953), Adelaide (1951), Echunga (1954) 1:63,360.



Map 2. The general pattern of geology in and near Adelaide, South Australia.

variety of parent materials both separately as in the hills, and mixed together as on the alluvial plains. They thus establish themselves as being the normal soil under the general local conditions for pedogenesis.

As far as the hills are concerned, rainfall and solid geology are so distributed as to reinforce each other in producing soils other than red brown earths at the extremes. The maps show that podzolic soils predominate in the wetter more arenaceous high country, and that calcimorphic soils increase notably in the drier less arenaceous more calcareous parts. The exception geologically in the southern corner will be discussed later. The two extensive occurrences of arenaceous Tertiary sediments near Tea Tree Gully and Happy Valley are similar geologically and topographically and happen to occur in the same general rainfall regime. They both produce solodic/solonetzic soils.

The geological map shows two areas of unusually prominent magnesite development. The arenaceous Tertiary sediments with their solodic/solonetzic soils near Tea Tree Gully are adjacent to one and the other runs across the head of the drainage system that issues westwards through Elizabeth to where, again, solodic/solonetzic soils have formed. It could reasonably be argued that the same magnesitic influence might be present in the Stonyfell and Marion areas of solodic/solonetzic soils, even though published geological maps do not make a point of showing magnesites as such in those parts of the Torrensian Series drained by either Second Creek or Sturt Creek. However this argument, though by no means excluded, is very much less potent in its application to the catchment area upslope from the arenaceous Tertiary sediments east and south of the Happy Valley reservoir.

It seems then that the arenaceous Tertiary sediments preferentially produce solodic/solonetzic soils. Though the outwash from magnesite rich areas produces similar solodic/solonetzic trends in proluvial sediments which would otherwise give rise under Adelaide conditions to red brown earths, there is no conclusive field or experimental evidence that the magnesium ion plays a determinative part in solodic/solonetzic pedogenesis.

The alluvial soils shown on the map follow the main drainage lines as usual and require no further explanation.

Two outstanding features remain, however, unexplained by the solid geology, rainfall, or topography. They are the black soils and the coastwards extension of calcimorphic soils.

The black soils

The black soils have a very precise distribution and relationship to the landscape. In the immediate environs of Adelaide they are for the most part appressed as a thin band against the base of the hills scarp. Here, their most general development is at about the 600 ft. contour level, and they occur less continuously down slope to about 200 ft. As noted earlier in the paper they completely disappear on the slopes above Mitchell Park, to re-appear as a concentrated mass on the O'Halloran Hill plain at a height of 600 ft. Again they occur downslope from here mixed in with local sedentary soils. Moving now to the opposite side of Adelaide, their northern occurrence on the small plain south-west of One Tree Hill is at a slightly higher elevation at 800 ft. and once more they are mixed in with other soils downslope as shown on Map 1. This higher elevation is, however, not an isolated occurrence. Another plain, almost identical in form and soil morphology occurs at about 850 ft. as the Gomersal plain twenty miles further north-west.

Using soils evidence as proposed earlier (Wells, 1963) there appears to have been a similar plain at the present 900 ft. contour level at Rhynie, 40 miles north of One Tree Hill, and another in the south at 600 ft. at Seaview, 8 miles south of O'Halloran Hill (Ward, 196-).

It would appear then that this evidence from different places many miles apart is in good agreement with the evidence studied in detail in the Barossa district (Wells, 1963), where the black soils were shown to have had their origin in an extensive late-Tertiary clay plain.

The remarkable 600 ft. conformity in elevation of the highest extensive occurrences of black earths south of Adelaide, the 200 ft. jump in their elevation at One Tree Hill, and its gentle rise northwards from Adelaide suggest post Tertiary fault activity east of the Para fault to the north of Adelaide compared with marked stability in the south, or else two late or post Tertiary periods of deposition of remarkably similar clay sediments separated by a period of faulting. There are at present no satisfactory data to establish an identity between the deposits nor to indicate the origin of the very considerable quantities of clay involved in the construction of the postulated extensive plain or plains.

The calcimorphic soils

The terra rossa and rendzina soils in the hills could conceivably be accounted for by the calcareous nature of the underlying rocks. Downslope from them there is in the north a band of red brown earths, then solodic/solonetzic soils. Further coastwards there are highly calcareous mallee soils. In the Adelaide area there is a considerable widening of the terra-rossa rendzina zone and in the south the partly arenaceous Marinoan sediments which might be expected to produce red brown earths as others do, in fact have terra rossas and rendzinas on their coastal leg. Such calcareousness in these places seems beyond the ability of the Precambrian rocks to have supplied, so an external source must be postulated. Evidence and theories on the subject have been extensively reported elsewhere, and need not be elaborated further (Crocker, 1946; Ward, 196-). The position of the terra rossas and rendzinas in the landscape demands that the calcareous accession must have been considerably later than the accumulation of the black clay.

CONCLUSIONS

There is a nice enough accord between the geology of the area as shown on Map 2 and the general distribution of podsolic soils, red brown earths, terra rossas, rendzinas and alluvial soils as shown on Map 1 to argue that the soils have arisen from the particular rocks without the intervention of any other factor or process. However, some other mechanism must be adduced to account for the black earths and some of the calcimorphic soils. The solution adopted here has been to postulate a late Tertiary or early Quaternary clay plain being formed, and an even more recent accession of calcareous material over at least the coastwards parts of the landscape.

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Map 2 was compiled by C. B. Wells from Geological Survey of S.A., Department of Mines, Adelaide maps: Gawler 1" = 1 mile (1953). Adelaide 1" = 1 mile (1951). Echunga 1" = 1 mile (1954).

LATE CAINOZOIC SEDIMENTATION IN NORTHERN SPENCER GULF, SOUTH AUSTRALIA

BY J.B. FIRMAN

Summary

Because of its unique position, fronting the Southern Ocean, the southern margin of the Australian continent provides many situations where the relationships between superposed or juxtaposed marine, transitional and continental deposits and associated land surfaces can be worked out. One of these situations in the South Australian portion of the southern continental margin is examined.

Sediments of Late Cainozoic age were deposited in a compound rift which now contains Spencer and St. Vincent Gulfs and Lake Torrens.

Two sequences of clay, gravel and sand appear in a bore at the head of Spencer Gulf: CL lower sequence at least 300 feet thick, which is correlated with sediments of known Tertiary age in the St. Vincents Basin, and 'in upper sequence laid down in a piedmont-valley &it environment, which is correlated wit11 the "Pleistocene mottled clays" near Adelaide. Above the upper piedmont-valley flat deposits is a sequence of Anadara-bearing limestone, clay and sand laid down in littoral and marine gulf environments.

It is suggested that a strong regression of the sea occurred after deposition of the Anadara-bearing limestone and that one of the features marking the regression is a lime-cemented crust on the shelly limestone, which can be traced shoreward to A limy crust in gravelly soil. The soil crust, or kunkar, is tentatively equated with the kunkar in Bakara soil of Plate Pleistocene age in the Murray Basin.

Quaternary events are reconstructed and related to soil and landscape development. Two marine ingressions and two regressions are inferred from vertical changes in lithology and from littoral deposits marking earlier positions of the strandline.

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by J. B. Firman

[Read 10 June 1965]

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INTRODUCTION

The southern margin of the Australian continent spans 36 degrees of longitude or about 2,400 miles measured along the 35th parallel. Much of Late Cainozoic geological history in the Southern Hemisphere is recorded in the sedimentary basins, or on the massifs between the basins, by weathered rocks, soils, sediments and landforms. There are many situations near the southern coast where correlation between marine deposits of the ocean basins, transitional and continental deposits, and land surfaces can be worked out. Shifts in the strand and fluctuations in environment consequent upon the profound climatic changes of the Quaternary are recorded here also.

Many of the marine, transitional and continental deposits, together with their related land surfaces are superposed or juxtaposed in the South Australian portion of the continental margin.

The sediments described in this paper were deposited in a compound rift which occupied much the same area as the present Spencer and St. Vincent Gulfs and the low-lying tract extending northwards through Lake Torrens, (see Locality Map—Fig. 1). Lithofacies and structural details set out in bore logs and on Geological Survey maps clearly show that the rift, a second order geomorphic feature, was well developed in early Tertiary Time.

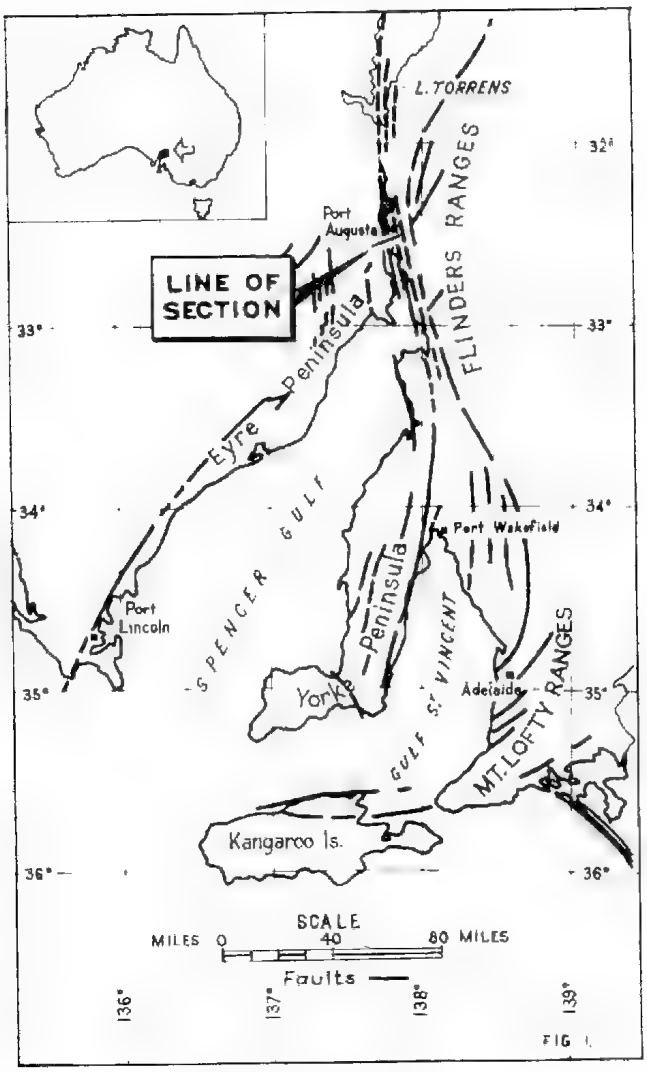


Fig. 1. Locality Map.

TECTONISM

The horst and grabens and associated faults within and bounding the rift have been discussed in a general way by Fenner, 1930, and others, and in some detail with reference to specific areas by Miles, 1952 and Campana, 1955. The more prominent faults are shown on Fig. 1, after Johns, R. K. (1964). Thomson (1965) stresses the oscillation of fault blocks as an important tectonic feature as early as the Precambrian. Early marginal faults were covered by later Tertiary deposits. Major faulting ceased at the end of the Pliocene, although displacement on some faults continued into the Pleistocene. Epeirogenic uplift of at least 200 feet since mid-Tertiary time can be demonstrated for the area as a whole, with uplift increasing in the Mt. Lofty Ranges (amounting to 600 feet in the Mt. Lofty Ranges in Late Pliocene times, according to Glaessner and Wade in Glaessner, M. F. and Parkin, L. W., 1958).

PROVENANCE

Much of the terrigenous material in Tertiary and Quaternary sedimentary sequences in Spencer Gulf is derived from older Precambrian metamorphics and younger Precambrian to Lower Palaeozoic sediments of the Mt. Lofty-Flinders Ranges and Yorke and Eyre Peninsula massifs. At the head of Spencer Gulf, coarser clastics in Quaternary deposits can be traced to known rock units of the adjoining ranges. East of the section, in the Flinders Ranges, peaks rise to 3,174 feet above sea level at Mt. Brown. West of the section, the Arcoona Plateau (Johns, op. cit.) has a general elevation of about 600 feet with monadnocks rising to over 1,000 feet above sea level.

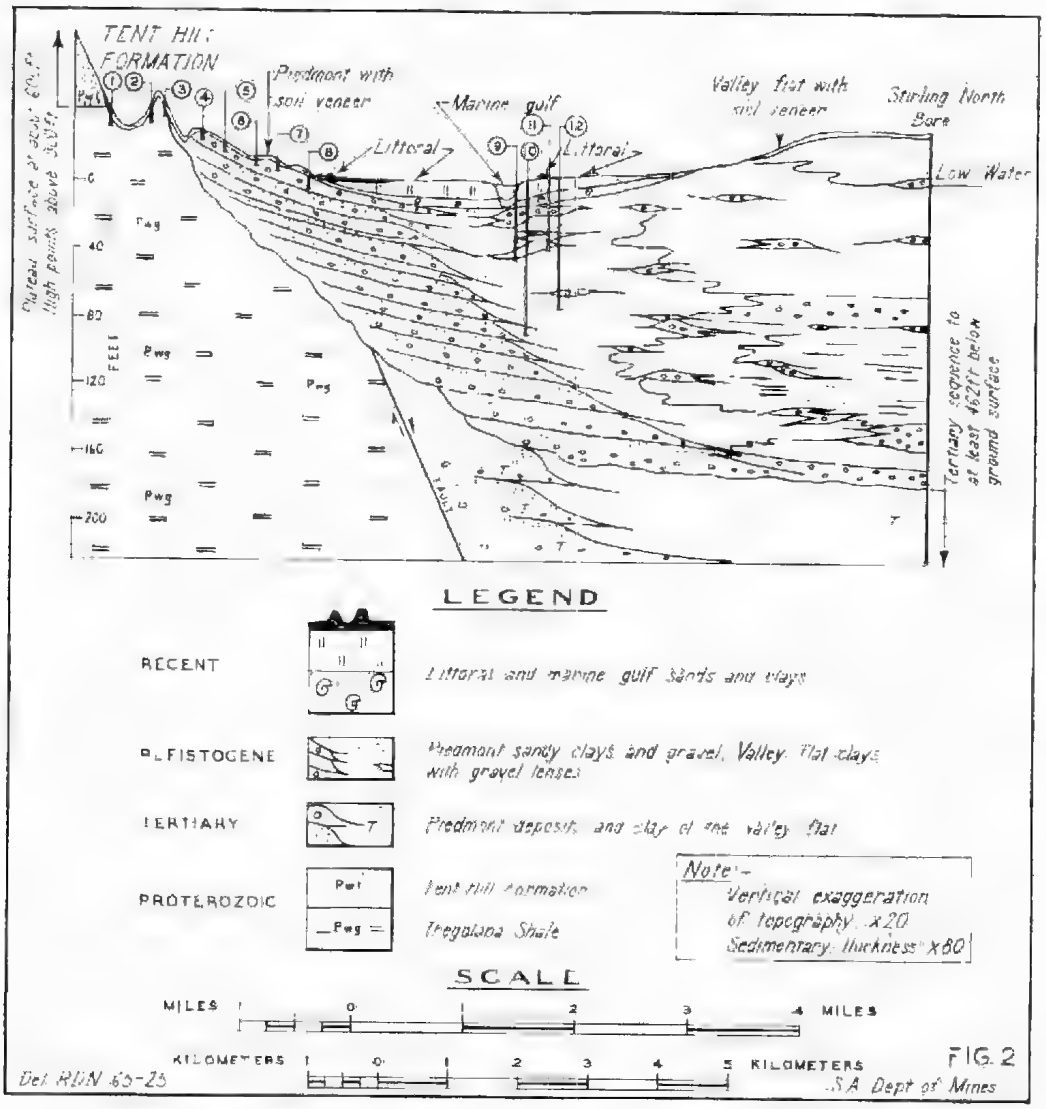


Fig. 2. Diagrammatic structure section, Spencer Gulf, South Australia. For details from Bore 1 to Bore 12 see Fig. 3. Note that the shell-bearing sediments shown in the upper block in the legend are taken to be Late Pleistocene in this report.

SEDIMENTS AND TIME BOUNDARIES

At least 462 feet of ?non-marine sediment are known from an abandoned bore at the head of Spencer Gulf near Port Augusta (Hullett, 1882). The materials described can be divided into two sequences; a distinctive 150-200 feet thick upper sequence of clay with sand and gravel lenses and with limy B horizons of fossil soils in a piedmont-valley flat environment, and a lower sequence of white, blue, yellow and black[1] clays, gravels and sands, at least 300 feet thick, which contains lignitic clays and carbonaceous sands (see Fig. 2). The upper sequence is correlated with the "Pleistocene mottled clays"[2] near Adelaide on the basis of lithology, environment and occurrence within connected morphostratigraphic units as defined in Frye and Willman (1962). The lower sequence is correlated with sediments of known Tertiary age in the adjoining St. Vincents Basin on the basis of colour, lithology and carbonaceous material.

A thin sequence of littoral and marine gulf deposits overlies the upper piedmont-valley flat clay with sand and gravel lenses. The sequence contains shelly limestone with *Anadara trapezia*, silty clay with plant fibre and shelly sands of the beach ridges and shallow channels. The top of the shelly limestone is strongly lime-cemented and this feature can be traced shorewards through littoral shelly granule and pebble conglomerates to a limy crust in gravelly soil (see Fig. 3).

The Pliocene-Pleistocene boundary in this area may be deeper than the base of the piedmont-valley flat deposits. This is suggested by comparison with similar sequences near Adelaide in the St. Vincent Basin. Here Ludbrook, 1963, may be interpreted to show that if " . . . the extinction of warm-water Yatalan fauna" represents "the onset of colder conditions at the end of the Pliocene", then a sandy sequence 150 feet thick occurs between the marine Dry Creek Sands of Pliocene age and the overlying piedmont-valley flat deposits of Pleistocene age ("Pleistocene mottled clays").

The Pleistocene-Recent boundary has not been precisely determined in the section area, but the lime-cemented top of the *Anadara*-bearing limestone is now thought to have formed at the same time as a calcareous crust ("Kunkar") which is a fossil 'B' horizon in adjacent gravelly and brown soil. The kunkar in this area may be equivalent to the kunkar in Bakara Soil (Firman, 1964), which is thought to be of late Pleistocene age. Materials stratigraphically above the crust or lime-cemented top of the *Anadara*-bearing beds are taken as Recent in this report. Radiocarbon dating, proposed for materials from this area, may help to place the time boundary and will also provide important information on the time of strandline movements in Spencer Gulf.

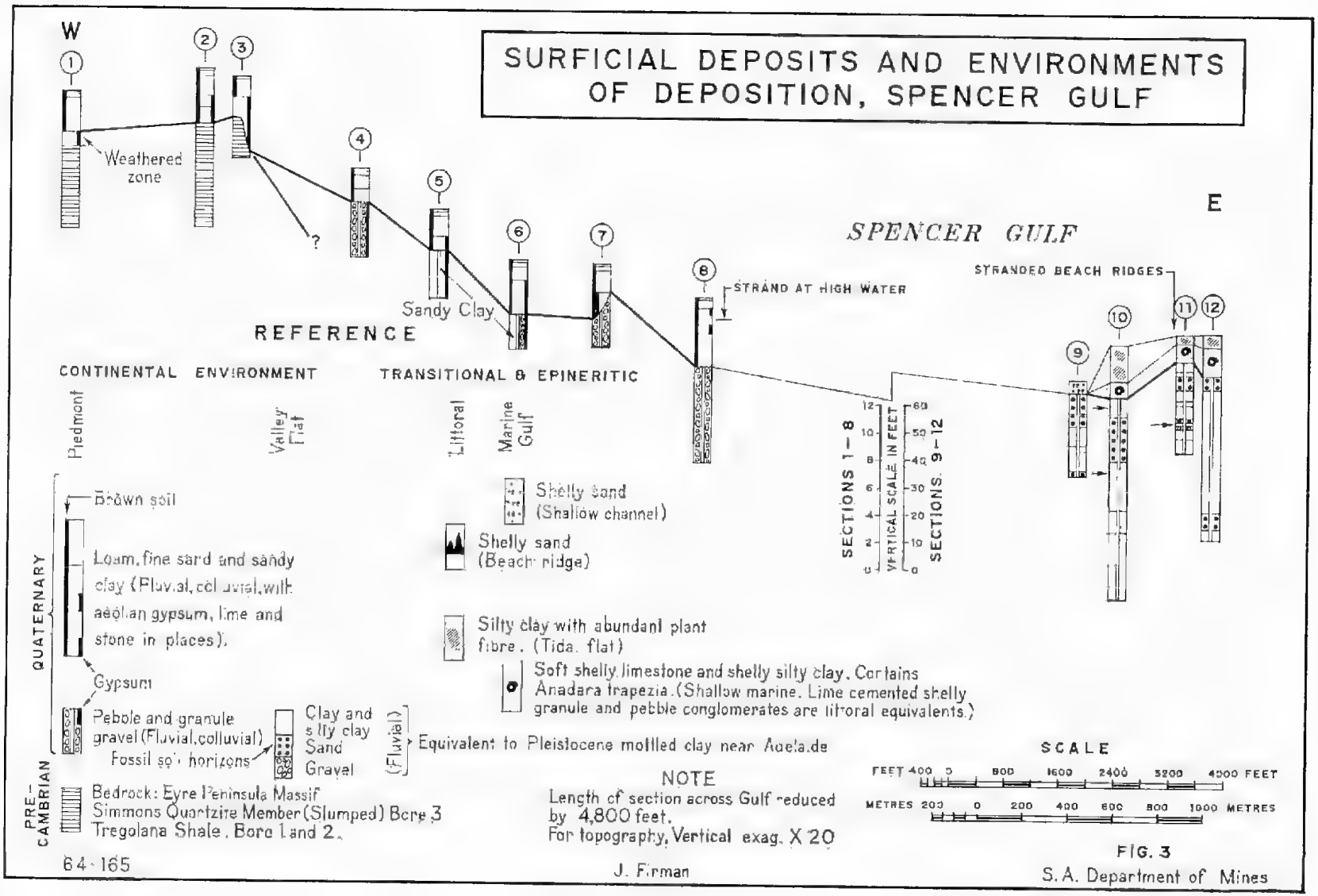
QUATERNARY EVENTS

Quaternary geological events begin with deposition of clays, sands and gravels in the rift, coarser clastics of the piedmont facies on the margin near the massifs and valley flat deposits in the rift centre.[3] The topographic profile can be reconstructed to show that the upper surface of this sequence was as much as 180 feet above the present floor of the gulf. That is, about 180 feet of the sequence has been removed by erosion prior to marine ingression. The Gulf now lies west of the old rift centre (Fig. 2). The asymmetry may be due, in part

[1] Colours from original log.

[2] Informal name in common use in South Australia.

[3] The sedimentary sequence here described is much the same as the sequence near Adelaide in the St. Vincent Basin (see Firman, 1963).


SURFICIAL DEPOSITS AND ENVIRONMENTS OF DEPOSITION, SPENCER GULF
W
E
SPENCER GULF
STRAND AT HIGH WATER
STRANDED BEACH RIDGES
Weathered zone
Sandy Clay
REFERENCE
CONTINENTAL ENVIRONMENT
TRANSITIONAL & EPINERITIC
Piedmont
Valley Flat
Littoral
Marine Gulf
SECTIONS 1 – 8
SECTIONS. 9 – 12
VERTICAL SCALE IN FEET
Brown soil
Loam, fine sand and sandy clay (Fluvial, colluvial, with aeolian gypsum, lime and stone in places).
Gypsum
Pebble and granule gravel (Fluvial, colluvial)
Fossil soil horizons
Clay and silty clay
Sand
Gravel
(Fluvial)
Equivalent to Pleistocene mottled clay near Adelaide
QUATERNARY
PRE-CAMBRIAN
Bedrock: Eyre Peninsula Massif
Simmons Quartzite Member (Slumped) Bore 3
Tregolana Shale. Bore 1 and 2.
Shelly sand (Shallow channel)
Shelly sand (Beach ridge)
Silty clay with abundant plant fibre. (Tidal flat)
Soft shelly limestone and shelly silty clay. Contains Anadara trapezia. (Shallow marine. Lime cemented shelly granule and pebble conglomerates are littoral equivalents.)
NOTE
Length of section across Gulf reduced by 4,800 feet.
For topography, Vertical exag. X 20
SCALE
FEET 400 0 800 1600 2400 3200 4000 FEET
METRES 200 0 200 400 600 800 1000 METRES
64-165
J. Firman
FIG. 3
S.A. Department of Mines

to westward tilting of the fault block below the gulf. A reconstruction of topography immediately prior to the ingression and deposition of the *Anadara*-bearing beds on the gulf floor can be made by connecting the tops of marine cliffs near the present strand. At this time the upper surface of the piedmont-valley flat deposits was 25 feet above the present floor of the gulf (about 13 feet above L.W.O.S.T.). A feature of interest at the present top of the unit is the presence of abundant massive crystalline gypsum indicating that here, as elsewhere in Australia during this part of Quaternary time, sulphates were being deposited in drying playas.

Marine ingression, the first such event recorded here in the Tertiary-Quaternary sequence, is shown by soft shelly limestone and shelly silty clay ("marl") containing *Anadara trapezia*. Outcrops of the littoral equivalent of this unit are found well above the high tide mark and inland behind ridges of beach gravel that barred old stream channels during this early high strand of the sea. The vertical position of materials in this area suggests a stand about 10 feet above L.W.O.S.T., but similar materials elsewhere are found higher in the landscape (up to 25 feet above L.W.O.S.T. near Pt. Wakefield). Stranded marine cliffs may have been first formed at this time.

Regression led to strong incision of streams, with erosion of the upper clays and gravels near the ranges, and a first accession of lime here at the base of the brown soil profile. The top of the exposed *Anadara*-bearing limestone was cemented by lime. Similar lime-cemented materials are known from the floor of Gulf St. Vincent 70 feet below sea-level, suggesting that this was a major regression. The later development of the brown soil is due to sedimentary layering and soil differentiation (see Fig. 3).

A return of the sea, bringing a tidal flat environment to the Gulf margin, led to deposition of silty clay with abundant plant fibres. This early phase of the ingression was succeeded by a high stand of the sea of perhaps five feet, which is marked elsewhere along the gulf margins by shell beds.

Coarse shelly sand of the stranded beach ridges marks a later regression. The formation of a deep off-shore channel, as shown on the east side of the section, also marks a low stand of the sea, perhaps slightly below modern sea level. Similar features are well developed at other places along the South Australian coast, near Port MacDonnell for example, where they connect an older and higher littoral environment with the modern coast. In some places surface drainage was restricted and evaporation reached the stage of halite precipitation.

Modern streams have breached the old gravel bars of the 10 ft. sea level. Modern deposits are alluvial sands and gravels of the present stream courses, dune sands formed by aeolian working of stranded beach ridges, granule and pebble beds forming beaches in the present littoral zone, and the shelly sands and silts of the gulf floor and the off-shore channels.

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Information derived from surveys by the writer along the route of the Port Augusta-Eucla telephone link and the Port Augusta-Whyalla power line has been combined with data from unpublished Geological Survey reports made by K. R. Miles and G. F. Whitten (Site investigations at the Port Augusta power station) and L. Keith Ward (Foundation investigations at the Port Augusta bridge site).

Thanks are due to Dr. N. H. Ludbrook and Mr. B. P. Thomson for helpful criticism of the text.

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GROWTH RING CHARACTERISTICS IN AN ARID ZONE CONIFER

BY R. T. LANGE

Summary

Growth rings in logs of Callitris coluniellaris F.v.M. from near Woomera have been studied, and some of their characteristics correlated with features of rainfall records. Evidence is presented that these trees produced about one ring per year, in some years more and in some years, none.

GROWTH RING CHARACTERISTICS IN AN ARID ZONE CONIFER

by R. T. Lange[1]

[Read 12 August 1965]

SUMMARY

Growth rings in logs of *Callitris columellaris* F.v.M. from near Woomera have been studied, and some of their characteristics correlated with features of rainfall records. Evidence is presented that these trees produced about one ring per year, in some years more and in some years, none.

Callitris columellaris F.v.M. is an Australian coniferous tree. It ranges widely[2] throughout Australia, and extends into arid regions, where it usually grows in stands limited to local niches, but is sufficiently abundant on some sheep stations to provide logs and rails for buildings and yards. In March, 1965, three trees felled for posts were observed near "The Pines" station, 10 miles east of Woomera in central South Australia. They were of matched size, from the same stand, and appeared approximately contemporaneous. Transverse sections were taken from their butts, and growth ring characteristics examined in these arid zone conifers which grew in an area where average rainfall is less than 7 inches per year (Table 1).

Table 1

Mean monthly rainfall at Pimba, South Australia, over a 30-year period (1931-61).

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
0·66	0·98	0·43	0·39	0·62	0·61	0·49	0·57	0·41	0·61	0·52	0·47	6·76

(*Data from C.B.M. records*)

In the laboratory, the sections were ground flat then polished. Observed stereoscopically at 40X magnification, growth rings were clearly observable, the three trees exhibiting 77, 83 and 90 respectively. All sections were eccentric, so band widths were measured along the maximum radius. Fig. 1 presents band-width data.

Each band-width graph shows two sorts of fluctuations, a basal type fluctuating over widths up to about 3 mm., with a mean about 1·5 mm., and superimposed on this, outstanding amplitudes at three positions *a*, *b* and *c*. The characteristics of these wide-band regions are consistent over all trees. Region

[1] Department of Botany, the University of Adelaide, South Australia.

[2] Mrs. C. Offler[1] has pointed out that this binomial covers specimens described under *C. intratropica* Benth. & Hook. f. (1880); *C. hugelii* (Carr.) Franco (1952) [Synonym—*C. glauca*, Baker & Smith (1908) nom illeg.]; and *C. columellaris* F.v.M. (1866) [Synonym—*C. arenosa* Cunningham, ex Baker & Smith (1910) nom. illeg.]. Although these 3 species are maintained by some authors(e.g. Garden), Blake considers them as a single species with a disjunct distribution.

a consists of two abnormally broad rings separated by one or two very narrow ones. Wide-band region *b* consists of a single spike, on all three graphs. Region *c* is made up of a prolonged succession of widely-fluctuating band widths. This wide-band pattern is expressed, however, over a variable number of rings, from about 55 in tree 1 to about 80 in tree 2. The positions of regions *a*, *b* and *c* centripetally in the growth-ring sequence is approximately the same

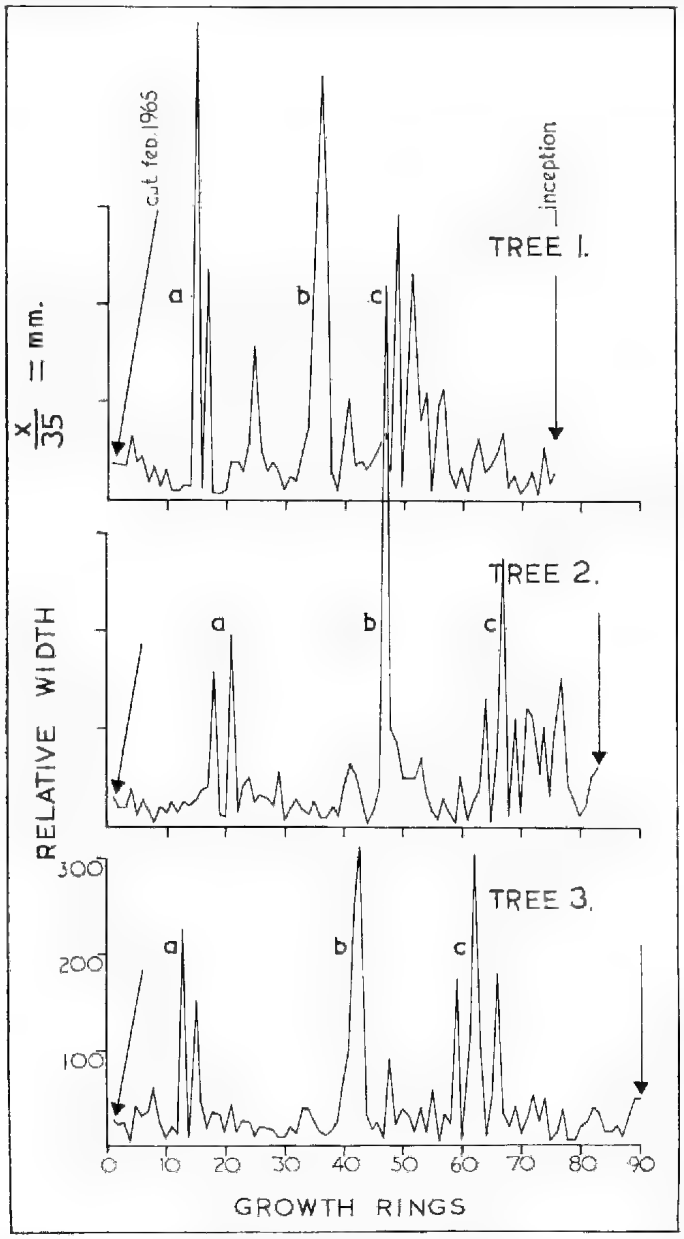

Fig. 7. Widths of successive growth rings in trunks of three *Callitris columellaris* from near Pimba, South Australia. Measurements are in stereomicroscope eyepiece graduations, 35 of which equal one millimeter.

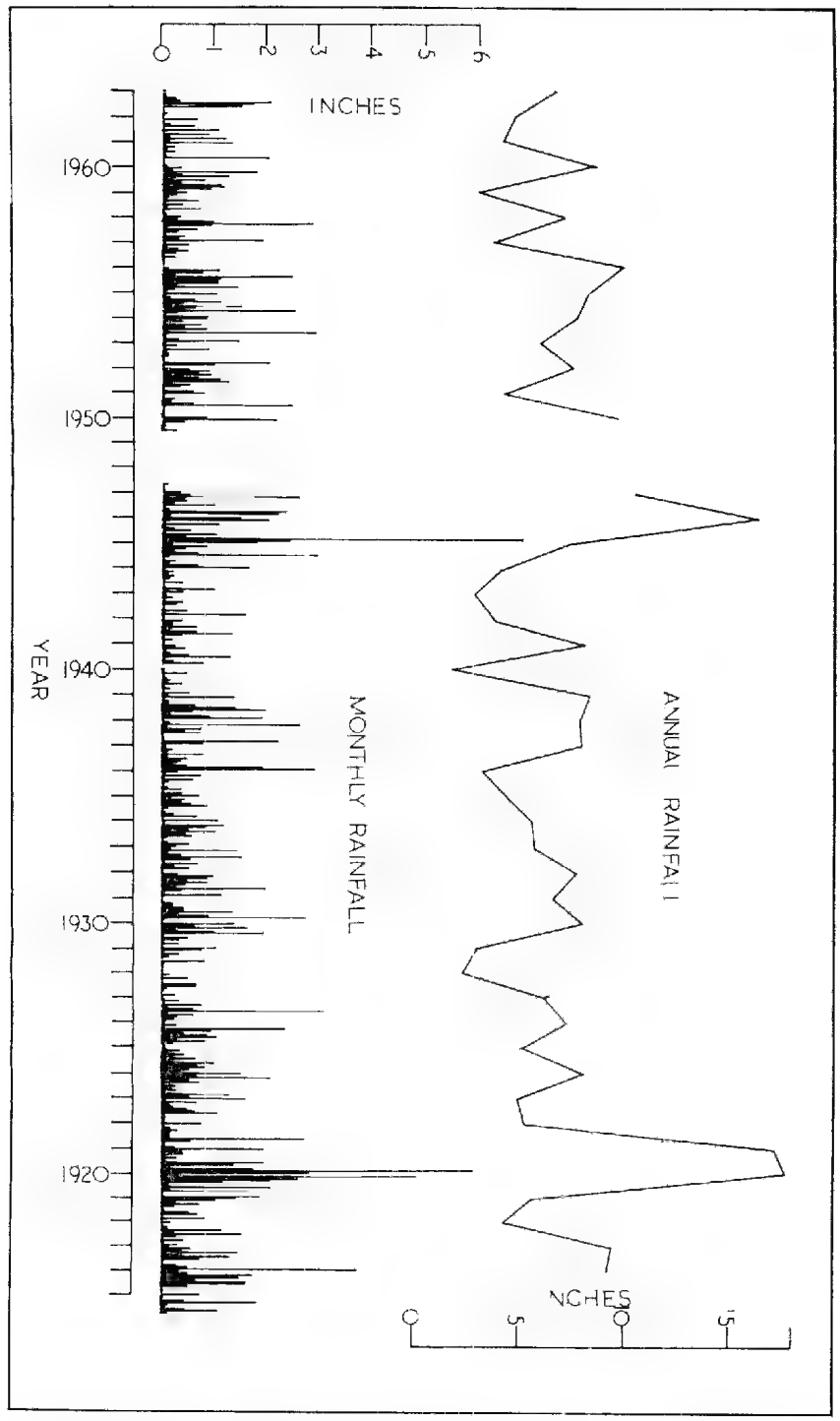

Fig. 2. Total annual and total monthly rainfall recorded at Pimba, South Australia. Data is from C.B.M. records.

but tree 1 (with only 77 rings) has the wide bands crowded abaxially to an extent which brings band *c* of tree 1 close to band *b* position of trees 2 and 3.

If ring width is a response, then Fig. 1 indicates that all three trees have the same history of responses. The extent of agreement between the outstanding aspects of their growth-ring patterns (the same numbers, and kinds in sequence, of broad-band regions) is most unlikely to be fortuitous. However, tree 1 records the broad-band pattern in about 55 rings, while trees 2 and 3 record it in about 75. This implies that these trees from the same area varied in the number of rings produced over the same time.

Correlations may be sought between these tree-ring patterns and any environmental variable for which a history of recordings is available, which limits this account to correlation study of quantitative relationships between rings and rainfall at the nearest rain gauge, which is about 10 miles west at Pimba, where rainfall has been recorded since 1915 (Fig. 2). It is not implied that Pimba rainfall should reflect the Pines rainfall; rather a considerable disparity is expected, but the rare years with outstandingly-high rainfall might be the same for both.

Correlations were sought between ring-width graphs and rainfall graphs over the entire range of both. No precise inter-relationships were apparent. The only plausible correlations were between wide-band position and the years with a monthly rainfall > 4 inches (Fig. 3), or years with a total rainfall > 15 inches. For trees 2 and 3, probabilities of rainfall and ring width characteristics coinciding within the observed ranges (see Fig. 3) appear to be significant, viz.:

Tree 3

$$p = \frac{12}{49} \cdot \frac{5}{49} = 0{\cdot}03$$

Tree 2

$$p = \frac{6}{49} \cdot \frac{7}{49} = 0{\cdot}02$$

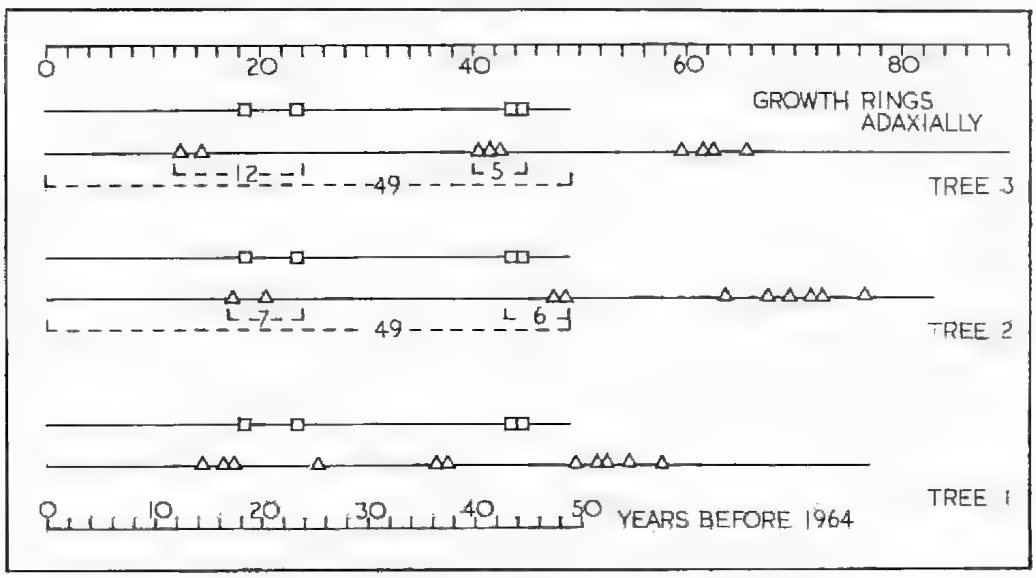

Fig. 3. Correlation between outstanding widths in the centripetal order of growth rings (△) and years in reverse order from 1964 with a month of rainfall > 4" (□).

The weight of evidence points to an imprecise relationship between broad-bands and wet years, and hence between growth-ring numbers and time in years, that is, growth rings tend to be produced about one per year. An analysis of the broad-ring pattern, however, indicated that the three trees varied by about 20 rings in 80 years, averaging > one per year over some periods (*a* to *b*, tree 1, *o* to *a*, tree 3), and < one over others (*a* to *b*, tree 2). Tree 1 consistently averaged < one, except for the period following 1945, but it is not possible to determine if this tree occupied a less favourable site in the stand. It is obvious, however, that even slight allowance for such irregularity would greatly increase significance in Fig. 3.

Annual periodicity in these trees is hardly relatable to rainfall cycle, because the rainfall regime does not follow a seasonal pattern. Broad-band region *c* appears to constitute an imprecise biological recording of a run of wetter years about 1900, prior to the establishment of the Pimba rain gauge. Old trees in the stand will hold further indications of pre-guage rainfall.

PROCOPTODON GOLIAH (MACROPODIDAE, MARSUPIALIA) FROM WESTERN EYRE PENINSULA, SOUTH AUSTRALIA

BY D. MERRILEES AND W. D. L. RIDE

Summary

Procoptodon goliall (Sthenurinae, Macropodidae) is recorded from the vicinity of Calca, western Eyre Peninsula, South Australia.

PROCOPTODON GOLIAH (MACROPODIDAE, MARSUPIALIA) FROM WESTERN EYRE PENINSULA, SOUTH AUSTRALIA

by D. Merrilees* and W. D. L. Ride*

(Communicated by N. H. Ludbrook)

[Read 12 August 1965]

SUMMARY

Procoptodon goliah (Sthenurinae, Macropodidae) is recorded from the vicinity of Calca, western Eyre Peninsula, South Australia.

INTRODUCTION

Fragments of bones and teeth collected by J. E. Johnson from a well near Calca, on western Eyre Peninsula, were sent to us for examination from the South Australian Department of Mines in November, 1963. The occurrence has been noted previously by Segnit (1938, p. 8) under the general term "numerous fossil bones".

MATERIAL AND LOCALITY

Portion of a molar tooth (Geol. Surv. S. Aust. Palaeontology collection, No. V1), a fairly complete incisor (V3), an incisor fragment (V4), portion of a calcaneum (V5), portion of a (?) cuboid (V6), and about 50 small fragments of bone (collectively V7) were examined. These were recovered from depths between 16 ft. and 26 ft. in well No. 65 north-west of Calca Hill, east of Beard's Bay, Section 87, Hundred of Wrenfordsley, County Robinson. The occurrence is described by Segnit (1938), who reports that bones were recovered from a yellowish calcareous very sandy clay also containing fragments of shells, overlain by 13½ feet of travertine limestone and calcareous sandy clay.

DESCRIPTION AND COMPARISONS

Dental terminology used below follows Ride (1961) and Ride (1964).

V1 appears to be the anterior portion (trigonid, i.e. protolophid and paraconid, with associated midlink and "cingulum") of a right M_3 or M_4 tooth of *Procoptodon goliah* Owen. Owen described and figured a specimen (now Brit. Mus. M 1897—see Lydekker, 1887) from Queensland (Owen, 1874), of which we have a plaster cast (W. Aust. Mus. 62.8.18) and a photograph, and V1 has been compared with these. There are some minor differences in the relation of the midlink to the edges of the protolophid, and in the height of the anterior "cingulum" relative to the paraconid (see Plate 1). However, we have no hesitation in ascribing V1 to *Procoptodon goliah*.

V3 is probably an upper left first incisor. All sthenurine I^1 teeth we have seen are rather peg-like, curving teeth with much more enamel on the buccal than on the mesial aspects, and therefore show an enamel margin sloping forward and downward over the convex face of the tooth. These generalizations apply equally to the I^1 teeth of *Thylacoleo*, but in size and in detail of the

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course of the enamel, V3 agrees much more closely with *Sthenurus* (as exemplified in *S. occidentalis* and *S. gilli*) than with *Thylacoleo*. Consequently, we accept V3 as sthenurine, and because of its association with V1, tentatively ascribe it to *Procoptodon*.

The upper incisors of *Procoptodon* are not known with certainty, but Ride (1959) has discussed and figured a rostrum from Wellington Caves, New South Wales, which he ascribes to *Procoptodon*. In general, the incisors of this specimen resemble those of *Sthenurus occidentalis* (see Anderson, 1932) and of *S. gilli* (see Merrilees, 1965), though there are some differences in form and in relative sizes of the components of the incisor row between *S. occidentalis* and *S. gilli* and between either and Ride's *Procoptodon*.

V3 is smaller than one would expect from a macropod with so large a mandible as *Procoptodon goliah*, being little larger than I^1 in the smallest of the Sthenurinae, *S. gilli*, recently described from Strathdownie, Western Victoria and from Haystall Cave, near Naracoorte, South Australia (Merrilees, 1965). However, since the relative proportions of the three incisors within known *Sthenurus* tooth rows differ from species to species, it would not be entirely unexpected for I^1 in *Procoptodon goliah* to be small.

V4 is a fragment probably representing the anterobuccal edge of a large third upper incisor. It shows part of the enamel margin and in this and in the shape of the enamel surface it resembles *Sthenurus occidentalis* Glauert from Mammoth Cave, Western Australia, and a similar animal occurring at Haystall Cave and at Strathdownie (Merrilees, 1965). However, V4 must have derived from a larger tooth than I^3 in any of these three samples of *Sthenurus*. Again tentatively, we refer V4 to *Procoptodon*.

V5 is the antero-dorsal portion of a right calcaneum, in form rather resembling the modern western grey kangaroo, but some 1½ times the linear dimensions of a large adult male grey kangaroo. Owen (1876, Plate 23, Fig. 4) figures, without description, a right calcaneum ascribed by him to *Procoptodon goliah*, but the grounds for this ascription appear to have been that it was "indicative of a hind foot shorter in proportion to its breadth, and yet retaining unmistakable macropodal characters" rather than direct association observed in the field. V5 does not quite match Owen's figure. However, its proportions suggest that it was broader relative to its length than the calcaneum of the modern grey kangaroo, and on these grounds, and because of its association with V1, we refer it tentatively to *Procoptodon*.

V6 may be portion of the cuboid of a large macropod, but we cannot positively identify this nor any of the fragments collectively labelled V7. Many of these fragments obviously derive from a large animal, and thus it is possible that all the fragments examined may represent the same individual specimen of *Procoptodon goliah*.

OTHER OCCURRENCES OF *PROCOPTODON*

Woods (1960) reports *P. goliah* from the Pleistocene Darling Downs deposits, but not from the (?) Pliocene Chinchilla Sand of Queensland. McCoy (1879) records *P. goliah* as "not uncommon" in Victoria, figuring a specimen from Lake Timboon; he listed these occurrences as Pliocene, though apparently they are now taken to be Pleistocene, since neither Gill (1957) nor Stirton (1957) mentions them in discussion of Victorian Tertiary marsupials, while Chapman and Crespin (1935) associate "extinct marsupials" with "volcanic

tuffs and alluvials at Lake Colongulac and Timboon" under "Pleistocene". *Procoptodon* has been reported from Lake Menindee, N.S.W., by Tindale (1955), and by Tedford (1955). A radiocarbon date has been reported for this material, but there is some confusion over its applicability (see Dury, 1964, p. 106, No. 75, and Lundelius, 1963, p. 77 footnote; also Tindale, 1964). Owen himself records *P. goliah* from "the Breccia-cave of Wellington Valley", N.S.W. (Owen, 1874, p. 797).

Simpson (1930) lists *P. rapha* from King Island, probably on the basis of an early record, later amended to *Sthenurus* (see Scott, 1917; Anderson, 1932, p. 383, footnote).

A *Procoptodon* close to *P. goliah* has been reported in the late Pleistocene Malkuni fauna of the Tirari Desert, South Australia, but not in Tertiary faunas, by Stirton, Tedford and Miller (1961). The genus is not known from Western Australia.

Thus *Procoptodon* as at present understood appears to be confined to the Quaternary, and its presence in the Calca deposit supports the Quaternary estimate of Segnit (1938) made from the associated shell fossils and from the field evidence.

ACKNOWLEDGMENTS

We are grateful to the Director of Mines, South Australia, and to Dr. N. H. Ludbrook for the opportunity to examine the specimens described, which are relevant to our own work on the related *Sthenurus*.

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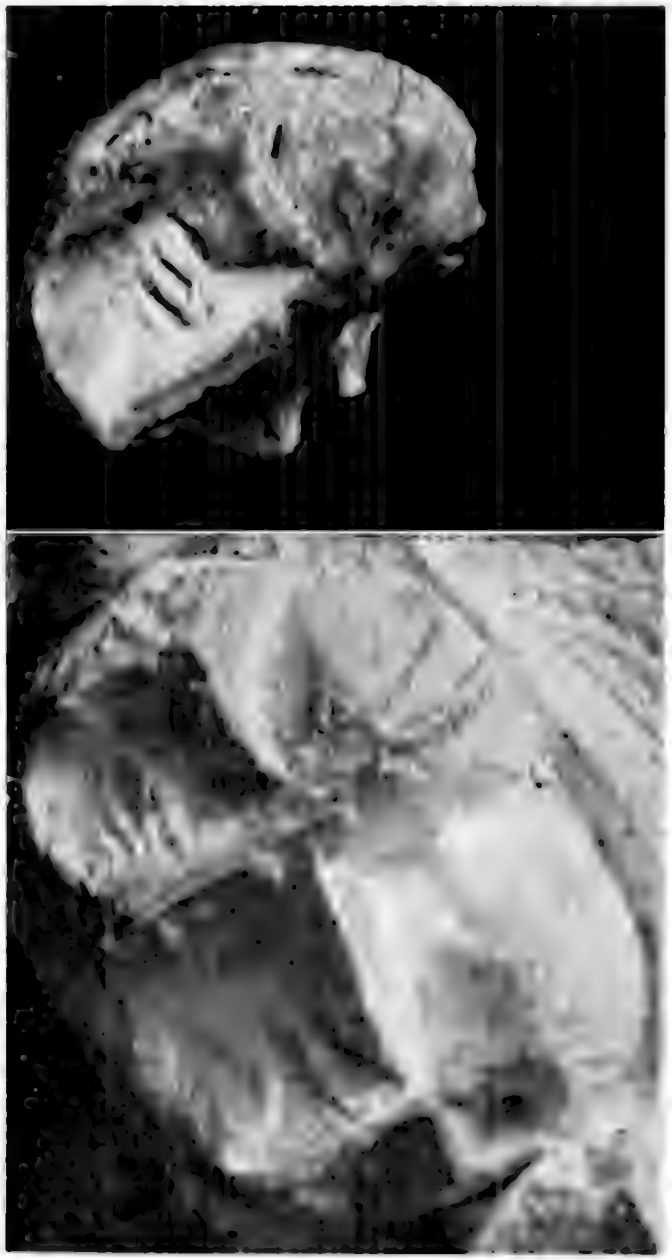


Above: Anterior fragment of a molar tooth from Calca, S.A. (Specimen V1).

Below: M_3 in plaster cast of Brit. Mus. spec. 1897 (*Procoptodon goliah*).

TAXONOMIC REVISION OF SOME AUSTRALIAN ENDEMIC GENERA OF *CRUCIFERAE*

BY ELIZABETH A. SHAW

Summary

A taxonomic revision has been made of the Australian species of Cruciferae which were included by O. E. Schulz (1924) in the genera Arabidella, Blennodia, Drabastrum, Geococcus, Harmisodoxa, Lemphoria Micromystria, Pachvmitus, Pseudarabidella and Scambopus. Recent Australian authors, following Bentham (1863), have treated these species as belonging to Blennodia and Geococcus.

In the present revision the species included by Schultz in Arabidella, Lemphoria, Micromystria and Pseudarabidella are now placed in the genus ,4rabidellu.

Two new species, Arabidella glauceccens Shaw and Harmsiodoxa puberula Shaw, and a new variety, Harmsiodoxa brevipes var. major Shaw, are here described.

Harmsiodoxa cunninghamii (Benth) Schulz has been shown to be a synonym of *H.* blennodiodes (FvM) Schulz, Pachumitus lucae (FvM) Schulz is treated as a synonym of *P.* cardaminoides (FvM) Schultz, and Scambopus richardsii (FvM) Schulz has been shown to be a species of Phlegmatospermum Schultz.

TAXONOMIC REVISION OF SOME AUSTRALIAN ENDEMIC GENERA OF *CRUCIFERAE*

by Elizabeth A. Shaw*

[Read 12 August 1965]

SUMMARY

A taxonomic revision has been made of the Australian species of *Cruciferae* which were included by O. E. Schulz (1924) in the genera *Arabidella, Blennodia, Drabastrum, Geococcus, Harmsiodoxa, Lemphoria, Micromystria, Pachymitus, Pseudarabidella* and *Scambopus*. Recent Australian authors, following Bentham (1863), have treated these species as belonging to *Blennodia* and *Geococcus*.

In the present revision the species included by Schulz in *Arabidella, Lemphoria, Micromystria* and *Pseudarabidella* are now placed in the genus *Arabidella*.

Two new species, *Arabidella glaucescens* Shaw and *Harmsiodoxa puberula* Shaw, and a new variety, *Harmsiodoxa brevipes* var. *major* Shaw, are here described.

Harmsiodoxa cunninghamii (Benth)Schulz has been shown to be a synonym of *H. blennodioides* (FvM)Schulz, *Pachymitus lucae* (FvM)Schulz is treated as a synonym of *P. cardaminoides* (FvM)Schulz, and *Scambopus richardsii* (FvM)Schulz has been shown to be a species of *Phlegmatospermum* Schulz.

INTRODUCTION

Plants belonging to the family *Cruciferae* can be easily recognized as such if they bear flowers or fruits. However, within this family it is difficult to satisfactorily determine generic and, to a lesser extent, specific limits. Treatments during this century vary from that of E. H. L. Krause (1902) who recognized only one genus, Crucifera, to that of O. E. Schulz (1936) who, in his revision of the family for the second edition of Die natürlichen Pflanzenfamilien, recognized 351 genera including about 2500 species.

From the second edition of J. M. Black's Flora of South Australia (1948) it can be estimated that there are in Australia about 50 endemic species of *Cruciferae*, most of them included in the genera *Blennodia, Lepidium, Stenopetalum, Cardamine* and *Menkea*, the remainder in *Cuphonotus, Hymenolobus, Phlegmatospermum, Capsella* or *Geococcus*. In this present work only those species which have at any time been placed in or associated with *Blennodia* or *Geococcus* have been considered.

Black lists eleven species of *Blennodia* which occur in South Australia and mentions that, in all, this genus includes about fifteen species.

* State Herbarium of South Australia, Adelaide. This work was submitted as a thesis for the degree of Doctor of Philosophy, Department of Botany, University of Adelaide. It was carried out during the tenure of an award under the British Commonwealth Scholarship and Fellowship Plan.

The first to be described was *Blennodia canescens* R.Br. (1849); of the others eleven species were described by Ferdinand Mueller, most of them before 1860 and generally in *Erysimum* or *Sisymbrium*. One was described by George Bentham (1863) as a *Blennodia*, one by Ralph Tate (1885) as a *Sisymbrium*, and one by Black (1917) as a variety of *B. canescens*.

In 1855 Mueller transferred to *Sisymbrium* three species which he himself had originally described in *Erysimum*, and by the time of the publication of his Systematic Census of Australian Plants (1882) Mueller had made at least one intergeneric transfer of each species described by himself, as well as transferring *Blennodia canescens* first to *Sisymbrium* (1869) and then to *Erysimum* (1877). In some cases he introduced new epithets for species already described and these superfluous names figured in new combinations.

The broad concept of *Blennodia* which was adopted by Black, originated with Bentham who, in the first volume of his Flora Australiensis (1863), included all the species of this group then described (ten) in *Blennodia*, as well as there describing a new species, *B. cunninghamii*. This view was never accepted by Mueller; in his first major work, Plants Indigenous to the Colony of Victoria (1860-1862), Mueller placed four of these species in *Sisymbrium*, four in *Blennodia*, and one, originally described as a *Blennodia* by Mueller himself, in *Capsella*. The tenth species does not occur in Victoria.

In The Native Plants of Victoria (1879a) Mueller referred three of the species previously (1862) treated as *Blennodia* to *Erysimum*, this being the genus in which they were originally described. The treatment in his later works is essentially the same as in this one.

In the first comprehensive flora of South Australia Ralph Tate (1890) followed Mueller closely, placing all the species under consideration in either *Erysimum* or *Sisymbrium*. However, eight years later Tate rebelled against the dictates of Mueller and stated that he thought all these species to belong in *Blennodia*. This view was accepted by Black in the first edition of his Flora of South Australia (1924).

Also in 1924 appeared O. E. Schulz's monograph of the tribe *Sisymbrieae* for Das Pflanzenreich and here he sharply departed from earlier treatments.

Schulz retained the genus *Blennodia* but included in it only *B. canescens* R.Br., distributing the other thirteen species known to him among eight new genera, i.e., *Arabidella* (FvM)Schulz, *Pseudarabidella* Schulz, *Drabastrum* Schulz, *Scambopus* Schulz, *Harmsiodoxa* Schulz, *Pachymitus* Schulz, *Lemphoria* Schulz and *Micromystria* Schulz. All of these genera he included in the subtribe *Arabidopsidinae* except for *Arabidella*, which he placed in the subtribe *Sisymbriinae*. In Schulz's system the only essential difference between these subtribes is that plants belonging to the former have seeds which exude mucus when moistened; those in the latter do not.

In his monograph of the family for the second edition of Die natürlichen Pflanzenfamilien Schulz (1936) followed the same system except that he removed *Blennodia* from the tribe *Sisymbrieae* to the *Hesperideae*.

Although Black accepted *Cuphonotus* and *Phlegmatospermum*, two other Australian genera described by Schulz (1933), he considered the eight new genera within the "Blennodia group" to be ill-founded. In 1937 Black criticized them as having "been divided . . . on very slight characters", a remark which is misleading, for it is these "slight characters" which must often be used in delimiting genera in this family. In the second edition of his flora (1948) Black made no mention of Schulz's work, not even listing his new combinations as synonyms.

Geococcus was described by Harvey in 1855 from specimens and notes sent to him from Western Australia by James Drummond. It has generally been accepted as a distinct genus, although in the Flora Australiensis Bentham, after describing the only species, *G. pusillus* Drumm. ex Harv., remarked that it is perhaps only a form of *Blennodia cardaminoides* Benth., a view later adopted by Mueller and by Tate.

As a result of these varied ideas about the circumscription of *Blennodia* and *Geococcus* the present work was undertaken. There is available in the Australian herbaria much more material than any previous worker had been able to see and the relevant collections at Kew, Berlin and Vienna were borrowed. In 1963, a visit was made to the British Museum (Natural History) where some critical material, including the holotype of *Blennodia canescens*, is housed. During the course of the study the writer made several trips in South Australia for making collections and field observations. Efforts were made to expand the scope of the collections of these plants and the writer is grateful to all those people who took particular pains to collect endemic *Cruciferae*.

Survey of the Nomenclatural History of the Species Included in Blennodia (Sensu Lato) and Geococcus.

In 1849 Robert Brown, discussing the plants collected by Charles Sturt's expedition of 1844-1846, described the genus *Blennodia* and one species, *B. canescens*. In his generic description, Brown wrote, "Cruciferarum genus, prope Matthiolam. Char.gen- Calyx clausus . . . Stigma bilobum, dilatatum, . . . Semina aptera pube fibrosomucose tecta! Cotyledones incumbentes." After describing *Blennodia canescens* he continued:

"This plant has entirely the habit, and in many important points the structure of Matthiola, near which in a strictly natural method it must be placed, differing, however, in having incumbent cotyledons, and in the mucus covering of its seeds. The mucus proceeds from short tubes covering the whole surface of the testa, each containing a spiral fibre, which seems to be distinct from the membrane of the tube. A structure essentially similar is known to occur generally in several families: to what extent or in what genera of Cruciferae it may exist I have not ascertained: it is not found, however, in those species of Matthiola which I have examined."

The name *Blennodia* (Gk βλεννώδης = slimy) refers to this production of mucus. On the holotype sheet of *B. canescens* in the herbarium of the British Museum in Brown's hand is a note, "Blennosperma vel Blennodia", but the name *Blennosperma*, had been used by Lessing (1832) for an American genus of *Compositae*.

Although the name *Blennodia canescens* was accepted by Ferdinand Mueller in his botanical reports on the expeditions led by Gregory and Babbage (1859, 1859a), and by Bentham in the Flora Australiensis (1863), Mueller in 1869 transferred this species to *Sisymbrium* as *S. blennodia*, the epithet *canescens* being preoccupied in this genus. Mueller mentioned that the seeds of *S. blennodia* are mucose and irregularly biseriate in the fruit, but added that these facts did not prevent its inclusion in *Sisymbrium*.

In 1877 Mueller transferred this species to *Erysimum* as *E. blennodia*. This combination was generally accepted until 1898, when use of the original one was revived by Tate. Since then *Blennodia canescens* has been generally accepted; it was used by Black in both editions of his Flora and by Schulz in 1924 and 1936.

Black (1917), in discussing the plants collected on the South Australian Museum's expedition to the Strzelecki and Cooper's Creeks, mentioned a form of *B. canescens* collected at Lake Blanche, saying, "The specimens agree well with other northern ones except that the seeds are bordered by a rather broad wing, while those of the type are, as usual in the genus, quite wingless. I therefore propose calling this variety 'pterosperma'." In the first edition of his Flora (1924) Black referred to it as *B. pterosperma*, and the next year published a Latin description.

In Das Pflanzenreich (1924) Schulz did not mention this variety. In Die natürlichen Pflanzenfamilien (1936) Schulz said that *Blennodia* R.Br. includes only one species (*B. canescens*), but remarked, "B. pterosperma J. M. Black . . . soll nach dem Autor nicht verschleimende Samen haben."

It is true that Black originally described the seeds as "haud mucosa", but he later (1937) noted that examination of ripe seeds had proved them to be mucose. It is presumably because Schulz thought the seeds non-mucose that he did not commit himself to any decision about the existence of *B. pterosperma* as a distinct species.

Ferdinand Mueller's stay in South Australia was brief, from December of 1847 to August of 1852, but he made several short collecting trips around Adelaide and to the Murray River, and a longer one which took him into the southern part of the Flinders Ranges during October and November, 1851.

In February, 1853, Mueller described six new species of *Erysimum*, all based on material which he had collected in South Australia.

The first two are *E. brevipes* and *E. blennodioides*. The name *Erysimum brevipes* was generally accepted throughout the rest of the nineteenth century, being used by Mueller (1879a, 1885) and by Ralph Tate in his Flora of Extratropical South Australia (1890). In 1855 Mueller had referred this species to *Blennodia* but did not make the necessary combination; this he did do in Plants Indigenous to the Colony of Victoria (1862) and *B. brevipes* was used by Bentham and later by Black in both editions of his flora.

Turczaninow in 1855 published *Alyssopsis drummondii*, basing the description on Drummond, series 4, no. 128 from "Swan River".

He was reluctant to include this species in *Alyssopsis* but did so for want of a better place. Turczaninow remarked that although this plant differed in some respects from his concept of *Alyssopsis*, the differences were not great enough to warrant creation of a new genus for it.

In 1877 Mueller mentioned *A. drummondii* Turcz. as a synonym of *Sisymbrium brevipes*, this latter an illegitimate combination based on *E. brevipes* Gardner (1931) made the combination *Blennodia drummondii*; he here made no direct reference to Turczaninow's publication, but cited *Sisymbrium brachypodum* as a synonym. *S. brachypodum* FvM. (1869) is a legitimate combination, being the correct one if the taxon under consideration be treated as a *Sisymbrium*. Mueller twice (1877, 1878) does mention *Alyssopsis drummondii* as synonymous with *S. brachypodum* and it was for this reason that Gardner cited it with his new combination in *Blennodia*.

Schulz (1924) described a new genus *Harmsiodoxa* in which he placed *E. brevipes*, *Erysimum blennodioides* FvM. (1853) and *Blennodia cunninghamii* Benth. (1863); he retained *Harmsiodoxa* with these three species in the second edition of Die natürlichen Pflanzenfamilien (1936).

Erysimum blennodioides was published in 1853, but two years later Mueller used the combination *Erysimum blennodes* to refer to this species. *Erysimum*

blennodes is in this place (Trans.Phil.Soc.Vict.1(1855)100) a *nomen nudum* and, although Mueller used it at least twice more, was apparently never associated with a description.

In Plants Indigenous to the Colony of Victoria (1862) Mueller described and figured *Blennodia lasiocarpa*, citing as a synonym "Erysimum blennodes *F.M. in Linnaea*, 1852, 367". As it stands this citation is wrong for the combination *Erysimum blennodes* was first used only in 1855; it is, however, possible that "Erysimum blennodioides" was intended for the reference is to the place of publication of the latter combination. It seems that Mueller used the new epithet "lasiocarpa" because he feared that the combination *Blennodia blennodioides* would be tautological. The combination *Blennodia lasiocarpa* was accepted by Bentham and by Black (1924).

In 1869 Mueller transferred this species to *Sisymbrium* as *S. lasiocarpum* and in 1879 to *Erysimum* as *E. lasiocarpum* and this latter combination was generally used until the beginning of the twentieth century. Druce in 1917 finally made the combination *Blennodia blennodioides* and this has been used in Australia since then.

The third species which Schulz included in the genus *Harmsiodoxa*, *H. cunninghamii* (Benth.)Schulz, was described as *Blennodia cunninghamii* by Bentham in 1863. In 1882 Mueller transferred this species to *Erysimum*; beyond this, there seems to be no mention of it in the literature.

In addition to *E. brevipes* and *E. blennodioides* Mueller described in Linnaea in 1853 four more species of *Erysimum*, all based on plants collected during his trip in the Flinders Ranges in 1851. These are *E. filifolium*, *E. trisectum*, *E. nasturtiifolium* and *E. curvipes*; the first three may be conveniently discussed together.

In 1853 Mueller transferred *E. filifolium* to *Sisymbrium*, making an illegitimate combination which is antedated by *S. filifolium* Willd. (1800). It was, however, used by Mueller in his first and second censuses and by Tate in his flora. Bentham, of course, considered this species to be a *Blennodia*, as he did *E. trisectum*; this was eventually accepted by Tate and later by Black.

As mentioned before, *Erysimum trisectum* was published together with *E. filifolium* and the similarities between the two were repeatedly stressed by Mueller. In 1855 he redescribed the former species as *Sisymbrium trisectum* and this was the name generally used during the nineteenth century, Bentham's combination, *Blennodia trisecta*, being ignored until used by Tate (1898) and later by Black in both editions of his flora.

In 1863 Bentham described *B. trisecta* var. *brachycarpa*, basing it on a collection made on McDouall Stuart's expedition. He remarked that it differed from the "common form" only in having fruit "shortly oblong" and "very turgid". Schulz (1924) accepted this variety, repeating Bentham's comments. At the same time, he described *Arabidella trisecta* var. *hybophora*, characterizing it as "Caulis inferne cum petiolis papillis minutis tuberculiformibus obsessus", and remarking that it is found with the typical variety. Neither of these varieties was mentioned by Black.

The species originally described as *E. nasturtium* was, in 1855, together with *E. filifolium* and *E. trisectum*, transferred by Mueller to *Sisymbrium* as *S. nasturtioides*, this new epithet being necessary because of the earlier publication of *S. nasturtium* Thunb. (1794). This was the combination used by Mueller in the rest of his works and by Tate in his flora.

When Bentham in 1863 transferred this species to *Blennodia* he unfortunately retained the epithet "nasturtioides", making an illegitimate combination for the epithet "nasturtium" was not preoccupied in *Blennodia*. Black apparently did not realize this and used *B. nasturtioides* in both editions of his flora, although the combination *Blennodia nasturtium* (FvM.)Druce had been made in 1917.

In the Flora Australiensis Bentham described under *B. nasturtioides* a variety "pinnatifida", basing it on a single collection made by Burkitt in New South Wales "between [the] Darling and Lachlan rivers". Burkitt's plants were small fruiting specimens with most of the leaves withered; Bentham decribed them as having "leaves small, on long pedicels, with few short lateral lobes and a larger terminal one", thus differing from the typical variety with "leaves usually pinnately divided into a few linear rather thick segments". This variety was retained by Schulz (1921) but there seems to be no other mention of it.

Mueller always thought *E. trisectum* and *E. nasturtium* to be quite closely related, at least belonging in the same subgenus, *Arabidella*, of *Erysimum*. Although he seems to have never published anything to this effect, there is in the National Herbarium of Victoria a specimen, probably collected in South Australia, which is labelled in Mueller's hand "Erysimum (Arabidella) nasturtium".

When Schulz revised the tribe *Sisymbrieae* for Das Pflanzenreich he raised Mueller's subgenus *Arabidella* to generic rank, but made it monospecific, including only *A. trisecta* (FvM)Schulz. For *E. filifolium* he created a new genus *Pseudarabidella*, and for *E. nasturtium* and one other species, the genus *Micromystria*.

The second species included by Schulz in *Micromystria* is *M. eremigena* (FvM.)Schulz, described by Mueller in 1861 from collections made in Queensland and New South Wales. Mueller noted that, "A Sisymbrio nasturtioide . . . videtur specifice distinctum." Bentham transferred this species to *Blennodia*, misspelling the epithet as "eremigera", and this combination (with the correct spelling) was used by Black in both editions of his flora.

The genus *Arabidella* Schulz placed in the subtribe *Sisymbriinae* of the *Sisymbrieae*, *Pseudarabidella* and *Micromystria* into the *Sisymbrieae Arabidopsidinae*. In Schulz's treatment the only essential difference between these subtribes is that the *Sisymbriinae* are said to have seeds "humida haud mucilaginosa" while seeds of the *Arabidopsidinae* are mucose. He said of *Pseudarabidella* ". . . semina humida mucilaginosa (sec.Bentham), igitur ab Arabidella differt.". Schulz never saw material of *P. filifolia*, basing his description on those of Mueller and Bentham and on a drawing sent him from Kew. In the second edition of Die naturlichen Pflanzenfamilien this arrangement was not altered.

An important figure in the history of South Australian botany is Ralph Tate who came from England to Adelaide in 1875 and during the next twenty years collected extensively throughout South Australia. In September of 1883 Tate collected at Termination Hill, in the northern part of the Lake Torrens basin, a crucifer which he sent to Mueller with a note in which he referred to it as "a Sisymbrium which I cannot attach to any described Australian species."

Tate himself described this in 1885 as *Sisymbrium procumbens*. In the protologue he remarked, "Among Australian congeners, *S. procumbens* approaches to *S. nasturtioides*, from which it differs in habit, form of leaves, in the spreading not erect fruiting pedicels, stouter pods, etc."

Tate used this combination in his flora as did Max Koch (1898) in his report on plants collected at Mount Lyndhurst in the northern Flinders Ranges. However, in the same number of the Transactions of the Royal Society of South Australia as Koch's report, Tate put an end to the inclusion of these Australian *Cruciferae* in *Erysimum* or *Sisymbrium*.

In his paper "Dimorphism in two South Australian Cruciferous Plants", Tate (1898) wrote:

"The majority of Australian botanists influenced by their compeer [Mueller] have accepted his dictum that *Blennodia* is made up of species of the genera *Sisymbrium* and *Erysimum*. A critical examination of the 10 species of the Australian flora, collectively included under these two generic names, satisfies me that the venation of the capsule is not that proper to *Sisymbrium*: as in all the species, there is only a midrib, without a lateral vein on each side. . . . There is no justification for the employment of *Sisymbrium* for some of our crucifers, and I take, therefore, this opportunity to refer my *S. procumbens* to *Blennodia* as *B. procumbens*, Tate. 1898." This combination was used by Black in both editions of his flora.

Schulz (1924) created for this species a new genus *Lemphoria* placed in the *Sisymbrieae-Arabidopsidinae*.

The last of the species described in Linnaea was *Erysimum curvipes*, based on a collection made at Crystal Brook in South Australia. This combination was generally used by Mueller and by Tate, although in the report (1859a) on the collections made by the Babbage expedition Mueller used the combination *Blennodia curvipes*, also used by Bentham and later by Black. Mueller (1869) transferred this species to *Sisymbrium*, a move accepted by no one.

Schulz in 1924 published the genus *Scambopus* in which he included *S. curvipes* and the erstwhile *Erysimum richardsii* FvM. He apparently saw no material of either species for his generic description says, in part, "Plantae mihi tantum delineatae ex herbario Kewensi visae . . .", and his specific descriptions were adapted from those of Mueller and Bentham.

Erysimum richardsii FvM. is described in the tenth volume of Fragmenta Phytographiae Australiae (1877), the description being based on a collection made at Eucla in Western Australia by Mrs. Richards. In the protologue Mueller wrote, "Erysimum Richardsii (Sect. Blennodia)" and this seems to be the only published indication that Mueller considered there to be a section *Blennodia* in *Erysimum*. After describing the plant and commenting that he had seen no mature fruit, Mueller concluded, "Species ab E. eremigem et E. nasturtioide petalis majoribus et praecipue stylo bene evoluto diagnoscenda."

The combination *Blennodia richardsii* was used by Tate in 1879 and 1898, but both times as a *nomen nudum*. It was validly made only in the first edition of Black's flora (1924). Black wrote: "*B. Richardsii*, FvM. (*Erysimum Richardsii* FvM. *Sisymbrium Richardsii*, FvM.) [this latter a combination made by Mueller in the first Census and used by Tate in his flora] was described by Mueller from flowering specimens collected in 1877 between Fowler's Bay and Eucla, but the specimen preserved in the Tate Herbarium appears to belong to the South Australian form of *Hutchinsia Drummondii*."

Schulz missed this comment for in the second edition of Die natürlichen Pflanzenfamilien (1936) he retained *Scambopus richardsii*. The last word on the matter was had by Black who in 1937 wrote: "It seems impossible to decide the generic position of *Erysimum richardsii*, F.v.M. . . . until we have ripe fruits

and seeds. . . . From the notched, laterally compressed ovary [of the type] it appears to be a *Phlegmatospermum* rather than a *Blennodia* and is perhaps only a form of *Ph. cochlearinum*. Helms' specimen from Arkaringa Creek, identified as *Sisymbrium Richardsii* by Mueller and Tate, is certainly *Ph. cochlearinum*."

In 1855 Mueller described *Sisymbrium cardaminoides* from plants collected near the mouth of the Murray River. He was not sure of the individuality of this species, writing in Plants Indigenous to the Colony of Victoria, "As a doubtful plant the *Sisymbrium cardaminoides* . . . is likewise excluded, its diversity from S. Thalianum (Gaudin, Flora Helvet. iv 438) having not yet been convincingly proved."

In the Flora Australiensis Bentham described *Blennodia cardaminoides* citing "B. cardaminoides F.Muell. Herb. (as a Sisymbrium)". This suggests that he may not have known of Mueller's valid publication of *S. cardaminoides*; thus Bentham's *B. cardaminoides* cannot necessarily be interpreted as if based on Mueller's type although Bentham's citation of specimens makes it probable that he had seen it. The combination *B. cardaminoides* has been generally accepted and was used by Black.

Erysimum lucae FvM. was described in 1877 from a collection made by T. P. Lucas near the junction of the Murray and Darling Rivers. Mueller remarked that it stood closest to *E. cardaminoides* but seemed specifically distinct because of its larger size.

Schulz (1924) included *B. cardaminoides* and *E. lucae* in his genus *Pachymitus*. He also described *P. cardaminoides* var. *dasycarpus*, differing from the typical variety which, according to Schulz, has glabrous fruits, in having "siliquae pilis bifurcatis brevibus parce vestitae".

He had seen no specimen of *P. lucae*, only a drawing sent him from Kew, and borrowed his description from Mueller.

In the first part of Key to the System of Victorian Plants Mueller, commenting on *Sisymbrium cardaminoides*, wrote: ". . . fruits in a stemless state of this plant very short, rather thick and turgid, singly forming on their stalks and during maturation burying themselves in the ground: the flowers of this state very minute."

This "state" refers to what is usually considered to be *Geococcus pusillus* Drumm. ex Harv. (1855). This doubt about the individuality of *G. pusillus* seems to have arisen with Bentham (1863) who wrote: ". . . it may very likely be a *Blennodia*, of some species of which it has the radical leaves." The problem was taken up by Tate (1898) who, after discussing the comparatively few specimens of "so-called *Geococcus pusillus*" available to him, concluded that these plants really represented one of "the two very dissimilar states of *Blennodia cardaminoides*, which have in common virtually only leaf form."

A second species of *Geococcus*, *G. fiedleri* Schenermann (1937), was described from a plant adventitious in a garden in Leipzig where it had been introduced with Australian wool waste. This species was discussed by Black (1940) who then accepted it as including all the South Australian collections available to him, but later considered *G. fiedleri* to be only a synonym of *G. pusillus*.

Somewhat remote geographically from those species so far discussed is *Blennodia alpestris* FvM. (1855a) which is known only from the mountainous areas of south-eastern New South Wales and the adjacent parts of Victoria. Although described as a *Blennodia* by Mueller, he was uncertain of its correct generic position for he wrote: ". . . as the cotyledons are at times slightly bent

inwards, I am uncertain whether the genus ought not to be united with *Diplotaxis* or *Moricandia*". In Plants indigenous to the Colony of Victoria Mueller transferred this species to *Capsella* as *C. blennodina*, considering it to form a link between that genus and *Blennodia*. Bentham retained it in *Blennodia* although admitting it to have certain affinities with *Capsella*.

Mueller in 1869 transferred it to *Sisymbrium* as *S. alpestre*, but ten years later moved it to *Erysimum* as *E. capsellinum*, a name retained in later works. It underwent a further name change to *E. blennodinum*, by Otto Kuntze (1891), before being placed by Schulz as the only species in his new genus *Drabastrum* based on a manuscript name used by Mueller.

These, then, are the main points of the nomenclatural history of these species at the time that this study was begun.

Characters of the Genera here Discussed

Calyx: There are usually four sepals although monstrous flowers may have fewer or more. The calyx whorls are here referred to by their position in relation to the ovary; the median sepals are those inserted in line with the replum, the lateral sepals, those in a plane at right angles to that of the replum and septum. The calyx can be described as "open" or "closed". If open the sepals are more or less spreading and this is the more common in this group; indeed, in some species, for example, *Arabidella trisecta*, the sepals are at full anthesis horizontal or even further bent back.

The closed calyx is seen only in the two species of *Blennodia*. In these the sepals are usually erect and the margins overlapping; this is not absolutely constant for some fully-opened flowers are seen with sepals slightly spreading, spreading at least to the extent that the margins do not quite touch. However, for practical purposes the calyx in these species can be described as closed for the sepals are either parallel to the ovary or at only a slight angle from it.

Size of the sepals varies considerably within a particular species, but is quite constant among the fully opened flowers on an individual plant. In shape the sepals vary from oblong or ovate to deltate or, rarely, suborbicular. The lateral sepals are usually wider than the median and more often ovate or deltate than oblong. Usually they are subacute to acute and are often saccate; this latter feature is constantly seen in both species of *Blennodia*, but only occasionally in the other genera. The median sepals are usually oblong or almost so and rounded. They are not uncommonly emarginate but are very rarely saccate.

Usually the sepals are green although they are occasionally lavender or partly so. They are bordered, almost to the base, by a narrow hyaline margin which is colourless or lavender. In pubescent species there are usually a few hairs, especially near the tip. The sepals are generally caducous, but sometimes remain until the fruit is quite well developed.

Corolla: Most of the *Cruciferae* have flowers with four petals, a trait which is constant throughout this group. The petals are usually longer than the sepals although in *Geococcus pusillus* they may be of the same length. Size is quite constant among flowers of a single plant, although it may vary surprisingly much within a species.

The petals are usually white or yellow, although plants from predominantly white-flowered species may have many flowers with pink or lavender petals; this seems to be not the case in yellow-flowered species. The venation varies to the extent that a petal can be described as "finely" or "coarsely" veined.

Usually the petals taper into an obvious claw. The blades are usually oblong to (ob-)ovate to suborbicular and rounded or truncate; if the latter they are often retuse or marginate. The claw is usually more or less linear and is sometimes winged. In some species, for example, *Arabidella triscecta*, the blade is at right angles to the claw when the petal is fully expanded.

Especially in some of the smaller-flowered species it is not uncommon to find petals with no obvious distinction between blade and claw or with only a very short claw. These petals are usually spathulate or obovate to deltate and are usually smaller than the distinctly clawed ones. This feature is not necessarily constant within a species; a good example is *Arabidella nasturtium* in which both clawed petals with suborbicular blades and clawless obovate petals, as well as all the transitional forms between the two, may be seen.

Androecium: Within this group the flowers have constantly six stamens although these sometimes do not all fully develop; this seems to be particularly true of the lateral ones.

The filaments are linear or conspicuously widened at the base, the latter more common in small-flowered species. Quite often the filaments of the lateral stamens are unequally widened, the greater width being on the lateral side of the vein.

The anthers are dorsifixed and the connective is barely visible. They are usually oblong to square, although sometimes ones which are sagittate at the base are seen, and are rounded or truncate.

Nectaries: These glands are outgrowths of the receptacle and stand at the level of the bases of the stamens. They follow a quite constant pattern, the differences among the species being mainly the result of varying degrees of development, these in turn being influenced by the space available within the developing bud. When fully developed the glands form an extrastaminal ring which completely surrounds the bases of the stamens. In this group they are usually seen only partly developed.

In the common arrangement one can distinguish between lateral and median glands. The lateral glands are rings of tissue, each surrounding the base of a lateral stamen and usually open on the inner side, less often open or emarginate on the outer side. They may be circular or triangular, square to pentagonal or hexagonal or, alternatively, vee- or horseshoe-shaped. Differences within either of these two groups seem to be of minor importance although it is apparently of some taxonomic significance that a species falls within one rather than the other of these two groups.

From this basic circular or vee-shaped gland is produced, one on each side, a "lateral appendage" which curves around the base of the adjacent diagonal stamen. It is called this for descriptive purposes; in fact it is part of the entire extrastaminal ring. The tips of the appendages from opposite glands approach each other and may sometimes touch, but apparently are never fused.

If the lateral glands are less well developed, each may appear as four lobes of tissue, one at each angle of a hypothetical square gland, or as semicircular pieces of tissue, each one subtended by a petal, the pieces actually being the arms of the lateral appendages. These poorly developed glands are seen in the herbaceous species of *Arabidella*.

The median glands, if present, are more or less conical pieces of tissue, one between the bases of the members of each pair of diagonal stamens. Unfortunately presence or absence of the median glands is not a constant character, it is an expression of the degree of development of the glandular system and

can vary from plant to plant of a particular species. This is especially noticeable in *Arabidella eremigena*.

Gynoecium: The ovary is usually sessile although in a few species, e.g., *Arabidella glaucescens*, it is on a short gynophore. It is linear to fusiform to ampulliform and usually terete. Occasionally the ovary is compressed, but compression is usually more obvious after ripening has begun. In most species the ovary is glabrous, even though the fruit is pubescent, but in both species of *Blennodia* it is densely tomentose.

The style is slender and linear or, in *Blennodia canescens*, very short and widened, eventually becoming almost spherical. The stigmas are usually depressed-capitate, but are sometimes two-lobed. The bilobed stigmas either have the lobes extended over the placentas or over the valves, in the latter case appearing tectiform if seen from the dorsal aspect. This is best seen in *Blennodia canescens*.

The flowering pedicels are slender and usually erect to slightly spreading, even in those species in which the fruiting pedicels are horizontal or recurved, in section they are terete or quadrangular.

Fruit: Within this group the fruits are quite variable in size but not in form. They are usually siliquas, in a few cases, siliculas, terete or compressed. If the fruit is terete, the valves are convex and nearly semicircular in section and this is the most common condition; in a somewhat modified form the fruits are quadrangular and the valves almost right-angled in section. This is seen in *Scambopus curvipes* and *Drabastrum alpestre*.

When the fruit is compressed dorsi-ventrally and is thus latisept, the valves are almost flat and this is commonly seen in *Blennodia*; in such fruits the valves are often somewhat constricted between the seeds. The laterally compressed fruit is less commonly found within this group, although fruits of *Arabidella eremigena* and *A. procumbens* are often angustisept; the valves are then very convex or keeled. It may be noted that although terete and latisept fruits may occur in one species, as well as terete and angustisept together, latisept and angustisept fruits seem not to occur in the same species.

Proximally the valves are usually rounded or truncate; distally, rounded to subacute. There is a more or less distinct vein and when the fruit is fully ripe there is often a reticulum of secondary veins making the valve appear striated. Fruits of *Arabidella trisecta* sometimes have three parallel veins, the lateral ones being rather indistinct, but this is not constant. Although the usual colour is brown, one often sees red or magenta pigmentation, especially along the vein and at the edges of the valves. The valves usually fit smoothly against the replum, but in *Scambopus curvipes* and *Pachymitus cardaminoides* they are reflexed and flared at the proximal end.

The fruits are sessile or shortly stipitate, the stipe elongating very little during maturation. Usually there is a style which is linear and slender or obconical although in *Blennodia canescens* and *B. pterosperma* it is often much widened and almost spherical. In most cases the stigma is depressed-capitate and as wide as or slightly wider than the style, but in *B. canescens* it is tectiform. Very often the stigma shows at least a trace of purple pigmentation.

The funicles are short and slender, usually linear to deltate, straight or curved and almost always pendulous. In this group the septum is thin and fragile and is sometimes fenestrate by a longitudinal slit. Usually it is white, less often colourless, and is opaque or hyaline; it is smooth or rugulose, then being wrinkled especially between the seeds and along the margins.

The fruiting racemes are always quite loose and may reach a considerable length, as much as 30 cm in *Arabidella glaucescens*. The pedicels are usually quite slender, although those of *Harmsiodoxa brevipes* are stout (often 1 mm in diameter) and very short. In *Pachymitus cardaminoides* the pedicels, although slender proximally, become quite thickened just below the calyx. Usually the pedicels are somewhat spreading, but they may be horizontal and quite rigid or even recurved as in *Blennodia pterosperma* and *Scambopus curvipes*.

Seeds: The seeds are usually oblong to (ob-)ovate and quite plump, but those of *B. pterosperma* are flattened. Seeds of this species are always surrounded by a membranous wing, a feature seen less often in *B. canescens* and *Arabidella filifolia*.

The testa varies from yellow through red-brown to brown and often is slightly darker at the hilum. Usually it is finely papillose, but the testa of seeds of *Drabastrum alpestre* is coarsely reticulate.

The outstanding feature of the testa is its ability to exude mucus when moistened. In the outer layer are "slime cells" which very rapidly take up water. The contents of these cells are quickly exuded and rupture the cuticle which can then be seen as fragments on the surface of the sheath of mucus. The mucus seems to be generally produced from all parts of the testa although in some species there is a small area near the hilum which seems to be not mucose. Each papilla seems to extrude a strand of mucus and the result is a coat of mucus enveloping the entire seed.

In some genera, especially *Harmsiodoxa*, *Blennodia* and *Scambopus*, the mucus is exuded as distinct oblongs, one from each papilla, each oblong seeming to contain a grey spirally coiled thread: to the naked eye this mucus is grey and under low magnification appears distinctly radiate. In *Arabidella*, however, the mucus is exuded as cubes, hemispheres, or cones, again one from each papilla, but not containing the thread. This mucus is colourless, and also appears more or less radiate under low magnification, under higher magnification it is seen that this apparent radiate quality is caused by the overlapping rows of cubes or hemispheres, the optical properties of the mucus being such that the edges of each individual exudate seem accentuated.

Under low magnification (about 80 times) the testa appears three-layered. The inner layer is of light colour and is probably the endosperm, the two outer layers being the testa proper and they themselves covered by a cuticle. The outer layer is the thicker and pieces of it can easily be chipped off; it is quite light in colour and bears the papillae or reticulations. It is this layer which produces the mucus; it is made up of vertically placed oblong cells which are somewhat conical at the top and these cones give the testa its papillose appearance. From each of these cells is produced a discrete mucose mass.

The seed is entirely filled by the embryo which in this group is notorrhizal. The radicle is usually straight although in *Arabidella filifolia* it is generally curved to one side, making the seed appear skew. The cotyledons are usually oblong or elliptic and about the same length as the radicle.

On germination the radicle first elongates and ruptures the testa; as it lengthens the cotyledons unfold and push off the testa. In the very young seedling the shape of the cotyledons does not differ noticeably from species to species; the first true leaves are similar to the cotyledons, being oblong and usually entire, and it seems to be only the second-formed leaves which show any of the specific characters, although in pubescent species the first leaves do bear a few hairs.

Not all species could be grown from seed, but the following did reach a stage at which the first few leaves could be seen: *Arabidella trisecta*, *A. nasturtium*, *A. glaucescens*, *Blennodia canescens*, *Harmsiodoxa blennodioides* and *H. brevipes*. At the early stages about all that is possible is to separate the entire- or triseet-leaved species from those with pinnatisect leaves.

Pubescence: The hairs found on members of the *Cruciferae* are almost always unicellular; these are simple or, quite often, bifurcate or many-armed and complexly branched. There also occur, but rarely, capitate hairs which are either unicellular or divided by horizontal walls.

Within this group only *Arabidella glaucescens*, *A. filifolia*, *A. nasturtium* and *A. procumbens*, are quite glabrous. *A. eremigena* bears simple hairs; *A. trisecta* is usually described as glabrous, but almost all the plants seen have had on the lower parts of the stems and proximal parts of the leaves more or less numerous oblong to hemispherical papillae.

In the other genera the hairs are predominantly of the branched sort and occur on all parts of the plant except the stamens. In both species of *Blennodia* they are usually shortly stipitate and irregularly branched; in *Scambopus*, *Pachymitus*, *Harmsiodoxa* and *Geococcus* the hairs are shortly stipitate or sessile and are often twice bifurcate. Usually there are no constant differences among the hairs found on various parts of a particular plant, but in two species of *Harmsiodoxa* and in *Scambopus* the hairs at the distal end of the fruit valves are often simple or bifurcate with one arm very short, while those on the other parts of the plant are more branched.

Vegetative characters: Of the species discussed here four are perennial and suffruticose; the others are normally ephemerals, completing their life cycle within a few months. The suffruticose species are usually many-stemmed, the stems arising either at ground level or from a short main stem when the plant is fully developed. These stems are equal and usually each is terminated by an inflorescence.

Often the primary stems are branched; the secondary stems bear inflorescences, but are sometimes much reduced, the inflorescences then seeming to arise from the leaf axils. *Drabastrum alpestre* may have several stem systems, these arising from a woody rhizomatous part.

The herbaceous species are also many-stemmed, the stems arising from ground level; very often they are unequal, the main central stem being leafless and shorter than the lateral stems. In some cases the central stem does not develop and its terminal inflorescence seems to arise from the base of the plant. The lateral stems are erect, decumbent or prostrate; the latter is seen only in *Arabidella procumbens* and in a growth form of *Harmsiodoxa brevipes*. Usually the leafy lateral stems bear tertiary branches in the axils; as in the suffruticose species the axillary stems sometimes do not develop, so that there occur axillary inflorescences.

Geococcus pusillus is quite prostrate, consisting initially of only a rosette of leaves; older plants are quite complex in structure, the result of the interwining at ground level of short secondary stems, leaf petioles and fruiting pedicels.

The root is usually slender and short, and bears a few laterals. In the perennial species it is often woody and thick, the upper lateral roots as well becoming woody. *Drabastrum alpestre* forms an underground rhizomatous part made up of the woody root and the basal parts of the aerial stem systems.

The stems are terete or finely fluted or quadrangular. When the plant is mature they are brown or reddish-purple in the herbaceous species and in the suffruticose species, brown to cream. In the latter there is usually a thick excoriating bark, at least at the base of the plant.

The basal leaves are usually crowded and rosulate; they are always petiolate and rather variable in shape of the blade which can be oblong or (ob-)ovate or elliptic to suborbicular. They are sometimes entire or finely dentate, but most commonly are lyrate-pinnatifid so that the terminal lobe is the largest, the lateral segments gradually decreasing in size towards the leaf base. Usually the basal leaves are less than 10 cm in length, but plants growing under favourable conditions may have leaves as long as 20 cm.

The lowermost cauline leaves may resemble the basal ones in shape but are always smaller. Towards the top of the stem they become still smaller and are shortly petiolate or sessile. These upper leaves are usually (ob-)ovate or elliptic and are usually entire or dentate although those of *Arabidella eremigena* and *A. procumbens* may be quite deeply divided.

Four species of *Arabidella* have leaves which are narrow and entire or bi-or tri-sect or even more intricately divided. Three of these species are suffruticose and never have basal leaves, at least not clustered in a rosette. The leaves in these species are usually rather fleshy and are often glaucous.

The cauline leaves are solitary or fasciculate; they appear to be randomly scattered but the usual phyllotaxis is 5/8. In no species are the leaves amplexicaul or sagittate.

The flowers are borne on ebracteate racemes which are terminal on the stems. Initially the inflorescence appears corymbose but after anthesis begins the axis elongates and the infructescence is always racemose. The inflorescences vary in number of flowers, but there are rarely more than sixty.

Arabidella trisecta often has a few buds below the lowermost fruits but this is rarely seen in any of the other species. Very often one sees inflorescences which appear to be basal or axillary as a result of stems failing to develop. The fruits which develop from the basal inflorescences are usually borne on pedicels somewhat longer than those of the upper racemes.

An unusual case is that of *Geococcus pusillus* which is essentially stemless and has basal inflorescences of very small but perfect flowers. After flowering the fruit stalks elongate and turn downward, burying the fruit if the soil is soft enough. This species is usually found in sandy soil but when growing in harder soil the fruits are often only partly buried and misshapen.

Survey of Systematic Treatments of the Cruciferae with Discussion of the Characters used in Circumscribing Taxa of Infrafamilial Rank

A. P. de Candolle (1821)—O. E. Schulz (1924, 1936):

The first more or less modern system for the *Cruciferae* was that of de Candolle in his Systema Naturale (1821). Here are recognized 95 genera distributed among 21 tribes in 5 subordines (subfamilies). His chief criterion for distinguishing the subfamilies was the arrangement of the cotyledons in relation to the radicle, a character still thought to be of value in delimiting groups of infrafamilial rank.

The following subfamilies were recognised: (1) *Pleurorhizeae* (the cotyledons accumbent and flat); (ii) *Notorhizeae* (cotyledons incumbent and flat); (iii) *Orthoploceae* (the cotyledons incumbent, but longitudinally folded, the radicle lying in the sinus thus formed); (iv) *Spirolobeae* (the cotyledons incumbent but spirally rolled upon themselves); (v) *Diplecolobeae* (cotyledons incumbent and twice folded transversely).

Within each subfamily the main criterion for delimiting tribes is the nature of the fruit (i.e., nucamentum, lomentum, silicula or siliqua; latisept or angustisept). For example, in subfamily *Pleurorhizeae* the tribes are (a) *Pleurorhizeae Siliquosae* (*Arabideae*), b) *P. Latiseptae* (*Alyssineae*), (c) *P. Angustiseptae* (*Thlaspideae*), (d) *P. Nucamentaceae* (*Euclideae*), (e) *P. Septulatae* (*Anastaticeae*), a group with dehiscent fruits in which the valves bear transverse processes on the inner side, and (f) *P. Lomentaceae* (*Cakileineae*). In describing the tribes de Candolle also mentioned certain features of the seeds, but these do not affect the arrangement dictated by the nature of the fruit.

For the circumscription of genera the characters are firstly those of the fruit (terete, angled or compressed; linear or non-linear; sessile or stipitate). Also used are the characters of the valves (convex or flattened, nerved or nerveless), the seeds (compressed or plump, biseriate or uniseriate) and the sepals (saccate or not, calyx closed or open). Occasionally mentioned are features of the petals and filaments.

de Candolle realized the artificiality of previous systems and hoped that he had produced a natural one. However, because of his reliance on only a few characters his system, too, was purely artificial. Still, Hayek (1911) considered it one of the best produced to his time, its strength lying in the fact that characters derived from the seed were used before those from the fruit. This system was the basis for many which followed, incorporating various modifications.

The first major work of Ferdinand Mueller was Plants Indigenous to the Colony of Victoria (1862) in which he used no characters not used by de Candolle in his treatment of the *Cruciferae*. Mueller here discussed only three genera relevant to the present work; that is, *Sisymbrium* (*S. nasturtioides* and *S. trisectum*), *Blennodia* (*B. lasiocarpa*, *B. brevipes* and *B. curvipes*) and *Capsella* (*C. blennodina*). The main distinguishing features in the descriptions are drawn from the calyx (erect or spreading, saccate or not), the fruit (cylindrical or ellipsoid) and the seeds (numerous or few, uniseriate or irregularly biseriate).

His chief reason for separating *Sisymbrium* from *Blennodia* was that the latter has mucose seeds, but it is surprising that Mueller did not know that the seeds of both his *S. nasturtioides* and *S. trisectum* are mucose. He noted that *Sisymbrium* is most distinguished from *Erysimum* by having fruits more cylindrical than quadrangular, while *Blennodia* is to be distinguished from *Erysimum* by its mucilaginous testa. *Capsella* is set apart from all the rest by the fruits having a rather low ratio of length to width.

After de Candolle the first to treat the entire family were Bentham and Hooker (1862) who, by using fruit and seed characters, divided it into five series. The series were divided into ten tribes, these being separated by characters of the embryo and fruit and by arrangement of the seeds. Characters used for circumscribing genera were, among others, sepals erect or spreading, basally saccate or equal, fruit terete or compressed, septum smooth or wrinkled, and characters and arrangement of the seeds.

Blennodia, with six species, was included in the tribe *Camelineae* under Series A, the plants in this series being described as having "Siliqua elongata v.

brevis, per totam longitudinem dehiscens. Valvae intus continuae, rarius septiferae, planae v. concavae, nec septo contrarie compressae, septo cum valvis aequilato." Among other genera placed in *Camelineae* are *Stenopetalum*, *Geococcus* and *Menkea*.

After the generic description of *Blennodia* Bentham and Hooker remarked "Genus vix a *Capsella* distinguendum". This is surprising for *Capsella* is placed in the tribe *Lepidineae* under Series B, this series described as having "Siliqua brevis, pertotam longitudinem dehiscens. Valvae intus continuae, valde concavae, septo contrarie compressa, septum saepe angustissimum". In a note they mentioned that "Siliquae valvae septo contrarie occurrunt etiam in . . . *Blennodia* . . . inter *Camelineas*". Bentham and Hooker certainly noted the diversity of the species included in *Blennodia* and one wonders that they did not split the genus.

With the possible exception of the production of mucus by the testa, they used no characters not used by de Candolle. The system was criticized by Hayek who pointed out that Bentham and Hooker knew a great many more genera than did de Candolle, but were unable to produce a system which could be regarded as an improvement over his. He felt that their use of fruit characters before those of the embryo was particularly unfortunate for it split some natural groups.

In Bentham's Flora Australiensis (1863) the system followed is that of Bentham and Hooker although there is no division into supra-generic groups. Bentham included in *Blennodia* all the species then described (eleven). The generic characters used are those used in the Genera Plantarum — in fact, the descriptions are essentially those of the earlier work.

Of *Blennodia* Bentham remarked that it is "differing from *Sisymbrium*, to which some species have been referred, by the seeds never so completely overlapping each other as to form a single row, and generally in the copious mucus of the seeds; which is, however, not constant in all the species. From *Capsella* it differs in the longer pod, and in the dissepiment broader in proportion to the transverse diameter of the pod."

Bentham's inclusion of these eleven species in *Blennodia* is not better than Mueller's distribution of them among *Erysimum*, *Sisymbrium* and *Blennodia*. They differ from *Sisymbrium* (in its modern delimitation) in having mucose seeds. *Erysimum* has a closed calyx and lateral glands which completely encircle the shorter stamens; the first feature is seen also in *Blennodia canescens* and *B. pterosperma*, both of which have, however, lateral glands open on the interior.

These eleven species differ so much among themselves that it is difficult to imagine that Bentham who saw quite good material of these plants could have considered them congeneric.

After Bentham and Hooker the next major treatment of the family as a whole was that done by Prantl for the first edition of Die natürlichen Pflanzenfamilien (1890).

Between 1863 and 1890 there appeared only a few general discussions of the *Cruciferae*, such as those of Baillon (1872) and Pomel (1883), and treatments of various regional floras; but none of these modified the treatment of the Australian genera or, with a few exceptions, used any characters not used by de Candolle and by Bentham and Hooker.

Velenovsky in 1883 put forth a system for the family in which he essentially ignored the long-used embryo characters, but introduced the nature of the nectaries as a character of importance. These glands had long been recog-

nized as being of some systematic value, but Velenovsky was the first to use them in delimiting major divisions of the family. Unfortunately, he investigated only a comparatively few genera, none of these being Australian.

After Velenovsky, Prantl was the first to break away entirely from de Candolle's system—not, however, with always happy results. Prantl pointed out that use of de Candolle's characters of fruit and embryo produces an artificial system, widely separating very similar genera.

He also complained that use of fruit characters tended to separate related genera, noting that "siliqua" and "silicula" are variable concepts and useful only within certain limits; he also criticized the concept of "angustisept" and "latisept" as used by de Candolle. Prantl meant that these characters can be misleading if used in making major divisions of the family; they are certainly essential in circumscribing groups of lower rank.

Prantl admitted that although it was easy to criticize de Candolle's system, it was equally difficult to construct a new one. He felt it his duty to find new characters and thought he had done so by using the structure of the stigma (i.e., capitate or bilobed). Other characters that he considered useful were arrangement of the nectaries, branching of the hairs and disposition of the epidermal cells of the septum. By these he characterized individual "Verwandtschaftkreise" or tribes.

To arrange the tribes into a natural system he used some further characters: the biseriate arrangement of the seeds he considered to be the most primitive, also treating the dehiscent, two-valved, many-seeded fruit as more primitive than the indehiscent, few- or one-seeded fruit. Prantl complained that he found this construction of a system especially difficult because he lacked material from tropical areas and from temperate regions in the Southern Hemisphere, areas where he supposed the most primitive of the forms to occur.

Still Prantl thought that he had constructed rather natural subtribes, but admitted to having difficulty in expressing the relationships among them; he did, however, present a table in which various phylogenetic lines are tentatively shown.

Hayek criticized sharply Prantl's system, especially objecting to his use of characters of pubescence in delimiting tribes. As Hayek pointed out, the absence or presence of hairs, and the branching of them or the lack of it, are useful characters only at the specific or generic level. The division of all the known genera of *Cruciferae* into two groups on the basis of the occurrence of simple or branched hairs tends to widely separate some closely related genera. Furthermore, Prantl placed too little reliance on characters of fruit and seed; this led to unlikely groupings, such as the inclusion of *Sisymbrium* and *Cakile* in the subtribe *Sisymbriinae*. Prantl's table showing probable phylogenetic lines Hayek dismissed as fantasy and he called the series *Lepidiinae-Sisymbriinae-Vellinae* "ein phylogenetisches Unding".

In circumscribing genera Prantl used no new characters, relying on such things as presence or absence of the septum, nature of the calyx and the arrangement of the epidermal cells of the septum. There seems to have been no particular criticism of his generic concepts.

In Prantl's system *Blennodia*, said to include eleven species, and *Geococcus* are placed with sixteen other genera of uncertain position. He mentioned *B. trisecta* Benth. as being glabrous, *B. eremigena* Benth. as having simple hairs, and *B. lasiocarpa* as having branched hairs, but said that he had been able to study only scanty material of the glabrous species.

Prantl commented that the stigma suggests that of the *Thelypodieae*, described as "ringsum gleich entwickelt", but added that he could not decide if such diversity in pubescence could occur in a single genus. Prantl's tribe *Thelypodieae* includes such genera as *Pringlea, Streptanthus, Hexaptera* and *Chamira*, none of which show any real resemblance to plants of the *Blennodia* group.

Of *Geococcus* Prantl said only that it seemed to be related to *Blennodia*. In his description of the genus he mentioned a form with erect stems and the appearance of a *Cardamine*; this is probably based on a misunderstanding of Bentham's remark that *G. pusillus* could perhaps be a form of *Blennodia cardaminoides*.

There have been only a few attempts to construct for the *Cruciferae* a system based on anatomical characters. The most ambitious was that of Schweindler (1905) based on the work of Heinricher (1886) who divided the family into five groups according to the orientation of the myrosin cells in the leaves.

Schweindler investigated more genera and suggested three major groups, i.e., Exo-Idioblastae, in which the myrosin cells are exclusively in the mesophyll and contain chlorophyll, Endo-Idioblastae, in which the myrosin tubes are free of chlorophyll and are closely associated with the vascular bundles, and Hetero-Idioblastae, with both sorts of myrosin cells. These three groups are equivalent to subfamilies; the last includes only the tribe *Isatidinae*, but the Exo-Idioblastae are divided among eight tribes and the Endo-Idioblastae among five.

Schweindler's work is commented upon at some length by Hayek who said that these groups certainly should not stand at the rank of subfamilies, although the orientation of these cells seemed to be of some value in characterizing smaller groups. Hayek's main objection to Schweindler's use of this character was that it separated too widely closely related groups.

Hayek himself devised a method of investigating these cells in herbarium material, and in most of his descriptions of genera and of groups of higher rank, mentioned their position in the leaf, but they seem to have had no great part in influencing his delimitations of groups of any rank.

Hayek's own system (1911) was the first truely natural one and a marked improvement on that of Prantl. He knew 231 genera which were divided among ten tribes, most of which include several subtribes. The characters which Hayek used to delimit groups of supra-generic rank are chiefly drawn from the fruit, the nectaries, the myrosin cells, the stigma and the epidermal cells of the septum.

He greatly reduced Prantl's list of genera of uncertain position, having only four such. One of these was *Geococcus* which, he suggested, might be included in his tribe *Schizopetalae*; in Hayek's system this tribe includes five subtribes, one being *Stenopetalinae*, and stands near the beginning of the system, being placed in a direct evolutionary line from the *Thelypodieae* which are the most primitive tribe.

Blennodia, apparently including the eleven species mentioned by Prantl, Hayek with some misgivings placed in his *Arabideae-Sisymbriinae*, together with such genera as *Sisymbrium, Descurainia, Alyssopsis* and *Chrysochamela*. He remarked that the genus was too little known for him to be certain of its place in the system, but that it very probably belonged here. Unfortunately, Hayek was unable to see material of more than three species, *Arabidella trisecta, Harmsiodoxa brevipes*, and *H. blennodioides*, but this was enough to convince

him that the genus should be split. He was impressed by the diversity of trichome types in *Blennodia* (*sensu* Bentham) and twice noted that it was unlikely that they could be found in a single genus. He also commented on the difference in nectaries between *A. trisecta*, on the one hand, and *H. brevipes* and *H. blennodioides* on the other.

Hayek suggested that the capitate stigma indicated some relationship with the *Thelypodieae*, but concluded that *Blennodia* included Australian representatives of the *Sisymbriinae* which are only rather distantly related to the other genera in this subtribe.

Hayek's system, by far the best produced to that time, was lightly dismissed by Schulz (1936) who repeated the criticism made by Thellung (1913) that it was further removed from the practical requirements of determination than was Prantl's system. This criticism, which implies some defect inherent in the system, is not justified.

To support his criticism Thellung presented Hayek's conspectus, which gives the main features of tribes and subtribes and is not intended for purposes of determination, together with Prantl's dichotomous key to tribes and subtribes. The key is naturally better adapted to determinations than is the conspectus.

Hayek's system is, by far, more nearly natural than is Prantl's and it is only unfortunate that he did not construct a key; it should also be noted that Hayek's paper is of value for his survey, with criticisms, of earlier treatments of the *Cruciferae*.

O. E. Schulz (1924, 1936):

The genus *Blennodia* (sensu Bentham) was finally split when O. E. Schulz (1924) published the revision of the tribe *Sisymbrieae* of "Das Pflanzenreich". Here the eleven species known to Bentham and Prantl are, with three subsequently described ones, distributed among the following nine genera: *Blennodia* R.Br. (*B. canescens* R.Br.); *Arabidella* (FvM.)Schulz (*A. trisecta* (FvM.) Schulz); *Pseudarabidella* Schulz (*P. filifolia* (FvM.)Schulz); *Drabastrum* Schulz (*D. alpestre* (FvM.)Schulz); *Harmsiodoxa* Schulz (*H. blennodioides* (FvM.)Schulz, *H. brevipes* (FvM.)Schulz, *H. cunninghamii* (Benth.)Schulz), *Micromystria* Schulz (*M. nasturtium* (FvM.)Schulz, *M. eremigena* (FvM.) Schulz); *Scambopus* Schulz (*S. curvipes* (FvM.)Schulz, *S. richardsii* (FvM.) Schulz); *Pachymitus* Schulz (*P. cardaminoides* (FvM.)Schulz, *P. lucae* (FvM.) Schulz); *Lemphoria* Schulz (*L. procumbens* (Tate)Schulz). Included with these is *Geococcus* Drumm. ex. Harv. (*G. pusillus* Drumm. ex Harv.).

Eight of these genera, including *Blennodia* itself, as well as *Geococcus*, are placed in the subtribe *Arabidopsidinae* Schulz which is chiefly distinguished from the other subtribes by the fact that its seeds are mucose. *Arabidella* (FvM.) Schulz is in the subtribe *Sisymbriinae* only because Schulz believed its seeds to be non-mucose.

Schulz commented on the difficulties of determining generic limits when good distinctive characters are not known. However, he concluded that the *Sisymbricae* form a very natural group which, by use of "oft subtile Charaktere", can be divided among six subtribes. In doing so characters such as the orientation of the nectaries, size of the seeds, nature of the testa, possession of glandular hairs and division of the leaves are useful. It may be noted that these last two characters, possession of glandular hairs and of bipinnatipartite leaves, serve to separate the subtribe *Descurainiinae* from the others.

Schulz continued to say that in delimiting genera he used all constant characters, especially those of the more important organs, and mentioned that among these are the number of ovules, size of the stigma, nature of the fruit, nervation of the septum and presence of a wing on the seed.

Other characters used by Schulz, as drawn from his generic descriptions, are position of the calyx (erect or spreading), presence or absence of a median nectary, details of the septum (smooth or rugulose), type of pubescence and dissection of the leaves. For delimitation of species, Schulz relied mainly on details of the flowers and fruit as well as on differences in habit and details of pubescence and leaf dissection.

In Schulz's final work on the *Cruciferae*, the monograph of the family for the second edition of Die natürlichen Pflanzenfamilien (1936), his disposition of these genera is the same except that *Blennodia* is removed from the tribe *Sisymbrieae* to the *Hesperideae*. The essential differences between these tribes are that the *Sisymbrieae* have sepals almost always spreading and a stigma described as depressed-capitate or, sometimes, bilobed, while the *Hesperideae* have sepals erect and a stigma which is bilobed, the lobes sometimes being carpidial. These things being so, *Blennodia* certainly fits more naturally into the latter tribe, and it is precisely by these characters that it differs most sharply from the other Australian genera.

In circumscribing these new genera Schulz made very astute use of a wide range of morphological characters – it must be noted that nowhere did he use the anatomical feature of the myrosin cells and, in fact, did not mention them in any of his descriptions.

Although Schulz saw only a very limited amount of material his treatment of the Australian *Cruciferae* is good. These genera can easily be recognized in a subjective, intuitive manner, but it is more difficult to express clearly the differences among them and to show why they should be separated. In this Schulz was remarkably successful.

Blennodia is well distinguished by its having a closed calyx and tectiform stigma, the other genera having an open calyx and a more or less depressed-capitate stigma. The other eight genera are distinguished one from the other by varying combinations of characters which are often subtle, although, according to Schulz, *Arabidella* is immediately set apart by having non-mucose seeds. Of the remaining genera, none can be said to have any one striking and distinctive feature.

Among the characters which seem, in Schulz's treatment, to be of most importance in this group are shape and colour of the petals, nature of the filaments (linear or basally expanded), presence or absence of the median glands, details of the structure of the lateral glands, number of ovules per ovary, shape of the fruit (e.g., linear or ellipsoid), habit and, to some extent, the nature of the fruiting pedicels.

Unfortunately, Schulz's descriptions of *Scambopus* and *Pseudarabidella* are rather short because he saw only some drawings sent him from Kew and had to rely on these and on the descriptions of Mueller and of Bentham.

Schulz described no new species in this group, but did describe two new varieties, one in *Arabidella trisecta* and one in *Pachymitus cardaminoides*. Neither of these is "good"; both were published because Schulz had seen insufficient material to quite appreciate the range of variation within these species.

It must be emphasized that Schulz made a great move forward in splitting the genus *Blennodia* (sensu Bentham). There are certainly some inaccuracies in his descriptions, and, in some cases, the generic limits must be modified, but these are only the result of his having seen such a small amount of material. In the present revision two new species and a new variety in another species are recognized, but Schulz had probably seen no representatives of any of these newly-described taxa.

Schulz's system was criticized by Janchen (1942) who pointed out that Schulz paid little attention to the principles set out by Hayek for the construction of a phylogenetic system for this family. Janchen's criticisms of Schulz's work are entirely at the level of the supra-generic groupings. However, the present work is concerned chiefly with generic circumscriptions and Janchen did not criticize Schulz's work in this respect.

The writer herself is not qualified to judge Schulz's delimitation of tribes and subtribes and so must accept his major groups.

Present revision:

On the whole, the criteria used in circumscribing the genera and the species differ little from those used by Schulz. It is often difficult to delimit groups of any rank in this family and subtle differences must be used. Characteristics of any plant organ may be useful, but they are not all of equal taxonomic value.

Most useful in circumscribing genera in the group here studied are shape of the fruit (linear or fusiform, terete or compressed), nature of the nectaries, position of the sepals (erect or spreading), nature of the stigma (tectiform or depressed-capitate), and the sort of mucus exuded by the testa, this last a character which, to the writer's knowledge, has not been used before.

For example, the fact that the mucus exuded by seeds of *Arabidella* species is clear helps to distinguish this genus from *Scambopus* and *Harmsiodoxa* in which each exudate of mucus appears to contain a spirally coiled thread.

In delimiting species details of fruit (sessile or stipitate), seeds (plump or flattened, winged or wingless), habit (suffruticose or herbaceous, erect or prostrate), size and shape of the floral organs, pubescence (glabrous or pubescent, hairs erect or appressed, distribution pattern of differing sorts of hairs on the fruit valves), and leaves (entire or trisect or pinnatisect) have been used.

With the exception of the type of mucus exuded by the testa these characters have been used before. However, although the characters used are not new, the results, in some respects, are.

One must agree with Schulz that *Blennodia* stands well apart from all the other Australian *Cruciferae* and it is now difficult to imagine that any other of these species could have been included in *Blennodia*. For the present Schulz's system must be accepted and this genus seems more likely to belong in the tribe *Hesperideae* than in the *Sisymbrieae*.

Of Schulz's new genera, *Drabastrum*, *Scambopus* and *Pachymitus* must stand almost as he circumscribed them, except that from the latter two genera one species each is removed. Each of these genera is monospecific and within this group stands somewhat isolated.

Harmsiodoxa still includes three species, but one is newly-described and *H. cunninghamii* has been shown to be a synonym of *H. blennodioides*. It

must be admitted that *Scambopus* is closely related to *Harmsiodoxa* and some would probably join these two genera. However, *S. curvipes* differs from the three species of *Harmsiodoxa* in having median glands, the fruit quadrangular rather than terete or slightly latisept, and pedicels recurved rather than somewhat spreading. These differences seem enough to warrant retaining *Scambopus* as a distinct genus.

Drabastrum resembles *Scambopus* in having many features in common with *Harmsiodoxa*, but it too differs in fruit and in the sort of mucus exuded by the testa. In all species of *Harmsiodoxa* the mucus is of the sort in which each exudate appears to contain a grey thread; in *Drabastrum* the mucus is clear. For these reasons, and because of the geographical and ecological isolation of *D. alpestre*, it seems more realistic to maintain it as a distinct genus.

Geococcus (*G. pusillus* only) is maintained. It may be related to *Pachymitus* and does resemble this genus in some ways, but it is certainly not to be considered a mere form of *P. cardaminoides*.

The largest of the genera is *Arabidella*, including six species. *Pseudarabidella filifolia* (FvM.)Schulz is so much like *A. trisecta* that it seems impossible to maintain them in distinct genera. The seeds of *A. trisecta* are mucose to the same degree as are those of *P. filifolia*; this knowledge removes the only difference between these genera in Schulz's treatment.

J. M. Black (1937) commented that most of the collections of *P. filifolia* had leaves trisect rather than entire, the "typical form" being rather rare. This form which has trisect leaves and also differs from the "typical form" in having fruits more often ellipsoid rather than linear, as well as in some other respects, has been separated as a distinct species, *A. glaucescens*.

The species included by Schulz in *Micromystria* and *Lemphoria* have, in the present revision, been also included in *Arabidella*. These species are herbaceous and differ considerably in habit from the suffruticose *A. trisecta*, *A. filifolia* and *A. glaucescens*, but the resemblances between these groups are strong enough to make it certain that they all belong in the genus *Arabidella*. The relationships within this genus are discussed with the general discussion of these species.

If Schulz's division of the family be accepted, *Blennodia* must remain in the tribe *Hesperideae* and the other genera, including *Arabidella*, in the *Sisymbrieae-Arabidopsidinae*. These genera are distinct, one from the other, but have enough characters in common to warrant their inclusion in this subtribe.

Material Investigated

Specimens from the following private and State herbaria have been examined: A. C. Beauglehole, Gorae West, Victoria (BEAUGLEHOLE); State Herbarium of South Australia, Adelaide (AD); Waite Agricultural Research Institute, Adelaide (ADW); Botanisches Museum, Berlin-Dahlem (B); British Museum (Natural History), London (BM); Botanic Museum and Herbarium, Brisbane (BRI); C.S.I.R.O., Divisions of Plant Industry and Land Research and Regional Survey, Canberra (CANB); Herbarium, Royal Botanic Gardens, Kew (K); National Herbarium of Victoria, Melbourne (MEL); University of New England, Armidale, N.S.W. (NE); Animal Industry Branch, Northern Territory Administration, Alice Springs, N.T. (NT); National Herbarium of New South Wales, Sydney (NSW); State Herbarium of Western Australia, Perth(PERTH); Herbarium, School of Biological Sciences, University of Sydney (SYD); Naturhistorisches Museum, Wien (W).

In all, 1,224 sheets were seen, but for most species only a selection of the plants examined is cited in order to indicate the known geographical distribution. Locality, date of collection

and collector's name are cited; when any of this information is not known, its absence is indicated by a question mark.

The following herbaria are cited as holders of duplicates from AD: Gray Herbarium of Harvard University, Cambridge, Massachusetts (GH); Rijksherbarium, Leiden, Netherlands (L); Muséum National d'Histoire Naturelle, Laboratoire de Phanérogamie, Paris (P); Rancho Santa Ana Botanic Garden, Claremont, California (RSA); Botanical Institute, Tokyo (TI); Herbarium of the University of California, Berkeley, California (UC); Botanisches Garten und Museum der Universität Zürich, Zürich, Switzerland (Z).

Key to the Genera of Cruciferae with Dehiscent Fruits and Incumbent Cotyledons which are now known in Australia

1. Fruit compressed dorsi-ventrally or terete, valves flat or rounded, septum broad.
   2. Fruit usually 4-angled, valves with prominent nerve.
      3. Fruit linear, leaves amplexicaul — *Conringia**
      3. Fruit fusiform, leaves not amplexicaul
         4. Fruiting pedicels spreading — **Drabastrum**
         4. Fruiting pedicels recurved — **Scambopus**
   2. Fruit rounded or flattened, valves with nerve distinct to obsolete
      5. Seeds mucose
         6. Fruit obovoid, cauline leaves sagittate — *Camelina**
         6. Fruit linear to fusiform, cauline leaves not sagittate
            7. Petals drawn into slender point — *Stenopetalum*
            7. Petals obtuse
               8. Sepals erect, stigma 2-lobed or tectiform — **Blennodia**
               8. Sepals spreading, stigma capitate
                  9. Plant prostrate, fruit buried — **Geococcus**
                  9. Plant erect, fruit aerial
                     10. Plants glabrous, papillose or with simple hairs — **Arabidella**
                     10. Plants with branched hairs
                        11. Fruit fusiform — **Harmsiodoxa**
                        11. Fruit linear — **Pachymitus**
      5. Seeds not mucose
         12. Fruit linear, septum fully developed — *Sisymbrium**
         12. Fruit spherical to obovoid, septum reduced to a narrow rim — *Menkea*
1. Fruit compressed laterally, valves very convex or keeled, septum narrow
   13. Fruit linear — **Arabidella**
   13. Fruit orbicular to ovate or obcordate
      14. Fruit notched at summit
         15. Ovary with ca. 100-200 ovules — *Carinavalva*
         15. Ovary with fewer than 100 ovules
            16. Ovary with 2 ovules — *Lepidium*
            16. Ovary with ca. 10-30 ovules — *Capsella*
      14. Fruit entire at summit
         17. Fruit valves rounded — *Cuphonotus*
         17. Fruit valves keeled or winged
            18. Ovary with ca. 100-200 ovules — *Carinavalva*
            18. Ovary with ca. 10-25 ovules — *Hymenolobus*

N.B.: The genera marked by an asterisk are those represented in Australia by introduced species only; genera in bold are those treated in this revision.

Blennodia R.Br.

(*βλεννώδης* = mucose: the seeds are mucose when moistened)

R. Brown in Sturt, Exped. 2(1849)67; FvM., Pl. Col. Vict. 1(1862)40; Benth. & Hook., Gen. Pl. 1(1862)61,82; Benth., Pl. Austral. 1(1863)73; Prantl, Pflfam. 3(1891)204; Bailey, Qld. Flora 1(1899)46; Hayek, Beih. Bot. Centralbl. 27(1911)167,186,325; Maiden & Betche, Cens. N.S.W. Pl. (1916) 83; Black, Fl. S. Austral. (1924)246; Schulz, Pflreh. 86(1936)265; Schulz, Pflfam.ed.2 17b(1936)571; Black, Fl. S. Austral. ed.2(1948)374.
Type species: *Blennodia canescens* R.Br.

Description: *Calyx* closed; *sepals* erect or very slightly spreading, usually green, less often lavender, with a narrow pink or colourless hyaline margin, on abaxial side sparsely pubescent with shortly stipitate branched hairs; *lateral sepals* narrowly oblong, usually slightly wider than the median, basally saccate, distally tapering and acute to subacute; *median sepals* narrowly oblong to obovate, not basally saccate or, rarely, slightly so, distally tapering gently and rounded to truncate. *Petals* about twice as long as the sepals, white to lavender, with distinct blade and claw; blades oblong to obovate, entire or sinuate, rounded or truncate, often retuse or emarginate, finely veined, tapering into a more or less linear claw about as long as or slightly longer than the blade. *Stamens* 6, erect, filaments linear or dilated toward the base, sometimes distinctly winged, the filaments of the diagonal stamens often unequally widened, the greater width being on the lateral side of the vein, white or pink; anthers oblong, obtuse, yellow. *Lateral glands* each surrounding the base of a lateral stamen, horseshoe- or vee-shaped, open on the interior; *median glands* small, triangular, one on either side of the median line or, if more fully developed, forming a thinly torose ridge at the base of the diagonal stamens. *Pistil* not stipitate, cylindrical, densely tomentose with shortly stipitate irregularly branched hairs, rarely with a few simple hairs; *ovules* biseriate on slender pendulous funicles, ca. 20-40 per cell; *style* linear, stout, short or obsolete; *stigma* fleshy, depressed-capitate or, as seen from the median line, tectiform, broader than the style. *Fruit* bilocular, bivalved, dehiscent, not stipitate, linear, elongate and straight, terete or slightly flattened dorso-ventrally, therefore, latisept; *valves* convex or flat, with a distinct midnerve and a fine network of more or less parallel anastomosing veins, often somewhat constricted between the seeds, brown or reddish-purple, sparsely to densely pubescent with sessile or shortly stipitate branched hairs, proximally rounded to truncate, distally rounded; *style* linear to broadly obconical, sometimes greatly thickened and almost spherical or obsolete; *stigma* capitate or tectiform, usually centrally depressed, usually purple, often not as wide as the style. *Septum* white or colourless, opaque or translucent, sometimes fenestrate at the distal end, with median nerve, smooth or rugose; *funicles* short, triangular to linear, usually slightly curved, sometimes falcate. *Seeds* subbiseriate, ca. 20-40 per cell, broadly elliptic, plump or flattened, wingless or surrounded by a membranous wing; testa light golden-brown to dark brown, finely papillose, when moistened, mucose, the mucus exuded as discrete spiral threads, thus appearing radiate; *embryo* exactly notorrhizal, the radicle slightly longer than the cotyledons. *Plant* annual, herbaceous, usually many-stemmed, erect, canescent or tomentose with simple or irregularly branched hairs; *stems* arising from a basal rosette of leaves, equal or with a leafless or almost so central stem and leafy decumbent lateral stems, these often branched, the secondary stems sometimes reduced to the terminal inflorescence. *Basal leaves* rosulate, obovate to oblong, pinnatifid or, less often,

entire, tapering into slender petioles. *Cauline leaves* scattered, obovate to elliptic, entire or remotely dentate, rarely pinnatifid, usually sessile, occasionally on a short linear to cuneate petiole. *Root* a slender taproot. *Inflorescences* ebracteate, terminal on stems, dense, initially corymbose but after anthesis elongating and then racemose; *buds* just before anthesis oblong; *flowering pedicels* sometimes rather stout, erect or spreading or recurved; *fruiting pedicels* erect to spreading or recurved.

Two species in semi-arid parts of the Northern Territory, South Australia, Queensland and New South Wales.

Key to the species of *Blennodia*:

A Fruiting pedicels erect, seeds plump ... 1. *B. canescens*

A Fruiting pedicels recurved, seeds flattened ... 2. *B. pterosperma*

Relationships: The genus *Blennodia* is not closely related to any other Australian members of the family. In technical characters this genus has most in common with some species of *Hesperis* L. and *Blennodia* certainly fits more naturally into the tribe *Hesperideae* than into the *Sisymbrieae*.

1. Blennodia canescens R.Br.

(*canescens* = hoary; the dense pubescence gives the plant a hoary appearance)

R. Brown in Sturt, Exped. 2(1849)67; FvM., Enum. Pl. Gregory (1859)4; FvM., Rep. Babb. Exped. (1859)7; Benth., Fl. Austral. 1(1863)76; Tate, Trans. Roy. Soc. S. Aust. 22(1898)123; Bailey, Qld. Flora 1(1899)48; Black, Trans. Roy. Soc. S. Aust. 39(1915)830; Maiden & Betche, Cens. N.S.W. Pl. (1916)83; Ising, Trans. Roy. Soc. S. Aust. 46(1922)597; Black, Fl. S. Austral. (1924)248; Schulz, Pflrch. 86(1924)266; Murray, Trans. Roy. Soc. S. Aust. 55(1933)105; Black, Trans. Roy. Soc. S. Aust. 61(1937)243; Black, Fl. S. Austral. ed.2(1948)376; Jessup, Trans. Roy. Soc. S. Aust. 74(1951) 244,245,262; Chippendale, Trans. Roy. Soc. S. Aust. 82(1959)329.— *Sisymbrium blennodia* FvM., Fragm. 7(1869)20 [non *Sisymbrium canescens* Nutt., Gen. Am 2(1818)68]— *Erysimum blennodia* (FvM.)FvM., Fragm. 10 (1876)78 [non *Erysimum canescens* Moench, Meth. Suppl. (1794)86]; Tate, Trans. Roy. Soc. S. Aust. 3(1880)51; FvM., Census 1(1882)5; Tate, Trans. Roy. Soc. S. Aust. 6(1883)101; Winnecke, Trans Roy. Soc. S. Aust. 8(1886) 10; FvM., Trans. Roy. Soc. S. Aust. 9(1887)213; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; FvM., Sec. Census 1(1889)9; Tate, Fl. S. Austral. (1890) 16,206; FvM., Trans. Roy. Soc. S. Aust. 13(1890)96; FvM. & Tate, Trans. Roy. Soc. S. Aust. 19(1896)335; Koch, Trans. Roy. Soc. S. Aust. 22(1898)102.

Both *Sisymbrium blennodia* FvM. and *Erysimum blennodia* (FvM.) FvM. are nomenclatural synonyms of *Blennodia canescens* R.Br., these names being based on the same type.

Figures: Schulz, Pflrch. 86(1924)fig.58; Schulz, Pflfam. ed.2 17b(1936) fig.347; Blake, Proc. Roy. Soc. Qld. 49(1938)fig. 23; Figure 1A, B, E-L.

Description: *Plant* herbaceous annual canescent with sessile or shortly stipitate stellate or irregularly branched hairs; *root* a slender taproot; *stems* few to many, to about 50cm, erect, terete or, often, finely fluted, more or less leafy, often reddish-purple, arising from a basal rosette of leaves. *Basal leaves* to 12cm in length, sinuate-pinnatifid with 2-5 lobes per side, the lobes more or less linear and obtuse to subacute; more rarely entire or with a few small teeth, these leaves usually linear to narrowly spathulate; leaves tapering into a long slender petiole. *Cauline leaves* 3-5 [-7]cm in length, broadly linear or spathulate, usually entire or with a few teeth per side, obtuse to subacute, sessile or on a cuneate base, or, more rarely, shortly petiolate. *Inflorescences* usually

10-25-flowered, dense, then elongating after anthesis; *flowering pedicels* 3-10 [-15]mm in length, rather stout, erect to slightly spreading; *buds* oblong-ovate, almost oblong just before anthesis. *Sepals* oblong to obovate, green or, especially in northern material, lavender, usually with a narrow hyaline margin; *lateral sepals* [4·7-] 5·2-6·0 [-6·5]mm long, [1·2-] 1·5-1·8 [-2·0]mm wide, average ratio length to width 3·4:1, usually more or less oblong, acute to subacute, basally saccate; *median sepals* [4·4-] 5·0-5·5 [-5·8]mm long, [0·9-] 1·2-1·7 [-2·1]mm wide, average ratio length to width 3·8:1, usually more or less oblong, tapering distally and obtuse, not, or only very slightly, basally saccate. *Petals* about twice as long as the sepals, ca. 9·5-13·0mm long, clawed; blades ca. 3·0-6·7 x 2·0-3·7mm, ratio length to width 1·3:1-2·5:1, average 1·7:1, oblong to broadly cuneate, apically rounded, truncate or emarginate, tapering into a more or less linear claw, often winged, usually slightly longer than the blade, blade averaging 44 per cent of the total petal length; petals white, pink or lavender, the last seen especially on northern material, *in sicco* yellowish to dark brown. *Lateral stamens* [4·7-] 5·5-6·0 [-6·5]mm long, filaments usually more or less linear, 0·4-1·0mm wide, green to pink; anthers 1·6-2·3mm long, average 2·0mm, rectangular, obtuse, yellow; *diagonal stamens* [6·5-] 7·0-8·0mm long, filaments 0·5-0·8mm wide, linear or widened toward the base, the widening being greater on the lateral side of the vein; anthers 1·2-2·0mm long, average 1·6mm, oblong, obtuse, yellow. *Pistil* 4·0-6·5 mm long, cylindrical, not stipitate or on a short linear stipe, densely tomentose with very short hairs; *style* obsolete or short and linear, crowned with a fleshy tectiform or capitate stigma, this usually depressed; *nectaries* as in generic description, usually well-developed, bright green. *Fruiting pedicels* [4-] 8-13 [-16]mm long, 0·4-0·7 [-1·0]mm, averaging 0·6mm in diameter, rather stout, spreading to erect; *fruit* [1·5-] 2·5-4·0 [-5·5]cm long, septum 1·4-2·3mm wide, usually less than 2·0mm; valves with distinct but not prominent nerve, usually not constricted between seeds, rather densely pubescent, proximally usually truncate, distally rounded to subacute; *style* [2·0-] 2·5-4·0mm, linear or broadly obconical or so thickened as to be almost spherical; stigma tectiform or sometimes reduced and appearing depressed-capitate, usually purple; *septum* white, usually opaque and rugulose with median nerve, the epidermal cells being square to oblong, sometimes irregularly pentagonal, with straight or slightly curved walls; *funicles* to about 0·5mm in length, more or less linear to broadly triangular, usually slightly curved, pendulous. *Seeds* ca. 1·1-1·5 x 0·7-1·0mm, subbiseriate, ca. 20-40 per cell, oval, plump, wingless or occasionally with a small obtusely triangular wing at the distal end; testa golden- to dark-brown, usually with a darker area at the hilum, when moistened, exuding a radiate mucus to 2mm wide, the mucus emerging as a distinct spiral thread from each papilla of the testa as soon as moistened; *embryo* with radicle same length or slightly longer than the cotyledons; average thickness of embryos from soaked seeds 0·44mm.

TYPE LOCALITY: "Lacus arenosis depressis".

HOLOTYPUS: C. Stuit. No. 12 — BM!

SOUTH AUSTRALIA: — Mulnorina Stn.; 18.7.1955; *R. Hill 134* — AD. Mt. Lyndhurst; Aug. 1809; *M. Koch 329* — AD, NSW 53725; 8km E. Macumba H.S.; 3.9.1931; *Ising 2501* — AD; 1 mile S. Oodnadatta; 18.9.1963, *Shaw 225* — AD; 20 miles N. William Creek; 6.8.1963, *Kuchel 697* — AD; Everard Park H.S.; 12.8.1963; *Wilson 2579* — AD, UC, Z; Coondambo Siding; 2.8.1963; *Kuchel 555* — AD; Tarcoola; 21.9.1920; *Ising* — AD; Wynbring; Sept 1920; *Ising 1393* — MEL, NSW 53717, BH!;

NEW SOUTH WALES: — between the Darling and Lachlan, ?; *Burkitt* — MEL.; Yandama Stn.; July, 1910; *Collier* — NSW 53727.

QUEENSLAND: — Thylungra; 4.7.1942; *Allen 237* — CANB, NE; between Stokes Range and Cooper's Creek; ?; *Wheeler* — MEL.

NORTHERN TERRITORY: — 18 miles S.S.E. of Indiana Sta.; 11.9.1956; *Lazarides* 5965 — NT, PERTH, CANB, BRI, AD, NSW 53731: 19 miles S.E. of Alice Springs Township; 17.8.1956; *Lazarides* 5721 — NT, PERTH, AD, NSW 53732: 5 miles S.W. of Deep Well Stn.; 19.8.1956; *Lazarides* 5747 — NT, AD, BRI, NSW 53730, CANB, PERTH: Hermannsburg; 1906-1908; *Strehlow 4* — B: 1 mile W. Umbeara Well; 7.7.1955; *Chippendale* — NT 1356, CANB, BRI, NSW 53718, AD:

WESTERN AUSTRALIA: Perth [Kalgoorlie?]; Sept., 1913; *Ashby* — BM.

One hundred and twenty sheets were seen.

Distribution: In the Northern Territory *B. canescens* is known from the area between Alice Springs and the South Australian border, and from the Simpson Desert; it probably occurs also in the south-western part of the Northern Territory, but has not yet been collected there.

In South Australia it is found in the north-western and northern parts of the State, but apparently not in the Flinders Ranges and the Lake Frome Basin, its absence here surprising for it has been collected in the adjacent parts of New South Wales.

From New South Wales and Queensland there are only scattered collections, but these are from the north-western and south-western parts of the respective States. Blake mentions it as being very common in the Channel Country in south-western Queensland.

In the herbarium of the British Museum is a collection made by Ashby in Western Australia and labelled "Perth"; however, the label bears a pencil note suggesting that it was probably collected near Kalgoorlie and this is more likely. *B. canescens* probably occurs in the eastern part of Western Australia, for in South Australia it has been collected as far west as Ooldea and Wynbring. — *Map.* 1.

Observations: There is comparatively little variation in growth form and size of the floral organs and fruit. The most conspicuous variation is in size and shape of the style which can be linear or globose or any shape between these. In the flowering stage, the stigma is almost always rectiform (the lobes over the valves), but in the fruit this is often difficult to see as the stigma becomes distorted by growth of the style.

The petals are usually white, but pink or lavender petals are not uncommon. These seem to occur at random for they have been reported on plants from Mt. Lyndhurst, Arcoona and De Rose Hill, all in South Australia, and from Ooraminna Pass and Henbury in the Northern Territory. Unfortunately, unless a note was made at the time of collection one cannot be sure of the colour for originally white petals sometimes take on a lavender tinge when dried. Sepals are sometimes pink or lavender, but this seems to be not correlated with petal colour for coloured sepals are found on flowers with either white or coloured petals.

The testa is finely papillose, when moistened mucus is rapidly exuded as a long and distinct spiral thread, one from each papilla. It should be noted that the seeds have usually been described as wingless; sometimes are found seeds bearing a small triangular wing at the distal end. One also sees seeds which are apparently surrounded by a narrow wing, but this is a consequence of incomplete development of the embryo with the peripheral parts of the integuments being flattened around it.

To the unaided eye the entire plant looks hoary. All parts except the petals and stamens and root are covered with hairs which are usually shortly stipitate, although some few are sessile, and are irregularly branched or bifurcate. Many of the hairs, especially on the leaves, are twice bifurcate; that is, each arm of a

bifurcate hair is again forked. There sometimes are a few additional arms on these hairs, but the basic pattern is twice bifurcate.

Ecology and Biology: This species is not uncommon in semi-arid parts of South Australia and the adjacent parts of Queensland, New South Wales and the Northern Territory. Usually it grows in deep sand and under favourable conditions large sand hills may be covered with it. *Allen s.n.* (CANB, NE) from Thylungra, Queensland, is annotated as having grown on "red stony Gidgea and Boree flats" and *Chippendale s.n.* (AD, NT 2381) is described as "common in small area, on rocky ground", but these are probably less common occurrences.

Collections from Arcoona (*Murray 84* — AD) are noted as occurring on "bluebush [Kochia] flat and sandhills" and Jessup (1951), in discussing the *Acacia linophylla-A. ramulosa* association which occurs on sandhills on Arcoona and neighbouring stations west of Lake Torrens, mentions *B. canescens* as, along with *Calandrinia remota* and *Myriocephalus stuartii*, being common after winter rains. He also remarked that it occurs rather rarely in mulga (*Acacia aneura*) swamps in the same area.

Lazarides 5965 (AD, BRI, CANB, NSW 53731, NT, PERTH) from near Indiana Station in the Northern Territory is noted as being "common on creek-bank with *Chloris acicularis* and *Lepidium* spp."; *Lazarides 5721* (AD, NT, PERTH, NSW 53732), collected 19 miles south-east of Alice Springs, was "with *Acacia estrophiolata* and annuals on fine clayey sand". Also in clayey sand was *Lazarides 5747* (AD, BRI, CANB, NSW 53730, NT, PERTH) from Deep Well Station, annotated as occurring with *Triodia basedowii* and *Casuarina decaisneana*; *Perry 5501* (AD, CANB, NT, PERTH), collected near Mt. Cavanagh Station, was "with sparse *Acacia aneura* and *A. kempeana* on deep red sand on granite".

This species is a member of the large group of ephemerals which appear after rain in the semi-arid country. Probably mature seeds will germinate at any season, but only those plants coming up in autumn to early spring have a chance of fruiting and setting seed. It seems that the seed, when shed, is not fully mature, but requires an after-ripening period.

The months for flowering are July, August and September, although a plant collected on the Mulligan River in south-western Queensland in February, 1904, bears flowers and fruit.

Uses and Common Names: Usually this species does not occur in large enough quantities in any area to be of much importance as a fodder plant, although Jessup (1951) mentions *B. canescens* as being "quite palatable" (to mature merino sheep) and "fairly common".

The plants have sweetly scented flowers and under favourable conditions are large and showy, looking much like *Matthiola*. For this reason it is usually called "wild" or "native stock", although Blake (1938) remarks that it is called "heliotrope" in south-western Queensland.

Relationships: *Blennodia canescens* is very closely related to *B. pterosperma* and differs from it in only a few respects. The most obvious difference lies in the spreading pedicels of *B. canescens* which, although sometimes almost horizontal, are never recurved. Also *B. canescens* seems never to have hairs on the

replum, a feature constantly seen in *B. pterosperma*. The two are compared below:

B. canescens	*B. pterosperma*
style apparently never obsolete	style sometimes obsolete
septum opaque, rugulose	septum translucent, smooth
seeds plump, almost always wingless	seeds flattened, surrounded by a wing
fruiting pedicels ca. 0·4-1·0 mm in diameter	fruiting pedicels ca. 0·3-0·6 mm in diameter
fruiting pedicels spreading to erect	fruiting pedicels almost always recurved.

2. **Blennodia pterosperma** (Black)Black

πτερόν = wing; σπέρμα = seed; the seed is surrounded by a membranous wing) Black, Fl. S. Austral. (1924)248; Black, Trans. Roy. Soc. S. Aust. 49(1925) 272; Ising, Trans. Roy. Soc. S. Aust. 51(1933)186; Schulz, Pflfam. ed. 2 17b (1936)571; Black, Trans. Roy. Soc. S. Aust. 61(1937)243; Eardley, Trans. Roy. Soc. S. Aust. 70(1946)162; Black, Fl. S. Austral. ed. 2 (1948)376; Chippendale, Trans. Roy. Soc. S. Aust. 82(1959)329. — *Blennodia canescens* var. *pterosperma* Black, Trans. Roy. Soc. S. Aust. 41(1917)638 (*basionym*); Black, Trans. Roy. Soc. S. Aust. 42(1918)173.
Figures: Black, Trans. Roy. Soc. S. Aust. 41(1917)t.41, fig. 1; — Figure 1C, D, M.

Description: *Plant* herbaceous annual, tomentose with sessile or shortly stipitate stellate or irregularly branched hairs, rarely, beset with a few simple hairs as well as the other; *root* a slender taproot; *stems* few to many, to about 50 cm, erect, terete or finely fluted, rather sparsely leaved, brown-green or reddish-purple in colour, arising from a basal rosette of leaves. *Basal leaves* to ca. 7 cm long, sinuate-pinnatifid with 2-5 lobes per side, the lobes usually obtuse or, more often, linear to spathulate with margin entire or with a few small teeth, obtuse to subacute; leaves tapering into a slender petiole to 4 cm long. *Cauline leaves* to ca. 6 cm long and 4 cm wide, pinatifid with 2-3 linear lobes per side, terminal lobe subacute or, less often, acute; or entire or with a few small teeth; tapering into a short narrow petiole or, often, sessile on a narrowly cuneate base. *Inflorescences* averaging about 20-flowered, dense, elongating after anthesis; *flowering pedicels* 4-8 mm long, erect to slightly spreading, later becoming recurved in most cases; buds oblong just before anthesis. *Sepals* oblong to narrowly obovate, usually green, less often lavender, with a narrow hyaline margin; *lateral sepals* [4·3-] 5·5-6·0 [-6·5] x [1·2] 1·5-2·0 [2·3] mm average ratio length to width 3·1:1, oblong, tapering distally and subacute to acute, basally saccate; *median sepals* [4·5-] 5·0-5·5 [-6·0] x [1·1-] 1·4-1·6 [-1·8] mm, average ratio length to width 3·9:1, oblong to narrowly obovate, rounded to truncate, not, or rarely, very slightly saccate. *Petals* about twice as long as the sepals, ca. 9·5-13·0 mm long, clawed; blades ca. 3·2-6·3 x 2·0-4·5 mm, ratio length to width 1·2:1-2·0:1, average 1·6:1, oblong to ovate, apically rounded, truncate or, less often, emarginate, tapering into a linear claw, this usually expanded slightly distally or proximally, slightly longer than the blade, blade averaging 40 per cent of the total petal length; petals white, pink or lavender, the last seen more often in northern specimens, *in sicco* dark brown or yellowish. *Lateral stamens* [4·0-] 4·5-5·0 [-5·5] mm long, filaments linear, average 0·5 mm wide, tapering slightly distally, green, pink or lavender; anthers

1·6-2·3 mm, average 1·9 mm, oblong, obtuse, yellow; *diagonal stamens* [5·8-] 6·1-6·7 [-7·4] mm, filaments to 0·8 mm, linear or broadened proximally, this often unequal, the greater width being on the lateral side of the vein, green, pink or lavender; anthers 1·5-2·1 mm, average 1·7 mm, oblong, obtuse, yellow. *Pistil* 4·0-6·5 mm long, cylindrical, not stipitate or on a short linear stipe, densely tomentose with very short hairs; *style* obsolete or short and linear; *stigma* fleshy, tectiform or depressed-capitate; *nectaries* as generic description, green, very often not well developed. *Fruiting pedicels* to ca. 18 mm long, 0·3-0·6 mm, average 0·1 mm in diameter, rather slender, spreading or, in most cases, recurved. *Fruit* 4·5-7·0 cm long, septum 1·2-2·5 mm, usually less than 1·7 mm, straight or slightly curved; valves with prominent nerve, usually slightly constricted between seeds, with rather scattered pubescence, proximally usually rounded, rarely, truncate, distally rounded or subacute; *style* 0·7-1·4 mm, linear, or obsolete; *stigma* tectiform or depressed-capitate, usually purple; *septum* white or colourless, vitreous and smooth, with median nerve, often fenestrate at the distal end, the epidermal cells of the center usually more or less oblong with very sinuous margins, occasionally with almost straight or slightly curved margins, those cells toward the edge more nearly square, with straight margins, the peripheral area often somewhat rugulose; *funicles* usually more or less linear straight or curved, pendulous; *replum* usually with a few scattered hairs. *Seeds* ca. 1·3-1·6 x 0·9-1·1 mm, subbiseriate, ca. 25-40 per cell, oval, flattened, surrounded by a membranous wing to 0·5 mm in width at the chalazal end; testa light golden-brown, usually with a darker area at the hilum, when moistened exuding a narrow radiate mucus, especially on the wing, the mucus emerging from each papilla of the testa as a hyaline oblong, each containing a grey spiral thread; *embryo* exactly notorrhizal, the radicle slightly longer than the cotyledons; average thickness of embryos from soaked seeds 0·28 mm.

TYPE LOCALITY: "Lake Blanche".

HOLOTYPUS: Lake Blanche; 19.9.1916; S.A. White — AD 96146049!

SOUTH AUSTRALIA: — Birdsville Track; Spt. 1960; *Browning* — ADW; between Nappamerrie and Innamincka; 13.8.1962; *Jackson 429* — AD; east shore of Lake Frome; 28-31.8.1952; *Peake-Jones* — AD; approx. 5 miles N. Cooper's Creek; 24.8.1960; *Lothian 269* — AD, UC, Z; 18 km N. Andamooka Stn.; 25.9.1960; *Filson 3216* — AD; Parachilna 3.9.1941; *Cleland* — AD; 38 miles east Dalhousie Springs; 9.8.1963; *Lothian 1419* — AD.

NEW SOUTH WALES: — Mootwingee; Aug. 1962; *Gardiner* — AD; Fort Grey; Aug. 1921; *MacGillivray*.

QUEENSLAND: — near Nappamerrie Stn.; 15.8.1962; *Jackson 447* — AD;

NORTHERN TERRITORY: — Simpson Desert, about 60-65 miles S.E. Ringwood Stn.; 8.9.1955; *Chippendale* — NSW 53715, NT 1610; sandy watercourse, Charlotte Waters, 27.5.1939; *Crocker* — AD;

Fifty-eight sheets were seen.

Distribution: Known from South Australia, the Northern Territory, New South Wales and Queensland, but apparently much less widely spread than is *B. canescens*. In South Australia the collections are chiefly from the north-eastern part of the State, with a few from the Flinders Ranges, the western part of the Simpson Desert, and a single collection from 18 km north of Andamooka (*Filson 3216* — AD) which is the only one from the area south-west of Lake Eyre.

The Northern Territory collections are from the Simpson Desert and the area between Alice Springs and Charlotte Waters. The seven collections made in New South Wales are all from the far north-western part of the State. Two collections from Queensland are from the south-western part. — *Map 2*.

Observations: *B. pterosperma* is even more constant in its characters than is *B. canescens*, the only real variation being in size of the style. Black (1925) said "stigmate fere sessile", but there is often a quite conspicuous style as much

as 1½ mm long. The most noticeable feature is the occurrence of recurved fruiting pedicels; when the plant is in flower the pedicels are usually only spreading, but with maturation of the ovary the pedicels gradually turn downwards. However, in any given plant there may be a few pedicels which remain spreading.

As in *B. canescens*, the petals may be white or lavender; coloured petals seem to occur at random in a population and to be correlated with no other feature. Collections which definitely had lavender petals have been made at Pandie-Pandie (*Lothian 436* — AD), between Innamincka and Nappamerrie (*Jackson 429* — AD) and several other places in the north-eastern part of South Australia, as well as at scattered localities in the Flinders Ranges and near Lakes Torrens and Frome. In this species, too, the sepals may be pink or lavender, but this is again independent of petal colour.

A distinctive feature of the septum is the transparent band running along either side of the vein. The epidermal cells are usually fusiform and quite acute or oblong, with straight or wavy edges. This central band may take up half the total width of the septum and even to the unaided eye is conspicuous. The apparent difference is perhaps the result of some difference in the middle layer of the septum, for the epidermal cells themselves seem to be much the same across its width.

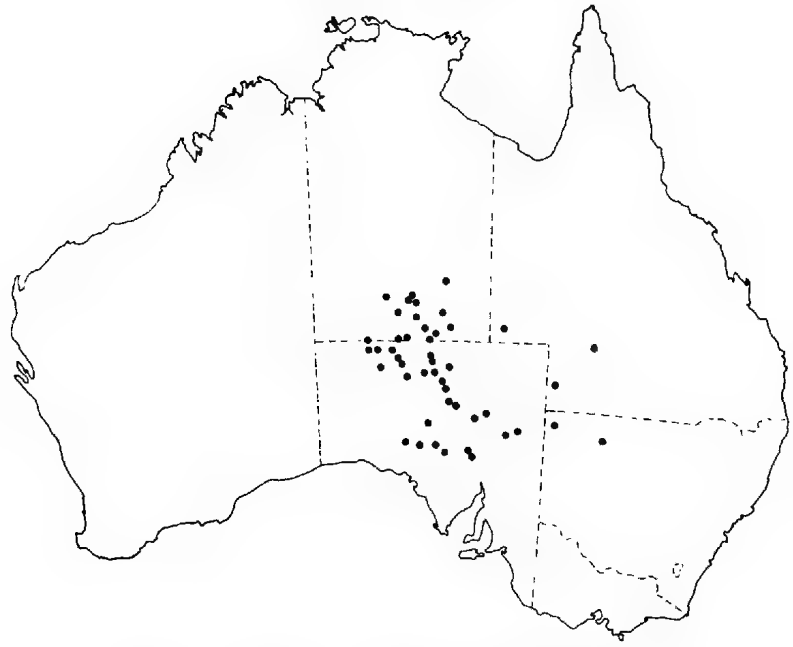
The seeds are more flattened than are those of *B. canescens* and are surrounded by a membranous wing. When moistened, mucus is rapidly exuded as discrete oblong bodies, one appearing to come from each papilla, each of which contains a grey coiled thread; this is seen especially well on the wing.

The pubescence is essentially the same as that of *B. canescens*, the plant having an overall hoary appearance. The hairs are usually shortly stipitate and are irregularly branched, often being twice bifurcate. On the fruit valves the hairs are usually not much more than ca. ¼ mm long with the arms usually flattened in a plane parallel to the valve. On the leaves they are much the same except that comparatively more are almost sessile and there is an admixture of trifurcate ones. The cauline hairs are the same, but slightly longer, about ½-¾ mm long.

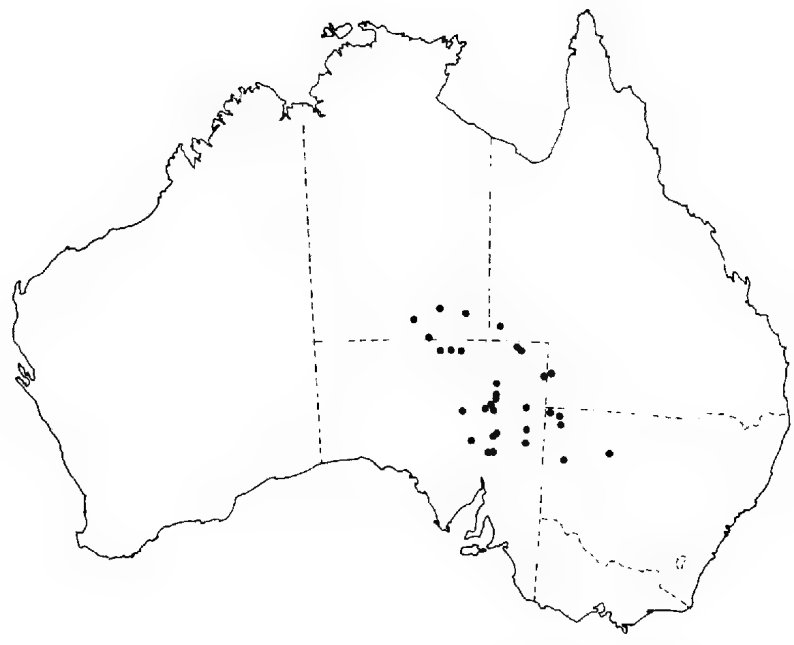
Specimens of *B. canescens* and *B. pterosperma* look slightly different and this would seem to be due to some subtle difference in the pubescence. It has, however, proved impossible to find any constant difference between them and one cannot satisfactorily determine material which is purely vegetative or bearing flowers only. Fruits of *B. pterosperma* generally have scattered hairs on the replum, but these are not always present on the young ovary. It also seems generally true that the ovary of *B. pterosperma* is less stout than that of *B. canescens*, but this difference is neither great enough nor constant enough to be of value in making determinations.

Ecology and Biology: Much of what is true of *Blennodia canescens* is true also of this species. It commonly occurs on deep sand; the writer has seen it growing densely on sand hills north of Leigh Creek where it was with other ephemerals — *Compositae*, *Zygophyllum*, *Euphorbia*, *Portulacca*, etc. Other plants with which it has been found associated in south-western Queensland and north-eastern South Australia are species of *Senecio*, *Frankenia*, *Crotalaria* and *Scaevola*.

Probably *B. pterosperma* may spread rather quickly for the flat winged seeds would be easily carried by the wind. The earliest collections available were made in 1885 (*Mulligan River; Cornish* — MEL) and in 1888 (*between the Finke River and Charlotte Water; Kempe* — MEL); none were then made until 1916 (the holotype). During this time several collections of *B. canescens* were



Map 1. Distribution of *Blennodia canescens* R.Br.



Map 2. Distribution of *Blennodia pterosperma* (Black) Black.

made in areas where *B. pterosperma* might now be expected and it seems possible that *B. pterosperma* is less common than is the other species. Yet, in favourable seasons, it occurs in profusion in rather restricted areas.

Uses and Common Names: Apparently no uses for this species have been recorded. It is known as "wild" or "native stock".

Relationships: It is somewhat surprising that Black originally described this species as agreeing with *B. canescens* except for the seeds being winged. Certainly the recurved pedicels of *B. pterosperma* are very distinctive and could not be confused with those of *B. canescens*. The writer agrees with Black's later conclusion that these two are distinct species.

Arabidella (FvM)Schulz

(Arabidella = diminutive of Arabis L.)

Schulz, Pflrch. 86(1924)177; Schulz, Pflfam. ed. 2 17b(1936)612.— *Erysimum* subgenus *Arabidella* FvM., Linnaea 25(1853)368.— *Pseudarabidella* Schulz, Pflrch. 86(1924)257; Schulz, Pflfam. ed. 2 17b(1936)636. (ψευδής = false, *Arabidella* = genus in this family).— *Micromystria* Schulz, Pflrch. 86(1924)263; Schulz, Pflfam. ed. 2 17b(1936)639. (μικρός = small, μυστρίον = spoon; the filaments of *Arabidella nasturtium* (FvM)Shaw are basally dilated).— *Lemphoria* Schulz, Pflrch. 86(1924)267; Schulz, Pflfam. ed. 2 17b(1936)640. (λέμφος = mucus; the seeds are mucose).

Typical species: *Arabidella trisecta* (FvM.)Schulz.

Description: *Calyx* open; *sepals* spreading or, less often, almost erect, not saccate, usually green or yellow-green, sometimes lavender, with a narrow colourless or lavender hyaline margin and bearing on the abaxial side a few hairs near the tip; *lateral sepals* usually oblong, sometimes obovate, usually absolutely and relatively wider than the median, distally gently tapering and subacute or, less often, rounded; *median sepals* oblong or obovate to elliptic (sometimes suborbicular), proximally usually gently tapering, distally rounded or, less commonly, subacute, sometimes slightly cucullate. *Petals* as long as the sepals to about twice as long, white or yellow, very rarely lavender, obovate to cuneate, or with distinct blade and claw; if clawed, claw usually more or less linear or slightly widened basally, as long as or shorter than the blade, then usually suborbicular to obovate, rarely rhombic, entire or sinuate, apically rounded to truncate, then sometimes retuse or emarginate, finely or coarsely veined, often blade at right angles to the claw or further reflexed. *Stamens* 6, erect or somewhat spreading, filaments linear and slightly widened at the base, or much expanded and spathulate, usually yellow to green, occasionally pink to lavender; *anthers* usually oblong, less often almost square or more or less sagittate, rounded or truncate, yellow. *Nectaries* of a quite constant pattern, but showing varying degrees of development; *lateral glands* each surrounding the base of a lateral stamen, annuliform to hexagonal, usually open on the inner side, open or, often, only emarginate on the exterior, producing from each side of each gland a lateral appendage curving around the base of the adjacent diagonal stamen; sometimes not fully developed and then usually appearing as semi-circular or oblong lobes of tissue, each subtended by a petal; *median glands*, if present, single oblong or deltoid lobes of tissue lying between the bases of the diagonal stamens; at fullest development, lateral and median glands approximate, but not fused. *Pistil* not stipitate or on a short linear stipe, linear or fusiform, terete or slightly flattened dorso-ventrally (latisept), glabrous or sparsely pubescent (*A. eremigena*); *ovules* usually biseriate, oblong to oval,

on slender pendulous funicles, ca. 16-45 per cell; *style* linear to broadly obconical, short, rarely obsolete; *stigma* fleshy, depressed-capitate or, sometimes, almost tectiform, as wide as or slightly wider than the style. *Fruit* bilocular, bivalved, dehiscent, not stipitate or on a short stipe, linear, straight or slightly curved, terete or flattened dorso-ventrally or laterally; *valves* almost flat or slightly or very convex, with a distinct midnerve and, when mature, usually a reticulum of secondary veins, sometimes slightly constricted between seeds, brown, often with reddish or magenta pigmentation especially at the margins, glabrous or pubescent with simple hairs, proximally rounded to truncate, less often, subacute, distally rounded or tapering and subacute; *style* linear to broadly obconical or very short and stout or obsolete; *stigma* usually depressed-capitate, sometimes much depressed and cuplike or almost tectiform, as wide as or slightly wider than the style. *Septum* white or colourless opaque or translucent, sometimes fenestrate by a longitudinal slit, nerve obsolete or more or less distinct, smooth or rugulose, especially at the margins and between the seeds; *funicles* linear or slightly broadened proximally to almost deltoid, straight or curved, pendulous. *Seeds* uniseriate to biseriate, oblong to oval, plump or slightly flattened, sometimes (*A. filifolia*) with a small wing at the distal end; *testa* yellow or yellow-brown to reddish-brown, slightly darker at the hilum, very finely papillose; when moistened exuding from each papilla a discrete oblong body in cone of mucus; *embryo* exactly or obliquely notorrhizal, cotyledons usually oblong, slightly shorter than the radicle. *Plant* perennial, suffruticose and many-stemmed, erect, or annual, herbaceous, erect or prostrate, glabrous or finely papillose or pubescent with simple hairs; *stems* arising from ground level or from a short main stem; if herbaceous, sometimes with a leafless central stem and leafy lateral stems arising from a basal rosette of leaves, the central stem sometimes reduced to an apparently basal inflorescence. *Basal leaves* (present in herbaceous species only) rosulate, usually obovate to narrowly so, entire or pinnatifid, petiolate. *Cauline leaves* (in species with a basal rosette) usually few, scattered, pinnatifid with 1-7 lobes per side or, rarely, entire, shortly petiolate or sessile on cuneate bases; otherwise solitary or fasciculate, filiform to linear, entire or bi- or tri- sect, sometimes with regular dichotomous divisions of the second and third order, sessile. *Root* a taproot, slender or short, stout and woody. *Inflorescences* ebracteate, terminal on stems, initially corymbose but after anthesis elongating and racemose, sometimes stem reduced so inflorescence seems basal; *buds* immediately before anthesis oblong to ovoid or obovoid; *flowering pedicels* slender, ascending to slightly spreading; *fruiting pedicels* slender, almost erect or spreading to horizontal.

Six species in semi-arid parts of Western Australia, South Australia, the Northern Territory, Queensland, New South Wales and Victoria.

Key to the species of *Arabidella*:

A Plants herbaceous
  B Leaves mostly bisect or trisect ..... 4. *A. nasturtium*
  B Leaves pinnatisect or lyrate-pinnatifid
    C Plants glabrous ..... 6. *A. procumbens*
    C Plants pubescent ..... 5. *A. eremigena*

A Plants suffruticose
  D Plants straggling shrubs, leaves mostly entire ..... 3. *A. filifolia*
  D Plants erect, leaves mostly bisect or trisect
    E Fruit usually sessile, linear, plant usually papillose, leaves less than 0·5 mm wide ..... 1. *A. trisecta*
    E Fruit usually stipitate, linear-ellipsoid, plant glabrous, leaves ca. 1·5-1·5 mm wide ..... 2. *A. glaucescens*

1. **Arabidella trisecta** (FvM)Schulz

(*tres* = three, *secta* = cut; the leaves are often divided into three segments)

Schulz, Pflrch. 86(1924)179; Black, Trans. Roy. Soc. S. Aust. 61(1937)243. – *Erysimum trisectum* FvM., Linnaea 25(1853)368 in obs. (*basionym*). – *Sisymbrium trisectum* FvM., Trans. Vict. Inst. 1(1855)114; FvM., Hook. J. Bot. Kew Misc. 8(1856)4; FvM., Rep. Babb. Exped. (1859)7; FvM., Pl.Col.Vict. 1(1860-1862)39; FvM., Fragm. 7(1869)20; FvM., Fragm. 11 (1879)60; FvM., Nat.Pl.Vict. 1(1879)33; Tate, Trans. Roy. Soc. S. Aust. 3(1880)51; FvM., Census 1(1882)5; Tate, Trans. Roy. Soc. S. Aust. 6(1883) 101; FvM., Key Vict.Pl. 2(1885)7; FvM., Key Viet Pl. 1(1887-1888)131; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; FvM., Sec.Census 1(1889)9, Tate, Fl.S.Austral. (1890)16, 206; FvM. et Tate, Trans. Roy. Soc. S. Aust. 13 (1890)96; 16(1896)335; Koch, Trans. Roy. Soc. S. Aust. 22(1898)102. – *Blennodia trisecta* (FvM.)Benth., Fl.Austral. 1(1863)74; Turner, Forage Pl. Austral. (1891)2; Tate, Trans. Roy. Soc. S. Aust. 22(1898)123; Bailey, Qld. Flora 1(1899)47; Black, Trans. Roy. Soc. S. Aust. 39(1915)830; Maiden & Betche, Cens. N.S.W. Pl. (1916)63; Black, Trans. Roy. Soc. S. Aust. 41(1917) 45, 638; Ising, Trans. Roy. Soc. S. Aust. 46(1922)588, 597; Black, Fl.S.Austral. (1924)247; Black, Trans. Roy. Soc. S. Aust. 61(1937)243; Black, Fl.S.Austral. ed. 2 (1948)375; Jessup, Trans. Roy. Soc. S. Aust. 74(1951)243, 248, 250. – *Arabidella trisecta* var. *hybophora* Schulz, Pflrch. 86(1924)179.

The first three of the above names are nomenclatural synonyms of *Arabidella trisecta*, being based on the same type. The name *Arabidella trisecta* var. *hybophora* which is based on a different type is discussed below.

Excluded: *Arabidella trisecta* var. *brachycarpa* (Benth.) Schulz (*Blennodia trisecta* var. *brachycarpa* Benth.) = *Arabidella glaucescens* Shaw.

Figures: Turner, Forage Pl. Austral. (1891) fig. 2; Hayek, Beih. Bot. Centralbl. 27(1911) fig. 8 (11); Schulz, Pflrch. 86(1924) fig. 33; Schulz, Pflfam. ed. 2 17b(1936) fig. 382; – Figs. 2A, 3G-N.

TYPIFICATION: Since no collections were cited and no localities mentioned with the description of *Erysimum trisectum* FvM., it was necessary to choose a lectotype for this name. With the description of *Sisymbrium trisectum* several localities are mentioned. However, *S. trisectum* FvM. (1855) cannot be necessarily regarded as a nomenclatural synonym of *E. trisectum* FvM. (1853) for no reference is made to the earlier publication of the latter name.

To avoid future confusion it is necessary to choose, if possible, as lectotype of *Sisymbrium trisectum* FvM. a plant which it is certain that Mueller saw before 1853 and took into account in describing *E. trisectum*. There are four specimens from Crystal Brook and Gudnaka in the southern part of the Flinders Ranges which Mueller collected in October, 1851, and one from Morundie on the Murray River collected by him in February of the same year.

From these five MEL 758 has been chosen as lectotype of both names because it fits a locality mentioned with the description of *S. trisectum* ("on Spencer's Gulf"), it is an entire plant and the best of the five, and it bears some pertinent annotations in Mueller's hand. These are "Arabis trisecta, F. Muell." and "Erysimum (Arabidella) trisecta Ferd. Mull.Nov.Holl. austral.".

It agrees well with both descriptions and with the choice of this lectotype for both the names *Erysimum trisectum* FvM. and *Sisymbrium trisectum* FvM. they become nomenclatural synonyms.

Two varieties must be considered. One is *Blennodia trisecta* var. *brachycarpa* Benth. (1863), accepted also by Schulz, and based on a collection made in 1859 on McDouall Stuart's expedition. Bentham wrote:

"These specimens, . . ., are in fruit only; the habit and foliage are precisely those of the common form gathered with them, but the pods are shortly oblong and very turgid, about 2 lines long; they may possibly be accidentally abnormal."

The existing specimen appears to be a fragment of a plant of *A. glaucescens* with very young fruit and it seems best that this name be treated as a taxonomic synonym of *A. glaucescens*.

A. trisecta var. *hybophora* Schulz (1924) was thought to be distinct because of its bearing papillae. However, almost all plants of *A. trisecta* bear papillae and it does not seem justified to maintain this variety. To prevent future confusion it is necessary to choose a lectotype. Schulz said only "Mit der typischen Pflanze."; there are only two specimens annotated by Schulz as "var. hybophora" and dated before 1924. One of these is *Koch 221* (B), the other a collection from Crystal Brook (W). The latter bears no collector's name, but does have a label "Plantae Müllerianae" and was almost certainly collected by Mueller. This latter is chosen as lectotype because it is a better specimen than the other, comes from the lectotype locality of *A. trisecta* and was possibly collected at the same time as this lectotype.

Description: *Plant* an erect woody undershrub, when in fruit to about 60 cm high, but usually less, glabrous or the stems and proximal parts of the leaves covered with oblong to broadly triangular papillae, these usually less than 1 mm long and flattened; *root* a stout woody taproot to ca. 1·5 cm diameter; stems to ca. ¾ cm in diameter near the base, arising from ground level or from a short main stem, terete or quadrangular or finely fluted, erect or slightly spreading, light in colour, when older usually with excoriating bark. *Leaves* (all cauline) to ca. 4 cm long, to ca. 1 mm, usually less than ½ mm in width, solitary or clustered, often seeming very densely clustered because of short leafy branches arising in the leaf axils; very rarely entire, usually bi- or tri sect, the primary sectors often further divided, sometimes with regular dichotomous divisions of the second or third order; segments linear, narrow or, not uncommonly, narrowly spathulate toward the tips, rounded to acute, the segments usually arising from about the same level, the divided part usually less than half the total length; *in vivo* somewhat fleshy, *in sicco* fragile and usually much wrinkled, often with red pigmentation at the tips. *Inflorescences* usually ca. 30- to 40-flowered, sometimes reduced to 1 or a few flowers arising in a leaf axil, rather loose before anthesis, elongating afterward, length from the lowest flower to tip to ca. 15 cm; *flowering pedicels* to ca. 12 mm long, ca. 0·15-0·25 mm in diameter, terete to quadrangular, ascending slightly spreading; *buds* just before anthesis more or less obovoid, often a few scattered buds below the opened flowers. *Sepals* oblong or elliptic or obovate, usually green, occasionally lavender, with a narrow hyaline margin, sometimes slightly cucullate distally, not saccate, initially erect but gradually spreading to horizontal or further bent back; *lateral sepals* ca. 2·8-4·4 mm long, ca. 1·1-1·9 mm wide, average 3·8 x 1·4 mm, ratio length to width 2·2:1-3·3:1, distally subacute to rounded; *median sepals* ca. 3·1-4·6 mm long, ca. 1·0-2·1 mm wide, average 3·8 x 1·6 mm, ratio length to width 1·8:1-2·9:1, distally rounded. *Petals* as long as the sepals to 1½ times as long, ca. 3·0-6·0 mm long, average 4·5 mm, white or cream-coloured, occasionally bright yellow, yellowish *in sicco*; blades ca. 2·2-4·2 mm long, ca. 1·7-4·5 mm wide, average 3·2 x 3·1 mm, ratio length to width of blade 0·9:1-1·3:1, usually suborbicular, less often broadly oblong to square, usually entire or sinuate, rarely retuse, usually densely veined, tapering suddenly into a narrow linear claw ca. 0·2-0·6 mm wide, the blade averaging 73 per cent of the total petal length, often reflexed so the blade at right angle to the claw. *Stamens* with filaments slender, linear or slightly widened at the base, white to green; *anthers* narrowly oblong or, less often, almost halberd-shaped, obtuse; *lateral stamens* ca. 3·2-4·2 mm long, average 3·6 mm, anthers ca. 1·5-2·1 mm, average 1·7 mm, *diagonal stamens* ca. 2·9-4·5 mm, average 3·8 mm, anthers ca. 1·5-2·2 mm, average 1·8 mm. *Pistil* ca. 2·5-4·0 [-5·0] mm long, not stipitate or on a very short stipe, linear, terete or slightly flattened dorso-ventrally; *style* linear to broadly clonate, short; *stigma* fleshy, depressed-capitate, as wide as or slightly wider than the style; *ovules* ca. 40-90 per ovary, more or less oblong, biseriate on slender linear to

narrowly triangular funicles; *lateral glands* hexagonal or pentagonal to circular, usually open on the interior, sometimes submarginate to open on the exterior, producing on each side of each gland a lateral appendage curving around the base of the adjacent diagonal stamen; *median glands* oblong lobes of tissue lying between the bases of the diagonal stamens, rarely two- or three- lobed, the glands approximate, conspicuously fleshy and torulose, usually bright green. *Fruiting pedicels* usually ca. 1·0-1·5 cm long, exceptionally to 2·0 cm, ca. 0·3 mm diameter, expanded to ca. 0·5-0·7 mm just below the calyx, terete or obtusely triangular, erect to slightly spreading, usually straight. Fruit ca. [0·6-] 1·0-4·0 cm long, usually 2·0-3·0 cm, ca. 0·8-1·5 mm, usually 0·9-1·3 mm across the septum, terete or latisept, linear, straight or slightly curved, usually not stipitate, but sometimes shortly so, the stipe ca. 0·1-0·4 mm long; *valves* somewhat convex to flat, proximally obtuse to truncate, sometimes retuse, distally subacute to rounded, sometimes truncate and retuse, with stout vein and, when mature, a reticulum of anastomosing secondary veins, often with red or magenta pigmentation especially at the margins; *style* linear to broadly obconical, ca. 0·4-1·4 mm, usually 0·7 mm long; *stigma* small, depressed-capitate, sometimes cuplike, about as wide as the style; *septum* white, with indistinct nerve, opaque and rugulose or translucent and smooth to vitreous; *funicles* slender, linear to narrowly triangular, pendulous. *Seeds* ca. 0·7-0·9 mm long, ca. 0·4-0·6 mm wide, uniseriate to subbiseriate, ovoid to oblong, plump; testa orange to reddish-brown with dark red pigmentation at the hilum, when moistened exuding a narrow band of mucus to ca. 1 mm wide, the mucus emerging in discrete oblongs and thus appearing radiate; *embryo* exactly notorrhizal, the radicle slightly longer than the cotyledons.

TYPE LOCALITY: (*Sisymbrium trisectum* FvM., 1855)— "In the desert, on the Murray River, on Spencer's and St.Vincent's Gulf, and near Lake Torrens".

LECTOTYPUS: Crystal Brook; Oct., 1851; Mueller — MEL 758!

SOUTH AUSTRALIA: - Muloorina Stn.: 18.7.1955; *Hill 138* — AD; Mumpeowie H.S.; 30.8.1960; *Lothian 692* — AD; 7 miles north of Leigh Creek township; 29.8.1963; *Shaw 183* - AD; Mt. Parry Cap; 4.6.1883; *Tate* — AD; Mt. Lyndhurst; Aug. 1898; *Koch 221* — AD, B, BRI, NSW 53547; Chambers Gorge near Mt. Chambers; 12.9.1956; *Eichler 12581* — AD; Parachilna; 3.6.1961; *Donner 77* — AD; 3 miles north of Hawker; 25.8.1961; *Shaw 7, 9, 11* — AD; Cudnaka [Kanyaka]; Oct. 1851; *Mueller* — MEL 778; Koonamore — near Bindy-i Bur; 17.8.1956; *Eichler 12525* — AD; between Orroroo-Peterborough; 24.9.1936; *Clarke* — ADW; Morunde, Murray River; Feb. 1851; *Mueller* — MEL 760; 25 miles east of Burra on Burra-Morgan road; 20.8.1963; *Shaw 167* — AD; Crystal Brook; Oct. 1851; Mueller — W (lectotype of *Arabidella trisecta* var. *hylophora* Schulz); Yudnapinna; April, 1939; *Douglas* — ADW; Arcoona, also Oakden Hills; Sept. 1927; *Murray 130* — AD; 2 miles N. Mt. Willoughby Stn., 4.8.1963, *Kuchel 616* — AD; ca. 50 miles W. Oodnadatta on Hawkes Nest Well road; 19.9.1963; *Shaw 233* — AD; 7 km south of Ooldea; 22.9.1960; *Whibley 761* — AD, Z, UC; Cook; 6.9.1959; *Eichler 16179* — AD; Hughes; Sept. 1920; *Ising 1549* — AD, BRI, MEL, NSW 53543;

VICTORIA: — Swan Hill; ?; *Ross* - MEL; high limestone cliffs of the Murray immediately south of Boundary Point, extreme N.W. corner of Victoria; 30.8.1948; *Willis* — CANB, MEL;

NEW SOUTH WALES: — Cobar; Sept. 1911; *Cleland* — AD; [near Lake Burrumbart]; 10.5.1836; *Mitchell 141* — MEL; Balranald; 1878; *Lucas 70* — MEL; Tarella; Aug. 1887; *Bauerlen 26* — MEL; Camp Menindie; 15.10.1860; *Victorian Exploring Expedition* — MEL; Tibooburra; 24.10.1949; *Constable* — NSW 10488; Broken Hill; 20.8.1939, *Pidgeon & Vickery* — NSW 53560; Mazar Stn.; 24.7.1955; *Constable* - NSW 36570, NT; River Darling; 18.9.1860; *Victorian Exploring Expedition* — MEL;

QUEENSLAND: — Queensland, Australia; 1863 ?; *Mueller* — BM;

NORTHERN TERRITORY: — near Alice Springs; 1882; *Kempe* — MEL; 8 miles east of Mt. Sir Henry, Ayer's Range; June, 1926; *Baseilote 43* — AD;

WESTERN AUSTRALIA: — Eucla; 1882; *Oliver* — MEL; Mt. Margaret; 11.8.1931; *Gardner 2471* — PERTH; Coolgardie; June, 1899; *Helms* — NSW 53565;

In all, 217 sheets were seen.

Distribution: Known from Western Australia, the Northern Territory, South Australia, New South Wales and Victoria; probably also in south-western Queensland, but there is only one collection from this State.

In Western Australia from the Kalgoorlie area and the far south-eastern part of the State. In the Northern Territory near Alice Springs and south-west of there toward the Musgrave Ranges.

The bulk of the available material is from South Australia and most of this from the Flinders Ranges and south-east of them toward the Murray River. The southernmost collection is from Morundie on the Murray (*Mueller* — MEL 769), and at the present this species is found as far south as the latitude of Morgan on the Murray River. There are also scattered collections from the area south-west of Oodnadatta and from stations along the transcontinental rail-line.

In New South Wales occurs in the north-western part of the State, at least as far east as Cobar, and to the south-east as far as Balranald. In Victoria from the north-western part along the Murray River. — *Map 3*.

Observations: There is little morphological variation, although in the north-western part of New South Wales and probably also in adjacent parts of South Australia and Queensland is a form intermediate between *A. trisecta* and *A. glaucescens*. This has fruits shortly stipitate and usually on rather spreading pedicels, features suggesting *A. glaucescens*, but the leaves are those of *A. trisecta*.

Usually the plant branches from ground level, but in the southern part of the Flinders Ranges are found plants with a short main stem of 3-4 cm length before the first branches. These plants also have leaves slightly shorter (ca. 1 cm) than most.

Generally the petals are white, but in August, 1963, the writer collected north of Leigh Creek a form with bright yellow petals. From Leigh Creek to the Frome River, just north of Marree, it occurred to the apparent exclusion of the ordinary white-flowered form; it was generally growing with populations of *A. nasturtium* and it is possible that some hybridisation had occurred.

When this was investigated further it was found that yellow-flowered plants had been collected at Marree (*Hill 88* — AD), Murnpeowie (*Lothian 692* — AD) and possibly at Mt. Lyndhurst (*Koch 325* — NSW 53546), all places in the northern part of the Flinders Ranges or just to the north of them. It was also found that the plants are almost entirely lacking papillae.

There are collections of seemingly glabrous *A. trisecta* from other areas; several are from the Flinders Ranges, but there are also ones from Coruna (*Reed s.n.* — AD), Arcuona (*Woodroffe 6166* — ADW), 50 miles west of Oodnadatta (*Shaw 233* — AD), Maralinga (*Shilling 57* — AD), and from New South Wales; for example, from Cobar (*Curran 9* — MEL), Tibooburra (*Constable s.n.* — NSW 10458), Silverton (*Charsley s.n.* — MEL) and other places in the north-western part of the State.

Unfortunately it is impossible to know if these were yellow-flowered; when the plants are dried petals of both colour forms tend to become a uniform yellow-brown and unless a note was made at the time of collection, one cannot be sure of petal colour. It would be of interest to know more of the distribution of this yellow-flowered form and of any correlation between this condition and the absence or extreme paucity of papillae. The presence of yellow petals is possibly controlled by alleles of a single gene and may be the result of some introgression from the *A. nasturtium* gene pool. Still in many places,

especially in the southern part of the Flinders Ranges, and in the area between Morgan and Burra, populations of *A. trisecta* and *A. nasturtium* grow side by side and there is no obvious evidence of hybridization between them.

To some extent collectors have confused *A. trisecta* with *A. glaucescens*, an error made by Max Koch (1898). Koch remarked that he had found three forms of *Sisymbrium trisectum* FvM. (under his numbers 221, 325 and 328). His 221 he considered to be probably the "typical form" and collections under this number are the ordinary papillose *A. trisecta*. Of *Koch* 325 he said,

> "[it] has pale-yellow flowers, and being generally found in the presence of *S. nasturtioides*, it may be a hybrid."

Koch 325 (NSW 53546) seems to be a young plant of the usual form (or of the yellow-flowered one?).

> However, *Koch* 328 (AD, NSW 53545) is *A. glaucescens*; Koch said of it,
>
> "The foliage of this form is denser, the leaves are broader, somewhat thick and succulent, and the racemes more robust",

and this is a good comparison of *A. glaucescens* with *A. trisecta*.

It may be mentioned here that the fact of two or more of Koch's collections bearing the same number does not mean that they were made from the same plant, from the same population, at the same time, or even in the same locality; it means only that he considered these collections to represent the same species.

Although Schulz believed *A. trisecta* to have non-mucose seeds and so placed *Arabidella* in the subtribe *Sisymbriinae*, the seeds do exude a narrow mucus when moistened. The mucus is exuded as discrete oblong bodies, one from each papilla on the testa, and in transmitted light seems radiate; it is usually about 0·1 mm wide after an extended period of soaking. However, immature seeds and those from old collections may show no exudation of mucus.

Ecology and Biology: Characteristically *A. trisecta* is a plant of disturbed soils and in the semi-arid parts of South Australia it grows abundantly along roadsides and drainage ditches. Usually it seems to be not in deep sand, but in loamy, clayey or rocky soils. This was especially noted near Mt. Willoughby Station where steep rocky banks rise from one side of the Evelyn Creek; on them were *A. trisecta* and *A. glaucescens*, but neither was seen in the sandy soil on the other side of the creek.

Among notes with collections are "on a gibber plain — depression on edge of sand" (*Lothian* 692 — AD), "stony ground" (*Helms s.n.* — AD), "common on calcrete rise" (*Ford* 339 — CANB), and "very common in some depressions; red-brown loam with limestone fragments and outcrops" (*Hubbard* 8404 — BRI): from north-western Victoria *Willis s.n.* (MEL) is noted as occurring on "stony travertine plains (in'mallee savannah') — not uncommon, but apparently restricted to the open stony ground".

Black (1917) remarked that it is "only met with in the stony country" and Ising (1922), discussing the vegetation of the Ooldea region, wrote,

> "In depressions [in salt bush formation] there was less vegetation than on the higher ground; the smaller plants (annuals chiefly) were absent, and the formation was decidedly an open one. It was in this station that the following plants were seen: . . . *Blennodia trisecta* . . ."

Jessup (1951) mentioned it as being rare west of Lake Torrens.

In South Australia the writer has observed this species in a triangular area of about 600 square miles bounded on the north and north-east by the road

from Burra to Morgan, on the south by the road from Eudunda to Morgan and on the west by a line connecting Burra and Eudunda. The eastern part of this triangle lies on the flats along the Murray River, an area covered with mallee and with chenopodiaceous shrubs; here *A. trisecta* is a common roadside plant, often occurring with *A. nasturtium*. The western part, however, includes the eastern slopes of the Mt. Lofty Ranges and here it is not found, at least not in the south-western corner of the triangle which has a higher rainfall. In the southern part of this area *A. trisecta* is found only at elevations of less than about 600 feet above sea-level. Its absence on the eastern slopes of the ranges may be partly artificially induced by the more intensive agricultural activity here, but is more probably the result of the higher rainfall. *A. trisecta* will probably not grow in an area with an annual rainfall of more than about 10 inches.

In the Flinders Ranges *A. trisecta* is often seen with galled inflorescences, a phenomenon apparently restricted to this area and here seen also on *A. filifolia*.

Flowering and fruiting usually occur in August to September, but flowers, at least, probably could be found at almost any time of the year. This species is remarkably tenacious of life – during the summer almost the entire plant dies back, only a few inches remaining above ground. Very often small plants are several years old, for they have a heavy woody root which could not have developed in only a few years. With the coming of winter rains the plants grow quickly and produce fruiting racemes which may extend for as much as 30 cm beyond the leafy part of the plant. However, after even the lightest rains, very small plants may produce a few flowers, but these do not usually develop into fruit.

Uses and Common Names: Described by Turner (1891) as "a capital fodder plant for the smaller herbivora, sheep being particularly fond of it".

However, (*Woodroofe 6166* – ADW) from Arcoona, west of Lake Torrens, is labelled as "suspected of poisoning sheep". Jessup (1951) gives no palatability rating for it.

There seem to be no common names. Turner (l.c.) referred to it as "three-leaved mustard bush", but it is unlikely that this name was ever in use.

Relationships: *Arabidella trisecta* is probably most closely related to *A. nasturtium* which forms a transition between the suffruticose and herbaceous species. The position of *A. trisecta* in this genus is discussed under *A. nasturtium* and *A. filifolia*.

2. Arabidella glaucescens Shaw, sp. nov.

(γλαυκός = blue-grey; the foliage is glaucous when fresh)

Blennodia filifolia [non (FvM.)Benth.] Black, Fl.S.Austral. (1924)247. (1929)687; Black, Trans. Roy. Soc. S. Aust. 61(1937)243; Eardley, Trans. Roy. Soc. S. Aust. 70(1946)162; Black, Fl.S.Austral. ed. 2 (1948)375.– *Blennodia trisecta* var. *brachycarpa* Benth., Fl.Austral. 1(1863)74.– *Arabidella trisecta* var. *brachycarpa* (Benth.)Schulz, Pflrch. 86(1924)179.

Blennodia filifolia is, in the publications cited, a misapplied name, referring to plants now placed in *A. glaucescens*. *Arabidella trisecta* var. *brachycarpa* is a taxonomic synonym of *A. glaucescens* being based on the type of *Blennodia trisecta* var. *brachycarpa* which is discussed under *Arabidella trisecta*.

Figures: 2B, 3A-F, O, P.

DIAGNOSIS: Suffrutex, caulibus usque ad 1 m altis, rigidis, adscendentibus, glabris; foliis radicalibus nullis; foliis caulinis usque ad 7 cm longis, fasciculatis vel solis, pleraumque bi- vel tri- sectis, rarius integris, segmentis linearis ca. 0·5-1·5 mm latis, aequilongis, carnosis, in vivo glaucis; inflorescentibus ca. 50- usque ad 60- floribus; pedicelli fructiferi ca. 7-13 mm longis, 0·3-0·6 mm diametro, teretibus vel quadrangularis, erectis vel patentibus, glabris; siliquis ca. 8-33 mm longis, 1·0-2·5 mm latis, teretibus vel latiseptis, linearis vel ellipsoideis, plerumque stipitatis (usque ad 2·2 mm); stylis ca. 0·7-2·5 mm longis, 0·3-0·6 mm diametro; stigmatibus carnosis, depresso-capitatis, saepe stylo latioribus; seminibus ca. 0·8-1·2 mm longis, biseriatis, oblongis vel ellipsoideis; cotyledonibus incumbentibus exacte.

Holotypus: ca. 43 miles west of Oodnadatta on Hawkes Nest Well road, 19.9.1963, Shaw 231 — AD 96407053!

Description: *Plant* an erect woody undershrub, when fruiting to almost 1 m high, but usually less; *root* a very woody taproot, to 2 cm diameter at ground level, usually less; *stems* to 1 cm in diameter, terete or finely fluted, glabrous, arising from near ground level, rigid and ascendant, usually whitish or cream-coloured, basally with exfoliating bark. *Leaves* (all cauline) to ca. 7 cm long, usually less than 5 cm, more or less linear, clustered or, often, solitary (but then rather closely placed); rarely entire, usually bi- or tri- sect, the primary segments often further bi- or tri- sect; segments ca. 0·5-1·5 mm wide, usually less than 1·0 mm, tapering to 0·3-0·5 mm, more or less linear, subacute to rounded, usually arising at the same level and of about the same length, although the secondary segments often unequal; *in vivo* quite succulent and glaucous; *in sicco* brittle. *Inflorescences* usually ca. 50- or 60-flowered, initially dense, much laxer after anthesis, sometimes if borne on a secondary branch reduced to 1 or a few flowers arising in a leaf axil; *flowering pedicels* to ca. 15 mm long and ca. 0·2-0·4 mm in diameter, terete or quadrangular; *buds* just before anthesis ovate to oblong. *Sepals* narrowly obovate or elliptic or oblong to ovate, green or yellow-green; *lateral sepals* ca. 3·0-3·3 mm long, ca. 1·1-2·5 mm wide, average 4·5 x 2·0 mm, ratio length to width 1·7:1-3·9:1, distally rounded to subacute; *median sepals* ca. [3·6-] 4·0-5·6 mm long, ca. 1·2-2·4 mm wide, average 4·7 x 1·8 mm, ratio length to width 2·2:1-3·7:1, distally usually rounded, sometimes slightly emarginate. *Petals* to twice as long as the sepals, ca. 4·5-8·0 mm long, average 5·7 mm, white or cream-coloured; blades ca. 2·5-4·5 mm long, ca. 2·0-4 7 mm wide, average 3·2 x 3·5 mm, ratio length to width of blade 0·8:1-1·4:1, often suborbicular or ovate or obovate, entire or sinuate, coarsely veined, tapering suddenly into a linear or basally expanded claw, the claw ca. 0·3-0·9 mm wide, the blade averaging 57 per cent of the total petal length, often reflexed so that blade at right angles to the claw. *Stamens* with filaments slender, linear or slightly widened at the base, white or pale green; anthers oblong or sagittate, obtuse, *lateral stamens* ca. 3·4-5·7 mm, average 4·6 mm, anthers ca. 1·3-2·5 mm, average 2·0 mm; *diagonal stamens* ca. 3·8-6·2 mm, average 4·9 mm, anthers ca. 1·5-2·6 mm, average 2·0 mm. *Pistil* ca. 2·7-6·0 mm, usually slightly stipitate, sometimes not so, linear to fusiform, terete or broadly elliptic; *style* linear or clouate; stigma depressed-capitate; *ovules* to 0·8 mm, more or less oblong, biseriate on slender pendulous funicles, ca. 35-70; *lateral nectaries* pentagonal to square or suborbicular, usually open on interior, slightly emarginate on the exterior, producing on each side of each gland a lateral appendage encircling the base of the adjacent diagonal stamen; *median nectary* a deltoid lobe of tissue between the bases of the diagonal stamens, simple or two- or three-lobed. *Fruiting pedicels* usually ca. 7-13 mm, exceptionally to 20 mm, ca. 0·3-0·6 mm diameter, terete or obtusely quadrangular, erect or spreading, usually at an angle of about 45 degrees from the stem, straight or slightly curved distally. *Fruit* ca. 8-33 mm long, ca. 1·0-2·5 mm across the septum, latisept or terete, linear or ellipsoid, straight or slightly curved, usually on a linear stipe to 1·5 mm, exceptionally to 2·2 mm; *valves*

convex, proximally rounded to truncate, distally rounded to subacute, with distinct vein; *style* linear to broadly obconical, ca. 0·7-2·5 mm long, ca. 0·3-0·6 mm diameter, ratio length to width 1·4:1-6·3:1; *stigma* fleshy, depressed-capitate, as wide as the style or to twice its width; *septum* white, with median nerve, usually translucent, but sometimes opaquely vitreous, smooth or slightly rugulose between seeds and at the edges; *funicles* slender, more or less linear or narrowly deltate, straight or curved. *Seeds* ca. 0·8-1·2 mm long, ca. 0·4-0·7 mm wide, biseriate, oblong to ellipsoid, straight or curved slightly, plump; *testa* yellow-brown or dull reddish-brown, slightly darker at the hilum, when moistened exuding mucus to ca. 0·15 mm wide, the mucus exuded as discrete oblongs and thus appearing radiate; *embryo* exactly notorrhizal, radicle usually slightly longer than the cotyledons.

South Australia:—Head of valley, 5 miles north of Mungeranie homestead; 24.8.1960; *Lothian 318* — AD: about 8 miles south-west Marree; 14.7.1955; *Hill 86* — AD: Anna Creek; 10.9.1930; *Cleland* — AD: Mt. Lyndhurst; Aug. 1898; *Koch 328* — NSW 53545; Chambers Gorge; 12.9.1956; *Eichler 12578* — AD, L, K, UC: 4 miles north of Oodnadatta; 14.8.1963; *Lothian 2042* — AD, UC, Z: 45 miles west of Oodnadatta township; 13.9.1955; *Perry 5539* — AD, CANB, NT: upper Arkaringa Creek; 18.5.1891; *Helms* — AD, MEL: Wintinna Creek; 19.9.1963; *Shaw 237* — AD: Evelyn Downs; 27.8.1952; *Ising* — AD: 5 miles north of Coober Pedy; 13.8.1962; *Kuchel 415* — AD: 90 miles west of Todmorden Stn.; 8.7.1914; *White* — AD: Musgrave Range; July, 1926; *Basedow* — AD:

Northern Territory or South Australia: N.W. interior of South Australia; 1859; *McDouall Stuart's Expedition* (holotype of *Blennodia trisecta* var. *brachycarpa* Benth.) — MEL;

Fifty-six sheets were seen.

Distribution: In South Australia known from the areas west and north-east of Lake Eyre and from the northern part of the Flinders Ranges.—*Map 4.*

In the north-western part of New South Wales and the adjacent parts of Queensland occur plants which have almost the fruit of this species, but the leaves of *A. trisecta.*

Observations: This is one of the most variable species of *Arabidella*, fruit shape and, to a much lesser extent, leaf width varying. West of Lake Eyre the plants have leaves with the segments not more than about 1·0-1·2 mm wide and fruit which are usually ellipsoid. However, east of Lake Eyre and in the northern parts of the Flinders Ranges the plants have coarser leaves, about 1·0-1·5 mm wide, and the fruits are more nearly linear. These eastern plants also tend to bear fruit with a linear style about the same width as the stigma; the western ones more often have obconical styles not so wide as the stigma.

Fruit of these two forms are compared in the following tabulation:

	Western Form (25 plants)	*Eastern Form* (11 plants)
fruit length (mm)	9-19	10-27
fruit width (mm)	1·1-2·4	1·0-2·5
ratio L/W	4·7:1-10·3:1	7·5:1-19·5:1
average L/W	7·7:1	12·8:1
style width (mm)	0·25-0·6	0·25-0·6
stigma width (mm)	0·4-1·2	0·4-0·7 [-1·0]
stipe length (mm) aver.	2·5	5·6

All possible combinations of these characters may be seen on one raceme (e.g., Anna Creek; *Cleland* — AD).

Ecology and Biology: In the far north of South Australia *A. glaucescens* occupies the ecological niche filled by *A. trisecta* in more southerly areas. It

is usually seen in disturbed soil along roadsides and drainage ditches, as well as on rocky hillsides and on creek banks where there has been water erosion.

South-west of Oodnadatta *A. glaucescens* is far more common than is *A. trisecta*, while in the immediate vicinity of Oodnadatta and to the north-east it seems to have completely replaced *A. trisecta*. *A. glaucescens* is a larger and more conspicuous plant than *A. trisecta* and has more fragrant flowers. The writer has seen these two species side by side, the flowers of *A. glaucescens* surrounded by insects, those of *A. trisecta* attracting almost none.

Flowering and fruiting generally occur in August and September, but with favourable rains the plants might flower in any month, although they would probably not reach fruiting stage.

Uses and Common Names: None known.

Relationships: *A. glaucescens* is most closely related to *A. filifolia* and *A. trisecta*; it differs from the former in habit and foliage and from *A. trisecta* in fruit and foliage (see discussion under *A. filifolia*).

If one hypothesizes a restriction of *A. trisecta* (or a very near ancestor) and perhaps also of *A. filifolia* to mountainous refuges during the post-Pleistocene aridity, *A. glaucescens* would then seem to have evolved after climatic conditions improved and *A. trisecta* had (re-)colonized the flatter country.

Probably, if this were so, *A. glaucescens* would have arisen from what was a Flinders Ranges population of *A. trisecta*. The high country in the north-west of South Australia was also a refuge during the arid periods, but neither *A. trisecta* nor *A. glaucescens* appear to be at all common in this area. The present range of *A. glaucescens* is quite distinct from that of *A. trisecta* although there are no known climatic or edaphic factors to explain this.

There are plants in north-western New South Wales and the adjacent parts of Queensland which have the stipitate, almost linear fruits of the eastern form of *A. glaucescens*, but leaves which resemble those of *A. trisecta*. In floral characters they are intermediate, the organs being slightly larger than those of *A. trisecta*. The plants vary a certain amount among themselves, but none of them can be definitely assigned to either *A. trisecta* or *A. glaucescens*. They perhaps have evolved from an arid period population of *A. trisecta* restricted to the Barrier Range in north-western New South Wales for both *A. trisecta* and this form occur in that area.

The following collections belong to this intermediate form:

New South Wales:—Tibooburra; Feb. 1950; *Burges* — SYD: Tibooburra; Jan. 1913; *Couch* — NSW 53568; Tibooburra; 2.11.1947; *Black* — AD: Mt. Poole Station to Milparinka; Aug. 1939; *Brough & Beadle* — SYD: near Wittabrinna Station, ca. 4 miles north of Tibooburra; 6.6.1955; *Johnson & Constable* — NE, NSW 36582, NT: 4 miles south of Milparinka; 17.11.1949; *Reik & Common* — CANB: Fowler's Gap, 70 miles north of Broken Hill; Aug. 1955. *Beadle* — NSW 53542: Brewarrina; Nov. 1903; *Boorman* — NSW 53566: Evelyn Creek north of Barrier Range; 1887; *King* — MEL: Broken Hill; Dec. 1917; *Andrews* — NSW 53562: Broken Hill; Sept. 1931; *Dwyer* — NSW 53735: Darling River; ?; B. — MEL: Menindie; ?.?. — MEL:

Queensland: — between Nappamerrie (Qld.) and Innamincka (S.A.) about 20 km e.n.e. of Innamincka; 12.8.1962: *Jackson 407* — AD: Gilruth Plains, Cunnamulla; 17.7.1947; *Allen* — CANB, NE: Coonamurra, near Eulo; 20.9.1938; *Everist 1683* — BRI: Northhampton Downs, near Blackall; 26.8.1935; *Everist 1254* — BRI:

Queensland or South Australia: Cooper's Creek; ?; *Bailey* — NSW 53567:

3. Arabidella filifolia (FvM)Shaw, comb. nov.

(filum = thread, folium = leaf; the leaves are usually narrow and undivided)

Erysimum filifolium FvM., Linnaea 25(1853)368 (*basionym*).— *Sisymbrium filifolium* (FvM.)FvM., Trans. Vict. Inst 1(1855)115 in obs. (nom. illegit.) [non Willd., Sp.Pl. 3(1800)495]; FvM., Pl.Col. Vict. 1(1860-1862) 40; Tate, Trans. Roy. Soc. S. Aust. 3(1880)51; FvM., Census 1(1882)5; Tate, Trans. Roy. Soc. S. Aust. 6(1883)101; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; FvM., Sec. Census 1(1889)9; Tate, Fl.S.Austral. (1890)16, 206; Koch, Trans. Roy. Soc. S. Aust. 24(1900)81.— *Blennodia filifolia* (FvM.)Benth., Fl.Austral. 1(1863)73; Tate, Trans. Roy. Soc. S. Aust. 22 (1898)123; Maiden & Betche, Cens. N.S.W. Pl. (1916)83; Black, Fl.S. Austral. (1924)247; (1929)687; Black, Trans. Roy. Soc. S. Aust. 61(1937) 243; Black, Fl.S.Austral. ed. 2 (1948)375.— *Pseudarabidella filifolia* (FvM.)Schulz, Pflrch. 86(1924)257; Black, Trans. Roy. Soc. S. Aust. 61 (1937)243.

The above names are nomenclatural synonyms of *Arabidella filifolia*, being based on the same type.

Figures: Figure 4. N.B.: In Turner (1891) is given an illustration and description of a plant listed as "Blennodia filifolia Benth.". However, the plant shown in the illustration appears to be *Lepidium leptopetalum* FvM., and the description refers also to this species.

Description: Plant a straggling shrub; *root* not seen; *stems* to ca. 3 feet in length, terete or finely ridged, glabrous, sometimes much branched. *Leaves* (all cauline) to ca. 5·5 cm long, to ca. 1·7 mm wide, usually 0·8-1·2 mm, filiform, solitary or, more often, clustered, usually entire, sometimes bi- or tri- sect, rounded to acute, sometimes narrowly spathulate distally, *in vivo* rather fleshy, *in sicco* very brittle. *Inflorescences* to ca. 30-flowered, rather louse; *flowering pedicels* terete or quadrangular; *buds* ovoid to spherical; *flowers* very sweetly scented. *Sepals* usually green, occasionally lavender; *lateral sepals* ca. [3·0-] 3·3-4·3 [-4·7] mm long, ca. 1·3-1·9 [-2·3] mm wide, oblong or narrowly obovate, not basally saccate; *median sepals* ca. 3·3-4·5 [-5·0] mm long, ca. 1·4-2·2 mm wide, not basally saccate. *Petals* to 1½ times sepals in length, ca. 4·3-6·1 mm long, average 5·3 mm, white; blade ca. [1·8-] 2·5-3·5 mm long, ca. 2·2-3·6 mm wide, average 2·8 x 2·8 mm, ratio length to width of blade 0·8:1-1·4:1, average 1·0:1, suborbicular or rhombic, distally subacute to rounded, margin entire or sinuate, tapering suddenly into a linear claw, the blade averaging 52 per cent of the total petal length, often reflexed so blade at right angle to the claw. *Stamens* with filaments slender, linear, sometimes slightly expanded basally, ca. 0·2-0·5 mm, usually 0·3 mm wide, white; anthers rather narrowly oblong, sometimes sagittate; *lateral stamens* ca. 3·3-4·1 [-4·7] mm, average 3·9 mm, anthers ca. 1·1-1·8 mm, average 1·5 mm; *diagonal stamens* ca. 3·6-4·7 [-5·3] mm, average 4·2 mm, anthers ca. 1·2-1·8 mm, average 1·6 mm. *Pistil* ca. 2·5-4·0 mm, shortly stipitate, linear, terete or quadrangular; *style* present; *stigma* depressed-capitate or almost tectiform; *ovules* ca. 40-70 per ovary; *lateral glands* roughly pentagonal, open or only emarginate on interior, sometimes emarginate on exterior, producing on each side of each gland a lateral appendage encircling the bases of the adjacent diagonal stamen; *median gland* a triangular or oblong piece of tissue between the bases of the diagonal stamens, simple or with 2 or 3 small lobes or teeth, the lateral and median glands approximate but not fused. *Fruiting pedicels* ca. 7-14 mm long, to 0·6 mm, usually 0·3-0·4 mm in diameter, terete, usually at an angle from the stem greater than 45 degrees, often horizontal or almost so, sometimes slightly

recurved. *Fruiting raceme* usually quite loose. *Fruit* ca. 7-28 mm long, usually 12-18 mm, ca. 1·0-2·0 mm, usually 1·2-1·8 mm wide across the septum, latisept, on a stipe ca. 0·3-1·3 mm, usually 0·5-0·8 mm, long; valves shallowly convex, proximally rounded or, often, subacute; distally subacute to acute; *style* ca. 0·6-2·1 mm, usually 0·8-1·3 mm, slender and linear; *stigma* small, depressed-capitate; *septum* white, hyaline, nerve usually visible, often spongy and wrinkled between the seeds, epidermal cells small, rounded to pentagonal, regular in size. *Seeds* ca. 1·3-1·6 mm long, ca. 0·6-0·8 mm wide, biseriate, usually oblong, straight or slightly curved, somewhat flattened, often with a small triangular to semi-circular wing at distal end; testa light yellow-brown, usually with some red pigment at the hilum, when moistened, copiously mucose; mucus exuded as discrete oblongs, therefore appearing radiate, ca. ¼ mm wide; *embryo* obliquely notorrhizal, the radicle slightly twisted to one side, cotyledons narrowly oblong, usually truncate, usually slightly shorter than the radicle.

TYPE LOCALITY: "Prope rivum Crystal Brook."

HOLOTYPUS: Crystal Brook; Nov., 1851; Mueller — MEL 766!

ISOTYPUS (?): K.

SOUTH AUSTRALIA:—Mt. Parry Gap; 9.6.1883; *Tate* — AD: Parachilna Gorge; 9.10.1958; *Fraser* — AD: Wilpena Creek; 31.8.1963; *Shaw 200* — AD: Brachina Gorge; 7.9.1961; *Symon 1411* — AD, ADW, UC, Z: 10 miles N. of Hawker; 20.8.1963; *Kuchel 735* — AD: Apoinga; 29.9.1892; *Brummitt* — AD: Comona (Iron Knob); ?; *Cleland* (W.L.) — AD: near Whyalla-Kimba road, on hill of the Middleback Ranges; 2.X.1958; *Wilson 157* — AD:

Twenty sheets were seen.

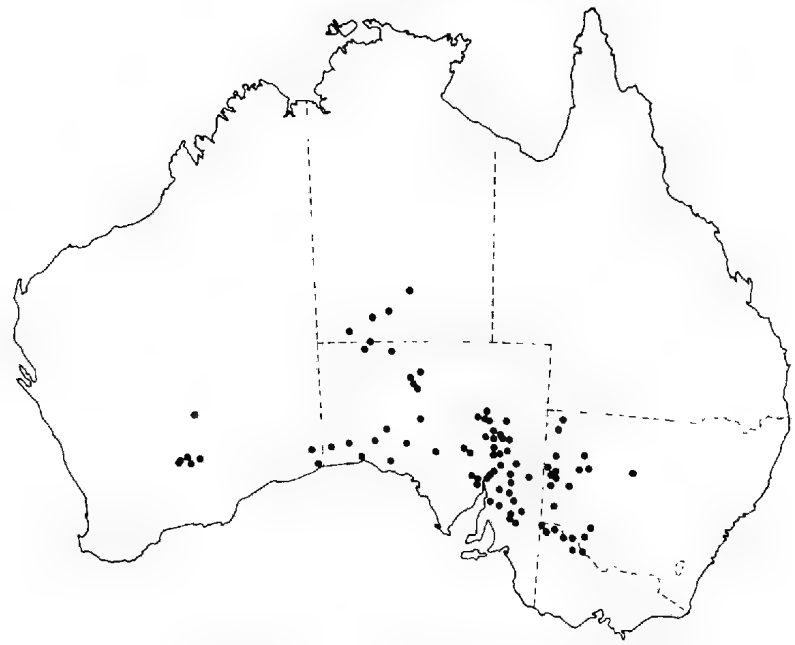
Distribution: Apparently now restricted to the Flinders Ranges and the Middleback Ranges, the latter south-west of Port Augusta, with a single collection from Iron Knob, about 35 miles north of Mt. Middleback. The southernmost locality is that of the holotype. The writer has several times searched for this species in this vicinity, but without success. The Crystal Brook area has been used for agricultural purposes since about 1860 and it is likely that *A. filifolia* is now gone from there. — *Map 4.*

Observations: *A. filifolia* shows little variation. In discussing this species, Black (1937) remarked that the leaves are mostly bisect or trisect, but he was including with the true *A. filifolia* the plants now referred to *A. glaucescens* which do have divided leaves; *A. filifolia* has predominantly linear entire leaves and trisect ones are very uncommon.

Ecology and Biology: *A. filifolia* occurs on rather rough ground. It is a large straggling shrub and often grows on the steep rocky walls above creeks. The writer has seen this species in some quantity along the Wilpena Creek where it almost covered a 30-foot high rocky wall above the creek. It also occurs among rocks on hillsides — in fact, in places where the available moisture is likely to be held. This species seems to require a greater supply of water than do the other suffruticose species.

Flowering and fruiting usually occur in September and October, but it is likely that flowers and fruit could be found throughout the year except in severe drought conditions. The flowers are very sweetly scented and attract many insects; the inflorescences are often galled, as are those of *A. trisecta* in the Flinders Ranges, but it is not known which insect is responsible for these.

Uses and Common Names: None known.



Map 3. Distribution of *Arabidella trisecta* (FvM.)Schulz.

Map 4. Distribution of *Arabidella glaucescens* Shaw ●. Distribution of *Arabidella filifolia* (FvM.)Shaw ×.

Relationships: *A. filifolia* is most closely related to *A. trisecta* and to *A. glaucescens*. Black (1929, 1937) considered this species and *A. trisecta* to differ from each other only in fruit characters, but he was including with *A. filifolia* the trisect-leaved plants with stipitate fruits now placed in *A. glaucescens*.

The three suffruticose species of Arabidella are compared below.

	A. trisecta	*A. filifolia*	*A. glaucescens*
leaves	trisect	entire	trisect
leaf width (mm)	usu. < 0·5	usu. 0·8-1·2 mm	usu. 0·5-1·5 mm
fruit	sessile	stipitate	stipitate
petal length (mm)	4·5	5·3	5·7
seed length (mm)	0·7-0·9	1·3-1·6	0·8-1·2
habit	compact, erect	straggling	compact, erect

In nectary structure *A. filifolia* is closer to *A. glaucescens* than to *A. trisecta*. In the first two the glands are often two- or three-lobed and the glandular ring is jagged. In *A. trisecta* the median glands are usually simple and the glands as a whole are smooth and rounded.

Usually the fruits of *A. filifolia* are slightly wider in proportion to length than those of *A. trisecta* and approach *A. glaucescens* which often has ellipsoid fruit. South and east of Lake Eyre there is a form of this latter species with more slender fruit than is usual, and plants of this form and of *A. filifolia* may be much alike in fruit characters (see discussion under *A. glaucescens*).

The pattern of distribution suggests that *A. filifolia* is probably descended from an *A. trisecta*-like ancestor and has become confined to an ecological niche much more narrow than that occupied by *A. trisecta* and *A. glaucescens*. Since both *A. trisecta* and *A. filifolia* occur in the Flinders Ranges, an area which was one of the main refugia during the post-Pleistocene aridity, it could be suggested that *A. filifolia*, which seems to have less tolerance to aridity than does *A. trisecta*, has been restricted to the Flinders Ranges and the eastern Eyre Peninsula ranges while *A. trisecta* has been able to (re-)colonize the semi-arid plains.

The distribution of this species closely parallels that of *Ranunculus hamatosetosus* Eichler (Trans. Roy. Soc. S. Aust. 81: 175-183, 1958), which also occurs in the Flinders Ranges and extends southward into the Mt. Lofty Ranges as far as Eden Valley, about 35 miles north-east of Adelaide. There is also a single collection from Iron Knob. It would be interesting to know if *R. hamatosetosus* is more widely spread on the Eyre Peninsula and also if there are other species showing this sort of distribution.

4. **Arabidella nasturtium** (FvM)Shaw, comb. nov.

(nasturtium = *Nasturtium* L., a genus in this family; because of the supposed resemblance of this species to a species of *Nasturtium*.)

Erysimum nasturtium FvM., Linnaea 25(1853)368 (*basionym*)— *Sisymbrium nasturtioides* FvM., Trans. Vict. Inst. 1(1855)115 [non *Sisymbrium nasturtium* Thunb., Fl. Jap. (1784)260]; FvM., Pl. Col. Vict. 1(1860-1862) 39; FvM., Fragm. 10(1876)53; FvM., Nat. Pl. Vict. (1879)32; Tate, Trans. Roy. Soc. S. Aust. 3(1880)51; FvM., Census 1(1882)5; FvM., Key Vict. Pl.

2(1885)7; Tate, Trans. Roy. Soc. S. Aust. 7(1885)67 in obs.; FvM., Key Vict. Pl. 1(1887-1888)130; Cleland, Trans. Roy. Soc. S. Aust. 10(1888)78; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; FvM. Sec. Census 1(1889)9; Tate, Fl. S. Austral. (1890)16, 206; FvM. et Tate, Trans. Roy. Soc. S. Aust. 16(1896)335; Koch, Trans. Roy. Soc. S. Aust. 22(1898)102.— *Blennodia nasturtioides* (FvM.)Benth., Fl. Austral. 1(1863)74 (*nom. illegit.*); Turner, Forage Pl. Austral. (1891)3; Bailey, Qld. Flora 1(1899)47; Maiden & Betche, Cens. N.S.W. Pl. (1916)83; Black, Trans. Roy. Soc. S. Aust. 41 (1917)631, 638; Black, Fl. S. Austral. (1924)247; Murray, Trans. Roy. Soc. S. Aust. 55(1931)99; Black, Fl. S. Austral. ed. 2 (1948)375.— *Blennodia nasturtium* (FvM.)Druce, Rep. Bot. Exch. Club 4(1917)609.— *Micromystria nasturtium* (FvM.)Schulz, Pflrch. 86(1924)264.

The above names are all nomenclatural synonyms of *Arabidella nasturtium*, being based on the same type. Excluded: *Micromystria nasturtium* var. *pinnatifida*(Benth.) Schulz, based on *Blennodia nasturtium* var. *pinnatifida* Benth., = *Arabidella procumbens* (Tate)Shaw).

Figures: Turner, Forage Pl. Austral. (1891) fig. 3; Schulz, Pflrch. 86(1924) fig. 57; Schulz, Pflfam. ed. 2 17b(1936) fig. 408; Beadle, Veg. & Past. West. N.S.W. (1948) fig. 71;— Figure 5.

Description: *Plant* probably annual, many-stemmed, glabrous; *root* a slender taproot, usually ca. 1 mm diameter; *stems* terete or finely fluted, exceptionally to ca. 30 cm high, but usually less than 25 cm, fruiting plants from 3 cm high, green to dark reddish-brown, initially rising from a basal rosette of leaves, usually unequal with an erect leafless or almost so, central stem and longer decumbent lateral stems, these leafy and sometimes much branched, these secondary branches sometimes much reduced so that the terminal inflorescence appears to arise directly from the leaf axil. *Basal leaves* to ca. 3 cm long, slender, to 2 mm, but usually less than 1 mm wide, linear, bi- or tri- sect or, rarely, entire; if trisect (the most usual condition), the central segment usually longer than the lateral segments (to 2x), these often having at or near the base a very small lobe, occasionally appearing as only a tooth; segments generally subacute to rounded, the lateral segments and teeth more often tending to subacute; lateral segments often falcate, the central one usually straight; if trisect, the lateral segments usually arising from about the same level, if bisect the segments usually of unequal length. *Cauline leaves* as basal leaves, but shorter, to ca. 2 cm long. *Inflorescences* usually 20-30-flowered, dense, elongating only a little until the ovaries of the lowermost flowers begin maturation, rarely with very remote buds below the lowest flowers, sometimes axillary as the result of the non-development of stems, very rarely basal; *buds* immediately before anthesis spherical to ovoid; *flowering pedicels* slender, terete. *Sepals* oblong to (ob-)ovate, yellow to green with a narrow hyaline yellow or colourless margin; *lateral sepals* ca. 1·8-3·5 mm long, ca. 0·7-1·6 mm wide, the average 2·7 x 1·2 mm, the ratio length to 1·5:1-3·0:1, distally rounded to subacute; *median sepals* ca. 1·7-3·6 mm long, ca. 0·7-1·9 mm wide, the average 2·7 x 1·3 mm, ratio length to width 1·3:1-3·6:1, distally rounded, narrowly oblong to suborbicular. *Petals* as long as or slightly longer than the sepals, ca. 2·1-4·2 mm long, ca. 0·8-2·0 mm wide, the average 2·5 x 1·5 mm, the ratio length to width 1·4:1-2·9:1; blade suborbicular, tapering into a claw ca. 0·3-0·5 mm wide, the claw usually about 40 per cent of the total length of the blade, or blade broadly obovate, the ratio length to width of the blade 0·9:1-1·7:1, or the petal as a whole gradually becoming, with a diminution of the claw, obovate; distally rounded to truncate, sometimes retuse, margins entire or sinuate; usually bright yellow, rarely almost white, *in sicco* often dark brown. *Stamens* with filaments linear, ca. 0·1-0·2 mm wide, dilated at the base, usually yellow, less often

white or pale green; anthers usually broadly oblong, often almost quadrate, obtuse to truncate; *lateral stamens* ca. 1·7-4·5 mm long, average 2·6 mm, lateral anthers ca. 0·6-1·9 mm long, average 1·0 mm; *diagonal stamens* ca. 2·1-4·9 mm, average 3·0 mm, diagonal anthers ca. 0·3-1·9 mm long, average 1·0 mm. *Pistil* ca. 2·0-4·0 mm long, not stipitate or on a very short stipe, terete, linear or tapering slightly proximally and distally; *style* short, linear; *stigma* fleshy, depressed-capitate, slightly wider than the style; *ovules* ca. 20-60 per ovary, usually about 40, oval to round on slender pendulous funicles; *glands* quite variable, depending on the degree of development; *lateral glands* hexagonal to pentagonal to suborbicular, usually open on the exterior, emarginate to open on the interior, producing on each side of each gland a lateral appendage encircling the base of the adjacent diagonal stamen, the adjacent lateral appendages almost touching on the median line but not fused, the lateral glands sometimes only incompletely developed; *median glands*, if present, small conical lobes of tissue between the bases of the members of each pair of diagonal stamens, but often obsolete. *Fruiting pedicels* ca. [4-] 6-10 [-13] mm long, ca. 0·15-0·3 mm in diameter, slender, usually terete or quadrangular, usually spreading at about 45 degrees from the stem, but varying from nearly erect to nearly horizontal, often with much reddish pigment. *Fruit* ca. 6·0-25 mm long, usually ca. 10-20 mm, ca. 0·7-1·6 mm, usually ca. 0·9-1·2 mm across the septum, usually not stipitate, sometimes on a very short stipe; linear, straight or slightly curved, usually terete, often with red pigmentation in the replum and style; valves linear, quite convex with a distinct nerve, when mature, stramineate, sometimes slightly compressed between the seeds, proximally usually rounded, but may be truncate to subacute, distally rounded to subacute, often with red pigmentation especially at the edges; *styles* usually ca. 0·4-0·8 [-1·1] mm long, sometimes obsolete, slender, linear or slightly expanded distally; *stigma* small, depressed-capitate, as wide as or barely wider than the style; *septum* white, translucent, nerve often indistinct, usually wrinkled between seeds; *funicles* often filiform or narrowly triangular, usually pendulous, slightly curved; *seeds* ca. 0·7-1·0 mm long, ca. 0·4-0·6 mm wide, usually subbiseriate to biseriate, ca. 5-30 per locule, ovoid to oblong, somewhat flattened; testa yellow to light yellow-brown, usually with darker pigmentation at the hilum, very finely papillose, when moistened, exuding mucus to ca. 0·15 mm in width, the mucus clear and greyish, exuded as oblong bodies, one from each papilla on the testa, thus appearing finely radiate; *embryo* exactly or slightly obliquely notorrhizal, the radicle usually slightly longer than the cotyledons which are of equal length.

Type Locality: "In locis humidis inter flumina Hoet et Hill nec non ad rivum Rocky Creek."

Holotypus: Zwischen dem Hott and Hill River, auch nach der Rocky Creek zu auf trockenen Wiesen; Oct. 1851; Mueller — MEL 7741

Isotypus?: Possibly an isotype is a plant now in B collected by Mueller at Rocky River, but undated; perhaps also to be associated is a MEL collection "N. Holl. austral interior; ?; Mueller" — annotated by Mueller "Erysimum (Arabidella) nasturtium".

South Australia:— Pandie-Pandie; 26.8.1960; *Lothian 150* — AD, UC, Z; Callana 21.8.1931; *Ising 2096* — AD; Mt. Lyndhurst; Aug. 1899; *Koch 201* — K, BRI, MEL, NSW 55705, AD; 7 miles north of Beltana; 29.8.1963; *Shaw 182* — AD; 2 miles south of Hawker; 22.8.1960; *Lothian 226* — AD; 5 miles west of Port Augusta; 28.8.1955, *Hilton 1978* — ADW; 6 miles north of Yunta; 28.7.1963; *Shaw 137* — AD; Canegrass; 21.9.1937; *Ising* — AD; 14 miles west of Floreton on Burra-Morgan road, 15.8.1963; *Shaw 150*, AD; Yarrowie, St Vincent's Gulf; ?; *Wehl* — MEL; 5 miles north of William Creek; 7.8.1963; *Lothian 1315* AD; Yudnapinna, 12.7.1951; *Hilton 711* — ADW; 1 mile N.W. Oodnadatta; 18.6.1953; *Symon* — ADW; Arkaringa Creek; 14.5.1891; *Helms* — MEL, NSW 53698, AD;

Victoria: Murray Valley Highway, near Piangil, N.W. Vic.; 4.9.1945; *Willis* — MEL;

New South Wales: — Jew's Lagoon (N.W. of Natrabri); Aug. 1936; *Blakely* — NSW 53694: Burren Junction; Sept. 1912; *White* — NSW 53700: Goorianawa; Aug. 1893; *Lamonte 169* — MEL, BM: Angledool Sta.; Aug. 1915; the manager — NSW 53704: "Birrahirramah", Pokataroo; 13.8.1952; *Waterhouse 3* — NSW 53710: Walgett; Oct. 1899; *Little* — NSW 53709: Bourke district; Aug. 1896; *Maiden* — NSW 53691: Hillston-Hay road; 9.10.1947; *Constable* — NSW 53701: Langawirra; July, 1930; *Morris 2768* — ADW, BRI: Lachlan River; 1817; *Cunningham 240* — BM: Hay; 6.9.1954; *Whaite 1673* — NSW 53588: "Zara" (near (Deniliquin): 19.9.1951; *Moore* — CANB: 5 miles north of Coally Sta.; 7.6.1955: *Johnson & Constable* — K, NT, NSW 39994: Mt. Murchison; ?; *Giles* — MEL.: Wilcannia; 20.8.1939; *Pidgeon & Vickery* — NSW 53693: Menindie aerodrome, ca. 1 mile west of township; 16.7.1955; *Constable* — K, NT, NSW 39991: Willow Pt., Anabranch of the Darling — 63 miles north of Wentworth, 27.7.1955; *Constable* — K, NSW 39995; Queensland:— Bullgaroo; 3.7.1942; *Allen 229* — NE. Tanbar; 20.6.1949; *Everist* — CANB;

Western Australia: — Giles, Rawlinson Range; 22.6.1960; *Cleland* — AD: Coolgardie road, ca. 7 miles south-west of Kalgoorlie, W. Aust.; 12.9.1951; *Kemsley* — MEL:

One hundred and sixty-five sheets were seen.

Distribution: Known from Western Australia, the Northern Territory, South Australia, Queensland, New South Wales and Victoria. In Western Australia only a few localities are known and these are scattered from Giles in the far-eastern part of the State to Coolgardie in the south-central part.

There are several collections from South Australia, but there is a great gap between the Western Australian localities and the westernmost ones in South Australia. This species is common in the Flinders Ranges and south-east toward the Murray River; it is also found in the Lake Torrens Basin and to the west and south of Lake Eyre.

In Queensland there are only a few collections from the southern part. In New South Wales the collections suggest that *A. nasturtium* might be generally distributed throughout this State west of the Dividing Range. There is only one collection from the far north-western part of Victoria. — *Map 6.*

Observations: In habit this species shows little variation, although in 1963 several collections superficially much like *A. triseeta* were made in the areas around Oodnadatta and Marree.

In some cases these plants are almost woody at the base. When collecting in the Oodnadatta area in September, 1963, the writer was impressed by the difference in general appearance between these plants and those to the south-east of the Flinders Ranges. Apart from the 1963 collections there are only a few from the far north, most of these made by E. H. Ising at Evelyn Downs (about 130 km south-west of Oodnadatta); these collections are all like the more southerly ones. The winter of 1963 was a good season in the Oodnadatta area and it seems that these collections represent *A. nasturtium* growing under very favourable conditions.

Petal shape varies widely but seems not correlated with other morphological characters. The petals sometimes resemble those of *A. triseeta*; that is, with blade almost orbicular and suddenly tapering into a linear claw, but they are smaller (average length 3·1 mm *vs.* 4·5 mm). At the other extreme are obovate and clawless petals which are almost indistinguishable from those of *A. procumbens*. These are usually smaller than the clawed petals, with an average length of 2·4 mm. There exist all intermediates between the extremes and on most plants the petals are between the two in shape. On an individual plant, the petals are quite constant in shape, but may vary quite sharply between members of the same population.

The degree of development of the glands also varies from the fully developed lateral and median glands, as seen in *A. triseeta*, to the reduced lateral glands, with no median ones, seen in *A. procumbens*. There is, however, no

apparent connection between petals of the "trisecta-type" and fully developed glands and none between "procumbens" petals and poorly developed glands. Petals of the "trisecta-type", or much like them, seem to be more usually found on South Australian plants, while plants from New South Wales more often tend toward the "procumbens-type".

The fruits are either terete with quite smoothly flattened valves, or somewhat flattened and with the valves slightly constricted between the seeds. When terete they are much like those sometimes found on *A. eremigena*. Very rarely do they have the flat sessile stigma of *A. procumbens*.

One collection made near Coolgardie (*Kemsley s.n.* — PERTH) is rather different. The basal leaves resemble those of *A. procumbens*, being entire or finely lobed; also the leaves are wider (to 3 mm) than the usual, and the lateral lobes generally less than 1 mm long. Affixed to the sheet is a copy of a report sent to J. H. Willis by R. H. Anderson of Sydney. This says, in part,

> "Its nearest affinity would appear to be with *B. nasturtium* (FvM.)Druce . . . , but it differs from that species in the longer and more slender style, the smaller stigma and in the leaves, which are more like those of *B. procumbens*(Tate) J. M. Black. The habit is that of *B. nasturtium* rather than *B. procumbens*. It may prove to be an undescribed species, or possibly western form of *B. nasturtium*. Further collection in intermediate areas may decide this."

The most distinctive feature is the shape of the fruit; they are narrowly elliptic and usually subacute proximally and subacute to rounded distally. They bear a short linear style about 0·4-0·6 mm long and depressed-capitate stigma which is broader than the style.

The floral organs are like those of *A. nasturtium*, although the filaments are slightly longer in relation to the overall length of the stamens, and the torus is quite flattened, forming a rim of tissue just beneath the glands. The glands are in the arrangement usual in *A. nasturtium*, but are shallow and not well-developed; there seem to be no median glands although the appendages of the lateral glands do touch and on casual examination seem to form a complete extrastaminal ring.

Of the other Western Australian material, a plant from Giles (*Cleland s.n.* — AD) seems to be ordinary *A. nasturtium*. However, plants from Frasers Range (*anon.* — MEL) and Cummening (*Heal s.n.* — MEL) are somewhat like the Coolgardie plant. They are small and bear not mature fruit, but the lateral glands are shallow and median glands are absent; the flowers examined do not show a torus so conspicuously flattened as does the Kemsley collection and the leaves are more like those of *A. nasturtium*. At present it seems best to refer these plants to *A. nasturtium*, but further collections from Western Australia and the adjacent parts of South Australia are needed.

Ecology and Biology: *A. nasturtium* is much like *A. trisecta*, being common along roadsides in the southern semi-arid parts of South Australia. However, where *A. trisecta* occupies the edges of drainage ditches and the soil heaped up by roadsides *A. nasturtium* usually is found, sometimes in profusion, in slight depressions where water has accumulated. Along the Burra-Morgan road and north of Yunta the writer has seen areas of more than an acre which appeared completely yellow when seen from a short distance.

It is variously recorded as occurring on "old sanddune in S.A. and flood plain" near the Birdsville Track, "on a sandy hillside above a creek", among "gibbers, lake bed", and several times from sandy clays, these all in South

Australia. From New South Wales notes are "in black soil", "on heavy grey loam", "localized in depressions", "on heavy soil" and "scald area in sandy soil". *Allen s.n.* (CANB) from Bullgaroo, Queensland, is noted as having grown on "heavy brown soil" and *Everist 4030* (CANB) from Tanbar, Queensland, as occurring "in heavy grey clay on flooded flat".

Beadle (1948) notes that it is widely spread throughout the western part of New South Wales and adds that it becomes more common in areas which are heavily stocked. Speaking of pastures in the northern part of the State he said, "Further heavy grazing leads to . . . the dominance of . . . , useless crucifers, and composites, notably *Blennodia nasturtioides* . . ."

Flowering and fruiting are usually in August and September, but there are scattered occurrences in May, June, July and October. Turner (1891) remarks that the seeds germinate readily after spring rains.

Uses and Common Names: According to Turner (1891) a favourite food for sheep, but Beadle (1948) remarks that it is unpalatable and of no value as a fodder.

The names "mustard bush" and "pinnate-leaved mustard bush" have been recorded but seem to be not used.

Relationships: It is most closely related to *A. trisecta* from which it differs only in habit and minor features of flower and fruit. It is also closely related to *A. eremigena* and forms a link between *A. trisecta*, *A. filifolia* and *A. glaucescens* on the one hand, and *A. eremigena* and *A. procumbens* on the other. Were it not for the existence of *A. nasturtium* it would seem better to place these two latter species in a genus distinct from *Arabidella*.

A. eremigena and *A. procumbens* differ most from the other species in having angustisept fruits; this is constant in *A. procumbens* and is often seen in *A. eremigena*, especially in plants from the western part of the range. In the eastern part, however, are found plants with terete fruits and if they were not pubescent, it would be difficult to distinguish them from *A. nasturtium*. These two species also differ from the others in lacking median glands; here, too, *A. nasturtium* is intermediate, some plants having the well-developed glands of, for example, *A. trisecta*, others the reduced glands typical of *A. eremigena* and *A. procumbens*. In habit, too, *A. nasturtium* connects the entirely herbaceous *A. eremigena* and *A. procumbens* with the three suffruticose species.

It is interesting to note that *A. trisecta* and *A. nasturtium* have the widest distributions, chiefly in South Australia and New South Wales. The other species are to a much greater degree restricted in area.

It could perhaps be hypothesized that the other species of *Arabidella* have arisen from an *A. trisecta*-like ancestor, *A. filifolia* and *A. glaucescens* retaining the shrubby habit, but becoming modified chiefly in fruit characters. *A. nasturtium*, *A. eremigena* and *A. procumbens* have, however, lost the suffruticose habit, all have much smaller flowers, and the last two have developed a fruit quite different from that of *A. trisecta*. *A. eremigena* and *A. procumbens* stand much further from *A. trisecta* than do either *A. filifolia* or *A. glaucescens*.

Some of these are probably species which are quite young evolutionarily, a fact which would help to account for the great variation seen in them. However, in spite of all the differences among them they form a quite natural group which is not closely related to any other Australian genus.

5. Arabidella eremigena (FvM)Shaw, comb. nov.

(*ἐρημία* = desert, *γενός* = race; the first collections were made in semi-arid parts of Queensland and New South Wales.)

Sisymbrium eremigenum FvM., Fragm. 2(1861)143 (*basionym*); FvM., Census 1(1882)5; FvM., Sec. Census 1(1889)9.— *Blennodia eremigena* (FvM.)Benth., Fl. Austral. 1(1863)74 "eremigera"; Bailey, Qld. Flora 1(1899)47; Maiden & Betche, Cens. N.S.W. Pl. (1916)83; Black, Fl. S. Austral. (1929)687; Johnson et Cleland, Trans. Roy. Soc. S. Aust. 67(1943) 154; Eardley, Trans. Roy. Soc. S. Aust. 70(1946)162.— *Micromystria eremigena* (FvM.)Schulz, Pflrch. 86(1924)264.

The above names are nomenclatural synonyms of *Arabidella eremigena*, being based on the same type.

Figures: Figure 6.

TYPIFICATION: With the original description are mentioned collections made by Sir Thomas Mitchell on the Balonne River in southern Queensland and by Dr. Beckler "prope Bamamero" on the Darling River in New South Wales.

Of the Mitchell collections available the only one which it seems certain that Mueller saw is MEL 772, collected at "Balloula [?] (eastern subtropical Australia)" and dated November 11, 1846. Of Beckler's collections from Bamamero [Pamamaroo, near Menindie, N.S.W.] only two are in MEL and it is probable that they were seen by Mueller.

From these three the Mitchell collection has been chosen as lectotype for it is a better specimen than the others and is representative of a considerable part of the total collections of this species.

Mueller wrote "Siliquae ½-1" longa, ⅓-¼" lata", but both the Balonne River plant and those from Pamamaroo have fruits about ½ inch long and on these plants the writer has seen none approaching one inch in length. Otherwise the plants agree with the description.

Description: *Plant* probably annual, many-stemmed, pubescent, including sepals and ovary, with erect or appressed simple hairs; *root* slender, usually ca. 1 mm diameter, but to 3 mm; *stems* to ca. 35 cm, but as short as 5 cm, usually terete, less often quadrangular or otherwise angled, arising from a basal rosette of leaves, usually erect, sometimes decumbent or prostrate, often much branched, usually equal or the central stem leafless and shorter than the leafy lateral stems, sometimes much reduced. *Basal leaves* to ca. 6 cm, usually obovate and pinnatifid with 4-5 lobes per side, these more or less linear and usually entire but sometimes remotely dentate or with secondary lobes, the terminal lobe usually narrowly spathulate; the leaves rarely spathulate and entire; leaves tapering into a slender petiole about as long as the blade. *Cauline leaves* to ca. 4 cm, but usually less than 2 cm, usually pinnatifid with 1-4 lobes per side, these opposite or alternate, spathulate or linear, straight or falcate-curved, rounded to subacute, sometimes finely dentate or with small teeth in the sinuses, the terminal lobe linear or obovate to narrowly spathulate, entire or with 1 or 2 small teeth, rounded to subacute, leaves sessile to very shortly petiolate. *Inflorescences* to about 45-flowered, dense, after anthesis elongating to ca. 15 cm, occasionally with scattered buds below the lowermost flowers, sometimes basal or axillary as result of non-development of stems. *Buds* more or less spherical. *Sepals* oblong, green or lavender with a narrow hyaline, colourless or lavender margin, often persistent below the young fruit: *lateral sepals* ca. 1·9-2·8 mm long, ca. 0·7-1·4 mm wide, average 2·3 x 1·0 mm, the ratio length to width 1·6:1-3·6:1, distally subacute, seldom rounded; *median sepals* ca. 2·0-3·0 mm long, ca. 0·8-1·5 mm wide, average 2·1 x 1·0 mm, the ratio length to width 1·8:1-2·8:1, distally rounded to subacute, sometimes slightly cucullate. *Petals*

about 1½ times as long as the sepals, ca. 2·5-3·9 mm long, ca. 0·9-2·0 mm wide, the average 3·2 x 1·3 mm, ratio length to width 1·7:1-3·5:1, oblong to spathulate, sometimes gradually tapering into a broad claw, distally rounded or truncate, then sometimes retuse or emarginate, usually white or yellow, rarely lavender, rather coarsely veined. *Stamens* with filaments distally linear, basally suddenly widening and cochlear or only slightly broadened, usually white or pale green, occasionally lavender; *lateral stamens* ca. 1·8-3·4 mm, average 2·5 mm; anthers ca. 0·7-1·5 mm, average 0·9 mm; *diagonal stamens* ca. 2·0-3·4 mm, average 2·5 mm; anthers ca. 0·6-1·4 mm, average 0·9 mm. *Pistil* ca. 1·6-2·5 [-3·2] mm, not stipitate, linear, usually terete, glabrous or sparsely pubescent; *style* linear to shorty obconical; *stigma* depressed-capitate, slightly wider than the style; *ovules* ca. 50 per ovary; *lateral nectaries* reduced to triangular or oblong or ovoid lobes of tissue, one on each side of each lateral stamen; *median nectaries* lacking. *Fruiting pedicels* ca. 3-11 [-15] mm long, ca. 0·2-0·4 [-0·5] mm, usually ca. 0·3 mm, in diameter, linear, terete or quadrangular or flattened, sometimes slightly expanded distally, usually spreading at 45 degrees or less from the stem, but sometimes horizontal or slightly recurved. *Fruit* ca. 4-20 mm long, ca. 0·6-1·4 mm across the septum, not stipitate, linear and straight, usually augustisept, less often terete; valves convex or keeled with a distinct nerve and, when mature, stramineate or reticulate, glabrous or sparsely to densely pubescent; proximally usually truncate, sometimes rounded, distally rounded or tapering and subacute; *style* less than 1 mm to obsolete, linear to broadly obconical; *stigma* depressed-capitate or almost tectiform, as wide as or slightly wider than the style; *septum* white, opaque, sometimes fenestrate with a longitudinal slit, nerve indistinct, usually smooth or, sometimes, rugulose, especially at the margins; *funicles* linear or narrowly triangular, straight or slightly curved. *Seeds* ca. 0·7-1·1 mm x 0·4-0·6 mm, uniseriate, ovoid to oblong, straight, plump; testa light yellow-brown or orange-brown to red-brown, usually with dark red or black pigmentation at the hilum; when moistened, rapidly exuding mucus to ca. 0·15 mm wide, the mucus clear and greyish, exuded as discrete short cones, less often as cylinders or clavate bodies, thus appearing radiate; *embryo* exactly or obliquely notorrhizal, the radicle shorter or longer than, or equal to, the usually oblong cotyledons.

TYPE LOCALITY: "Ad flumen Balonne. Sir Th. Mitchell. Ad flumen Darling prope Bamamero. Dr. Beckler."

LECTOTYPUS: Balloniæ [?] (eastern subtrop. Australia); 11.11.1846; Mitchell — MEL 772!

SOUTH AUSTRALIA:— between Nappamerrie and Innamincka, 12.8.1962; *Jackson 409* — UC, Z, AD; Tinga-Tingana; 23.9.1916; *White* — AD; Marree; 30.6.1930; *George* — ADW; Cowarie Stn.— Camp 37, Simpson Desert Expedition; 24.7.1939; *Crocker* — AD;

QUEENSLAND:— near Balmy Creek; 30.8.1846; *Mitchell 207* — BM; Roma; 25.10.1933; *White 9556* — BRI; "Warrie", Nindigully; 19.7.1937; *Roe 10* — CANB; Gilruth Plains, Cunnamulla; Oct. 1942; *Allen 441, 444* — CANB; Currawilla — about 100 miles W. Windorah; 9.6.1949; *Everist 3931* — BRI, CANB, K; Birdsville; 31.8.1957; *Filmer* — AD;

NEW SOUTH WALES:— Collarenebri; 2.9.1951; *Waterhouse* — SYD; Hungerford-Brindingabba, Oct. 1912; *Boorman* — NSW 53594; Glenroy Stn., Wanaaring; 8.8.1948; *Riches 16* — CANB, BRI; Milparinka; 25.9.1921; *Morris 827* — NSW 53590; Yancannia; 20.8.1923; *MacGillivray* — ADW; Turella; Aug. 1887; *Bauerlen 74* — MEL; Bamamero [Pamamaroo], Darling River; Dec. 1860; *Beckler* — MEL 773.

Fifty-eight sheets were seen.

Distribution: Known from north-eastern South Australia, south-western Queensland and north-western New South Wales. In South Australia the southernmost locality is Marree and it has not been reported from the area west of Lake Eyre. In Queensland it has been collected as far east as the longitude of Roma, and in New South Wales it has been found at Collarenebri,

almost exactly south of Roma. Collarenebri is almost 300 miles east of Hungerford from which is the next most easterly collection in New South Wales, but it is probable that *A. eremigena* occurs in the intermediate areas. — *Map 5.*

Observations: From north-eastern South Australia to eastern Queensland can be traced a clinal variation in some characters, the most obvious being fruit length (the most short-fruited plants from the western part of the range) and type of pubescence. The lectotype, from near the eastern limit of the range, bears simple hairs curved upward at the base and then appressed to the organ bearing them; the maximum length is about 0·4 mm, but they are usually about ¼ mm long. The fruit, glabrous or almost so, are usually about 10 mm long, although some reach 15 mm. Although most of the entire fruits on the plant were crushed in pressing, they seem to have been almost terete; the style is linear, about 0·3 mm long, and bears a small depressed-capitate stigma as wide as the style.

A representative short-fruited South Australian specimen (*Crocker* — AD) from near Cowarie Station, bears flattened simple hairs usually about ½ mm or slightly longer, which are often twisted and almost erect. In width they are usually about 0·05 mm, although some are 0·1; they are usually subacute, but the shorter ones, especially, may be spathulate. The valves are sparsely pubescent with hairs similar to, but slightly shorter than, those on the other plant parts.

The valves are noticeably convex and the fruits angustisept, the average width across the septum about 0·7 mm, the average fruit width, measured across the valves, about 1·4 mm. The style is obsolete or very shortly obconical (0·1-0·2 mm) and the stigma is flat and depressed. The floral organs, especially sepals and stamens, are slightly shorter than those of the lectotype.

From west to east there is an increase in fruit length, a transition from erect to appressed hairs, a change from angustisept to terete fruits, a trend toward glabrous fruit and a slight increase in size of the floral organs. Although on casual inspection the lectotype and the Cowarie Station plant might seem to belong to different species, a series of intermediates proves the connection between them. Because the intermediates do exist there has been made no separation of the South Australian material as representing an infraspecific taxon. Further collections from north-eastern South Australia, and south-western Queensland would probably support this decision.

The plants described are extremes and there are many sorts of intermediates; the appressed hairs, which are not infrequently distally spathulate, may be found on fruit valves of plants which otherwise bear erect hairs, even though these appressed hairs are usually associated with the glabrous-fruited eastern form.

The plants from Pamamaroo cited by Mueller seem somewhat out of place, for in their fruit they resemble more closely the extreme eastern material than they do the other collections from the north-western part of New South Wales, although they do have the longer erect hairs characteristic of the western plants.

Noteworthy are plants collected near Eulo, Queensland (*Young 65* — BRI; *Everist 1682* — BRI) which have glabrous fruit with very convex valves and longer styles (0·6-1·0 mm); the width across the septum is about 0·7-1·3 mm, that across the valves about 1·7-2·2 mm. Although they differ from the rest of the collections by the very convex valves and longer styles, they seem certainly to belong to this species.

Ecology and Biology: This species is found both on sand and on heavier soils. *Crocker s.n.; 27.7.1939* (AD) from north-east of Lake Eyre is annotated

as growing on the edge of a small claypan and material from New South Wales was collected from "river flats" and "mulga scrub". Notes with Queensland plants include "hard brown pebbly clay loam", "red-brown sandy loam among gidgea scrub", "in chocolate clay soil" and "in loose alluvial sand in shallow gully". This species is ephemeral, and probably appears very quickly after spring and summer rains. Its range lies chiefly in an area of irregular rainfalls between the regions of maximum summer and maximum winter rains.

Flowering and fruiting is usually in July-September but flowering probably can come at any time after rains.

Uses and Common Names: Eaten by stock and said to be "good sheep feed" (*Riches 16* — CANB. BRI). Beadle (Veg. & Past. West. N.S.W., 1948) refers to *Blennodia cardaminoides* as a useful fodder plant, but it is probable that the plants to which he referred are really *A. eremigena*; the collections made by Beadle which were determined as *Blennodia cardaminoides* are *A. eremigena*.

In the north-eastern part of South Australia these plants are steamed like spinach and eaten by the aborigines. Names recorded in this area are "priddiwalkatji" (Ngameni tribe) and "priddiwarrukatji" (Wonka-nguru tribe) (see Johnson and Cleland, Trans. Roy. Soc. S. Aust. 67(1943)154).

Relationships: *A. eremigena* is most closely related to *A. nasturtium* and *A. procumbens*. It differs from the former in being pubescent and in having leaves normally pinnatisect rather than trisect. Although the terete fruits of some plants of *A. eremigena* strongly suggest those of some plants of *A. nasturtium*, the angustisept ones point out the connection with *A. procumbens*. It otherwise differs from *A. procumbens* in being pubescent, in having smaller floral organs and in being usually erect in habit.

As is mentioned under *A. nasturtium*, *A. eremigena* and *A. procumbens* form a group rather distinct from the suffruticose species of *Arabidella*, but connected with them through *A. nasturtium*.

6. **Arabidella procumbens** (Tate)Shaw, comb. nov.

(procumbens = leaning forward, spreading; the stems are prostrate)

Blennodia nasturtioides var. *pinnatifida* Benth., Fl. Austral. 1(1863)74; Maiden and Betche, Cens. N.S.W. Pl. (1916)83. — *Sisymbrium procumbens* Tate, Trans. Roy. Soc. S. Aust. 7(1885)67 (*basionym*); Tate, Trans. Roy. Soc. S. Aust. 6(1883)101 (*nom. nud.*); Tate, Trans. Roy. Soc. S. Aust. 7(1885)72; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; Tate, Fl. S. Austral. (1890)16, 206; Koch, Trans. Roy. Soc. S. Aust. 22(1898)102. — *Blennodia procumbens* (Tate)Tate, Trans. Roy. Soc. S. Aust. 22(1898)123; Black, Fl. S. Austral. (1924)247; Black, Fl. S. Austral. (1929)687; Black, Fl. S. Austral. ed. 2 (1948)375. — *Lemphoria procumbens* (Tate)Schulz. Pflrch. 86(1924) 268. — *Micromystria nasturtium* var. *pinnatifida* (Benth.)Schulz. Pflrch. 86(1924)264.

Micromystria nasturtium var. *pinnatifida* is a tasmannic synonym of *Arabidella procumbens*, being based on the type of *Blennodia nasturtioides* var. *pinnatifida* Benth. which is discussed below; the other names cited above are nomenclatural synonyms of *A. procumbens*, being based on a common type.

Figures: Schulz. Pflrch. 86(1924)fig.1; Schulz, Pflzn. ed. 2 17b(1936) fig. 124; Troll, Die Infloresz. (1964)fig.466(3), 467;— Figure 7.

Description: *Plant* herbaceous, usually prostrate, glabrous, many-stemmed; *root* a slender short taproot; *stems* to ca. 15 cm, central stem leafless or reduced, the terminal inflorescence then appearing to arise from the basal rosette of leaves, lateral stems usually procumbent, sometimes ascendant. *Basal leaves* to ca. 5 cm, rarely entire, usually lyrate-pinnatifid with 3-7 lobes per side, lobes opposite or, less often, alternate, usually obtuse, the terminal lobe obovate-oblong, rounded or, more rarely, subacute, leaves tapering into a comparatively long slender petiole. *Cauline leaves* to ca. 2·5 cm, as basal leaves, but sometimes almost sessile. *Inflorescences* to 30-flowered, but usually less, initially very dense, elongating after anthesis; *buds* ovate to spherical; *flowering pedicels* terete, slender. *Sepals* oblong to ovate, green with a narrow hyaline margin, distally slightly tapering and rounded to subacute, not saccate basally; *lateral sepals* ca. 1·8-2·3 mm long, ca. 0·6-0·8 mm wide; *median sepals* ca. 1·7-2·3 mm long, ca. 0·5-0·6 mm wide, usually rounded distally and sometimes slightly cucullate. *Petals* slightly longer than the sepals, ca. [1·4-] 1·6-2·0 [-2·2] mm long, ca. [0·4-] 0·5 [-0·7] mm wide, usually with no distinction between blade and claw, cuneate to obovate, rounded to truncate, sometimes retuse, yellow or white (latter *fide* Schulz). *Stamens* with filaments slender and linear, slightly dilated at the base, white or pale green; *lateral stamens* ca. 1·8-2·0 mm, anthers obtuse, oblong, ca. 0·4-0·5 mm; *diagonal stamens* ca. 1·9-2·3 mm, anthers as those of lateral stamens. *Pistil* ca. 2·5 mm, not stipitate or, rarely, very shortly so, linear, terete or flattened dorso-ventrally; *style* very short and stout or obsolete; *stigma* fleshy, depressed-capitate or more or less two-lobed, *ovules* ca. 60 per ovary, biseriate, ovate on thin straight funicles; *lateral glands* usually reduced to more or less bilobed semicircular pieces of tissue, one on each side of each lateral stamen, or if more fully developed, suborbicular to pentagonal, producing lateral appendages, those of the opposite glands nearly meeting on the median line; *median glands* obsolete. *Fruiting pedicels* usually to 1·5 cm long, exceptionally to ca. 2·5 cm, slender, spreading, sometimes recurved or pendulous. *Fruit* ca. [4] 10-17 mm long, ca. 0·7-1·2 mm wide across the septum, terete or flattened laterally, therefore angustisept, linear, straight, not stipitate or on a very short stipe (to ca. 0·3 mm); valves convex, sometimes carinate, proximally tapering and rounded, sometimes subacute or almost truncate, distally rounded to truncate, with a slender nerve and, when mature, longitudinal striations; *style* stout and short or obsolete; *stigma* fleshy, depressed-capitate or more or less bilobed; *septum* white with a median nerve, hyaline, not fenestrate; *funicles* to ca. 0·5 mm long, slender, linear, pendulous. *Seeds* ca. 0·6-0·8 mm long, ca. 0·4-0·5 mm wide, biseriate, oblong to ovoid plump; testa yellow to light brown with red to orange-brown pigmentation at the hilum, when moistened, exuding a narrow mucus to ca. 0·1 mm, mucus exuded as discrete hemispheres or short oblong bodies, thus appearing radiate; *embryo* exactly notorrhizal, with radicle usually slightly longer than the narrowly oblong cotyledons.

Type: Lectotype: "Claypans near Termination Hill, Lake Torrens Plain".

Holotypus: Claypan, Ideyaka near Termination Hill; 2.9.1883; Tate — AD 96445354!

Isotypi: Lake Torrens Plain near Termination Hill; 2.9.1883; Tate — MEL 767, MELI

South Australia: — Östlich und westlich von Flinders Range, Leighs Creek, Farina, Lake Torrens Gebiet, 1902-1904; *Baselow 365* — B; William Creek, 10.9.1932; *Cleland* — AD; ca. 38 miles E. Dalhousie Springs; 9.8.1963; *Lothian 1591* — AD; Continents Plain near Mt. Barry Station; 13.7.1952; *Ising* — AD;

New South Wales: — Between the Darling and Lachlan; ?; *Burkitt* — MEL (holotype *B. usturtioides* var. *pinnatifida* Benth.); Livingstone; Aug. 1942; *Beadle* — SYD; near Billilla, Darling River; Aug. 1942; *Beadle* — SYD; 50 miles northeast of Menindie; Aug. 1942;

Beadle — NSW 53597: Kooringhirry [= Koonenberry]; Sept. 1887; *Bauerlen 200* — MEL: Paldrumatta Bore; 23.7.1900; *Corbett* — MEL, NSW 53599: Barrier Range; 1889; *Irvine* — B, W:

Without Locality: ?; ?; *Tate?* — NSW 53598:

These citations include all material seen.

Distribution: Known only from north-western New South Wales and the Lake Eyre basin in South Australia. This species may be more widely spread but it is inconspicuous and probably short-lived, so escapes the notice of collectors. — *Map 5.*

Observations: There is little variation in this species. It is usually a rather straggling prostrate plant with scattered leaves and, often, fruit arising from the basal rosette of leaves because of the non-development of a stem.

Schulz (1924) describes this species as having white petals, but Tate described them as yellow and on all the plants seen by the writer they have been yellow. Although Schulz refers to the seeds as being "humida valde mucosa" and in his drawing shows them as exuding a broad radiate mucus, all these examined by the writer have exuded only a narrow band of mucus. Also Schulz described the septum as "saepe fenestratum", but the writer has seen no fenestrate septa on either of the collections in B and W which were seen and annotated by Schulz.

Ecology and Biology: Little is known of this species; the available notes indicate that it grows in areas which have been flooded and would hold water for some time. The type collection was made on a clay pan and other comments with collections are "flat area between dunes", "lake bed", and "on tracks in mud on dry lake bed". Beadle (Veg. & Past. West. N.S.W., 1948) mentions that it is one of the few species capable of colonizing claypans, among the others being *Menkea australis* and *Marsilea drummondii*.

Flowering and fruiting seem usually to be in July to September, but probably occur after rains at any time of year.

Uses and Common Names: Beadle (1948) described it as being of no fodder value. Schulz quotes Basedow as giving the name "creeping mustard bush" but it is unlikely that this name is ever used.

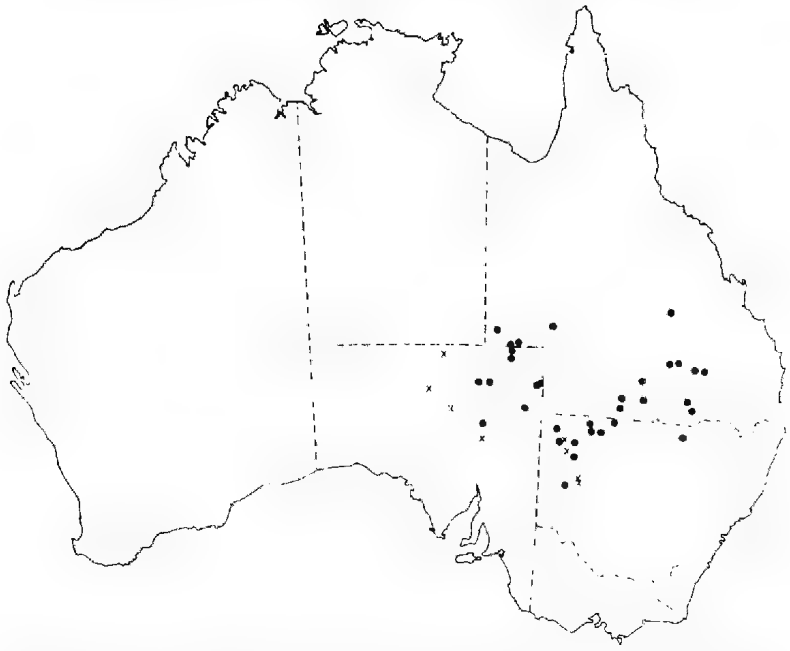
Relationships: Tate (1885) remarked of this species,

> "Among Australian congeners, *S. procumbens* approaches to *S. nasturtioides*, from which it differs in habit, form of leaves, in the spreading not erect pedicels, stouter pods, etc."

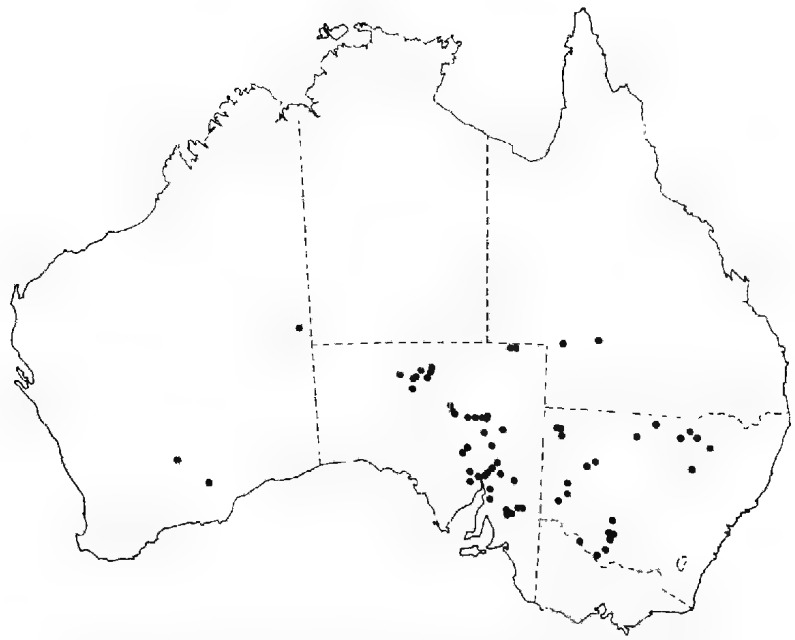
It is certainly related to *A. nasturtium*, but the pinnatifid leaves and the angustisept fruits, along with the reduced lateral glands, suggest rather a closer relation to *A. eremigena*.

This species and *A. eremigena* stand rather remote from the suffruticose species of *Arabidella*, but are connected with them through *A. nasturtium*, as is mentioned under the latter species.

Note: *Blennodia nasturtioides* var. *pinnatifida* was described from a single collection made by Burkitt in New South Wales. Bentham described it as having "leaves small, on long petioles, with few short lateral lobes and a larger terminal one". The Burkitt specimen is, however, *A. procumbens*.



Map 5. Distribution of *Arabidella eremigena* (FvM.)Shaw ●. Distribution of *Arabidella procumbens* (Tate)Shaw ×.



Map 6. Distribution of *Arabidella nasturtium* (FvM.)Shaw.

Harmsiodoxa Schulz

(Harms and δόξα = praise; named in honour of Hermann Harms.)

Schulz, Pflrch. 86(1824)260; Schulz, Pflfam. ed. 2 17b(1936)638.

Lectotype species: *Harmsiodoxa blennodioides* (FvM.) Schulz.

Description: *Calyx* open; *sepals* spreading or, occasionally, almost erect, usually green, sometimes lavender, with a narrow hyaline margin, on the abaxial side usually pubescent with sessile or shortly stipitate branched hairs, the margins, however, not pubescent; *lateral sepals* oblong to obovate or deltate, usually absolutely and relatively wider than the median, usually slightly saccate, distally somewhat tapering and usually subacute to acute, less commonly, rounded; *median sepals* oblong to narrowly obovate, sometimes elliptic, proximally usually somewhat tapered, not saccate, distally rounded, sometimes slightly emarginate. *Petals* usually 1½ times, to 2½ times, the sepals in length, white, pink or lavender, usually with distinct blade and claw, but not uncommonly without such distinction and then obdeltate or obovate; if clawed, claw usually more or less linear and about as long as or slightly shorter than the blade; blade suborbicular or obovate, sometimes oblong, usually entire or sinuate, apically usually rounded, sometimes truncate and then retuse or emarginate, usually quite coarsely veined, tapering suddenly or gradually into the claw. *Stamens* 6, erect or somewhat spreading, filaments linear and slightly dilated at the base, or more broadened and spathulate, often widened unevenly, the greater width on the lateral side of the vein, white or pale green, sometimes pink or lavender; anthers oblong or almost quadrate, rounded or, sometimes, subacute, yellow. *Lateral nectaries* each surrounding the base of a lateral stamen, generally triangular to pentagonal, sometimes square or suborbicular, usually quite shallow, open on the interior, open or emarginate on the outer side, producing from each side of each gland a lateral appendage encircling the base of the adjacent diagonal stamen and forming there a distinct triangular lobe; *median nectaries* usually obsolete, but very rarely glandular tissue occurring between the bases of the diagonal stamens, the tips of the lateral appendages approximate but not fused. *Pistil* not stipitate, linear to ampulliform, terete, glabrous or pubescent with short branched hairs; *ovules* usually subbiseriate, suborbicular to elliptic, pendulous on short slender curved funicles, ca. 4-14 per cell; *style* linear or slightly obconical, short or as long as the ovary; *stigma* fleshy, depressed-capitate, as wide as or slightly wider than the style. *Fruit* bilocular, bivalved, dehiscent, not stipitate, linear or fusiform, straight or curved, terete or quadrangular or somewhat flattened dorsiventrally (latisept); valves usually quite convex, with a more or less obvious midnerve, when mature brown, often with some red or magenta pigmentation, the exterior pubescent with sessile or shortly stipitate bifurcate to ramose or simple hairs, the simple hairs often restricted to the distal end, interior of the valve glabrous or sparsely pubescent with short bifurcate hairs, valves proximally tapering slightly and truncate or rounded, rarely subacute, distally rounded to subacute; *style* linear or slightly obconical; *stigma* depressed-capitate, as wide as or slightly wider than the style. *Septum* white, usually opaque, apparently not fenestrate, with a more or less distinct vein, smooth or rugulose especially at the margins and/or the proximal end; *funicles* linear or narrowly triangular, straight or slightly curved, pendulous. *Seeds* usually subbiseriate ca. 3-12 per cell, oblong to ovate or obovate, plump, not winged; testa orange-brown to dark red-brown, slightly darker at the hilum, finely papillose, when moistened exuding from each papilla a cylinder of mucus, each cylinder seeming to contain a tightly coiled grey spiral thread; *embryo*

exactly or slightly obliquely notorrhizal, cotyledons elliptic to oblong, rounded or truncate, usually slightly shorter than the radicle. *Plant* probably annual, herbaceous, few- to many-stemmed, usually erect, occasionally prostrate and spreading, pubescent, including sepals and ovary, with simple or sessile or shortly stipitate bifurcate or branched hairs. *stems* arising from a basal rosette of leaves and equal, or a central leafless stem and leafy lateral stems, the central stem sometimes reduced to an apparently basal inflorescence, stems sometimes much branched. *Basal leaves* rosulate, usually obovate or oblanceolate, rarely entire, usually dentate or, most commonly, pinnately lobed, sometimes very deeply so, usually on slender petioles, sometimes almost sessile. *Cauline leaves* scattered, usually obovate to elliptic, entire or rather coarsely dentate, occasionally, especially lower leaves, pinnately lobed, shortly petiolate or sessile on cuneate bases. *Root* a slender taproot. *Inflorescences* ebracteate, terminal on stems, dense, initially corymbose but after anthesis elongating and racemose, the central stems sometimes reduced so inflorescence seems basal; *buds* immediately before anthesis spherical to ovoid or oblong; *flowering pedicels* short, slender; *fruiting pedicels* very short and quite stout, erect or somewhat spreading or, rather slender and slightly spreading to almost horizontal, rarely slightly recurved.

Three species in semi-arid parts of Western Australia, the Northern Territory, South Australia, Queensland, New South Wales and Victoria.

Key to the species of *Harmsiodoxa*:

A Pedicels as long as or longer than the fruit

B Fruit with short almost sessile hairs, all of about same length

C Valves glabrous inside; petals ca. 4-8 mm long ..... 2. *H. puberula*

C Valves pubescent inside; petals ca. 2·5-4 mm long ..... 3 b. *H. brevipes* var. *major*

B Fruit with longer hairs, those at distal end longer than those at proximal end ..... 1. *H. blennodioides*

A Pedicels shorter than the fruit

D Valves with distal hairs simple, erect, to ca. 1 mm ..... 3 a. *H. brevipes* var. *brevipes*

D Valves with distal hairs branched, appressed, to ca. ¼ mm ..... 3 b. *H. brevipes* var. *major*

1. Harmsiodoxa blennodioides (FvM)Schulz

(blennodioides = like *Blennodia* R.Br.; because of the resemblance of this species to *Blennodia canescens* R.Br.)

Schulz, Pflrch. 86(1924)261.— *Erysimum blennodioides* FvM., Linnaea 25 (1853)367 (*basionym*): FvM., Census 1(1882)5; FvM., Sec. Census 1(1889) 9.— *Erysimum blennoides* FvM., Trans. Phil. Soc. Vict. 1(1855)100 (*nom. nud.*); FvM., Pl. Col. Vict. 1(1862)40, *pro. syn.*; FvM., Fragm. 11(1878)27 (*nom. nud.*).— *Blennodia lasiocarpa* FvM., Trans. Phil. Soc. Vict. 1(1855) 100 (*nom. nud.*): FvM., Enum. Pl. Gregory (1859)4 (*nom. semi-nud.*); FvM., Pl. Col. Vict. 1(1862)10; Benth., Fl. Austral. 1(1863)76; Turner, Forage Pl. Austral. 1(1891)4; Tate, Trans. Roy. Soc. S. Aust. 22(1898)123, Bailey, Qld. Flora 1(1899)47; Maiden & Betche, Gens. N.S.W. Pl. (1916)83;

Black, Trans. Roy. Soc. S. Aust. 41(1917)637; Black, Fl. S. Austral. (1924) 247; (1929)687.— *Blennodia cunninghamii* Benth., Fl. Austral. 1(1863)76; Bailey, Qld. Flora 1(1899)48; Maiden & Betche, Cens. N.S.W. Pl. (1916) 83.— *Sisymbrium lasiocarpum* (FvM.)FvM., Fragm. 7(1869)20.— *Erysimum lasiocarpum* (FvM.)FvM., Nat. Pl. Vict. 1(1879)34; FvM., Fragm. 11(1879)60; Tepper, Trans. Roy. Soc. S. Aust. 3(1880)34; Tate, Trans. Roy. Soc. S. Aust. 3(1880)51; Kempe, Trans. Roy. Soc. S. Aust. 3(1880)129; FvM., Key Vict. Pl. 2(1885)7; FvM., Key Vict. Pl. 1(1887-1888)129; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; Tate, Fl. S. Austral. (1890)16, 206; Tate, Horn Exped. pt. 3(1896)138; Koch, Trans. Roy. Soc. S. Aust. 24(1900) 81.— *Erysimum cunninghamii* (Benth)FvM., Census 1(1882)5.— *Blennodia blennodioides* (FvM.)Druce, Rep. Bot. Exch. Club. 4(1917)609; Ising, Trans. Roy. Soc. S. Aust. 61(1937)222; Eardley, Trans. Roy. Soc. S. Aust. 70(1946)162; Black, Fl. S. Austral. ed. 2(1948)376; Chippendale, Trans. Roy. Soc. S. Aust. ed. 2(1948)376; Chippendale, Trans. Roy. Soc. S. Aust. 82(1959)329.— *Harmsiodoxa cunninghamii* (Benth.) Schulz, Pflzch. 86(1924)282.

Erysimum blennodioides, *Erysimum blennodes*, *Blennodia lasiocarpa*, *Sisymbrium lasiocarpum*, *Erysimum lasiocarpum* and *Blennodia blennodioides* are nomenclatural synonyms of *Harmsiodoxa blennodioides*, being based on a single type. *Erysimum cunninghamii* and *Harmsiodoxa cunninghamii* are taxonomic synonyms of the above names, being based on the type of *Blennodia cunninghamii* which is discussed below.

Figures: FvM., Pl. Col. Vict. 1(1862)t.2; FvM., Nat. Pl. Vict. 1(1879)fig.6; FvM., Key Vict. Pl. 2(1885)fig.8; Turner, Forage Pl. Austral. (1891)fig.4; Black, Fl. S. Austral. ed. 2(1948)fig.600; Hayek, Beih. Bot. Centralbl. 27 (1911)fig.2 (12);—Figure 8.

Typification: As Mueller cited no specimens with his description, it was necessary to choose a lectotype. The locality given, "Ad ripam fluminis Murray arenosam inter locum Morunde et versuram orientalem" is between Morundie, which was a station on the western bank of the Murray River, just south of present-day Blanchetown, and Morgan, where the river bends to the east.

MEL 768 is a plant collected by Mueller in February, 1851, the locality being given as "Murray Banks". It was annotated by Mueller as "Erysimum (Varinia) blennodioides Ferd. Mull. n.g., antia sub nom. Blennodia canescente erratim missum". As this plant agrees with the description, was collected by Mueller before the date of publication of the name and does not disagree in locality with Mueller's citation, it seemed best to choose it as lectotype. This conclusion is supported by Mueller's comment on the label that the taxon represented here was earlier, and erroneously, associated with *Blennodia canescens* — hence the epithet "blennodioides". There are other Mueller collections which were considered, but they are undated and give much less information on the label.

It should be noted that Mueller apparently never published *Varinia* either as the name of a genus or of a sub-genus of *Erysimum*. Besides his use of it on the lectotype sheet here, it also appears on a collection of *E. brevipes* var. *brevipes* from Cudnaka [Kanyaka] which was annotated by Mueller as "Erysimum (Varenia) brevipes".

Description: *Plant* herbaceous annual, densely pubescent, including sepals and, sometimes, the ovary, with sessile or shortly stipitate branched hairs; *stems* to ca. 30 cm high, few or many, terete or finely fluted, erect, more or less leafy, arising from a basal rosette of leaves, equal or the central stem leafless; lateral branches numerous, often much branched. *Basal leaves* to ca. 10 cm long, ca. 2 cm wide, narrowly obovate, coarsely lobed or toothed, 1-3 lobes or teeth per side, these more or less triangular, rounded to subacute, usually opposite, often with small secondary teeth, especially on the distal side, terminal lobe broadly triangular usually; sometimes blade with only few small acute teeth, but always tapering into a long slender petiole. *Cauline leaves* to ca. 8 cm long, usually much shorter, to ca. 2 cm wide, more or less obovate, with ca. 1-4 coarse acute teeth or acute-subacute lobes per side or irregularly dentate with several

teeth per side, terminal lobe more or less triangular, acute to subacute; sessile on cuneate base or tapering into a slender linear petiole. *Inflorescences* to ca. 40-flowered, initially dense, elongating after anthesis; *flowering pedicels* slender, erect to spreading; *buds* before anthesis oblong to ovoid. *Sepals* usually green, sometimes lavender, with a narrow hyaline margin extending almost to the base, adaxially glabrous, abaxially densely pubescent with bifurcate or branched hairs; *lateral sepals* ca. 2·0-3·1 mm long, ca. [0·9-] 1·1-1·8 mm wide, the average ratio length to width 1·8:1, broadly oblong to deltate, apically subacute to acute, occasionally rounded, basally usually slightly saccate; *median sepals* ca. 1·7-3·0 mm long, ca. 0·8-1·5 mm wide, the average ratio length to width 2·2:1, oblong to narrowly obovate, apically rounded, sometimes tapering distally and thus approaching the narrowly deltate form of the lateral sepals. *Petals* ca. 3·6-6·0 mm long, usually with distinct blade and claw, white, sometimes pink or lavender; blade ca. 2·0-3·7 mm long, ca. 1·9-3·7 mm wide, average ratio length to width 1·1:1, oblong, suborbicular or broadly obovate, usually quite coarsely veined, margin entire, apically rounded or, less often, truncate and then often emarginate, tapering gradually into the more or less linear claw, this usually slightly shorter than the blade; sometimes without obvious distinction between blade and claw, the petal then elongatedly deltate, average ratio length to width 1·9:1. *Stamens* usually with filaments linear distally but proximally expanded and often narrowly spathulate, white or pale green, sometimes pale pink or lavender; anthers oblong or, less often, quadrate, usually rounded or subacute; *lateral stamens* ca. 1·5-3·3 mm, anthers ca. 0·6-1·1 mm; *diagonal stamens* ca. 2·1-4·1 mm, filaments often unequally broadened, the greater width on the lateral side, anthers ca. 0·5-1·0 mm. *Pistil* ca. 1·6-3·4 mm, ampulliform to almost linear, terete, not stipitate, pubescent or, often, glabrous; *style* long, slender, to same length as pistil; *stigma* depressed-capitate, usually slightly wider than the style; *ovules* ca. 10-25 per cell, suborbicular to oval, pendulous on slender curved funicles. *Fruiting pedicels* ca. 2·5-13·0 mm long, ca. 0·3-0·7 mm diameter, spreading to horizontal, usually at an angle from the stem of 45-90 degrees, linear or slightly expanded distally, terete or quadrangular. *Lateral nectaries* pentagonal to triangular, often open both on interior and exterior, on each side with a lateral appendage forming a distinct lobe at the base of each diagonal stamen; *median nectaries* obsolete. *Fruit* when mature ca. 4-25 mm, usually less than 15 mm long, across the septum ca. 1·1-3·0 mm, more or less fusiform-curved or straight, not stipitate; valves quite convex, proximally rounded to truncate, distally subacute to rounded, with a more or less prominent vein, the proximal third with sessile or shortly stipitate bifurcate or tau-shaped hairs grading distally into terete or flattened-acute simple hairs; *style* slender, linear, ca. 0·5-2·0 mm long, ca. 0·1-0·3 mm diameter; *stigma* depressed-capitate, often wider than the style; *septum* white, opaque, with more or less distinct vein, smooth except proximally where often rugulose, epidermal cells small and regular; *funicles* short, slender, pendulous. *Seeds* ca. 1·2-2·2 mm long, ca. 0·7-1·2 mm wide, broadly oblong to obovate (3:2), plump, subbiseriate, ca. 3-12 per cell; testa dull red-brown with slightly darker area at the hilum, densely papillose, when moistened exuding mucus as a slender cylinder, one from each papilla, the mucus thus having a radiate appearance; *embryo* exactly notorrhizal, radicle as long as or slightly longer than the cotyledons, cotyledons oblong, rounded or truncate.

TYPE LOCALITY: "Ad ripam fluminis Murray arenosam inter locum Morunde et versuram orientalem".

LECTOTYPUS: Murray Banks; Feb., 1851; Mueller — MEL 768!

SOUTH AUSTRALIA:— Camp 31, Simpson Desert Expedition; 18.7.1939; *Crocker* — AD: sandhills 15 miles west of Innamincka; 2.10.1916; *White* — AD: Strzelecki Creek; ?; Tate? —

AD: Koonamore; 14.8.1956; *Eichler 12466* — AD: Alligator Gorge; 1.10.1960; *Hill 1025* — AD: Morgan; 8.9.1883; *Tate* — AD: N. Holl. austr. — in itinere fl. Murray ostiam versus collegit; April, 1849; *Hillebrand* — MEL: 20 miles west of Emu; 3.9.1956; *Forde 468* — CANB: along track to Mt. Davies, ca. 65 km west of Musgrave Park Homestead; 6.9.1963; *Eichler 17296* — AD, BSA:

Victoria: Lake Boga; 24.9.1903; *Bird 12* — MEL: Onyen; Sept., 1913; *Williamson* — NSW 53623: Mildura; July, 1946; *Williams* — AD: near junction of Darling and Murray River, Victoria; Oct., 1887; *Minchin* — MEL: Jeparit; 8.9.1916; *W.R.A.B.* — MEL:

New South Wales: — Collarenebri; 1951; *Waterhouse* — SYD: Baraldine; 3.11.1954; *Johnson & Constable* — NSW 39890: Dubbo-Beni road; 23.8.1950; *Constable* — NSW 16458: Trangie-Narramine; 27.8.1947; *Moore 616* — CANB: Bogan Gate; Nov., 1906; *Boorman* — NSW 53643: Ardlethan; 30.9.1916; *Cambage 4183* — NSW 53635: Urana; Sept., 1893; ? — NSW 53632; "Zara", via Wanganella; Aug., 1903; *Officer* — NSW 53629: Emmonia; 23.8.1958; *Carolin 674* — SYD: Bourke; Aug., 1896; *Maiden* — NSW 53674; Nyngan; 11.9.1947; *Constable* — NSW 4456: Cobar; Sept., 1939; *Beadle* — SYD: Yandama Stn.; July, 1910; *Collier* — NSW 53677: Wilcannia; Sept., 1910; *Cleeny* — NSW 53667, NSW 53667, NSW 53668: Broken Hill; 23.8.1939; *Pidgeon & Vickery* — NSW 53649: Lake Kudgee H.S., 62 miles south of Broken Hill; 21.7.1955; *Constable* — NSW 39958, NT: in campis aridis ad fl. Murray; lacum Bonaree et juxta flum. Murrumbidgee; ?: *Mueller* — MEL:

Queensland:— Sub-tropical New Holland; 1846; *Mitchell* — K: Darling Downs near Wallangarra; Sept. 1944; *Clemens* — BRI: Roma; 26.10.1933; *White 9434* — BRI: about 5 miles north of St. George; 12.9.1959; *Everist 6107* — BRI: Curriwillughi [Currawillinghi]: ?: *Dallun* — MEL: Northhampton Downs, near Blackall; 27.8.1935; *Everist 1279* — BRI: Mitchell district, 3 miles west of Blackall; 29.3.1940; *Everist 2083* — BRI: Augathella; Sept. 1947; *Brass & White 26* — BRI: 15 miles west of Cunnamulla; 26.7.1948; *Roe* — NE: between Stokes Range and Coopers Creek; 1861; *Wheeler* — MEL:

Northern Territory:— View Ellery Creek; 23.9.1955; *Burbidge* — CANB: between Alice Springs and Charlotte Waters; May, 1875, *Giles* — MEL: 36 miles north-east Angas Downs homestead; 30.8.1955; *Chippendale* — BRI, CANB, NSW 53627, NT:

Two hundred and sixteen sheets were seen.

Distribution: Known from semi-arid parts of the Northern Territory, South Australia, Queensland, New South Wales and Victoria; probably also in the south-eastern part of Western Australia.

There are only a few collections from the Northern Territory and these are from the area south and south-west of Alice Springs. In South Australia it is spread across the northern part of the State and south to the Murray River.

In Queensland it occurs in the south-central part, the easternmost collection being from Wallangarra, about 125 miles south-west of Brisbane. The bulk of the collections are from New South Wales, where it seems to be generally distributed throughout the State west of the Dividing Range, the most easterly locality being in the Warrumbungle Mountains about 300 miles north-west of Sydney.

The Victorian collections are from the north-western part of the State, — *Map 5*.

Observations: The most conspicuous variation in this species is in petal colour, size and shape, fruit shape and the sort of pubescence on the valves.

The petals may be white, pink or lavender, and those three colours may appear at random in a population. The petals may be clawed with a suborbicular blade, or with no obvious distinction into blade and claw, the petals then being elongatedly deltate. Usually the petals of an individual flower are quite constant in size, but may vary considerably in shape.

Fruit shape and pubescence vary a great deal, but this is not at random for example, plants from Victoria can always be distinguished from those from the Northern Territory. The available Victorian plants, all from the north-western corner of the State, have fruits which are fusiform and usually falcate-

Generally the valves taper proximally and are rounded to truncate; distally they are also tapered and subacute to acute. The styles are slender, usually less than 0·2 mm in diameter and are usually about 1·0-2 0 mm long, although some plants bear shorter ones.

The most striking feature of these Victorian plants is the pubescence on the valves; they bear simple flattened hairs which may be 0·1 mm in width and 1·5 mm long. The longest hairs are on the distal ends of the valves; toward the proximal end they are shorter and mixed with shortly stipitate, erect, bifurcate hairs. Certain of the older collections seem to have glabrous fruits, but the hairs have been broken off.

With the Victorian plants may be compared Northern Territory material. The pubescence on the fruit is rather sparse and the distal hairs are predominantly bifurcate, with unequal arms and usually less than ¼ mm long. Mixed with these are simple hairs which are usually slightly longer, to about 0·4 mm. The bifurcate hairs are shortly stipitate and all are terete. At the proximal end the hairs are bifurcate, these usually having equal arms, or tau-shaped or, less often, simple.

The Northern Territory plants have fruits nearly linear or slightly wider at the distal end — the valves are slightly tapered and rounded at both ends. The styles are usually about 0·7 x 0·2 mm, and the stigma is more often the same width as the style. It may be noted that these plants have fruits which are almost terete and straight; some appear angustisept, but this is probably caused during pressing. On the Victorian plants the fruits are latisept.

These forms are the extremes of a series which can be followed across Queensland and through New South Wales. In these States are found intermediates with all possible combinations of fruit and pubescence characters.

The material from South Australia is not abundant but does sample many parts of the State. Collections from the western part, such as *Tietkens s.n.* (AD) from Ooldea and *Forde 468* (AD) from near Ernu tend toward the Northern Territory form. Those from the central-eastern part, for example, *Eichler 12466* (AD) from Koonamore and *Ising s.n.* (AD) from Canegrass are more like the Victorian form.

Plants from the north-eastern part of South Australia, such as *Crocker s.n.* (AD) from the Warburton River and *Tate s.n.* (AD) from the Strzelecki Creek are intermediates with varying combinations of fruit and pubescence characters. *Wehl s.n.* (MEL.) from Yarrowie [Appila] tends toward the Victorian form, while *Hill 1025* (AD) from Alligator Gorge near Port Augusta bears fruit which in shape and style characteristics resemble the Victorian plants, although the pubescence is rather of the Northern Territory form.

In South Australia it seems that plants from west and north-west of the Flinders Ranges are outliers of the Northern Territory form; those east of the Flinders and Mt. Lofty Ranges are of the Victorian form, while those from the north-eastern plains and the few collected within the ranges are intermediates.

The Queensland plants are of interest; many of them show a combination of characters which can, for convenience, be referred to as the Queensland form. This is intermediate between the Northern Territory and Victorian forms; it has the fruit shape and large admixture of bifurcate hairs characteristic of the Northern Territory plants, but the styles are longer and thinner.

Some of these have previously been determined as *Blennodia cunninghamii* Benth., the reluctance to identify them with *H. blennodioides* being understandable, as they are quite different from the typical Victorian form. Almost all possible combinations of characters appear in these Queensland plants, many

of them really being a short-haired Victorian form. Among representative Queensland collections are *White 9434* (BRI), *Smith & Everist 921* (BRI), *Everist 1279* (BRI), *1457* (BRI, CANB), *1620* (BRI), *2083* (BRI) and *White 11629* (BRI). From south-western Queensland there are only collections which are all intermediates between the Northern Territory and Queensland forms.

Fruit shape differs somewhat, the Northern Territory and Queensland forms having fruits which are usually straight and not tapered; the Victorian form, however, generally bears fruit curved and narrowed at the proximal end. Dimensions are compared in the following table:

	N.T.	*Qld.*	*Vict.*
fruit length (mm)			
max.	12·0	9·2	13·5
aver.	9·3	7·7	9·3
min.	7·3	5·2	6·0
fruit width (mm)			
max.	1·9	2·0	3·3
aver.	1·6	1·4	2·1
min.	1·3	1·1	1·3
max. width (fruit) / basal width			
max.	2·3 : 1	2·8 : 1	3·4 : 1
aver.	1·8 : 1	2·0 : 1	2·7 : 1
min.	1·6 : 1	1·7 : 1	2·2 : 1
length (style) / width (aver.)	3·4 : 1	7·2 : 1	4·9 : 1
length distal hairs (mm)			
max.	0·25	0·40	2·0
aver.	0·20	0·25	1·0
min.	0·13	0·15	0·6

In New South Wales can be traced the transition between the Northern Territory and Victorian forms. Here *H. blennodioides* occurs on the western slopes of the Dividing Ranges and on the plains lying to the west. Plants from the northern part of the State resemble the Queensland form, but to the southward Victorian characteristics predominate. Those from the far western part of New South Wales are like those in the adjacent parts of South Australia and resemble the Victorian plants.

Generally, the hairs on the vegetative parts are sessile or shortly stipitate; they are often once or twice bifurcate although many can be described only as irregularly branched. There is not such a high percentage of cruciform hairs as is found on plants of *H. puberula*.

Ecology and Biology: *H. blennodioides* seems more or less restricted to sandy or light soils, although there are scattered references to its occurrence on heavier soils. Beadle (Veg. & Past. West. N.S.W., 1948) noted that in parts of western New South Wales it is common in well-stocked areas and added that heavy grazing of pastures can lead to a complete monopolization of them by this species.

Flowering and fruiting usually occur in July to September, but flowering plants have been collected in every month except February. Turner (1891) commented that the seed germinates freely after spring rains and added that

the plant makes its growth during the hottest part of the year. However, there is comparatively little material which has been collected during the summer months.

As with several of these species, if the plant is well developed and then receives no rain during a period of several weeks, it quickly dies back, eventually losing its leaves. If rain falls between the beginning of leaf fall and the time of death, the plant develops new lateral shoots and the process is repeated. Plants placed in water have remained alive for almost four months, during this time producing several new side shoots on which flowers were borne.

Uses and Common Names: Turner (1891) remarks that these plants have a somewhat pungent taste which makes them attractive to stock. Beadle (1948) describes this species as being palatable to sheep and a valuable fodder.

Turner cites "hairy podded cress" as a common name but this seems to be not used.

Relationships: *H. blennodioides* seems equally closely related to *H. brevipes* and to *H. puberula*. On fruit characteristics alone it may be difficult to separate the first two for the pubescence pattern on the exterior of the fruit is similar as is fruit shape in many cases. However, *H. blennodioides* has fruit valves glabrous on the inner surface, while those of *H. brevipes* are pubescent. *H. brevipes* is the only species in the "Blennodia group" which shows this phenomenon.

H. puberula may be distinguished from the others by the slightly larger fruit and by its short appressed hairs.

NOTE: In 1863 Bentham published the name *Blennodia cunninghamii*, describing it in the following manner:

"A tufted herbaceous perennial, more or less hoary with soft stellate hairs, occasionally mixed with simple ones; annual stems erect or decumbent at the base, from a few inches to 1 ft. high, slightly branched. Radical leaves petiolate, 1 to 2 in. long, oblong or lanceolate, coarsely toothed or shortly pinnatifid; stem-leaves small and few, from lanceolate to nearly obovate. Flowers small, apparently white. Fruiting racemes loose, 2 to 4 in. long, with spreading pedicels. Pod 4 to 5 lines long, acute at the top and at the base, tipped by a very short subulate style, pubescent with simple or stellate hairs, or nearly glabrous; valves very convex, with a prominent midrib. Seeds oval-oblong, smooth, the funicus rather copious.

Queensland. Flats on the Maranoa, Mitchell.

N.S. Wales. Bathurst Plains and other parts of the interior of the colony, A. Cunningham, Fraser."[22]

The chief differences between a plant answering to this description and one of *H. blennodioides* are the following:—"pod . . ., acute at the top and at the base"; usually the fruits of *H. blennodioides* are rounded to truncate at the base:—"valves very convex, with a prominent midrib"; the valves of *H. blennodioides* usually cannot be described as very convex and the midrib, although distinct, is not prominent.

The following nine collections are those which probably have been seen and determined as *Blennodia cunninghamii* by Bentham:

BM: N.S.W.; Fraser — Arabis species found on all the Barren Lands west of Fields plains advanced in flower in June and July.

This plant is *H. blennodioides*.

K: (1) 16 July — Arabis-A. Cunningham — ex Herb. Hook.
This plant is *H. blennodioides*.

(2) Nov. Holl. — Fraser — ex Herb. Hook.
This plant is *H. blennodioides*.

(3) Sub-Tropical New Holland — 1846 — Sir T. L. Mitchell — ex Herb. Hook.
There are two plants, both of them *H. blennodioides*.

(4) Interior N.S.W. — 1817 — A. Cunningham 248.
This is also *H. blennodioides*.

(5) Lacrosse Island, Cambridge Gulf. N.W. Coast of Australia — 1819 — A. Cunningham 248.
This plant is *H. blennodioides* and agrees with Cunningham's other 248. The locality given is certainly wrong.

(6) Sub-Tropical New Holland — Aug. 1846 — Sir T. L. Mitchell 497 — Camp 29 — ex Herb. Hook.
This plant bears no fruit, only buds and flowers; it is very possibly the Queensland form of *H. blennodioides*.

(7) N.S.W. — Colony 1822 — A. Cunningham — ex Herb. Hook.
This plant agrees with Bentham's description in having a short style and a prominent midrib. It is not *H. blennodioides* and resembles a young plant of *Drabastrum alpestre* although the fruit are in shape more nearly those of the former than of the latter species.

Dr. S. T. Blake, at present Australian liaison officer at Kew, who was asked to re-examine the plant, also thinks it *D. alpestre*.

MEL: Arabis sp. Bathurst plains — A. Cunningham — MEL 775.
These plants are not *H. blennodioides*; they seem to be the same as K(7) above and probably are *Drabastrum alpestre*.

The Mitchell collections from subtropical New Holland dated 1846 [K(3)] include two plants mounted on a single sheet together with a Cunningham collection [K(1)]. If the better of the Mitchell plants (that on the right) be chosen as lectotype of the name *Blennodia cunninghamii* this name and *Harmsiodoxa blennodioides* become taxonomic synonyms.

It seems certain that the taxon which Bentham had in mind when describing *B. cunninghamii* is *H. blennodioides*: the discrepancies in the description of the former seem to have entered through the inclusion of the Cunningham plants [K(7), MEL 775].

All the plants which have, since Bentham's time, been determined (by Schulz and by others) as *B. cunninghamii* are *H. blennodioides*, very often the Queensland form.

2. **Harmsiodoxa puberula** Shaw, sp. nov.

(puberula = downy, with short hairs; the pubescence of this species is short and appressed)

Figures: Figure 9.

Diagnosis: Herba annua vel perennis(?), caulibus usque ad 50 cm altis, tenuibus, adscendentibus vel decumbentibus, stellato-puberula (sepalis et ovario incl.) pilis sessilibus vel breviter stipitatis ramosis adpressis; foliis radicalibus usque ad 12 cm longis, laminis late oblanceolatis vel oblongis, dentatis vel pinnatilobis, utrinque lobis 3-5, in petiolos tenues angustatis; foliis caulinis usque ad 10 cm longis, 2½ cm latis, oblanceolatis vel obovatis, integris vel remote dentatis, utrinque 2-4 dentibus, inferioribus pinnatilobis non numquam, utrinque lobis 3-5 linearis vel triangularis, sessilis vel breviter petiolatis; inflorescentibus ca. 20- usque ad 30- floribus; pedicellis fructiferis ca. 4-12 mm longis, ca. 0·6-0·9 mm diametro, erectis vel patentibus; siliquis usque ad 2·5 cm longis, ca. 1·4-3·0 mm latis, teretibus vel latiseptis, linearis vel late fusiformibus; valvis pubescentibus, pilis omnis brevibus, ramosis, adpressis, sessilibus vel brevissime stipitatis; stylis ca. 0·8-1·6 mm longis, ca. 0·3 mm diametro; stigmatibus capitatis, plerumque depressis, seminibus ca. 1·7-2·0 mm longis, subbiseriatis, oblongis vel ellipsoideis, cotyledonibus incumbentibus exacte.

Holotypus: Flood plain near Cadelga; 29.8.1960; Lothian 606 — AD 96045034]

Description: *Plant* herbaceous annual, pubescent, including sepals and ovary, with sessile or very shortly stipitate bifurcate or branched hairs; stems to ca. 50 cm high, few to many, terete or finely fluted, erect, more or less leafy, arising from a basal rosette of leaves, equal or with a central leafless stem, slightly shorter than the leafy lateral stems which are often much branched. *Basal leaves* to 12 cm, usually less than 6 cm long, with blades broadly oblanceolate to oblong, finely dentate, the teeth acute or obtuse, or sinuate or pinnately lobed, lobes 3-5 per side, more or less triangular, subacute to rounded, apically rounded to subacute, tapering suddenly into a slender petiole, sometimes dentate, as long as or slightly longer than the blade. *Cauline leaves* to ca. 10 cm long,

usually less than 5 cm, to 2½ cm wide, oblanceolate to obovate, lower leaves tapering into a slender petiole to as long as the blade; upper leaves shortly petiolate or almost sessile, entire or sinuate or remotely toothed, 2-4 per side, usually opposite and acute to rounded or sometimes pinnately lobed with 3-5 linear or triangular lobes per side, subacute to rounded, apically rounded or, less often, subacute. *Inflorescences* usually ca. 20-30-flowered, initially dense, but elongating after anthesis; *flowering pedicels* 4-7 [-12] mm long, slender, erect to spreading; *buds* before anthesis oblong, spherical or ovate. *Sepals* green or lavender, with a narrow hyaline margin, adaxial side glabrous, abaxial side pubescent with ramose hairs; *lateral sepals* ca. 2·9-3·6 [-3·9] mm long, ca. [1·2-] 1·6-2·0 mm wide, the average ratio length to width 1·9:1, oblong to lanceolate, apically subacute or, sometimes rounded, basally usually slightly saccate; *median sepals* ca. 2·7-3·5 mm long, ca. 0·9-1·6 mm wide, the average ratio length to width 2·3:1, oblong, apically rounded, basally slightly tapering, not saccate. *Petals* ca. 4·0-8·2 mm long, usually lavender, sometimes white, *in sicco* usually white or yellow; blades ca. 2·0-5·0 mm long, ca. 2·0-5·0 mm wide, ratio length to width 0·8:1-1·4:1, average 1·0:1, orbicular to obovate, densely veined, entire or sinuate, sometimes emarginate apically and almost cordate, tapering suddenly or gradually into a linear claw usually about the same length as the blade or slightly shorter, the blade averaging 56 per cent of the total petal length. *Lateral stamens* [2·7-] 3·0-4·3 mm long, filaments linear or slightly expanded at the base, straight or slightly curved; anthers ca. 0·8-1·5 mm, oblong or slightly narrowed at apex, yellow; *diagonal stamens* ca. 3·4-4·4 [-4·7] mm long, otherwise as lateral stamens; anthers ca. 0·8-1·2 mm, otherwise as those of the lateral stamens. *Pistil* ca. 2·5-3·5 mm long, linear, terete, not stipitate, pubescent with short branched hairs or, rarely, subglabrous; *style* linear or slightly obconical; *stigma* fleshy, depressed-capitate, as wide as or slightly wider than the style; *ovules* ca. 10-25 per ovary; *funicles* slender, pendulous; *lateral glands* triangular or square or circular, open on the interior, producing on each side a lateral appendage forming a distinct triangular lobe at the base of each diagonal stamen; *median glands* obsolete. *Fruiting pedicels* ca. 4-12 mm long, ca. 0·6-0·9 mm in diameter, erect to spreading, very rarely slightly recurved. *Fruit* to ca. 2·5 mm long, ca. 1·4-3·0 mm across the septum, usually linear or broadly fusiform, straight or sometimes falcate-curved; valves proximally tapering gently and truncate or, sometimes, rounded, distally subacute to slightly rounded, with a distinct, but not prominent, vein, quite densely pubescent with small sessile or very shortly stipitate, bifurcate or branched hairs, those at the distal end differing from those at proximal end; *style* ca. 0·8-1·6 mm long, ca. 0·3 mm wide, linear or slightly obconical; *stigma* usually depressed-capitate, as wide as or slightly wider than the style; *septum* white, semi-opaque, with more or less distinct vein, epidermal cells irregular in outline; *funicles* linear or slightly widened at the base, straight or slightly curved, pendulous. *Seeds* ca. 1·7-2·0 mm long, ca. 1·1-1·4 mm wide, oblong to ovoid; testa orange-brown to red-brown with slightly darker pigmentation at the hilum, finely punctate, when moistened exuding mucus as tightly coiled threads one from each papilla, thus appearing radiate; seeds ca. 3-10 per cell, subbiseriate; *embryo* exactly notorrhizal, radicle of same length as or slightly longer than the oval cotyledons.

South Australia:—60 miles east-south-east of Bluff (Roseberth) along Miranda track; 29.8.1960; *Lothian* 595 — AD, UC, Z: Paralana Hot Springs; 22.8.1963; *Kuchel* 956 — AD:

New South Wales:—Pilliga; Sept., 1932; *Rupp* 25 — NSW 53601: Louth; Sept., 1910; *Abraham* 479 — NSW 53606: Bootra-Urisino; ?; *Morris* 946 — ADW: Milparinka; Aug., 1939; *F.B. and N.C.B.* — SYD: Wilcannia; 20.8.1939; *Pidgeon and Vickery* — NSW 53604, NSW 53602:

QUEENSLAND:—Taubar; 20.6.1949; *Everist 4029* — BRI, CANB: Thargomindah; 3.9.1923; *MacGillivray* — BRI, ADW:

NORTHERN TERRITORY OR SOUTH AUSTRALIA:—South of Charlotte Water; Sept., 1885; *Kempe* — MEL:

Seventeen sheets were seen.

Distribution: There are only a few collections, but these indicate that it occurs in the far north-eastern part of South Australia, in south-western Queensland and in north-western and north-central New South Wales. — *Map 7*.

Observations: The few collections show little variation and it is usually easy to distinguish from the other species of *Harmsiodoxa* and from other *Cruciferae* found in Australia. Unfortunately there is only one collection bearing ripe fruit (*Vickery s.n.* — NSW 53603) and this is composed only of a number of fruiting racemes, but there seems no doubt that these belong to this species.

The hairs are usually sessile or almost so and are often cruciform with bifurcate arms. The arms are generally parallel to the organ bearing the hair, and the hairs often appear stellate. The plant, with the exception of stamens, style and replum, is pubescent and to the unaided eye looks canescent.

Ecology and Biology: Little is known of this species, but it seems to grow both in sand and in heavier soils. *Lothian 595* (AD) is annotated "Blennodia on low sandhill . . ." while other comments are "in heavy grey clay on flooded flat" (*Everist 4029* — BRI, CANB), "grey clay, overgrazed Mitchell grass pastures" (*Roe s.n.* — NE), "occasional on treeless plains" (*Johnson and Constable 937* — NSW 39948) and "pine box woodland" (*Beadle s.n.* — SYD). Flowering and fruiting occurs chiefly in the months July to October.

Uses and Common Names: There appear to be neither uses nor common names recorded.

Relationships: *H. puberula* seems equally closely related to *H. blennodioides* and to *H. brevipes*. It is most obviously distinguished from them by the very short appressed hairs.

3. Harmsiodoxa brevipes (FvM)Schulz

(brevis = short, pes = foot; the fruiting pedicels are short)

Schulz, Pflzch. 86(1924)263.

Erysimum brevipes FvM., Linnaea 25(1853)367 (*basionym*): FvM., Trans. Phil. Soc. Vict. 1(1855)100; FvM., Nat. Pl. Vict. 1(1879)33; Tepper, Trans. Roy. Soc. S. Aust. 3(1880)34; Tate, Trans. Roy. Soc. S. Aust. 3(1880)51; FvM., Census 1(1882)5; Tate, Trans. Roy. Soc. S. Aust. 4(1882)104; Rep. Field Nat. Soc., Trans. Roy. Soc. S. Aust. 8(1886)193; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; FvM., Sec. Census 1(1889)9; Tate, Fl. S. Austral. (1890) 16, 206; FvM. et Tate, Trans. Roy. Soc. S. Aust. 16(1896)335; Koch, Trans. Roy. Soc. S. Aust. 22(1898)102.— *Blennodia brevipes* (FvM.)FvM., Pl. Col. Vict. 1(1862)11; Benth., Fl. Austral. 1(1863)75; Tate, Trans. Roy. Soc. S. Aust. 22(1898)123; Maiden & Betche, Cens. N.S.W. Pl. (1916)83; Ostenf., Dansk. Vidensk. Selsk. Biol. Medd. 3/2(1921)65; Black, Fl. S. Austral. (1924)247; Black, Trans. Roy. Soc. S. Aust. 62(1938)101; Black, Fl. S. Austral. ed. 2 (1948)375. [This species was referred to *Blennodia* by Mueller, Trans. Phil. Soc. Vict. 1(1855)100, but the necessary combination was not made.].— *Sisymbrium brachypodum* FvM., Fragm. 7(1869) 20;

FvM., Fragm. 10(1877)119; FvM., Fragm. 11(1878)6 [*βραχύς* = short; *πούς* = foot].— *Sisymbrium brevipes* (FvM.)FvM., Fragm. 10(1876)53 (*nom. illegit.*) [non Kar. et Kir., Bull. Soc. Nat. Mosc. 15(1842)154].

The above names are nomenclatural synonyms of *Harmsiodoxa brevipes*, being based on the same type.

Figures: Hayek, Beih. Bot. Centralbl. 27(1911)fig.8(13); Black, (1924) fig.113 A-E; Schulz, (1924)fig.7A; Black, (1948)fig.529 A-E; — Figure 10.

Description: *Plant* small herbaceous annual, pubescent including sepals and ovary with simple or sessile or shortly stipitate bifurcate or branched hairs; *stems* to ca. 40 cm high, but usually much less, few to many, erect or prostrate with spreading branches, equal or with a leafless central stem and longer lateral stems, often reddish-purple; *root* a slender taproot, ca. 0·5 mm diameter at ground level. *Basal leaves* to ca. 13 cm long, but usually less than 4 cm, blades remotely dentate to coarsely pinnatisect, lobes opposite or almost exactly alternate, rounded or, often, mucronulate, primary lobes sometimes with a smaller triangular-rounded lobe or tooth on distal side, terminal lobe usually more or less triangular, leaves tapering into slender petioles or, less often, almost sessile. *Cauline leaves* ca. 0·5-3·5 [-4·0] cm long, oval to obovate, lowermost leaves shortly petiolate and almost pinnatifid, upper leaves with 2 or 3 coarse acute teeth on a side, terminal lobe obtuse to subacute, sessile on cuneate base or on a short petiole. *Inflorescences* usually with fewer than 20 flowers, initially dense, then elongating; *flowering pedicels* slender, erect or somewhat spreading. *Sepals* green with a narrow hyaline margin, adaxially glabrous, abaxially pubescent with shortly stipitate forked hairs, rarely with simple hairs; *lateral sepals* ca. 1·6-2·7 mm long, ca. 0·6-1·2 mm wide, the average ratio length to width 2·4:1, oblong to obovate to deltate, apically usually rounded or subacute, basally usually slightly saccate; *median sepals* ca. 1·5-2·7 mm long, ca. 0·6-1·2 mm wide, the average ratio length to width 2·5:1, more or less oblong or basally slightly narrowed and almost oval, apically rounded, sometimes slightly cucullate, basally not saccate. *Petals* ca. 2·2-4·1 mm long, lavender, pink or white, *in sicco* usually yellow, usually with obvious distinction between blade and claw; blade ca. 1·0-1·7 [-2·0] mm long, ca. 0·7-1·4 mm wide, ratio length to width 1·1:1-2·1:1, average 1·4:1, usually obovate, sometimes suborbicular or almost oblong, coarsely veined, margin entire or sinuate, apically rounded to truncate, then sometimes emarginate, usually tapering into a slender more or less linear claw, usually slightly longer than the blade, the blade averaging 47 per cent of the total petal length; sometimes with no distinction between blade and claw, the petal then usually narrowly obovate, the average ratio length to width 3·1:1. *Stamens* usually with filaments linear to tapered distally and slightly broadened at the base, sometimes narrowly clavate, green or, often, lavender, usually darker distally; anthers oblong, sometimes quadrate, usually rounded, yellow; *lateral stamens* ca. 1·6-3·0 mm long, anthers ca. 0·3-0·8 mm, usually 0·4-0·5 mm long; *diagonal stamens* ca. 1·8-3·2 mm long, anthers ca. 0·3-0·7 mm, usually 0·3-0·5 mm, filaments often broader on lateral side of vein. *Pistil* ca. 1·5-3·5 mm, ampulliform to ovoid, terete, not stipitate, shortly pubescent; *style* short, linear; *stigma* depressed-capitate, as wide as or slightly wider than the style; *ovules* ca. 8-11, suborbicular to ovoid; *funicles* short, slender, pendulous; *lateral glands* not fully developed, a more or less crescent-shaped lobe of tissue, one on each side of each lateral stamen, sometimes only a small lobe at the base of each diagonal stamen; *median glands* obsolete. *Fruiting pedicels* ca. 1·0-3·5 [-7·0] mm long, ca. 0·4-0·7 mm in diameter, spreading to erect, terete or, often, quadrangular. *Fruit* ca. 0·6-1·7 cm, usually 1·0-1·2 cm long, ca. 2·0-2·5 mm in width across the septum, fusiform-curved, tapering at

proximal end, not stipitate, terete or slightly compressed dorsu-ventrally, therefore latisept; valves convex, proximally rounded to narrowly truncate, distally rounded to narrowly truncate or subacute, vein almost obsolete, inner surface usually sparsely pubescent with bifurcate hairs, exterior pubescent with hairs usually sessile or shortly stipitate, bifurcate proximally, distally hairs usually simple, erect, often flattened at the base, acute to ca. 1·0 mm, longer than proximal hairs; *style* ca. 0·4-1·0 mm linear; *stigma* small, depressed-capitate, as wide as or slightly wider than the style; *septum* white, opaque, with vein, rugose, especially at edges, epidermal cells small, rounded, round to more or less oblong, irregularly arranged. *Seeds* ca. 1·2-1·7 mm long, ca. 0·9-1·3 mm wide, more or less oblong, plump; testa dull red-brown to dark brown, slightly darker at the hilum, testa with small tuberculiform papillae, when moistened, exuding mucus in cylinders, each containing a tightly coiled spiral thread, thus appearing radiate, subbiseriate, ca. 4-6 per cell; *embryo* exactly or slightly obliquely notorrhizal, usually with radicle about same length as the cotyledons.

TYPE LOCALITY: "In collibus subarenosis juxta omnem Rocky River".

HOLOTYPUS: In collibus subarenosis prope Rocky River; Oct. 1851; Mueller — MEL 7571

SOUTH AUSTRALIA:— Wilpena — lower slopes Mt. John; 4.9.1961; *Symon 1339* — ADW; Hallbury; 6.9.1909; *Black*(?) — AD; Loveday; 10.9.1942; *Gauba* — W; ca. 15 km west-south-west of Purnong, 1·5 km north-east of turnoff to Walker Flat on road from Purnong to Mannum; 11.8.1963; *Eichler 16205* — AD; Ardrossan; Oct. 1879; *Tepper* — AD; Mt. Wudinna; 7.9.1938, *John* — AD; Arkaringa Creek; 13.5.1891; *Helms* — MEL; Fowler's Bay; ?; *Richards* — MEL;

VICTORIA: Swan Hill; ?; *Gummow* — MEL; 3 miles north 65-mile post on Sturt Highway along track to Berribbee Tank; 2.9.1948; *Willis* — MEL; near Beulah; 15.9.1903; *Reader* — MEL; Jeparit; 11.9.1916; *W.R.A.B.* — MEL;

NEW SOUTH WALES:—Lake Cargelligo Dist.; 1903; *St. Eloy D'Alton* — MEL;

WESTERN AUSTRALIA:—Eucla; 1877; *Richards* — MEL; Fraser Range; 12.10.1891; *Helms* — MEL; Cowcowing; Sept.-Oct. 1904; *Koch* — PERTH.

Sixty-two sheets were seen.

Distribution: This is the most widely spread species of *Harmsiodoxa*, occurring in Western Australia, South Australia, Victoria and, apparently, in New South Wales.

In South Australia this species seems most common in the southern part of the Flinders Ranges and on the plains to the south-east, although there are scattered collections from the far north, the Yorke Peninsula, the Eyre Peninsula, and near the head of the Great Australian Bight. It extends further south than most of this group, the southern-most collection (*Ising coll.* — AD) being from near Kinchina, about 5 miles west of Murray Bridge.

In Victoria it is restricted to the drier areas of the north-west. From New South Wales there is only one collection; this seeming rarity in New South Wales is surprising for this species does occur in north-western Victoria and eastern South Australia. — *Map 7.*

Observation: There is little variation except in length of the fruiting pedicels and length of the hairs on the fruit valves. The pedicels are usually short and stout, but occasionally are as long as 7 mm. Unless the inner surface of the valves is checked for the presence of pubescence, a plant with longer pedicels which is only in fruit is often difficult to distinguish from some forms of *H. blennodioides*. However, the flowers of *H. brevipes* are considerably smaller than those of other species of *Harmsiodoxa*.

The fruit show the same pubescence pattern as those of *H. blennodioides*. At the proximal end the hairs are usually bifurcate with more or less erect arms; toward the distal end there are gradually more hairs which are simple

or with one arm shorter than the other. The hairs are shortly stipitate; those at the proximal end are usually less than 0·3 mm long — at the distal end they may be as much as 1 mm, but are usually less. The other parts of the plant have hairs which are shortly stipitate to sessile and bi- or trifurcate to irregularly branched.

Ecology and Biology: As is true of the other species of *Harmsiodoxa*, *H. brevipes* generally occurs in the more southerly semi-arid areas and usually grows in sandy soil. The chief period of flowering and fruiting is in July through October, but, given rain, flowering probably occurs at any time of year. *Willis s.n.* (MEL), from the far north-west of Victoria, is annotated "common in open grassy situations on low sandhills with *B. cardaminoides* FvM."

Uses and Common Names: None known.

3a. **Harmsiodoxa brevipes var. major Shaw, var. nov.**

Diagnosis: A varietate typica differt:

Foliis radicalibus plerumque integris vel sinuatis; pedicellis fructiferis ca. 2-7 [-15] mm longis, ca. 0·5-0·8 [-1·0] mm diametro; valvis exteriore canescentibus pilis bifurcatis vel ramosis, sessilis vel brevissime stipitatis; septis levioribus; seminibus ca. 1·5-2·1 mm longis, ca. 1·0-1·4 mm latis, prorata longioribus.

Holotypus: Evelyn Downs; 19.7.1952; Ising — AD 96112032!

South Australia:—Mt. Lyndhurst; Aug. 1898; *Koch 330* — B; Mt. Lyndhurst; Oct. 1898; *Koch 330* — BRI, MEL, NSW 53608; Arcoona Creek — south of Arcoona Bluff Range; 16.9.1956; *Eichler 12664* — B, GH, Z, AD; Arkaringa Creek, 12 miles north of Mt. Barry; 30.8.1955; *Ising* — AD, UC; Evelyn Downs; Oct. 1950; *Ising* — AD, KW;

New South Wales:—Lachlan River; 1879; *Tucker 47* — MEL;

Twenty sheets were seen.

Distribution: This variety has been collected in the Flinders Ranges, south-west of Lake Eyre and in the vicinity of Evelyn Downs Station, about 90 miles south-west of Oodnadatta, as well as in south-central New South Wales. — *Map 7*.

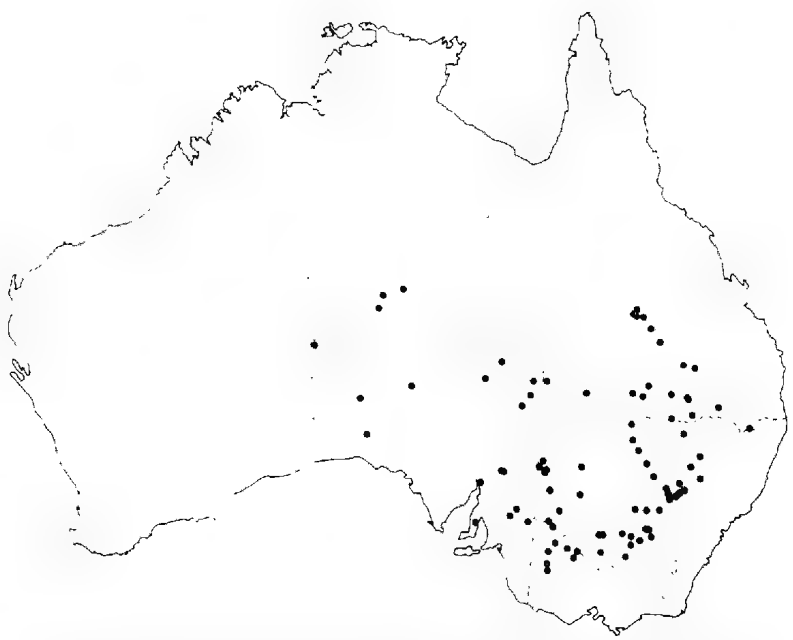
Observations: The pattern of pubescence is much the same as for the typical variety, but the hairs of the distal end of the valves are not strikingly longer and are often evenly bifurcate. On all parts of the plant the hairs seem quite silky and are often appressed to the organ bearing them. Were it not for the smaller flowers, some specimens of this variety could be confused with *H. puberula*.

It is usually easy to recognize *H. brevipes*, but two collections from the Arcoona area in the Flinders Ranges (*Eichler 12664, 12827* — AD) are difficult. These are both rather robust plants which seem intermediate between *H. brevipes* and *H. blennodioides*. The fruit are on longer pedicels than is usual for *H. brevipes* but the flowers are, in size, much more like those of *H. brevipes* than those of *H. blennodioides*. For the present it seems best to refer them to *H. brevipes* var. *major*.

Ecology and Biology: So far as is known the ecological requirements are the same as for the typical variety. Flowering and fruiting seem to occur chiefly in July to October; probably flowering, at least, can take place at any season after rain.

Uses and Common Names: *Koch 330* is annotated "good fodder". No common names are known.

Map 7. Distribution of *Harmsiodoxa brevipes* (FvM.)Schulz ●; var. *major* Shaw ×. Distribution of *Harmsiodoxa puberula* Shaw ▲.



Map 8. Distribution of *Harmsiodoxa blennodioides* (FvM.)Schulz.

Note: A possible synonym of *H. brevipes* is *Alyssopsis drummondii* Turcz., Bull. Soc. Nat. Mosc. 27/2(1854)291. Turczaninow described this species citing *Drummond, series 4, no. 128*, collected in Western Australia, and this description agrees with *H. brevipes*. Turczaninow was not certain to what genus this plant belonged and included it in *Alyssopsis* for want of a better place. In 1877 and 1878 Mueller remarked that *A. drummondii* Turcz. was synonymous with his *Sisymbrium brachypodum* and Schulz (1924) cited *A. drummondii* Turcz. as a synonym of *Harmsiodoxa brevipes*.

There are in BM, W, and K collections labelled as no. 128 from Drummond's fourth series and these plants are all *H. brevipes* var. *brevipes*. From KW was received a photograph of the plant from Turczaninow's herbarium which is labelled as "Drummond, 4th series, no. 128". On the label is written *Alyssopsis drummondii*, but this plant is not the same as the other collections under this number and does not agree with Turczaninow's description.

It is woody at the base and suggests a suffruticose perennial which has just put forth a new season's growth. Also the fruits, which seem to be young, are on long slender pedicels and seem to be almost obovoid; the inflorescence appears to be not so dense as it is in *H. brevipes*.

Authentic material of *H. brevipes* var. *brevipes* was then sent to Kiev for comparison with the Turczaninow plant. Dr. D. N. Dobrotslujewa, Curator of the Herbarium, replied that in the moving of their collections during the war the label from the authentic specimen of *A. drummondii* Turcz. must have become erroneously attached to another plant which was the one photographed.

Until Turczaninow's type is found and examined it is impossible to cite with certainty *Alyssopsis drummondii* Turcz. as a synonym of *H. brevipes* (FvM.)Schulz.

Scambopus Schulz

(σκαμβός = curved, πούς = foot; the fruiting pedicels are recurved)

Schulz, Pflrch. 86(1924)259; Schulz, Pflfam. ed. 2 17b(1936)637.

Description: *Calyx* open; *sepals* usually spreading, occasionally erect or almost so, usually green with a narrow hyaline margin, pubescent on the abaxial side with shortly stipitate bifurcate or branched hairs; *lateral sepals* oblong or deltate, usually slightly wider than the median sepals, sometimes slightly saccate basally, distally rounded to subacute; *median sepals* usually more or less oblong, less often obovate, not basally saccate, distally rounded to truncate, sometimes slightly cucullate. *Petals* usually slightly longer than the sepals, to about twice as long, yellow, clawless or with a very short linear claw, usually suborbicular to obovate, sometimes deltate, entire or, rarely, retuse or emarginate, rounded to truncate, rather coarsely veined. *Stamens* 6, erect or somewhat spreading, filaments slender distally but suddenly widening at the base, often spathulate, white to yellow or pale green; anthers oblong, obtuse, yellow. *Lateral glands* each surrounding the base of a lateral stamen, circular to square, usually open both on the interior and exterior, producing from each side of each gland a lateral appendage curving around the base of the adjacent diagonal stamen; *median gland* a triangular to oblong lobe of tissue between the bases of the members of each pair of diagonal stamens; median glands and the tips of the lateral appendages touching but not fused, when fully developed. *Pistil* not stipitate, ampulliform to linear, terete or slightly compressed laterally, therefore angustisept, glabrous or pubescent with hairs mostly simple; *ovules* subbiseriate, ca. 8-22 per cell, oblong to ovate, pendulous on slender linear or narrowly triangular funicles; *style* linear or narrowly obconical; *stigma* depressed-capitate, as wide as or slightly wider than the style. *Fruit* bilocular, bivalved, dehiscent, not stipitate, fusiform and usually curved, quadrangular or slightly latisept; *valves* very convex, generally keeled, with a prominent nerve and,

when mature, a reticulum of secondary veins, brown, usually with magenta pigmentation on the midrib, pubescent with simple or sessile or shortly stipitate bifurcate or branched hairs, proximally tapering and subacute to rounded, usually slightly recurved, distally tapering and usually subacute; *style* linear and short, slender; *stigma* depressed-capitate, as wide as or slightly wider than the style. *Septum* white, opaque, with nerve, slightly rugose; *funicles* linear to narrowly triangular, pendulous. *Seeds* generally subbiseriate, ca. 3-20 per cell, oblong, plump, not winged; testa reddish-brown, with darker pigmentation at the hilum, papillose, when moistened, mucose, the mucus exuded as discrete grey, elongate spirally coiled threads, one from each cell of the testa, the mucus thus appearing radiate; *embryo* exactly notorrhizal, the cotyledons slightly longer than the radicle. *Plant* probably annual, herbaceous, several-stemmed, erect, pubescent, including the sepals, with sessile or shortly stipitate branched hairs; *stems* arising from a basal rosette of leaves, equal or with a leafless central stem and remotely leaved decumbent lateral stems. *Basal leaves* rosulate, usually narrowly obovate, entire or dentate or pinnatisect, petiolate. *Cauline leaves* scattered, obovate to linear, entire or dentate, on slender petioles or almost sessile on narrow cuneate bases. *Root* a slender taproot. *Inflorescences* ebracteate, terminal on stems, initially corymbose, but after anthesis elongating and racemose; *buds* just before anthesis more or less oblong; *flowering pedicels* slender, usually spreading, sometimes almost erect; *fruiting pedicels* slender, spreading, usually recurved and then ascendant or almost horizontal and straight.

One species in South Australia in the Flinders and Gawler Ranges and the Lake Torrens basin.

Scambopus curvipes (FvM.)Schulz.

Excluded Species: *Scambopus richardsii* (FvM.)Schulz, Pflzch. 86(1924)260. *Erysimum richardsii* FvM., Fragm. 10(1877)105 (*basionym*) — *Sisymbrium richardsii* (FvM.) FvM., Census 1(1882)5.— *Blennodia richardsii* (FvM)FvM., ex Tate, Trans. Phil. Soc. Ad. (1879)121 (*nom. nud.*)— *Blennodia richardsii* (FvM.)FvM. ex Black, Fl. S. Austral. (1924)247.

The holotype, collected at Eucla, Western Australia, bears no ripe fruit, but the appressed simple hairs and the very much angustisept ovary indicate that it is a species of *Phlegmatospermum* Schulz. This was first pointed out by Black (1937) who suggested that the Helms collections from the Arkaringa Creek which was determined as *Sisymbrium richardsii* by Mueller and Tate are *P. cochleatinum*.

Relationships: *Scambopus* is apparently most closely related to *Harmsiodoxa*. However, it differs from *Harmsiodoxa* in having median glands and in usually having fruits which are quadrangular rather than terete or slightly latisept. Admittedly these are not great differences and a quadrangular fruit is not very far removed from a terete one; however, rather minor differences must often be used in circumscribing genera in this family and *Scambopus* is quite distinct from *Harmsiodoxa*.

The quadrangular fruit is somewhat suggestive of that of *Drabastrum*, but there are really no other significant similarities between the two and it is unlikely that they are closely related.

Mueller also recognized the similarities between *Harmsiodoxa* and *Scambopus*; in MEL is a plant collected by Mueller in November, 1851, probably near Crystal Brook, South Australia. It is labelled, in Mueller's hand, "Erysimum curvipes Ferd. Muell." but also bears Mueller's note, "Subgen: Varenia [n.g.] erysimoides"; this was later crossed out, presumably by Mueller himself. This is the same name for a subgenus of *Erysimum* which occurs on sheets of

H. blennodioides and *H. brevipes*.

It is unfortunate that Mueller did not publish any of his ideas about relationships within these groups. The grouping of *H. blennodioides*, *H. brevipes* and *S. curvipes* under *Varenia*, and of *Arabidella trisecta*, *A. filifolia* and *A. nasturtium* under *Arabidella*, as is suggested in Mueller's annotations, would have presented a much more natural arrangement than does Mueller's published work.

Scambopus curvipes (FvM.)Schulz

(curvus = bent; pes = foot; the fruiting pedicels are recurved)

Schulz, Pflrch. 86(1924)259.— *Erysimum curvipes* FvM., Linnaea 25(1853) 368 (*basionym*); FvM., Trans. Phil. Soc. Vict. 1(1855)100; FvM., Nat. Pl. Vict. 1(1879)34; Tate, Trans. Roy. Soc. S. Aust. 3(1880)51; FvM., Census 1(1882)5; FvM., Key Vict. Pl. 2(1885)7; FvM., Key Vict. Pl. 1(1887-1888) 129; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; FvM., Sec. Census 1(1889) 9; Tate, Fl. S. Austral. (1890)16, 206.— *Blennodia curvipes* (FvM.)FvM., Rep. Babb. Exped. (1859)7; FvM., Pl. Col. Vict. 1(1862)42; Benth., Fl. Austral. 1(1863)75; Tate, Trans. Roy. Soc. S. Aust. 22(1898)123; Maiden & Betche, Cens. N.S.W. Pl. (1916)83; Black, Trans. Roy. Soc. S. Aust. 45 (1921)12; Ising, Trans. Roy. Soc. S. Aust. 46(1922)597; Black, Fl. S. Austral. (1924)247; Black, Fl. S. Austral. ed. 2 (1948)375.— *Sisymbrium curvipes* (FvM.)FvM., Fragm. 7(1869)20.

Erysimum curvipes, *Blennodia curvipes* and *Sisymbrium curvipes* are nomenclatural synonyms of *Scambopus curvipes*, these names being based on a single type.
Figures: Figure 11.

Description: *Plant* herbaceous, pubescent; *stems* to ca 30 cm high, exceptionally to 50 cm, terete or finely fluted, rigid. *Basal leaves* usually less than 6-8 cm long, exceptionally to 16 cm, entire or with 1,2 or several rounded to acute teeth per side or pinnatifid with as many as 6 lobes per side, these opposite or alternate, usually subacute, often very small toward base of leaf, leaves rounded to subacute distally, tapering into a narrow petiole. *Cauline leaves* usually less than ca. 3½ cm long, entire or with a few small teeth per side, or ca. 3-5 cm, exceptionally to 10 cm, pinnatifid with usually three lobes or teeth per side, sessile or shortly petiolate. *Inflorescences* usually ca. 10-20-flowered, dense, after anthesis elongating; *flowering pedicels* slender, usually spreading; *buds* more or less oblong. *Sepals* usually oblong or deltate to ovate, usually green with a narrow hyaline margin; *lateral sepals* ca. 2·6-4·0 mm long, ca. 1·0-2·0 mm wide, average 3·3 x 1·4 mm, ratio length to width 1·8:1-3·1:1, oblong to deltate, rounded to subacute, sometimes slightly saccate basally; *median sepals* ca. 2·9-4·0 mm long, ca. 1·0-1·9 mm wide, average 3·4 x 1·5 mm, ratio length to width 1·8:1-3·2:1, more or less oblong or ovate, rounded to truncate, sometimes slightly cucullate, not basally saccate. *Petals* to about twice as long as the sepals, ca. 3·4-6·6 mm long, ca. 2·4-5·3 mm wide, average 4·9 x 3·8 mm, ratio length to width 1·1-1·1·5:1, usually suborbicular to ovate, not clawed or with a very short claw less than 0·5 mm in length. *Lateral stamens* ca. [2·4-] 3·1-4·0 mm long, average 3·3 mm, filaments ca. 0·1-0·2 mm diameter distally, basally expanded to ca. 0·5-0·7 mm, white, yellow or pale green; anthers ca. 1·0-1·7 mm, average 1·4 mm, oblong, yellow; *diagonal stamens* ca. 2·6-4·1 mm long, average 3·4 mm, otherwise as lateral stamens; anthers ca. 1·0-1·8 mm, average 1·4 mm, as those of the lateral stamens. *Pistil* ca. 2·0-4·0 mm long, ampulliform to linear, terete or slightly angustisept, not stipitate, glabrous or pubescent; *style* linear or narrowly obconical; *stigma*

depressed-capitate; *nectaries* as in generic description. *Fruiting pedicels* ca. 1-2 cm long, sometimes to 3 cm, ca. 0·4-0·7 mm in diameter, slender, usually recurved. *Fruit* ca. 10-20 mm, usually 10-15 mm long, septum usually ca. 2 mm wide, but to 3 mm; valves convex or keeled, with a prominent nerve, pubescent, hairs to ca. 0·5 mm, usually shorter at proximal end of the valve; *style* ca. 0·5-1·3 mm, linear and slender, *stigma* depressed-capitate. *Seeds* ca. 1·1-1·5 x 0·9-1·1 mm, subbiseriate, ca. 3-20 per cell, oval, plump, not winged; testa reddish-brown, at the hilum with darker pigmentation; *embryo* exactly notorrhizal, cotyledons slightly longer than the radicle.

Type Locality: "Prope rivum Crystal Brook".

Holotypus: Crystal Brook; Oct., 1851; F. Mueller — MEL 769!

Isotypus?: S. Australia, Crystal Brook; ?; ex Herb. Muell. — K.

South Australia:—28 miles S. Parachilna; 26.8.1961; *Shaw 31* — AD; Waite House; 3.7.1954; *Hilton 502, 513* — ADW; Whyalla-Kimba; July, 1955; *Higginson* — AD, UC, Z; Tarcoola; 22.9.1920; *Ising 1767* — MEL, NSW 53571, BRI;

In all thirty sheets were seen.

Distribution: This species seems to occur only in South Australia, where it has been collected in the Flinders Ranges, the ranges south-west of Port Augusta, the Lake Torrens basin and at Tarcoola. As is true of several species in this group, the holotype was collected at Crystal Brook in the southern part of the Flinders Ranges; this area has for many years been used for agricultural purposes and it is unlikely that this species still occurs here. — *Map 10.*

Observations: The most noticeable variation is in size and foliage. The plants in *Shaw 31* (AD) are only a few inches high and are bearing fruit; with these can be compared some of the Yudnapinna plants which are as much as 30 cm high. These differences in size are only the consequence of more or less favourable conditions.

Although the leaves usually have been described as entire or remotely toothed, the basal leaves are often pinnatisect. This is especially noticeable on some of the Yudnapinna plants. It should be remarked that this species seems to lose its leaves easily, for many of the collections are entirely leafless, being only bare stems and fruiting racemes.

Mueller described the corolla parts as being scarcely longer than the sepals and this was repeated by Schulz, but in all the plants examined the petals have been at least 1½ times to twice as long as the sepals. In fact, the flowers are rather conspicuous because of the large expanse of blade beyond the calyx. It should also be noted that the seeds seem to be not more than 1½ mm long although Schulz described them as being 2 mm in length.

Ecology and Biology: Little is known of *S. curvipes* in these respects, but it probably occurs most commonly on light sandy soils. *Murray 131* (ADW) is annotated as occurring on "sandhills or bluebush flat" and on collections from Yudnapinna it is said to be very common in this area. The writer has seen this species in the field only once, between Hawker and Parachilna in the Flinders Ranges, and here it was growing on sandy soil in depressions by the roadside.

Uses and Common Names: Neither uses nor common names have been recorded.

Relationships: These are discussed under the genus *Scambopus*.

Drabastrum (FvM)Schulz

(Draba = genus in this family)

Schulz, Pflrch. 86(1924)257; Schulz, Pflfam. ed. 2 17b(1936)636.— *Blennodia* sect. *Drabastrum* FvM., Trans. Phil. Soc. Vict. 1(1855)100.

Description: *Calyx* open, sepals spreading or, less often, almost erect, basally not saccate, usually green, sometimes lavender, with a narrow hyaline margin, usually sparsely pubescent on the abaxial side; *lateral sepals* oblong to obovate, usually wider than the median, distally usually subacute; *median sepals* often oblong, sometimes obovate, distally rounded, sometimes slightly cucullate. *Petals* about 1½ to 3 times as long as the sepals, usually white, sometimes lavender, with distinction between blade and claw; blade oblong to broadly obovate or suborbicular, entire or sinuate, rounded or truncate, sometimes retuse or emarginate, coarsely veined, tapering suddenly into a slender linear claw. *Stamens* 6, somewhat spreading, filaments linear or slightly dilated at the base, white, often becoming violet distally; anthers quadrate to shortly oblong, obtuse, yellow. *Lateral glands* each surrounding the base of a lateral stamen, subquadrate, emarginate on interior, open on the exterior, with short lateral appendages, or, reduced to a small triangle of tissue on either side of each of the stamens; median glands lacking. *Pistil* not stipitate, linear to fusiform or narrowly ampulliform, straight, terete, glabrous; *ovules* irregularly biseriate, pendulous on slender linear funicles, ca. 5-12 per cell; *stigma* small, depressed-capitate, usually slightly wider than the style. *Fruit* bilocular, bivalved, dehiscent, not stipitate, ellipsoid to obovoid, usually slightly curved, terete or quadrangular; valves very convex, often almost keeled, with stout nerve and often a coarse reticulum of secondary veins, often reddish-purple, glabrous or rarely, with a few scattered branched hairs, proximally tapering and almost truncate, rarely, rounded, distally acute to rounded; *style* linear, slender, short; *stigma* depressed-capitate, as wide as or slightly wider than the style. *Septum* white, opaque, sometimes fenestrate, nerved, proximally horizontally wrinkled; *funicles* linear, slender, slightly curved, pendulous. *Seeds* irregularly biseriate, ca. 1-9 per cell, ovoid, plump, not winged; testa shiny, dark red-brown or brown, slightly darker at the hilum, conspicuously reticulate, when moistened, mucose, the mucus exuded as discrete hemispheres or short oblongs, often appearing non-radiate; *embryo* exactly notorrhizal, radicle straight, longer or shorter than the broadly linear to suborbicular cotyledons. *Plant* perennial with woody base, few- to many-stemmed, erect, usually low, densely pubescent to, and including, the sepals with sessile or shortly stipitate branched hairs; *stems* arising from a basal rosette of leaves, equal or, more commonly, with a leafless central stem and remotely leaved lateral stems. *Basal leaves* rosulate, narrowly obovate to narrowly spathulate, finely dentate or, not uncommonly, pinnatifid; usually on petioles as long as, or to 2½ times the blade, very rarely almost sessile on cuneate bases. *Cauline leaves* few, scattered, more or less obovate, entire or coarsely dentate, sessile on cuneate bases or very shortly petiolate. *Root* stout and woody. *Inflorescences* ebracteate, terminal on stems, initially dense, but elongating after anthesis; *buds* just before anthesis spherical to ovoid; *flowering pedicels* slender, usually somewhat spreading; *fruiting pedicels* rigid, spreading to horizontal or almost so, straight or slightly curved.

One species in alpine and subalpine parts of New South Wales and Victoria.

Drabastrum alpestre (FvM.)Schulz.

Relationships: *Drabastrum* stands quite isolated from the other genera in this group; if it is at all closely related to any it must be to *Harmsiodoxa*, the

absence of a median gland and the fusiform fruits suggesting the affinity with the latter genus. It differs very much from *Blennodia* and it is difficult to understand Mueller's originally describing *D. alpestre* as a species of *Blennodia*.

Although Mueller at one time included this species in *Capsella* and Bentham commented that it seemed to form a transition between *Capsella* and *Blennodia* (*sensu* Bentham), it differs from *Capsella* in not having a laterally compressed fruit. The valves are somewhat keeled but the width in the plane of the septum is not significantly less than that in the plane at right angles to that of the septum.

On some of Mueller's own collections of *D. alpestre* are annotations in his hand suggesting that it might be better placed in *Moricandia* or *Diplotaxis*. He chiefly based these suggestions on the fact that "the cotyledons are at times slightly bent inwards". The writer has seen no evidence of this in any of the collections, including Mueller's own, which have been examined. Furthermore, the cotyledons of both *Moricandia* and *Diplotaxis* are not "slightly bent"; these genera belong to the tribe *Brassiceae* and the cotyledons are conduplicate. *Drabastrum* also differs from these two genera in many other respects, particularly in the nature of the fruit.

1. **Drabastrum alpestre** (FvM)Schulz

(alpestre = of the alps; this species occurs chiefly in the Australian Alps).

Schulz, Pflrch. 86(1924)257.— *Blennodia alpestris* FvM., Trans. Phil. Soc. Vict. 1(1855)100 (*basionym*); FvM., Pl. Col. Vict. 1(1860-1862)40; Benth., Fl. Austral. 1(1863)77; Maiden & Betche, Cens. N.S.W. Pl. (1916)83.— *Capsella blennodina* FvM., Pl. Col. Vict. 1(1860-1862)42.— *Sisymbrium alpestre* (FvM.)FvM., Fragm. 7(1869)20.— *Erysimum capsellinum* FvM., Nat. Pl. Vict. 1(1879)35; FvM., Census 1(1882)5; FvM., Key Vict. Pl. 2(1885)7; FvM., Key Vict. Pl. 1(1887-1888)129; FvM., Sec. Census 1(1869) 9.— *Erysimum blennodinum* (FvM.)Kuntze, Revis. gen. pl. 2(1891)933

Blennodia alpestris, Capsella blennodina, Sisymbrium alpestre, Erysimum capsellinum and *Erysimum blennodinum* are nomenclatural synonyms of *Drabastrum alpestre*, these names being based on a single type.

Figures: Schulz, Pflrch. 86(1924)fig.15; Schulz, Pflfam. ed. 2 17b(1936) fig.406. — Figure 12.

Description: *Plant* an undershrub, sometimes with a woody underground rhizomatous part bearing at least two aerial stem systems; *stems* to 30 cm high but usually much less, exceptionally to ca. 40 cm, erect, rigid, terete or finely fluted, reddish-brown or reddish-purple; *root* often with woody laterals. *Basal leaves* ca. [1-] 2-4 [-6] cm long, to ca. 1½ cm wide, usually with 3-4 coarse teeth per side or a few small acute teeth, or pinnatifid or entire or sinuate, rounded to subacute, sparsely pubescent or subglabrous, petioles sometimes remotely toothed and short. *Cauline leaves* ca. 0·3-0·8 [-1·5] cm long, to ca. 1 cm wide, often with 1, less often with 2 broadly acute teeth per side, sometimes entire, usually subacute, subglabrous, sessile or shortly petiolate. *Inflorescences* to ca. 30-flowered, dense, after anthesis elongating and often very loose; *flowering pedicels* usually terete; *fruiting racemes* to 12 cm long, usually much less; *fruiting pedicels* to ca. 1½ cm. *Sepals* usually oblong to ovate, usually green, sometimes lavender, with a narrow hyaline margin; *lateral sepals* ca. 2·1-3·4 mm long, ca. 1·0-1·9 mm wide, average 2·9 x 1·5 mm, ratio length to width 1·8:1-2·1:1, often broadly obovate or oblong, usually subacute, not saccate; *median sepals* ca. 2·3-3·5 mm long, ca. 0·8-1·5 mm wide, average

2·0 x 1·2 mm, ratio length to width 2·1:1-2·0:1, oblong to obovate, rounded and sometimes cucullate, not saccate. *Petals* to about twice as long as the sepals, ca. 4·0-6·3 mm long, average 5·3 mm, clawed; blades ca. 2·5-4·5 mm long, ca. 2·0-3·7 mm wide, average 3·4 x 2·9 mm, ratio length to width 1·0:1-1·4:1, oblong to suborbicular, sometimes almost obcordate, rounded or truncate, tapering into a slender linear claw, the blade averaging 65 per cent of the total petal length; petals white or lavender, often only the claw and the lower part of the blade lavender, the veins usually purple. *Lateral stamens* ca. 2·0-2·8 mm, average 2·3 mm, filaments to 0·5 mm wide, linear or slightly expanded basally, white or lavender; *anthers* ca. 0·6-1·0 mm, average 0·8 mm, quadrate to oblong, yellow; *diagonal stamens* ca. 2·5-4·0 mm, average 3·1 mm, otherwise as lateral stamens; *anthers* ca. 0·5-1·0 mm, average 0·7 mm, as those of lateral stamens. *Pistil* ca. 2·3-3·2 mm long, linear to fusiform or ampulliform, straight, terete, glabrous; *style* linear, slender; *stigma* depressed-capitate; *nectaries* as generic description. *Fruiting pedicels* ca. 4-8 [-14] mm long, average 0·4-0·5 mm diameter, spreading to horizontal, densely pubescent. *Fruit* ca. 4-8 [-12] mm long, ca. 1·2-2·0 mm wide across the septum; epidermal cells of the septum more or less rectangular with straight or sinuate walls, becoming irregular in shape toward the edges; *style* ca. [0·4-] 0·7-0·8 [-1·1] x 0·1-0·3 mm; *stigma* depressed-capitate. *Seeds* ca. 0·8-1·2 mm long, ca. 0·6-0·8 mm wide, irregularly biseriate, usually 5-6 per cell, these mostly in the distal end of the fruit, ovoid, plump, not winged; mucus exuded to ca. ½ mm; *embryo* exactly notorrhizal, cotyledons longer or shorter than the radicle.

Type Locality: "In subalpine grassy places on the sources of the Murray and Snowy Rivers."

Holotypus: Sources of the Murray and Snowy Rivers; 4-5000 '; Feb. 1854 [*fide* Willis]; Mueller — MEL 776!

Isotypi: K!, BM!, MEL 777!

New South Wales: Cooma to Nimitibelle; Dec. 1896; *Maiden* — NSW 53577: Cooma; 2.11.1908; *Cambage 2104* — NSW 53578; Cooma; Sept. 1913, *Boorman* — NSW 53576, BM, MEL; Happy Jack's Plain, headwaters of the Happy Jack River ca. 15 miles S. of Kiandra; 18.1.1958; *Thompson* — NSW 53580; Murray River, N.S.Wales; ?; ? — MEL; Oldbury on Trap Mountain, upwards of 300 ft. altitude; ?; *Atkinson* — MEL;

Victoria: Suggan Buggan; Oct. 1939; *Hunter* — MEL; Himmonmujie near Omeo (junction of Livingstone Ck. and Mitta Mitta River), 27.9.1882; *Stirling* — MEL; Mitta Mitta; ?, ?; — K;

In all, 18 sheets were seen.

Distribution: This species occurs in the mountains south-west of Sydney and extends southward into Victoria. Most of the collections in New South Wales are from the area south of the Australian Capital Territory, but *D. alpestre* has been collected as far north as Bathurst, N.S.W. — *Map 10*.

Observations: Most of the available plants are less than 15 cm high, although the Suggan Buggan River specimen, an almost leafless stem bearing an infructescence, is 40 cm long. Apart from this, there is no noteworthy variation.

The most distinctive organs are the petals and the seeds. The petals are usually white with the veins purple, although sometimes the claw and the lower part of the blade, or the entire petal may be coloured. The seeds are plump and a deep reddish-brown in colour; the testa is coarsely reticulate and the mucus is exuded as discrete bodies, one from each infrareticular area. The reticulate outer layer of the testa is easily removed, exposing the finely reticulate inner layer. Within these is a thin whitish layer of endosperm.

Uses and Common Names: Neither uses nor common names have been recorded.

Relationships: These are discussed under *Drabastrum* (FvM)Schulz.

Pachymitus Schulz

(παχύς = thick, μίτος = thread; the fruiting pedicels of *P. cardaminoides* are stout)

Schulz, Pflrch. 86(1924)266; Schulz, Pflfam. ed. 2 17b(1936)639.

Description: *Calyx* open; *sepals* spreading or, less often, almost erect, usually green with a narrow hyaline margin and on the abaxial side sparsely pubescent with shortly stipitate branched hairs; *lateral sepals* usually more or less oblong, sometimes obovate or ovate, usually broader than the median, sometimes slightly saccate basally, distally rounded to subacute; *median sepals* usually oblong or narrowly obovate, proximally slightly tapering, not saccate, distally rounded or, less often, subacute, often slightly cucullate. *Petals* to twice as long as the sepals, probably always white, usually cuneate to narrowly obovate and without distinction into blade and claw, entire or sinuate, apically rounded or truncate, then often slightly retuse or emarginate, coarsely veined, sometimes clawed, then the blade oblong, often broadly so, or obovate to suborbicular, tapering gradually into a rather slender claw, the same length as the blade or slightly longer. *Stamens* 6, erect or somewhat spreading, filaments more or less linear or slightly dilated basally, white or pale green, the diagonal filaments often suddenly contracted and slightly curved distally; anthers oblong or almost quadrate, obtuse, yellow. *Lateral glands* each surrounding the base of a lateral stamen, usually quadrangular and open on the interior and the exterior, often the sides suppressed, the gland then appearing as four lobes of tissue, producing from each side of each gland a lateral appendage curving around the base of the adjacent diagonal stamen; *median glands*, if present, oblong or triangular pieces of tissue between the bases of the members of each pair of diagonal stamens. *Pistil* not stipitate, linear, more or less terete, glabrous. *ovules* subbiseriate to biseriate, oblong to elliptic, pendulous on short linear funicles, ca. 10-20 per cell; *style* usually obconical, sometimes linear; *stigma* fleshy, depressed-capitate, usually slightly wider than the style. *Fruit* bilocular, bivalved, dehiscent, not stipitate or on a very short stipe, linear, straight or slightly curved, terete or quadrangular; *valves* convex to keeled, with a prominent vein and a less distinct reticulum of veins more or less parallel to the longitudinal axis, often somewhat constricted between the seeds, shiny, often, when ripe, reddish-purple, subglabrous or generally pubescent with simple or sessile or very shortly stipitate bifurcate hairs, the hairs usually denser distally; valves proximally tapered and usually rounded, rarely truncate, but not uncommonly subacute, almost always flared or reflexed, distally tapering slightly and rounded to truncate, sometimes retuse or emarginate; *style* linear or slightly tapering distally or obconical; *stigma* small, depressed-capitate, as wide as or slightly wider than the style. *Septum* white, opaque, vein more or less distinct, slightly rugulose; funicles linear, short, straight or slightly curved, pendulous. *Seeds* uniseriate to subbiseriate, ca. 10-20 per cell, oblong to ovoid, plump; testa dull orange-brown, finely papillose, when moistened, mucose. The mucus exuded as discrete oblongs, each with a conical central core, thus having a finely radiate appearance. *Plant* probably annual, herbaceous, few- to many-stemmed, erect, pubescent, including the sepals, with simple or shortly stipitate tau-shaped or branched hairs; *stems* arising from a basal rosette of leaves, equal, or a leafless central stem with leafy lateral stems. *Basal leaves* rosulate, lobed or pinnatifid, often deeply dissected, or remotely dentate, petiolate. *Cauline leaves* scattered, ovate to elliptic, entire or coarsely dentate, sometimes deeply dissected, shortly petiolate or sessile on cuneate bases. *Root* a slender taproot. *Inflorescences* ebracteate, terminal on the stems, initially rather dense and therefore corymbose, but after anthesis elongating and racemose, sometimes quite

lax, sometimes stems much reduced so inflorescence appears basal; *buds* immediately before anthesis spherical to oblong; *flowering pedicels* slender, more or less erect; *fruiting pedicels* rigid, gradually expanded distally, usually spreading to horizontal, rarely almost erect.

One species in the Murray lands of South Australia and the adjacent parts of Victoria.

Pachymitus cardaminoides (FvM.)Schulz.

Treated as a synonym of *P. cardaminoides* is *P. lucae* (FvM.)Schulz.

Relationships: *Pachymitus* has several features in common with the other genera of the "Blennodia group", but is nevertheless quite distinct from them. It differs from *Harmsiodoxa* in having median glands, in having fruit which are linear rather than fusiform, and in the sort of mucus exuded by the testa. From *Scambopus* it differs most in the shape of the fruit and in the type of mucus. From the other genera of this group it is also set apart by characters of this sort.

Pachymitus cardaminoides (FvM.)Schulz

(cardaminoides = like *Cardamine* L., a genus in this family)

Schulz, Pflrch. 86(1924)266.— *Sisymbrium cardaminoides* FvM., Trans. Phil. Soc. Viet. 1(1855)34 (*basionym*); FvM., Hook. J. Bot. Kew Misc. 8 (1856)4; FvM., Pl. Col. Viet. 1(1860-1862)40; FvM., Fragm. 11(1878)27; FvM., Nat. Pl. Viet. 1(1879)32; Tate, Trans. Roy. Soc. S. Aust. 3(1890)51; FvM., Census 1(1882)5; FvM., Key Viet. Pl. 2(1885)7; Key Viet. Pl. 1 (1887-1888)131; Tate, Trans. Roy. Soc. S. Aust. 12(1889)71; FvM., Sec. Census 1(1889)9; Tate, Fl. S. Austral. (1890)17, 206; Tate, Trans. Roy. Soc. S. Aust. 22(1898)123.— *Blennodia cardaminoides* Benth., Fl. Austral. 1(1863)75; Tate, Trans. Roy. Soc. S. Aust. 22(1898)123, 124, 239; Bailey, Qld. Flora 1(1899)47; Maiden & Betche, Cens. N.S.W. Pl. (1916)83; Black, Trans. Roy. Soc. S. Aust. 41(1917)638; Black, Fl. S. Austral. (1924)247; Black, Fl. S. Austral. ed. 2(1948)376.— *Erysimum cardaminoides* (FvM.) FvM., Fragm. 11(1879)59 *in obs.*— *Erysimum lucae* FvM., Fragm. 11 (1879)59.— *Sisymbrium lucae* (FvM.)FvM., Census 1(1882)5; FvM., Key Viet. Pl. 1(1887-1888)131.— *Blennodia lucae* (FvM.)Maid. et Betche, Census N.S.W. Pl. (1916)83.— *Pachymitus lucae* (FvM.)Schulz, Pflrch. 86(1924)267.

Sisymbrium cardaminoides FvM., *Erysimum cardaminoides* (FvM.)FvM., and *Blennodia cardaminoides* Benth. are nomenclatural synonyms of *Pachymitus cardaminoides* (FvM.) Schulz, these names being based on a single type; *Sisymbrium lucae* (FvM.)FvM., *Blennodia lucae* (FvM.)Maid. et Betche and *Pachymitus lucae* (FvM.)Schulz are taxonomic synonyms of the preceding names, being based on the type of *Erysimum lucae* FvM. which is discussed below.

Figure: Figure 13.

NOTE: Although *Sisymbrium cardaminoides* was published by Mueller in 1855, Bentham (1863) cited "B. cardaminoides, F. Muell. Herb. (as a Sisymbrium)". The form of this citation suggests that Bentham may not have known of the valid publication of *S. cardaminoides*. Therefore one cannot necessarily interpret Bentham's species as being based on the type of *S. cardaminoides*.

To avoid confusion it seems advisable to choose the holotype of *S. cardaminoides* as lectotype of *B. cardaminoides*, making the two names nomenclatural synonyms. This is possible if Bentham saw the type of *S. cardaminoides* FvM.; this appears probable from Bentham's citation of specimens.

The type locality of *S. cardaminoides* is given as "On sandridges near the entrance of the Murray River". The only collection made by Mueller which agrees with this locality and is dated before the publication of *S. cardaminoides* is MEL 762. It was collected by Mueller on October 5, 1848, and the locality is given as "In campis arenosis inter Straitalbin

[Strathalbyn] et Wellington", this is only a few miles from where the Murray River enters the sea.

This collection was seen by Bentham for it bears his mark on the label and is probably the one referred to by him as coming from South Australia. Therefore, this collection which is the holotype of *S. cardaminoides* is chosen as the lectotype of *B. cardaminoides* Benth.; the two names thus becoming nomenclatural synonyms.

In 1924 Schulz published *P. cardaminoides* var. *dasycarpus*, distinguished from the typical variety, said to have glabrous fruit, by having the fruit sparsely pubescent. It does not seem justified to maintain this variety for on no plant seen by the writer have all the fruits been either glabrous or pubescent.

However, there seems to exist no collection annotated by Schulz as being the variety var. *dasycarpus*. Until such a collection is found it is necessary to maintain the name, although it has been used by no one after Schulz.

The name *Erysimum lucae* was published in 1879 by Mueller who based it on a collection made by Lucas near the junction of the Murray and Darling Rivers. The type collection made in September, 1878, by T. P. Lucas and labelled as being from Balranald (MEL 7701) is a rather robust specimen of *P. cardaminoides*. In K is a collection made by Lucas at Balranald which is probably an isotype.

Description: *Plant* herbaceous, pubescent; *stems* usually less than 30 cm, but in favourable conditions may be much taller, terete or finely fluted, usually pubescent, but occasionally subglabrous, then usually more densely pubescent on the adaxial side of the fruiting pedicels, usually reddish purple. *Basal leaves* exceptionally to 20 cm, but usually less than 12 cm, to 3 cm in width, usually less than 2 cm, pinnately lobed, lobes usually opposite, linear to deltate, usually acute, sometimes rounded, horizontal or runcinate, often with a small acute tooth in the distal sinus; terminal lobe deltate or suborbicular or elliptic, sometimes with one coarse subacute tooth per side, sometimes mucronate; leaves tapering into a long slender petiole. *Cauline leaves* to ca. 5 cm long and ca. 3 cm wide, entire or remotely dentate with small, more or less deltate, acute teeth or deeply pinnatisect with 1-3 linear to narrowly deltate, acute to subacute lobes per side, the terminal lobe acute to rounded. *Inflorescences* to ca. 40-flowered, usually ca. 25- to 30-flowered, usually dense; *flowering pedicels* ca. 0·2 mm diameter, slender, not much expanded, more or less erect; *buds* spherical to oblong. *Sepals* oblong to ovate or obovate, usually green with a narrow hyaline margin; *lateral sepals* ca. 2·1-3·0 mm long, ca. 0·8-1·3 mm wide, average 2·6 x 1·1 mm, ratio length to width 2·1:1-3·0:1, usually oblong, rounded to subacute, sometimes slightly saccate basally, *median sepals* ca. 2·3-3·3 mm long, ca. 0·8-1·1 mm wide, average 2·7 x 1·0 mm, ratio length to width 2·5:1-3·3:1, oblong or narrowly obovate, rounded or subacute, often slightly cucullate, not basally saccate. *Petals* about twice as long as the sepals, ca. 3·5-5·6 mm long, ca. 1·1-2·7 mm wide, average 4·9-1·8 mm, ratio length to width 2·0:1-3·7:1, cuneate to obovate, if clawed, ratio length to width of blade 1·0:1-1·2:1, blade averaging 53 per cent of the total petal length. *Lateral stamens* ca. 2·5-4·1 mm, average 3·4 mm, filaments linear or slightly expanded basally, white or pale green; *anthers* ca. 0·5-0·9 mm, average 0·7 mm, oblong to quadrate, obtuse, yellow; *diagonal stamens* ca. 2·0-3·2 mm, average 2·6 mm, filaments sometimes suddenly contracted distally, otherwise as those of the lateral stamens; anthers ca. 0·5-0·9 mm, average 0·7 mm, otherwise as those of the lateral stamens. *Pistil* ca. 3·5-5·5 mm, linear, straight, terete, glabrous; *style* linear to obconical; *stigma* fleshy, depressed-capitate. *Fruiting pedicels* ca. 4·5-16 mm, exceptionally to 40 mm (reduced basal raceme), diameter at proximal end ca. 0·3-0·7 mm, at the distal 0·4-1·1 mm, usually about twice to three times as wide at distal as at proximal end, usually spreading at an angle greater than 45 degrees, rarely at ca. 15 degrees, usually straight, sometimes slightly curved, occasionally somewhat reflexed and then ascendant. *Fruit* ca. 8-19 mm long, ca. 0·7-1·6 mm across the septum; valves convex to keeled, with a prominent vein,

proximally flared, pubescent with hairs to ca. 0·2 mm long; *style* to ca. 1·2 mm, sometimes very short, then ca. 0·3-0·4 mm; *stigma* depressed-capitate. *Seeds* ca. 0·8-1·0 x 0·5-0·6 mm, uniseriate to biseriate, ca. 10-20 per cell, oblong to ovoid, plump; mucus appearing finely radiate; *embryo* exactly notorrhizal, radicle slightly longer than the cotyledons.

Type Locality: "On sandridges near the entrance of the Murray River."

Lectotypus: In campis arenosis inter Straitalbin [Strathalbyn] et Wellington; 5.10.1848; Mueller — MEL 762!

South Australia:—Loveday; 20.7.1942; *Gayba* — W; Karoonda; 18.8.1924; *Cleland* — AD; Pt. Pomonda, Lake Alexandrina; 3.10.1880; *Tate* — AD;

New South Wales:—Lake Cargelligo; Sept. 1918; *Boorman* — NSW 53582; Brookong-Wagga Wagga; 1873; *Crouch* — MEL; Zara, via Hay; Aug. 1903; *Officer* — MEL; Lower Lachlan River; Sept. 1878; *Mueller* — MEL; Darling and Murray River junction; 1880; *Warburton* — NSW 53591.

Victoria:—3 miles N. of 65-mile post on Sturt Highway, along track to Berribee Tank; 2.9.1948; *Willis* — MEL; Jeparit; 20.9.1898; *Williamson 584* — MEL; Dimboola and Nhill; 12.11.1899; *St.Eloy D'Alton* 5 — MEL; Glenelg River; ?; Robertson — MEL 765, K;

Sixty-five sheets were seen.

Distribution: This species is known from Victoria, New South Wales and South Australia. In Victoria the collections extend from the far north-western corner to the lower Glenelg River in the south-west. In New South Wales it seems restricted to the south-western part of the State.

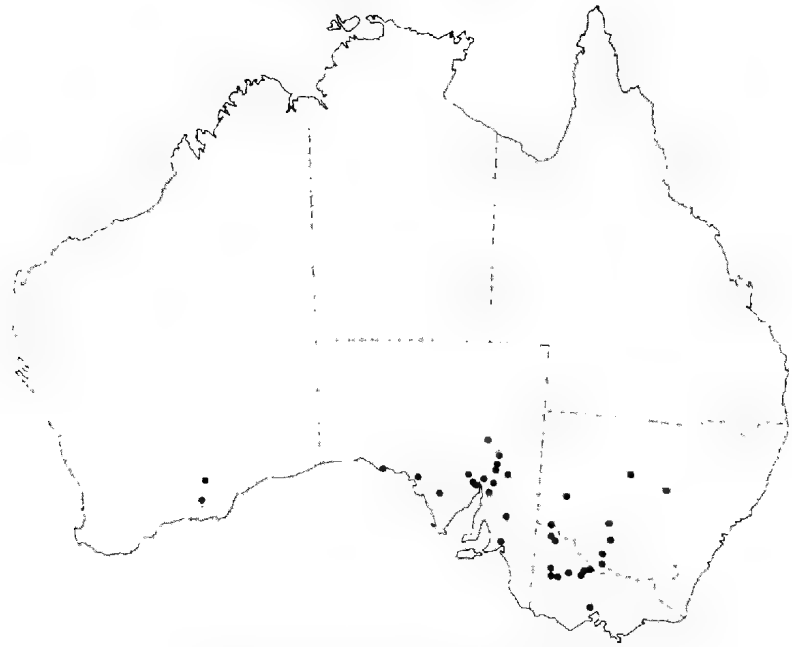
In South Australia *P. cardaminoides* seems to be most common along the Murray River, although there are collections from Ardrossan on the Yorke Peninsula, Mt. Remarkable, and Monalena. — *Map 10.*

Observations: The genus owes its name to the stout fruiting pedicels which are often of a greater diameter at the distal end than at the proximal end. However, this is not constant and there are many plants with pedicels which are quite linear.

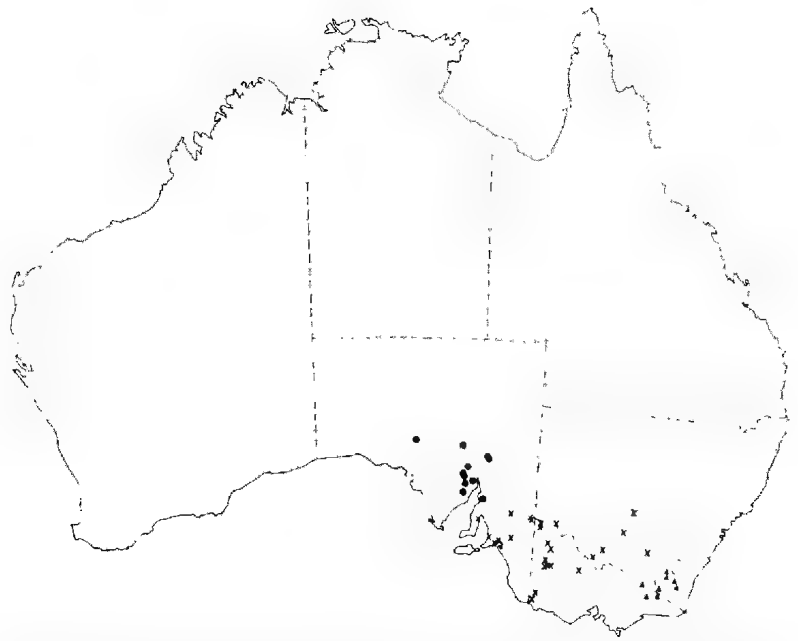
The pubescence presents no distinctive features, being made up of short branched hairs. The fruit valves are almost glabrous with a few hairs at the distal end. These may be simple, or sessile or very shortly stipitate bifurcate hairs to about ¼ mm long. The leaves bear sessile or shortly stipitate bifurcate to stellate hairs.

The cauline hairs are almost sessile and branched with the arms appressed to the stem, or stipitate and tau-shaped or bi- or trifurcate, or even more complexly branched. These stem hairs may be as much as ¾ mm long, but are usually shorter. Occasionally, even though the hairs on the stems are branched, there may be long simple hairs on the adaxial side of the fruiting pedicels and the secondary stems.

It has often been suggested that *Geococcus pusillus* Drumm. ex Harv. is a form of this species. The writer feels that this is not so; even when *P. cardaminoides* is stunted it does not approach the habit of *G. pusillus* which is essentially stemless. Also *G. pusillus* always has much smaller flowers, a differently shaped ovary (conical as opposed to linear for *P. cardaminoides*) and a smaller fruit. The fruit of *G. pusillus* is often somewhat misshapen as a result of its being forced into the earth, but even when one finds a plant with fruit which have not been buried, they are not of the size and shape of those of



Map 9. Distribution of *Geococcus pusillus* Drumm. ex. Harv.



Map 10. Distribution of *Scambopus curvipes* (FvM.)Schulz ●; Distribution of *Pachymitus cardaminoides* (FvM.)Schulz ×. Distribution of *Drabastrum alpestre* (FvM.)Schulz ▲.

P. cardaminoides.

Ecology and Biology: *P. cardaminoides* is an ephemeral and appears after winter rains. The most usual months for flowering are August through October.

It probably occurs most commonly on light sandy soils; among annotations with collections of this species are "sandridges" (*Reader s.n.*; 16.9.1903 – MEL), "open grassy sandhills" (*Willis s.n.*; 3.9.1948 — MEL), and "heaths on the Glenelg River" (*Robertson s.n.* — MEL 765, K).

Uses and Common Names: Neither uses nor common names have been recorded.

Relationships: These are discussed under *Pachymitus* Schulz.

Geococcus Drumm. ex Harv.

(γῆ = earth, κόκκος = fruit; the fruits are buried in the ground)

Drummond ex Harvey, Hook. J. Bot. Kew Misc. 7(1855)52; Walp. Ann. 4(1857)208; Benth. & Hook., Gen. Pl. 1(1862)83; Benth., Fl. Austral. 1 (1863)79; Prantl, Pflfam. 3(2)(1890)205; Tate, Fl. S. Austral. (1890)205; Tate, Fl. S. Austral. (1890)17, 206; Bailey, Qld. Flora (1899)49; Hayek. Beih. Bot. Centralbl. 27(1911)324; Maiden & Betche, Cens. N.S.W. Pl. (1916)84; Black, Fl. S. Austral. (1924)248; Schulz, Pflrch. 86(1924)258; Schulz, Pflfam. ed. 2 17b(1936)637; Black, Fl. S. Austral. ed.2 (1948)376.

Description: *Calyx* open; *sepals* usually spreading, sometimes almost erect, usually pale green with a narrow hyaline margin, sparsely pubescent on the adaxial side with sessile to shortly stipitate irregularly branched hairs; *lateral sepals* ovate to deltate, usually slightly wider than the median sepals, not saccate basally, distally acute to subacute; *median sepals* oblong to obovate, not saccate basally, distally subacute to rounded. *Petals* often about the same length as the sepals, but sometimes slightly longer or shorter, white or cream-coloured, clawless or the blade tapering gradually into a more or less linear claw, obovate to ovate, subacute to rounded, rather coarsely veined. *Stamens* 6, erect or slightly spreading, filaments more or less clavate, usually expanded proximally, white or pale green; *anthers* oblong to square, rounded to truncate, yellow. *Lateral glands* indistinct, appearing as oblong or semicircular pieces of tissue, each subtended by a petal; *median glands* apparently obsolete. *Pistil* not stipitate, more or less conical, terete or slightly compressed dorso-ventrally, glabrous or very sparsely pubescent with very shortly stipitate irregularly branched hairs; *ovules* subbiseriate to biseriate, ca. 4-20 per cell, oblong, pendulous on slender linear funicles; *style* very short and obconical or obsolete; *stigma* small, depressed-capitate, as wide as the style if present. *Fruit* bilocular, bivalved, dehiscent, not stipitate, usually linear, sometimes nearly square in outline, almost always latisept, rarely terete, brown, glabrous or pubescent with sessile or shortly stipitate bifurcate to irregularly branched hairs; *valves* usually almost flat, rarely convex, usually with a distinct nerve and, when mature, a reticulum of secondary veins, proximally rounded to truncate, reflexed or flared so that from the dorso-ventral aspect the fruit is sagittate, distally rounded to subacute; *style* short and linear or obconical or obsolete; *stigma* depressed-capitate, as wide as the style. *Septum* pale-yellow or cream-coloured, opaque, with nerve, smooth, coriaceous; *funicles* linear to narrowly triangular. *Seeds* subbiseriate to biseriate, ca. 2-12 per cell, oblong to obovate, plump, not winged; testa light orange-brown with darker pigmentation at the hilum, papillose, when

moistened slightly mucose, the mucus exuded as very small oblong to hemispherical bodies, one from each papilla; *embryo* notorrhizal, the cotyledons usually shorter than the radicle and shortly stipitate. *Plant* annual, herbaceous, short-stemmed, prostrate, pubescent, including the sepals, with sessile or shortly stipitate branched hairs; main stem almost always much reduced so terminal inflorescence appears basal; lateral stems usually very short and often much thickened, prostrate, bearing very crowded leaves. *Basal leaves* rosulate, erect or spreading, more or less linear, pinnatisect, petiolate. *Cauline leaves* crowded on stems, otherwise as the basal leaves. *Root* a slender taproot. *Inflorescences* ebracteate, terminal on stems, initially dense and elongating only slightly after anthesis; *buds* just before anthesis obovoid to spherical; *flowering pedicels* slender, spreading or descendent; *fruiting pedicels* usually stout, almost always descendent and burying fruit in ground, sometimes horizontal and spreading.

One species in semi-arid parts of Western Australia, South Australia, New South Wales and Victoria.

Geococcus pusillus Drumm. ex Harv.

Treated as a taxonomic synonym of *G. pusillus* is *G. fiedleri* Scheuermann, Feddes Rep. 47(1939)262.

Relationships: *Geococcus* appears to be closely related to no other Australian genus. If it is related to any, it is to *Pachymitus* which it resembles somewhat in nature of the fruit.

Geococcus pusillus Drumm. ex Harv.

(*pusillus* = very small; the plant is a small prostrate annual)

Drumm. ex Harv., Hook. J. Bot., Kew Misc. 7(1855)52; FvM., Pl. Col. Vict. 1(1860-1862)223; Benth. Fl. Austral. 1(1863)80; FvM., Fragm. 7(1869)19; Fragm. 10(1876)33; Fragm. 11(1878)6; FvM., Nat. Pl. Vict. 1(1879)36; Tate, Trans. Roy. Soc. S. Aust. 3(1880)5, 90; Tepper, Trans. Roy. Soc. S. Aust. 3(1880)175, 177; FvM., Trans. Roy. Soc. S. Aust. 3(1880)172; FvM., Key Vict. Pl. 1(1887-1888)131; FvM., Sec. Census 1(1889)5; Tate, Fl. S. Austral. (1890)15, 17, 206; Tate, Trans. Roy. Soc. S. Aust. 22(1898)122, 123, 124; Bailey, Qld. Flora 1(1899)49; Reader, Vict. Nat. 21(1905)177; Ewart, Proc. Roy. Soc. Vict. 20(1907)79, 80; Maiden & Betche, Cens. N.S. Wales Pl. (1916)84; Black, Trans. Roy. Soc. S. Aust. 41(1917)45; Black, Fl. S. Austral. (1924)248; Schulz, Pflrch. 86(1824)256; Black, Trans. Roy. Soc. S. Aust. 58(1934)177; Black, Trans. Roy. Soc. S. Aust. 64(1940)373 in obs.; Fl. S. Austral. ed. 2 (1948)376; Troll, Die Infloresz. (1964)497.

Geococcus fiedleri Scheuermann, Feddes Rep. 47(1939)262; Black, Trans. Roy. Soc. S. Aust. 64(1940)372; Fl. S. Austral. ed. 2 (1948)377 (*pro syn.*). *G. fiedleri* Scheuermann is a taxonomic synonym of *G. pusillus* Drumm. ex Harv., being based on a different type.

Figures: Ewart, Proc. Roy. Soc. Vict. new ser. 20(1907) tt. 10A, 11; Black, Trans. Roy. Soc. S. Aust. 64(1940)fig.2; Troll, Die Infloresz. (1964)fig.472, 473; — Figure 14.

Description: *Plant* herbaceous prostrate annual, pubescent, including sepals and, sometimes, the pistil, with sessile or shortly stipitate branched hairs; stems few to many, very short and thickened, horizontal and spreading, often densely leaved, very often producing secondary stems. *Basal leaves* to 20 cm, but usually less than 10 cm. to 2 cm in width, usually more or less oblong and tapering proximally, pinnatifid, to ca. 15 lobes per side, these linear to deltate, opposite or alternate, usually rounded to subacute, sometimes acute, often bearing a

secondary lobe or tooth in the sinus on the distal side of the lobe; terminal lobe orbicular to obovate, usually with one secondary tooth or lobe on a side, leaves always tapering into a slender petiole. *Cauline leaves* very crowded, otherwise as basal leaves. *Inflorescences* few-flowered, initially dense, elongating very little after anthesis, that of the main stem always appearing basal as a result of suppression of the stem; *flowering pedicels* to ca. 2 cm long, slender, spreading or descendent; *buds* before anthesis obovoid to spherical. *Sepals* pale green, with a narrow hyaline margin, on abaxial side often sparsely pubescent, *lateral sepals* ca. 0·5-1·1 mm long, ca. 0·3-0·8 mm wide, average ratio length to width 1·5:1, more or less ovate to deltate, apically acute to subacute, basally not saccate; *median sepals* ca. 0·6-1·2 mm long, ca. 0·4-0·7 mm wide, average ratio length to width 1·6:1, oblong to obovate, subacute to rounded, basally not saccate. *Petals* ca. 0·6-1·0 mm long, ca. 0·2-0·4 mm wide, with obovate to ovate blade gradually tapering into a more or less linear claw, or clawless, the entire petal then obovate to ovate, rather coarsely veined, margin entire, apically rounded, white or cream-coloured. *Lateral stamens* ca. 0·7 mm, filaments expanded basally, white or pale green; *anthers* ca. 0·4 mm, oblong to square, rounded to truncate, yellow; *diagonal stamens* ca. 0·8 mm, filaments as those of the lateral stamens; anthers ca. 0·3 mm, as those of the lateral stamens. *Pistil* ca. 0·6-1·0 mm, not stipitate, more or less conical, terete or slightly compressed dorso-ventrally; *style* very short (ca. 0·2 mm) or obsolete; *stigma* depressed-capitate, about same width as the style. *Fruiting pedicels* to ca. 4 cm long, but length variable on a single plant, horizontal to descendent, often burying fruit in the ground. *Fruit* ca. 0·3-1·5 cm long, ca. 1·0-1·5 mm across the septum, epidermal cells of the septum usually oblong to fusiform, not stipitate, usually linear, almost always latisept, rarely terete; valves usually almost flat, usually with a distinct nerve and, when mature, a reticulum of secondary veins, proximally flared, *style* ca. 0·1-1·0 mm long, often obsolete; *stigma* depressed-capitate. *Seeds* ca. 1·1-1·3 x 0·7-0·8 mm, usually biseriate, usually 2-12 per cell, sometimes only 2 or 3 as result of abortion of many ovules, oblong to obovate, plump, mucus narrow; *embryo* exactly notorrhizal, cotyledons sometimes shortly stipitate, about same length as the radicle.

TYPE LOCALITY: "Hab. Northern Districts; among a cluster of Boordis' (a species of kangaroo-rat) holes on the limestone part of Conolly's station . . . J.D. Western Australia."

HOLOTYPUS: Between Moore and Murchison Rivers, W. Australia; 1853; J. Drummond — K!

ISOTYPUS (?): West Australia; 1854; Drummond 114 — BM!

SOUTH AUSTRALIA:—10 miles S. Blinman; 31.8.1963; *Shaw 198* — AD: Koonamore; 14.8.1956; *Eichler 12451* — K, L, P, TI, UC, B, GH, AD: Booleroo Centre; 30.7.1939; *Brooks* — ADW: Yorke Peninsula; ?; *Tepper* — MEL: 7 miles east of Iron Knob; 25.8.1928; *Cleland* — AD: Fowler's Bay; ?; *Richards* — MEL:

VICTORIA:—Terrick Pine Forest, E.S.E. of Pyramid Hill; 3.9.1945; *Willis* — MEL; Wilchipool; Nov. 1903; *Dyer* — MEL: Calder Highway at Hattah, N.W. Victoria; 6.9.1941; *Willis* — MEL: Dimboola; ?; *St. Eloy D'Alton* — MEL: You Yangs; 1.9.1910; *Pitcher* — MEL: head of Bullocky Springs Gully, Lower Glenelg River, far S.W. Victoria (11 miles S.W. Winnap); 31.10.1948; *Willis* — MEL:

NEW SOUTH WALES:—Trangie, 20.9.1951; *Biddlescombe* — CANB: Pulpalla near Cobar; Sept. 1884; *Josephson* — MEL: Yara, Wanganella: Sept. 1915; *Officer* — NSW 53335: Tolarno Stn., S. of Menindie, N.S.W.; 23.7.1960; *Burbidge 6639* — NSW 53537, CANB:

WESTERN AUSTRALIA:—Fraser Range; 9.8.1951; *Royce 3514* — PERTH, CANB: between Esperance Bay and Fraser's Range; 1876; *Dempster* — MEL:

In all, seventy sheets were seen.

Distribution: Occurs in semi-arid parts of Western Australia, South Australia, New South Wales and Victoria. In South Australia the greater part of

the collections are from the Flinders Ranges, but there are scattered ones from the Lake Frome basin, the Murray mallee area, and from the Yorke and Eyre Peninsulas.

The New South Wales collections are generally from the south-western part of the State. Those from Victoria are also from the western part of the State, where it has been collected near the coast, as well as from near Melbourne.

It is probably more widely distributed than these collections indicate, but it is inconspicuous and has probably been overlooked by collectors. — *Map* 9.

Observations: This species has often been said to be a form of *Pachymitus cardaminoides*, an idea which originated with Bentham (1863) who wrote:

> "This curious little plant, unknown from any other locality [other than that of the type] may possibly prove to be a condition of some species having usually dimorphous flowers, in which the more perfect ones are not developed. If so, it may very likely be a *Blennodia*, of some species of which it has the radical leaves."

This suggestion was elaborated upon by several subsequent authors who were reluctant to believe that *G. pusillus* could be a distinct species. Tepper (1880) wrote, "Geococcus pusillus is remarkable for being strongly suspected of having two widely different growth forms. The principal one pushes its fruit *below* the soil while perfecting and ripening; the other, generally a weaker plant, has an upright stalk, and resembles very much a *Cardamine*." This "other form" to which Tepper refers is certainly *P. cardaminoides*.

The writer finds it difficult to understand how it was possible to consider these plants to be forms of one species; they differ sharply in habit, fruit and flowers, and there appear to be no intermediate forms between them.

Mueller (1888) was the first to definitely state that *G. pusillus* was a synonym of *P. cardaminoides*. Under *Sisymbrium cardaminoides* he described the "Geococcus-state" of this species in the following manner:

> "Or in a stemless state of this plant [fruits] very short, rather thick and turgid, singly forming on their stalks, and during maturation burying themselves in the ground; the flowers of this state very minute."

The following year in his Second Census Mueller wrote, "Geococcus pusillus = Sisymbrium cardaminoides". In a note on *G. pusillus* for the Victorian Naturalist (1892), Mueller was apparently less sure of the identity of these two, remarking only that *G. pusillus* might be a stemless state of a plant normally developing otherwise, and saying, "Its foliage is not unlike the radical leaves of *Sisymbrium cardaminoides*, with which it is moreover not rarely associated."

Tate (1898) seemed to be somewhat uncertain of the status of *G. pusillus*. He praised "Bentham's perspicuity in regard to *G. pusillus*, which subsequent investigations have proved him to be correct". However, he continued to remark that in the light of the fact that *Blennodia* (*sensu* Bentham) was represented in Western Australia by only three species, *B. trisectum*, *B. richardsii* and *B. brevipes*, it was inconsistent to regard Drummond's plant as belonging to *B. cardaminoides*, pointing out that the "normal state" of this latter species was not known to occur in the area where Drummond's type was collected.

Tate mentioned three collections of "so-called" *G. pusillus* from South Australia which he had seen, one from Ardrossan gathered by Tepper, one from Mt. Remarkable made by Johncock, and one from Cradock. He admitted that although the foliage of these plants was like that of *P. cardaminoides*, the other plant parts did not agree with those of this species.

He went on to say, "These marked differences must be related to the habit of dimorphism . . . .", and remarked that he had a collection of *P. cardaminoides* from Cooper's Creek which showed single-flowered stalks horizontal among the radical leaves and suggested that this plant was showing a "slight passage towards a fully developed 'geococcusstate'." However, this collection from Cooper's Creek is *Arabidella eremigena* which often does have a few apparently basal flowers representing the inflorescence of a supressed stem. The writer has seen two of the South Australian collections mentioned by Tate, those of Tepper and of Johncock (both AD), and these are ordinary *G. pusillus*.

Tate concluded that there exist "two very dissimilar states of *Blennodia cardaminoides*, which have in common virtually only leaf form".

F. M. Reader (1905) published in the Victorian Naturalist some notes on *Geococcus pusillus* in which he clearly pointed out that this species is distinct from *P. cardaminoides*. He had observed the growth of *G. pusillus* and noted that in favourable conditions it may produce short ascendent stems. However, he was firm in maintaining it as a distinct species and *Geococcus* as a distinct genus.

The last mention of this problem seems to have been made by Ewart (1907) who suggested that "Geococcus pusillus might possibly be a form of Sisymbrium cardaminoides, produced as the result of continual grazing or cropping". However, Ewart concluded that *G. pusillus* should be maintained until such time as cultural experiments prove it to be only a form of another species.

The writer has several times observed this species in the field and has found no evidence that it is a form of *P. cardaminoides* or of any other species. It shows a considerable variation in fruit shape and in the lobing of the leaves, but it never approaches *P. cardaminoides* in habit or in nature of the fruit. It is true that the leaves may resemble the radical leaves of *P. cardaminoides*, but this is the only point of resemblance between them.

Furthermore, the writer has seen *G. pusillus* growing luxuriantly in areas where *P. cardaminoides* has never been found. There are records of the occurrence of the latter species in the northern part of South Australia, but these are all based on collections of *A. eremigena* which has often been confused with *P. cardaminoides*.

It must be emphatically stated that *Geococcus* is a genus quite distinct from *Pachymitus* and there is no evidence that *G. pusillus* ever approaches *P. cardaminoides*. It consistently has a different habit, much smaller flowers, fruits which are smaller and differently shaped, and slightly different nectaries.

Variation: The most conspicuous variation is in the lobing of the leaves and in fruit shape. Usually there are no more than about nine lobes on a side although there do occur plants bearing leaves with as many as fifteen. The lobes may be alternate or opposite or mixed – often the lobes at the distal end of the leaf are opposite while those toward the proximal end are much smaller and alternate.

Generally the leaves are less than 10 cm long, but they may reach 20 cm. A plant collected by the writer in the Flinders Ranges (*Shaw 202* – AD) was 48 cm in diameter when living.

The fruit is linear but may vary in ratio of length to width. Usually the fruit is 3 or 4 times as long as wide, but some fruits are almost square. Not uncommonly the fruit is twisted or bent and this is especially true if the plant grew in a hard soil. The valves are flared at the proximal end and in this respect do resemble those of *P. cardaminoides*.

In most cases the fruiting pedicels turn sharply downward so that the fruits are buried, but it is not unusual to see pedicels which are horizontal. The writer has seen only one plant with an aerial fruiting raceme (*Willis s.n.* — MEL); the raceme is about 2½ cm long and bears fruit which do not differ noticeably from those on the same plant which were buried.

The cause of the apparent geotropism of the fruiting pedicels is not known. It seems to be not a genuine geotropism for the writer suspended upside down several plants which when brought from the field already had the pedicels turned sharply downward. During a period of almost a month in suspension the pedicels grew almost 2 cm in length, but did not change from the direction in which they had originally been growing. It seems also to be not a case of negative phototropism for the pedicels of the suspended plants were growing toward the source of light.

Ecology and Biology: The writer has collected *G. pusillus* both on sand and on heavier soils.

Usually the plants grow closely together and under favourable conditions may cover an area of several square feet. Among the annotations are "sandy creekbed" (*Shaw 13* — AD), "very common on rocky hillside" (*Shaw 198* — AD), "clay soil" (*Biddescombe s.n.* — CANB) and "partially cleared area with low herbage on heavy soil" (*Burbidge s.n.* — NSW 53537).

Uses and Common Names: No uses have been recorded for *G. pusillus*. *Sutton and St. John s.n.* (MEL) bears the annotation "Earth cress" but this seems to be not a commonly used name.

NOTE: *G. fiedleri* Scheuermann (1939) was described as having leaves with 12-14 lobes per side and fruit 1 cm long which are lanceolate and acute. J. M. Black (1940) compared this description with the South Australian collections of *Geococcus* and decided that they were all *G. fiedleri*. However, in the second edition of his Flora (1948) Black included them in *G. pusillus* and cited *G. fiedleri* as a synonym.

The writer has seen the holotype of *G. fiedleri* (B); the collection is quite ordinary *G. pusillus*, perhaps larger than some, but this may be attributable to its having grown under favourable conditions. Thus *G. fiedleri* Scheuermann must be treated as a taxonomic synonym of *G. pusillus* Drumm. ex Harv.

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(Bold type indicates newly described taxa or new combinations; italics indicate synonyms. Numbers refer to the page on which the systematic treatment of a taxon begins or to that on which a name is cited in synonymy with another.)

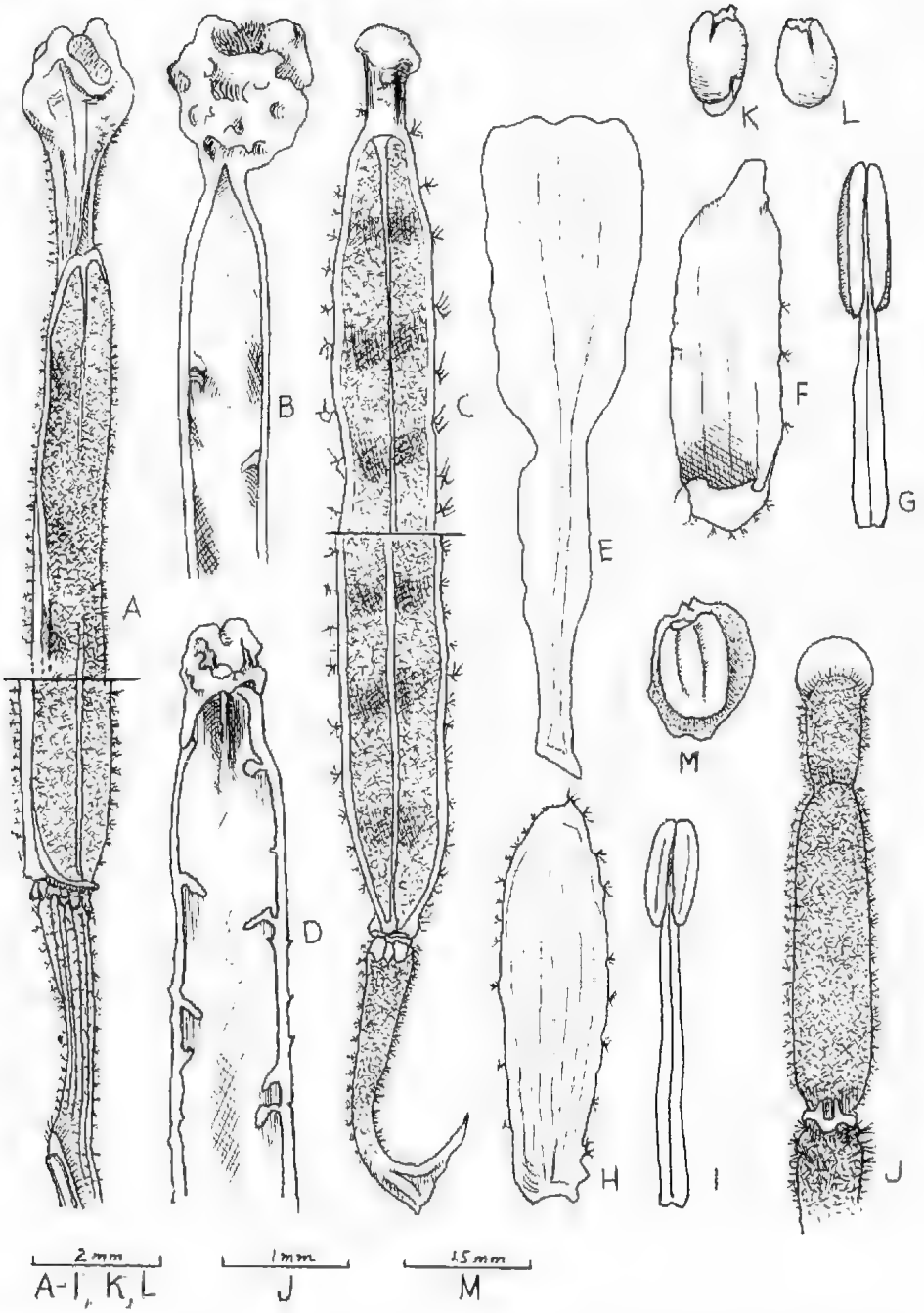

Fig. 1. *Blennodia canescens* R.Br. A, fruit; B, distal end of fruit; E, petal; F, lateral sepal; G, lateral stamen; H, median sepal; I, diagonal stamen; J, pistil; K, seed; L, seed—(A ex Ising 1192 — AD; B ex Cleland s.n. — AD; others ex Hill 134 — AD). *Blennodia pterosperma* (Black)Black. C, fruit; D, distal end of fruit; M, seed—(Shaw 185 — AD).

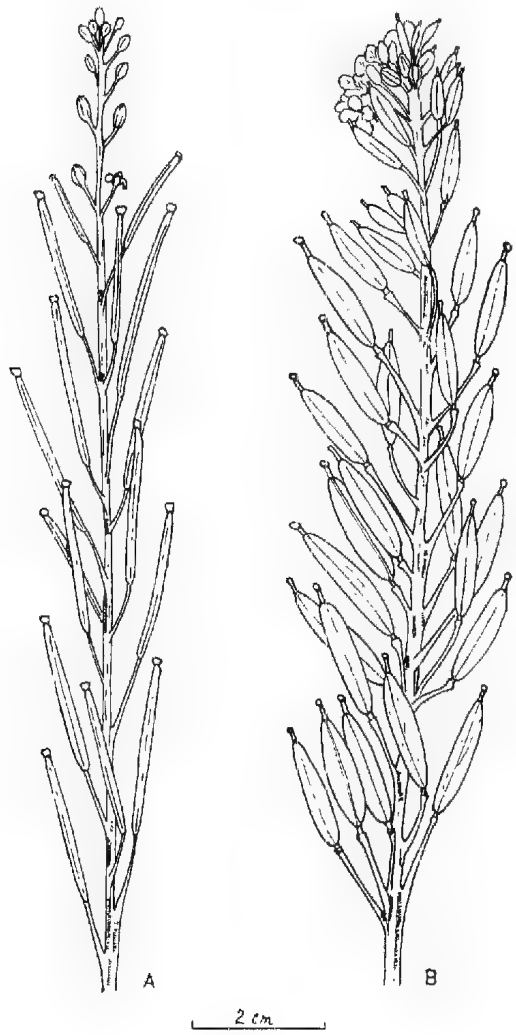

Fig. 2. A, *Arabidella trisecta* (FvM.)Schulz– fruiting raceme (Sharrad 1328 — AD); B, *Arabidella glaucescens* Shaw — fruiting raceme (Shaw 231 — AD).

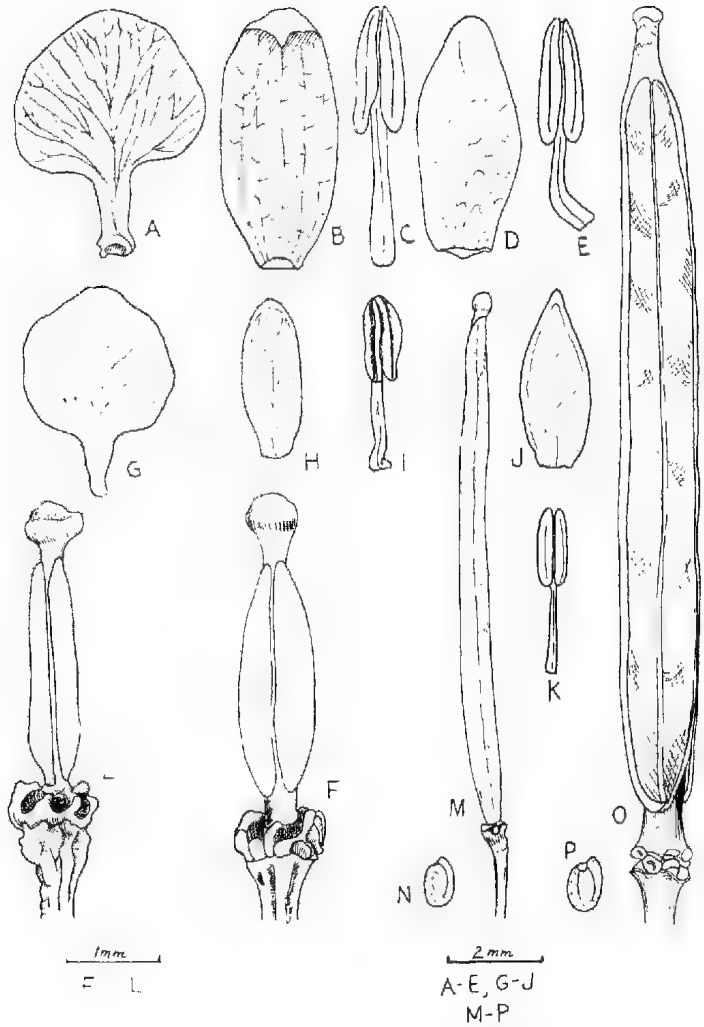

Fig. 3. *Arabidella glaucescens* Shaw. A, petal; B, median sepal; C, diagonal stamen; D, lateral sepal; E, lateral stamen; F, pistil; O, fruit; P, seed — (Shaw 231 — AD) . *Arabidella trisecta* (FvM.) Schulz. G, petal; H, median sepal; I, diagonal stamen; J, lateral sepal; K, lateral stamen; L, pistil; M, fruit; N, seed — (Sharrad 1328 — AD).

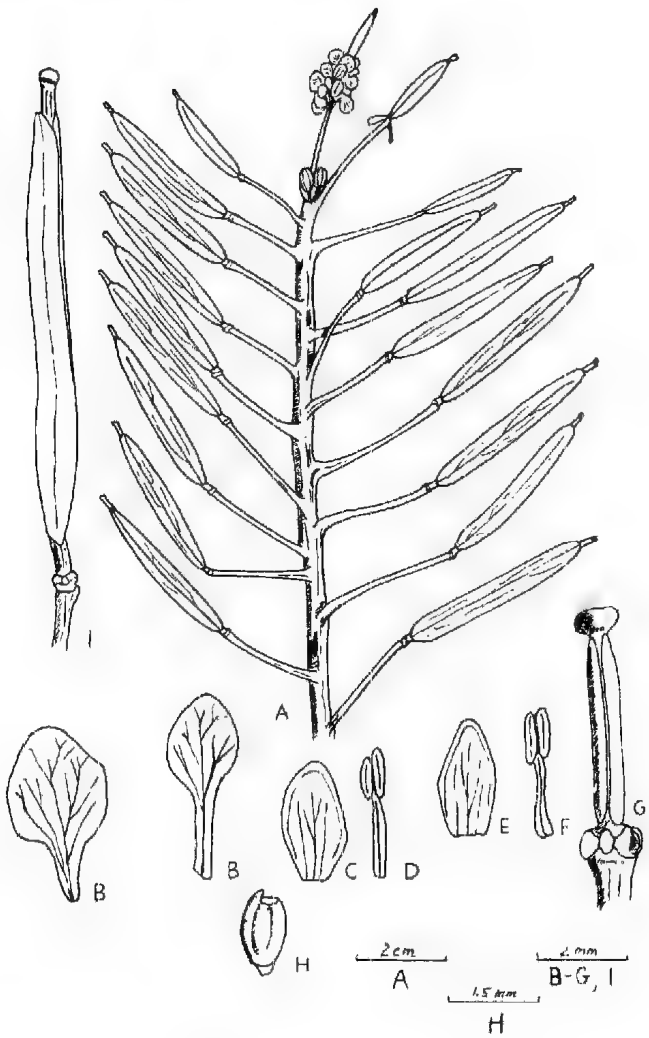

Fig. 4. *Arabidella filifolia* (FvM.)Shaw. A, fruiting raceme; B, petal; C, median stamen; D, diagonal stamen; E, lateral sepal; F, lateral stamen; G, pistil; H, seed; I, fruit — Sharrad 1331 — AD).

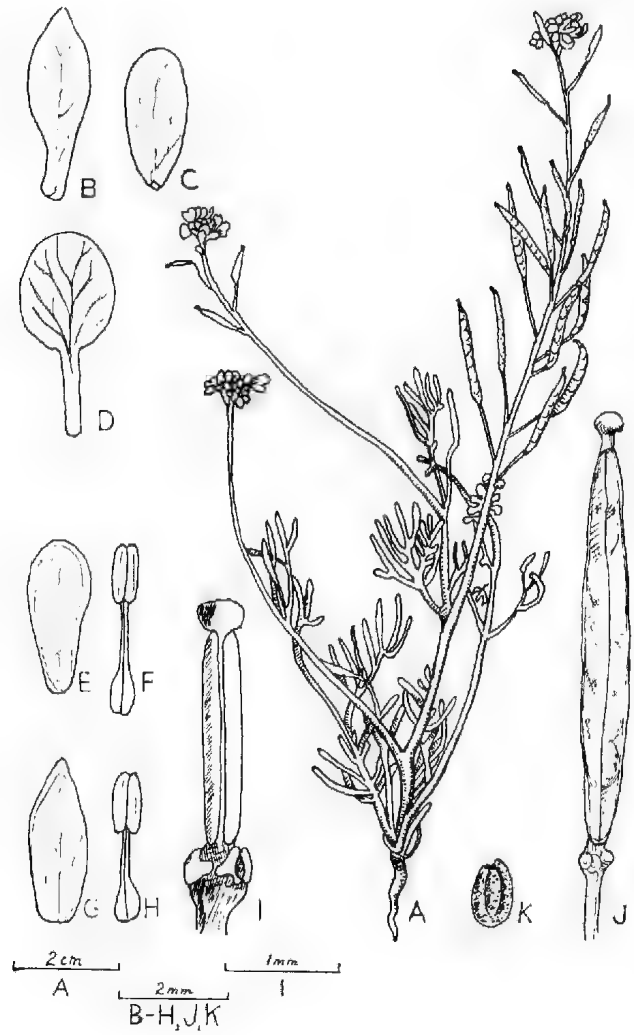

Fig. 5. *Arabidella nasturtium* (FvM.)Shaw. A, habit; B, C, D, petals; E, median sepal; F, diagonal stamen; G, lateral sepal; H, lateral stamen; I, pistil; J, fruit; K, seed — (B, C, ex Constable s.n. — NT; all others ex Shaw 46 — AD).

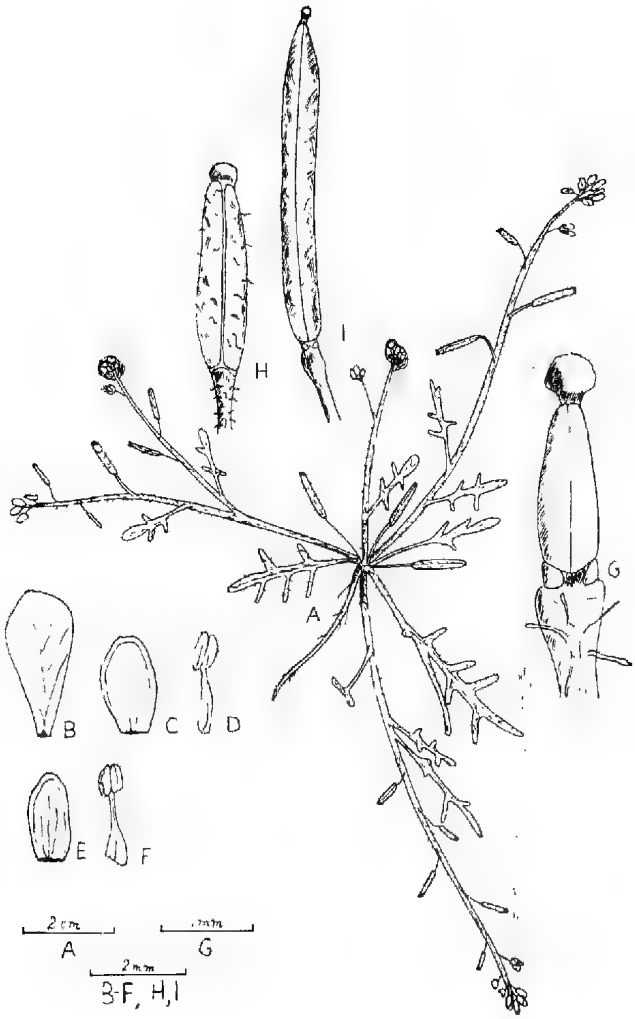

Fig. 6. *Arabidella eremigena* (FvM.)Shaw. A, habit; B, petal; C, median sepal; D, diagonal stamen; E, lateral sepal; F, lateral stamen; G, pistil; H, I, fruit — (I ex Everist 3529 — BRI; others ex MacGillivray s.n. — ADW).

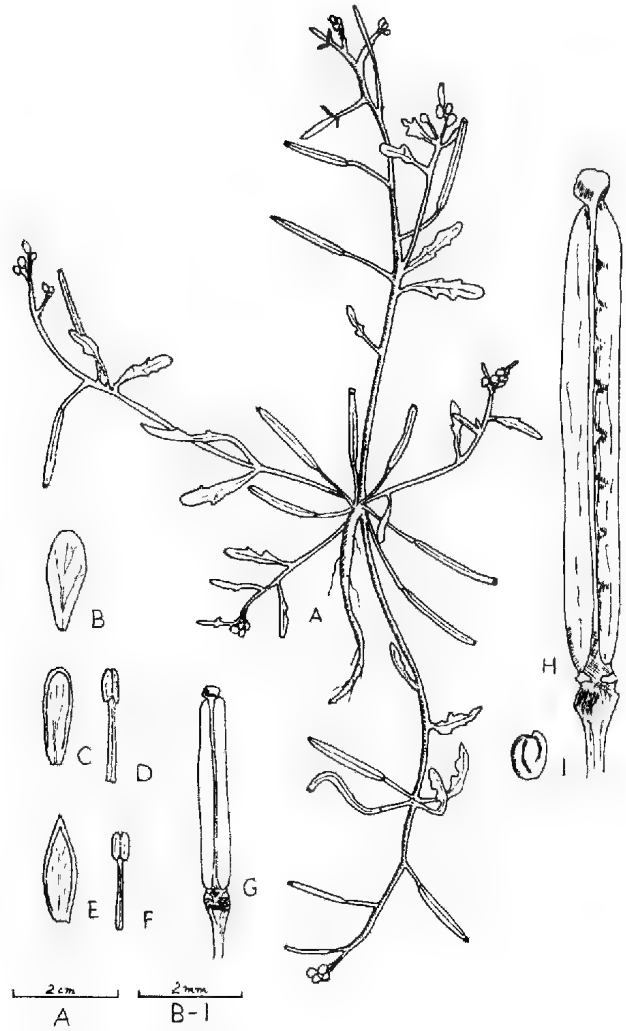

Fig. 7. *Arabidella procumbens* (Tate)Shaw. A, habit; B, petal; C, median sepal; D, diagonal stamen; E, lateral sepal; F, lateral stamen; G, pistil; H, fruit; I, seed — (Ising s.n. — AD).

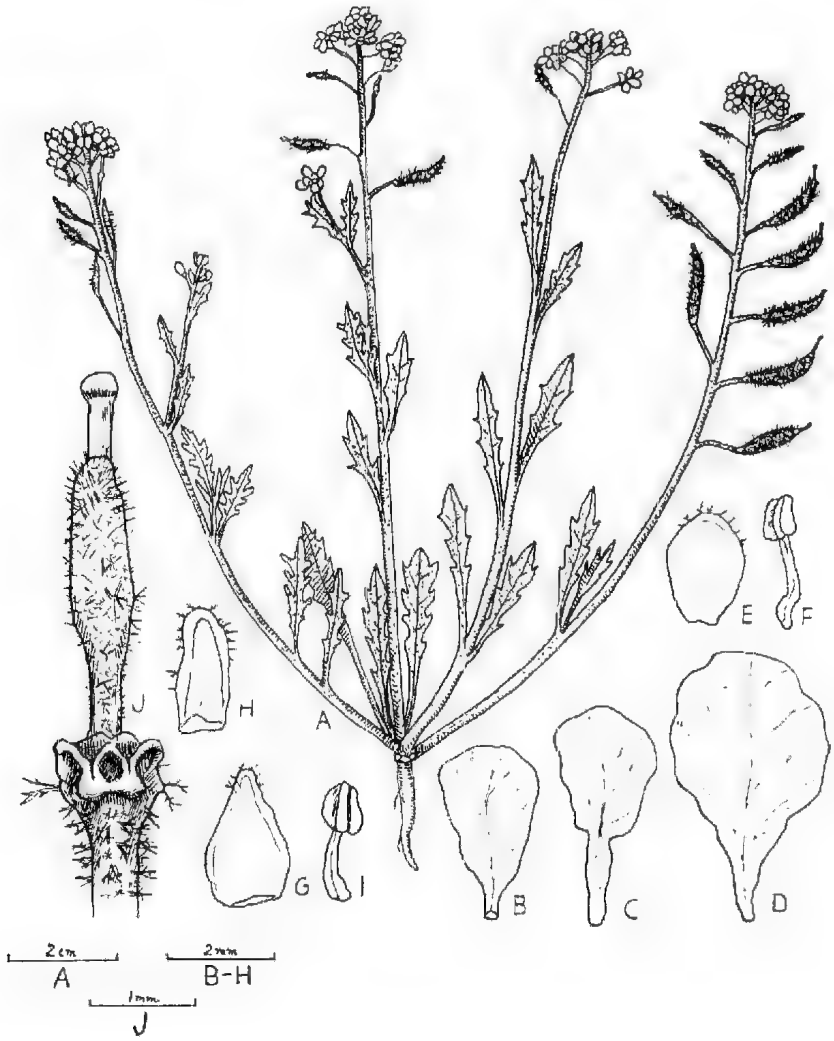

Fig. 8. *Harmsiodoxa blennodioides* (FvM.)Schulz. A, habit; B, C, D, petals; E, median sepal; F, diagonal stamen; G, H, lateral sepal; I, lateral stamen; J, pistil — (Williams s.n. — AD).

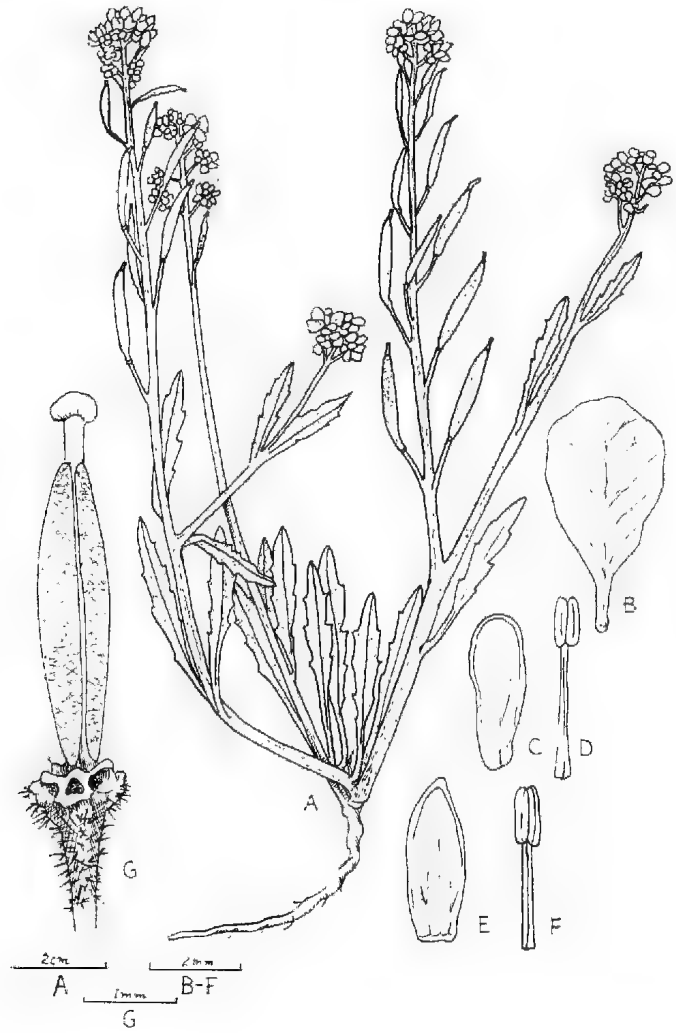

Fig. 9. *Harmsiodoxa puberula* Shaw. A, habit; B, petal; C, median sepal; D, diagonal stamen; E, lateral sepal; F, lateral stamen; G, pistil — (Lothian 606 — AD).

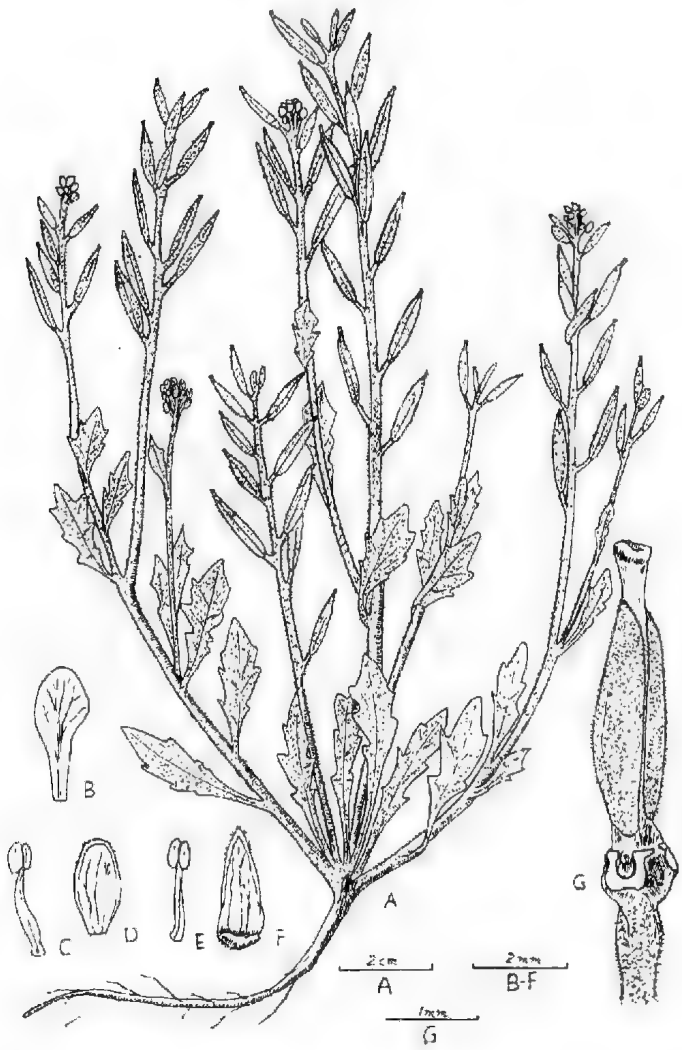

Fig. 10. *Harmsiodoxa brevipes* (FvM.)Schulz. A, habit; B, petal; C, diagonal stamen; D, median sepal; E, lateral stamen; F, lateral sepal; G, pistil — (Lothian 1348 — AD).

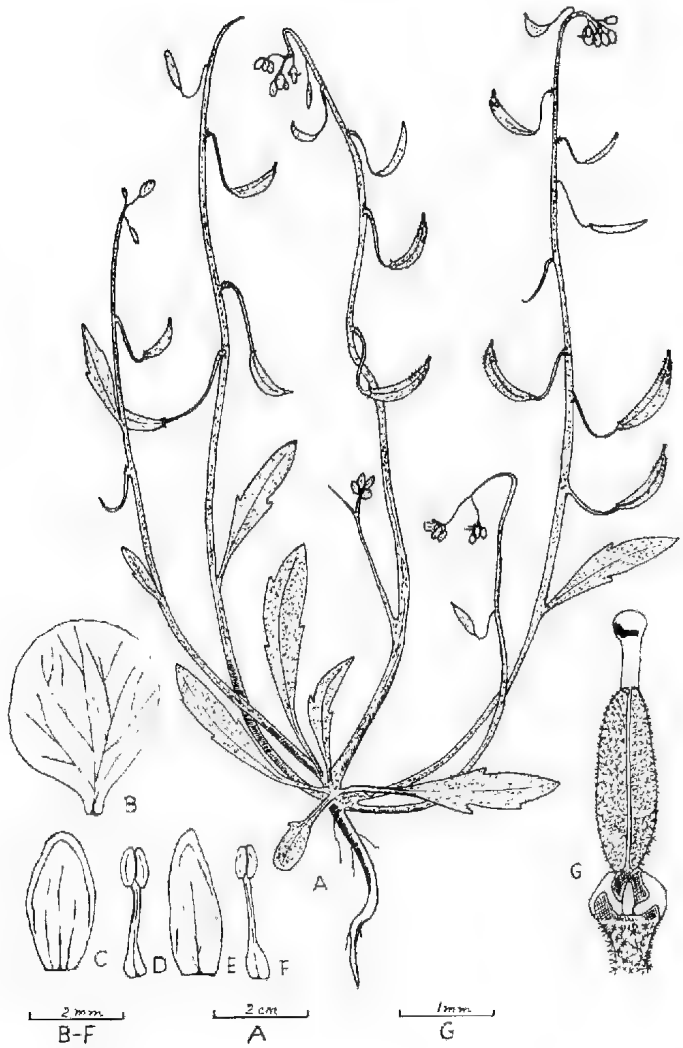

Fig. 11. *Scambopus curvipes* (FvM.)Schulz. A, habit; B, petal; C, median sepal; D, diagonal stamen; E, lateral sepal; F, lateral stamen; G, pistil — (Murray 131 — AD).

Fig. 12. *Drabastrum alpestre* (FvM.)Schulz. A, habit; B, petal; C, median sepal; D, diagonal stamen; E, lateral sepal; F, lateral stamen; G, pistil; H, fruit; I, seed — (Thompson s.n. — NSW 53580).

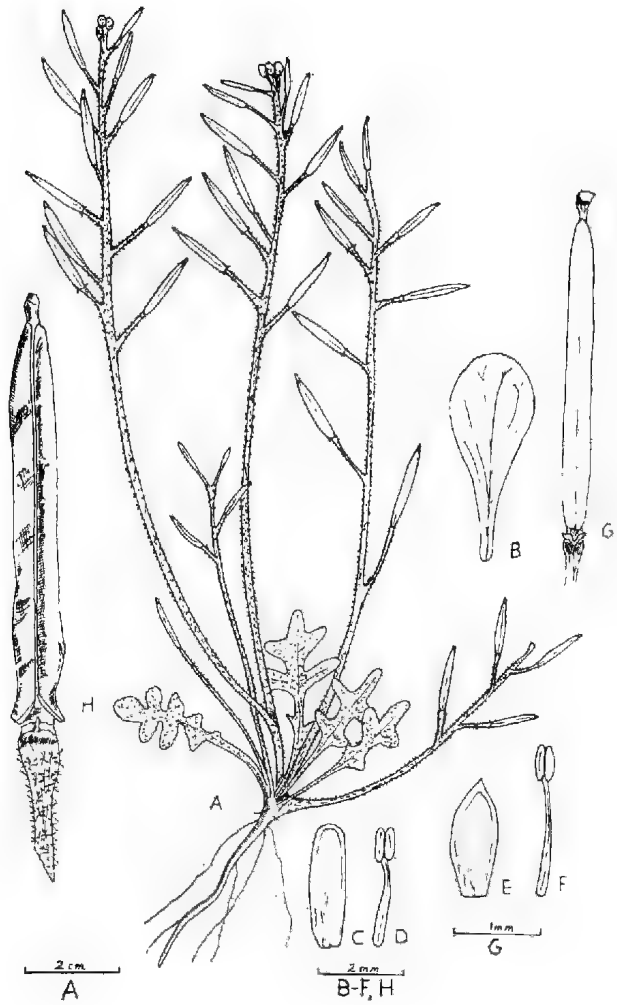

Fig. 13. *Pachymitus cardaminoides* (FvM.)Schulz. A, habit; B, petal; C, median sepal; D, diagonal stamen; E, lateral sepal; F, lateral stamen; G, pistil; H, fruit — (D'Alton 5 — MEL).

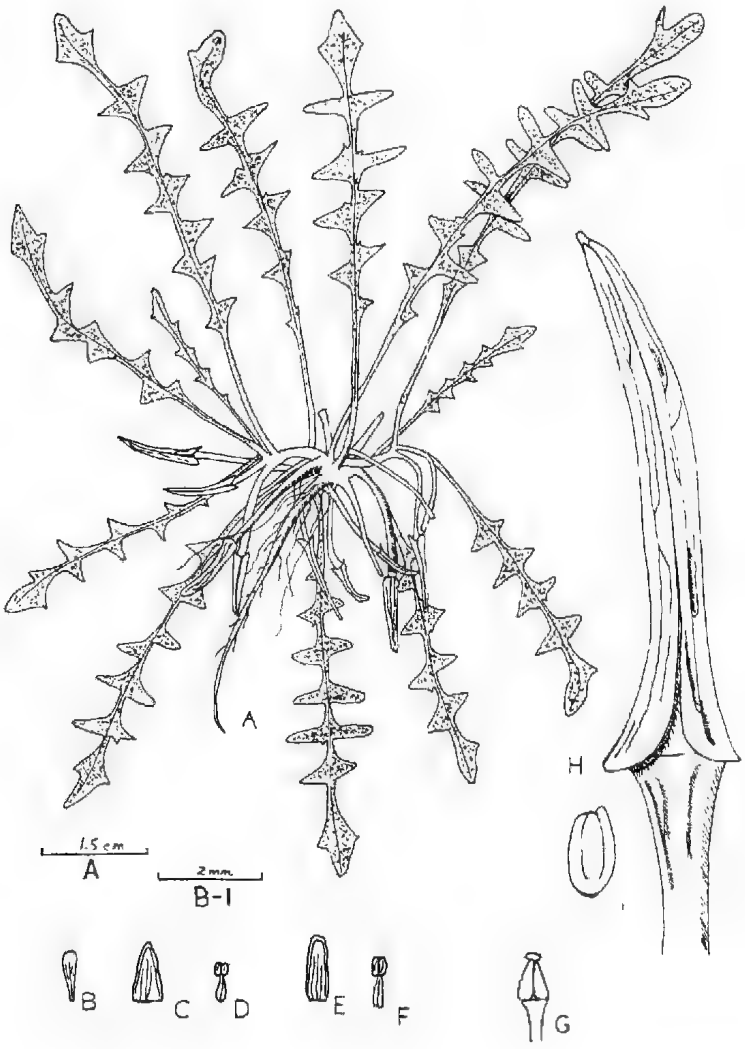

Fig. 14. *Geococcus pusillus* Drumm. ex Harv. A, habit; B, petal; C, lateral sepal; D, lateral stamen; E, median sepal; F, diagonal stamen; G, pistil; H, fruit; I, seed — (Eichler 12451 — AD).

AN HYPOTHESIS ON THE ORIGIN OF THUCHOLITE MINERALIZATION AT THE WALLAROO-MOONTA MINING FIELD, SOUTH AUSTRALIA

BY I. A. MUMME

Summary

Geological investigations during the period of active mining operations at this once-famous mining field showed that the distribution of Thucholite mineralization was predominantly associated with veins cross cutting the main bornite lodes (Jack, 1917). More recent geophysical investigations of the mine dumps showed the existence of a low but significant level of radioactivity which is above the normal level for the non-mineralized surrounding bedrock'. This fact strongly suggests the presence of minute quantities of a uranium mineral generally dispersed throughout the lode systems (Mumme, 1954; Woodrnansee, 1957).

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by I. A. Mumme*

[Read 12 August 1965]

Geological investigations during the period of active mining operations at this once-famous mining field showed that the distribution of Thucholite mineralization was predominantly associated with veins cross cutting the main hornite lodes (Jack, 1917). More recent geophysical investigations of the mine dumps showed the existence of a low but significant level of radioactivity which is above the normal level for the non-mineralized surrounding bedrock. This fact strongly suggests the presence of minute quantities of a uranium mineral generally dispersed throughout the lode systems (Mumme, 1954; Woodmansee, 1957).

The occurrences of thucholite mineralization at the Wallaroo-Moonta mining field in association with the copper-bearing lodes demonstrate a common origin for the minerals. Also, the occurrences of thucholite are found in a geological environment in which one would expect to encounter pitchblende as, for example, at the Hillside copper mine near Ardrossan.

Petrological examinations showed that the thucholite consists of hydrocarbons of variable composition which contain minute quantities of an intensely radioactive mineral which is probably uraninite or pitchblende. Mineragraphic investigations of this mineral suggest that the inclusions of the uranium mineral have in part been precipitated from hydrocarbon solutions (Davidson and Bowie, 1951). These facts suggest that paragenesis of the thucholite was as follows. Initially it is believed that enrichment of uranium and probably thorium occurred in a magma during progressive cooling and differentiation processes. Due to their low concentrations in the granite melt they would not form separate minerals at an early stage during the crystallization of the magma.

During processes of enrichment of thorium and uranium at the pegmatitic stage in the presence of high concentrations of mineralizing solutions, including water vapour, it is believed that the uranium was not taken up in accessory minerals, such as zircon, titanite or allanite, but separation occurred according to a process postulated by Larsen and Phlair (1954). By this process, separation of uranium is attributed to conversion of uranium to the hexavalent state during a late magmatic stage, whereby the soluble uranium compounds are readily carried off into the pegmatitic fluids and the thorium left behind to crystallize out as an accessory mineral in the parent magma.

The formation of the thucholite would appear to be due to polymerization of gases or liquid hydrocarbons by the action of alpha or beta activity due to the disintegration of uranium and its daughter products as suggested by Verandsky (1935).

On this basis the geological evidence strongly suggests that the natural organic gases, such as CH_4,C_2H_2, CO and CO_2, were of pegmatitic origin. Such an hypothesis is reasonable as natural occurrences of methane, etc., have been

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recorded in the deeper workings in the Witwatersrand (Young, 1917) and elsewhere in deep mines in geologically old rock formations and remote from petroliferous formations.

After the deposition of the primary uranium mineral during the hydrothermal stage of mineralization, it is believed that there was an introduction of gases and liquid hydrocarbons; the latter partially dissolving the primary uranium mineral. The solution of uranium in organic liquids particularly in the presence of mineral acids is well known (Davidson and Bowie, 1951).

Following solution of the uranium in the polymerized hydrocarbon, it is believed that cooling of the organic liquid occurred precipitating the uranium as minute inclusions and further polymerization due to bombardment by alpha and beta particles over a long period of geological time firadually hardened the hydrocarbon complex developing the characteristics of thucholite.

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SOME MEDUSAE (MAINLY SCYPHOMEDUSAE) FROM AUSTRALIAN COASTAL WATERS

BY P. L. KRAMP

Summary

A review is made of 19 species of Australian jellyfish, classified as follows: Order Coronatae, family Linuchidae. 1 species; Order Semaeostomeae, family Pelagiidae, 1 species, family Cyaneidae, 2 species, family Ulmaridae, 1 species; Order Rhizostomeae, family Cassiopeidae, 1 species, family Cepheidae, 2 species, family Mastigiidae, *3* species, family Lychnorhizidae, 1 species, family Catostylidae, 2 species; Order Leptomedusae, family Eirenidae, *3* species; Order Limnomedusae, family Olindiadidae, 2 species. The collection had been submitted from the South Australian Museum, rind was a representative collection of macroscopic material submitted in recent years, omitting only the order Cubomedusae; in many cases medical hail prompted the collection of the material.

In the material studied were seven species which have not previously been recorded from Australian waters, including one new species of the family Olindiadidae, *Gonionemus hamatus* sp. nov., from St. Vincent Gulf, South Australia. Morphologic and taxonomic reviews are made where necessary, and zoogeographic distribution is discussed. Field observations are recorded, including one of an apparent association between the rhizostome *Pseudorhiza haeckeli* Haacke, 1884, and the leptomedusan *Eirene menoni* Kramp, 1953, several of the latter being observed sheltering under the exumbrella of the rhizostome, in St. Vincent Gulf, South Australia.

SOME MEDUSAE (MAINLY SCYPHOMEDUSAE) FROM AUSTRALIAN COASTAL WATERS

by P. L. Kramp
(Zoological Museum, Copenhagen)

(*Communicated by R. V. Southcott*)

[Read 14 October 1965]

SUMMARY

A review is made of 19 species of Australian jellyfish, classified as follows: Order Coronatae, family Linuchidae, 1 species; Order Semaeostomeae, family Pelagiidae, 1 species, family Cyaneidae, 2 species, family Ulmaridae, 1 species; Order Rhizostomeae, family Cassiopeidae, 1 species, family Cepheidae, 2 species, family Mastigiidae, 3 species, family Lychnorhizidae, 1 species, family Catostylidae, 2 species; Order Leptomedusae, family Eirenidae, 3 species; Order Limnomedusae, family Olindiadidae, 2 species. The collection had been submitted from the South Australian Museum, and was a representative collection of macroscopic material submitted in recent years, omitting only the order Cubomedusae; in many cases medical problems had prompted the collection of the material.

In the material studied were seven species which have not previously been recorded from Australian waters, including one new species of the family Olindiadidae, *Coniomenus hamatus* sp. nov., from St. Vincent Gulf, South Australia. Morphologic and taxonomic reviews are made where necessary, and zoogeographic distribution is discussed. Field observations are recorded, including one of an apparent association between the rhizostome *Pseudorhiza haeckeli* Haacke, 1884, and the leptomedusan *Eirene menoni* Kramp, 1953, several of the latter being observed sheltering under the exumbrella of the rhizostome, in St. Vincent Gulf, South Australia.

INTRODUCTION

An interesting collection of Australian medusae was sent to me by Dr. R. V. Southcott, South Australian Museum, Adelaide. It has been a great pleasure to work up this collection, which contains 19 species, seven of which were not previously recorded from Australian waters. The majority of the species are Scyphomedusae (12 species), but there are also five species of Hydromedusae, one of which is a new species of the family Olindiadidae.

Previous Australian records are quoted for each species. Only the most important other references are given; full references up to 1910 may be obtained from A. G. Mayer (1910), and for the following period, up to 1959 or 1960, in P. L. Kramp (1961b).

Some species require morphological and systematic discussion, but most of the Rhizostomeae have been thoroughly treated in numerous papers by the late Dr. G. Stiasny of Leiden.

The localities, where the species were collected, are mentioned in succession from west to east on the southern coasts, northwards along the eastern coasts, and westwards along the coasts from Cape York towards Darwin in the Northern Territory. It is a great pity that we know so very little about the fauna off the coasts of the western half part of the Australian continent. Valuable zoogeographic results might be obtained by comparing the occurrence of

jellyfish and other pelagic animals in all Australian waters with the currents and other hydrographical conditions. It is remarkable that among the species represented in the present collection, nine have an entirely tropical distribution in other regions (*Linuche unguiculata*, *Cyanea buitendijki*, *Cassiopea ndrosia*, *Cephea octostyla*, *Netrostoma coeruleseens*, *Mastigias papua*, *Mastigias ocellatus*, *Acromitoides purpurus*, and the hydromedusa *Helgicirrha danaensis*), and in Australia these species are restricted to the coasts of Queensland or the Northern Territory. *Phyllorhiza punctata*, which, outside Australia, is known with certainty only from the Gulf of Siam, was taken in several Queensland localities, but some specimens were also found near Fremantle in Western Australia; it was originally described from Port Jackson, New South Wales, by Lendenfeld (1884). Only two species of Rhizostomeae, *Pseudorhiza haeckeli* and *Catostylus mosaicus*, are widely distributed and very common in Australian waters where both seem to be endemic. The three species of Semaeostomeae, *Pelagia noctiluca*, *Cyanea capillata* and *Aurelia aurita*, which have an almost world-wide distribution, seem to occur in all Australian waters. The distribution of the three Hydromedusae, *Eirene menoni*, *Phialopsis diegensis* and *Olindias singularis*, is dealt with in the text below.

The collection was accompanied by a detailed list of the localities, in several cases with interesting additional remarks on the colours of the living specimens and their local occurrence and behaviour: I have taken great pleasure in quoting from these remarks, forwarded by Dr. Southcott.

SYSTEMATIC ACCOUNT

CORONATAE

Linuche unguiculata (Swartz, 1788)

Linuche unguiculata Eschscholtz, 1829, p. 91.
Linergey aquila + *draco* Haeckel, 1880, p. 496.

Previous Australian Records: Mayer, 1915, pp. 160, 174. Torres Strait.

Material Examined: Thursday Island, December, 1961, 9 specimens.

The specimens are 9-11 mm high and 12-15 mm wide.

Pacific specimens of *Linuche* have frequently been referred to a distinct species or variety, *aquila* Haeckel, differing in the arrangement of the wart-like protuberances on the subumbrella, well illustrated by Mayer (1910, p. 560, text fig. 356), the warts being arranged in three circles in the Atlantic form, *unguiculata* but in only two in the Pacific *L. aquila*. The validity of this distinction has been doubted by several authors, and I can state that the difference is quite accidental and independent of geographical occurrence.

In the present North Australian specimens the arrangement of the subumbrellar warts is decidedly of the *aquila*-type, but with one exception it is the same in the numerous specimens deposited in the Zoological Museum of Copenhagen and derived from several localities, not merely in tropical Indo-Pacific waters, but also in samples from the western Atlantic. On the other hand, in a sample collected south-east of New Caledonia, thus in a Pacific locality ("Dana" Stn. 3620), three of the specimens (about 24 mm wide) show an approximation towards the *unguiculata*-type. The two outer circles of warts are as in all the other specimens examined by me, but an additional wart is present in the inner (proximal) part of each of the interradial spaces between

the gonads. It is minute in two of the specimens, fairly large in the third one and in all a well-developed wart is also attached to each of the gonads, as generally seen in the *aquila*-type.

I may add that the type specimens of *Linerges draco* Haeckel from the South China Sea, which are in our collection at Copenhagen, are in no way distinguishable from *Linuche unguiculata*, their subumbrellar warts being of the *aquila*-type. The same applies to cotypes of two other Haeckelian forms, *Linerges petasus* and *Liniscus sandalopterus*. We may thus safely state that the genus Linuche consists of only one species, *Linuche unguiculata* (Swartz).

Geographical Distribution: Tropical parts of the Indian and Pacific Oceans and the western Atlantic.

SEMAEOSTOMEAE

Pelagia noctiluca (Forskål)

Synonyms: *P. panopyra* Péron and Lesueur, *phosphora* Haeckel a.o.

Previous Australian Records: Haeckel, 1880, p. 509. Lendenfeld, 1887, p. 18. Mayer, 1915, p. 178, Queensland. Stiasny, 1931b, p. 31, Port Jackson. Dakin and Colefax, 1933, p. 198, New South Wales. Ranson, 1945, p. 315, Port Jackson. Krump, 1961a, p. 204, Green Island, Great Barrier Reef. Pope, 1963, p. 193. Thomas, 1963, p. 208, east Australia.

Material Examined: Off Sydney, New South Wales, at surface, 28.i.60, coll. J. Racek, 1 specimen, diam. ca. 6 cm. Circular Quay, Port Jackson, New South Wales, 12.v.60, coll. Maritime Services Board of New South Wales, 2 specimens, diam. 4·5-5 cm. Turu Cay, North Queensland, mid-November, 1961, coll. V. Wells, 1 specimen, diam. 3 cm.

Several species of *Pelagia* have been described, but it is now generally agreed that most of them are identical with the widely distributed *P. noctiluca* (Forskål). Specimens from Pacific and Malayan waters have frequently been referred to a separate species, *P. panopyra* (Péron and Lesueur), but studies by Stiasny (1934, 1935 and 1940) and Bigelow (1938) have rendered it highly probable that this form cannot be distinguished from *P. noctiluca*. In a recent paper, F. S. Russell (1964) has found that specimens from the Californian coast, formerly named *P. noctiluca* var. *panopyra* (Fox and Millott, 1954), belong to a separate and valid species, *P. colorata* Russell. Russell also maintains the Indo-Pacific species *P. flaveola* Eschscholtz as a valid species, in agreement with Stiasny (1935), who had examined numerous specimens of this species from Amboina; the species had formerly been observed on only a few occasions. It was well described and figured by Agassiz and Mayer (1902) as *P. tahitiana*. It is mainly characterized by very large and prominent, pointed nematocyst warts on the exumbrella, but it is also emphasized by the authors that the gonads are unusually large even in small specimens.

The specimens from the two localities near Sydney, mentioned above, are typical *P. noctiluca*; their nematocyst warts are numerous, small, round-oval, transversely wrinkled, and evenly distributed over the exumbrella. The specimen from northern Queensland is also *P. noctiluca*, but calls for some comment. Although it is only 30 mm wide, its gonads are remarkably voluminous, protruding very far downwards below the subumbrella, but the eggs are small and immature; the mouth tube is short and broad, the lips indistinct; the exumbrella warts are numerous and they are very small, of exactly the same appearance as in the larger specimens from Sydney. There is no reason, therefore, to presume that it might belong to *P. flaveola*. Moreover, the shape of

the umbrella is rather flattened, not highly vaulted as described in *P. flaveola*, and the colour is light pink, not yellow.

Geographical Distribution: Oceanic in the upper strata of all warm and temperate seas.

Cyanea capillata (L.)

Previous Australian Records: ? *Cyanea rosea* Quoy and Gaimard, 1824, p. 570, pl. 85, figs. 1, 2. Great Barrier Reef. *Cyanea annaskala* v. Lendenfeld, 1882-1887. Port Philip, Victoria; Port Jackson, New South Wales. *Cyanea muellerianthe* Haacke, 1886, p. 605, pl. 36, figs. 1-4. St. Vincent Gulf, South Australia. *Cyanea muellerianthe* Stiasny, 1922, p. 521, south of Cape Howe, Victoria. *Cyanea annaskala* Pope, 1949, p. 14. Sydney. *Cyanea capillata* Pope, 1953b, p. 111. New South Wales. *Cyanea* sp. Barnes, 1960, p. 996. North Australia.

Since the genus *Cyanea* was thoroughly revised by Stiasny and van der Maaden (1943), it is possible to determine the Australian species of this genus with certainty. With one exception (*C. bultendijki*, see below) all the specimens in the present collection belong to the widely distributed *C. capillata*, being very similar to specimens from northern Europe. We can safely state that *C. annaskala* von Lendenfeld and *C. muellerianthe* Haacke are synonyms of *C. capillata*. In all the present specimens the terminal branches of the lappet canals are numerous, densely set and with no or very few anastomoses. *C. rosea* Quoy and Gaimard, which was described from the Great Barrier Reef, is an altogether doubtful species; it may have been *C. capillata* and, at any rate, this was the first record of a *Cyanea* in Australian waters.

Material Examined:

(1) Coffin Bay, South Australia, 10.iii.1960. Coll. S. A. Shepherd. 2 specimens, diam. 7·5-10·5 cm.

(2) Port Lincoln, South Australia, about one mile out to sea, at surface. 27.iii.1961. Coll. Miss R. M. Arnott-Rogers. 4 specimens, diam 12, 13, 15, 17 cm (see remarks below).

(3) Port Lincoln, South Australia, from surface to 20 feet depth, 1.iii.1959. Coll. F. J. Mitchell and T. D. Scott. 2 specimens, diam. 8-10 cm (see remarks below).

(4) Pondalowie Bay, Yorke Peninsula, South Australia, 18.iv.1960. Coll. F. J. Mitchell. 1 specimen, diam. 14 cm.

(5) Elwood Beach, Victoria, 2.i.1961. Coll. S. Wiener. 3 specimens, diam. 3, 7, 8·5 cm. (see remarks below).

(6) Cairns, Queensland, 3.ii.1960. Coll. G. Rowell. 1 specimen, diam. ca. 26 cm. (see remarks below).

(7) Ellis Beach, Queensland, 18.i.1960. Coll. Fisher (see remarks below).

Remarks:

Re (2), Port Lincoln: 27.iii.1961. ". . . these medusae were very plentiful. The colour in life is brownish-yellow. The medusae were seen at the surface down to visible depths of 7 to 8 feet. At the time of collection there was a S.E. breeze and a dodge tide. The species causes stings on contact . . . these jellyfish tend to congregate under jetties. Later in the season, that is in April to May, 1961, in quiet weather these jellyfish formed large, thick masses near the surface, these masses forming a mat of hundreds of specimens, and such a mat would be found every mile or so in sailing."

Re (3), Port Lincoln, 1.iii.59: Mr. Mitchell states that in life these medusae are pinkish-orange, and that even the small ones have tentacles 9 feet (3 metres) long. The tentacles sting, forming a white elevated line or weal on the skin, about 3 mm across, and the resultant pain, itching and swelling lasts about half an hour. They were very abundant in Port Lincoln Harbour . . .

Re (5), Elwood Bay, 2.i.61: Dr. Wiener reports that during this present summer these jellyfish have been plentiful at Elwood Beach. "The tentacles of some specimens were 3-4 feet long. Many jellyfish had no or very short tentacles. . . . the tentacles caused pain, itchiness and erythema lasting for a few hours. [The medusae] are purple but the colour soon fades when they are removed from the sea."

Re (6), Cairns, 3.ii.60. Dr. Barnes reports: "Collected near entrance to the shipping channel leading into Cairns Harbour. Similar jellyfish (of variable colouration) [were] very numerous at that time following strong south-east winds . . . Colours before preservation were greyish-white, semi-opaque disc with brown-black lappets; tentacles transparent, almost colourless (bluish); fine subumbrellar filaments dirty string colour."

Re (7), Ellis Beach, 18.i.60. Dr. Barnes reports: "Collected near the rocks at the south end of Ellis Beach before midday on 18.i.60. Similar jellyfish had been numerous in the area during the previous few days. This specimen was stranded on the sandy beach, and subjected to wave damage. Colour before preservation was milky-white with dark chocolate markings on the disc."

It is remarkable how differently the colours of the living jellyfish are described by the various observers; it may partly depend on the size and the state of maturity of the specimens, but similar variations may also be observed in European waters.

As seen from the above, this jellyfish occurs in great numbers along the coasts from South Australia eastwards and northwards to Queensland. There are, unfortunately, no records of its being taken along the northern and western coasts.

Geographical Distribution: Almost cosmopolitan in coastal waters, mainly in arctic and temperate seas, less frequent in tropical regions.

Cyanea buitendijki Stiasny

C. capillata var. *buitendijki* Stiasny, 1919, p. 87, pl. 3, fig. 10.
C. buitendijki Stiasny and van der Maaden, 1943, p. 254, figs. 12, 13.

Material Examined: Darwin, Northern Territory, 9.xii.1958. Coll. L. Hickey. 1 specimen, diam. about 8 cm.

This species belong to the *nozakii*-group (Stiasny and van der Maaden, 1943), being closely related to *Cyanea nozakii* Kishinouye and *C. mjoebergi* Stiasny. In contradistinction to the *capillata*-group the *nozakii*-group is characterized by the rhopalar and the tentacular stomach pouches being connected by anastomoses through the gelatinous septa, whereas these septa are uninterrupted in the species of the *capillata*-group, separating the 16 stomach pouches completely from each other. Stiasny and van der Maaden recognize three species of the *nozakii*-group. In *C. nozakii*, which was described from Japan and has also been found in the Mergui Archipelago, near Nhatrang in Vietnam, and near Surabaja in Java, the marginal lappets contain a dense network of anastomosing canals, whereas no anastomoses are seen in the lappets in the two other species. As distinguishing characters between *C. mjoebergi*, which was found in north-western Australia, and *C. buitendijki*, which up to now has only been

observed near Amboina in the Banda Sea, the authors emphasize three points: (1) the lateral diverticula from the broad tentacular stomach pouches are irregular, tree-like ("bäumchenförmigen") in *C. mjoebergi*, straight and undivided in *buitendijki*; in the present specimen they are straight, but their margins are undulating. (2) The horse-shoe-shaped figures marking the insertions of the tentacles are narrower in *buitendijki* (2/1 or 3/1) than in *mjoebergi* (1·5/1), in the present specimen (1·7/1·3). In *mjoebergi* the radial muscular bands reach inwards halfway in between the sections of the circular muscle band, whereas in *buitendijki* the radial muscles are entirely outside the circular muscles; in this respect the present specimen is decidedly of the same type as in *buitendijki*. I do not hesitate therefore, to refer the north Australian specimen to *Cyanea buitendijki* Stiasny, though future examination of a more extensive range of material may possibly disclose a variability, which would make it necessary to unite the two forms.

Further Distribution: Amboina in the Malayan Archipelago, not previously recorded from Australia.

Aurelia aurita (L.)

(Figs. 1-2)

Previous Australian Records: *A. coerulea* Lendenfeld, 1884, p. 280. Port Jackson, New South Wales. Stiasny, 1924c, p. 69, fig. 6. Port Jackson and Port Hacking, near Sydney, New South Wales, Dakin and Colefax, 1933, p. 198.

Material Examined:

(1) South Australia, ca. June, 1961, no other data available. 1 specimen, diam. 12 cm.

(2) Creek, Port Price, South Australia, 4.vii.1959. Coll. J. H. Bell. 1 specimen, diam. 13 cm. (see remarks below).

(3) Port Price, South Australia, 10.vi.1961. Coll. J. H. Bell. 2 specimens, diam. 12-15 cm. (see remarks below).

(4) Green Island, north Queensland, 18.xii.1958. Coll. W. Costa, per J. H. Barnes. 1 specimen, diam. 5·5 cm (see remarks below).

(5) Swan River, near Perth, Western Australia, date not given, presumably summer-autumn, 1957-58. Coll. F. Barrett-Lennard. 2 specimens, diam. 9-10 cm. (shrunk).

These specimens of *Aurelia*, and apparently all others from Australian waters, belong to a variety of *Aurelia aurita*, which was first described by Lendenfeld (1884) as *A. coerulea*.

Most of the numerous species of *Aurelia*, which have been described, are local varieties of *A. aurita* (L.); only one or two other species are valid. *A. limbata* (Brandt, 1838) is a distinct species, occurring in the northern Pacific and north-western Atlantic, and it is a bad mistake to identify it with *A. labiata*, as Mayer did (1910, p. 628). All the canals, except the eight adradial, are much and profusely branched, with numerous lateral diverticula forming numerous anastomoses. In the living condition the medusa is conspicuously yellow with a brown margin.

A. solida Browne, 1905, has been recognized as a valid species by several authors. It is mainly characterized by the marginal sense organs pointing upwards towards the exumbrella. The mouth-arms are thin, narrow bands, slightly folded, the canals slender with few anastomoses. Its geographical distribution is very peculiar (tropical Indian Ocean and the warm parts of the eastern

Atlantic), and it seems very probable that it cannot be retained as a valid species or even as a separate variety of *A. aurita*.

The Indo-Pacific *A. labiata* Chamisso and Eysenhardt, 1820, is characterized by the umbrella margin being divided into 16 lobes, each of the eight primary lobes between the rhopalia being divided by a median cleft; the canal system is very similar to that in *A. aurita*. Most authors have considered it as a separate species but future studies may show that it cannot be regarded as specifically distinct from *A. aurita*.

All other forms of *Aurelia* certainly belong to *A. aurita* (L.). The structural differences between them are not very conspicuous and are, moreover, subject to individual variation and dependent on development or contraction. Some characteristic features separating different varieties or races may, however, be pointed out.

Among characters without taxonomic value may be mentioned: (a) colour; (b) thickness of the jelly and degree of vaulting of the umbrella; (c) shape and size of the subgenital pits, which may be changed in different ways during preservation; (d) the ratio of the gonadal to the umbrella diameter is variable within one and the same population, in the present Australian specimens varying between 33/100 and 46/100; (e) much stress has been laid upon the number of canals arising from each genital sinus between adjacent interrhopalar radial canals; this is, however, dependent on the age and developmental stage of the individuals, the genital portico "swallowing up" the basal parts of the canals during its outward growth, so that the number of "canal roots" is gradually increased, frequently amounting to 5 or 7.

Some importance for distinguishing between varieties or races of *A. aurita* may, however, be applied to the following characters:

(i) The mouth-arms; not their length, but the folding of their edges. In var. *maldivensis* (Bigelow), which occurs in the Indian Ocean from the Red Sea to the Malayan Archipelago, the structure of the mouth-arms is particularly complex, being large, curtain-like, their base massive, solid, with complexly folded, meandrine lips surrounding the mouth opening and hanging far down, while their distal parts are thin, slightly folded. In var. *colpota* (Brandt) the arms are broad, much folded and lobed throughout their length, in their basal part very wide, with a deep incision. Mayer (1910) has identified the Australian var. *coerulea* (Lendenfeld) with *colpota*, and Stiasny (1924c) likewise considers these two forms as closely related, which is a mistake; in *coerulea* the arms are solid, but their margins are thin, undulating, but not complexly folded, and there are no obvious basal incisions. In North Atlantic specimens of *A. aurita* the mouth-arms are likewise rather simple, their margins not conspicuously lobed but more densely crenulated than in *coerulea*.

(ii) The branching of the canals, whether densely or sparingly branched, and to what extent anastomoses occur. In this regard there is a conspicuous difference between specimens from north-western Europe and the Atlantic coast of North America, which in other respects are very similar to each other; in the distal portions of the canals there are many more anastomoses in American than in European specimens, in the various Indo-Pacific forms anastomoses seem to occur sparsely.

(iii) Formation of adradial notches or incisions in the umbrella margin. Such incisions are particularly conspicuous in *A. labiata*, but they may also be observed in other forms of *Aurelia*, though in greatly varying degree. Bigelow (1913, p. 98) has shown that secondary indentations in the margin of *A. limbata* are simply due to contraction of the umbrella. The present author has seen living *A. limbata* swimming in the sea on the west coast of Greenland, the

margin being eight- or sixteen-lobed in regular succession according to the expansion or contraction of the umbrella but the secondary notches disappeared completely when the specimens were preserved in formalin. To a lesser degree these secondary marginal notches may also appear in *A. aurita*, in European as well as in other populations; they are very inconspicuous and are rarely seen in North Atlantic specimens, but it is interesting to note that they are mentioned in the descriptions of all the Indo-Pacific forms, where they seem to be more inclined to remain after preservation.

On a former occasion (Kramp, 1942, pp. 109 *et seq.*) I have discussed these matters. The populations in northern Europe and on the Atlantic coast of North America are geographically separated and may be termed "geographical races"; but if the determinations and descriptions in the literature are correct, the geographical areas of distribution of the Indo-Pacific forms are apparently more or less overlapping, though the variety *coerulea* seems to be characteristic of Australian waters.

According to the literature, the Australian variety, *coerulea*, differs from the typical north-east Atlantic *A. aurita* mainly in the mouth-arms being broad, plump and only slightly crenulated, in the rhopalar marginal clefts being comparatively deep and in more or less conspicuous median notches in the eight primary marginal lappets.

Examination of the specimens in the present collection (see Fig. 1) and direct comparison with specimens from Danish waters confirm these statements. The rhopalar clefts are deeper in the Australian than in the Danish specimens. The difference in the mouth-arms is still more conspicuous; in the European specimens the margin of the arms is much more densely crenulated than in the Australian (see Fig. 2); in both forms the edges of the mouth-arms are provided with a row of numerous, minute tentaculae, which seem to be better developed in the Australian specimens. Median, adradial notches in the eight marginal lappets are clearly seen in the present specimens; they are seen only as fairly slight incurvations but it is remarkable that in all the specimens they have been retained after the preservation of the animals. It is also remarkable that the radiating canals issuing from the genital cavities are rather sparingly branched in their proximal portions, forming elongate furcations; even in the largest specimen observed, 15 cm. wide (Fig. 1), there are only three "canal roots" arising from each genital sinus; in their distal parts the canals are more densely branched, but there are no, or extremely few, anastomoses between them and then, at any rate, only in the immediate neighbourhood of the umbrella margin. The ratio of the gonadal to the umbrella diameter varies between 33/100 and 46/100; in the present state of preservation the genital pits are small and circular.

Remarks on the Occurrence of the Specimens.

Re (2), Port Price, 4.vii.59. Mr. Bell reports the specimen came from between the surface and 10 feet (3 metres) depth; the jellyfish occur in large numbers, pulsating and swimming with the tide.

Re (3), Port Price, 10.vi.61, surface to 20 feet depth. Mr. Bell remarks that this species was abundant, and the jellyfish were very sluggish, making hardly any attempt to swim, and were carried by the current.

Re (4), Green Island, 18.xii.58: "... drifting a few inches under the surface in approximately 100 feet (30 metres) of clear water off Opolu Cay. Bright sunshine, no wind, calm sea, still alive. No other jellyfish seen in vicinity."

Geographical Distribution: *Aurelia aurita* with its varieties has an almost cosmopolitan distribution in coastal waters.

RHIZOSTOMEAE

Cassiopea ndrosia Agassiz and Mayer, 1899

Previous Australian Records: Stiasny, 1933, pp. 913-922, fig. 1, Hayman Islands, Whitsunday Group, Queensland.

Material Examined: Hope Island, Queensland, no date. Coll. Mrs. Betts. 1 specimen, diam. 4·4 cm. Thursday Island, North Queensland, 10.xii.61, from inside of sunken vessel. Coll. H. W. Cunnings. 4 specimens, diam. 2-4 cm.

This species, originally described from the Fiji Islands (by Agassiz and Mayer, 1899), was dealt with in a special paper by Stiasny (1933), who examined two Australian specimens and stated that *C. ndrosia* is different from the West-Indian species, *C. xamachana* R. P. Bigelow, 1892.

The Australian localities are all on the coasts of Queensland.

Further Distribution: Fiji Islands and New Caledonia.

Cephea octostyla (Forskål)

Cephea octostyla L. Agassiz, 1862, p. 156.
Cephea octostyla Mayer, 1910, p. 652, fig. 405.
Cephea octostyla Stiasny, 1921, p. 73.

Material Examined: Green Island, Cairns, Queensland, 30.xii.59. Coll. Miss Jennifer Barnes. 1 specimen, diam. 3·0 cm.

A young medusa, taken off Rockhampton, Queensland, was, with some doubt, referred to this species by Stiasny (1926, p. 251). According to Stiasny (1921, p. 73) Forskål's *Medusa octostyla* is doubtful and not the same as *Cephea octostyla* L. Agassiz. The species is characterized by the presence of 4 to 12 long, tapering, wart-covered filaments in the middle region of the mouth-arms and cannot be confounded with *C. cephea* (Forskål), which on a former occasion has been recorded from the Great Barrier Reef (Kramp, 1961a, p. 204).

Further Distribution: Red Sea (Forskål), Philippines.

Netrostoma coerulescens Maas, 1903

Netrostoma coerulescens Maas, 1903, p. 35, pl. 5, figs. 37, 46; pl. 11, figs. 97, 103; pl. 12, fig. 109.
Cephea octostyla var. *coerulescens* Mayer, 1910, p. 653.
Netrostoma coerulescens Stiasny, 1921, p. 77, pl. 1, fig. 2; pl. 3, figs. 19, 20, textfigs. 3, 4.

Previous Australian Record: Stiasny, 1931b, p. 36, off Wilson Islet, Capricorn Group, Queensland.

Material Examined: Tongue Reef (north side), 30.i.60, at surface. Coll. T. Purcell. 1 specimen, diam. ca. 10 cm.

There are seven round-edged marginal lappets in each octant; the length of the mouth-arm is 7 cm.

Further Distribution: Widely distributed from the Arabian Sea to the Philippines; Japan.

Mastigias papua (Lesson 1829)

Previous Australian Records: Mayer, 1915, pp. 160, 193, Torres Strait. Stiasny, 1931a, p. 144, North Australia.

Material Examined:

(1) South Mission Beach, near Tully, north Queensland, 18.xii.60. Coll. J. H. Barnes. 4 specimens, diam. 15-25 mm. (see remarks below).

(2) Cairns Inlet, 13.xii.61. Coll. W. Monro. 1 specimen, diam. 17 mm.

(3) Esplanade, Cairns, Queensland, 21.xii.61. Coll. J. Kells, E. Buckler, E. Adams. 1 specimen, diam. 24 mm.

(4) Pebbly Beach, north Queensland, 9.i.59. Coll. J. Holden, per J. H. Barnes. 1 specimen, diam. 47 mm. (see remarks below).

(5) Pebbly Beach, north Queensland, 12.i.59. Coll. J. Holden, per J. H. Barnes. 1 specimen, diam. 35 mm. (see remarks below).

(6) Halfmoon Bay, north Queensland, 25.xii.61. Coll. W. Kay. 1 specimen, diam. 18 mm.

(7) Embley River, Weipa, Gulf of Carpentaria, Queensland, 6.x.61. Coll. Mrs. Betts. 1 specimen, diam. 25 mm.

This is the common and widely distributed Indo-Pacific species of *Mastigias*, characterized by the eight rhopalar canals being slender, usually communicating with the adjacent parts of the intracircular mesh-work of canals, and by the number of canal-roots in each octant being less than ten, usually seven to eight. All Australian records up to now are from the northern tropical waters.

Remarks on Occurrence and Colours:

Re (1), near Tully, 18.xii.60. "Tide falling, water murky, sea smooth, wind light north-east. Medusae captured in 2 to 3 feet of water 50 yards offshore, over fine sand. All specimens seen were swimming within 6 inches of the surface. Colour before preservation—variable from dark blue in smaller specimens to light brown in the largest. Strongest coloration on umbrella which also consistently showed small circular whitish spots."

Re (4), Pebbly Beach, 9.i.59. "Upper surface of bell olive-green with dark blue spots. On each of the eight mouth-arms there hangs a three-edged finger-like process, which is a dark, mottled purple colour and shaped like a three-bladed propeller in transverse section. Some 'fingers' have been damaged and there appears to have been a process of re-growth."

Re (5), Pebbly Beach, 12.i.59. ". . . Before preservation the upper surface was brown with many small white spots. Eight fleshy creamy-white mouth-arms were present, which bore numerous small white clubs, bright blue at the tip."

It is very interesting to note the different records of the colours in living specimens before preservation; previous records in the literature likewise state that the colours are very variable in this medusa.

Geographical Distribution: Widely distributed in tropical coastal waters in the Malayan Archipelago and western Pacific to the Fiji Islands and Japan.

Mastigias ocellatus (Modeer, 1791)

Mastigias ocellata Haeckel, 1880, p. 623.
Versura palmata Haeckel, 1880, p. 606, pl. 40, figs. 9-12.
Mastigias ocellata Mayer, 1910, p. 680.
Mastigias ocellata Stiasny, 1922, p. 530, figs. 4-6.
Mastigias ocellata Stiasny, 1924a, p. 490, figs. 2, 3.
Mastigias ocellatus Kramp, 1961b, p. 358.

Not previously recorded from Australia.

Material Examined: Clifton Beach, near Brisbane, Queensland, 29.xi.61, coll. L. Morrissey, 1 specimen, diam. 26 mm. North Queensland, no other data available, coll. C. Russell, 1962, 1 specimen, diam. 43 mm. Fanny Bay, Darwin, Northern Territory, 10.v.59, coll. C. P. Holman, 1 specimen, diam. 55 mm.

Modern descriptions of this species are given by Stiasny (1922 and 1924a), who also found (1922, p. 538) that the type specimen of "*Versura palmata*", Haeckel, 1880, was identical with *Mastigias ocellatus*.

In contradistinction to *M. papua* the rhopalar radial canals are broad, the four perradial being distinctly bottle-shaped without anastomoses with the intracircular meshwork of canals; there are many more canal roots, 15-20 in each octant; it is also distinguished by the small terminal appendages on its mouth-arms. Haeckel (1880) gave the number of marginal lappets as 12 per octant, and this is repeated in Mayer (1910) and, unfortunately, also in my "Synopsis" (Kramp, 1961b, p. 358). According to various other authors the number of lappets is 6 or 8 per octant, though Stiasny (1924a) found 6 in some and 12-14 in other octants of one and the same specimen. In the present specimens I have counted 8-10 lappets per octant.

From the time when "*Medusa ocellata*" Modeer was referred to the genus *Cephea* (by Péron and Lesueur, 1809, and L. Agassiz, 1862), the specific name was generally written *ocellata* but the correct spelling must be *ocellatus*.

Mastigias andersoni Stiasny, which has similar, bottle-shaped rhopalar canals is discussed below.

Further Distribution: Andaman Islands and Mergui Archipelago, Malayan Archipelago, Philippines, Hongkong.

Phyllorhiza punctata (Lendenfeld, 1884)

Phyllorhiza punctata Lendenfeld, 1884, pp. 296, 307, pl. 4, fig. 1; pl. 5, figs. 1-4.
Phyllorhiza punctata Stiasny, 1924c, p. 56, figs. 1-4.
Phyllorhiza punctata Stiasny, 1926, p. 255.
Phyllorhiza punctata Stiasny, 1931a, p. 144.

Previous Australian Records: Recorded from near Port Jackson, New South Wales, in all the papers mentioned above.

Material Examined: Cardwell, Queensland, 21.i.55, E. M. Anthony, 5 specimens, diam. 19, 25, 29, 30 and 45 mm. Darwin Wharf, Cairns, 25.xi.60, Bert Cummings, 1 specimen, diam. 27 mm. Esplanade, Cairns, 30.i.61, J. H. Barnes, 2 specimens, diam. 40 and 60 mm. Cairns Inlet, Queensland, 23.xi.61, 2 specimens, diam. 37 and 42 mm. Cairns, No. 2 Wharf, 13.xii.61, 1 specimen, diam. 110 mm. Cairns Inlet, Queensland, 13.xii.61, coll. J. H. Barnes, 3 specimens, diam. 20, 30 and 45 mm. Cairns Inlet, Queensland, 13.xii.61, coll. G. Rowell, 1

specimen, diam. 45 mm. Cairns Inlet, Queensland, 24.xii.61, 1 specimen, diam. 40 mm. Green Island, Cairns, Queensland, 20.xii.58, 1 specimen, diam. 30 mm. (see remarks below), coll. J. H. Barnes. Urquhart Point, Weipa, Queensland, 2.xi.61, coll. G. Webster, 2 specimens, diam. 45 and 55 mm. Swan River, Western Australia, presumably summer 1957-8, coll. F. Barrett-Lennard, 6 specimens, diam. 20-55 mm.

The genus *Phyllorhiza* has had a somewhat complicated history. The name was introduced by L. Agassiz (1862, p. 158) for a Chinese medusa, *P. chinensis*. Haeckel (1880, p. 588) added a new species, *P. trifolium*, and Lendenfeld (1884) described *P. punctata* from New South Wales, Australia. Mayer (1910, p. 684) regarded the two first species as doubtful, but retained the generic name and placed *P. punctata* as the type species. Later on two more species were described, *P. luzoni* Mayer (1915) from the Philippines (by Stiasny, 1921 and 1924c regarded as doubtful) and *Cotylorhizoides pacifica* Light, 1921; this latter species was referred to *Phyllorhiza* by Stiasny (1924c, p. 50).

Stiasny (1924c, p. 56, figs. 1-4) has examined new specimens from Port Jackson, New South Wales, and given a new, detailed description and also (p. 65) a new diagnosis of the genus *Phyllorhiza*. Additional specimens from Port Jackson were recorded by Stiasny (1926, p. 255), and finally he has examined Lendenfeld's type-specimens (1931a, p. 141).

Though the diagnosis of the genus *Phyllorhiza* seems to me to be rather vague, almost equal to *Mastigias*, I think it advisable to retain the name of *Phyllorhiza punctata* for Lendenfeld's medusa which, evidently, is a very common species in Australian waters not merely on the coasts of New South Wales, whence all previous records are derived, but also around Queensland and in Western Australia, as seen from the present collection.

As a matter of fact, when I first examined these numerous specimens I thought that they belonged to *Mastigias* and in many details they agreed with *M. andersoni*, which was described by Stiasny (1926, p. 252, fig. 3) from five specimens collected at Bowen Harbour, Port Denison, Queensland, and one from Observation Island, Gulf of Carpentaria. I am inclined to think that all these specimens really belonged to *Phyllorphiza punctata*, and the same may possibly also apply to the Australian specimens (from the Great Barrier Reef) of *Mastigias albipunctata* Stiasny, 1920, a species otherwise occurring in the Malayan Archipelago.

Phyllorhiza punctata resembles *Mastigias ocellatus* in the configuration of the radial rhopalar canals, which are broad; the perradial rhopalar canals are bottle-shaped and without anastomoses to the intracircular mesh work of canals, there are numerous "canal roots"; but the terminal appendages of the mouth-arms are usually very long, frequently as long as the diameter of the umbrella or more (also seen in some of the present specimens). The number of marginal lappets in each octant is almost regularly 6, the two median ones being broader than the others and with a median cleft; the same is emphasized in the description of *Mastigias andersoni*.

In the present collection is also a specimen of *Phyllorhiza punctata* from Hua Hin, Thailand (12°56′N., 100°02′E.), collected 15.iv.58 by W. J. S. Thompson; it is 50 mm wide. A medusa, recorded from southern Japan by Uchida (1954, pp. 211, 216) as *Phyllorhiza triformis* Haeckel (1880) may possibly belong to *P. punctata*. Dr. J. H. Barnes says of the specimen collected at Green Island, Cairns, 20.xii.58, ". . . Captured near the surface in 8 feet (about 2½ metres) of clear water over a sandy bottom, near Green Island jetty. Tide low and

rising, wind light north-west, raising small ripples only. Hot, bright, cloudless day. Colour before preservation, umbrella brown with blue circular spots; mouth-arms milky; appendage (club) from mouth-arms colourless with blue extremity."

Further Distribution: Gulf of Siam; ? southern Japan.

Pseudorhiza haeckeli (Haacke, 1884)

Pseudorhiza haeckelii Haacke, 1884, p. 291.
Monorhiza haeckelii Haacke, 1886, p. 614, pl. 37, figs. 1-9.
Pseudorhiza haeckelii Mayer, 1910, p. 683.
Pseudorhiza haeckelii Stiasny, 1921, p. 123.
Pseudorhiza haeckeli Thiel, 1926, p. 223; pl. 3.
Pseudorhiza haeckeli Stiasny, 1931a, pp. 149, 153.
Pseudorhiza haeckeli Kramp, 1961b, p. 367.

Previous Australian Records: Haacke, 1884 and 1886, St. Vincent Gulf, South Australia. Thiel, 1926, south-west Australia.

Material Examined:

(1) Port Lincoln, South Australia, 1.iii.59. Coll. F. J. Mitchell and T. D. Scott. 1 specimen, diam. 22 cm. (see remarks below).

(2) Somerton, S.A., on shore, 15.i.62. Coll. R. V. and Miss J. E. Southcott. One large specimen, fragmentary, determination uncertain (see remarks below).

(3) Off Marino Rocks, South Australia, 26.i.61, 50-300 yards from shore. Coll. Miss R. M. Arnott Rogers. 12 specimens, diam. 1·2-8·5 cm.

(4) Brighton, St. Vincent Gulf, S.A., 8.vi.57. Coll. R. V. Southcott. 1 specimen, large, fragmentary, according to notes 11-12 inches (28-30 cm.) (see remarks below).

(5) Port Noarlunga Reef, S.A., 8.i.61, at surface. Coll. D. Cooper, 2 specimens, diam. 1·5 and 3 cm.

(6) Aldinga Reef, South Australia, 12.ii.61. Coll. Underwater Research Group. 2 specimens, diam. 10 and 14 cm. (see remarks below).

(7) Arnhem Land, Northern Territory, Sept., 1961. Coll. V. Wells. 1 specimen, diam. 6 cm.

The genus *Pseudorhiza* was erected by Lendenfeld (1882b, p. 380; 1884, p. 293, pl. 3) for a medusa, *Pseudorhiza aurosa* n. gen., n. sp., collected near Port Philip (Victoria) and near Adelaide (South Australia), and never observed again; the description is insufficient and the figure probably misleading. As it was found in the same area where *P. haeckeli* Haacke occurs in considerable numbers, it seems reasonable to presume that the two species are identical, but the identity can never be ascertained with certainty. Stiasny (1931a) has examined the type-specimen of *P. aurosa* (from Port Philip), which was in poor condition and did not solve the question of the presumed identity of the two species. It seems to me advisable, therefore, to retain the name of *P. haeckeli* for the medusa, which was thoroughly described and elaborately figured by Haacke (1884 and 1886). Later on, several details were described by Thiel (1926), who examined some specimens from three localities between Fremantle and Bunbury on the west coast of Australia.

The principal difference between the two species is the absence of filaments on the mouth-arms of *P. aurosa* in contradistinction to *P. haeckeli*, in which, moreover, one of the mouth-arms (and only one) carries one enormously long and stout appendage near its outer end: it is triangular in cross-section and frequently longer than the diameter of the umbrella. It is present even in young specimens and nearly always retained after preservation; among 18 specimens in the present collection the appendix is lost in only three. Its length is variable as seen from the adjacent table:—

Diam. of umbrella mm.	Length of appendage in *Pseudorhiza haeckeli*, mm.										
	10	15	20	25	30	40	50	60	70	80	100
15	1	1	1	–	–	–	–	–	–	–	–
20	–	1	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	1	–	–	–	–	–
30	–	–	–	1	–	–	–	–	–	–	–
45	1	–	–	1	–	–	–	–	–	–	–
60	–	–	–	–	–	–	–	1	–	1	1
80	–	–	–	–	–	–	1	–	–	–	–
100	–	–	–	–	–	–	–	–	1	–	–
140	–	–	–	–	–	–	–	1	–	–	–
220	–	–	–	–	–	–	–	–	–	1	–

Haacke (1886, pp. 624 ff) gave a detailed description of young stages of this medusa. Examination of young specimens, 15-25 mm. wide, in the present collection shows that his description is perfectly correct in almost all respects. I shall make only a few additional remarks. The appearance of the exumbrella is very similar to Haacke's fig. 7 (pl. 37), except that in the central area the nematocyst warts are not arranged in definite circles. In a specimen only 11 mm wide, Haacke found only four rhopalia; the present individuals all have eight. In the smallest specimen, 15 mm wide, the mouth-arms are very similar to those in Haacke's fig. 6, though their edges are not perfectly smooth but already slightly frilled to some extent, and this is further developed in the slightly larger specimens; it is remarkable, however, that in these specimens the arm carrying the large appendage and its neighbours on either side are more densely frilled than those on the opposite side. Gastral filaments are short and very numerous in these young stages; gonads are hardly distinguishable. The number of centripetal canals arising from the ring-canal is usually nine in each octant, rarely ten or eleven: they are straight and undivided and all of equal length; in the youngest stage, 11 mm wide, Haacke found 4-5 centripetal canals, the median one longer than the others. As seen from the above table the large appendage on one of the mouth-arms may be longer than the diameter of the umbrella even in small specimens.

Remarks on Occurrence and Colours:

Re (1), Port Lincoln, 1.iii.59. ". . . Apparently this species does not occur far up Spencer Gulf . . ." "The jelly (mesogloea) is blue, the mouth-arms are translucent white, the surface of the bell carries a red reticular pattern."

Re (2), Somerton, 15.i.62. "Cast up on shore. In damaged condition, inactive; clear jelly with purple markings. There was no stinging effect on being handled."

Re (4), Brighton, 8.vi.57. "Bell about 11-12 inches across and jelly substance about an inch thick. The bell was patterned with a purplish-red reticular marking, somewhat hexagonal, and other streaks of this colour led away from it. The medusa broke up when I picked it up in my hands off the sand."

Re (6), Aldinga Reef, 12.ii.61. "The smaller of these two specimens had about 12 small jellyfish sheltering under the mantle. These were dispersed during efforts to guide the Scyphomedusan into a plastic bag, but several were subsequently captured . . ." (see below, *Eirene menoni*).

Distribution: *Pseudorhiza haeckeli* is evidently a very common jellyfish on the coasts of South Australia, but a specimen was also taken at Arnhem Land on the north coast, and it is recorded from three localities, Rottnest Island, Cockburn Sound, and Koombana Bay, between Fremantle and Bunbury on the west coast. It is known only from Australian waters.

Acromitoides purpurus (Mayer, 1910)

Catostylus purpurus Mayer, 1910, p. 671, fig. 412.
Acromitoides purpurus Stiasny, 1921, p. 136.
Acromitoides purpurus Stiasny, 1924b, p. 39, fig. 1.
Catostylus purpurus Southcott, 1963b, p. 57.

Material Examined: Normanton River, Gulf of Carpentaria, Queensland, 16.v.60, coll. P. F. Aitken, 4 specimens, diam. 12, 14, 16 and 18 cm. (see remarks below). Esplanade, Cairns, Queensland, 21.ii.59, coll. E. Coster, 1 specimen, diam. 5 cm.

The genus *Acromitoides* differs from *Catostylus* in the intracircular anastomosing network being in direct communication with the ring canal and the inter-rhopalar canals only, while in *Catostylus* it communicates with the rhopalar canals as well.

Remarks on the specimens from Normanton River, 16.v.60: "Mr. Aitken reports that these jellyfish were present in large numbers in the incoming tide; they were collected by dip-net from a boat. Colour varied from shades of light pink through light purple and light blue."

Further Distribution: Philippines: not previously recorded from Australia.

Catostylus mosaicus (Quoy and Gaimard, 1824)

Cephea mosaica Quoy & Gaimard, 1824, p. 569, pl. 85, fig. 3.
Rhizostoma mosaica Huxley, 1849, pp. 422, 432, pl. 38, figs. 26, 27; pl. 39, figs. 28-34.
Catostylus mosaicus L. Agassiz, 1862, p. 152.
Cramboessa mosaica Haeckel, 1880, p. 622.
Cramboessa mosaica Lendenfeld, 1883-1888.
Cramboessa mosaica Agassiz & Mayer, 1898, p. 16, pls. 2, 3.
Catostylus mosaicus Mayer, 1910, p. 666.
Catostylus mosaicus Southcott, 1960, p. 21; 1963a, p. 57.
Catostylus mosaicus Kramp, 1961b, p. 370, all records, 1910-1953.

Previous Australian Records: Quoy & Gaimard, 1824, and Huxley, 1849, Port Jackson, New South Wales. Haeckel, 1880, Lake Illawarra, New South Wales. Lendenfeld, 1887, p. 30, and preceding papers, Port Philip, Victoria. Agassiz and Mayer, 1898, p. 16, near Sydney, New South Wales, and near Brisbane, Cairns and Cooktown, Queensland. Mayer, 1915, p. 190, Moreton Bay, near Brisbane, Queensland. Stiasny, 1922, p. 554, Port Hacking, New South Wales.

Stiasny, 1924c, p. 66, Como, near Sydney. Stiasny, 1929, p. 214, Merauke, south coast of New Guinea. Stiasny, 1931b, p. 38, Port Curtis, Queensland. Pope, 1953a, pp. 16-21 (stinging). Southcott, 1960, p. 21 (stinging). Pope, 1963, p. 193 (stinging). Southcott, 1963a, p. 57 (stinging). Thomas, 1963, p. 208.

Material Examined: Clifton Beach, Queensland, 29.xi.61, coll. L. Morrissey, 1 specimen, diam. 17 mm. Esplanade, Cairns, Queensland, 21.ii.59, coll. E. Coster, 2 specimens, diam. 75 and 80 mm. Newell Beach, north Queensland, Dec., 1960-Jan., 1961, coll. Mrs. Betts, 1 specimen, diam. 25 mm.

This seems to be a common Australian medusa, originally described from Australia by Quoy & Gaimard (1824) and later on recorded from several localities from Melbourne northwards along the east coast to north Queensland and from the south coast of New Guinea. It has not been found anywhere else, apart from a record from the Philippines which (Mayer, 1917, p. 215) is regarded as uncertain by the author himself. Several Australian specimens have been examined by Stiasny (1921-1931); the present specimens fully agree with the descriptions given by this prominent expert on Rhizostomeae, and we may safely accept *C. mosaicus* as a valid species.

Distribution: Australia; ? Philippines.

LEPTOMEDUSAE

Eirene menoni (Kramp, 1953)

Phortis sp. Menon, 1932, p. 18.
Phortis lactea Ling, 1937, p. 357, figs. 9-10.
Eirene menoni Kramp, 1953, p. 286, pl. 2, fig. 6.

Previous Australian Records: Kramp, 1953, p. 286. Great Barrier Reef. Kramp, 1965 (in press). Near Sydney.

Material Examined: Aldinga Reef, South Australia, 2 miles off-shore, surface, 12.ii.61. Coll. Underwater Research Group, South Australia. 4 specimens.

The specimens are 13-17 mm. in diameter and have the following numbers of marginal tentacles:

diam., mm.	13	15	16	17
tentacles	44	ca. 44	ca. 40	ca. 54

The length of the gonads is very variable in this species; in the present specimens they extend from very near the ring-canal to more than half the distance upwards towards the base of the peduncle. The tentacles are all of almost equal length, without any young ones between the others.

Further Distribution: S.E. Africa; India; Macassar Strait to Chekiang Coast in China; Cook Islands in Polynesia.

Helgicirrha danduensis (Bigelow, 1904)

(Fig. 3)

Eirene danduensis Bigelow, 1904, p. 254, pl. 1, fig. 5; pl. 2, fig. 6
Helgicirrha danduensis Kramp, 1936, p. 255.
Helgicirrha danduensis Kramp, 1961b, p. 192.

Not previously recorded from Australia.

Material Examined: Lameroo Beach, Darwin, Northern Territory, 17.vi.62. Coll. R. V. Southcott. 1 specimen, diam. 5 mm., netted between surface and 0·5 m. depth, at 0-10 m. from shore.

This is one of the two Indo-West Pacific species of *Helgicirrha*, and it is distinguished from *L. malayensis* (which occurs on the Great Barrier Reef) by its very short oral lips, more elongated stomach, and by the greater distance between the tentacles. Direct comparison with specimens of both species from other localities has convinced me of the identity of the present specimen with *H. danduensis*. It is 5 mm. in diamer (thus in a rather young stage, since the medusa may obtain a size of 25 mm.). The peduncle is 2 mm. long, conical in its basal part, distal part cylindrical; the gonads are narrow, linear, extending from the base of the peduncle three-fifths outwards towards the bell margin. There are 32 tentacles, each with one pair of lateral cirri; between the tentacles there are two or three very small papillae and usually one marginal vesicle. As in most other specimens of *H. danduensis* examined by me on former occasions, the stomach is not particularly elongated, but the gastric tissue is continued somewhat up above the terminal constriction of the peduncle (Fig. 3). I cannot refer this specimen to the same species, *H. malayensis*, of which I have examined numerous specimens from the Great Barrier Reef (Kramp, 1953, p. 286) and from the Mergui Archipelago (Kramp, 1958, p. 355); it certainly belongs to *Helgicirrha danduensis*.

Further Distribution: Maldive Islands; Nicobar Islands; a doubtful record from Vietnam.

Phialopsis diegensis (Torrey, 1909)

Phialopsis diegensis Torrey, 1909, p. 23, fig. 9.
Phialopsis diegensis Kramp, 1961b, p. 193 (all references).

No previous records from Australia.

Material Examined: One mile north-east of northmost point of Torrens Island, South Australia, from surface to depth of 3 feet, 29.iv.61, coll. P. D. Grogan, 11 specimens; diam. 8-12 mm.

The apical jelly is uncommonly thick and vaulted; most of the marginal cirri are lost, and in most of the specimens the gonads are lost, but where present they are of the structure typical of this species.

Further Distribution: Mainly oceanic. Common in the Atlantic Ocean, mainly in its eastern parts, from the Irminger Sea to the Cape of Good Hope; off the east coast of Africa; California and south-west of the Galapagos Islands in the eastern Pacific. The occurrence in South Australia bridges the gap between the east Pacific and the western part of the Indian Ocean.

LIMNOMEDUSAE

Olindias singularis (Browne, 1905)

Olindias singularis Browne, 1905, p. 737, pl. 56, fig. 2; pl. 57, fig. 1.
Olindias singularis Bigelow, 1909, p. 109, pl. 4, fig. 1; pl. 31, figs. 1-10; pl. 32, fig. 8.
Olindias singularis Kramp, 1953, p. 298.
Olindias singularis Kramp, 1956, p. 237.
Olindias singularis Kramp, 1958, p. 366.
Olindias singularis Southcott, 1963b, p. 20, fig. 3B.

Previous Australian Records: Stiasny, 1931b, p. 27, Michaelmas Reef, off Cairns, north Queensland. Kramp, 1953, p. 298, Great Barrier Reef. Kramp, 1961a, p. 203, Green Island, off Cairns. Southcott, 1963b, p. 20, fig. 3B, widely distributed in Australia.

Material Examined: Marino Rocks, South Australia, surface to 3 feet depth, 18.ii.61, coll. Miss R. M. Arnott-Rogers, 5 specimens. Somerton, South Australia, 15.i.62, coll. R. V. Southcott, 5 specimens.

The localities are closely south of Adelaide on the eastern side of St. Vincent Gulf, and on both occasions the medusa was present in great numbers along the beach, right into the water's edge. According to notes by Dr. Southcott, the stinging effect of this medusa is rather considerable. *O. singularis* is distinguished by the presence of only one statocyst at the base of each of the primary tentacles, not a pair as in other species of *Olindias*, exceptions being rarely seen. This was stated by Bigelow (1909) and confirmed by the present writer in specimens from the Great Barrier Reef, the Nicobar Islands, Karachi in India, and the Iranian Gulf (Kramp, 1953, 1956, 1958 and 1961a). In the ten specimens mentioned above I have found a pair of statocysts at the base of only one tentacle in one individual and at two tentacles in another. The specimens, accordingly, further confirm the specific validity of this character.

The present specimens examined by me are fairly small, being 5-17 mm. in diamer; the medusa may attain a much greater size, though rarely more than 36 mm. The largest specimen I have seen was 53 mm. wide and had 116 primary and 68 secondary tentacles and 56 centripetal canals (Iranian Gulf, Kramp, 1956). The specimens from Somerton have the following dimensions:

diam. mm.	number of tentacles primary	secondary	number of centripetal canals
11	32	16	20
12	38	18	24
12	27	20	14
16	38	26	28
17	42	31	36

The small specimens from Marino Rocks, 5-11 mm. wide, are well preserved, with fully extended tentacles, the secondary tentacles up to 33 mm. long in the preserved condition.

Geographical Distribution: Widely distributed in the warm coastal waters of the Indian Ocean from the Iranian Gulf to the Malayan Archipelago; the Philippines; Australia; Low Archipelago in Polynesia, about 135° W.

Gonionemus hamatus n. sp.

(Figs. 4-6)

Material Examined: Henley, South Australia, at jetty, 3.v.61, coll. I. M. Thomas, 1 specimen, identification A483.

Description of Holotype (figs. 4-6): Diameter 7 mm., height 8 mm., with a bluntly conical apical projection, lateral walls moderately thick. Stomach with a very broad base, quickly narrowing towards a short, prismatic mouth tube with four sharp ridges; four short, but distinct oral lips, the margins of which are densely provided with prominent warts of nematocysts (Fig. 5).

Gonads (female with small eggs) along almost the entire length of the four radial canals, each gonad a laterally compressed, wavy band, uninterrupted in the free margin. Radial canals narrow, ring-canal fairly broad, velum very broad.

There are about 18 marginal tentacles of very unequal length, up to about 5 mm. long in their present condition, long and short ones apparently without any definite order (Fig. 4); the tentacles are hollow, with a very narrow central canal. Each of these tentacles is smooth in about its proximal one-third, but in the greater part of its length surrounded by densely set complete and rather prominent rings of nematocysts, up to 60 rings in the longest tentacles. The terminal tip is sharply inwardly bent like a hook, and just behind the hook is a half-moon-shaped, strongly developed adhesive pad (Fig. 6); long and well-extended tentacles may be more or less twisted, so that it may be difficult to see whether the adhesive pad is adaxial or abaxial, but in the shorter tentacles the position of the pad is distinctly seen to be adaxial. The tentacles are inserted at a short distance above the umbrella margin, and there is a well-developed round basal bulb with nematocysts just below the point of issue of the tentacle. Occasionally two tentacles issue from the same bulb: sometimes they are of about equal size, but as a rule one of them is small, arising from the lateral side of the bulb; such small tentacles are not persistent dwarf tentacles, but simply young tentacles of the same structure as the long ones, though in their youngest stage they lack an adhesive pad which, however, is soon developed. Only two of the eight tentacles placed in the four perradial and the four interradial points of the umbrella margin are retained, the others are lost, leaving a small basal stump, pointing upwards and placed at a somewhat higher level than the other tentacles; the two which are retained (one of them long, perradial, the other a young one, interradial) are of the same structure as all the other tentacles of the medusa.

There are no ocelli. Only a few statocysts can be discerned, and they are adradially situated, which may be accidental; the question of the full number of statocysts must be left open.

In the preserved condition the manubrium, radial canals, gonads and tentacle bulbs are faintly yellow.

Remarks: The specimen was taken by Mr. I. M. Thomas in a plankton net with a light at night at the jetty at Henley on the eastern shore of St. Vincent Gulf, South Australia.

SURVEY OF THE GENERA OF OLINDIADIDAE

A. With centripetal canals: *Olindias, Macotias, Olindioides, Eperetmus.*

B. Without centripetal canals:

1. Tentacles without adhesive pads: *Aglauropsis, Cossea, Craspedacusta, Nuarchus.*
2. Tentacles, some with and some without adhesive pads: *Cubaia, Vallentinia.*
3. All tentacles with adhesive pads: *Gonionemus, Scolionema.*

For some time I was inclined to think that the basal stumps of perradial and interradial tentacles which, mentioned above, are placed at a somewhat higher level than the other tentacles and are pointing upwards, might be the remnants of another kind of tentacles, perhaps similar to the tubular tentacles

of *Vallentinia*; but when I found one perradial and one interradial tentacle of exactly the same structure as the numerous ringed tentacles, I gave up that supposition. According to the above survey of the genera the new species belongs to the *Gonionemus* group, though in two important points it differs from the other members of that group.

In *Gonionemus vertens*, the juvenile form *G. vindobonensis*, and in *Scolionema suvaense* the adhesive pads of the tentacles are abaxial in position and separated by a remarkable distance from the tip of the tentacles, which is straight-pointed. In the present species the adhesive pads are adaxial and placed immediately inside the sharply hooked ends of the tentacles.

This might induce one to regard this species as the representative of a new genus; but to avoid the erection of another monotypic genus, based on a single individual, I should incline, for the time being, to regard the distinguishing characters as merely of specific value. This involves a slight alteration of the diagnoses of *Gonionemus* and *Scolionema*, omitting the word "abaxial" in connection with their adhesive pads. The two genera differ from each other only in the number of statocysts, "large and indefinite" in *Gonionemus*, "not exceeding 16" in *Scolionema*. This also seems to be a character of specific importance only and I propose, therefore, to replace *Scolionema suvaense* into the genus *Gonionemus*, where it was originally placed by Agassiz and Mayer, 1899.

The present new species then will find its natural position within the genus *Gonionemus*, the generic diagnosis of which will be as follows:

Gonionemus A. Agassiz, 1862: Olindiadidae with four radial canals; without centripetal canals; with numerous uniform tentacles, all with an adhesive pad near the outer end, and with rings of nematocysts.

Comprising the following species:

G. vertens A. Agassiz, 1862.

G. suvaensis Agassiz and Mayer, 1899.

G. vindobonensis Josephi, 1918.

G. hamatus n. sp.

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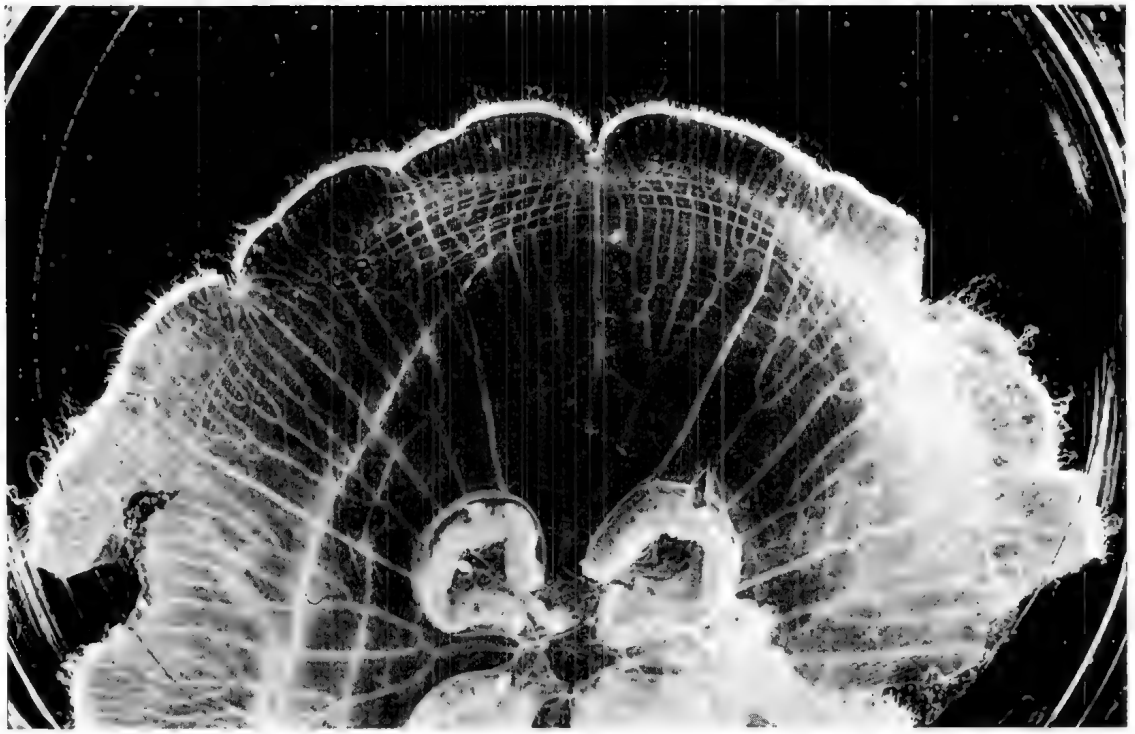


Fig. 1. *Aurelia aurita*, South Australia. Oral view of umbrella.

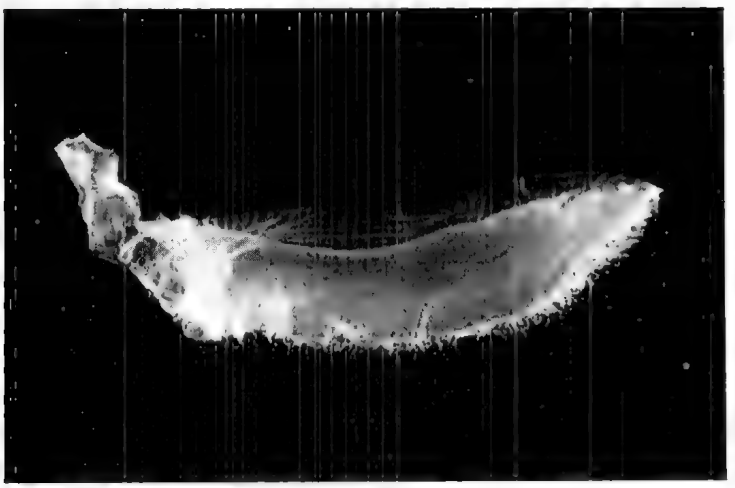


Fig. 2. *Aurelia aurita*, South Australia. Mouth-arm.

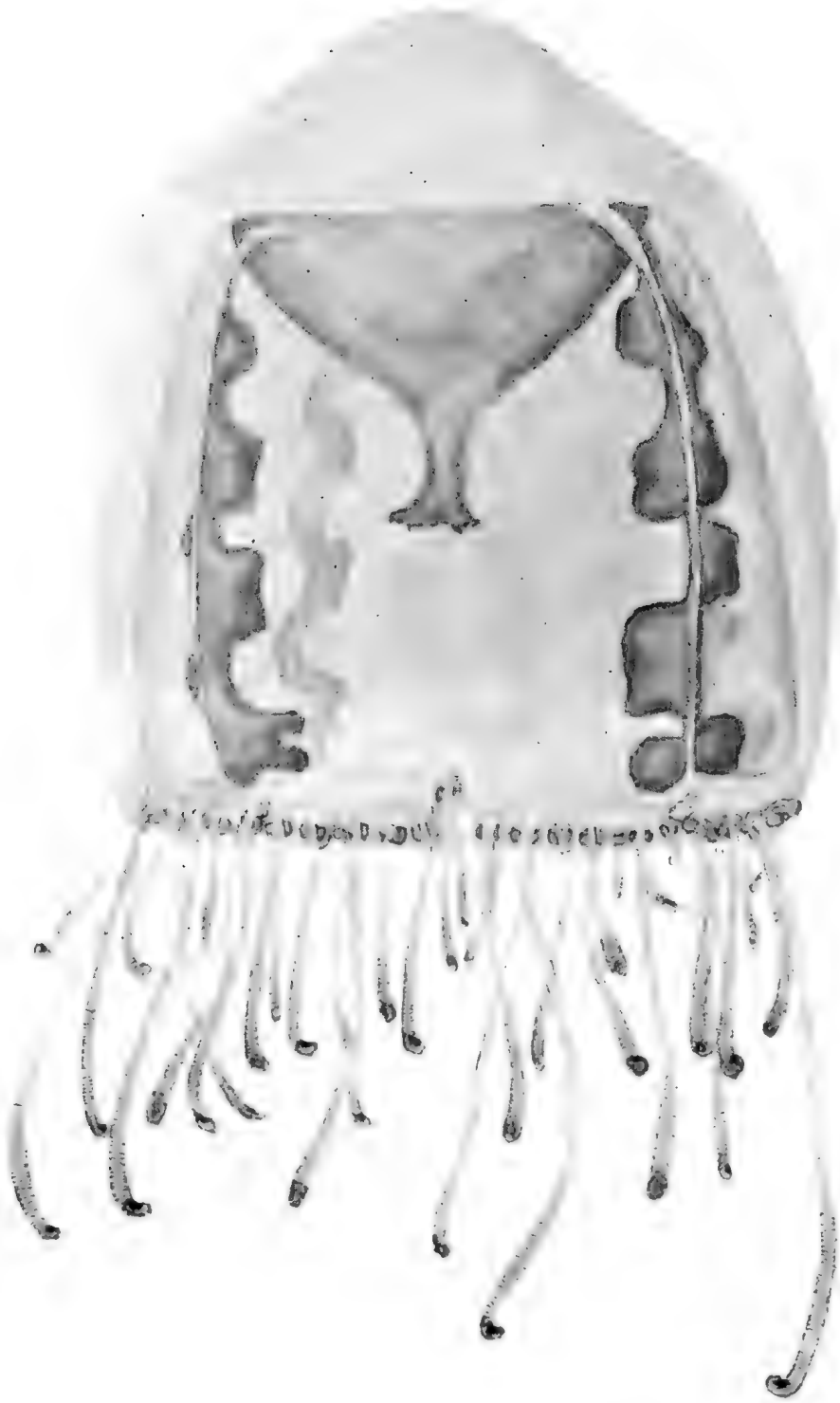


Fig. 4. *Gonionemus hamatus* n. sp. Type specimen, A483.

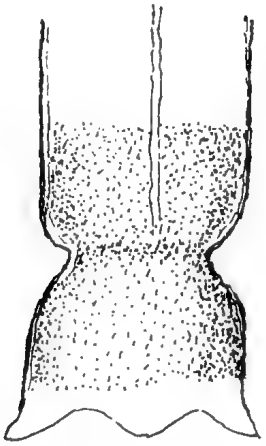


Fig. 3. *Helgicirrha danduensis*, Darwin, Northern Territory. Stomach and lower portion of peduncle; dotted area denotes position of gonads.

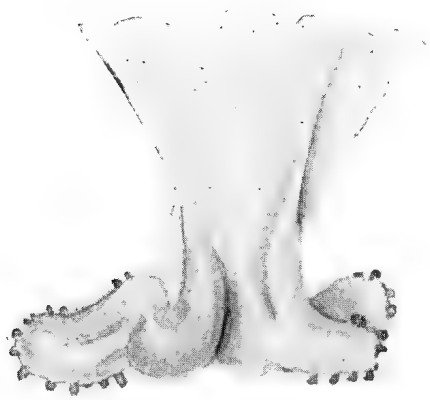


Fig. 5. *Gonionemus hamatus* n. sp. Oral lips, showing prominent warts of nematocysts.

Fig. 6. *Gonionemus hamatus* n. sp. Terminal end of tentacle, showing adhesive pad and rings of nematocysts.

TWO NEW SPECIES OF EMBADIUM (BORAGINACEAE)

BY ERNEST H. ISING

Summary

Two new species, Embadium uncinatum and *E.* johnstonii, are described and their characteristic details illustrated. The description of the genus Embadium is emended and a key provided to the three species of which the specimens preserved in Australian herbaria are enumerated, and the distribution is shown on a map. The position of Embadium within the genera of Boraginaceae is explained by quotations from letters of 1. M. Johnston and by a key to related genera in the South Australian flora.

TWO NEW SPECIES OF *EMBADIUM* (BORAGINACEAE)

by Ernest H. Ising*

(Communicated by Hj. Eichler)

[Read 14 October 1965]

SUMMARY

Two new species; *Embadium uncinatum* and *E. johnstonii*, are described and their characteristic details illustrated. The description of the genus *Embadium* is emended and a key provided to the three species of which the specimens preserved in Australian herbaria are enumerated, and the distribution is shown on a map. The position of *Embadium* within the genera of Boraginaceae is explained by quotations from letters of I. M. Johnston and by a key to related genera in the South Australian flora.

The genus *Embadium* Black was based on a collection by Miss B. J. Murray at Arcoona, west of Lake Torrens, South Australia. A specimen of this collection had been sent to the late Dr I. M. Johnston [Gray Herbarium (later Arnold Arboretum) Harvard University, Cambridge, Mass., U.S.A.], a well-known specialist of Boraginaceae, who considered it as a representative of the only species of a new genus. This was subsequently published by J. M. Black as *Embadium stagnense*, and Johnston's opinion on this plant was quoted.

In a further letter to J. M. Black, Johnston reiterates his views that the plant belongs to an undescribed genus with affinity with *Omphalodes* Moench. As this communication of the 7th April, 1931, remained unpublished, but its contents should be made available, it seems appropriate to quote it here in full:

"Dear Mr. Black,

I have received your letter of March 2nd and the specimens of plants that you mention sending. The little Borage that you send is one of the most interesting that has passed through my hands for a long time. I have worked at it over several different periods during the last few days and the more I study it the more I am convinced that you have not only a very distinct undescribed species, but a remarkable undescribed genus as well!

The facts are that the plant is so distinct I am quite uncertain where it belongs in the scheme of genera in its family. On my first survey of the plant I thought it must belong to the *Cynoglosseae* somewhere near *Omphalodes*. A close inspection of the plant, however, revealed the fact that the nutlet attachment is medial or submedial, quite as it is in the *Eritrichieae*. I naturally thought that it might be a curious derivative of your very distinctive Australian *Lappula*, *L. concava* which Brand has placed (I believe with questionable reasons) in a monotypic genus *Omphalolappula*. A study of *L. concava*, however, showed me that that species was typical of *Lappula* in the attachment of its nutlets and glochidiate nutlet appendages. Your plant certainly is not closely related to this Australian species of *Lappula*. In fact, if its belongs to the *Eritrichieae*, it must be placed near *Hackelia* and *Eritrichium* just where it keys out in my synopsis of the Old World genera. From these two genera, it is, of course, unquestionably distinct. Although technical characters place the plant with *Hackelia* and *Eritrichium* in the *Eritrichieae*, I must still confess that it does suggest to me each new time I examine it, the genus *Omphalodes* in the *Cynoglosseae*. There is considerable resemblance in the gross habit between your plant and stunted forms of

* State Herbarium of South Australia, Adelaide.

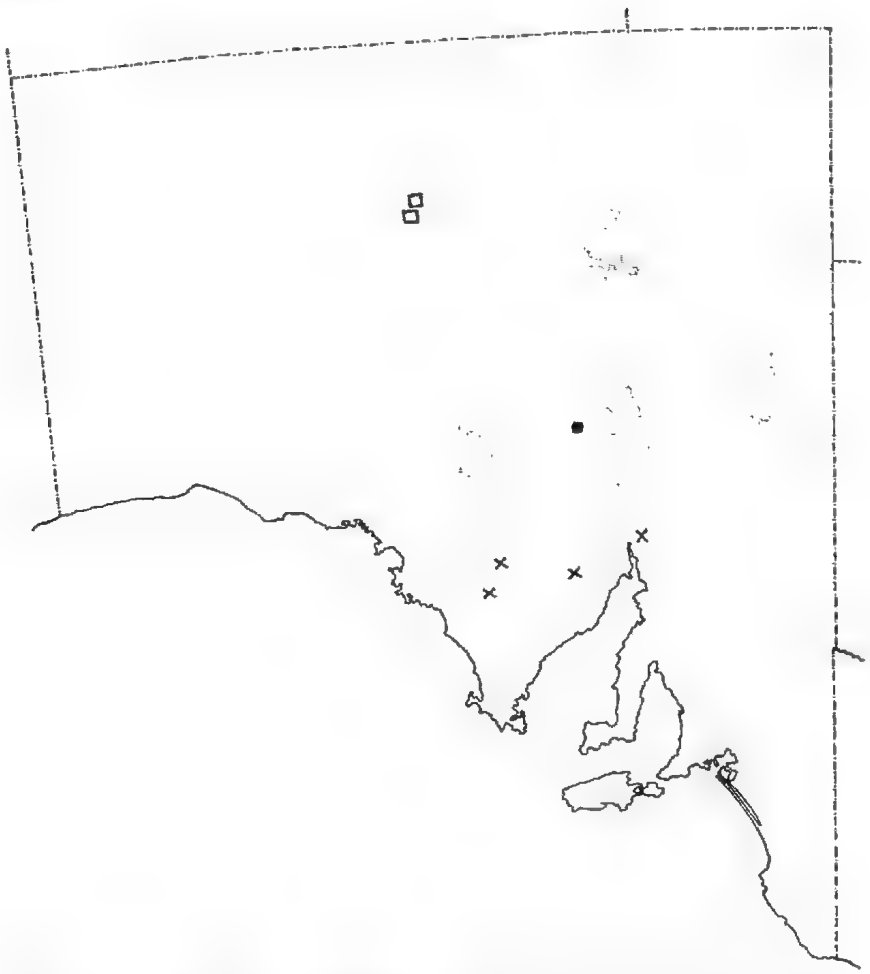
Omphalodes linifolia of Europe.

The distinctive characters of your plant are as follows: (1) the nutlets with small medial dorsal attachments, uncinate pubescence, lack of glochidiate appendages, and above all, with the curious crenate, tumid margins and crest-like tumid medial dorsal keel; (2) small, pyramidal gynobase surmounted by a short style which does not equal the height of the nutlet; (3) recurved pedicels springing from the axiles of foliaceous bracts; (4) very small, unappendaged white flowers, and finally (5) herbaceous and distinctly annual habit.

By all means I should advocate your describing it as a new species and a new genus!"

On 16.IX.1954 Johnston sent me a further note on *Embadium*, which may be of general interest, as follows:

"I have made a new study of *Embadium*, examining the more minute corolla structures, pollen, fruit-organisation, etc. I am convinced that it is most closely related to *Lappula* from which it differs in the medial rather than longitudinal nutlet attachment. The pollen agrees with that of *Lappula* and not at all closely with either *Eritrichium* or *Hackelia*, and not at all with *Omphalodes*. Like *Lappula* the oblong grains are slightly constricted at the equator and have 2 rows of pores, 3 above and 3 below the equator. The grains are small 13-16 x 10μ."



Map of South Australia showing the distribution of *Embadium* species: ● = *E. stagnense* Black; × = *E. uncinatum* Ising; □ = *E. johnstonii* Ising.

This was written when Dr. Johnston had received my No. 3627 which I considered to represent a new species, an opinion confirmed by Dr. Johnston. He regarded *Embadium* as a distinct genus and pointed out that it had affinities with *Omphalodes* Moench and *Eritrichium* Opiz which are not Australian genera. They lack the tumid margin and crest-like tumid, medial, dorsal keel of *Embadium* (the crest-like keel is absent in *Embadium johnstonii*). In *Embadium* there are no scales in the throat of the corolla which are present in *Omphalolappula*, *Lappula*, *Omphalodes* and *Eritrichium*. The nutlets of *Hackelia* are spiny as also in *Embadium uncinatum*. The nutlet areole is basal in *Eritrichium* and *Lappula* differing from the more or less central position of the areole in *Embadium* and *Omphalolappula*.

Thus it appears that *Embadium* is near to *Omphalodes* in the reflexed margin on the outer face and the areole on the inner face of the nutlet and also near to *Omphalolappula* in the areole.

Unfortunately, Dr. Johnston was not able to describe the new species represented by my No. 3627 before he died, and thus I took up the examination of all the material of the genus available from the Australian herbaria. Apart from two specimens from Melbourne (MEL), no specimens were received on loan. All other specimens were located at Adelaide (AD). The results of my investigation are presented hereunder.

All specimens placed in *Embadium* come from South Australian localities. Two new species are recognized and make an emendation of the generic description necessary (see below). The key to the genera of Boraginaceae in J. M. Black, Fl.S.Austral. ed.2(1957)708, should be altered as follows: Replace the key between "D. Torus conical or convex, at least half as long as nutlet" and "D. Torus almost flat . . ." by the following:

(1) Corolla with scales in the throat. Nutlets usually 4, beset with prickles.
  (2) Nutlets convex or flat on the outer face. *Cynoglossum*
  (2) Nutlets with a tuberculate hollow in the centre of the outer face. *Omphalolappula*

(1) Corolla without scales in the throat. Nutlets 2-4, with or without prickles, ovoid to trigonous.
  (3) Cymes bracteate. Stigma capitate. Nutlets 2-4, keeled along upper part of inner face.
    (4) Nutlets 2-4, rugose, without a tumid margin; areole occupying the lower part of the inner face. *Plagiobothrys*
    (4) Nutlets 4, smooth or ribbed, with a tumid reflexed margin; areole small, situated about the middle of the inner face. *Embadium*
  (3) Cymes ebracteate. *Ausiuckia*

Embadium Black, Trans.Roy.Soc.S.Austral.55(1931)141; Robertson in Black, Fl.S.Austral.ed.2(1957)716.

Calyx 5-sect to almost free sepals; corolla 5-lobed, without scales in the throat, 5 oblong horizontal impressions on the outside below the lobes corresponding to 5 protuberances inside the tube; stamens 5, included in corolla, filaments short, curved; style inserted between the 4 lobes of the ovary, shorter than nutlets, stigma capitate; nutlets 4, ovoid with a tumid margin incurved or inrolled towards the centre of the outer face which is slightly concave; crest on outer face medial, present or absent; areole fixed medially (just below the centre) to the pyramidal gynobasis, keeled above areole; embryo ovate, cotyledons broader and longer than the superior radicle. Annual herbs beset with hispid usually tuberculate bristles, fruiting pedicels recurved.— Type species: *E. stagnense* Black.

KEY TO SPECIES

(1) Crest on nutlet present. Stems ± decumbent, few.

(2) Crest inflated, oblong, entire and undulate at summit, unarmed. Nutlet with minute uncinae on inner face. Stem leaves usually lanceolate. 1. *E. stagnense*

(2b) Crest not inflated, flat, compressed lengthwise, divided into conical, contiguous sections with apical uncinae. Nutlet glabrous on inner face. Stem leaves elliptic to ovate. 2. *E. uncinatum*

(1b) Crest absent. Stems usually ascending or erect, numerous. Stem leaves lanceolate to ovate. 3. *E. johnstonii*

1. **Embadium stagnense** Black. Trans.Roy.Soc.S.Austral.55(1931)141, t.6, fig.7: Robertson in Black, Fl.S.Austral.ed.2(1957)716, fig. 1002.

Plant annual, slender, beset with hairs situated on tubercles. Stems radical, 1-8, decumbent 5-16 cm long; lateral branches few. Radical leaves oblanceolate, 15-45 mm long including the petiole which is usually longer than the lamina, obtuse; stem leaves elliptical, ovate to broad lanceolate, 5-15 mm long, ± sessile, obtuse. Flowers solitary, white, leaf opposed or not; pedicels 4-10 mm long. Calyx lobes ovate, 2 mm long, acute, persistent. Corolla tubular, ca. 1½ mm long; lobes obtuse, shorter than tube. Nutlets ca. 3 mm long, outer face almost

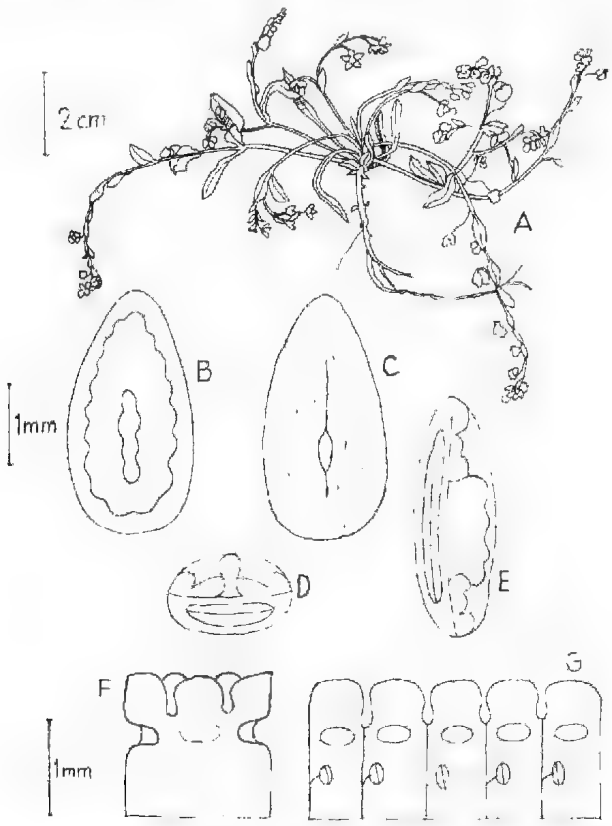


Fig. 1. *Embadium stagnense* Black – A: whole plant (B. J. Murray, isotype); B: nutlet outer face; C: nutlet inner face; D: transverse section of nutlet; E: longitudinal section of nutlet; F: corolla pressed flat; G: corolla spread open showing inside.

glabrous; margin undulate; crest medial, inflated, undulate, ca. as high as margin; inner face convex with sparse minute uncinae; keel short, situated above areole; areole lanceolate, situated just below middle of nutlet (Fig. 1).

Specimens examined: *B. J. Murray 99*: AD 96450111, 96450112 (holotype); MEL 7702: Arcoona, west of Lake Torrens, South Australia; 18.IX.1927.

2. **Embadium uncinatum** E.H.Ising, sp.nov.

Planta annua, graciles, pilis hispidis divaricatis vel erectis plerumque cum basi lata ornatis; caules radicales, 4-5, decumbentes, ad 30 cm longi; rami laterales pauci. Folia radicalia oblanceolata ca. 4 cm longa, petiolo (lamina aequilonga) includente. Folia caulina elliptica vel ovato-lanceolata, 16-25 mm longa et 5-9 mm lata, plerumque sessilia, distantia, tenuia, apicem versus in bracteas lanceolatas transeuntia. Flores solitarii, albi, (non semper) folio oppositi. Calycis segmenta ovata, 2-3 mm longa, persistentia. Corolla ca. 3 mm longa; lobi obtusi, ca. 1 mm longi. Nucula ca. 4 mm longa; facies exterior cum paucis pilis minutis tuberculatis ornata; margo lobis contiguis, conicis ornata; conicae in apici glochidiatae; crista supra prominentem medialem posita, erecta, plana, longitudinaliter compressa.

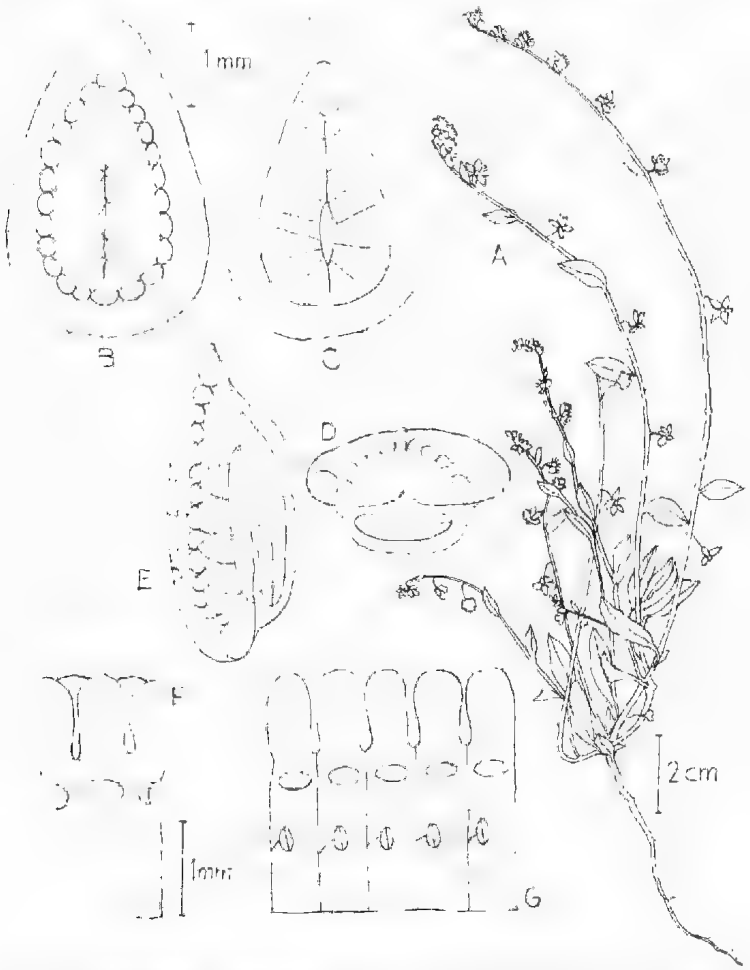


Fig. 2. *Embadium uncinatum* Ising — A: whole plant (P. G. Wilson 151, holotype); B: nutlet outer face; C: nutlet inner face; D: transverse section of nutlet; E: longitudinal section of nutlet; F: corolla pressed flat; G: corolla spread open showing inside.

4-5 lobata (lobis marginis similibus); facies interior convexa glabra, nitida cymbiforma; carina nuculam duplo brevior; areola lanceolata, brevis, nuculae infra median affixae; costae radiantes, paucae.

Holotypus. *P. C. Wilson 151*: AD 95928067; Whyalla-Kimba Road, Eyre Peninsula, South Australia; 2.X.1958.

Plant annual, slender, beset with hispid usually broad-based spreading to erect hairs; stems radical, 4 to 5, decumbent, to 30 cm long; lateral branches few. Leaves: radical, oblanceolate, ca. 4 cm long including petiole which is about as long as lamina; stem, elliptic to ovate-lanceolate, 16 to 25 mm long and 5-9 mm wide, usually sessile, distant, thin, passing into lanceolate bracts. Flowers solitary, white, leaf-opposed or not. Calyx segments ovate, 2-3 mm long, persistent. Corolla ca. 3 mm long; lobes obtuse ca. 1 mm long; nutlet ca. 4 mm long; outer face with a few minute tuberculate hairs; margin decorated with conical, contiguous lobes with apical incinae; crest situated on a medial ridge, erect, flat, compressed lengthwise, decorated with 4-5 lobes similar to those on the margin; inner face convex, glabrous, shining, cymbiform; keel half as long as nutlet; areole lanceolate, short, situated below centre of nutlet; ribs radiating, few. (Fig. 2.)

It is noticeable that this species has glochidiate appendages which also occur in *Cynoglossum*, in some species of *Hackelia*, and one species in each of *Omphalodes* and *Eritrichium*. But these appendages do not occur in the other two species of *Embadium*, viz., *E. stagnense* and *E. johnstonii*.

Further specimens examined: *Ruth E. Bennier s.n.*: MEL (fruits only consisting of 2 fragments with pedicels, sepals and 2 nutlets attached, and 2 loose nutlets; mounted in envelope with 7702): Near Quorn, southern end of Flinders Range, South Australia; Sept. 1945.— *E. H. Ising 3760*: AD 96150113; Gawler Range (south), Eyre Peninsula, South Australia; 12.IX.1938.— *id. 3750*: AD 96150107; Wudinna, Eyre Peninsula, 23.IX.1939.— *id. s.n.*: AD 96450108; Gawler Range (south, near Paney), Eyre Peninsula; 2.X.1939.

Specimens of both my numbers 3760 and 3750 were sent to Dr. I. M. Johnston in 1955, but up to the time of his death on 31.5.1960, no reply had been received nor could the specimens, correspondence or ms. notes with regard to them which might possibly have been prepared by him be traced at the Gray Herbarium and Arnold Arboretum.

The epithet refers to the minute hooks at the apex of the appendages on the nutlet margin and crest.

3. **Embadium johnstonii** E.H.Ising, sp. nov.

Planta, annua, gracilis, erecta, pilis hispidis albidulis appressis ornatis, basi tuberculatis vestitum. Caules radicales, numerosi, ascendentes vel erecti. Folia radicalia angusta, oblanceolata, 35-40 mm longa petiolo (lamina aequilonga) includento, obtusa. Folia caulina ovata vel lanceolata, apicem versus in bracteas transeuntia, 12-20 mm longa, obtusa, sessilia. Flores solitarii, albi (non semper) folio oppositi, pedicellis 2-8 mm longis. Calycis segmenta ovata, ca. 3 mm longa, acuta, persistentia. Corolla tubulata, ca. 2 mm longa, pluri-nervata, lobi obtusi, tubo breviores. Nucula ca. 2 mm longa; facies exterior glabra, margo integra, reflexa vel involuta; crista absens; facies interior convexa, glabra, nitida; carina nuculam duplo brevior; areola lanceolata, brevis, nuculae infra median affixae; costae radiantes, paucae.

Holotypus. *E. H. Ising 3842*: AD 96450103; Evelyn Downs, 90 miles south-west of Oodnadatta, South Australia; 24.IX.1955.

Plant annual, slender, erect, beset with hispid, whitish appressed hairs situated on tubercles. Stems radical, numerous, ascending or erect. Leaves: radical, narrow oblanceolate, 35-40 mm long including the petiole which is about as long as the lamina, obtuse; stem, ovate to lanceolate, reduced to bracts in upper part of stem, 12 to 20 mm long, obtuse, sessile. Flowers solitary, white, leaf-opposed or not, pedicels 2-8 mm long. Calyx segments ovate, ca. 3 mm long, acute, persistent. Corolla tubular, ca. 2 mm long; lobes obtuse, shorter than tube; nerves several. Nutlet ca. 2 mm long, outer face glabrous; margin entire, reflexed or inrolled; crest absent; inner face convex, glabrous, shining,

keel half as long as nutlet; areole lanceolate, short, situated below the centre of the nutlet; ribs radiating, few. (Fig. 3.)

Further specimens examined: *E. H. Ising 3842A*: AD 96450106; Evelyn Downs, via Oodnadatta, South Australia; 2.IX.1955.— *id. 3627*: AD 96450105; Evelyn Downs; IX, X.1950 [Johnston commented on this number in his letter of 16.IX.1954: "Your collection, No. 3627, obviously has its closest relation with *Embadium stagnense*, but until proved otherwise I cannot believe that it is con-specific with that species. The difference in nutlet organisation between the two collections is too great to be passed over. If you care to publish the plant as a new species by all means do so. . . ."].— *id. 4006*: AD 96450104; Evelyn Downs; IX, X.1949.— *T. R. N. Lothian 2152*: AD 96343136; Arkaringa Amphitheatre area, ca. 80 km south-west of Oodnadatta; 15.VIII.1963.

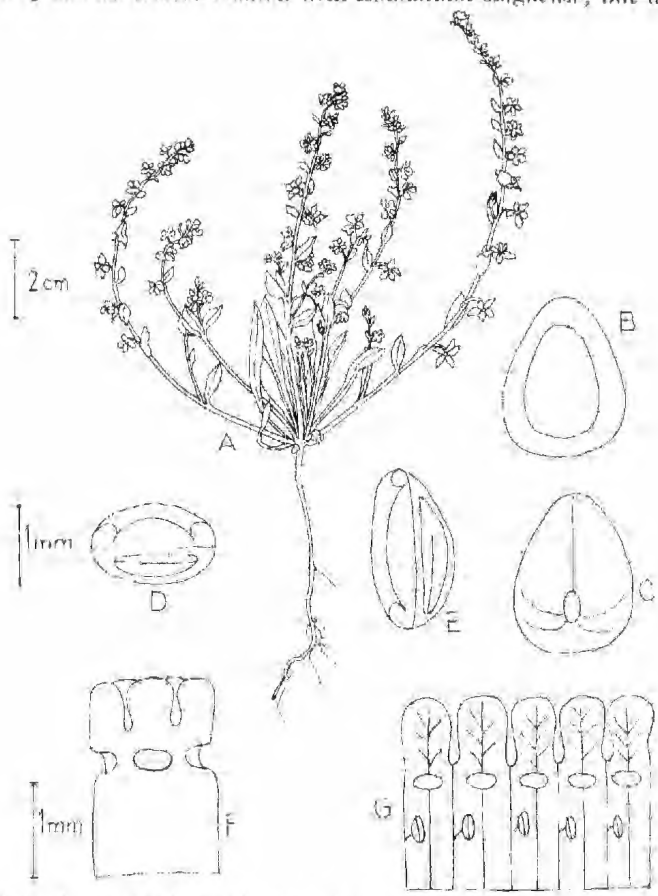


Fig. 3. *Embadium johnstonii* Ising — A: whole plant (E. H. Ising 3842, holotype); B: nutlet outer face; C: nutlet inner face; D: transverse section of nutlet; E: longitudinal section of nutlet; F: corolla pressed flat; G: corolla spread open showing inside.

This species is named in honour of the late Dr. Ivan M. Johnston.

ACKNOWLEDGMENTS

My thanks are expressed to the officers in charge of various Australian State Herbaria for searching for specimens of *Embadium* species or loaning specimens of cognate genera; also to Dr. Hj. Eichler for advice and for facilities at the State Herbarium of South Australia during the preparation of this report; to Mr. P. G. Wilson for the Latin descriptions herein; and to Mr. L. Dutkiewicz for assistance with the drawings.

Leonard Keith Ward, B.A., B.E., D.Sc., I.S.O. 1879-1964

Leonard Keith Ward died on the 30th September, 1964, after a long illness which had enforced his retirement from active participation in professional affairs for some fifteen years.

L. K. Ward was born in Sydney in 1879. After attending Sydney and Brisbane Grammar Schools, he entered Sydney University in 1897, graduating in Arts in 1900 and in Engineering in 1903, specializing in Geology. He was a pupil of Edgworth David, and a student contemporary of Douglas Mawson and W. G. Woolnough.

Immediately after graduation Ward spent three years in Broken Hill with the Broken Hill Pty. Co. Ltd., and in 1903 accepted appointment as a lecturer in mineralogy, petrology and mining geology in the Western Australian School of Mines in Kalgoorlie, a position he held for four years. In 1907 he took up duty as Assistant Government Geologist and Inspector of Mines in Tasmania, and it is from this position that the first published record of his work emerges. He carried out investigations of the silver-lead fields of Mt. Farrell, the tin field of Dundas, the Zeehan silver-lead field and the Mt. Balfour copper field, reports of which appear in publications of the Geological Survey of Tasmania. At this stage also he contributed to the Royal Society of Tasmania.

In 1911, Ward was appointed Director of Mines and Government Geologist in South Australia, succeeding H. Y. L. Brown, who had been Government Geologist since 1882. With Ward's appointment came a re-organization of the Department, including the recognition that additional staff was necessary, and R. Lockhart Jack was appointed as Ward's assistant.

Ward undertook systematic examination of the State's mineral and underground water resources, bringing to his natural interest in these matters an ability for systematic thinking and an unusual facility for clear writing. His reports and papers are outstanding for their lucidity, both to the scientific reader and to the layman. During the thirty-two years in which he occupied this office, Ward contributed many reports and papers in Government journals and in the proceedings of scientific societies. His interests ranged over mineral and hydrological investigations, petroleum exploration and the detailed examination of the State's coal resources, including the Leigh Creek field. The Bibliography of South Australian Geology contains some fifty references to his published work, including the revision of the Geological Map of the State in 1914 and 1928.

He served as a member of the Royal Commission on the Coal Industry in 1929-30 and on the Commonwealth Oil Advisory Committee.

In 1926 Ward was awarded the degree of Doctor of Science for a thesis on the geology of Central Australia, part of which was published by this Society in Vol. 49 of the Transaction, 1925. In January, 1942, he was recognised in the Birthday Honours with the award of the Imperial Service Order.

He retired in 1943, but continued to advise the Department of Mines in a consultant capacity.

Dr. Ward's service to the Royal Society was outstanding. He was a member of the Council from 1924-27 and 1933-35; Vice-President 1927-28, and President 1928-30. He was elected an Honorary Fellow of the Society and awarded the Verco Medal in 1955. Although in his latter years he was prevented from attending meetings of the Society, his interest in it and in all professional matters was maintained to the end.

He was a man to whom pretence was anathema, he took quiet delight in cutting the self-important down to size, and in bringing to light the true facts of any situation. His wisdom and kindliness and his fortitude during long years of physical discomfort will long be remembered by all privileged to know him.

L. W. P.

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